Analysis of Distribution of Secondary Minerals and their Associations on The Surface of Diamonds and in Derrivative Products of Metasomatically Altered Kimberlites

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Abstract

The theoretical and experimental studies resulted in establishing regularities in the distribution of secondary minerals and their associations in metasomatically altered diamond-bearing kimberlites and products of their processing.
Based on integrated mineralogical research, it was found out that the composition of the altered kimberlites and the fine-dispersed clayey slurries formed during their processing constituted the basis of hydrophilic formations on the surface of diamond crystals not recovered by the methods of grease and froth separation. Particles of these minerals concentrate in fine-dispersed slurry products of kimberlite ore processing, interact with the crystal surface, reduce their hydrophobic properties and, accordingly, recovery in processes of grease and froth separations into concentrates.

Keywords: kimberlites, secondary minerals, associations, slurries, hydrophilic diamond, flotation

Introduction

One of the reasons for the decrease in recovery of diamonds from kimberlite is the hydrophilicity the surface of the crystals and pinning her slurry coatings [Chanturia et al, 2013, Dvoichenkova et al, 2014]. Hydrophilization the surface of the diamond is most pronounced in the processing of hypergene altered kimberlites (Chanturia 2016 et al., Zhang et al., 2012).

The upper horizons of kimberlite pipes have been thoroughly studied and the technology of diamond recovery at mineral separation plants has been perfected for them. In the transition to the development of deep horizons of diamond deposits, ore blocks of intensely altered kimberlite rocks of complex material composition were discovered (Westhyzen et al., 2013).

In altered ore blocks, kimberlites are transformed due to metasomatic processes into clay minerals and talc, which constitute up to 96% of the binder mass. In all rocks, clay minerals with smectite laminates were noted: Na-smectite, mixed lattice talc-smectite and chlorite-smectite. The main cause of changes in the mineral composition of kimberlites are hypergenic processes occurring in the field under the influence of hypergenic hydrogeological processes (Zinchuk, 1994, 2000, Podchasov et al., 2004).

The purpose of the given studies was to establish the regularities of distribution of secondary minerals and their associations in kimberlite ores, slurry products of their processing, mineral formations on the surface of diamonds for their subsequent systematization and classification.

Research objects and methods

Samples of altered kimberlites taken from different horizons of kimberlite pipes were studied as objects of research. Secondary minerals and their associations contained in the initial kimberlite samples, slurry fractions of their processing and mineral formations on the surface of diamonds were studied. An experimental analysis of the mineral composition of the studied objects was carried out using semi-quantitative X-ray and thermographic methods and the following equipment: X-ray diffractometers DRON-2.0 (Burevestnik), DMAX-2400 (Rigaku), ARL X`TRA-155 (Thermo scientific), DTG-60AH thermal analyzer (Shimadzu), X'tra-155 diffractometer. The chemical composition of mineral components is determined by the micro-X-ray spectral analysis using a JXA-8800R microanalyzer. The study of the diamond surface was carried out by comparing the reference infrared spectra of passing layered minerals with foreign material streaks on diamonds.

The experiments were performed in the laboratories of the Research Institute of Comprehensive Exploitation of Mineral Resources under the Russian Academy of Science and the Scientific Research and Geological Exploration Enterprise of PJSC ALROSA.

At the first stage of the research, the initial samples of refractory altered kimberlites selected from different horizons of kimberlite pipes of Western Yakutia, were studied. At the second stage of the research, experiments were carried out to study the distribution of secondary minerals, their associations

Tab. 1. Distribution of secondary minerals in the studied samples of altered kimberlites
Tab. 1. Rozkład minerałów wtórnych w badanych próbkach kimberlitów

Minerals	Mine						
	"Mir"	"Internatsio-nalnaya"	"Butobin-skaya"	"Nurbins-kaya"	"Ubiley-naya"	"Aykhal"	"Udach-naya"
Serpentine	45	36	19	18	35	11	24
Mica	7	4	10	19	3	11	8
Chlorite	2	14	8	7	0	1	2
Talc	2	3	2	10	0	0,4	1,8
Calcite	34	5	31	17	41	20	49
Dolomite	0	14	17	20	3	47	11

in finely divided slurry products of processing rebellious kimberlite ores. At the third stage of the research, the surface of natural diamonds not recovered in the processes of grease and froth separations of altered kimberlites was studied.

Experimental work findings and their discussion

The performed studies in the samples of altered kimberlites helped diagnose secondary minerals and their associations. Regularities in the distribution of the diagnosed elements in the products of processing of kimberlite ores and on the surface of diamond crystals have been established [Chanturia et al, 2014].

