Natural Amalgam of Gold in Placers of the Ebelyakh Area – Indicator of Tectono-Fluid Activation (North-Eastern Siberian Platform)

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Abstract. The results of studying the typomorphic features of placer gold in the unique diamond-bearing placers of the Ebelakh river basin (Anabar diamond-bearing region) are given. Detailed study of the morphology, micro-relief of the surface and internal structure of the gold and photographing was performed using a scanning electron microscope JEOL JSM-6480LV. The gold fineness was determined using the Camebax-Micro microanalyzer and the JEOL OXFORD INCA-sight energy spectrometer. The internal structure of native gold was studied by etching gold in mounted thin sections using a proven method, using a reagent: HCl + HNO3 + FeCl3 × 6H2O + CrO3 + thiourea + water. It is determined that, modern placer occurrences were formed mainly due to the redeposition of fine high-grade gold from ancient gold-bearing intermediate sources. At the same time, in the placer of the Kamenisty creek a natural amalgam of gold is discovered, which is an aggregate consisting of several cemented rounded gold particles of small size (~0.25 mm) of various morphology. The cement is superimposed medium-grade gold with Hg content of up to 13.3%. Its internal structure is porous, and zoning is noted due to the uneven distribution of Hg. The surface of mercury gold is characterized by a brain-like microsculpture. Along with this, in some placers of the studied area, it was possible to find small (>0.2 mm) gold particles with a specific surface with the thinnest (first microns) fringe of mercury (ртутистого) gold. Obviously, these are single grains of the disintegrated aggregates of auro amalgam. We also found gold particles in an aluminosilicate film of variable Al, Si, K, Fe composition, and the smallest (1-2 microns) mineral phases of gold, sphalerite, galena, zincite and zinc-containing iron are identified on this film. It is assumed that natural amalgamation of placer gold occurred as a result of migration of mercury-containing gold-bearing hydrothermas on fault zones during tectonomagmatic activation. Based on the above-mentioned, it is assumed that there are adjacent sources of supply – low-temperature hydrothermal ore occurrences confined to the faults and formed as a result of tectonomagmatic activation processes. This proposition is confirmed by the identification of hydrothermal-metasomatic formations of K-spar-quartz-pyrite composition with disseminated gold-sulfide mineralization on the studied territory. The similarity of geological conditions of localization and the material composition of apocarbonate hydrothermal-metasomatic formations of the Ebelyakh area with the gold-bearing rocks of the Central Aldan ore district allow to estimate positively the prospects for their further study.
1. Introduction
In the North-east of the Siberian platform, there are unique diamond-bearing placers of the Ebelyakh river basin (Anabar diamond-bearing region), where more than 50% of the Russian potential for placer diamonds is concentrated [1]. Fine gold with a content of 10 to 300 mg/m3 is found in almost all these placers. Nature of primary sources of placer gold of the Ebelyakh area is not identified to date. In order to predict potential gold ore sources, we studied mineralogical-geochemical features of placer gold in the Ebelyakh river basin.

2. Methodology
Detailed study of the morphology, micro-relief of the surface and internal structure of the gold and photographing was performed using a scanning electron microscope JEOLJSM-6480LV. The gold fineness was determined using the Camebax-Micro microanalyzer and the JEOL OXFORD INCA-sight energy spectrometer. Gradation of fineness is given according to the classification proposed by N. V. Petrovskaya [2]. The internal structure of native gold was studied by etching gold in mounted thin sections using a proven method [2], using a reagent: HCl + HNO₃ + FeCl₃ × 6H₂O + CrO₃ + thiourea + water.

3. Geological-structural position
Geological structure of the studied territory involves carbonate rocks of the Cambrian, terrigenous deposits of the Permian and volcanogenic formations of the Triassic age, which are overlapped by incoherent Neogene and Quaternary sediments. Magmatic rocks are represented by the Triassic intrusive bodies of basic and alkaline-ultrabasic composition. Placers of the Ebelyakh river basin are within the Lena-Popigay uplift, complicated by the Billyakh depression and Ebellyakh uplift, which has the block nature of the structure. According to the data of the predecessors, disjunctive dislocations were of great importance in development of the region, and deep faults and faults of the sedimentary cover are identified in these dislocations. They form several systems of North-west, North-east, latitudinal and meridional direction, often involving zones of increased fracturing. During the Mesozoic tectonic-magmatic activation, the ancient systems of deep faults (Molodo-Popigay, Anabar-Eiekit) were rejuvenated, that led to the formation of a series of new faults [1, 2, 3]. It should be noted that most modern rivers have inherited paleovalleys of the Mesozoic watercourses formed on the faults.

4. Research results
Placer gold of the Ebelyakh river basin belongs to fine and very fine fractions. According to morphological features, lamellar (35%), toroidal (40%), spherical (15%) and clotted (10%) forms are identified. The surface of gold is thin-shagreen, often with casts of pressing of minerals pelitic material in the pits. The gold fineness is generally high (900-1000%), which is more than 90%. The internal structure of high-grade gold is determined by its deep transformations and is represented by recrystallization structures, translation lines, and a thick (<15 microns) very high-grade film. In general, the vast majority of the studied gold has undergone repeated redeposition through intermediate sources of different ages.

