

MICROINCLUSIONS IN FIBROUS DIAMONDS FROM YUBILEINAYA KIMBERLITE PIPE (YAKUTIA)

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INTRODUCTION

The Yubileinaya pipe is situated in the central part of the Daldyn-Alakit kimberlite field of the Yakutian diamondiferous province. The pipe age determined by the zircon-based U-Pb method is 358.1 Ma. (Davis et al., 1980). The new data on the inclusions of K-rich melts (Zedgenizov et al, 1998), Cr-Ca-rich majoritic garnet coexisting with a Cr-Ca-rich non-majoritic garnet and olivine (Sobolev et al, 2002), Fe-olivines (Sobolev et al, 2000) in Yubileinayan diamonds have been recently obtained. This fact was stimulus to investigate possible melt or fluid inclusions in Yubileinayan diamonds. Fluid or melt inclusions are valuable sources of direct information regarding the chemical composition of fluids in the upper mantle. It is known that fibrous diamonds contain numerous micro (<1µm) inclusions consisting of carbonates, water and incompatible elements. Such microinclusions are found in diamonds from Zaire, Botswana and South Africa (Navon et al, 1988; Akagi and Masuda, 1988, Schrauder and Navon, 1994, Izraeli et al., 2001). About 1% of the Yubileinayan diamonds have shapes which may be described as cubes (fibrous). Thus the present study focuses on the composition and origin of microinclusions in fibrous diamonds.

METHODS

Two fibrous cubes from Yubileynaya pipe (Ub-81 and Ub-541) have been studied. Double-polished sections 0.6 – 0.8 mm thick have been prepared from individual diamond crystals were studied using optical microscopes with transmitted and plane-polarized light. Surface of this sections was cleaned with HF and HNO₃. Shallow and subsurface inclusions were detected using backscattered electron-imaging and analysed for major-element composition using a JEOL JXA 8600 electron probe micro analyzer (EPMA) with Pioneer-Norvar EDS detector and automation system. Infrared spectra were recorded by the FTIR with Bruker IRscope II microscope coupled to a Nicolet 740 spectrometer for nitrogen concentration and

aggregation-state and for the water and carbonate content of the microinclusions.

RESULTS

Sample description

All studied crystals have dark gray center and some dark zones (Fig.1). They are relatively flat-faced crystals of cubic habit, colorless. The surface of crystals carries dissolution forms. There are no cracks. Small cracks in the sample Ub-81 are result of polishing. These diamonds fit variety II by Orlov. X-ray topography has shown fibrous internal structure of studied diamond.

There are many micro-inclusions inside the dark zones of studied crystals. The size of inclusions is about 1 µm.

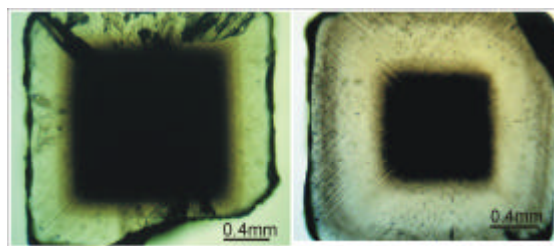


Figure 1: Polished sections of fibrous diamonds of cubic shape from Yubileinaya pipe (Ub-81 and Ub-541 resp.)

Epma analyses

EPMA detected two types of micro-inclusions: carbonatitic melt and sulfides. Diamond Ub-81 carry carbonatitic melt inclusions. The average composition of all the microinclusions is broadly similar. Their compositions vary the following ranges: SiO₂, 7 - 14 wt.%; TiO₂, 0 - 5,5 wt.%; BaO, 0 - 6 wt.%; Al₂O₃, 0 - 3 wt.%; FeO, 6 - 11 wt.%; MgO, 20 - 30 wt.%; CaO, 12 - 26 wt.%; Na₂O, 7 - 11 wt.%; K₂O, 16 - 27 wt.%; P₂O₅, 2 - 8 wt.%; SrO, 0,6 - 4 wt.%. All inclusions contain chlorine (3 - 6%) (Fig. 2). On a triangular Si+Al, K+Na, Mg+Ca+Fe diagram the compositional points are closely situated. This fact confirms the presence of true melt inclusions in diamond.

The sample Ub-541 contains S -Ni -Fe rich inclusions. They are characterized the wide S/S+Ni+Fe range and

the high Ni content (40 ± 7 wt.%). Similar high contents have been noted in the peridotitic MSS inclusions (about 15-36 wt.%, Yefimova et al, 1983; Bulanova et al., 1995). Two carbonatitic melt inclusions similar to Ub-81 melt inclusion compositions are present in diamond Ub-541 along with sulfide

inclusions. Some of these sulfide inclusions are composed of alkalis and Mg.

