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GEOLOGY

A Unique Ore-Placer Area of the Amur Region with High-Hg Gold

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Abstract—This work presents the geological structure and a description of the gold-ore occurrences and gold placers of the Un'ya-Bom ore-placer cluster of the Amur gold-bearing province. The host rocks are Late Paleozoic and Mesozoic black shales. Intrusive formations occur rarely. The sublatitudinal Un'ya Thrust is the principal ore-controlling structure. Paleozoic sandstones are thrust over Mesozoic flysch deposits along the Un'ya Thrust. The gold-ore occurrences are represented by quartz-vein zones. The ores are gold–quartz, low-sulfide. Ore minerals are arsenopyrite, scheelite, ferberite, galena, and native gold. High-Hg native gold was revealed in the ore occurrences and placers. The high Hg content in native gold is explained by the presence of the frontal part of the gold-bearing column located within the cluster; the rich placers were formed due to crushing of this column.

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The Un'ya-Bom ore-placer cluster is situated at the northwestern flank of the Dzhagdy-Selemdzha Zone of the Amur gold-bearing province [1]. What makes the cluster unique is the high-Hg native gold that occurs in the rich placers and numerous ore occurrences of the gold–quartz formation. We have studied this phenomenon.

The ore-placer is generally composed of Late Paleozoic and Mesozoic terrigenous, so-called, black shale deposits; intrusive formations are extremely rare (Fig. 1). The geological pattern of the distribution of the gold mineralization and the placers is analogous to the ore-placer clusters of the Central Kolyma gold-bearing province [4]. Publication [3] shows that the Au contents in the ore-hosting Amkan and Dzheskogon suites are close to Clarke values of 4.4 and 6.6 mg/t, correspondingly, which excludes the theory of the metamorphic origin of the gold mineralization in the Un'ya-Bom cluster and point to its hydrothermal origin.

The Un'ya Thrust, along which the Paleozoic deposits of the Dzheskogon Suite are thrust over the Mesozoic flysch deposits of the Amkan Suite, is an ore-controlling structure [3]. Faults of northeastern strike are less common. Paleozoic formations are folded into the large sublatitudinal synclinal fold. The Bochagor Suite rocks are exposed at the core of the syncline, and the rocks of the Nekter and Dzheskogon Suites are in the syncline limbs. Generally, the ore cluster is associated with the allochthonous and autochthonous zones of the sublatitudinal Un'ya Thrust.

Gold mineralization and placers resulting from crushing are distributed within a narrow (15–20 km) elongated (80 km) sublatitudinal zone. In the western part of the cluster, the zone is mostly attributed to the allochthon; in the eastern part, to the autochthon of the Un'ya Thrust. The thrust apparently serves as a screening structure. Gold mineralization is often attributed to the node where the thrust is intersected by northwest-striking strike-slip faults or normal-strike-slip faults (Alekseevskoe occurrence, Schastlivoe occurrence, Chertova Lestnitsa occurrence, etc.). These faults are ore-generating structures.

The ore occurrences are presented by gold-bearing quartz veins and vein zones. They belong to a gold–quartz formation of a hydrothermal group. Ores are low-sulfide, and the amount of ore minerals, among which scheelite, arsenopyrite, galena, and native gold dominate, is no greater than 1–5%. Gold is relatively high-grade (880–900‰). The characteristic feature of gold is the significant content of an Hg admixture (up to 9.37%) which creates a solid solution with gold. The Alekseevskoe and Schastlivoye gold-ore occurrences are the most typical (Fig. 2).

