

Mineralogy of Diamonds from the Ozerneya Pipe, Ottorzhnets Body, Pervomaiskaya and Novogodnyaya Veins, Yakutia

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Abstract—The paper presents the results of a comprehensive mineralogical study, including IR and UV spectroscopy, of diamonds and related solid inclusions from kimberlitic bodies and veins located adjacent to the Yubileynaya pipe, the largest (59 ha) in the Siberian Platform. This pipe is characterized by a complex structure with diatreme and crater facies of kimberlitic magmatism. The typomorphic features of diamonds from the Ozerneya kimberlitic pipe, Pervomaiskaya and Novogodnyaya veins, and Ottorzhnets kimberlitic body, as well as the Carboniferous–Permian terrigenous sedimentary rocks that overlie the Yubileynaya pipe, are described and compared with those of the Yubileynaya pipe. The typomorphic features of diamonds from the earliest phase of kimberlitic magmatism are emphasized. Diamonds from the Ozerneya pipe are similar to those from the Komsomol'skaya pipe, which is characterized by a low content of typical round crystals and a high content of eclogite-type inclusions in high-quality diamonds of variety I after Yu.L. Orlov. The typomorphic and genetic features of diamonds testify to the multiphase nature of the kimberlitic magmatism of Middle Paleozoic age (about 360 Ma ago). These features are discussed in terms of variation in diamond genesis and types of this mineral.

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INTRODUCTION

The kimberlitic field that comprises the Yubileynaya pipe and the adjacent (within the limits of operating open pit) diamond occurrences is located 15 km northwest of the settlement of Aikhal. The Ozerneya satellite pipe and the Ottorzhnets kimberlitic body are situated nearby. A NE-trending dike swarm accompanies the Yubileynaya pipe.

The Ozerneya pipe is located several tens of meters from the Yubileynaya pipe. This is an oval-shaped body (in plan view) overlain by Upper Paleozoic sedimentary rocks. The contacts of this pipe with country rocks are relatively steep and inclined into the pipe. The pipe is composed of kimberlitic breccia containing up to 35% sedimentary rock fragments (two times greater than in the Yubileynaya pipe) and approximately 8% pseudomorphs after olivine, which is, conversely, half as much as in the Yubileynaya deposit. Xenoliths of crystalline rocks derived from the basement are abundant. The pyrope/picrolilmenite ratio is inverse as compared with that in rocks from the Yubileynaya pipe.

The Ottorzhnets kimberlitic body is shut off from the above pipes; it does not have a feeder and resides in Upper Paleozoic rocks and trap. The western portion of this body outcrops. As has been established, this root-

less kimberlitic body is a shallow-seated fragment of the southeastern flank of the Yubileynaya pipe cut off by a trap sill and displaced for several hundred meters (Kryuchkov et al., 1994a, 1994b; Shamshina et al., 1989). Currently, this block is elevated above the level of the main pipe by more than 35 m. As a result of the dynamic effect of the trap sill, the Ottorzhnets kimberlitic body was delaminated, folded, and crushed and then underwent hydrothermal and supergene alterations. Three types of rocks (porphyritic kimberlite, autolithic breccia, and tuffaceous breccia), which are comparable with those from the Yubileynaya pipe, have been identified within the Ottorzhnets body.

EXPERIMENTAL

This study is based on the results of a comprehensive mineralogical examination of 1047 diamond crystals from drill cores and large-volume samples associated with specific varieties of kimberlitic rocks. The particle size distribution, morphological features of crystals (varieties, habit, twins and intergrowths, etching sculpture), transparency, color, extent of ferrugination, photoluminescence (PL), mineralogy of solid inclusions, degree of preservation, fracturing, and nature of chips were studied. Diamonds of three size classes were examined: $-4 + 2$ mm (tens of crystals) and $-2 + 1$ and $-1 + 0.5$ mm (hundreds of crystals of

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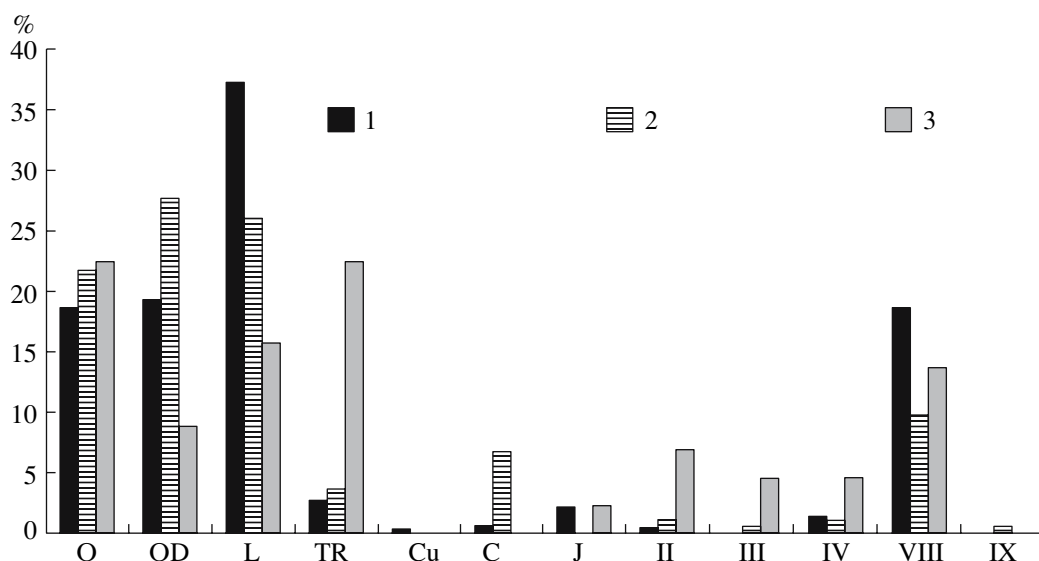


Fig. 1. Typomorphic features of diamonds from the Ozernaya pipe (1), Ottorzhenets kimberlitic body (2), and Pervomaiskaya vein (3). (O) Octahedrons, (OD) octahedron + dodecahedron transitional type, (L) laminate rhombic dodecahedrons, (TR) typical round crystals, (Cu) cubes, (C) chips, (J) Januses of variety I, (II) variety II (yellow-orange cuboids), (III) variety III (gray cubes), (IV) variety IV (diamonds with a shell), (VIII) variety VIII, (IX) variety IX after Orlov (1984).

each class). The amount of examined diamonds is statistically representative for their characterization.

