Typomorphism of fine placer gold and potential primary sources of the Anabar mineral subprovince (North-eastern Siberian Platform)

Boris Gerasimov¹

¹Diamond and Precious Metal Geology Institute, Siberian Branch, Russian Academy of Sciences, 39, prosp. Lenina, Yakutsk, Russia, 677000.

Bgerasimov@yandex.ru

Abstract. Typomorphic features of placer gold of the Anabar and Bolshaya Kuonamka river basins are studied with the aim of determining its indicators and forecasting potential primary sources. All analytical work was carried out in the department of physico-chemical methods of analysis IGABM SB RAS. A detailed study of the morphology, surface microrelief, photographing was performed on a JSM - 6480 LV scanning (microscope) microscope of JEOL company with Oxford Instruments analytical prefixes (wave and energy dispersive spectrometers). Gold fineness is determined on Camebax-micro X-ray microanalyzer a «Cameca» firms. It is shown that the main sources for the gold are auriferous reservoir rocks of Neogene-Quaternary age. The indicator typomorphic features of the gold include a small size (-0.5 mm), scaly and platy forms, rough shagreen surface with casts of minerals pressing, and high fineness (900-999‰). The most highly informative feature is a strongly modified internal structure of the gold showing evidence of granulation and recrystallization. Autochthonous gold of ore habit is also found. Characteristic features of this type of gold are a very small size (-0.2 mm), angular-cloidy forms of individual particles, rough porous surface, widely ranging fineness (535 to 999‰), heterogeneous chemical composition, and a complex, multi-phase internal structure. This indicates the presence of neighboring primary sources. Hydrothermal-metasomatic formations with disseminated gold-sulfide mineralization, discovered at the places of tectonic jointing of carbonate rocks, developed in fault zones could be such sources. Considering epigenetic mineral associations, quartz-potassium feldspar and quartz hydrothermal-metasomatic formations are identified. Ore mineralization of disseminated type is represented by (in decreasing order) pyrite, gold, chalcopyrite, galena, sphalerite and silver. Gold is found in native form and in association with pyrite (quartz metasomatites) and potassium feldspar metasomatites. Thus, as a result of performed studies, indicator typomorphic features of autochthonous fine gold are identified. Near-fault hydrothermal-metasomatic formations with gold-sulfide disseminated mineralization are discovered in the studied area for the first time and examined.

1. Introduction
The study region is located in the north-east of the Siberian platform and occupies basins of the Bolshaya and Malaya Kuonamka rivers, draining eastern framing of the Anabar shield, as well as the Anabar river basin, which tributaries flow across the Cambrian carbonate rocks. Numerous complex gold-diamondiferous placers occur here. Identification of primary sources of fine gold is one of the
important unsolved problems. In this connection, the study of complex of typomorphic features of placer gold as an indicator of a possible type of the source, as well as analysis of the tectonic structure of the region with the aimed of determining areas with potential for localization of prospective primary sources of fine gold are important. For that purpose, typomorphism of gold from the Billyakh river (Anabar river tributary) and the Neiabayt creek (Bolshaya Kuonamka river tributary) was studied, as well as hydrothermal-metasomatic formations, localized in fault zones.

2. Methodology
A detailed study of the morphology, surface microrelief, gold inner structure, photographing, as well as analytical studies of polished sections were performed on a JSM - 6480 LV scanning (microscope) microscope of JEOL company with Oxford Instruments analytical prefixes (wave and energy dispersive spectrometers). Gold fineness is determined on Camebax-micro X-ray microanalyzer a «Cameca» firms. All analytical work was carried out in the department of physico-chemical methods of analysis DPMGI SB RAS (analysts Popova S.K., Sannikova A.E., Khristoforova N.V.). Gradation on particle size and gold fineness was performed according to the classification of Petrovskaya N.V. [1]. The inner structure of native gold was studied by gold etching in mounted thin sections in accordance with proven methodology [2], using the chemical agent: HCl + HNO3 + FeCl3 × 6H2O + CrO3 + thiourea + water.

3. Results and discussion
Placer gold of the samples, selected from alluvial deposits of the Billyakh river, draining dolomites of the Anabar formation of the Cambrian, was studied. Analysis of the granulometric composition of gold showed that fine gold of fraction -0,5 mm prevails – ≈ 90%. Considering morphological features, the main part of gold is characterized by scaly and platy forms, thin rough-shagreen surface with casts of minerals pressing.

