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Native Gold from Alluvial Sediments of the Kyvvozh Region and Its Possible Sources (Vol–Vym Uplift, Central Timan)

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Abstract—The most possible genetic types of primary sources are determined on the basis of study of typomorphic features of gold from alluvial sediments of the Kyvvozh region of Central Timan, including economic placers. The size of gold particles widely varies, reaching small nuggets; there are rounded, weakly rounded, and nonrounded particles. Many of them underwent recurrent deformations in form of envelope curves, pits, and fractures. Most gold grains have high-fineness rims. Native gold always contains Ag and, locally, Cu, Pd, and Hg. There are frequent blocky gold particles with high-Ag veinlet zones. Native gold is intergrown with and contains inclusions of pyrite and galena and rarely minerals of the cobaltite–gersdorffite series, ankerite, galenobismuthite, native bismuth, and aurostibite, as well as sudovikovite $PtSe_2$, which is identified for the first time in the region. Three types of native gold are recognized: (1) homogenous Ag-bearing, (2) blocky with high-Ag veinlet zones, and (3) rare Ag-bearing with Cu and Pd. The morphology, composition, and structure of placer gold indicate its contribution from various (including proximal) sources. The NW-oriented zones of hydrothermal stringer-disseminated sulfide mineralization, which are partly exposed during placer exploitation, are most interesting. Native gold with Cu and Pd is most likely related to the derivatives of basic magmatism. The Vol–Vym, Tsil'ma, and Chetlas uplifts of Central Timan can be considered the promising for primary gold and deserve further study and searching works.

Keywords: native gold, Central Timan, alluvium, typomorphism, trace elements, mineral inclusions, primary sources

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INTRODUCTION

Central Timan belongs to promising ore regions for gold, diamonds, titanium, rare metals, and bauxites. Ideas on metallogeny of gold are the least elaborated: the genetic types of primary mineralization are unclear, and the few available placers are poorly studied.

The study of geological structure of the region and prospecting works are being conducted for many years. In the 1980s, the Ichet-Yu gold–rare metal–diamond paleoplacer was discovered in the northern part of the Vol–Vym Uplift, which is confined to the Devonian gravelites and conglomerates. At the same time, A.A. Kotov, A.M. Plyakin, M.Yu. Ostrizhnoi, V.A. Kapustin, F.L. Yumanov, V.A. Dudar, I.M. Parmuzin, and other geologists of the Ukhta Geological Exploration Expedition carried out specific searching works for placer gold spanning a significant territory of Central and South Timan. A wide occurrence of placer gold was established in Quaternary deposits and platinum group minerals were found in assemblage with native gold. During prospecting for diamonds of 1988–1989, V.A. Dudar, P.P. Bitkov, and V.G. Shamet'ko found economic contents of placer gold including large (up to the nuggets) in floodplain–riverbed sediments of the Kyvvozh Creek. Later, F.A. Kulbakova, P.P. Bitkov, and M.M. Dunyashev found the terrace and floodplain–riverbed placers in the Srednii Kyvvozh, Levy Kyvvozh, and Dim'tem'el creeks, which are combined in the Kyvvozh gold placer field. In 2009–2014, V.P. Savel'ev and other geologists of AO Ukhtageoservis conducted prospecting works with calculation of gold reserves of the Srednii Kyvvozh, Kyvvozh, and Dimtem'el placers, which later were partly exploited.

The main data on gold potential of the Kyvvozh region are provided in unpublished reports and are partly published (Dudar, 1996; Maiorova, 1996; Makeev et al., 1996; Makeev, Dudar, 2003; *Timanski*..., 2009; Glukhov et al., 2018). In spite of a significant volume of geological works, no primary sources of placer gold have been revealed. A geological restudy of the Kyvvozh region was conducted by the Karpinsky Russian Geological Research Institute (St. Petersburg, Russia) together with the Institute of Geology, Komi Scientific Center, Ural Branch, Russian Academy of Sciences (Syktyvkar, Russia) in recent years. The aim of our studies was the identification of the degree of roundness, composition, structure, and