The physical methods were selected according to the recommendations on comprehensive diamond examination given by Kaminsky et al. (1988) and Klyuev et al. (1979, open-file report). Most of these techniques have been applied to Russian and foreign diamond deposits (Sobolev, 1974; Gorshkov et al., 1998; Mineeva et al., 2000). The research methods were previously described in detail by Zinchuk and Koptil (2004).

MINERALOGY OF DIAMONDS FROM THE OTTORZHENETS BODY

About 2000 diamonds were recovered from the Ottorzhenets kimberlitic body in the process of core and large-volume sampling, and 480 diamonds, mainly of size class $-4 + 0.5$ mm, were examined. In general, the specific features of these diamonds are close to those from the Yubileinaya pipe and virtually identical to the crystals from porphyritic kimberlite of its eastern shoot (Khar'kiv et al., 1998; Zinchuk and Koptil, 2002). At the same time, the amount of corroded crystals is even greater than that in tuffaceous breccia of the Yubileinaya pipe (Zhikhareva and Zudin, 1987). Diamonds from the Ottorzhenets body are somewhat larger than those from porphyritic kimberlite of the western and eastern shoots but appreciably smaller than those from autolithic kimberlitic breccia.

In variety of crystals and their habit, diamonds from the Ottorzhenets body (Fig. 1) are virtually identical to those from the Yubileinaya pipe, which has no ana-

logues among other kimberlitic bodies of Western Yakutia. A high content of colored diamonds pertaining to varieties II and IV after Orlov (1984) is characteristic of the Ottorzhenets body. These diamonds are close in their mineralogical and physical properties to the metamorphic crystals from the Kumdykol deposit in Kazakhstan (Lavrova et al., 1999). The abundance of twins and intergrowths is slightly higher than their average abundance in the Yubileinaya pipe but is close to that in porphyritic kimberlite from the eastern and western shoots and tuffaceous breccia. The average content of natural etched crystals in the Ottorzhenets body is higher than in the Yubileinaya pipe and is approximately the same as in porphyritic kimberlite from the eastern shoot and in tuffaceous breccia.

The Ottorzhenets body is enriched in frosted, corroded, and cavernous crystals in comparison with most varieties of kimberlitic rocks in the Yubileinaya pipe (Zhikhareva and Zudin, 1987) except tuffaceous breccia and the Carboniferous–Permian sediments. This implies that diamonds from kimberlite of the Ottorzhenets body, tuffaceous breccia of the Yubileinaya pipe, and the Carboniferous–Permian sediments were corroded after their crystallization and dissolution. Corrosion as carbon oxidizing to form CO_2 probably occurred at 380°C or a higher temperature (Orlov, 1962, 1977). Typical trisoctahedroids of etching were detected among diamonds from the Ottorzhenets body (Kvasnitsa et al., 1999). Crystals of such habit are absent in other Yakutian deposits except the Novinka placer, adjacent to the Internatsional'naya pipe, and the placers located in the northeastern Siberian Platform.

The transparency and color of diamonds from the Ottorzhnets kimberlitic body are the same as in the Yubileinaya pipe. Transparent crystals amount to approximately 75% of all diamonds. The abundance of yellow-green diamonds in the Ottorzhnets body does not differ from that in the Yubileinaya pipe. Distorted diamonds of rhombic dodecahedral habit are predominant among colored diamonds of variety IV in both the Ottorzhnets body and the Yubileinaya pipe. The Ottorzhnets body differs from the Yubileinaya pipe only in the presence of a small amount (approximately 2.3%) of ironshot diamonds.

Diamonds with green PL in UV radiation are predominant in the Ottorzhnets body. In PL features, the diamonds from this body are identical to those from the porphyritic kimberlite of the eastern shoot of the Yubileinaya pipe. Approximately half of the Ottorzhnets diamonds contain solid inclusions of graphite and, less frequently, olivine and chrome spinel. Sporadic inclusions of omphacite and orange garnet are also noted. The bulk amount of solid inclusions in diamonds from the Ottorzhnets body is approximately the same as in the Yubileinaya pipe.

Broken crystals, fragments, and chips make up about 63% of diamonds from the Ottorzhnets kimberlitic body. The degree of diamond preservation is close to that in the Yubileinaya pipe, including porphyritic kimberlite of the eastern shoot. Fractured diamond crystals are dominant in the Ottorzhnets body, and their percentage is slightly higher than the average value in the Yubileinaya pipe but is close to the porphyritic kimberlite from the eastern shoot.

The higher abundance of natural etched (corroded and frosted) diamond crystals in the Ottorzhnets kimberlitic body in comparison with the Yubileinaya pipe is explained by the thermal effect of the trap intrusion.