The Alekseevskoe gold-ore occurrence is situated in the upper reaches of Alekseevskii Creek, a left-bank tributary of the Sirik-Makit River. The gold-ore occurrence is presented by the northeast-striking quartz vein zone. The zone is located in the allochthone of the Un'ya Trust, which is composed of sand-

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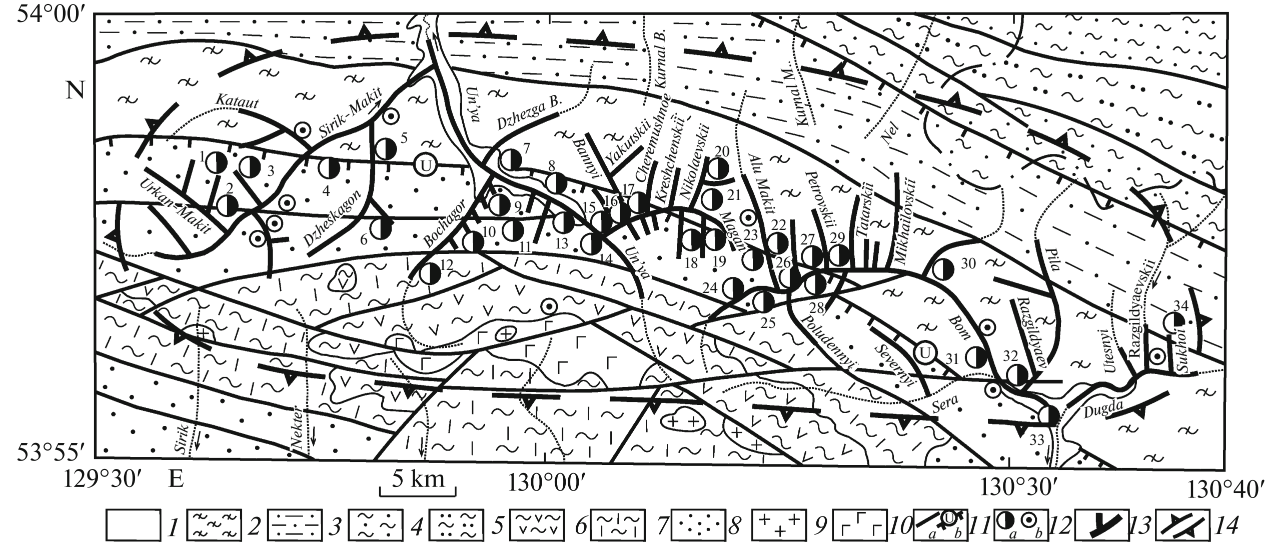

Fig. 1. The Un'ya-Bom ore-placer cluster, geological structure. *1*, Quaternary alluvial and alluvial–deluvial sand, clay, pebble; *2*, Lower Jurassic Amkan Suite, thin periodic interlayering of siltstone, claystone, and sandstone; *3*, Lower Jurassic Kurnal Suite: sandstone; interlayers of siltstone, tuffaceous sandstone, tuffaceous siltstone, gritstone, and conglomerates; *4*, Upper Triassic Nel Suite: siltstone, tuffite, clay shale, sandstone; *5*, Upper Triassic Muyakan Suite: sandstone, siltstone, gritstone; *6*, Lower Permian Bochagor Suite: green schists, quartzite, phyllite, marmorized limestone; *8*, Upper Carboniferous Dzheskogon Suite(?): sandstone, siltstone, gritstone, green schists, marmorized limestone; *9*, plagiogranite, granite, granodiorite, monzogabbro of Lower Permian Pikan complex; *11*, rupture dislocations: (*a*) steeply inclined; (*b*) thrusts; *12a*, ore occurrences: (1) Alekseevskoe, (2) Sirik-Makit, (3) Schasnlivoe, (4) Dzheskogon-2, (5) Dzheskogon-1, (6) Elizavetinskoe, (7) Dzhega B., (8) Un'ya, (9) Bochagor-1, (10) Bochagor-2, (11) Sovetskoe, (12) Gniloe, (13) Landyr'; (14) Un'inskoe, (15) Bannoe; (16) Magan, (17) Cheremushnoe, (18) Sheelitovoe, (19) Khaimovskoe, (20) Severnoe, (21) Maganskoe, (22) Alu-Makit, (23) Bom, (24) Bomskaya Zhila, (25) Zharkovskaya Terrasa, (26) Ninninskoe, (27) Veselaya Gorka, (28) Bom Ninninskoe, (29) Petrovskoe, (30) Chertova Lestnitsa, (31) Bom-Sera, (32) Pila, (33) Dugda, (34) Nopolevoe; *12b*, points of gold mineralization; *13*, gold placers; *14*, cluster boundaries.

stones of the Dzheskogon Suite and consists of several echelonlike quartz veins with a thickness of 0.5–3.0 m. Some veins are tilted at angles of 30–70 degrees to the southeast (140°–170°); vertical veins and veins tilted at angles of 70 degrees to the northwest are less common. Ore minerals of the veins are presented by arsenopyrite, scheelite, galena, chalcopyrite, and native gold. The content of Au is 1–7 g/t; W, 0.1%; As, 3%; Zn and Pb, 0.01%. Ore mineralization belongs to the gold–quartz formation.