FTIR spectra

FTIR spectroscopy indicates that the nitrogen aggregation state of cubic diamonds Ub-81 and Ub-541 is IaA- type. The measured nitrogen content is 1300 – 1500 ppm.

The small bands at 1630 cm^{-1} and the more intense ones at 3420 cm^{-1} indicate the presence of water molecules in the diamond Ub-81 (Fig. 3). In the Ub-541 this bands are too small. Peaks at 3107 and 1405 cm^{-1} , being due to hydrogen in the diamond, detected in both samples. The intensities of the two characteristic carbonate bands at 1430 and 876 cm^{-1} (CO_3^{2-}) are strongly correlated and their presence indicate on the existence of carbonate in the inclusions. In diamond Ub-81 this bands are strong (Fig. 3), in agreement with the detection of carbonatitic melt inclusions by EPMA. Similar carbonate-rich samples were reported in diamonds from Zaire and Botswana (Navon, 1988; Schrauder., 1994).

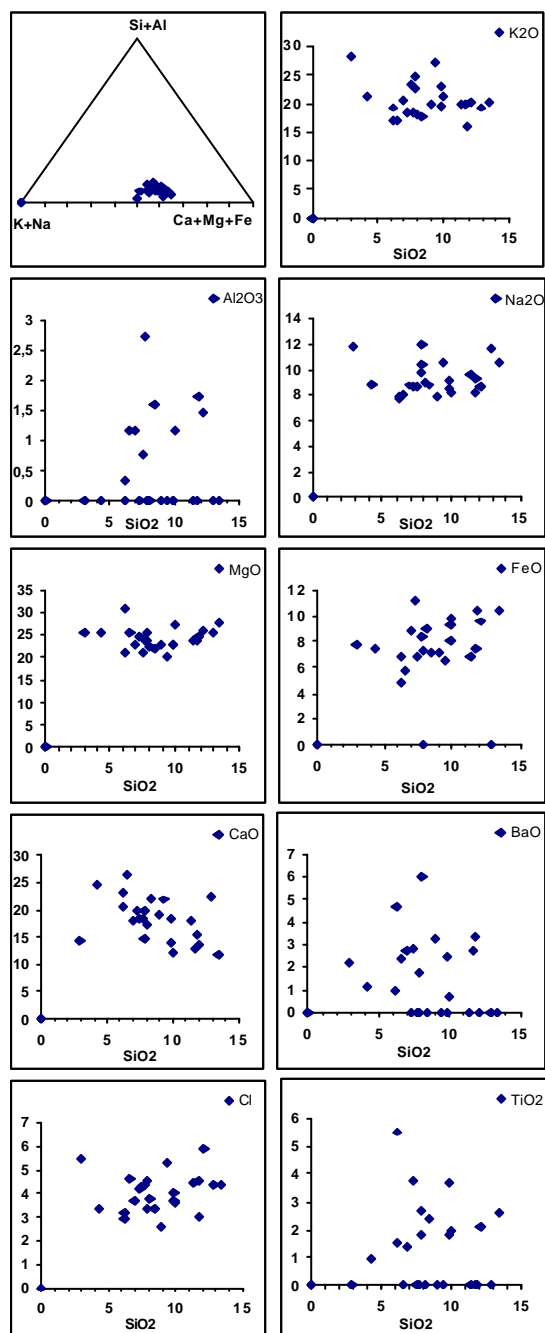


Figure 2: Concentrations of K_2O , Na_2O , Al_2O_3 , MgO , FeO , CaO , BaO , TiO_2 , Cl vs. SiO_2 of melt (or fluid) micro-inclusions in fibrous diamond Ub-81 from Yubileynaya pipe.

