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Forming Conditions of Technogenic Gold-bearing Objects and Technological Properties of Gold from Gold Extraction Plant Tailings

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Abstract

The article deals with the formation of technogenic gold-bearing objects in the form of tailing dumps of gold extraction plants and features of technological properties of gold during long-term storage in tailings. It is shown that the formation of such objects is affected by technological, geological, mining, and landscape-climatic factors, as well as by processes of subsequent hypergenesis. The result is the transformation of mineral associations during the formation and storage of stale tails, lithologic-filtration heterogeneity of technogenic mass, gold redistribution in waste products, and the change in the gold typomorphic properties. The regularities of the formation of gold concentration zones in the tailing dumps during hydraulic storage and tailings storage have been established for one gold extraction plant. The mineral composition, particle-size analysis, and water-physical properties of stale tails confirmed the formation of typical and characteristic technological zones in the tailing dump, requiring the use of different technology for additional gold recovery.

Keywords: Technogenic deposit, gold, pre-extraction, tailing dump of gold extraction plant, hypergenic processes, mineral association transformations, morphometric parameters.

INTRODUCTION

Although a huge number of available technogenic mineral formations, two types of technogenic deposits are in demand in Russia today: they are technogenic placers of gold, platinum, and tin, as sources of extraction of these metals; and dumps of overburden rocks of mineral deposits for the production of building materials [1]. Technogenic placers, tails of ore dressing (gravity, flotation, magnetic separation, cyanide and combined processing), heap leach stacks, metallurgical clinker and cakes are classified as technogenic mineral deposits of noble metals [2]. Among technogenic objects accounted for by the State balance of technogenic mineral reserves, gold-containing deposits are dominant, over 100 [3]. Many types of anthropogenic mineral deposits of precious metals can be included in additional processing, but this requires the use of new, original technologies [2, 4].

Gold reserves in technogenic mineral formations are considered as the most important in the total balance of Russian gold mining. Bevolsky B.I. with co-authors [5] estimated the general gold resource in the dumping complexes of Russia as 5 thousand tons, which is about half of all metal extracted from placers. According to other estimates, gold reserves in the Russian technogenic dumps make up at least 18% of the placer gold reserves [6]. For example, only dumps of washed sand formed as a result of development of placers in the Magadan region amount to 1.5 billion m^3 and, according to estimates, contain about 500 tons of gold [1].

Most technogenic deposits of gold do not decrease in value in time, but on the contrary become more valuable and essential for re-processing due to the degradation of readily available gold reserves in solid ores and placers and reduction of industrial conditions, as well as due to the rise in price of mining and processing of raw materials.

Technogenic gold deposits include the stale tails of gold recovery factories, spoilage off-balance ores resulted from the extraction of gold deposits, and gold-containing waste (tailings, slimes) formed in course of ore dressing or processing of gold-bearing concentrates (cinder, cakes, ash) of complex deposits of ferrous, non-ferrous, noble and other metals.

The geological and technological assessment show that many tailing dumps of gold recovery have been classified as technogenic gold deposits with approved gold reserves and are currently in high demand by industry. Among the largest objects, it is possible to mark the tailing dumps of Baleyskaya gold recovery works in the Chita region (stale tails contain about 37 tons at 0.9 g/t) and the tails of Matrosov Mine in the Magadan region (4.9 tons of gold at av. 1.66 g/t) [6]. The percolation tails of gold extracting plants, which can contain free native gold, show considerable promise [7].

For comprehensive development of technogenic gold-bearing objects, especially tailing dumps, agreeably to the ecological compatibility and economic efficiency, it is necessary to identify the follows: the forming conditions of a gold-bearing object, geological features of technogenic formations, geochemical processes occurring during long-term storage of technogenic products, and the influence of geochemical barriers. There is a need to research morphometric parameters and technological properties of gold contained in stale tails, to study topography, hydrogeology, and regularities of lithologic-filtration heterogeneity of the technogenic mass, and to establish correlations between the topography of the tailing dump and gold concentration zoning. The regularities obtained will provide an opportunity to adapt traditional methods of enrichment for additional extraction of gold from technogenic objects and a comprehensive approach to the development of tailing dumps of gold recovery plants on combined enrichment technologies [8].

Makarov V.A., Morozova Y.P., and Kovlekova I.I. [6, 9, 10] developed the systematics of technogenic gold-bearing objects and revealed conditions for their formation. Depending on the conditions of development, technogenic formations of mineral raw materials in work [11] are divided into dumps, tailing dumps and areas within the mining allotment. In turn, the tailing dumps are divided into: alluvial, bulk and tailing dumps of dry storage.

