Diamondiferous microxenoliths and xenocrysts from the Nyurbinskaya kimberlite pipe, Yakutia

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Introduction

Mineral inclusions in diamonds and their intergrowths provide important information about the composition of the subcontinental lithospheric mantle involved in the processes of diamond formation. Newly discovered kimberlitic pipes of the Nakyn kimberlite field (Yakutia) are characterised by the very high proportion (more than 50%) of diamonds of eclogitic paragenesis (Botuobinskaya pipe; Mityukhin, Spetsius, 2005). Here we present the new results of study of five samples of diamondiferous microxenoliths and garnet xenocrysts from the Nyurbinskaya kimberlite pipe, located in this field. The studied samples are microxenolith of diamondiferous peridotite, microxenolith of diamondiferous eclogite, and 3 intergrowths of single pyrope grains with diamonds. Samples are up to 4 mm in diameter and all of them fall in a sieve class -4+2 mm.

Geological Background

The Nakyn kimberlite field is located in the east of the Siberian platform, in the Vilui-Markha deep fault zone, a northeast-trending structure associated with the middle Paleozoic Vilui rift system. The well-known Mir pipe (Malobotuobia kimberlite field) also is located in that zone ~350 km southwest of the Nakyn field, a magmatic complex that includes tholeiitic and alkaline basalts, kimberlites, and explosion breccias (Tomshin et al., 1998). Only two kimberlite pipes (Botuobinskaya and Nyurbinskaya) have been discovered; both are diamondiferous. The kimberlites originally intruded an early Paleozoic terrigenous-carbonate sequence and were covered by Jurassic terrigenous sediments 30-80 m thick. The Rb-Sr isochron method gives an age of 364 +/-9 Ma for the Botuobinskaya pipe and 364 +/-5 Ma for the Nyurbinskaya pipe (Agashev et al., 2001).

Sample Description

Samples Nyurb-1, Nyurb-2 and Nyurb-3 are intergrowths of single pyrope grains with diamonds. Nurb-1 sample consists of purple pyrope grain and irregular intergrowth of several diamonds of octahedral habit (Fig. 1 and 2a). Nyurb-2 is intergrowth of purple pyrope grain and single diamond crystal of octahedral habit (Fig. 2b). Nyurb-3 is red pyrope grain with a system of parallel cracks. Two diamond crystals of octahedral habit found along one of such cracks. Both diamonds are colorless and have step-like structure of octahedral surfaces (Fig. 2c).

Figure 1: Nyurb-1 - pyrope xenocryst and irregular intergrowth of several diamonds of octahedral habit. Width of sample ~4 mm.

Clinopyroxene of the diamondiferous bimineral eclogite microxenolith (Nyurb-4) is completely altered. Diamond in this xenolith is colorless step-like octahedron with slightly rounded edges (Fig. 2d).

Microxenolith of diamondiferous peridotite (Nyurb-5) mainly consists of two large diamond crystals. Cpx, Grt and Chr are fresh, while Ol and Opx are completely altered. Diamonds are colorless crystals of cubooctaedral shape (Fig. 2e). One diamond crystal contains mineral inclusion of chromite and olivines (Ol - visual identification). The chromite diamond inclusion was exposed to the surface by polishing and studied *in situ*.

Mineral Chemistry

The compositions of the primary phases and chromite diamond inclusion (Nyurb-5) are presented in Figure 3 and Tables 1 and 2. Garnets in all samples are homogeneous. Pyropes from heavy concentrate and from studied samples are plotted on the Fig. 3 for comparison.

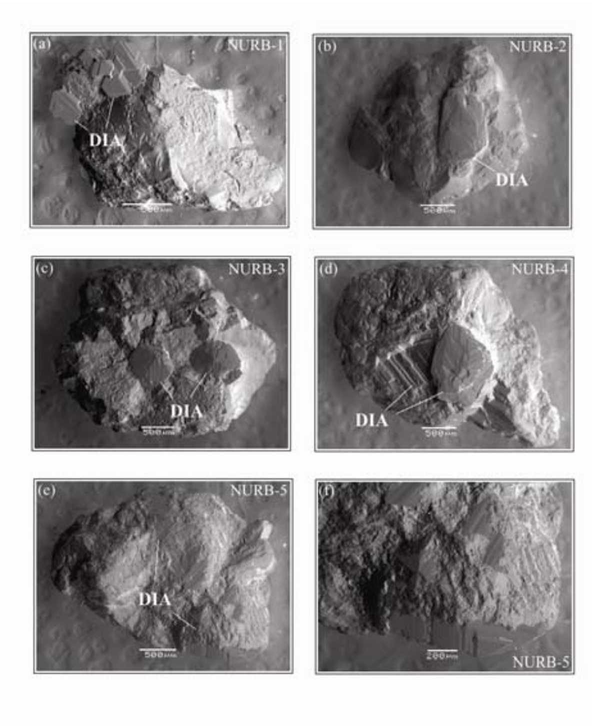

Figure 2: SEM images of individual samples.

