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GEOLOGY

Au–Bi–Te Mineralization of the Kontaktovyi Stock in Northeast Russia

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In recent years, interest in gold deposits in granitoid intrusions has been boosted by the successful development of gold deposits in Alaska and Australia, such as Fort Knox (>350 t), Pogo (150 t), Dublin Gulch (>100 t), and Tefler (>500 t) [1]. At present, more than 30 deposits of this type have been discovered in various metallogenic belts of Northeast Asia [2]. Many of these deposits can be large and superlarge objects [3]. In previous publications, we discussed examples of ore occurrences and deposits in the Yana–Kolyma metallogenic belt and the perivolcanic zone of the Okhotsk–Chukot volcanogenic belt (OCVB) [4, 5]. However, some ore occurrences associated with granite porphyry stocks are confined to sedimentary sequences at the base of the OCVB. These stocks were likely to be emplaced in the course of the tectonomagmatic cycle of the Late Juras-

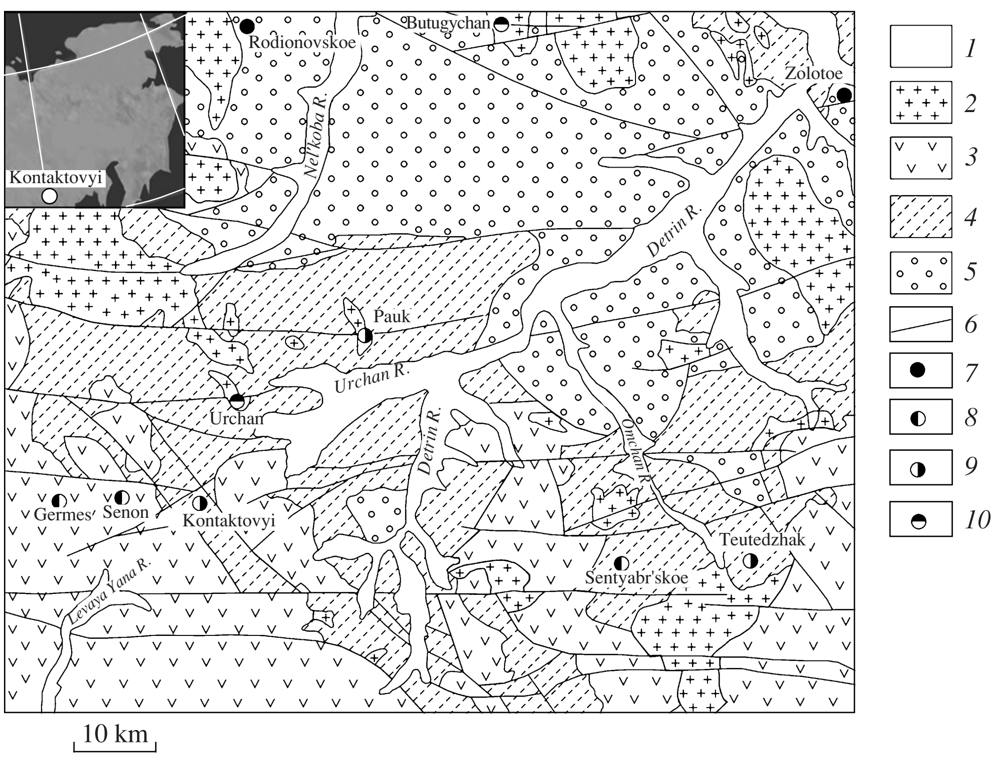

Fig. 1. Tectonic position of the Kontaktovyi stock in regional structures. (*1*) Alluvial sediments; (*2*) Early–Late Mesozoic granites; (*3*) Late Mesozoic effusives; (*4*) Jurassic and Triassic terrigenous sequences; (*5*) Permian rocks; (*6*) faults; (*7–10*) ore deposits: (*7*) gold–quartz, (*8*) gold–silver, (*9*) gold–rare metal, (*10*) tin.