The Schastlivoe gold-ore occurrence is attributed to the upper reaches of Schastlivyi Creek, a left-bank tributary of the Sirik-Makit River. The ore field is composed of flysch deposits of the Amkan Suite and sandstones of the Dzheskogon Suite divided by the sublatitudinal Un'ya Thrust. Gold-ore mineralization is concentrated in the allochthon, less often in the autochthone of the thrust. Gold-ore mineralization is represented by quartz veins and vein series attributed to northeast-striking feathering fault ruptures. The veins are composed of coarse quartz (95–98%), albite (1–4%), calcite (1–2%), sericite, and chlorite. Scheelite, arsenopyrite, ferberite, galena, and native gold dominate among ore minerals; pyrite, pyrrhotine, chalcopyrite, and sphalerite are less common. The content of sulfides is no more than 2–5%. Gold generally associates with arsenopyrite, scheelite, and galena. The Au content in the veins varies from "traces" to 10–14.2 g/t; W up to 1%; As up to 3%; Pb, 0.05%. The Au/Ag ratio varies from 1 : 30 to 4 : 1. Gold mineralization belongs to the gold–quartz formation.

Gold is fine grained, cloddy, liquid-like–platy, crystalline, drusoid, and wirelike. There are intergrowths of gold with arsenopyrite and scheelite. The X-ray spectral analysis of the gold content showed variation of the gold grade from 840 to 895‰ (Table 1). The main admixtures are Ag (6.7—7.66%) and Hg (1.72—9.37%). Mercury is evenly distributed on a shear flat of gold grains. The edges of grains are bordered by an Hg-enriched rim 10–15 μm thick. The uniform high levels of the Hg content in native gold indicate significant Hg concentrations in gold-ore hydrothermal solutions and codeposition of Au, Ag, and Hg from the solutions. However, at the end of the ore deposition, the Hg concentration in hydrotherms, apparently, increased resulting in the formation of a rim with a high Hg content.

The Un'ya-Bom cluster has long been known by the gold placers. Gold placer deposits were discovered in 1887. The gold placers are concentrated in the sublatitudinal zone 80 km in length extending from the Sirik-Makit Basin in the west to the Dugda Basin in