In the formation of anthropogenic gold-bearing object Makarov V.A. singled out the technological and geological-geochemical stages [12]. At the first stage of formation of the technogenic deposit, technological (anthropogenic) factors that are determined by the system for extracting gold from the bowels, the technology of storing and dumping tailings and wastes of mining production, at the second - natural mining-geological and landscape-climatic ones are determining. Geological and mining technical factors are formed depending on the mineral and chemical composition of the enclosing rocks and initial ores, the conditions of their occurrence, the granulometric and morphological characteristics, and the physical properties of the enclosing rocks. Landscape-climatic factors are the climate of the region (precipitation, temperature, the presence of permafrost), geomorphological (log, slope, river valley, etc.), biological (the presence of vegetation, bacterial composition).

In the formation of industrial gold concentrations in technogenic gold-bearing objects as a result of technogenesis, two opposite tendencies are noted. In the opinion of V.A. Makarov [12] in the development of gold deposits, where gold is the main component and tailings and dumps contain predominantly lost metal, processes of gold dispersion are dominant. The gold contents are 5-10 times lower than in the original products. This type of objects is characterized by redistribution of gold at the geological and geochemical stages under the influence of natural factors. Such objects become of industrial importance in time with the reduction in the conditions for mineral raw materials.

Academicians K.N. Trubetskoy and V.N. Umantsa [13] found that in the tailings of copper complexes industrial concentrations of gold are formed mainly at the technological stage. The mechanism of concentration is determined by mineralogical and technological properties of initial materials, form of gold, and by the extracting technology. In this case, gold can accumulate both because of increased mobility (fine gold in the slime pits) and due to its inertness (sand-gravel mixtures in the inwash head parts).

A specific feature of technogenic products is a strong change of physical and physical-chemical properties of constituent components due to oxidation, leaching, redeposition, and other processes, especially in the long-term storage in the waste. Most researchers [11, 14, and 15] consider technogenesis associated with mining as short in time and locale in space hypergenesis, reflecting the "reaction" of rocks and ores lifted from the bowels to new environmental conditions. In the opinion of V.A. Makarov [12] for gold-bearing objects, such impacts are expressed in changing structure and composition of ores, sands and host rocks, in the gold redistribution in the dumping complex, and the alteration of gold typomorphic properties.

Technogenic gold in dumps is characterized by such technological properties as morphology, phase composition, and hydraulic size. Native gold shows forms of dendrites, complex aggregates, isometric grains, plates, flakes, plates, and wires. As gold roundness increases, it has a more rounded shape and smooth surface. The increased gold roundness favours higher deposition rate and facilitated recovery. However, to concentrate small classes, the degree of flattening is more important, which increase worsens the gravity extraction.

In technogenic formations gold occurs in free form, as intergrowths with other minerals, in oxidized films, in sulfides and silicates, in amalgam, in sorbents (coal), and in technological aggregations. The distribution of gold in phases sharply changes after the leaching of ores. The analysis of native gold variability in tailings of gravity enrichment, using amalgamation, revealed the following features [6, 12, 16]: both free gold and metallic mercury are present in the tails; the of bound gold content is an order of magnitude greater than contents of free gold and gold-mercury amalgam. The maximal concentrations of gold and mercury are localized near runners.

In the flotation tailings of gold ore enrichment, a portion of free gold rarely exceeds 10-15% of its total content [16]. In similar tails of the enriching gold-bearing non-ferrous ores, a part of free gold can reach 60-80%. Bound gold is more often associated with sulfides. Although sulfides can be significantly oxidized, gold does not free from the intergrowths, but remains in association with iron oxides and hydroxides [16]. On oxidation, iron oxides and hydroxides sometimes completely replace sulfides with gold dissemination, so that the latter can be found in the dense "shirt" of secondary minerals [17].

Plaksin I.N. [18] determined that free gold from dressing tails generally shows surface passivating films, arising in the ore milling and flotation. The over-milling of ores results in the deformation of free gold grains, reduction in their hydraulic size, and contamination with sludge and with fine iron hardening and other heavy metals, which inevitably decreases the efficiency of subsequent gold extraction from tailings.

In technogenic dumps, the gold size is governed by the limit of fineness of gold efficiently recovered, using applied recovery equipment. According to I.I. Kovlekova [6], small and fine size classes, resulting from the pulp drift, mainly represent the bulk of gold in gold recovery tailing dumps, so modal fineness of technogenic gold does not exceed 0.3 mm.

