Formation of Industrial Gold-bearing Objects in the Development of placers on the Marakan River (Eastern Siberia)

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Abstract
The authors have studied technogenic and mineral formations that were arisen during the development of the Marakan gold placer (Eastern Siberia). Free gold is established in technogenic and mineral formations, which is due to technological and geological reasons. The mineral composition of man-made dumps includes a large amount of sulfides. During placers mining oxidation of sulfides occurs, with the release of gold in them. In acidic man-made waters, gold moves in dissolved form, precipitates and restores gold in the metallic phases. Based on the study of free gold and the theoretical prerequisites for the formation of chemogenically and biogenically deposited gold, the technogenic dumps of the Marakan deposit may have zones of increased concentration of newly formed free gold.

Keywords: man-mademineralformations, man-madewaters, freegold, boundgold

Introduction
The valley of the Marakan River is located in Russia in the north of the Irkutsk region, in the Bodaibo district. Loose formations of eluvial, alluvial, fluvioglacial, deluvial origin are widespread in the valley of the Marakan River.

The alluvial terraces of the gold-bearing placer of the Marakan River have a complex structure. They are represented by normal (interglacial) and fluvioglacial alluvium. Placer gold occurrence is confined to zones of normal (interglacial) alluvium. It consists of a deep placer and placer of buried terraces of several levels. The bedrock is composed from carbonaceous slates with interspersed sulfides and thin interlayers of marbles. The deep part of the placer is composed by alluvium and is represented by a pebble-boulder-gravel material with clay (the eluvial-alluvial part). The main gold-bearing placer is associated with these deposits. The total thickness of the gold-bearing strata can reach 50 m. The placer is buried under glacial, upper Pleistocene and modern alluvial sediments (Mungalov et al. 1975).

Gold mining and production of primary concentrate is carried out by a gravitational method on an industrial instrument PPM-5 (deroker).

The objects of study were technogenic-mineral formations arising after the enrichment of the placer. Gold content is estimated from the material of boulder-pebble (+ 50mm) and gravel-sand (-50mm) precipitation after the devices of hydraulic washing. Boulder-pebble sediments are washed fragments of rock with the practical absence of clay-sandy aggregate. The composition of the detrital material can be judged on the geological structure of the raft. Sandy complexes are characterized by good sorting. Man-made dumps are well-washed and sorted formation (fig. 1). In the bulk, they are composed from rounded sandstone and shale fragments, as well as a large proportion of quartz and sulfides. The bulk sulfides are represented by oxidized and non-oxidized pyrite. The clay fraction is carried by the water stream from the instruments to the sumps, where the solid phase is gradually deposited on the bottom of the reservoir.

Figure 1 *Man-made dumps of placer on the MarakanRiver.*

The mineral composition of the heavy fraction is represented by sulfides (pyrrhotite, pyrite, chalcopyrite), ore (ilmenite, hematite, magnetite) and hypergene (limonite) oxides, garnet. A small amount of rutile, zircon, epidote is found.

The placer gold of the Marakan River valley is represented by grains of small, medium and large classes (tab. 1). Gold is rolled over and semi-rolled, lamellar and tabular forms. The color of gold is golden yellow. There are particles of gold with yellowish films, and reddish-brown crusts of iron hydroxides (fig. 2).

According to previous studies, it was found that the distribution of free gold in sandy sediments is uneven. This is due to their gravitational differentiation. In places where pulp is discharged from sluices, the gold content in sandy sediments reaches tens of grams per ton. This material is transported by bulldozers to the general dump. Itslocationisrelativelylocalandirregular.

Methods

The authors tested several sites of technogenic and mineral formations. 105 samples were collected and analyzed with a total volume of 1076 liters over a network of 2×2 m and 1×1 m. Sampling was performed near industrial devices in fresh technogenic deposits from the surface. A single sample with a volume of 20 liters was removed from the wells with a size of 0.3 × 0.3 m and a depth of about 0.2-0.3 m. The optimum volume of a schlich test, and the sampling step for man-made placers, are determined on the basis of previous methodological work. The sample was washed with a tray up to the "black" concentrate; the sample volume was 5–10 litres. After washing, the obtained black concentrate was dried. Visible gold was selected and weighed. The concentrate was reduced at the Perm State University, according to the following methodology: drying, separation of magnetic and electromagnetic fractions, sieving according to size classes, heavy-medium separation.

Results

According to the results of the mineralogical analysis, the average gold content on the PPM-5 device was 0.1 g/m^3, the bulk of the gold loss is concentrated in the sand dumps.