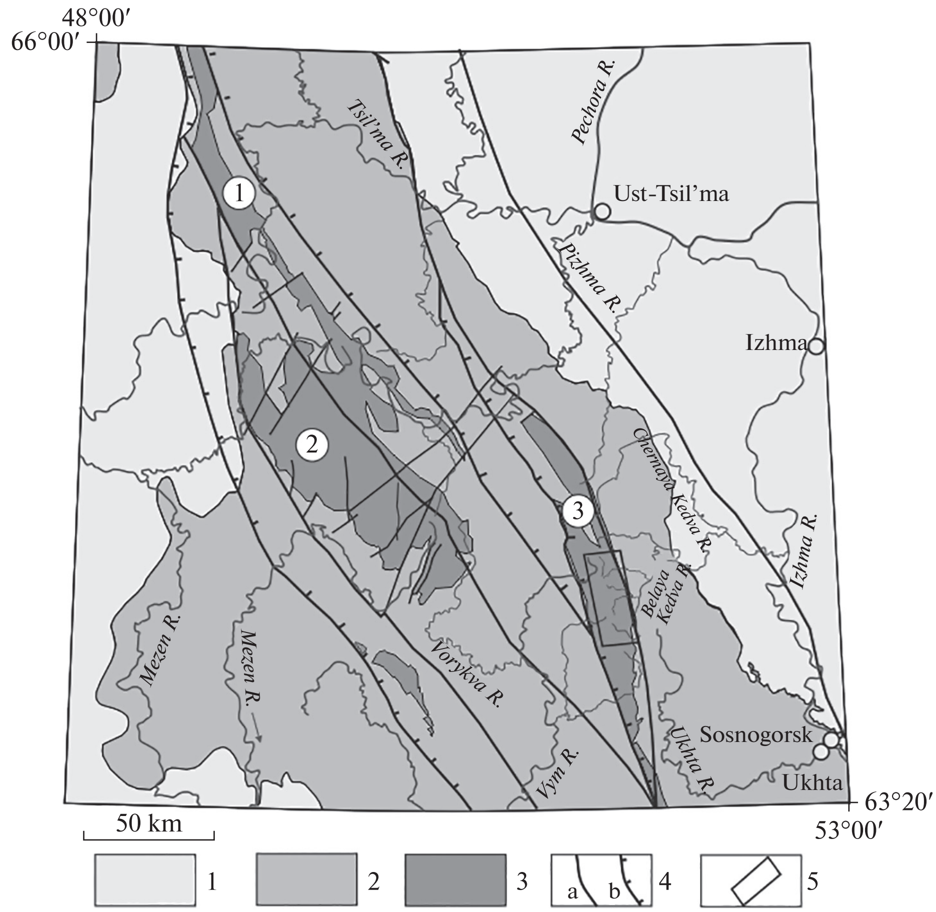

Fig. 1. Scheme of location of uplifts of the Riphean basement of Central Timan. (1) Mesozoic rocks; (2) Paleozoic rocks; (3) Riphean rocks; (4) (a) faults and (b) thrusts; (5) Kyvvozh region. Uplifts: (1) Tsil'ma; (2) Chetlas; (3) Vol–Vym.

other typomorphic features of native gold from alluvial sediments including economic placers and, therefore, the determination of the distance of gold transportation and a genetic type of possible primary sources, and the identification of most promising areas.

GEOLOGICAL STRUCTURE OF THE REGION

In the geological respect, Central Timan is part of the large Timan fold-thrust structure, which is elongated in the NW direction and belongs to the Pechora Plate, bounding it from the south (Gertsen, 1987; *Timanskii...*, 2009; *Gosudarstvennaya...*, 2015). Two structural stages are distinguished: a Riphean basement composed of metamorphosed and strongly dislocated terrigenous and terrigenous–carbonate sequences and a platform cover composed of Phanerozoic sedimentary and volcanosedimentary rocks. There is a series of large NW-trending faults, in particular, the Central Timan Thrust and West and East Timan faults. The Riphean rocks are exposed within the Chetlas, Vol–Vym, and Tsil'ma uplifts (Fig. 1).

The Vol–Vym Uplift is a horst-anticline. Its axial part exposes the Riphean rocks, which in the wings are overlain by Paleozoic sediments with strong angular and stratigraphic unconformity. The flattened drainage divide areas and depressions are waterlogged. The exposure of rocks in the region is poor. Small primary outcrops are observed in the central part of the uplift in valleys of the largest Pok'yu and Belaya Kedva rivers and Srednii Kyvvozh, Kyvvozh, and Dimtem'el creeks.