Gold in the tailing dumps is mobile and can be carried by water flows both during filling dumps and after that. Mechanical migration of gold occurs in technological water flows at points of pulp discharge, which is typical for the material 1.0-0.05 mm in size, and in streams of atmospheric precipitation [9]. Mechanical movement of gold is noted both inside the tailing dumps and outside them connected with the activity of storm and floodwaters, as well as with water flows draining through the tails.

As the main mechanism of gold migration in tailing dumps is the movement of particles in process water streams and atmospheric precipitation, it is probably that the topography of the tailings bed, as well as the filtration properties of the tailing mass, significantly affect the gold distribution in the alluvial technogenic massifs, including the stale gold recovery tails.

The migration character is defined by a number of technological and mineralogical factors [19-21], including the nature of tailing wash, gold form (free or bound), hydraulic size of gold-bearing minerals, granular composition of tails, water cut of tails, and climate.

It is generally recognized [10, 12, 16] that high gold concentrations in tailings are regularly located independent of a type of gold-bearing tailings: gold contents stably increase in the bottom part of the storage and decrease evenly from the head of the storage to the rear.

In long-term storage of technogenic products, geochemical processes of dissolution, re-deposition, and re-dissolution of gold occur, depending on the area of its emissions, mineral composition and texture-structural features of rocks, physical and mechanical properties of the environment [16]. The larger are the gold participles, the less are they dissolve. Dominantly, microscopic and fine gold, which migrates easy in the dump massif upon release from enclosing minerals, passes in solutions.

The main solvents of gold are aqueous solutions of $FeCl_2$; $Fe_2(SO_4)_3$; $CuCl_2$; Cu SO_4; NaCl; HCl; and H_2SO_4. It is established that gold is also dissolved by the waste water containing halogenide, nitrates and sulfates of alkali metals, and organic acids [16]. Fine gold can be converted to a colloidal solution, and colloidal gold is stabilized by colloidal silica, sodium carbonate, and $Fe(OH)_3$ [16].

The concentration of technogenic gold is affected by geochemical barriers. The gold concentration as a result of its re-deposition from solutions depends on the oxygen, reducing, carbonate, sulfate, carbonaceous, sulfide, and sorption geochemical barriers and their combinations [16].

To reveal the structure of technogenic gold deposits and composition of gold-bearing material formed under the influence of technogenesis and subsequent hypergenesis, specific morphological parameters of gold in tailing dumps, identification of zones of local concentration of precious metals in anthropogenic massif is necessary to select the most rational technology for the development of a technogenic gold mining facility and efficient technology for extraction gold from the dead tails of gold extractive fabs uk.

OBJECT AND METHODS OF RESEARCH

The object of the research was the conservated dump of the stale tails of a currently inactive gold recovery plant located in the Republic of Bashkortostan. The next research methods were used: granulometric, chemical, X-ray phase, mineralogical, assay, and phase analysis, as well as image analysis using the SIAMS-600 software package. The tailings filtration coefficient was defined in the laboratory with G.N. Kamenskii device by the standard procedure [22].

RESULTS AND DISCUSSION

The tailing dump of the gold recovery plant holds tailings processed for several decades from various gold-bearing ores of the Republic of Bashkortostan and other regions, as well as from gold-bearing ores of oxidation zones of some copper-pyrite deposits. The tailings dump was formed with a concentrated discharge of tail pulp through a pipe 800 mm in diameter without stacking the tailings.

The constant water mirror is at a depth of 4.0 m. The waters are megacodorous, not actively circulating. There is an active water inflow due to atmospheric precipitation along the tailing dump surface to its north-west corner formed due to water-resistant surface clays and slope of the tailings surface. The groundwater level is at a shallow depth (3-4 m) and the technogenic massif is mainly flooded.

Geologically, the tailing dump is a loose mass composed of sandy-argillaceous reddish-brown substance concentrated as a technological placer on the waterproof clay foundation 0.6-1.0 m thick. Based on the drilling results and petrographic descriptions of cores, lithologically, the sands are represented by alternating lenses of loosely bound silt and fine-grained sands, as well as silty clays and clays from 0.5 to 1.0 m in thickness. A total thickness ranges from 6 - 7 m to 10 m, depending on the bottom topography.

According to the mineralogical analysis, the sands are composed of quartz (50-60%), feldspars (microcline, orthoclase, plagioclase, 20-25%), and mica-clay minerals (kaolinite, muscovite, sericite, etc., 5-10%). The secondary minerals are limonite and other iron oxides, skorodit, cerussite (6-9%) and sulfides (pyrite, marcasite, pyrrhotite, chalcopyrite, 1-2%) [23].