![Figure 1. Internal structure of well-rounded high grade gold in the Billyakh river basin derived from rocks of intermediate: a-b) recrystallization structures; c) granulation structures](image)

It has intensively transformed inner structure that is expressed by structures of recrystallization, granulation and formation of thick high grade film (figure 1, a-c). Scaly particles prevail. In these particles, high grade gold almost completely replaces primary more low grade gold. Relict primary gold preserves on in central parts of such gold particles. In general, gold of over 76% fineness prevails. Combination of identified typomorphic features of the main part of the studied gold indicates long presence in exogenetic conditions and its redeposition from intermediate sources. The Neogene-Quaternary gold-bearing deposits, wide spread in watershed divide area of the Billyakh river basin, could be such intermediate sources. Along with this gold, very fine (-0.2 mm) particles of gold of ore habit of platy, angular-cloddy and dendritic forms are found in all studied samples – up to 15% (figure 2, a-d).
Their surface is uneven spongy and porous. Fineness varies within wide intervals – from low (535‰) to very high (999‰). Analysis of gold fineness and its morphological features showed that only gold particles of ore habit have relatively low (799-700‰) and low (699-500‰) fineness. In several samples, the portion of low grade gold (699-500‰) reaches 8%. During structural etching of gold, its heterogenous multi-phase structure becomes apparent (figure 3, a-d). Central parts of gold particles are composed of low grade (500-600‰) phase, represented by grains of oval form of 10-50 microns of size (figure 3, d). Intergranular spaces are filled with high grade gold (figure 3, c). Studied gold particles are almost not transformed in hydrodynamic conditions, just very thin porous often discontinuous margins of very high grade gold are observed on several gold particles. These clearly show the supply of slightly altered gold into modern alluvium from neighboring primary sources.

**Figure 2.** Morphological features of unrounded gold: a – subrounded gold particle with dendritic outgrowths at the surface; b – angular-cloddy gold with a rough porous surface; c – fracture-type unrounded gold with a rough surface; d – unrounded gold of irregular form
Near fault hydrothermal-metasomatic formations (HMF), found by as a result of field works in headstream of the Billyakh creek, can be potential primary sources of this gold. Studied HMF are developed on the Cambrian dolomites and are localized in the fault zone. Disseminated gold-sulfide mineralization is identified in them. Quartz - potassium feldspar and quartz HMF are identified.

Quartz – potassium feldspar HMF are rust-brown. Their structure is predominantly banded, network-veinlet, due to development of differently oriented veinlets of ferrum oxides – products of pyrite decay. At daylight surface, these rocks are fairly quickly weathered – often transform into thin rust fine-dispersed mass. Potassium feldspars (PFS) are developed mainly in crush microzones and microfractures of dolomites (figure 4), and in veinlets of siliceous-iron-aluminosilicate composition, penetrating carbonate rocks. The thickness of these veinlets is from tenths of mm to several mm in swells. PFS is characterized by small dimensions and crystalline forms. Ore minerals in quartz-iron-aluminosilicate veinlets are represented by very fine particles and phases of native gold, pyrite, arsenopyrite, sphalerite and galena. Barite also often occurs as very small veinlets in microfractures of dolomites. It should be noted that the regeneration of carbonate minerals with an increase of their dimensions is well visible urr microscopic studying.

Figure 3. Internal structure of unrounded gold (etched by an aqua regia-based reagent): a) general view in a polished section; b-d) details: b) three-phase gold, c) high-fineness gold in intergranular space, d- low-fineness gold grains of oval forms
Figure 4. Potassium feldspar metasomatites: a – small crystals of potassium feldspar (fs), pyrite (py) and very small gold particle (Au) in dolomite fracture; b – disseminated pyrite mineralization (light, py) and small crystals of potassium feldspar (fs) in the altered dolomite (do).

Figure 5. Quartz metasomatites: a) dolomite relics (do) in the central part of quartz (q) oolite (thin section; b) sulfide (Py) mineralization on quartz metasomatite; c) small grains of native gold (Au)

A typical feature of quartz HMS is their oolite structure, taken from carbonate rocks. In these formations, quartz almost completely replaces dolomites. Only very small their relics are observed in the central parts of oolites (figure 5). Quartz is mainly represented by colloform-sinter particles, and chalcedony-like differences. Ore disseminated mineralization is localized mainly in peripheral parts of globular nodules – oolites and is represented by mainly by pyrite and goethite, by chalcopyrite and galena as sharply subordinated minerals. Pyrite, completely replacing quartz in oolite nodules, is
observed sometimes. Gold occurs mainly in free native type, rarely in association with pyrite. Its size depends on the first microns to 15 µm along the long axis. Particles with an admixture of mercury from 0.5 to 2.6%.

