Experimental Substantiation of the Involvement of Final Tailings of the Enrichment of Diamond-Containing Raw Materials into Recycling

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Abstract. Mineralogical and granulometric analyses of final tailing samples from a diamond-containing ore processing plant have been performed. The presence of finely dispersed particles of hydrophilic mineral formations, capable to attach to the surface of diamonds, has been identified, that should be taken into account in the processes of re-separation of diamond-containing tail products.

1. Introduction
The final tailings of diamond-recovery plants are aqueous slurries of finely ground kimberlite ores, from which diamond crystals are recovered as much as possible. However, existing technologies for processing diamond-containing raw materials do not make it possible to extract in full the small classes of diamonds (-2 + 0.5) mm that enables considering granular fractions of final tailings as promising technogenic diamond-bearing deposits that require evaluation of the feasibility of their involving in reprocessing.

The high content of associations of altered kimberlite minerals, finely dispersed fractions and thin-layered silicates, typical for most deposits of diamond-containing raw materials, presupposes the presence of mineral formations capable to alter the natural properties of the surface of diamond crystals and to form stable slurries in the tailings pond volume [1-5].

In view of the foregoing, the task of determining the qualitative and quantitative characteristics of the mineral composition of the final tailings of diamond recovery plants is relevant for assessing the feasibility of their involvement in re-processing.

2. Research Targets
Sand and finely-crushed, heavy and light fractions of final tailings of the beneficiation of diamond-containing raw materials selected as per the depth of their occurrence have been studied as research targets.
3. Research methods and techniques
Experimental studies were carried out in AK ALROSA NIGP and IPKON RAN laboratories. The diamond-containing material used as the research target was selected by the employees of AK ALROSA Research Institute using the method of geological testing throughout the entire tailing section of the beneficiation plant from the core of three wells from different depths.

The initial assessment of the structure of the selected samples was performed by visual inspection. The analysis of the distribution of sample material by the size of mineral particles has been performed in laboratory conditions. For the first time the granulometric composition of the ore material of tailings was determined by dividing into grain-size categories of a fairly narrow interval: (2+1; -1+0,5; -0,5+0,1; -0,1+0,05; -0,05+0) mm.

The output of large grades has been determined by the method of weighing, and the fractions (-0,05 - +0,01) mm, (-0,01- +0,001) mm and <0,001 mm were identified by the method of sedimentation. On the basis of the granulometric analysis, the percentage ratio of the fineness grades in each of the studied samples was determined from the depth of occurrence of tailings.

The mineral composition of final tailings was studied by X-ray analysis using diffractometry and thermal analysis methods with a temperature change from 0 to 1600°C. The quantitative determination of the mineral components in the test samples was calculated using the principle that the area and intensity of the maxima in the diffractograms are directly proportional to the mineral content corresponding to these maxima.

4. Discussion of findings
Figure 1 shows the results of studying the granulometric composition of final tailings.
Figure 1. The content of granulometric grades of fineness in the examined samples of final tailings (mean values, weight %).

On the diagrams shown, one can see that the material of the studied samples is represented mainly by small fineness grades, evenly distributed over the volume of samples and containing up to 50% of finely dispersed fractions (-0.05 mm).

The test samples of final tailings are classified as a calcite-dolomite formation with an increased content of quartz (Figure 2). In some samples feldspars have been diagnosed. Kimberlite minerals are represented by phlogopite and serpentine, which are concentrated mainly at a depth of up to 5 m. Minerals of the smectite and chlorite groups are concentrated at a depth below 2 m. The average phlogopite and serpentine content in the samples is about 10%, and smectites and chlorites do not exceed 8 - 12%.
Figures 3 and 4 show the X-ray diffraction patterns of the clay fraction of the -0.05 mm sample (Fig. 3a, b, Fig. 4a). An X-ray amorphous phase with a particle size of less than 0.001 mm was additionally studied by thermographic analysis (Figure 4b).

The nature of peak jumps in the diffractograms made it possible to diagnose chlorite, mixed layers, smectites, minerals of the mica and hydromica groups, as well as finely dispersed quartz and talc in the studied samples. On fraction <0.001 mm thermograms, it is well seen that at 674°C serpentine is clearly determined, and at 808°C - carbonates (Figure 4b).

Thus, the performed complex of experimental studies of final mill tailings of diamond-containing raw materials enabled diagnosing the main minerals of sand and finely dispersed fractions of final tailings and also establishing the uniformity of their distribution over narrow granulometric size grades.

The mineralogical analysis of the test samples of final mill tailings of diamond-containing raw materials, mineral associations, which are certain derivatives of the main kimberlite minerals, have been identified. A comparative analysis of the content of the main mineral components in the initial diamond-containing raw material and tailing products of its beneficiation was conducted, taking into account the data available in scientific literature on the main minerals of kimberlites and their secondary alterations [6-8] and the results of mineralogical studies of final tailings.

Figure 2. Distribution of minerals in the test samples of final tailings.
Figure 3. Diffractograms of the studied samples A - fraction (-0.05 + 0.01) mm; B - fraction (-0.01 + 0.001) mm.

Figure 4. Diffractogram (A) and thermogram (B) of the studied sample of the fraction (<0.001 mm).

The results of the analysis show that the studied tailings, in comparison with the average composition of the initial diamond-containing raw material, are characterized by an increased content of calcite-dolomite mineral formations with a high (up to 50%) content of finely dispersed serpentine-carbonate clay fractions, which presence must be taken into account in the process of final tailings recycling.