The formation regularities of gold concentration zones in the tailing dump massif were studied. Based on the drilling exploration tests, gold distribution patterns at different depths of the tailing dump were plotted at intervals of 1 m. They demonstrated that through the tailing dump the gold mass fraction irregularly varies from 0.3 to 5.8 g / t both along the strike and in depth. An increase in gold mass fraction is observed with an increase in the tailings depth (Table 1). Based on the testing results, sections with different gold productivity were outlined at the tailing dump: with a gold content lesser than 0.7 g / t; 0.7-1.0; 1.0-1.2; 1.2-1.4 g / t [8].

According to the phase analysis, gold mainly is in free form, 75% of it is associated with 0.074 mm class; 25.4 - 42.9% of gold is bound, mainly with quartz. The gold distribution over granulometric classes is almost uniform.

Table 1: Average mass fraction of gold at different depths of the tailing dump.

Level [m]	Mass fraction of gold [g/t]
0 – 1	0,896
1 – 2	1,004
2 – 3	1,192
3 – 4	1,181
4 – 5	1,238
5 – 6	1,288
6 – 7	1,310
7 – 8	1,461
8 – 9	1,253
9 – 10	1,463

Based on the gold distribution analysis it was concluded that on the hydraulic storing and keeping of the tailings, fine gold is distributed very evenly throughout the body of the tailing dump. High gold contents are observed in the northern, northeastern, and southwestern parts of the tailing dump, corresponding with the topography of its bed. They are correlated with deep areas, the bed depressions, and with the places of concentrated pulp discharge.

The chemical analysis of samples (Table 2) indicates that the dead tails contain not only metal ions, such as copper, zinc, lead, arsenic, but also sulfate ions and hydrocarbonates, demonstrating the active oxidation of sulphides and the formation of water-soluble sulfates.

In long-term storage of finely divided tailings, mineral associations of deposited tailings undergo significant changes as a result of hypergenesis. This can affect both the technological properties of technogenic raw materials and their possible recycling. Based on the composition of the newly formed mineral phases and filter solutions, it can be concluded that nonmetallic minerals also underwent significant changes. Hypergenesis leads to a higher role of chlorites, hydrochlorites, and other new fine and colloidal formations, which significantly reduces the intergranular volume of the tail mass.

Table 2: Chemical composition of stale tails.

Component	Cu	Pb	Cd	Zn	Cr	Hg	As	Se	Chlorides	Hydro-carbonates	Sulphates
Content [% of mass]	0,073	0,086	$2{,}1\cdot10^{-4}$	0,091	$16{,}8\cdot10^{-4}$	$14{,}8\cdot10^{-4}$	0,051	0,045	0,012	0,0292	0,047

During the storing of the tailings, the material was differentiated according to a particle size and density (sedimentogenesis), resulting in a technogenic heterogeneity of the tailings. However, the differentiation in size continued in the tailed tails. The finest particles and weathering products were removed from the dusty artificial soils and concentrated in clay-like ones. Fine fractions, like hypergenic products, were removed by filtering solutions and time flows and concentrated in the lowest parts of the tailing dump. This led to the formation of several typical technological zones characterized by their size, gold morphometric parameters, and composition of host rocks, watering productive horizons. Such zones require various technological processes for their processing [23]. This is confirmed by mineralogy, granulometric composition, and technological properties of studied samples of stale tails. Sample 1 was collected in the beach zone of the tailing dump at a depth of 2 m; samples 2 and 3 were collected in the deepest part of the technogenic deposit at depths of 2 and 7 m, respectively. The samples are the most typical for these tailings.

Sample 1 was composed of gray granular material with particles smaller than 3 mm. The sieve analysis (Table 3) showed that a sample is represented by the class -0.074 mm at 18%. Pure white and milky quartz dominated (70%). Quartz grains are isometric, acute-angled, and mostly translucent. Among them, there are colored grains (5-7%) mostly brownish grains with iron hydroxides (about 5%), the rest are gray. Dense, angular, opaque grains of feldspar in the form of elongated gray plates and translucent green chlorite grains were observed, as well as individual elongated particles of authigenic (secondary) mica. The sample contained grains of biotite, greenish quartz, and sericite. Biotite occurred in the form of elongated black particles and plates. Ore mineral grains are pyrite and bornite.