Secondary minerals are the minerals formed in kimberlites at the postmagmatic stage during the hydrothermal transformation of rocks at temperatures below 600°C (Zinchuk, 1994, 2000; Podchasov et al., 2004)

At the first stage of the research, the mineral and phase composition analysis showed that in these samples these minerals make up the main volume of kimberlite rocks (90–95%), with the main ones being serpentine and carbonates. Associations of secondary minerals have been diagnosed: serpentine – carbonates, chlorite – serpentines, talc – serpentines, smectite – serpentines, talc-carbonates, smectite-carbonates.

Table 1 shows the average results of the performed study of the composition of kimberlite samples, and the distribution of the diagnosed secondary minerals in them.

The analysis of the Distribution of secondary minerals made it possible to conclude about the mineral composition and the degree of alteration of the kimberlite samples under study and classify them according to the following characteristics: secondary mineralization and the degree of alteration.

By the nature of secondary mineralization, the objects under study can be divided into four groups.

1. Serpentized and chloritized ones, represented by samples of altered kimberlites of “Mir” and “International” pipes.
2. Carbonatized with the dominance of calcite, represented by samples of altered kimberlites of “Yubileinaya” and “Udachnaya” pipes.
3. Carbonatized with the dominance of dolomite, represented by samples of altered kimberlites of “Aikhal” pipes.
4. Serpentized, chloritized and carbonatized with the same distribution of calcite and dolomite, represented by samples of altered kimberlites of “Nyurbinskaya” and “Botuobinskaya” pipes.

In accordance with the content of clay minerals and the distribution of associations of secondary minerals, the studied objects are classified into two main groups: altered and slightly altered. The first group includes samples of altered kimberlites of the “International”, “Botuobinskaya”, “Nyurbinskaya” and “Mir” pipes, in which secondary minerals and their associations are often diagnosed, and also in large quantities. The second group includes samples of altered kimberlites of the “Udachnaya”, “Aikhal”, “Yubileynaya” pipes, in which the secondary minerals and their associations are diagnosed less frequently and in smaller quantities.

At the second stage of the research, the distribution of secondary minerals, their associations in finely divided slurry products of processing of rebellious kimberlite ores were studied.

It has been established that the slurry sands contain fewer secondary minerals - serpentine, chlorite, talc, and calcite. However, the content of quartz increases in them, the amount of X-ray amorphous and amorphous phases represented by finely dispersed smectite and mixed layers also increases. The content of talc-smectite-serpentine associations, which have an enhanced ability to interact with the surface of diamond crystals, increases.

The studies of the distribution of secondary minerals in various granulometric classes of the fineness of shown in table 3, revealed that when the size of the slurry particles decreases, their content of smectite and X-ray amorphous phases increases. An intensive increase in the small classes of talc-serpentine and smectite-serpentine associations typical for altered kimberlites, has been established. At the same time, the fine classes of the slimes studied, the amount of talc-serpentine associations relative to the initial samples of kimberlites increases approximately twice and smectite-serpentine in 8 times.

At the third stage of the research, the surface of natural diamonds that are not recovered in the processes of grease and froth separations of altered kimberlites was studied.

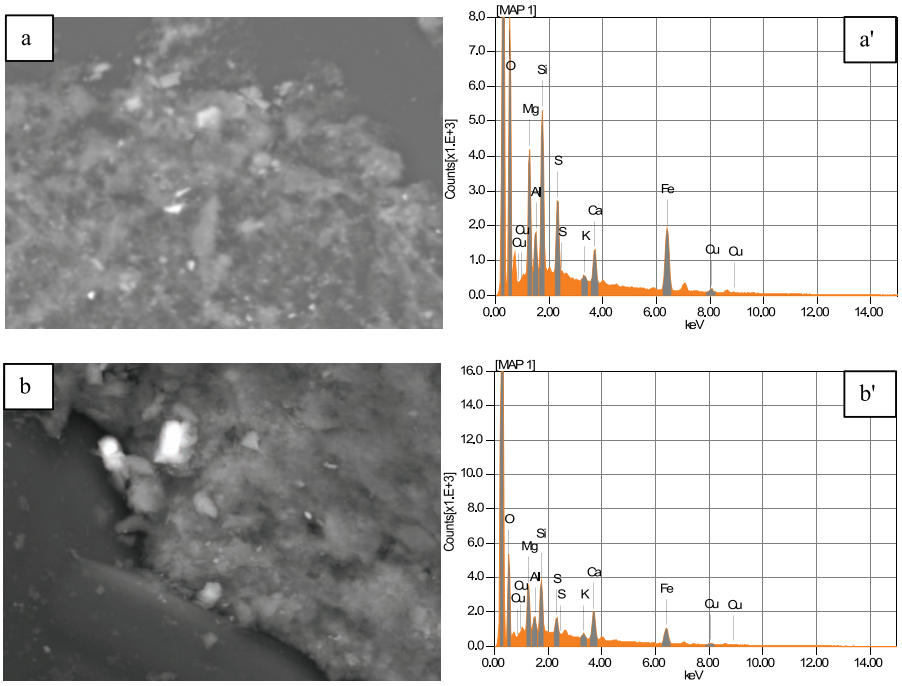
Additional bands of mineral impurities on their surface in the region λ of 670 cm^{-1}, 1010 cm^{-1} and 3675 cm^{-1} were recorded in the IR spectra of the investigated diamonds. The presence of silicate minerals of talc group, similar to the composition of fine slurries of industrial pulps, was identified by the arrangement of lines in the IR spectra of the diamond surface.