The diamonds differ in their morphological features, internal structure, and specific properties. Morphological varieties of diamonds are distinguished on the basis of the mineralogical classification proposed by Orlov (1984) and having thorough physical substantiation (Bokii et al., 1986; Galimov, 1984). Furthermore, the diamond varieties are subdivided into groups and crystal types of different habit and face structure (Gnevushev and Bartoshinsky, 1959; Bartoshinsky and Kvasnitsa, 1991; Zinchuk et al., 1999; Afanas'ev et al., 2000). The classification of diamonds used in this study may be readily converted into the modern mineralogical classifications of diamonds applied abroad (Harris et al., 1975; Sunagawa, 1984; *The Properties...*, 1979, 1992).

In terms of Orlov's classification mentioned above, we recognize crystals of varieties I, II, III, and IV and polycrystalline aggregates of varieties VI, VIII, and IX. Genetic types of diamonds were described in detail previously (Zinchuk and Koptil, 2004).

MINERALOGY OF DIAMONDS FROM THE OZERNAYA PIPE

About 2000 diamonds were recovered from core and large-volume samples in the Ozernaya pipe during geological exploration, and 502 crystals, mainly of size class $-4 + 0.5$ mm, were examined. In general, diamonds from this pipe appreciably differ from those that occur in the Yubileinaya pipe and the Ottorzhnets body. The percentage of crystals pertaining to large-size classes is nearly twice as high as in the Yubileinaya pipe.

In morphological features, diamonds from the Ozernaya pipe (Fig. 1) are distinguished from those in the Yubileinaya pipe and are close to diamonds from the Sytykan and Udachnaya pipes. Crystals of variety I are predominant (95%). Many diamonds of this variety (37.1%) are laminar rhombic dodecahedrons, whereas the content of typical round diamonds is very low (2.6%). A significant amount (5.6%) of rhombic dodecahedrons with a tiled-columnar sculpture is a typomorphic feature of diamonds from the Ozernaya pipe. Similar crystals are characteristic of the Dal'nyaya pipe.

As in the Yubileinaya pipe, the morphology of diamonds depends on the crystal size: octahedrons increase in number and rhombic dodecahedrons decrease with diminishing grain size. Twins and intergrowths in the Ozernaya pipe amount to approximately 30% of all diamonds; i.e., their percentage is less than the average value in the Yubileinaya pipe. Natural etched crystals are approximately half of all diamonds. The content of corroded, frosted, cavernous, and tiled-columnar single crystals is higher than in the Yubileinaya pipe. Diamonds with variable transparency are predominant in the Ozernaya pipe (85%). The relative amount of colored crystals is low, especially as concerns yellow-green diamonds (1.2%). In general, the transparency of diamonds from the Ozernaya pipe is higher than that of diamonds from the Yubileinaya pipe. Crystals with green spots of radiative origin (0.2–1.0% of all diamonds) are characteristic of the Ozernaya pipe.

More than half of the diamonds in the Ozernaya pipe (51.9%) are characterized by blue PL in UV radiation, and many crystals show green PL. In cathodoluminescence, diamonds from the Ozernaya pipe markedly differ from those in the Yubileinaya pipe, being similar in this respect to the Udachnaya and Sytykan pipes.

The total abundance of solid inclusions in diamonds from the Ozernaya pipe is 37.5%, which is lower than in the Yubileinaya pipe. Diamonds with syngenetic inclusions amount to 3% of all inclusion-bearing diamonds. Olivine is the most abundant syngenetic inclusion; one inclusion of orange garnet has been observed.

As in the Yubileinaya pipe, broken diamonds are predominant in the Ozernaya pipe. Unbroken crystals are rare (34.7%), as in the Yubileinaya pipe and other

