Pokhilenko N.P., Sobolev N.V., Agashev A.M., Vavilov M.A., Pokhilenko L.N., Malygina L.N. Anomalous kimberlites of the Snap Lake Area, Canada, and Nakyn Field, Yakutia: evidence of abnormal character of mantle sources and lithosphere structure.

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Discovery of the Nakyn kimberlite field in Yakutia and the Snap Lake kimberlite dyke system in Canada belong to the most important achievements of the 20th century end. The first can overlap on it's economic significance well-known Mirninsky field, the second is discovery of the biggest primary diamond deposit in the American Continent in whole representing qualitative new type of large diamond deposits (Pokhilenko et al., 1998; 2000; 2001 a). It is impossible to connect these new objects with known kimberlites of contrast groups 1 and 2 because they carry definite geochemical characteristics of kimberlites both groups. So, the Nakyn field kimberlites are close to kimberlites of group 2 on their character of REE distribution and La/Nb (0.95) and Nb/Zr (0.29) ratios, where as a number of their isotope characteristics are close to those of kimberlites of group 2: εNd – from +0.87 to –0.65; IR $^{87}Sr/^{86}Sr$ = 0.70586 – 0.70684; $^{143}Nd/^{144}Nd$ = 0.512136 – 0.512214 (Agashev et al., 2001 a). REE distribution and isotope characteristics mentioned above of the Snap Lake area kimberlites are close to ones characteristic for the group 1 kimberlites, but in the same time these rocks are intermediate between the kimberlites of group 1 and 2 on their content of the most incompatible elements (Pb, Rb, La, Ce), and their Ba and Th contents are close to those of kimberlites of group 2 (Pokhilenko et al., 2000; 2001 a; Agashev et al., 2001 b). Low values of Ti/K ratio are characteristic to the studied anomalous kimberlites in the whole, and their variations have intermediate character in comparison with those of kimberlites of group 1 and 2.

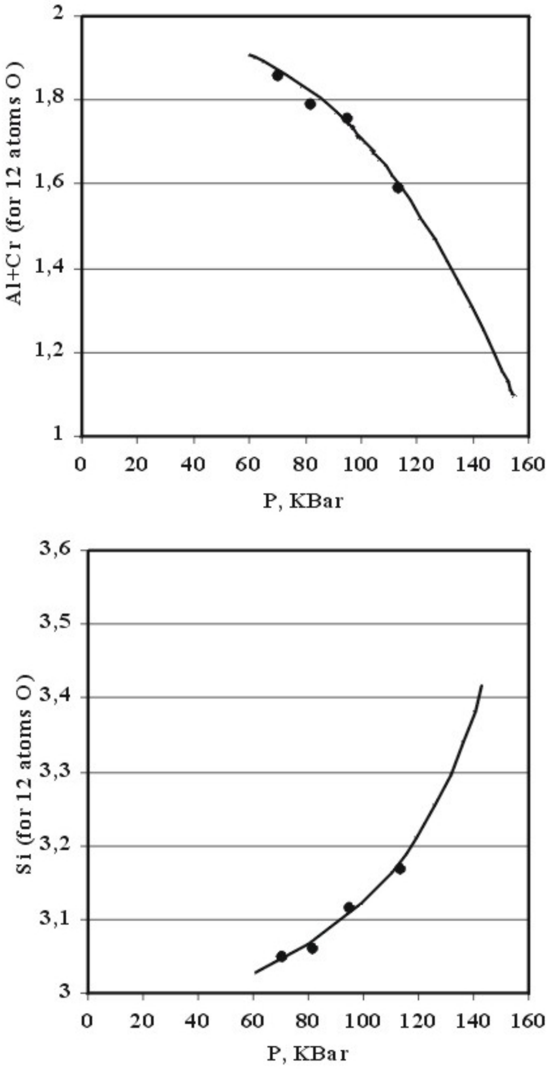

Fig. 1. Si and Al+Cr contents in the garnet inclusions in diamonds of the Snap Lake area. The calibrate curves from (Irifune, 1987)