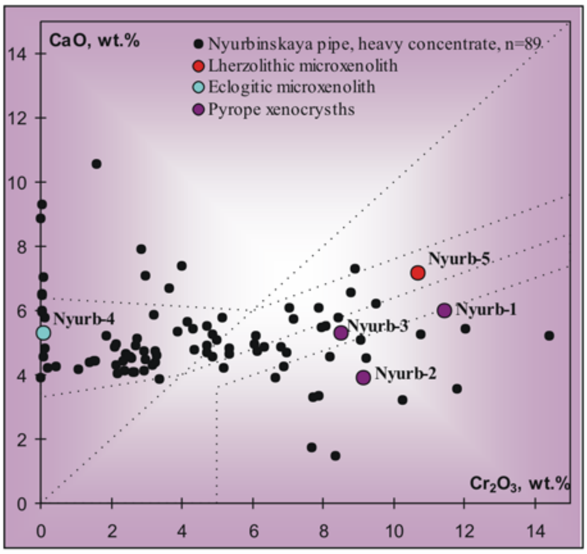

Figure 3: Cr_2O_3 vs CaO in garnets. Fields after Sobolev et al. (1973).

Nyurb-1 and Nyurb-2 are high-chromium subcalcic pyropes with Cr_2O_3 - 11.4% and 9.1%, and CaO contents - 6% and 3.9%, accordingly. Nyurb-3 is lherzolitic pyrope (Cr_2O_3 – 8.5%, CaO – 5.3%). Garnet composition from the eclogitic microxenolith (Nyurb-4) corresponds to pyrope-almandine series (*65.8Pyr21.3Alm7.9Gross*). The contents of CaO, Cr_2O_3, and TiO_2 are 5.3, 0.09 and 0.53 wt.%, accordingly.

Garnet from peridotitic microxenolith has a high CaO (7.1%) content and fall into lherzolitic field (Cr_2O_3 – 10.8%). Chromite from xenolith fall into diamond inclusion field (Cr_2O_3 - 63.6%, TiO_2 - 0.61%). Chromite diamond inclusion has lower TiO_2 - 0.09% and FeO – 16.0%. Chromite diamond inclusion also has lower Fe^{3+} content than chromite from xenolith and $Fe^{3+}/(Cr+Al+Fe^{3+})$ ratio fall into typical worldwide chromite diamond inclusion range from 0 to 0.06 (Fig.4; Malkovets et al., 2007).

Table 1: Composition of garnets.

Sample Mineral	Nyurb-1 Gar	Nyurb-2 Gar	Nyurb-3 Gar	Nyurb-4 Gar	Nyurb-5 Gar
SiO_2	40.7	41.7	41.8	40.9	41.2
TiO_2	0.28	0.08	0.20	0.53	0.20
Al_2O_3	14.3	16.4	16.7	21.8	15.1
Cr_2O_3	11.4	9.12	8.52	0.09	10.7
FeO	7.03	7.30	7.35	15.0	7.23
MnO	0.43	0.42	0.42	0.44	0.47
MgO	19.2	20.8	19.7	15.6	17.9
CaO	5.99	3.93	5.30	5.32	7.16
Na_2O	0.07	0.02	0.03	0.14	0.01
K_2O	0.002	0.004	0.008	0	0.017
Total	99.49	99.79	99.97	99.89	99.91

Table 2: Composition of clinopyroxene and chromites.