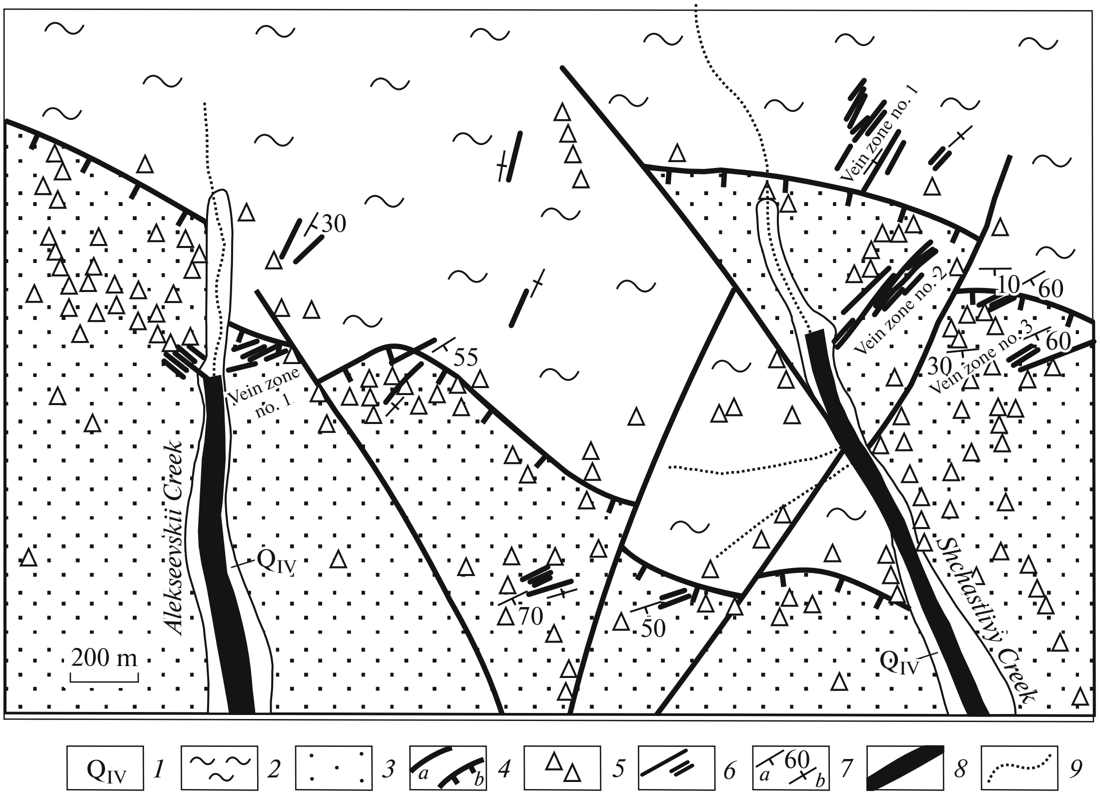

Fig. 2. Alekseevskoe and Schastlivoe gold-ore occurrences. *1*, Quaternary alluvial sand, pebble; *2*, interlayering of siltstone, claystone, and sandstone of the Lower Jurassic Amkan Suite; *3*, sandstone with interlayers of gritstone and claystone of the lower subsuite of the Dzheskogon Suite of the Upper Carboniferous; *4*, steeply inclined faults (*a*), thrusts (*b*); *5*, talus of quartz vein; *6*, gold-bearing quartz veins and vein zones; *7*, vein bedding: inclined (*a*), vertical (*b*); *8*, gold placers; *9*, water courses.

the east. The total production of accounting gold was ~31.189 tons.

In the gold placers, native gold is single-type, mostly coarse. Gold nuggets from 1–10 to 730 g in weight were found. Sometimes, traces of intergrowths of gold crystals with other minerals are revealed on gold nuggets (Fig. 3). Intergrowths of placer gold grains with quartz are of frequent occurrence. In the gold placers, it is common to find sheelite, pyrite, sometimes arsenopyrite, galena, sperrylite, and cinnabarite among accessory minerals of gold. It proves that the gold placers are formed due to crushing of the mineralized gold–quartz formation with the same minerals–admixtures contained in ores.

Gold is of high-grade (875–900‰). Placer gold, like ore gold, is characterized by a high content of the Hg admixture (up to 3.8%) and minor admixtures of Fe, Ti, Bi, Cu, Al, Mn, Ca, and Mg. Hg is concentrated in the central part of gold grains decreasing to several tenths of a percent in the high-grade shell typical for placer gold. This indicates a lack of amalgamation in placer gold mining.

It is observed that the grain size of placer gold decreases from west to east, from mainly coarse grained gold in the placers of the Sirik-Makit and Un'ya Basins to mainly medium and fine grained gold in the placers of the Bom and Dugda Basins. Productivity of the placers decreases in the same direction. Therefore, 11.4 and 11.5 tons of gold were extracted