Sample 2 was sandy-clayey homogeneous yellowish-brown material. A large content of brown quartz with thin films of iron hydroxides was noted. The sample was finer then Sample 1, 25% represented by the -0.074 mm class. Among fine powdery mass, large, strong particles from 0.5 to 1 mm in siaze were clearly distinguished. The bulk of the sample (60-70%) was composed of clayey and micaceous minerals. Kaolinite, relatively clear and with signs of iron hydroxides, was distinctly was notes, as well brown montmorillonite as dense earthy aggregates. Among mica-like, sericite was distinguished. The rest of the sample (30-40%) was represented by yellowish-gray grains of quartz and feldspar.

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Table 3: Granulometric compositions of stale tails.

Classes size [mm]	Sample 1		Sample 2		Sample 3	
	Private outcome [%]	Total outcome by plus [%]	Private outcome [%]	Total outcome by plus [%]	Private outcome [%]	Total outcome by plus [%]
+3	0,38	0,38	0,47	0,47	0	0
-3+1	9,37	9,75	10,31	10,78	0,85	0,85
-1+0,5	28,0	37,75	24,01	34,79	4,95	5,8
-0,5+0,125	38,7	76,45	34,18	68,97	27,24	33,04
-0,125+0,071	5,51	81,96	4,27	73,24	10,25	43,29
-0,071+0,063	2,10	84,06	3,1	76,34	5,43	48,72
-0,063+0,040	1,94	86,0	2,06	78,4	6,09	54,81
-0,040+0	14,0	100,0	21,6	100,0	45,19	100,0
Total:	100,0		100,0		100,0	

Sample 3 was essentially clayey, light yellowish-brown psammite-pelite mass, a weathering product of quartz-feldspar mass of tails. A sample of 62% was represented by a class less than 0.074 mm. Nonmetallic minerals are represented by quartz, sericite, and chlorite. Secondary minerals were limonite, skorodite, manganese oxides, montmorillonite, etc.

Mineralogical analysis of these samples showed that along with non-clay minerals (quartz, feldspar, sulfides) tails contain chlorite, mica, kaolinite, and montmorillonite. Despite the presence of clay minerals, the tails behave as a non-cohesive material. They are no plastic, insignificantly hygroscopic, and weakly bond. They do not swell. Such properties are due to both dominant quartz and feldspar in composition and trace concentration of montmorillonite. In samples under study, particles lesser 5 µm in a diameter are mainly represented by mica and chlorite. Thus, these tails are closer to non-cohesive soils than to clays. According to the lithological classification the tailings correspond with silts and to geotechnic one with silty soils.

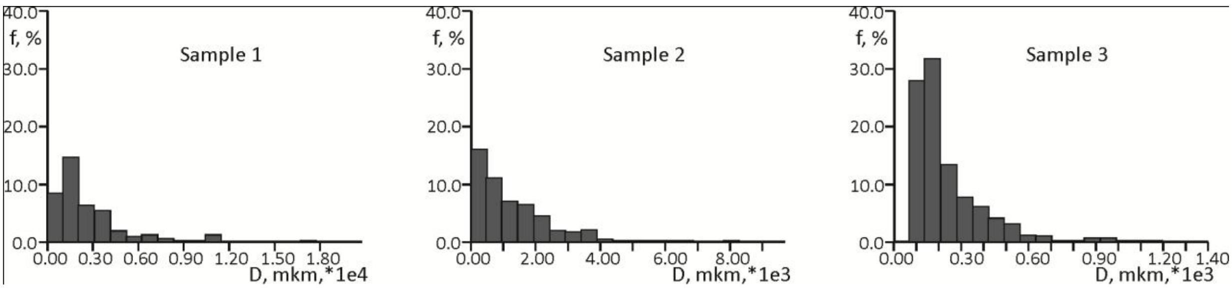

Figure 1: Distribution by particle size in the investigated tail samples.

To assess the fineness of a thin class, a planimetric method was used (Fig. 1) with the SIAMS-600 instrument. Histograms indicate an increased number of fine classes (-10 µm or less) in sample 3 collected in the deepest part of the tailings.

On water-physical properties (Table 4), in samples 1 and 2 selected in the upper layers of the tailings the filtration coefficient was sufficiently high the samples to be classified as moisture permeable. Sample 3 collected in the bottom layer characterized by the largest content of fine clay particles had the lowest coefficient of filtration and the maximal humidity of the tails.

Table 4: Water-physical properties of stale tails.