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sic–Early Cretaceous Uda–Murgal island-arc volcano-plutonic belt [6]. The most promising ore occurrence was discovered in 2005 in the Kontaktovyi (i.e., Contact) granite porphyry stock (Fig. 1). In this connection, we should recall the following idea suggested by Nolan [7] as early as the 1930s: epithermal gold–telluride deposits in ore districts of the western United States are confined to small intrusions (subvolcanic bodies). In our classification of ore mineralization, deposits of this and other similar types belong to the upper stage of the intrusive-subvolcanic ore-magmatic system. In contrast, gold–rare metal deposits associated with hypabyssal granitoids belong to the lower stage. As will be shown below, the Kontaktovyi mineralization occupies an intermediate position between the two stages.

The Kontaktovyi ore district is bounded at the western and eastern flanks by NW-striking faults that extend far beyond the ore district (Fig. 1). The axial part of the ore district includes a narrow horst-shaped ridge with exposures of Jurassic and Triassic sedimentary rocks developed at the contact with Late Cretaceous effusives of the OCVB along NW-striking faults. At the southern and northern flanks, the ore district is bounded by large sublatitudinal faults with auxiliary shear fissure zones mainly oriented along the NE direction.

The Kontaktovyi stock (1500 × 1300 m in size) is composed of granite porphyries and quartz diorites of the Early Mesozoic Siberdyk intrusive complex. Contacts of the stock with host rocks are steep (70°–80°) at the western and southwestern flanks, gentle (20°–30°) on the eastern and east-southeastern flanks, and tectonic at the northern flank along the sublatitudinal fracture. Automagmatic breccias occur as lenticular dikes (up to 300 m long and approximately 20–30 m thick) in the central part of the stock. In plan view, they make up an ENE-facing arc that includes the central sector of the intrusive dome (Fig. 2). Contrast K, U, and Th anomalies associated with the granite porphyry stock extend to the east over a significant distance beyond the stock (700–800 m). The stock is also surrounded by intense secondary aureoles of Au (up to 0.5 g/t), As (up to $500 \cdot 10^{-3}$%), Bi (up to $50 \cdot 10^{-3}$%), Ag (up to 10 g/t), Pb, Cu, Zn, and other elements extending over a large area ($400–500 \cdot 1000$ m). High Sb contents (up to 40 g/t) are recorded at several sites, while high Te contents (50 g/t) are recorded at one site. The aureoles are not contoured along the dip of the gentle contact of the stock at the eastern flank.

Based on morphostructural reconstructions, the Kontaktovyi stock incorporates a ring-shaped intrusive dome with a diameter of ~2 km. Its central part is complicated by a compensation subsidence ring with a radius of 750–800 m (from the center of the structure). This subsidence structure includes a smaller dome (700–750 m in diameter) crosscut by radial fractures (Fig. 2). The central part of the intrusive dome hosts an aureole of a stockwork-stringer system (hereafter, stockwork-stringer zone) developed in the beresitized