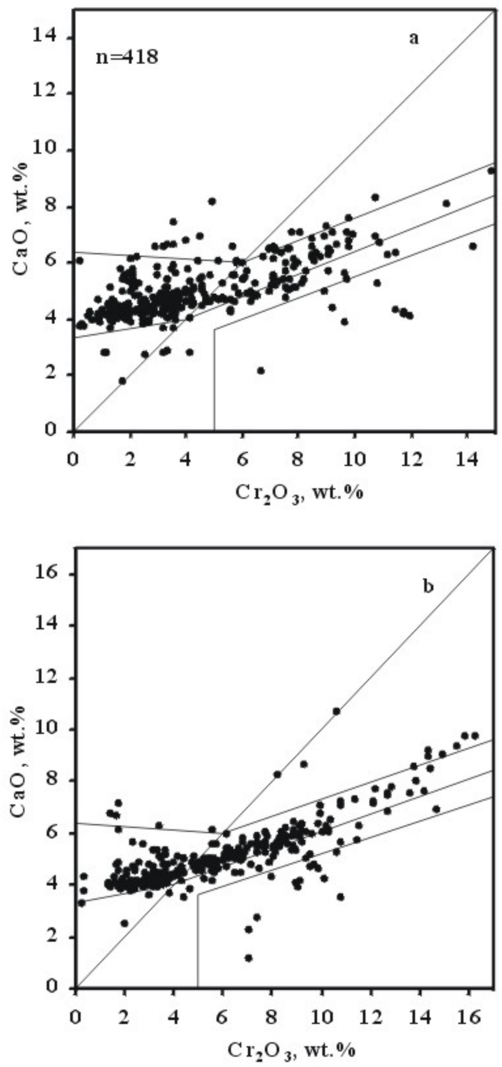

Fig. 2. Cr_2O_3-CaO plot for pyropes from the Nyurbinskaya pipe, Nakyn field, Yakutia (a) and kimberlites of the Snap Lake area, Canada (b).

REE distribution and isotope characteristics of the studied kimberlites suggest that their mantle sources were different from those for known ordinary kimberlites, and the most likely these sources were slightly carbonated depleted Cr-pyrope lherzolites situated in the lithospheric mantle roots (Agashev et al., 2001 b; Pokhilenko et al., 2001 b). The partial melting (0.5-2.5 %) of this kind of rock at pressures over 70 kbar can produce quite full series of studied kimberlite-carbonatite melts (Dalton, Presnall, 1998; Agashev et al., 2001 b). This assumption can be real in case of existence of depleted peridotites of lithospheric mantle at depth not less than 250 km beneath the Snap Lake area and Nakyn field at time of kimberlite emplacement. In the same time it is known that the maximum depth of distribution of depleted peridotites in the lithosphere cross sections is limited by values 190-200 km for the earlier studied regions of the Kapvaal Craton and Siberian Platform, and the secondary enriched peridotites of lithosphere – convecting asthenosphere interaction zone are developed at more deep levels (Pokhilenko et al., 1993; Boyd et al., 1997).

A special significance represent results of study of distribution and composition of the crystalline inclusions in diamonds from the Snap Lake area kimberlites in relation with the problem of this region lithosphere structure and composition. The crystalline inclusions from 109 diamond crystals of size –4+2 mm were studied. Minerals of ultramafic parageneses (UP) were found in 104 diamonds, eclogite paragenesis (EP) only in 5. Olivine predominate between the inclusions of UP minerals (was found in 84 diamond crystals), unusually high is also proportion of enstatite inclusions (in 21 crystals); sulphide inclusions in opposite are presented in much smaller proportion (in 15 crystals) in comparison with their amounts either in Siberian or South African diamonds, the same is valid for chromite inclusions found in 4 diamonds only. The UP Cr-pyropes were found in 10 crystals, and EP garnets – in 2 diamonds. The EP omphacites were presented in 5 diamonds, and in two cases they are associated with the EP garnet inclusions.

The most important results were obtained from the garnet inclusion study. Four from twelve diamonds contain garnet inclusions with significant amount of majorite component, and of special significance is detection of high admixture of this component (up to 17 mol. %) in subcalcic high-Cr pyropes. No doubt these pyropes are related to Cr-pyrope harzburgites of ***lithospheric mantle.*** As follows from experiments modeling natural ultramafic systems, pressures not less than 110 kbar are required to achieve 16-17 mol. % dissolution of majorite component into magnesian garnet (Irifune 1987, see Fig. 1), and such pressures correspond to depth over 300 km. Other indications of "sampling" by the Snap Lake area kimberlites of extremely deep levels of upper mantle include: a) high maximum K_2O admixture in clinopyroxene inclusions of both EP (up to 1.37 wt. %) and UP (0.71 wt. %); b) high Na_2O content in EP garnet inclusions (0.33 and 0.38 wt. %). Of special importance is the observation that in one of these garnets the Na content (0.046 for 12 atoms of O) is much higher than Ti (0.024 for 12 atoms of O). At full absence of P (< 0.001 for 12 atoms of O) it suggests that we have found the first reliable natural example of isomorphism on the scheme $R^{2+}Al \leftrightarrow NaSi^{VI}$, possibility of which was discussed earlier (Sobolev, Lavrentiev, 1971), with transition of some amount of Si into octahedrally coordinated sites.