Name of sample	Coefficient of filtration [m/day]	Humidity [%]	Weighted average particle diameter [mm]
sample 1	1,7	8,20	0,53
sample 2	0,89	12,7	0,50
sample 3	0,1	24,1	0,16

The filtration coefficients of narrow particle size classes were determined in order to evaluate the effects of small and fine particles on the filtration properties of the massif (Table 5). Thin clay particles complicate the filtration. Considering the presence of a large amount of goethite and hydrogoethite in the fine fraction of Sample 3, a material with a particle size of less than 0.044 mm was washed with a 2% solution of hydrochloric acid at a ratio of T: H = 1: 5. The yield of the washed product was 86% of the initial mass; the filtration coefficient increased significantly and reached to 0.26 m / day. It is obvious that the secondary iron minerals can be removed from the technogenic massif with a weak acid solution, therefore it is recommended to perform a preliminary acidification of the massif and to reverse the flows in the wells, which can significantly increase its filtration properties [23].

Table 5: Coefficients of filtration in accordance with size classes.

Grading class [mm]	Coefficient of filtration [m/day]		
	sample 1	sample 2	sample 3
-3+0,5	3,0	1,6	0,22
-0,5+0,071	1,53	1,34	0,048
-0,071+0	0,05	0,043	0,041

Based on mineralogical and lithological characteristics, granulometric composition, and filtration properties, the stale tails of the gold recovery plant can be divided into three groups. The first group is represented by clay-like soils, in which fractions of less than 0.025 mm predominate, and they can be regarded as artificial analogs of natural loams and sandy loams. These soils are mainly composed of talc and hydrochlorite, other minerals play a subordinate role. In small quantities in such soils there are extremely finely dispersed (colloidal) particles. These technogenic soils are poorly drained and characterized by low values of the filtration coefficient (0.03-0.9 m / day) and high water retention capacity.

The second group consists of disconnected artificial soils, close to dusty natural sands or silts, which are characterized by the maximum size of mineral particles. The amount of particles less than 0.025 mm in them usually does not exceed several percent, and particles less than 0.01 mm practically do not exist. The dusty sands are well drained. The coefficient of filtration of such soils is much higher and, as a result, the moisture content is much less than that of clayey soils.

The third group is mixed soils: interlayers of clay-like and disjointed soils, which in composition and properties occupy an intermediate position. In the conditions of interbedding of these soil types, the lithologic-filtration heterogeneity of the technogenic massif of the tailing dump was formed, which should be taken into account when choosing methods for its processing.

It is also necessary to take into consideration significant changes in the morphometric parameters of gold particles as a result of ore enrichment at the factory and during the long-term storage of tailings in the tailings dump. According to published photographs of gold-bearing products, the morphometric parameters of gold particles were evaluated by an optic-geometric method using the SIAMS-600 software package.

Ore gold (Fig. 2) is characterized by the value of the round shape factor within 0.35 ... 0.49 with a frequency of 90%.

Gold recovered during processing of boulder ore material with a size of 0.45 mm, + 0.03 mm is non-uniform, 72% of grains have the value of round shape factor to 0.50 (Fig. 3).

Figure 2: Ore gold.

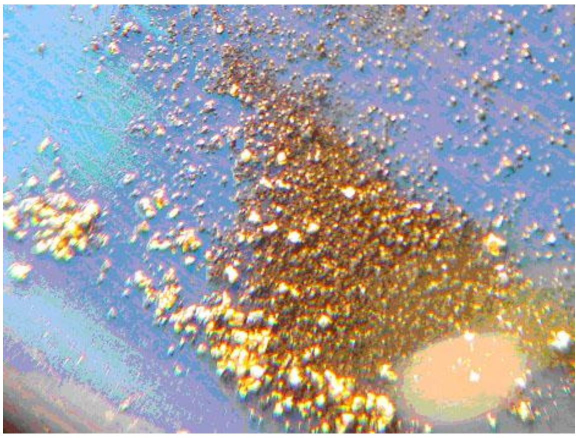

Figure 3: Ore gold of boulder ores graded 0.45 mm, + 0.03 mm.

The morphometric parameters of gold particles extracted from the tailings dump massif are characterized by high values of the round shape factor. For large gold mines (Figs 4, 5), the round factor of the form is 0.72 in 90% of cases, for fine gold particles the value of the round shape factor is even higher - 0.84 (Figure 6). Thus, long-term storage of tailings leads to a change in the typomorphic properties of gold - the value of the round shape factor increases 1.5.times.2 times compared with ore gold.