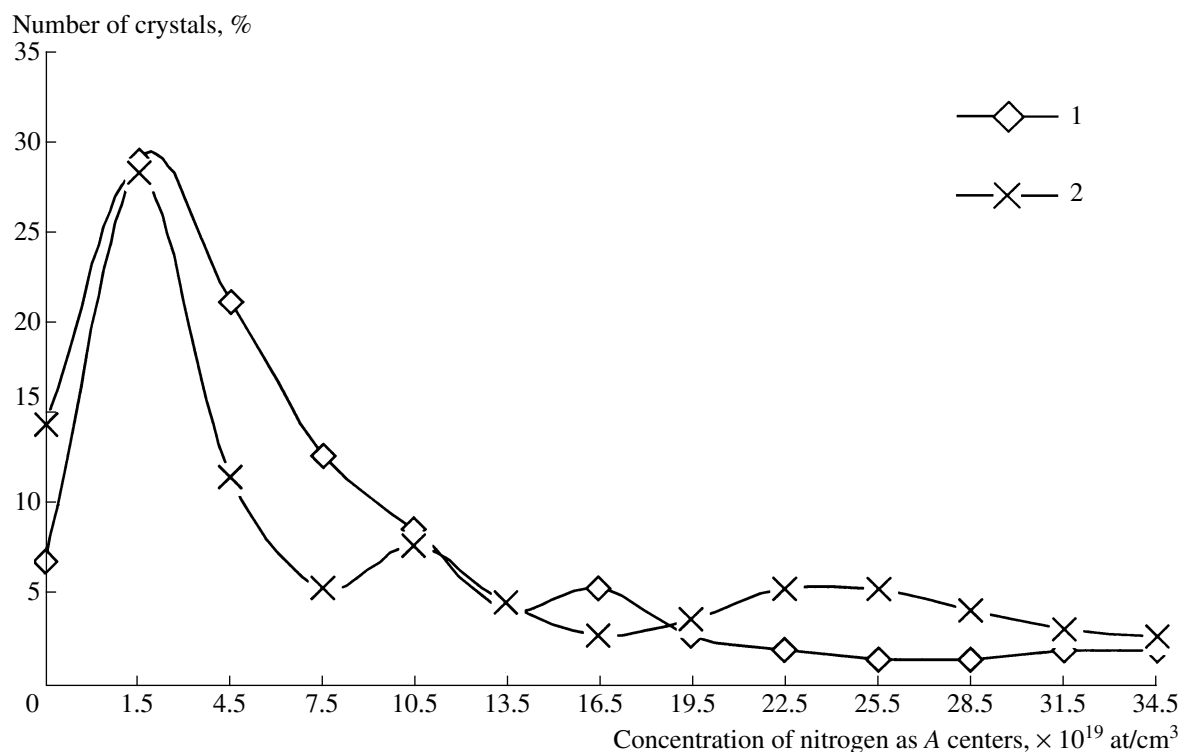


Fig. 2. Distribution of diamond crystals from the (1) Ozernaya pipe ($n = 134$) and (2) Pervomaiskaya vein ($n = 60$) in terms of the concentration of nitrogen impurity as A centers, after Bilenko (1982) and *Diamond Deposits...* (1984). n is the number of examined crystals.

deposits. Most diamonds are fractured. The amounts of technological and protomagmatic chips are almost equal. The large size of crystals, the relatively high content of transparent grains, and a lesser amount of flawed crystals pertaining to varieties IV and VIII and of grains with inclusions determine a higher quality of diamonds from the Ozernaya pipe in comparison with the Aikhal, Yubileinaya, and Sytykan pipes.

The results of IR and UV spectroscopy are shown in Figs. 2–5. The bi- and trimodal distributions of nitrogen impurity as an A center with the main maximum in the region $1.5\text{--}4.5 \times 10^{19} \text{ cm}^{-3}$ are generally consistent with the data reported by Bilenko (1982) for the UV range of the spectrum, but are more complicate due to a wider range of measurements.

According to the results of IR spectroscopy, the distribution of nitrogen impurity as an A center in diamonds in the Ozernaya pipe is bimodal with a distinct maximum (37%) within the low-nitrogen region at $4.5 \times 10^{19} \text{ cm}^{-3}$ and a weak broad maximum within the high-nitrogen region at $16.5\text{--}19.5 \times 10^{19} \text{ cm}^{-3}$. The extremely low concentration of nitrogen impurity as B1 and B2 centers differs diamonds from the Ozernaya pipe from diamonds in the Yubileinaya pipe and other deposits of the Daldyn–Alakit diamond-bearing district (Kaminsky et al., 1988; Sobolev and Lisoivan, 1978; Kaminsky and Khachatryan, 2001). The B1 center concentration in most diamonds (approximately 2/3 of the

examined crystals) ranges from 0.25 to $1.75 \times 10^{19} \text{ cm}^{-3}$ and the distribution pattern is a straight line gently sloping to the right. The distribution of nitrogen impurity as a B2 center looks the same; the majority of diamonds (approximately 2/3 of the examined crystals) fall in the range of low ($0.25\text{--}1.75 \times 10^{19} \text{ cm}^{-3}$) content of the B2 center.

The results obtained testify to variable proportions of nitrogen impurity as A, B1, and B2 centers in diamonds from kimberlitic bodies closely spaced within the same field but different in diamond grade as an indicator of the thermodynamic and geochemical conditions of diamond formation.

Hence, the results of IR spectroscopy corroborate the typomorphic features of diamonds and may serve as guides for identification of kimberlitic bodies and even separate shoots within a pipe. It is also evident that diamonds of variety I were derived from different mantle sources.

Thus, the typomorphic features of diamonds in the Ozernaya pipe are different from those in the Yubileinaya pipe. This difference indicates that the Ozernaya and Yubileinaya pipes are not coeval. Diamonds from the Ozernaya pipe are characterized by the predominance of grains from the dunite–harzburgite assemblage and the absence of crystals from the eclogitic assemblage (varieties II and IV) along with an elevated content of eclogitic inclu-