Along with the typical rounded high-grade gold in alluvial deposits of the Kamenisty creek, a natural amalgam of gold is found, which is about 10%. Auramalgama consists of several cemented rounded gold particles of small size (-0,25 mm) and different shapes (Figure 1, a, b). Cement is a superimposed gold with an Hg content of up to 13.3%. This gold also covers in the form of a film rounded gold particles of high or medium fineness (Figure 1, c). The distribution of Hg is irregular. The internal structure of this gold is porous, the zoning is identified (Figure 1, f), the fineness of medium. The surface of superimposed gold is characterized by brain-like microsculpture.
Figure 1. Natural gold amalgam of the Ebelakh area: $a$ – $b$-morphological features; $c$ – cross section of the gold amalgam and its chemical composition; $d$ – zonal internal structure of the superimposed mercury (прутстого) gold (etched with a reagent).

It should be noted that in alluvial deposits of the Ebelakh, Morgogor, Balagannakh and Kamenisty rivers, small (>0.2 mm) gold particles with a specific irregular surface (Figure 2, $a$) with the very thin (10 microns) film of mercury gold were also found (Figure 2, $b$).

Figure 2. Gold with the thinnest mercury margin: $a$ - clotted gold particle with a hook-like process; $b$-cross section and chemical composition.
Obviously, these are single grains of the disintegrated aggregates of auroamalgama. During transportation in the water-alluvial environment, this shell probably disappears completely, and the gold assumes a normal habit. Along with this, rounded gold particles of various morphology were found. Newly formed small (first microns) microcrystals of zincite, forming a thin film, were identified on the surface of these gold particles during a detailed microprobe study. The presence of zinc gives this gold not its usual color – from grayish to completely black. There are also gold particles in an aluminosilicate film of variable Al, Si, K, Fe composition; the smallest (1-2 microns) mineral phases of gold, sphalerite, (Figure 3) galena and zinc-containing iron are found on this film.

![Figure 3: Gold with margin: a - cross section and chemical composition of gold with a thin margin of zincite; b - cross section and chemical composition of gold with an aluminosilicate margin with the smallest mineral phase of sphalerite](image)

5. Discussion of results
Analysis of the literature data has shown that natural gold amalgam is found in the Quaternary placers of Uzbekistan, terrace deposits of the Zeya river basin, in placers of the Khankai terrain (Primorye), in the Mesozoic and modern placer occurrences of the East-European platform, etc. [7, 8, 9, 10]. Most researchers associate the genesis of natural amalgams of gold with the processes of tectonomagmatic activation. When these processes occurred, low-temperature gold-bearing hydrothermas enriched with mercury entered the zones of deep faults. In addition, according to published data, various associations of native metals and intermetallides of a wide elementary spectrum (Au, Ag, Fe, Ni, Co, Cr, Mn, Pb, Zn, Cd, Sb, Cu, Pt, Pd, Sn, Bi, Al, C,) as well as metal oxides, nitrides and cyanides of metals, cuprostibite, telluric Fe, zinc Cu are identified within the platform areas. This fact is considered by many geologists as evidence of fluid outgassing of the Earth, occurred within deep faults during tectonomagmatic activation (11, 12, 13, 14).

The formation of the natural amalgam of gold of the Ebelyakh river basin is explained by our assumption as follows. The migration of low-temperature gold-bearing hydrothermas enriched with mercury occurred on the faults, that were renewed in the Mesozoic, and possibly at a later time. Some of these solutions passed through gold-bearing deposits. At the same time, the processes of natural amalgamation of gold took place, and gold aggregates consisting of several grains of different morphology were formed as a result. The presence of an aluminosilicate film with the smallest mineral phases of zincite sphalerite on the rounded gold particles also indicates the manifestation of superimposed hydrothermal processes.

Thus, the identification of the natural amalgam of placer gold indicates the presence of primary sources – low-temperature hydrothermal ore occurrences, confined to the faults and formed as a result of tectonomagmatic activation processes. This is confirmed by our field studies, that resulted in
discovery of apocarbonate hydrothermal-metasomatic formations with disseminated gold-sulfide mineralization in the gutter of the placer of the Kamenisty creek in the zone of tectonic jointing. Epigenetic mineral association of these formations has a K-feldspar-quartz-pyrite composition. In addition, to the north of the studied area, in the Billyakh river basin we have also studied the near-fault apocorbanate K-feldspar and K-feldspar-quartz metasomatites with disseminated gold-sulfide mineralization [15]. It is noteworthy that the geological conditions of localization and material composition of these formations are similar to the gold-bearing metasomatites of the Central Aldan gold ore region.

Obviously, discovered hydrothermal-metasomatic formations require further more detailed study, that can generally shed light on the nature of the primary sources of fine and finely dispersed placer gold of the Ebelyakh river basin and the entire North-east of the Siberian platform.

6. Conclusions
The study of mineralogical-geochemical features of placer gold in the Ebelyakh river basin, comparison of the obtained data with the history of the geological development of the area and the results of field work allow us to make the following main conclusions:

1. The combination of identified typomorphic features of the prevailing part of the studied gold indicates that, modern placer gold-bearing occurrences of the Ebelyakh river basin were formed mainly due to the redeposition of fine high-grade gold from ancient gold-bearing intermediate sources.

2. Discovery of natural gold amalgam and gold particles with the thinnest mercury margin, as well as an aluminum silicate film with the smallest mineral phases of sphalerite and zincite indicate that, during tectonomagmatic activation in the fault zones, superimposed processes of low-temperature ore mineralization occurred. This is confirmed by identification of near-fault apocarbonate hydrothermal-metasomatic formations with disseminated gold-sulfide mineralization. The similarity of geological conditions of localization and the material composition of apocarbonate hydrothermal-metasomatic formations of the Ebelyakh area with the gold-bearing metasomatites of the Central Aldan ore district allow to estimate positively the prospects of further study.

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