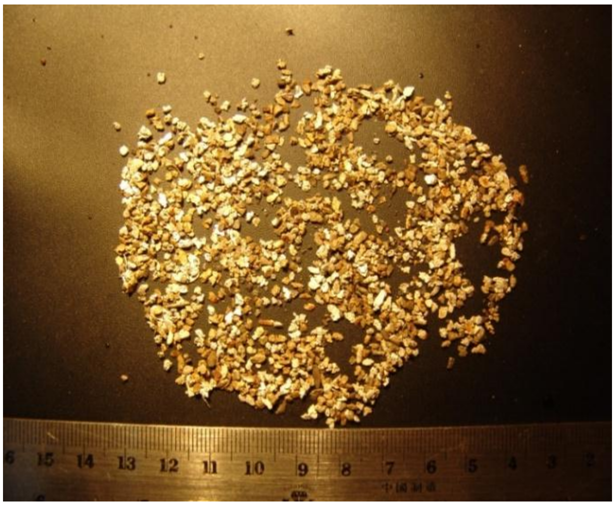

Figure 4: Large gold extracted from the tailing dumps.

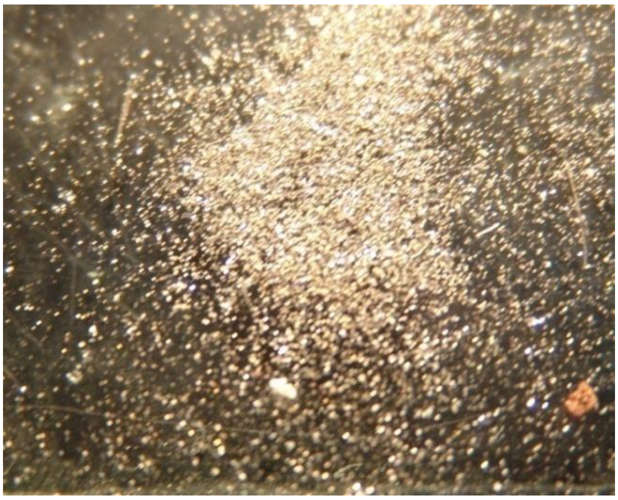

Figure 5: Amalgamated gold 0.090 μm in size.

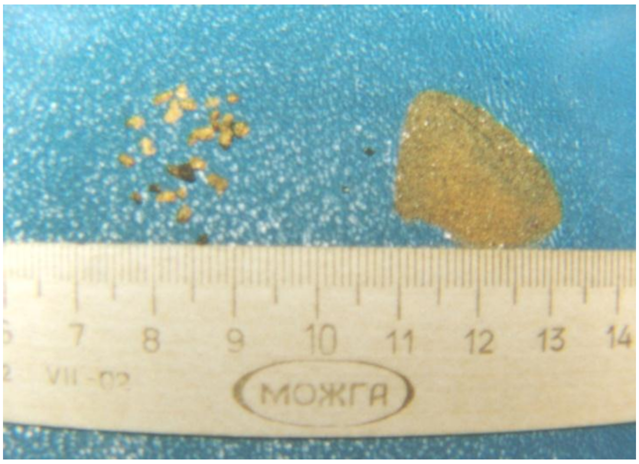

Figure 6: Gold extracted from the alluvial deposit tails, a size class of 2.5 mm and dust-like gold graded 0.063 μm + 0.016 μm.

CONCLUSION

Tailings of gold recovery factories on the reserves of metal contained in them are promising, investment-attractive objects of repeated gold mining.

To expand the prospects for rational development of technogenic gold reserves in the form of tailings, it is required to develop resource-replacing technological solutions that ensure the integrated development of technogenic mineral resources, maintenance of its economic utility and ecological function.

On the example of the tailing dump of the dead tailings of the recovery plant it was shown that in order to substantiate the technological solutions for additional extraction of gold from such technogenic mineral formations, it is necessary to study the forming conditions of technogenic gold-bearing objects, laws of transformation of mineral associations during the formation and storage of stale tailings, correlations between the topographic characteristics of the tailing dumps and zones of gold concentration of in its mass. It is required to study the filtration properties of the tailing dump massifs, since they significantly affect the gold distribution in alluvial technogenic formations. It is important to determine technological properties of the stale tailings and to establish the morphology of gold in the tailing dumps in order to justify the most expedient method and efficient devices for gold extracting.

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REFERENCES

[1] "On the state and protection of the environment of the Russian Federation in 2015", 2016, State report, NIA-Nature, Ministry of Natural Resources of Russia, Moscow, 639 p.

[2] Perepelitsyn, V.A., Rytvin, V.M., Koroteev, V.A., Makarov, A.B., Grigoriev, V.G., Gilvarg, S.I., Abyzov, V.A., Abyzov, A.N., and Tabulovich, F.A., 2013, "Technogenic mineral raw materials of the Urals", RIO UB RAS, Ekaterinburg, 332 p.

