ISSN 1028-334X, Doklady Earth Sciences, 2017, Vol. 472, Part 2, pp. 173–177. © Pleiades Publishing, Ltd., 2017.
Original Russian Text © V.A. Stepanov, V.G. Moyseenko, A.V. Melnikov, 2017, published in Doklady Akademii Nauk, 2017, Vol. 472, No. 6, pp. 681–685.

GEOLOGY

A Unique Ore-Placer Cluster with High-Hg Gold Mineralization in the Amur Region (Russia)

V. A. Stepanov[a]*, Academician V. G. Moyseenko, and A. V. Melnikov[b]

Received March 28, 2016

Abstract—This work presents the geological structure and a description of gold-ore manifestations and gold placers in the Un'ya—Bom ore-placer cluster of the Amur gold-bearing province. The host rocks are Late Paleozoic and Mesozoic black-shale formations. Intrusive formations are rare. The sublatitudinal Un'ya thrust fault, along which Paleozoic sandstones overlap Mesozoic flyschoid deposits, is regarded as an ore-controlling structure. Gold—quartz and low-sulfide ores are confined to quartz-vein zones. Ore minerals are arsenopyrite, scheelite, ferberite, galena, and native gold. Gold-ore manifestations and placers contain high-Hg native gold. The high Hg content in native gold is explained by the occurrence of the eroded frontal part of the gold-ore pipe in the ore cluster, a source of native gold.

DOI: 10.1134/S1028334X17020210

The Un'ya—Bom ore-placer cluster is in the northwestern flank of the Dzhagdy—Selemdzha zone of the Amur gold-bearing province [1]. The uniqueness of the cluster is that rich placers and numerous ore manifestations of gold—quartz formation contain high-Hg native gold. This work is aimed at studying this phenomenon.

Geologically, the Un'ya—Bom ore-placer cluster is composed of Late Paleozoic and Mesozoic terrigenous deposits (so-called black-shale formations) and quite rare intrusive formations (Fig. 1). The geological pattern of the emplacement of gold-ore mineralization and gold placers is similar to that characteristic of ore-placer clusters in the Central Kolyma gold-bearing province [4]. As is shown in [3], the Au contents in the ore-bearing rocks of the Amkan and Dzheskogon formations are close to bulk earth values (4.4 and 6.6 mg/t, respectively). This fact contradicts the version of metamorphic genesis of gold mineralization of the Un'ya-Bom cluster and evidences its hydrothermal origin.

[a] *Geotechnological Research Center, Far East Branch, Russian Academy of Sciences, Petropavlovsk-Kamchatsky, 683002 Russia*
[b] *Institute of Geology and Nature Management, Far East Branch, Russian Academy of Sciences, Blagoveshchensk, Amur oblast, 675000 Russia*
**e-mail: anton_amur@mail.ru*

The Un'ya thrust along which the Paleozoic rocks of the Dzheskogon Formation thrust over the flyschoid rocks of the Amkan Formation is an important ore-controlling structure [3]. The northeast-striking fault zones are less important. Paleozoic strata are folded into a large sublatitudinal synclinal fold with rocks of the Bochagor Formation in the core and rocks of the Nekter and Dzheskogon formations on the limb. In general, the gold-ore cluster is confined to allochthonous and autochthonous zones of the sublatitudinal Un'ya thrust fault.

Gold bearing-quartz veins and gold placers formed due to their destruction are concentrated within a narrow (15—20 km) elongated (80 km) sublatitudinal zone. In the western part of the cluster, this zone is confined predominantly to the allochthonous plate of the Un'ya thrust fault, and in the eastern part, it is limited to the autochthonous plate. It is likely that this thrust zone acts like a screening structure. Gold mineralization (Schastlivoe manifestation, Chertova Lestnitsa manifestation, etc.) is often confined to intersection nodes of the Un'ya thrust by northeast-striking strike-slip faults or oblique-slip faults, which play the role of ore-generating structures. Gold-ore manifestations are represented by gold-bearing quartz veins and vein zones. They belong to a gold-quartz formation of hydrothermal origin. Ores are low-sulfide with an amount of ore minerals dominated by scheelite, arsenopyrite, galena, and native gold, of no more than 1—5%. Gold is relatively high-grade (880—900‰). The