Table 1 *Sieve analysis of gold according to exploration data.*

Size of fraction, mm	Weight of fraction, g	Yield of fraction, %	Accumulated output of fraction,%
– 0,125	0,005	0,2	0,2
+0,125-0,25	0,051	2,2	2,4
+0,25-0,5	0,252	10,8	13,2
+0,5-1,0	0,553	23,6	36,8
+1,0-2,0	0,947	40,5	77,3
+0,2	0,532	22,7	100,0
	2,339	100,0	

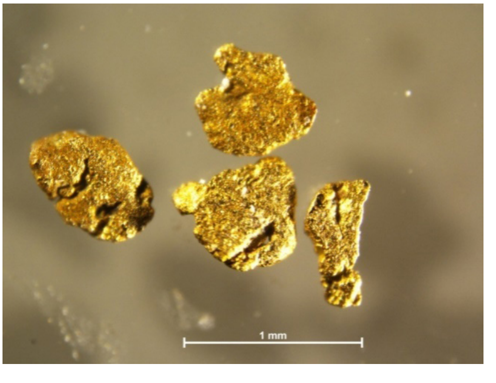

Figure 2 *Gold particles from sand dumps.*

Table 2 *Loss of the PPM-5 device.*

Size class, mm	Mass, g	Private output of fraction,%	Accumu-lated yield of fraction, %	Standard coefficient of extraction	Standard coefficient of loss	Extraction of gold, %	Loss of gold,%
-4,0	2,2	10,38	10,38	0,995	0,005	10,325	0,052
-2,0	2,3	10,85	21,23	0,995	0,005	10,795	0,054
-1,0	3,3	15,57	36,79	0,980	0,020	15,255	0,311
-0,5	5,3	25,00	61,79	0,930	0,069	23,275	1,725
-0,25	4,5	21,23	83,02	0,800	0,200	16,981	4,245
-0,15	3,4	16,04	99,06	0,500	0,500	8,019	8,019
-0,1	0,2	0,94	100,00	0,500	0,500	0,472	0,472
Total	21,2	100,00%				85,122	14,878

Loss of gold during enrichment on the PPM-5 device is shown in the tab. 2.

Discussion of results

The study of man-made gold-bearing dumps revealed the presence of oxidized pyrite. This suggests that under the action of water and air sulfides begin to oxidize. Because of this, the aqueous medium in the man-made dumps becomes acidic (pH 2.0-4.0). The increase in the acidity of industrial waters occurs during the winter time when these processes are intensified due to the freezing of precipitation (Osovetsky et al. 2016).

In the investigation of gold particles from man-made dumps, the presence of grains coated with iron hydroxides in the form of a film was established (fig. 3). Gold particles are completely covered with iron hydroxides. The presence of iron hydroxide films on the surface of gold particles indicates the decomposition of primary sulfides by industrial waters and the further precipitation of iron hydroxides on the surface of gold particles. Gold nanoparticles precipitate along with iron hydroxides.

Gold, like iron, is released during the oxidation of sulfides, and enters into the technogenic water. The release of gold from sulfides is facilitated by frosty weathering, and the presence of microorganisms: iron-oxidizing and sulfate-reducing bacteria. Gold from technogenic waters is deposited on primary gold-bearing phases (gold particles) and forms small crusts on the surface of gold. As a result of this process, there is a "growth" of gold in man-made dumps. (Naumovetal. 2017).

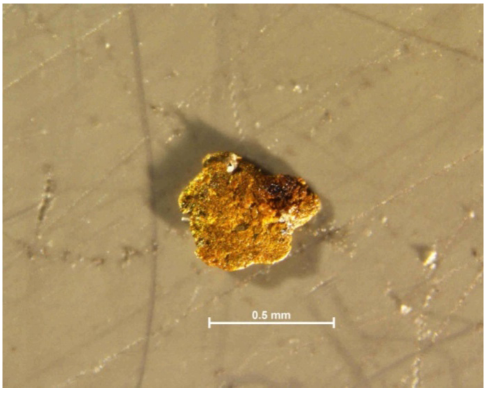

Figure 3 *Gold with iron hydroxides.*

It can be confirmed that dissolved gold is present in the dump waters. Gold from the dissolved form is deposited on the existing gold particles. An additional chemical carbonate barrier for the restoration of the metallic phases of gold may be marble interlayers from placer raft. Also of interest should be the clay fractions, in which dissolved gold could be sorbed on clay particles.

Conclusions

Due to the undertaken research, it can be assumed that the process of "growth" of gold is taking place in man-made dumps. Over time, substantial consolidation of the gold-bearing phases may occur. The proof of this process is the presence of technogenic newly formed gold in the dumps. One of the main factors influencing this process is man-made water. It is necessary to study in detail the morphology, and the internal structure of the gold of man-made objects of the Marakan placer. In the future, it is possible to create areas of controlled accumulation of industrial gold.

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