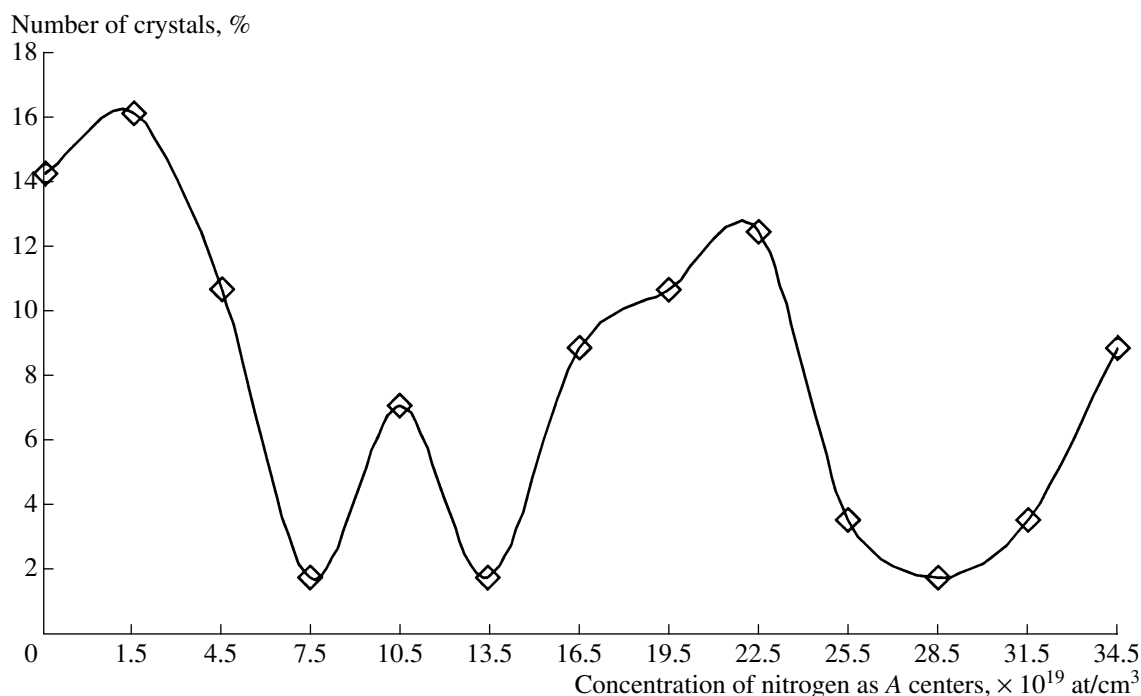


Fig. 3. Distribution of diamond crystals from the Ozernaya pipe ($n = 63$) in terms of the concentration of nitrogen impurity as A centers, after Yu.A. Klyuev (1985, 1986, open-file reports). n is the number of examined crystals.

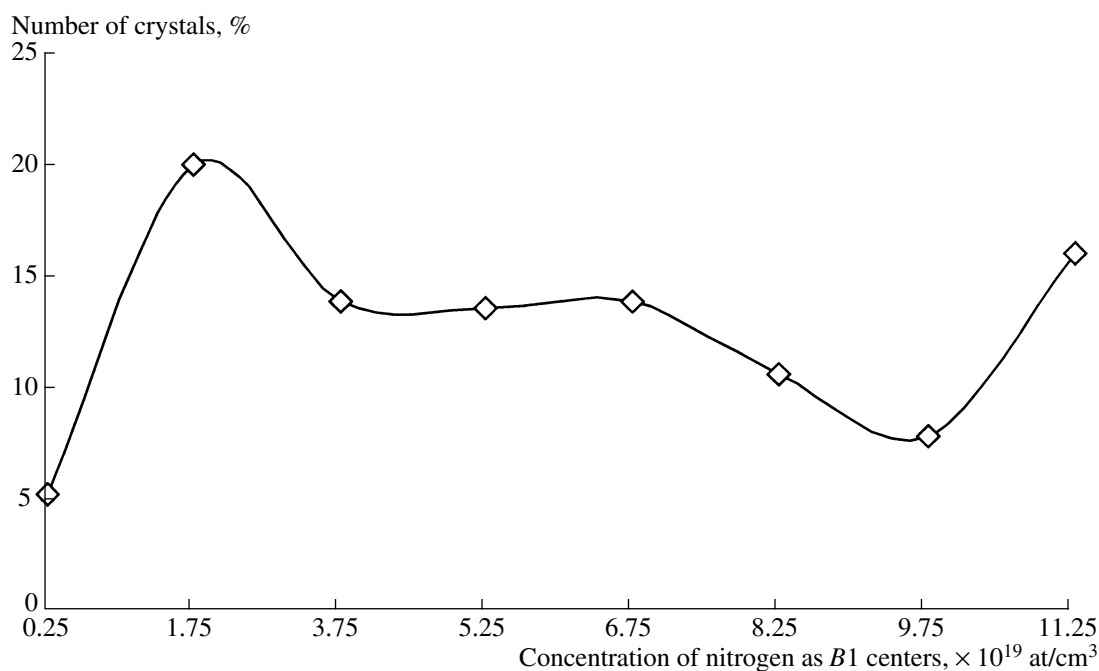


Fig. 4. Distribution of diamond crystals from the Ozernaya pipe ($n = 63$) in terms of the concentration of nitrogen impurity as B1 centers, after Yu.A. Klyuev (1985, 1986, open-file reports). n is the number of examined crystals.

sions (up to 10%, i.e., almost 20 times higher than in the Yubileynaya pipe) (Efimova and Sobolev, 1977). This specific feature brings the Ozernaya pipe closer to the Komsomol'skaya pipe in the Alakit–Markha kimberlitic field, located 17 km northwest of the

Aikhmal pipe. A large size and high quality of diamonds also draw the Ozernaya and Komsomol'skaya pipes together. The Ozernaya pipe might be mined in the future in parallel with the Yubileynaya pipe in the same open pit.

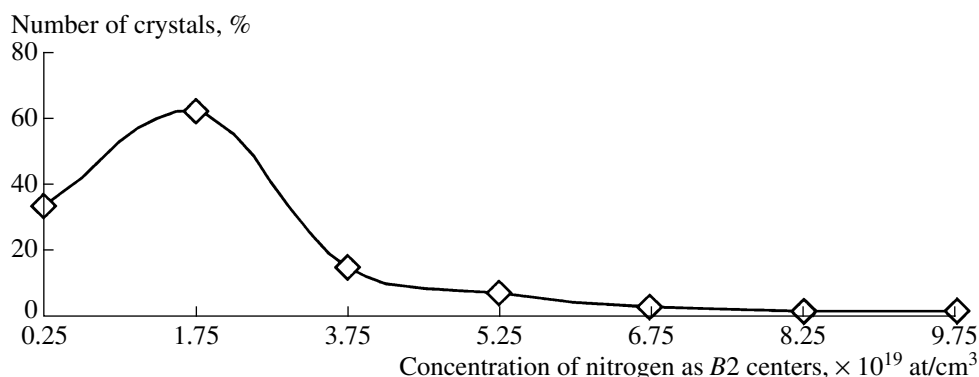


Fig. 5. Distribution of diamond crystals from the Ozernaya pipe ($n = 63$) in terms of the concentration of nitrogen impurity as B2 centers, after Yu.A. Klyuev (1985, 1986, open-file reports). n is the number of examined crystals.