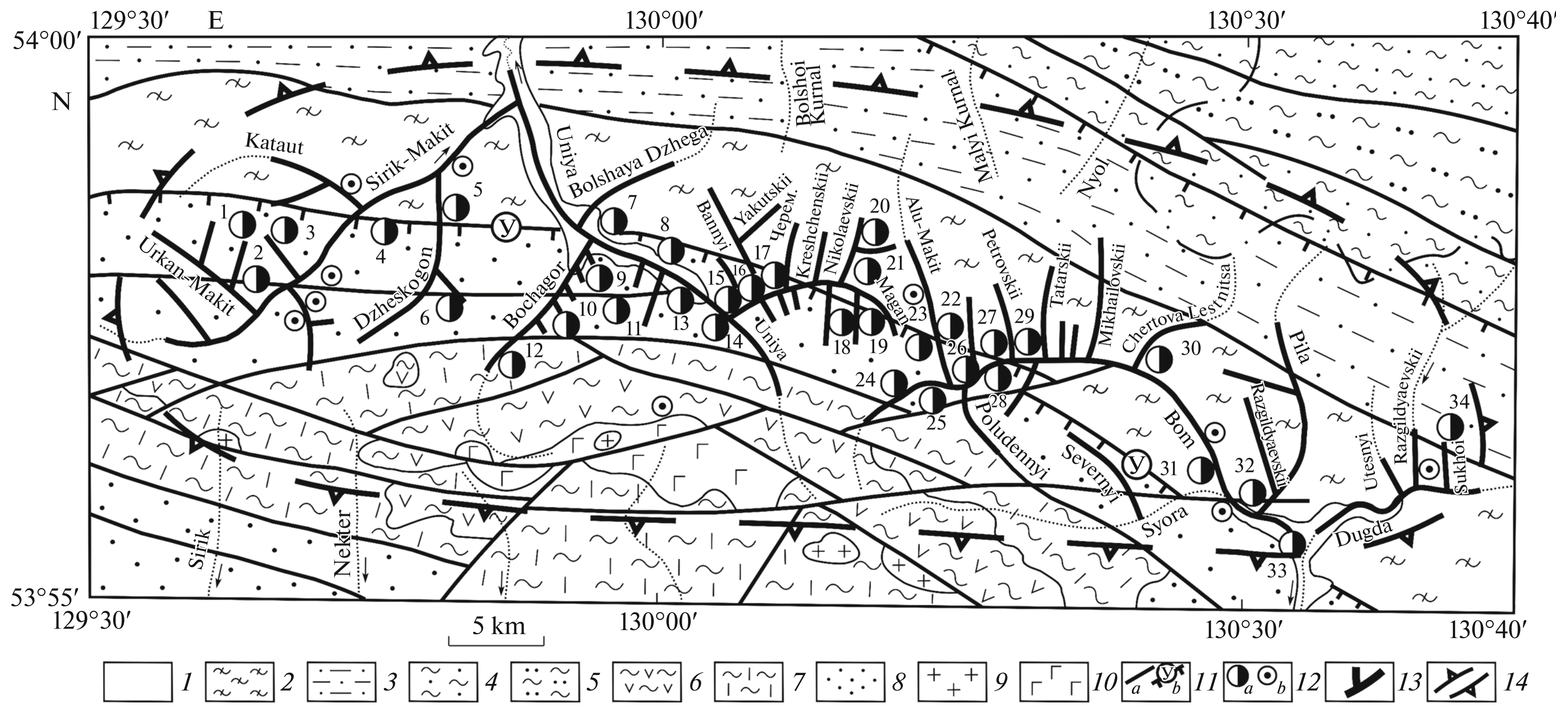

Fig. 1. Geological structure of the Un'ya–Bom gold ore-placer cluster. (*1*) Quaternary alluvial and alluvial–deluvial sands, clays, and pebble deposits; (*2*) Lower Jurassic Amkan Formation: thin rhythmic alternation of siltstones, mudstones, and sandstones; (*3*) Lower Jurassic Kurnal Formation: sandstones, interbeds of siltstones, tuffaceous sandstones, tuff siltstones, gravellites, and conglomerates; (*4*) Upper Triassic Nelskaya Formation: siltstone, tuffite, clayey shales, and sandstone; (*5*) Upper Triassic Muyakan Formation: sandstones, siltstones, and gravellites; (*6*) Lower Permian Bochagor Formation: green schists, quartzite, phyllite, and marmorized limestones; (*7*) Upper Carbonaceous (?) Nekter Formation: phyllites, siltstones, green schists, and marmorized limestones; (*8*) Upper Carbonaceous (?) Dzheskogon Formation: sandstones, siltstones, gravellites, green schists, and marmorized limestones; (*9*) Lower Permian plagiogranites, granites, and granodiorites of the Pikan complex; (*10*) gabbro, gabbro, monzogabbro, and gabbrodiorite of the Lower Permian Pikan Complex; (*11*) faults: (*a*) steeply dipping, (*b*) thrusts, (*12*) (*a*) gold