Sample Mineral	Nyurb-5 CPx	Nyurb-5 Chr DI	Nyurb-5 Chr
SiO_2	55.6	n/d	n/d
TiO_2	0.05	0.09	0.61
Al_2O_3	1.48	6.19	5.43
Cr_2O_3	3.24	64.9	63.6
FeO	1.75	16.0	18.8
MnO	0.09	0.21	0.26
MgO	15.5	11.7	10.7
CaO	19.12	n/d	n/d
Na_2O	2.21	n/d	n/d
K_2O	0.04	n/d	n/d
NiO	n/d	0.09	0.08
Total	99.07	99.17	99.48
$Fe^{3+}/(Cr+Al+Fe^{3+})$		0.018	0.032

Diamond Study

Diamond aggregate from Nyurb-1 show corrosion surface features. The individual crystals are colorless with nitrogen content from 325 to 377 ppm and aggregation state from 30 to 35 %B1. The diamond from Nyurb-2 has nitrogen content of around 100 ppm at aggregation state of 18 %B1. CL reveals their zonal structure with rounded core and octahedral overgrowth (Fig.4 a). No significant variation of carbon isotope composition is observed in this sample. Two diamonds recovered from Nyurb-3 have nitrogen content varying from 250 to 540 ppm and nitrogen aggregation state from 36 to 51 %B1. CL of one of them show cuboctahedral core overgrown with octahedron (Fig.4 b). The variations of $\delta^{13}C$ is non-systematic and insignificant (-5.1 to -6.2 ‰). Diamonds from Nyurb-5 with nearly cubic habit have nitrogen content and aggregation state in both crystals is closely similar (660-690 ppm and 10-13 %B1 accordingly). They show complex growth history with changing growth from octahedral to cuboid and back to octahedral (Fig.4 d). Carbon isotope ratio systematically changes from core to rim toward lighter compositions. One diamond from eclogite microxenolith (Nyurb-4) has 450 ppm nitrogen and 15 %B1 aggregation state. At least two growth stages are deduced from CL imagery and carbon isotope variations (Fig. 4 c).

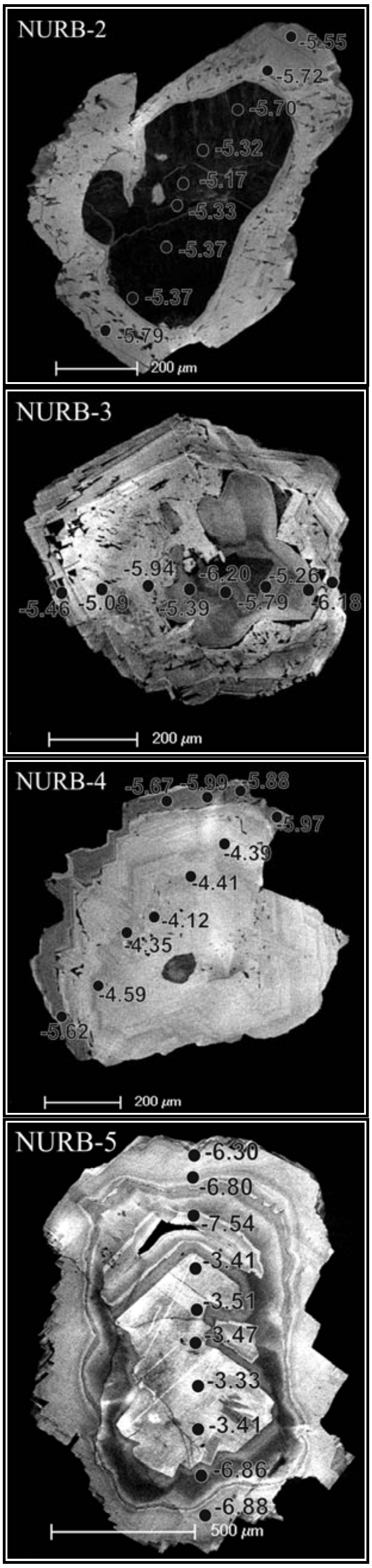

Figure 4: CL images and ion probe C-isotope data points.

Conclusions

Preliminary conclusions of this study are:

(i) P-type garnet of studied samples are of harzburgitic to lherzolitic compositions. Garnet from diamondiferous eclogite microxenolith has high Na_2O content (0.14%), suggesting its formation under high pressure conditions.

(ii) Typical mantle C-isotope data for our diamonds don't support the previously stated conclusion that the most diamondiferous microxenoliths from the Nyurbinskaya pipe are related to the crustal subduction (Spetsius et al., 2008).

(iii) Diamonds from studied samples have complex growth histories with several episodes of growth and resorption. The last growth stages for some diamonds are characterized by carbon isotope evolution toward lighter compositions.

This work was supported by Russian Foundation for Basic Research grants No.08-05-00751 (V.Malkovets) and No.07-05-00345 (N.Pokhilenko), a Macquarie University Research Fellowship (V.Malkovets), Macquarie University Research Grants, and an Australian Research Council (ARC) Discovery Grant (O'Reilly, Griffin).

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