The IR spectra of the diamonds studied disclosed additional streaks of mineral impurities on their surface in the region λ of 670 cm^{-1}, 1010 cm^{-1} and 3675 cm^{-1}. The presence of silicate minerals of the talc group similar to the composition

Tab. 2. Distribution of secondary minerals in slurry classes of pulp of altered kimberlites processing
Tab. 2. Rozkład minerałów wtórnych w klasach ziarnowych wzbogacanych kimberlitów

Minerals	Mine			
	the processed ore	Class -0.05 + 0.01 mm	Class -0.01 + 0.001 mm	Class -0.001 mm
Serpentine	18	12	11	15
Mica	17	3	3	1
Chlorite	8	7	7	7
Talc	9	2	1	1
Smectite	2	3	3	3
Calcite	17	7	5	3
Dolomite	19	17	8	3
Quartz	3	7	4	3
Fine minerals associations (x-ray amorphous)	1	37	53	72

Fig. 3. Talc is mixed-layer smectite formations on the surface of diamonds isolated from the kimberlites of the Mir (a) and Internatsionalnaya (b) pipes and results of their x-ray spectral analysis (a', b')
Rys. 3. Talk pod postacią warstw smektytu powierzchni diamentów wydzielonych z kimberlitów z Mir (a) i Internatsionalnaya (b) oraz wyniki spektralnej analizy rentgenowskiej (a', b')



of fine-dispersed slurries of industrial pulps was identified by the line locations in the infrared spectra of the diamond surface.

In addition, the identity of changes in the spectrograms of the diamonds surface in various deposits has been established (Figure 3).

The nature of the location of the Si-O and OH-lines on the spectrograms of the diamond surface in two kimberlite deposits enabled to establish the presence of the talc group silicates with an increased content of oxygen and aluminum.

The diagnosed hydrophilic mineral formations on the surface of the studied diamond crystals are identical in composition and distribution of secondary minerals and their associations to the initial samples and slurry classes of modified kimberlites. The obtained results give grounds to believe that fixing of slurry classes of hypergenic minerals on the surface of diamonds is an important reason for reducing their floatability.

Conclusions

Thus, based on the results of comprehensive mineralogical studies, it has been found that in accordance with the content of clay minerals and the distribution of associations of secondary minerals, the kimberlite ores can be classified into two main groups: altered and slightly altered.

The content of smectite, mixed-layer formations, quartz, talc and X-ray amorphous (finely dispersed) phases increases in slurry products of processed kimberlites with lower values of the quantity of main secondary minerals - carbonates, serpentine and chlorite. In the formed fine-dispersed slurry fractions, the number of paragenetic associations of secondary minerals of kimberlites decreases and the number of associations typical for altered kimberlites increases substantially. Hydrophilic mineral formations on the surface of the studied diamond crystals are identical in composition and distribution of secondary minerals and their associations to the original samples of altered kimberlites.

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Analiza rozkładu minerałów wtórnych i ich rozkładu na powierzchni diamentów i produktów pochodnych metasomatycznie zmienionych kimberlitów

Przeprowadzono analizę teoretyczną i badania eksperymentalne w celu ustalenia prawidłowości w rozkładzie minerałów wtórnych i ich związków w metasomatycznie zmienionych diamentach kimberlitowych i produktach ich przetwarzania. Na podstawie zintegrowanych badań mineralogicznych stwierdzono, że zmienione kimberlity i drobnoziarniste produkty ich metamorfozy stanowiły hydrofilowe formacje na powierzchni kryształów diamentu, które nie zostały odzyskane metodami flotacji pianowej. Cząstki tych minerałów koncentrują się w drobno zdyspergowanych produktach przerobu rudy kimberlitowej, oddziałują z powierzchnią kryształu, redukują ich właściwości hydrofobowe i odpowiednio przechodzą w procesach flotacji do koncentratów.

Słowa kluczowe: kimberlit, minerały wtórne, asocjacje, zawiesiny, diament hydrofilowy, flotacja