ore manifestations (1, Alekseevskoe; 2, Sirik-Makit; 3, Schastlivoe; 4, Dzheskogon-2; 5, Dzheskogon-1; 6, Elizavetinskoe; 7, Dzhega Bol; 8, Un'ya; 9, Bochagor-1; 10, Bochagor-2; 11, Sovetskoe; 12, Gniloe; 13, Landur'; 14, Un'inskoe; 15, Bannoe; 16, Magan; 17, Cheremushnoe; 18, Scheelitovoe; 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-Syora; 32, Pila; 33, Dugda; 34, Topolevoe); (*b*) Au mineralization observation points; 13, gold placers; 14, a cluster boundary.

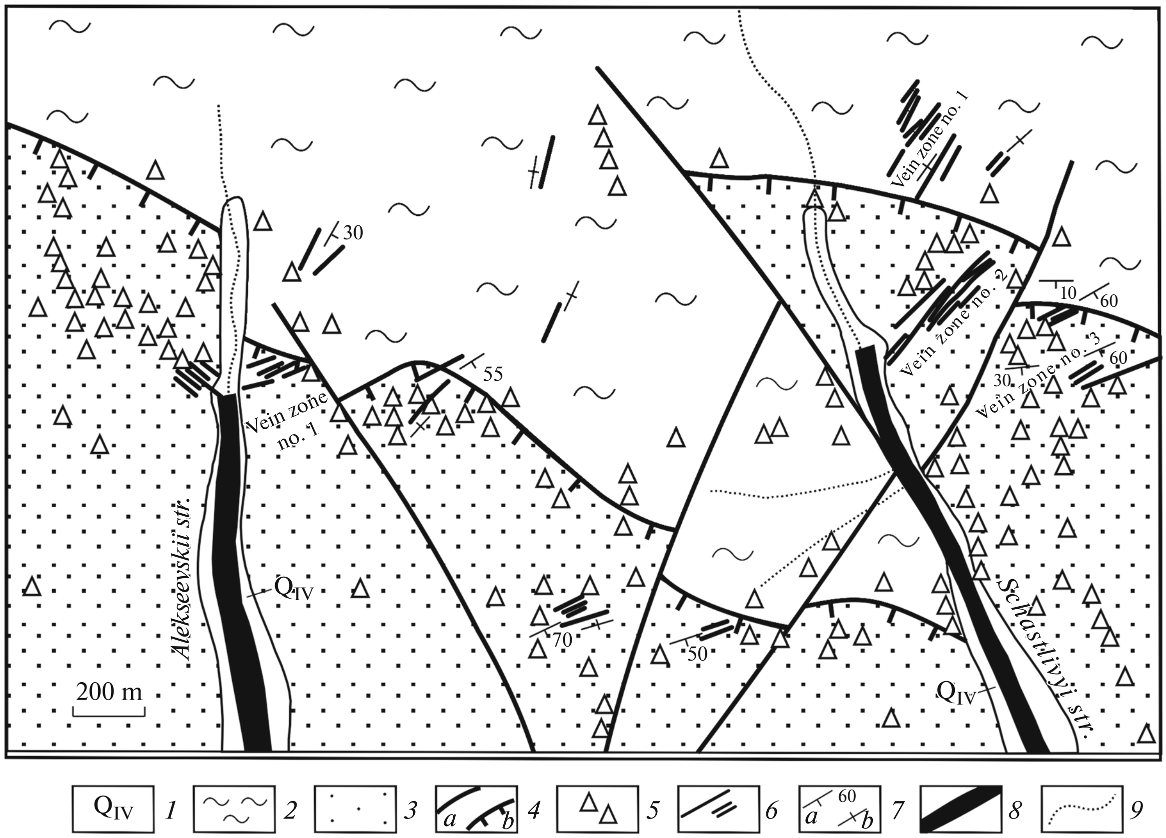

Fig. 2. Alekseevskoe and Schastlivoe gold-ore manifestations: (*1*) Quaternary alluvial sands and gravels, (*2*) alternation of siltstones, mudstones, and sandstones of the Lower Jurassic Amkan Formation, (*3*) sandstones with interbeds of gravellites and mudstones (lower subformation of the Dzheskogon Formation, Upper Carboniferous), (*4*) steeply dipping faults (*a*), thrusts (*b*), (*5*) pile of gangue quartz, (*6*) gold-bearing quartz veins, vein zones, (*7*) bedding of veins: oblique (*a*), vertical (*b*), (*8*) gold placers, (*9*) water streams.

main feature is a large admixture of Hg (up to 9.37%). A solid solution of mercury with gold is formed.