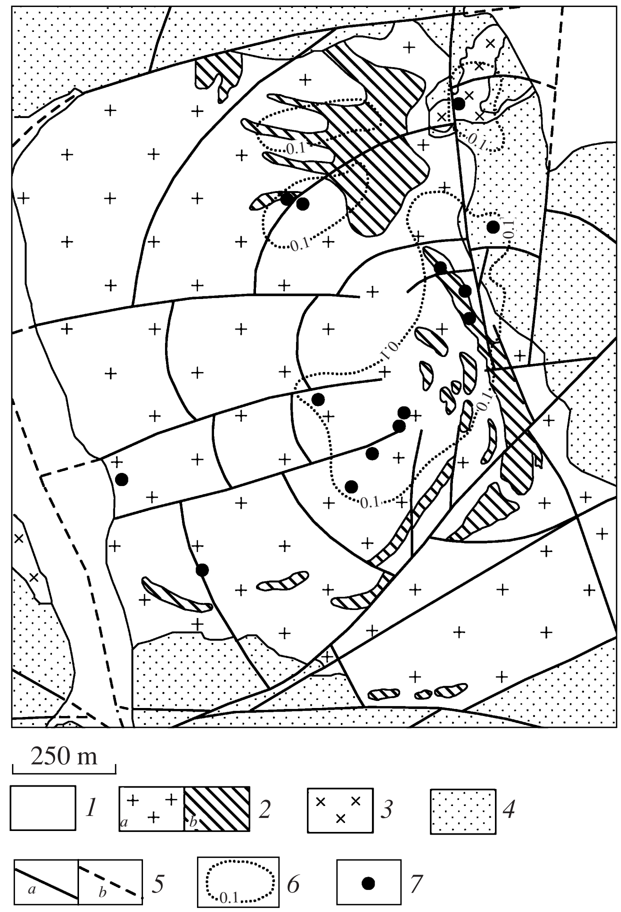

Fig. 2. Morphostructural scheme of the Kontaktovyi stock and its framing. (*1, 2*) Granite porphyries (*a*), autometasomatic breccia (*b*); (*3*) diorite porphyries; (*4*) Lower Triassic hornfelsized siltstones; (*5*) faults: (*a*) proven, (*b*) buried under friable sediments; (*6*) endogenous aureole bounded by the Au content of 0.1 g/t; (*7*) samples with the Au content >1 g/t.

granite porphyries, which are transformed into fine-crystalline albite–quartz metasomatic rocks with a relict porphyric texture. They are crosscut by a dense network of differently oriented albite–quartz and quartz veinlets ranging in thickness from 0.5–1 mm to 1–2 cm. Generally, the thickness varies from 4 to 5 mm. The veinlets are characterized by inconsistent sinuous forms with several pinchouts and offshoots. They have distinct and sinuous contacts. The veinlets are composed of polygonal quartz crystals with wavy extinction. The quartz grains have a rim of fine-flaky sericite, which is also confined to lenticular relicts of host rocks. Thin albite fringes are developed along the selvage of veinlets. Table 1 presents contents of trace elements in metasomatic rocks of the stock and its framing.

Results of the point sampling yielded the following maximal concentrations (g/t): Au 5.9, Bi >2000, As >1000, Pb >600, Ag >35, and Te >300. Au shows a significant positive correlation with As, Pb, Zn, Bi, and

Table 1. Contents of trace elements in metasomatic rocks of the Kontaktovyi stock and its framing

Composition	Au, g/t	Pb	As	W	Ni	Co	Bi	Mn	Ti	Ba	Mo	Sn	Cu	Ag	Zn	Te
		$n \cdot 10^{-3}$, %														
Granite porphyry	0.11	10.5	10.3	0.2	0.7	0.4	25.6	18	184	70	0.7	1.4	6.0	11.0	17.5	–
Automagmatic breccia of granite porphyries	0.07	4.7	5.2	0.2	1.0	1.2	0.9	39	358	53	0.9	0.8	7.0	3.5	19.8	–
Hornfelsized rocks of the framing	0.02	2.6	5.0	0.3	1.4	1.7	0.4	38	449	55	0.3	0.9	5.9	1.9	14.3	–
Metasomatically altered granite porphyries	0.66	17.8	24.1	0.3	0.8	0.3	237.7	11	150	52	1.1	1.7	4.9	14.1	11.5	–
Mica–feldspar–quartz metasomatite with quartz veinlets	2.63	20.0	25.0	0.6	0.8	0.1	3000.0	20	100	30	1.6	1.0	3	25	10	30.0

Note: Based on results of atomic absorption analysis in the laboratory of the Northeastern Complex Research Institute, Far East Division, Russian Academy of Sciences (Magadan).

