Results of complex diamonds' research from V. Grib pipe of Archangelsk kimberlite province

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The V. Grib kimberlite pipe, which contains high diamond grades, was discovered in 1996 in the Verkhotinskoe field of the Archangelsk kimberlite province. It is one of the two industrial diamond deposits in the Archangelsk region. Another one is M.V. Lomonosov deposit, which contains six kimberlite pipes. The petrology and mineralogy of the V. Grib pipe are similar to some of the kimberlite pipes in the Yakutian (for example, Mir, Udachnaya) and African provinces.

The complex research on diamonds from the V. Grib pipe was done using IR-spectroscopy, UV-luminescence, colored cathodoluminescence (CCL), optical spectroscopy and carbon isotope geochemistry. The size, shape, preservation, defects, color and micromorphology of the diamond crystals' surfaces were documented using an optical microscope and JEOL-820 scan. Conclusions about genesis, chemical conditions of diamond formation and evolution have been made.

Morphology

Features of the morphology and internal structure of diamonds have been investigated by analysing 700 diamond crystals. Most diamond crystals have a high preservation rate. Diamonds from the V. Grib's pipe in the +2mm size class are characterized by being: 39% highly transparent, 60% - transparent, 28% - with yellowish and grayish shades. There are high concentration of octahedral (32%), rhombododecahedral (29%), octahedral-dodecahedral (17%) diamond crystals and low concentration of cubic (6%) and pseudohemimorphic (7%) diamond crystals (Fig. 1). In comparison with Lomonosov deposit there are lower concentrations of tetrahexahedrons (1%) with concentration of rhombidodecahedrons being twice as little. The tracers of surface dissolution are not everywhere, mainly they are local triangular and square figures of an etched nature on the surface, roundness of facets, and dissolution at tops and edges.

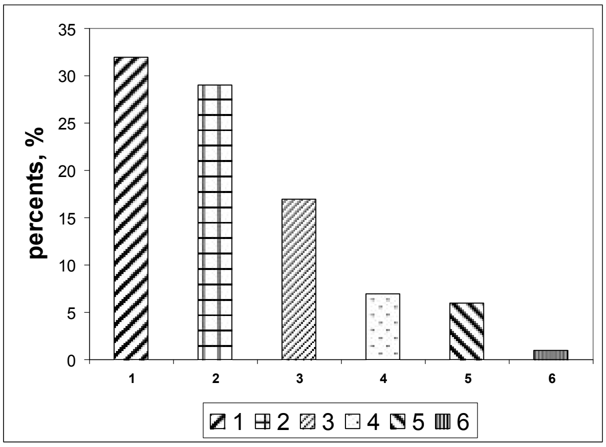

Fig. 1. Shape distribution of diamond crystals from the V. Grib pipe:
1 – octahedrons, 2 – dodecahedrons,
3 – octahedron-dodecahedrons,
4 – pseudohemimorphic crystals,
5 – cubes, 6 – tetrahexahedrons.

Features of morphology helped to determine the conditions of diamond evolution in the V. Grib pipe which was characterised by local alteration of fluid regime within the C-O-H system.

Luminescence

Crystals are characterized by blue and violet

(50%), yellow and green (10%) UV-luminescence. Sectorial growth of crystals has been identified by using UV-luminescence.

Investigation of internal morphology by CCL has shown that diamonds in the deposit have only blue luminescence. Some crystals are zoned with the alternation of blue and bluish zones of luminescence due to tangential growth. Most of the diamond crystals are not zoned. This indicates to slowly changing conditions in the diamond formation. Most of the diamond crystals have one or several diamond nucles of different shape in central part. They can be fragmented, dissolved or whole diamond crystals, which are different from the host diamond crystal in size, shape, colour or CCL. We consider these nucles to be the first generation crystals. They have higher concentration of nitrogen defects (N_{tot} > 1000 at. ppm) than the host diamond crystals.

This is the evidence of multistage diamond crystallization, variation in the composition and diamond formation conditions, fluid activity of kimberlite melt and metasomatic processes.

Natural and artificial irradiated green diamonds

We've investigated twelve green and bluish-green crystals. These colors are a result of GR1 and H3 structural defects which originated from radiation and have been identified by optical spectroscopy. The color is not everywhere: there are pigmental spots in some diamonds and sometimes GR1 and H3 defects disappeared with a change in diamond crystal's orientation in the optical device. The pigmental spots and spots on the surface, which can't be recognized with the naked eye, have no cathodeluminescence (Fig. 2). We assume that it is a result of partial destruction of the diamond's structure which turned the diamond into a metamict state at the places of radiation. In comparison with natural green samples, irradiated cut diamonds have a very intensive green colour and have no cathodoluminescense, but only on their surfaces. There are yellow and blue colours of cathodoluminescense inside the crystals (fig. 3). We also identified N2 and W7 ESR structural centres which points to the fact that the diamond crystals had a brown colour before the irradiation. Enhancing diamond colour by irradiation is one of the popular methods to raise the price of cut diamonds.