The most typical occurrences are the Alekseevskoe and Schastlivoe (Fig. 2).

The Aleseevskoe gold-ore manifestation extending in the upper reaches of the Alekseevskii River, a left tributary of the Sirik-Makit River, is represented by a Ne-striking quartz-vein zone. This zone is confined to the allochthonous plate of the Un'ya thrust zone, composed of sandstones of the Dzheskogon Formation enclosing several echelon quartz veins of 0.5–3 m thick. The ore minerals in veins are arsenopyrite, scheelite, galena, chalcopyrite, and native gold. The Au content is up to 1–5 g/t; W, 0.1%; As, 3%. Ore mineralization is attributed to the gold–quartz formation.

The Schastlivoe gold-ore manifestation is confined to the upper reaches of Schastlivy Creek, a left tributary of the Sirik-Makit River. The ore field is composed of flysch deposits of the Amkan Formation and sandstones of the Dzheskogon Formation separated by the sublatitudinal Un'ya thrust. Ore mineralization is localized in the allochthonous plate of the thrust, rarely, in the autochthonous plate. It is represented by quartz veins or series of quartz veins, confined to northeast-striking feathering fractures. Veins are filled with coarse-grained quartz (95–98%), albite (1–4%), calcite (1–2%), sericite, and chlorite. The Au content in quartz veins varies from trace amounts to 10–15 g/t. The contents of other elements are following: W, 1%; As, 3%; and the Au/Ag ratio varies from 1 : 30 to 4 : 1. Gold mineralization is related to the gold–quartz formation. Among ore minerals scheelite, arsenopyrite, ferberite, galena, and native gold dominate.

Gold in its morphology is fine-grained, lumpy, veinlike, platelike, crystalline, drusoid, and wirelike. According to X-ray spectroscopy of the Au composition, the rate of gold is 840–895‰ (table). The main impurities are Ag (6.70–7.66%) and Hg (1.72–9.37%). Mercury is uniformly distributed on the slice plane of gold particles. Grains are surrounded by rims of 10–15 microns thick, enriched with Hg. A uniform high Hg concentration in native gold is evidence of the significant Hg concentration in gold-bearing hydrothermal solutions and simultaneous deposition of Au, Ag, and Hg. It is obvious that by the end of ore depo-

Composition of Hg-bearing ore gold (microprobe data)

Grain no.	Composition, wt %			
	Au	Ag	Hg	Total
	Camebax			
1	89.25/84.75	6.75/6.75	3.86/8.95	99.86/100.45
2	91.25/84.00	6.75/6.70	1.72/9.37	99.72/100.07
	JXA-5A			
3	89.54/87.91	7.66/6.97	2.94/5.40	100.14/100.28
4	88.71/87.07	7.66/6.95	4.05/6.50	100.42/100.52
Average	87.77	7.02	5.32	

Above the line is the core; below the line is the rim. Analyses were performed on Camebax (Cameca), analyst S.M. Sandomirskaya, and JXA-5A (Jeol) equipment, analyst I.M. Romanenko.

sition the Hg concentration in the fluids increased, which resulted in the formation of high-Hg rims around gold grains.

The Un'ya–Bom gold-ore cluster has been famous for its rich Au placers for a long time. Placer gold mineralization was discovered in 1887 for the first time. Gold placers are concentrated in the 80 km sublatitudinal zone extending from the Sirik-Makit River basin in the west to the Dugda River basin in the east. In total, ~31.189 tons of registered gold were mined.