It should be noted that kimberlite of the Ozernaya pipe differs from that in the Yubileinaya pipe in an elevated content of almandine garnet, which is close in composition to the crustal garnets from crystalline schists. In our opinion, this indicates different conditions of kimberlite formation and a different depth of the magmatic chambers that fed the major and the satellite pipes. The same was pointed out previously for the doubled kimberlitic pipes Mir and Sputnik in the Lesser Botuoba diamond-bearing district, Yakutia (Khar'kiv et al., 1998). The Sputnik pipe is distinguished by an almost 30 times higher content of diamonds pertaining to variety I after Orlov (1984) and containing eclogitic inclusions.

MINERALOGY OF DIAMONDS FROM KIMBERLITIC VEINS IN THE VICINITY OF THE YUBILEINAYA PIPE

Fifty-six diamonds mainly of size class $-2 + 0.5$ mm were studied from kimberlitic veins in the area of the Yubileinaya pipe, including 45 diamonds from the Pervomaiskaya vein (to the northeast of the pipe), 5 crystals from a vein located close to the western shoot, and 6 diamonds from the Novogodnyaya vein. Such an amount of diamonds (except for the Pervomaiskaya vein) is not statistically representative, but provides a rough idea of their typomorphic features.

The Pervomaiskaya Vein

The size of the examined diamonds ranges from 4 to 0.5 mm. The largest crystal, of 0.64 carats (drill hole 311), is a smoky brown laminar rhombic dodecahedron of variety I after Orlov (1984) with numerous facets {100} containing ingrowths of smaller crystals. The fractured crystal is characterized by yellow-green PL and numerous inclusions of graphite. One yellow octahedron with a shell of diamond pertaining to variety IV after Orlov (1984) was detected in size class $-4 + 2$ mm. Nine obviously technogenic fragments of this crystal

ranging from -4 to $+0.5$ mm in size were excluded from the mineralogical description.

The colored flawed crystals that are characteristic of diamonds from the Pervomaiskaya vein (Fig. 1) comprise uniformly colored yellow cuboids of variety II (6.7%), gray cubes of variety III (4.4%), yellow and yellow-green combined polyhedrons (octahedrons and tetrahexahedroids) of variety IV (4.4%), and gray polycrystalline aggregates of variety VIII (13.4%). The total content of colored flawed crystals is 28.9%, which is the maximum value in the Alakit–Markha kimberlitic field.

In addition, a high content (22.1%) of round crystals belonging to variety I after Orlov (1984) is characteristic of the examined diamonds. These crystals mainly are dodecahedroids with shagreen and bands of plastic deformation (17.8%) of the vein type (Afanas'ev et al., 1974). Laminar octahedral, rhombic dodecahedral, and combined diamonds amount to 46.7% of the total crystals. An extremely high content (13.4%) of flat-faced octahedrons in size class $-1 + 0.5$ mm with trigonal growth layers, which are often complicated by flat faces of a rhombic dodecahedron, trisoctahedron, or cube (Kvasnitsa et al., 1999), is characteristic of this group. Crystals pertain to the eclogitic type and are frequently gray and graphitized. Numerous diamonds of this kind were found previously among fragments of eclogitic nodules in the Udachnaya West pipe in association with gray cubes (variety III) and polycrystalline aggregates (variety VIII after Orlov (1984)). The established 1.5-fold prevalence of octahedrons (22.3%) over laminar rhombic dodecahedrons is not typical of kimberlite in the Yubileinaya pipe.

A high content of twins and intergrowths (42.2%) with a predominance of irregular intergrowths (20.0%) mainly in the class $-1 + 0.5$ mm is a typomorphic feature of the studied diamonds, which brings them together with microcrystals of the class $-0.5 + 0.2$ mm from some kimberlitic bodies in the Alakit–Markha field (Radiovolnovaya, Vostok, 30 let Aikhala, Bobkov, and Shchukin), where the content of such microcrystals

ranges from 38.6 to 72.0% of the total number of crystals (Kvasnitsa et al., 1999). Etching sculptures are not characteristic of the examined diamonds (11.1%) and occur only as scars.

Diamonds from the Pervomaiskaya vein are distinguished by low transparency with a predominance of translucent crystals. The low transparency is related to the high abundance (57.5%) of variously colored diamonds. Gray diamonds (due to graphite inclusions) of varieties VIII, III, and partly I (22.2%); smoky brown and violet-brown (due to plastic deformation) crystals of variety I (17.7%); yellow and yellow-orange diamonds of varieties II and IV; and yellow-green and dirty green crystals of variety IV after Orlov (1984) are predominant. The contents of yellow (variety IV) and gray (variety VIII) diamonds in the classes $-4 + 2$ and $-2 + 1$ mm are elevated in comparison with the class $-1 + 0.5$ mm.

Crystals with solid inclusions are appreciably predominant (64.4%). Epigenetic graphite-sulfide inclusions in the form of rosettes (44.4%) and with numerous flakes of epigenetic graphite (17.8%) are recognized; one inclusion of chrome spinel (2.2%) has been detected.

Crystals with blue PL (15.6%) are combined with crystals that reveal orange (15.6%) and yellow (8.8%) or weak and uncertain PL (20.0%) and crystals devoid of visible luminescence in UV radiation. Yellow and orange PL is largely characteristic of yellow cubes (variety II), gray aggregates (variety VIII), and gray octahedrons of the eclogitic type (variety I after Orlov (1984)). It is noteworthy that, in spite of the imperfection of diamonds, the percentage of unbroken and only slightly damaged crystals is rather high (46.6%); the amount of broken (26.7%) and fragmented (20.5%) crystals is also significant. Protomagmatic spalls on diamonds are abundant (35.6%).