[3] Bykhovsky, L.Z., and Sporyhina, L.V., 2011, "Technogenic waste as a reserve of replenishment of the mineral and raw materials base: the state and problems of development", Mineral Resources of Russia, Economics and Management, (4), pp. 15-20.

[4] Shadrunova, I.V., Volkova, N.A., Mastyugin, S.A., and Gorlova, O.E., 2013 "Technological, economic and environmental aspects of processing technogenic raw materials of mining and metallurgical enterprises of the Urals", Ecology and Industry of Russia, (8), pp. 16-21.

[5] Benevolsky, B.I. and Shevtsov, T.P., 2000, "On the Potential of Technogenic Gold Placers in the Russian

Federation", Mineral Resources of Russia, Economics and Management, (1), pp. 14-18.

[6] Kovlekov, I.I., 2002, "Technogenic gold of Yakutia", MGGU Publishing house, Moscow, 303 p.

[7] Mustafin, S.K., 2004, "Gold in the waste of mining, processing and processing of mineral raw materials: the problem of evaluation and extraction", Proc. Int. Conf. Renovation: waste - technology - income, Ufa, pp. 154-155.

[8] Chanturia, V.A., Shadrunova, I.V., and Gorlova, O.E., 1012, "Adaptation of separation processes of mineral processing to technogenic raw materials: problems and solutions", Enrichment of ores, (5), pp. 43-50.

[9] Makarov, V.A., 1988, "Types of man-made gold-bearing raw materials and features of the methodology of its geological and technological assessment", Abs. Int. Sc. Conf. Metallurgy of the 21st century: a step into the future, Krasnoyarsk, pp. 177-178.

[10] Morozov, Y.P., 2001, Theoretical justification and development of new methods and apparatus for extracting fine-grained precious metals from ores and technogenic raw materials, D.T.Sc. Thesis, UGGA, Ekaterinburg, 34 p.

[11] Khabirov, V.V., Zabelsky, V.K., and Vorobyov, A.E., 1994, "Progressive technologies of extraction and processing of gold-bearing raw materials", Nedra, Moscow, 272 p.

[12] Makarov, V.A., 2001, "Conditions for the formation of man-made gold-bearing objects and features of the methodology of their geological and technological assessment", D.T.Sc. Thesis, KGTSMiZ, TPU, Tomsk, 30 p.

[13] Trubetskoi, K.N. and Umanets, V.N., 1992, "Integrated development of technogenic deposits", Mining J., (1), pp. 12-16.

[14] Naumov, V.A., 1994, "Features of the formation and distribution of precious metals in technogenic placers and dumps of the Urals", Proc. High Schools. Mining J., (8), pp. 39-50.

[15] Chaplygin, N.N. and Zhulkovsky, D.V., 2005, Mining: a resource assessment, Mining J., (4), pp 9-11.

[16] Bocharov, V.A. and Ignatkina, V.A., 2003, "Technology of enrichment of gold-bearing raw materials", «Ore and Metals» Publishing House, Moscow, 406 p.

[17] "Underground and heap leaching of uranium, gold and other metals. Gold", Ed. M.I., Fazlullina, (2), «Ore and Metals» Publishing House, Moscow, 328 p, 2005.

[18] Plaksin, I.N., 1958, "Metallurgy of precious metals", Metallurgizdat, Moscow.

[19] Makarov, V.A., 1988, "Types of technogenic gold-bearing raw materials and features of the methodology of its geological and technological assessment", Abst. Int. Sc. Conf. Metallurgy of the 21st century: a step into the future, Krasnoyarsk, pp 177-178.

[20] Kozin, V.Z., Morozov, Y.P., Koryukin, B.M., Koltunov, A.V., Tarchevskaya, I.G., and Komlev, S.G., 1996, "Tailings and tailings of concentrating factories", Proc. High Schools. Mining J., (3-4), pp. 103-116.

[21] Chanturia, V.A., Makarov, V.N., and Makarov, D.V., 1999, "Features of hypergenic processes in deposited mining wastes", Engineering ecology, (4), pp 2-9.

[22] Skabbanovich, M.A.,1972, "Methods for studying the physical and mechanical properties of soils", Nedra, Moscow, 312 p.

[23] Shadrunova, I.V., Gorlova, O.E., and Provalov, S.A., 2011, "Adaptive methods of gold recovery from tailing dumps of gold recovery factories", Mining Information and Analytical Bulletin, (9), pp 180-185.