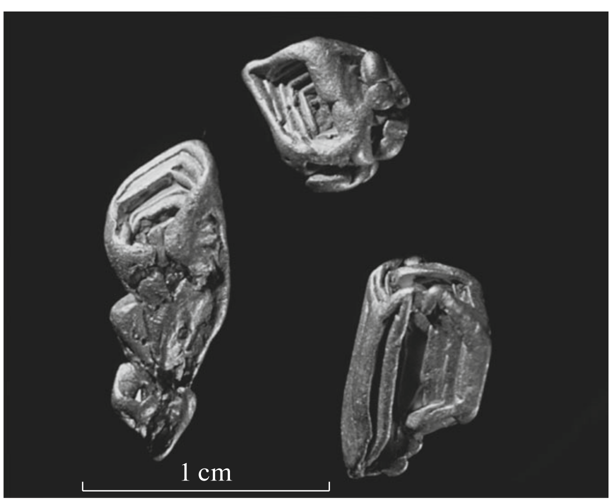

Fig. 3. Small gold nuggets with imprints of induction faces of syngenetic native gold, pyrite, and quartz from a gold placer of Dzheskogon Creek. Nuggets are stored in the Fersman Mineralogical Museum, Russian Academy of Sciences, Moscow (http://www.fmm.ru).

Native gold in placers is of the same type, predominantly occurring as large particles. There are gold nuggets weighing from 1–10 to 730 g; sometimes, there exist signs of joint growth of Au crystals and other minerals (Fig. 3). In addition, there are numerous growths of placer gold particles with quartz. Among the accessory minerals in gold placers, scheelite and pyrite dominate; sometimes arsenopyrite, galena, sperrylite, and cinnabar occur. This is evidence of the formation of gold placers due to disintegration of gold–quartz veins, containing the same minerals–admixtures in ores.

The rate of gold is high, reaching 875–900‰. As in the ore gold, a high Hg impurity is characteristic of placer gold (up to 3.8%). The impurities of other elements (Fe, Ti, Bi, Cu, Al, Mn, Ca, Mg) are insignificant. Hg is concentrated in the cores of gold particles. High-grade rims of gold particles, typical of placer gold [6], demonstrate that the Hg content decreases up to a few tenths of a percent. This is evidence of the absence of an amalgamation in the development of gold placers.

A reduction in the size of placer gold grains is noted from west to east: from the predominantly coarse-grained fraction in gold placers in the Sirik-Makit and Un'ya river basins to predominantly average- and fine-grained fractions in gold placers in the Bom and Dugda river basins. The productivity of Au placers decreases in the same direction. For example, gold placers in the Sirik-Makit and Un'ya river basins yielded 11.4 and 11.5 tons of gold, respectively, and in the basins of the Bom and Dugda rivers are 80 and 0.2 tons of gold, respectively.

Thus, the Un'ya–Bom gold-ore cluster of the Amur Province is represented by high-grade gold–quartz formation and associated rich gold placers. Native gold contains a considerable Hg impurity. The area of the Un'ya–Bom cluster is composed of Late Paleozoic and Mesozoic terrigenous (so-called black shale) formations, weakly metamorphosed to the greenschist facies. Intrusive formations are quite rare. Only within the ore manifestations Chertova Lestnitsa and Bomskaya Zhila are there rare diabase and porphyrite dykes. Gold ore mineralization (high-grade Hg gold) is confined to scattered quartz veins and veinlets. These facts indicate the occurrence of an upper frontal part of the gold-bearing pipe made of a gold–quartz formation of hydrothermal origin within the Un'ya–Bom gold-ore cluster. Therefore, the formation of gold ore mineralization was connected with the activity of hydrothermal fluids enriched in Au, Ag, and Hg. It seems reasonable to say that the data available on Au volatility in mercury vapors allow us to explain the joint accumulation and deposition of these elements occurring as high-Hg gold in the frontal part of the gold-ore pipe.

As in areas of Central Kolyma [4], the frontal part of the gold-bearing pipe is extremely favorable for formation of gold placers. Unfortunately, there is little opportunity to discover new gold-ore deposits. Gold ore manifestations such as Schastlivoe, Magan, and Bomskaya Zhila are the most promising for further exploration works. Moreover, it appears possible to uncover technogenic commercial placers at dumps of the largest waste 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,* Part 2: *Aurum and Hydrargyrum in Amur River Province* (Dal'nauka, Vladivostok, 2000) [in Russian].
4. V. A. Stepanov, *Zoning of Aurum-Quartz Metallizing Process in Central Kolyma* (Dal'nauka, Vladivostok, 2001) [in Russian].
5. V. A. Stepanov, A. V. Melnikov, A. S. Vakh, et al., *Gold Ore Amur River Province* (Amur State Univ., Blagoveshchensk, 2008) [in Russian].
6. M. S. Fisher, Bull. - Inst. Min. Metall. **2** (9) (1935).

Translated by D. Voroshchuk