The diamonds show an increased degree of fracturing, with a predominance of crystals having only sporadic fractures (51.1%) and a relatively great amount of severely fractured crystals (15.6%).

Thus, in general, diamonds from the Pervomaiskaya vein are similar to those from porphyritic kimberlite in the Yubileynaya pipe and the Ottorzhenets body but are distinguished by a two to three times higher content of colored crystals belonging to varieties II, III, IV, and VIII; specific gray octahedrons of variety I; and dodecahedroids of variety I after Orlov (1984) with shagreen and bands of plastic deformation of the vein type. The latter is consistent with our data on dodecahedroids of variety I with shagreen and bands of plastic deformation as a typomorphic feature of diamonds from both kimberlitic veins (Afanas'ev et al., 1974) and low-grade pipes related to a separate phase of kimberlitic magmatism (porphyritic kimberlite). This phase predated formation of highly productive kimberlitic bodies in the fields of the Daldyn-Alakit diamond district (Zinchuk et al., 1999).

A Vein in the Vicinity of the Western Shoot

Five crystals, mainly of size class $-1 + 0.5$ mm, were examined. The absence of colored diamonds of varieties II, III, IV, and VIII is a characteristic feature. Crystals of transitional habit from octahedral to rhombic dodecahedral (60%) are prevalent in variety I in combination with octahedrons and laminate rhombic dodecahedrons, occurring in equal amounts (20%), and in the absence of typical round diamonds.

Numerous diamonds (80%) are twins, intergrowths, and separate crystals without etching. Transparent crystals are predominant, most of which (60%) are slightly violet-brown. Eighty percent of diamonds contain epigenetic graphite-sulfide inclusions. The diamonds are characterized by blue (60%) and yellow-green (40%) PL. Eighty percent of diamonds are unbroken or slightly damaged, largely with sporadic fractures.

These diamonds are markedly different from those in the Pervomaiskaya vein and the porphyritic kimberlite of the western and eastern shoots of the Yubileynaya pipe and at the same time are similar to crystals from the Ozernaya pipe (the statistically unrepresentative amount of samples should be kept in mind).

The Novogodnyaya Vein

All examined diamonds from the Novogodnyaya vein are microcrystals of size class $-0.5 + 0.2$ mm. Octahedral and transitional from octahedral to rhombic dodecahedral crystals (50 and 33.3%, respectively) of variety I after Orlov (1984) are predominant, with laminate rhombic dodecahedrons and typical round diamonds being completely absent.

At the same time, an evenly colored yellow tetrahexahedroid (variety II) with orange PL, which is typical of the Yubileynaya pipe and absent in the other known primary deposits (except the Aikhal pipe), was found in the Novogodnyaya vein. A smoky brown graphitized irregular aggregate of octahedrons with trigonal growth layers of eclogitic type and signs of corrosion of variety I after Orlov (1984) occurs in this vein among diamonds of variety I, as in the Pervomaiskaya vein. The amount of diamonds with indications of natural etching but devoid of scars is low (8.3%). Transparent and translucent crystals (50 and 33.3%, respectively) are dominant. Violet-brown (33.3%) and yellow varieties are half of the total diamond crystals. Diamonds with epigenetic graphite-sulfide inclusions amount to one-third of the total crystals. Diamonds with blue PL (33.3%) are dominant, with sporadic crystals having orange, yellow-green, or weak uncertain PL and some crystals being completely devoid of luminescence. Unbroken and slightly damaged crystals (50%) are dominant; most of them (83.3%) are not fractured.

Thus, of the three kimberlitic veins described above, only the Pervomaiskaya vein may be compared with porphyritic kimberlite of the Yubileynaya pipe in high

contents of colored crystals of varieties II, III, IV, and VIII. At the same time, this vein is distinguished by elevated contents of dodecahedrons with shagreen and bands of vein-type plastic deformation and by gray graphitized flat-faced octahedrons of eclogitic type (variety I). These typomorphic features are characteristic of the early, relatively shallow-seated phase of kimberlitic magmatism in the area of the Yubileinaya and Ozerneya pipes. Dodecahedroids with shagreen and bands of plastic vein-type deformation of variety I are absent in the other two veins, as is typical of diamonds in veins that accompany kimberlite pipes. Taking into account the statistically unrepresentative amount of examined diamonds, these veins may be assumed to be offsets of the Yubileinaya and Ozerneya pipes.

MINERALOGY OF DIAMONDS FROM THE CARBONIFEROUS-PERMIAN SEDIMENTARY ROCKS

Sixty-nine diamonds of size class $-2 + 0.5$ mm were recovered from the Carboniferous-Permian sedimentary rocks during exploration of the underlying Yubileinaya pipe. These diamonds are similar to those from the pipe in morphology and other features. The proportions of varieties and habits of diamonds are the same as well. In particular, the content of colored diamonds with an outer shell of variety IV, which are typomorphic for the Yubileinaya pipe, is 6%. The other morphological features (twins, intergrowths, and etching sculptures) reveal the same similarity. It should be emphasized that the amount of etched crystals from the Carboniferous-Permian sedimentary rocks is equal to that from tuffaceous breccia and the Ottorzhennets kimberlitic body.

The Carboniferous-Permian rocks should be referred to as lagoonal-lacustrine deposits of short-range transport. The results of a comprehensive mineralogical study indicate that these deposits did not undergo rewashing, redeposition, or sorting of diamonds.