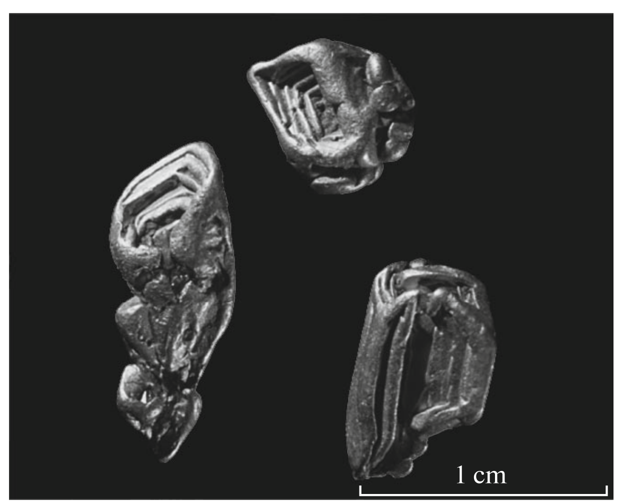

Fig. 3. The small gold nuggets with the planes of joint growth of gold, pyrite, and quartz crystals from the Dzheskogon Creek placer. The gold nuggets are kept in the Fersman Mineralogical Museum, Russian Academy of Sciences (http://www.fmm.ru).

Table 1. Composition of mercurous ore gold with data of the electron microprobe analysis

Grain number	Content, wt %			
	Au	Ag	Hg	Total
Camebax				
1	89.25	6.75	3.86	99.86
	84.75	6.75	8.95	100.45
2	91.25	6.75	1.72	99.72
	84.00	6.70	9.37	100.07
JXA-5A				
3	89.54	7.66	2.94	100.14
	87.91	6.97	5.40	100.28
4	88.71	7.66	4.05	100.42
	87.07	6.95	6.50	100.52
Average	87.77	7.02	5.32	

Above the line is the grain center, and below the line is the grain edge. Analyses were carried out on the Camebax apparatus (CAMECA), analyst S.M. Sandomirskaya, and JXA-5A (JEOL), analyst I.M. Romanenko.

from the placers in the Sirik-Makit and Un'ya Basins, and 80 and 0.2 tons in the Bom and Dugda Basins.

CONCLUSIONS

Gold mineralization of the gold–quartz formation, which contains high-grade gold with a high Hg content, and the accompanying rich gold placers are developed in the Un'ya-Bom cluster of the Amur province. The cluster is composed of Late Paleozoic and Mesozoic terrigenous black shale formations, slightly metamorphized in a green schist facies. Magmatic rocks are nearly nonexistent. Rare dykes of diabase and porphyrite occur only in the Chertova Lestnitsa and Bomskaya Zhila ore occurrences. Gold mineralization is presented by separated quartz veins and veinlets with high-grade gold with a high Hg content. These facts demonstrate the gold mineralization of the gold–quartz formation belonging to a hydrothermal group in the upper frontal part of the gold-bearing column located within the cluster. Therefore, geothermal fluids, which are enriched not only in Au and Ag, but also in Hg, took part in gold mineralization. The data on gold volatility in mercury gas, apparently, explain the joint accumulation and deposition of these elements in the form of high-Hg gold in the frontal part of the ore column.

Using the Central Kolyma as an example, it is clear from [4] that the frontal part of the gold-bearing column is extremely favorable to form gold placers. Although it is unlikely that large ore gold deposits will be discovered. The Schastlivoe, Maganskoe, and Bomskaya Zhila gold-ore occurrences are the most promising to carry out additional exploration. It is possible to reveal technogenic commercial placers in waste rocks of the largest recovered gold placers.

REFERENCES

1. V. A. Stepanov and V. G. Moiseenko, Dokl. Earth Sci. **421** (5), 779–781 (2008).
2. N. V. Petrovskaya, *Native Gold* (Nauka, Moscow, 1973) [in Russian].
3. V. A. Stepanov, *Geology of Aurum, Argentum and Hydrargyrum,* Pt. 2: *Aurum and Hydrargyrum of Amur River Province* (Dal'nauka, Vladivostok, 2000) [in Russian].
4. V. A. Stepanov, *Zoning of Silica Gold Metallization in Central Kolyma* (Dal'nauka, Vladivostok, 2001) [in Russian].
5. V. A. Stepanov, A. V. Mel'nikov, A. S. Vakh, et al., *Amur River Gold Ore Province* (Amur State Univ., Blagoveshchensk, 2008) [in Russian].
6. M. S. Fisher, Bull.-Inst. Min. Metall. **2** (9) (1935).

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