Table 2. Mineralogy and abundance of minerals in quartz veinlets of the Kontaktovyi stock

Mineral groups	Major	Secondary	Rare
Elements			Gold, bismuth
Sulfides and sulfosalts	Pyrite, arsenopyrite	Molybdenite, galena	Pyrrhotite
Oxides	Quartz, goethite		Zavaritskite (BiOF), Montanite* ($Bi_2TeO_{6 \times 2}H_2O$), Smirnite* (Bi_2TeO_5), Pingguite* ($Bi_6Te_2O_{13}$), Arsenobismite $Bi_2(AsO)_4(OH)_3$, Yecorite* $Bi_5Fe_3O_9(TeO_3)(TeO_4)_{2 \times 9}H_2O$, Gananite BiF_3
Carbonates	Calcite, dolomite		
Sulfates	Barite, hypside		Pitticite ($FeAsO_4SO_4H_2O$)
Tellurides			Hedleyte (Bi_2Te), Hessite (Ag_2Te)

Note: Asterisk denotes minerals confined to the Kontaktovyi stock. Rare minerals were identified with a Jeol 5610 LV electron microscope equipped with JED 2300 EDS (N.V. Trubkin, analyst).

Mo, while its correlation with Ag, Sb, and Ba is negative. The stockwork aureole (750–800 × 1200 m in size) extends in the submeridional direction. Veinlets are most developed in the central part of the dome characterized by the maximal metasomatic alteration of rocks (650 × 700 m in area). This area also includes virtually all samples with high Au contents. Clusters of veinlets are confined to zones with a high degree of jointing and maximal metasomatic alteration. Based on the size of colluvial debris, such zones are up to 20 m thick. The veinlets and jointing zones are mainly oriented along the northeastern and sublatitudinal directions (50°–80°). They crosscut both the altered granite porphyries and their automagmatic breccias.

Based on the size of chalcedony-type quartz fragments in the debris, some veins of the massive quartz are up to 20 cm thick. They have a vaguely banded structure owing to the alternation of white, yellowish white, and gray quartz bands, as well as the irregular distribution of ore mineralization. Only pyrite is identified reliably. The maximal contents of elements recorded in the veins are as follows (g/t): Sb 3000, Bi 2000, Ag 3–4, and Te 100. The Au content varies from 0.006 to 0.01 g/t.

In order to estimate the Au potential of stockwork-stringer zones along the low-angle watershed of the Kontaktovyi stock, we carried out a point sampling of the submeridional profile with a spacing of 20 m. The weight of samples varied from 3 to 5 kg. They were taken regularly from eluvial–colluvial sediments over an area of 5 × 5–6 × 6 m. Based on the results of the sampling, we outlined an approximately 480-m-long interval with minimal and maximal Au contents of 0.1 and 2.6 g/t, respectively, in the point samples. This interval includes an approximately 240-m-long NE-striking stockwork-stringer zone with an average Au grade of 0.6 g/t. We believe that the gold mineralization extends to a depth of 350 m along the valley of the Kontaktovyi Creek, because the Au content is as much as 1.2 g/t at the base of the right-hand wall of the valley. Based on five significant point samples, the average Au content is 2.5 g/t.