To assess the final tailings as a technogenic diamond deposit, the distribution of the diagnosed minerals by their density and depth of formation is of great importance, since the diamond crystals are concentrated in the heavy fraction of a mineral raw material extracted at a segregation density of 2.8 g/cm³.

The analysis of data on the distribution of heavy fraction in the sections studied through the entire thickness of the occurrence of final tailings showed that the content of heavy fraction in the grade (~2
of the heavy fraction is observed, which reaches its maximum in the depth interval of 3-8 m.

Figure 5. Distribution of the heavy fraction of minerals through depth of the studied final tailing samples.
5. Conclusion
As a result of the study of samples of tailings of diamond-containing raw materials, the main mineral associations have been diagnosed and regularity of their distribution, in terms of individual granulometric classes and tailings occurrence depth, has been determined. In addition, the factors have been identified that make it possible to recommend the tailings as secondary raw materials for additional extraction of valuable components:
- the similarity of the basic mineral composition and patterns of its distribution in the investigated tail sediments and initial ore raw materials,
- uniform distribution of mineral classes of size, both in the depth of tail sediments, and in the volume of individual samples,
- a high percentage of heavy mineral fraction concentrated in the uniformly overlapping seams of tail products, which predetermines an analogous distribution of diamond crystals due to the identical distribution of heavy mineral formations and diamonds.

Thus, taking into account the obtained data, the investigated tailings are recommended to be considered as technogenic diamond-containing formations, for which the development of technology for their reprocessing is required.

6. References
[1] Zuev A V, Dvoichenkova G P, Trofimova E A, Evdokimov V I, Bogachev V I 1997 Development and industrial exploitation of the technology of enrichment of diamond-containing raw materials using the electrochemical method of water treatment/ Records of the 1st Congress of Ore Enrichment Specialists of the CIS countries
[2] Bogachev V I, Zuev A V, Minenko V G 1999 The mechanism of passivation and activation of natural diamonds in the process of their recovery from kimberlites Report at the 2nd Congress of Ore Enrichment Specialists of the CIS countries M.: MISiS 112
[3] Trofimova E A, Zuev A V, Dvoichenkova G P, Bogachev V I 2000 Efficiency of application of membraneless electrochemical water treatment in the processes of enrichment of diamond-containing kimberlites Development of the ideas of I. N. Plaksin in the field of mineral enrichment and hydrometallurgy M.: Mining Institute named after A A Skochisky 327
[4] Dvoichenkova G P, Minenko V G, Kovalchuk O E and others 2012 Intensification of the process of froth separation of diamond-containing raw materials based on the electrochemical method of gas saturation of water systems Mining Journal 12 88-92
[5] Chanturia V A, Goryachev B E 2008 Enrichment of diamond-bearing kimberlites Progressive technologies of the comprehensive processing of mineral raw materials M.: Publishing house "Ruda i metally (Ore and Metals)" 151-163
[6] Chanturia V A, Trofimova E A, Dikov Yu P, Dvoichenkova G P, Bogachev V I, Zuev A A 1998 The relationship of surface and technological properties of diamonds in the enrichment of kimberlites Mining Journal 11–12 52-56
[7] Kulakova I I 2004 Chemistry of nanodiamond surfaces Physics of the Solid State vol 46 4 621–628
[8] Aleshin V G, Smekhnov A A, Kruk V B 1990 Chemistry of diamond surface Kyiv: Nauk. Dumka 200
[9] Chanturia V A, Trofimova E A, Dvoichenkova G P, Bogachev V I 2010 Mineral and organic nano-formation on natural diamonds: Conditions of their formation, methods of their removal Mining Journal 7 pp 68-71
[10] Chanturiya V A, Dvoichenkova G P, Kovalchuk O E, Kovalenko E G 2013 Change in the technological properties of diamonds under the conditions of processing the secondarily altered kimberlites Rudy i Metally 3 48–55
[11] Chanturiya V A, Dvoichenkova G P, Kovalchuk O E, Trofimova E A 2015 Features of the composition of the surface of hydrophilic diamonds and their role in the process of froth separation Physico-technical problems of the development of mineral resources 6
[12] Dvoychenkova G P 2014 Mineral formations on the surface of natural diamonds and the method of their destruction on the basis of electrochemically modified mineralized waters Physico-technical problems of the development of natural resources 4 159-171

[13] Maksimovsky E A, Fayner N I, Kosinova M L, Rumyantsev Yu M 2004 Investigation of the structure of thin nanocrystalline films Structural Chemistry journal 45

[14] Strickland R F 1971 Constable Kinetics and mechanism of crystallization Trans L.: Nedra Publishers 130

[15] McMillan P F and Hofmeister A M 1988 Infrared and Raman spectroscopy In: Reviews in Mineralogy Min. Soc. America. Washington. D.C. Spectroscopic methods in mineralogy and geology vol 18 99-159

[16] Garrels C, Christopher G 1967 Solutions, minerals, equilibria M.: Mir 407

[17] Naumov G B, Ruzhenko B N, Khodakovskiy I L 1971 Handbook of thermodynamic quantities M.: Atomizdat 240

[18] Goryachev B E 2010 Technology of diamond-bearing ores processing M: MISiS 326

[19] Rossman G R 1988 Vibrational spectroscopy of hydrous components In: Reviews in Mineralogy Min. Soc. America. Washington. D.C. Spectroscopic methods in mineralogy and geology vol 18 193-206

[20] Kulakova I I 2004 Chemistry of nanodiamond surfaces Physics of the Solid State vol 46 4 pp 621–628