DISCUSSION

With exception of a paper by Harris et al. (1979), we could not find in the published literature comparative characteristics of diamonds from several kimberlitic pipes located within the same field. The absence of these data does not allow comprehensive insight into the origin of diamond in kimberlites.

The geological structure, composition, and formation conditions of slightly eroded kimberlitic bodies are exemplified in the Yubileinaya pipe of the Daldyn-Alakit diamond district, Yakutia (Khar'kiv et al., 1998; Kryuchkov and Khar'kiv, 1989; Kryuchkov et al., 1994a, 1994b; Shamshina et al., 1989). However, the mineralogy and origin of diamonds were not considered in these publications. As is known, diamond has a wide range of mineralogical and physical attributes that

characterize the diversity of the thermodynamic and geochemical conditions of its formation. The detailed examination of discrete crystals and polycrystalline aggregates of diamonds from kimberlites has shown that varieties with certain typomorphic features (morphological, structural, geochemical, paragenetic, etc.) indicate the special crystallization conditions of each variety (Orlov, 1984). The occurrence of diverse varieties and polycrystalline aggregates of diamonds in the same kimberlitic pipe and separate shoots testifies to complex genesis of the mineral. In other words, the diamonds could not have originated under the same conditions and as products of the same process.

Diamonds are affected by epigenetic alteration, which frequently changes the primary morphology and even some physical properties of crystals. The distribution of diamond varieties demonstrates vertical inhomogeneity of the upper mantle beneath the same kimberlitic field and different depths of magmatic sources of kimberlitic bodies, even spatially juxtaposed but emplaced asynchronously. An elevated content of typical round diamonds mainly with shagreen and bands of plastic deformation of the vein type (Afanas'ev et al., 2000) is characteristic of veins of first-stage kimberlitic magmatism and is regarded as a negative factor of the diamond resource potential of kimberlites (Koptil, 1999). A predominance of distorted rhombic dodecahedral diamonds with a significant amount of typical round diamonds and dodecahedroids with shagreen and bands of plastic deformation is characteristic of this stage. The round diamonds and dodecahedroids are the final form of dissolution of octahedral crystals originating as a result of antiskeletal growth. The Ozerneya pipe was formed during the next phase of kimberlitic magmatism, which is characterized by a minimum rate of diamond dissolution and a very low content of typical round crystals in combination with an elevated content of eclogitic solid inclusions, a larger size of diamond crystals, and a high quality of diamonds. This brings the Ozerneya pipe together with the Komsomol'skaya pipe (the Daldyn-Alakit diamond-bearing district), which is distinguished by a low diamond resource potential but the best diamond quality in comparison with other Yakutian deposits. This circumstance allowed ALROSA Company to start mining the Ozerneya pipe in 2002. It may be suggested that stable P - T crystallization conditions of the Komsomol'skaya and Ozerneya pipes ensured the good preservation of diamonds during the ascent of kimberlitic magma and a low abundance of flawed crystals.

CONCLUSIONS

The study performed allowed us to obtain the characteristics of a particular field of kimberlitic bodies different in typomorphic features. Diamonds from the Ottorzhennets kimberlitic body are similar to those from porphyritic kimberlite of the Yubileinaya pipe. Natural etched (frosted and corroded) crystals (up to 3-4%),

which are similar to diamonds from tuffaceous breccia (2–3%), were established in the Ottorzhnets body.

Diamonds from the Ozernaya pipe are characterized by special typomorphic features that are markedly different from those of diamonds in the Yubileinaya pipe. In some properties, diamonds from the Ozernaya pipe are similar to crystals from the Udachnaya and Komso-mol'skaya pipes.

Diamonds from the Pervomaiskaya vein are generally close to those from porphyritic kimberlite in the eastern shoot of the Yubileinaya pipe and the Ottorzhnets kimberlitic body, but are distinguished by an elevated content of dodecahedroids of vein type and gray eclogitic octahedrons of variety I after Orlov (1984).

The typomorphic features of diamonds from the Yubileinaya pipe and the adjacent kimberlitic pipes and veins were studied by physical methods for the first time. The typomorphic features of diamonds pertaining to specific genetic varieties are distinguished by a set of properties that indicate the diversity of their thermodynamic and geochemical conditions of formation. The results of a comprehensive examination of diamonds from the Yubileinaya and Ozernaya pipes, the Ottorzhnets body, and kimberlitic veins show an important role of crystals from the eclogitic assemblage in the Pervomaiskaya vein and the Ozernaya pipe. A shallow-seated magmatic chamber with a significantly increased contribution of eclogitic diamonds is characteristic of the early phase of kimberlitic magmatism.

The data obtained indicate that multiple phases of kimberlitic magmatism may be documented within a local area of spatially juxtaposed kimberlitic pipes. According to our data, the diamonds of the Yubileinaya pipe are distinguished with confidence from those related to other kimberlitic bodies. The discovery of the sheetlike Ottorzhnets body, which contains diamonds with specific features typomorphic for the Yubileinaya pipe, suggests that this body is a fragment of porphyritic kimberlite of the eastern shoot that was cut off by a trap sill and displaced from the Yubileinaya pipe (Kryuchkov and Khar'kiv, 1989; Kryuchkov et al., 1994a, 1994b; Khar'kiv et al., 1998). A comprehensive mineralogical and physical examination of diamonds from the Yubileinaya pipe, the Ottorzhnets body, and the Pervomaiskaya vein has allowed us to take a further step in the study of diamonds that have a complex history and different origins and are related to multiple kimberlitic intrusions. The diamonds from the Carboniferous–Permian terrigenous rocks are typical of lagoonal–lacustrine facies of short-range transport that did not undergo rewashing and redeposition, i.e., a process that commonly provides sorting and improves the quality of diamonds.

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