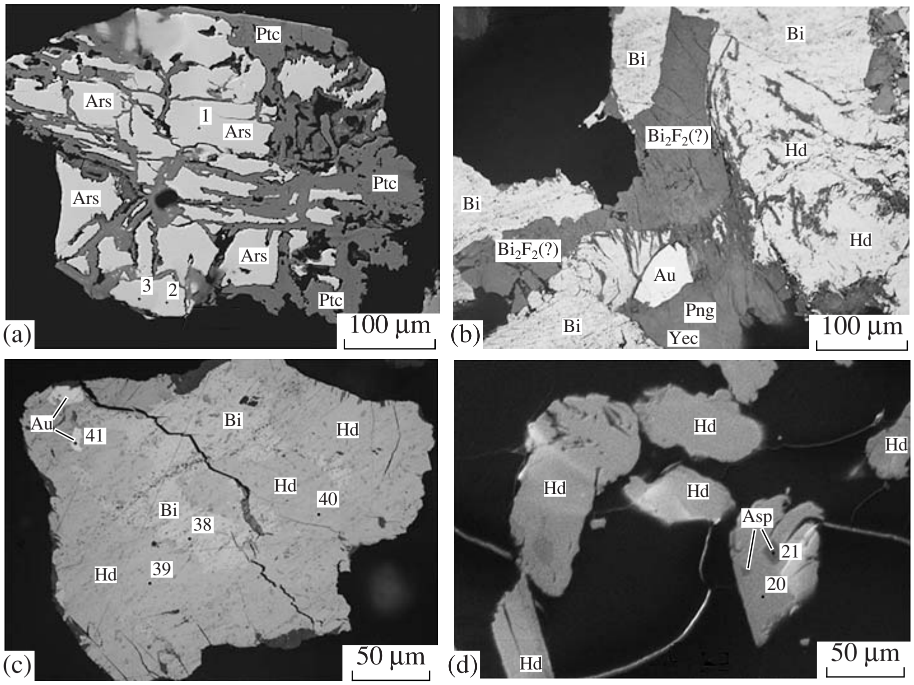

Fig. 3. Au–Bi–Te mineralization in the Kontaktovyi stock. (a) Oxidized arsenopyrite crystal (Ars) replaced in some places by pitticite (Ptc); (b) Au–Bi–Te mineral assemblage: (Hd) hedleyite, (Png) pingguite, (Yec) yecorite; (c) fine-dispersed gold in hedleyite; (d) relict arsenopyrite blocks in hedleyite. Numbers in photomicrographs designate microprobe analysis points.

The results of the mineralogical analysis revealed new data on the Au–Bi–Te mineralization of the Kontaktovyi ore occurrence. The mineralization is irregularly developed mainly near the selvages of veinlets. At present, 19 ore minerals have been identified here (Table 2). The major minerals are represented by the coarse-grained dissemination of pyrite, arsenopyrite, galena, and molybdenite (up to 1–2 mm). The arsenopyrite includes a very fine (30–40 μm) emulsion dissemination of native bismuth and gold. The development of fine dissemination of bismuth, tellurides, and gold is an indicator of the hypabyssal gold–rare metal mineralization [5]. In general, gold occurs as intergrowth with the native bismuth and hedleyite (Fig. 3c). Results of microprobe analysis show that the fineness of gold varies from 480 to 670–760 and 870–920. The purest gold includes a significant Cu admixture (up to 0.3%). The hedleyite includes tiny arsenopyrite crystals (Fig. 3d). Many ore minerals on the stock surface are commonly oxidized. The microprobe analysis made it possible to identify a great number of rare secondary Te-bearing minerals (Table 2; Figs. 3a, 3b).

In [8], we suggested that the absence of epithermal gold–telluride deposits in the Late Mesozoic OCVB and its framing is related to the significant erosion of subvolcanic intrusions and the insufficient investigation of ore districts in Northeast Russia. Based on structural–morphological features (ring structures and pipe-shaped orebody) and mineral compositions (chalcedony-type quartz, gold of different grades of fineness, and others), ore occurrences in the Kontaktovyi stock can be considered either as mineralization of the lower section of the epithermal stage or as the uppermost section of the hypabyssal gold–rare metal stage.

Let us list factors indicating the high potential of mineralization in the Kontaktovyi stock: (1) localization of mineralization in the granite porphyry stock; (2) the large area of the aureole of metasomatic rocks; (3) the morphological type of the body with ore potential (pipe-shaped orebody controlled by the granite porphyry intrusion of automagmatic breccias); (4) wide development of stockwork-stringer zones; (5) diverse assemblages of ore-associated elements (Au, As, Mo, Bi, Te, and Sb) and ore minerals (Bi–Au tellurides, native bismuth, and arsenopyrite with emulsion dissemination of native gold and bismuth); (6) sufficiently high contents of Au in stockwork-stringer zones (the presence of gold segregations of different degrees of fineness indicate the development of multistage mineralization and emphasizes a high possibility of the discovery of economic deposits in the stock); and (7) significant vertical extent of mineralization.

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