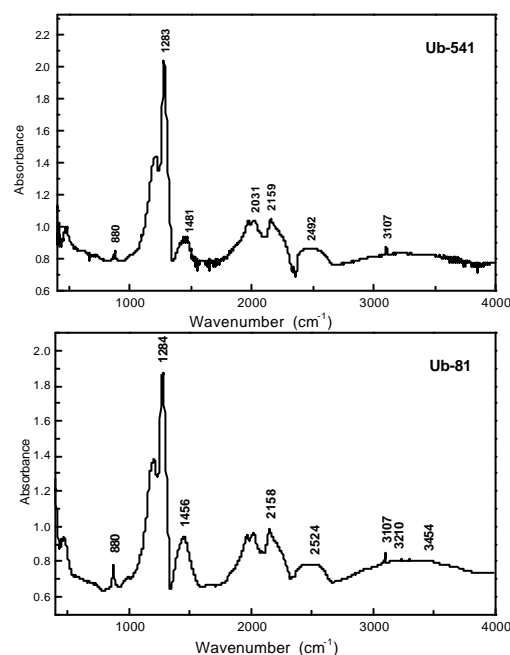


Figure 3: Infrared absorbance spectrum resulting from micro-inclusions in Yubileynayan diamonds ($400 - 4000\text{ cm}^{-1}$) with strong carbonate bands at 880 and 1456 cm^{-1} . Water bands at $3200 - 3450$ and 1640 cm^{-1} . Residual bands at 1284 (1283) and 3107 cm^{-1} are due to nitrogen and hydrogen in the diamonds.

CONCLUSION

The high content of volatiles and the uniform average composition of the micro-inclusions suggest that the original material trapped by diamond was a fluid-rich melt. Chlorine levels of 3 – 6 wt.%, reported here, are indeed much higher than those of kimberlites. The presence of volatiles in the microinclusions along with enrichment in K, Na, P, Sr suggests that the trapped material may represent an effective metasomatizing agent.

Broad compositional variations of S-Ni-Fe-inclusions, the constant Ni/(Ni+Fe), the presence of varying amounts of alkalis and Mg and the association with carbonatitic melts suggest that the sulfide-bearing micro-inclusions do not contain a mineral phase. Thus established inclusions are regarded as sulfide melts.

The fibrous diamonds are considered to have formed rapidly, and also very low aggregation state of nitrogen observed by IR study also suggests that the diamonds have been brought to the earth surface in relatively short time after their production (Boyd et al., 1994). Thus the microinclusions trapped in the diamonds could be the substance occurred at the initial stage of diamond formation. Finding sulfide melts along with carbonatitic melts imply that those two compositions coexisted during the growth of diamond.

REFERENCES

- Akagi, T., Masuda, A., 1988. Isotopic and elemental evidence for a relationship between kimberlite and Zaire cubic diamonds. *Nature* 334, 653-655.
- Boyd, S.R., Pineaur, F. and Javoy, M., 1994. Modelling the growth of natural diamonds. *Chem. Geol.* 116, 29-42.
- Bulanova, G.P., 1995. The formation of diamond. *J. Geochem. Explor.* 53, 1-23.
- Davis, G.L., Sobolev, N.V., Kharkiv, A.D., 1980. New data on the age of Yakutian kimberlites obtained by the U-Pb method on zircons. *Dokl. Akad. Nauk SSSR.* 254, 175-179 (in Russian).
- Izraeli, E.S., Harris, J.W., Navon, O., 2001. Brine inclusions in diamonds: a new upper mantle fluid. *Earth Planet. Sci. Lett.* 187, 323-332.
- Navon, O., Hutcheon, I.D., Rossman, G.R., Wasserburg, G.L., 1988. Mantle-derived fluids in diamond micro-inclusions. *Nature* 335, 784-789.
- Orlov, Yu.L., 1977. *The Mineralogy of the Diamond*. Wiley. New York.
- Schrauder, M., Navon, O., 1994. Hydrous and carbonatitic mantle fluids in fibrous diamonds from Jwaneng, Botswana. *Geochim. Cosmochim. Acta* 58 (2), 761-771.
- Sobolev, N.V., Logvinova, A.M., Zedgenizov, D.A., Yefimova, E.S., Lavrent'ev, Yu.G., 2000. Anomalous high Ni admixture in olivine inclusions from microdiamonds, the Yubileinaya kimberlite pipe, Yakutia. *Dokl. Akad. Nauk* 375(3), 393-396 (in Russian). English Translation: *Dokl. Earth Sci.* 375A, 1403-1406.
- Sobolev, N.V., Taylor, A.M., Logvinova, A.M., Seryotkin, Y.V., Koptil, V.I., Efimova, E.S., 2002. First report of majoritic-garnet diamond inclusions from Yakutian Kimberlites. AGU Fall Meeting, San Francisco, California, p. F1403.
- Yefimova, E.S., Sobolev, N.V., Pospelova, L.N., 1983. Sulfide inclusions in diamonds and specific features of their paragenesis. *Zapiski Vsesoyuznogo Mineralogicheskogo Obshchestva* 112, 300-310 (in Russian).
- Zedgenizov, D.A., Logvinova, A.M., Shatsky, V.S., Sobolev, N.V., 1998. Inclusions in microdiamonds from some kimberlite pipes (Yakutia). *Dokl. Akad. Nauk* 359(1), 74-78 (in Russian). English Translation: *Dokl. Earth Sci.* 359, 204-208.

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