Of special interest are results of pyrope composition study performed for the Nakyn field and the Snap Lake area kimberlites. It is known that the maximum values of Cr_2O_3 content for amount of ~ 300 grains of pyrope for earlier studied diamondiferous kimberlites of Yakutia and South Africa are limited by 11-12 wt. %. In the same time we observed for the comparable amounts of pyrope grains Cr_2O_3 contents up to 15 wt. % (Nyurbinskaya pipe, Nakyn field) and even up to 17 wt. % (Snap Lake kimberlites, see Fig. 2). This peculiarity of the anomalous kimberlite pyrope composition can be connected with existence in the lithosphere roots of studied regions of special conditions for full completion of the garnetization reaction for the ultradepleted peridotites with very high values of Cr/(Cr+Al) ratio (> 80 %). These conditions include necessity of presence of such ultradepleted peridotites at depth up to 220-230 km, and as it follows from obtained results it is quite possible for lithosphere beneath the Nakyn field and the Snap Lake area especially. As to ordinary lithosphere cross sections both the Siberian Platform and Kapvaal Craton it was mentioned above that maximum depths of distribution of depleted peridotites are limited by values 190-200 km.

Thus these results allow us to propose existence of abnormally thick lithosphere at time of kimberlite emplacement beneath the Nakyn field (Devonian time) and the Snap Lake area (Cambrian time). Moderate depleted peridotites strongly predominated in a thick interval from the Moho surface to at least 300 km (for the Snap Lake area). Diamondiferous harzburgites and depleted lherzolites contained at such depths Cr-pyropes with significant amounts of majorite component. Obtained results suggest as well that ultramafic rocks beneath the studied regions were significantly less depleted, less differentiated, and cooler than those underlying either the Siberian Platform or Kapvaal Craton. Relatively low depletion of diamondiferous peridotites of the Snap Lake area lithospheric mantle is indicated by relatively low average Mg # [100Mg/(Mg+Fe)] for olivine (92.0), enstatite (93.3) and pyrope (84.5) inclusions in diamonds of this area as well as by significantly higher average CaO content for Cr-pyrope inclusions (4.6 wt. %) compared to those for Cr-pyrope inclusions in Siberian and South African diamonds. Lower degree of differentiation of ultramafic rocks in the lithospheric mantle of studied regions is indicated by relatively smaller part of both harzburgite and wehrlite parageneses pyropes among the pyrope population from the Nakyn field and Snap Lake kimberlites than in piropes contained in ordinary diamondiferous kimberlites from Siberia and South Africa. Relatively low equilibrium temperatures of diamondiferous lithospheric mantle beneath the the Snap Lake area are indicated by very low contents of Ca in olivine (0.01-0.05; average- 0.021 wt. %) and in enstatite (0.16-0.42; average – 0.31 wt. %) inclusions together with data pointing to very high maximum pressures of the Snap Lake area diamond formation. Preliminary estimation of the Snap Lake lithosphere heat flow show us that it was at Cambrian time as low as 31-33 mWm^{-2}.

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References:

1. Agashev A.M., Watanabe T., Pokhilenko N.P., et al. // Geology, 2001 a, v 3, p. 267-270.
2. Agashev A.M., Pokhilenko N.P., McDonald J.A. et al. // The Slave-Kaapvaal Workshop Ext Abstr Vol., 2001 b, Merrickville, Ontario, unpaged.
3. Boyd F.R., Pokhilenko N.P., Pearson D.G., et al. // Contrib Mineral Petrol., 1997, v 128, p. 228-246.
4. Dalton J.B., Presnall D.C. // J Petrol., 1998, v 39, p. 1953-1964.
5. Irifune T. // Phys Earth Plan Int., 1987, v 45, p. 324-336.
6. Pokhilenko N.P., McDonald J.A., Hall A.E., Sobolev N.V. // The Slave-Kaapvaal Workshop Ext Abstr Vol., 2001 a, Merrickville, Ontario, unpaged.
7. Pokhilenko N.P., McDonald J.A., Melnyk W., et al. // Ext Abstr Vol 7th Intern Kimberlite Conf., 1998, Cape Town, p. 699-701.
8. Pokhilenko N.P., Sobolev N.V., Boyd F.R., et al. // Russian Geology and Geophysics, 1993, v 34, 1, p. 50-62.
9. Pokhilenko N.P., Sobolev N.V., McDonald J.A. et al. // Transact RAS, 2001 b, v 380, 3.
10. Pokhilenko N.P., Sobolev N.V., Tchernyi S.D., et al. // Transact RAS, 2000, v 372, 3, p. 356-360.
11. Sobolev N.V., Lavrentiev Y.G. // Contrib Mineral Petrol., 1971, v 31, p. 1-12.