The Nebaibyt river flows down the north-eastern slope of the Anabar massif on the Riphean dolomitic limestones. Gold from exploration pitted samples is studied. Considering dimensions, very fine gold of -0.25 mm fraction, prevails (55%). Gold is represented by platy form with rough shagreen surface, often with casts of mineral pressing. It is characterized by a strongly altered constitution with structures of recrystallization and granulation, and with thick high grade margins and very high grade intergranular veinlets (figure 6). This indicates repeated redeposition of gold from ancient intermediate sources to younger deposits. Thus, auriferous intermediate sources are major sources of gold of modern alluvial deposits of the Nebaibyt river.

![Figure 6](image-url)

Figure 6. Inner structure of gold from the Nebaibyt river: a) very high grade intergranular veinlets in high grade gold; b) structures of granulation of high grade gold

At the same time, in all studied samples, from first to ten percent, gold of ore habit is identified, which is represented by equant crystals, angular-cloddy and platy particles, and peculiar hooked individuals (figure. 7). As a rule, the fraction of poorly rounded gold is -0.25 mm. Its fineness varies within wide ranges – from low (electrum) to very high. Discovery of gold of ore habit suggests the presence of neighboring primary sources in the region.

Analysis of literature data showed that the tectonic crush zone extending in submeridional direction and covering the middle course of the Arbaibyt, Machala, Talakhtakh and Nebaibay rivers is the most potential for discovery of ore source [3], [4]. We studied cataclastic dolomitic limestones, exposed on the Machala and Talakhtakh river sides. Rocks are penetrated with thin quartz and calcite veinlets. Tectonic breccias are widespread.
Figure 7. Gold of ore habit, -0.25 mm fraction, Nebaibayt creek: a) hooked; b) crystals growth; c) oar-like; d) fusiform

As a result of electron-probe microanalysis of polished sections, made of the samples of this tectonic zone, disseminated precious-metal and sulfide mineralization of altered carbonate rocks is identified. Mineralization is represented by very small particles of gold, silver, pyrite, arsenopyrite, antimonite, molybdenite, argentite and native tin (figure 8). Gold and silver are developed mainly in quartz veinlets and are characterized by equant forms and small (up to 10 µm) size. Pyrite, represented mainly by cubic crystals and their aggregates, is most prevalent among sulfides. Very small (up to 5 µm) particles of antimonite, molybdenite, sphalerite, argentite and arsenopyrite occur as sharply subordinated minerals. Platy particles of native tin are rarely observed.
Figure 8. Forms of particles of ore minerals of the zone of disseminated gold-ore mineralization of the eastern framing of the Anabar massif: a) gold particle of teardrop-shape in microfracture of quartz; b) equant grain of silver in quartz veinlet; c) pyrite crystals in microfracture of dolomitic limestone; d) plate of native tin and grain of antimonite in carbonate matrix; e) equant particle of sphalerite; f) microcrystals of argentite in altered dolomite

Based on the above, it can be assumed that described occurrence of disseminated ore mineralization, localized in altered dolomitic limestones could be the primary source of very fine non-rounded autochthonous gold.

4. Conclusions
Study of mineralogical-geochemical features of gold from the placer occurrences of the Billyakh and Nebaibyt rivers and comparison with the geological structure of the region allowed to prove that its major sources were auriferous intermediate sources. Typical typomorphic features of this gold – small size of individuals (-0.5 mm), scaly and platy forms, rough shagreen surface with casts of minerals pressing, high fineness (900-999‰), as well as significantly altered inner structure.

At the same time, the discovery of autochthonous gold of very small sized (-0.2 mm) ore habit of angular-cloddy form with a wide range of fineness varieties (535-999‰) and complex, the multiphase internal structure suggests the presence of neighboring primary sources.

Hydrothermal-metasomatic formations with gold-sulfide disseminated mineralization, localized in fault zones in the field of carbonate rock development, probably were potential primary sources of very fine gold.

Acknowledgment(s)
Work is done on state assignment of DMPGI SB RAS and partly as part of the grant № 18-45-140018 of the Russian Foundation for Basic Research.

References
[1] N.V. Petrovskaya. Native gold. “Nauka” publishing house, Moscow. p. 347, 1973.
[2] N.V. Petrovskaya, M.I. Novgorodova and K.E. Frolova. “Nature of structures and substructures of endogenetic particles of native gold: Petrovskaya N.V., Fatyanov I.I.”, Mineralogy of native elements. FESB AS USSR publishing house, Vladivostok, p. 10-20, 1980.

[3] S.F. Dukhanin and E.N. Erlich. “Explanatory note to the map”, scale 1: 200 000 (Sheet R-49-XVII, XVIII – Anabarskaya series). Moscow, p. 70, 1967.

[4] A.V. Tolstov. “Mechanisms of origin and location of the principal ore-bearing formations of the northern part of the Siberian platform”, Manuscript of thesis for the degree of Doctor of geological-mineralogical sciences. Yakutsk, p. 312, 2006.