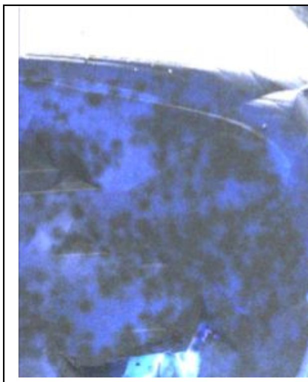	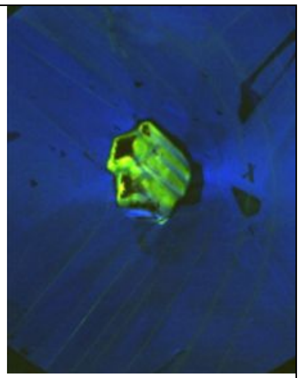
Fig. 2. The pigmental spots have no cathodeluminescence.	Fig. 3. Artificial irradiated cut diamond shows no CCL on the surface and yellow and blue CCL inside

IR-spectroscopy

Nitrogen concentrations in diamonds varies from 20 to 1474 at. ppm for A-form and from 1 to 1417 at. ppm for B-form. The proportion of aggregated nitrogen is 36%. Diamonds are characterized by high concentration of "platelets" (up to 32.5 st.un.) and low concentration of hydrogen (up to 5.5 cm^{-1}, average concentration is 0.76 cm^{-1}).

We split the crystals into three populations based on morphology and defects.

The first population (low nitrogen concentration): includes octahedral-dodecahedral crystals, most of them have octahedral shape with trigonal facets. This group is characterized by low total nitrogen (less then 600 at. ppm), hydrogen defects ($H<2.5$ cm^{-1}), "platelets" ($P<10$ cm^{-1}), with $\%N_B$ varying from 0 to 50%.

The second population (average nitrogen concentration): there are octahedral-dodecahedral crystals and octahedrons with ditrigonal facets. Total nitrogen concentration varies from 600 to 1200 at. ppm. $\%N_B$ varies from 40 to 60%. The concentration of hydrogen is not high, $0<H<5$ cm^{-1}. Concentration of "platelets" can be divided into two groups: one with low $P<3$ cm^{-1} and the other with high concentration $10<P<22$ cm^{-1}.

The third population (high nitrogen concentration): is a small group with crystals of different shapes. Total nitrogen concentration varies from 1200 to 3000 at. ppm. $\%N_B$ is less than 30%. This group is characterized by low hydrogen concentration ($0<H<6$ cm^{-1}) and a very high concentrations of "platelets" ($25<P<35$ cm^{-1}).

Isotopic geochemistry

First isotopic carbon composition data have been obtained from the examination of 62 diamonds. Values of $\delta^{13}C$ vary from -2,79 ‰ to -9,61 ‰ which is typical for ultrabasic kimberlites of the world.

Zoned crystals, which have different colours, UV-luminescence or CCL of central and peripheral zones, also have different isotopic compositions. We've determined that the peripheral parts have mostly lighter isotopic compositions than the central parts of the same diamond crystals.

Inclusions

We investigated singenetic inclusions in the diamond. Ultrabasic inclusions prevail: olivine, chromite and pyrope. Epigenetic inclusions include serpentine, saponite, magnetite as well as widespread sulphide mixtures. A specific feature of the V. Grib kimberlites, as well as of the other deposits of Archangelsk kimberlite province, is the low content of mineral inclusions and virtual absence of sulphides. There is high concentration of crystals with inclusions "diamond-in-diamond" type (more than 20%), which point to the discreteness of diamond formation.

Conclusions

Diamond crystals from the V. Grib pipe are characterized by high transparence and safety. Indicators of surface dissolution are not everywhere. Mainly, they are localized and therefore there are a large number of octahedral and octahedral-dodecahedral diamond crystals.

We split the crystals into three populations by morphology, nitrogen and hydrogen defects.

Isotopic carbon compositions are typical for kimberlite of ultrabasic origin of world deposits.

Ultrabasic inclusions prevail in the V. Grib pipe.

Multistaged diamond crystallization in the V. Grib pipe was shown by luminescence, the concentration of nitrogen defects, and inclusions of the "diamond-in-diamond" type.

Investigations of the concentrations of nitrogen defects and inclusions in the diamonds have allowed determination of the average temperature of diamond crystallization. Assuming that the diamonds were in the mantle for 3 billion years, then the temperature of diamond formation in the V. Grib pipe is estimated to be 1100-1250°C.

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