The Kyvvozh region occupies the central part of the Vol–Vym Uplift and is mostly composed of the Upper Riphean rocks, which underwent regional metamorphism of greenschist facies (Fig. 2). There are Kisly Ruchei and Vym groups. The Kisly Ruchei Group includes shales and sandstones of the Pizhma Formation, which are exposed in the southwestern part of the uplift. The main area of the region is composed of rocks of the Vym Group, which includes the Pok'yu and Lunvozh formations with a similar lithological composition characterized by dominant sericite–quartz–chlorite silty shales with lenses and interlayers of C-bearing sericite–quartz silty shales and beds of quartz and quarzitic sandstones.

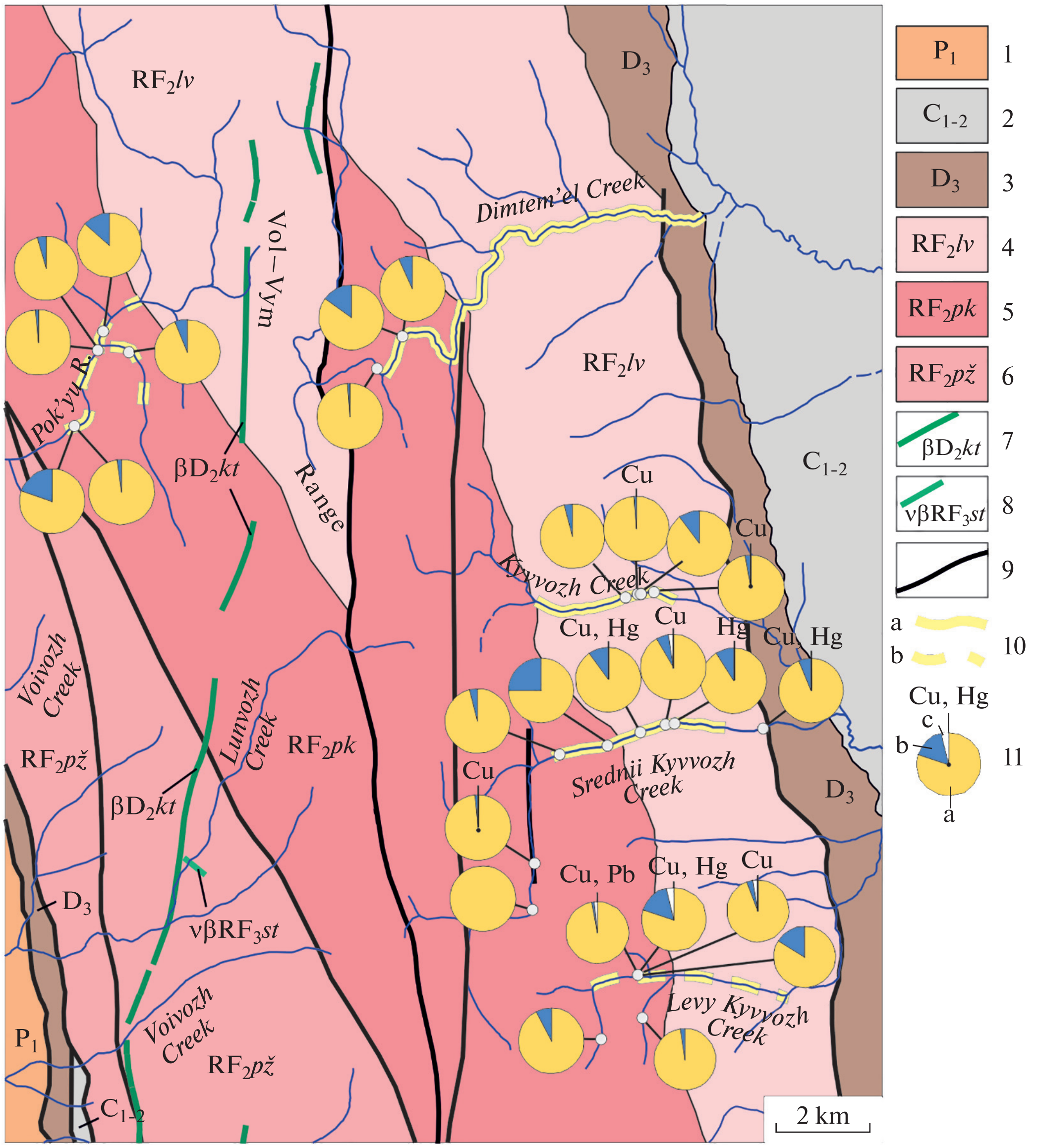

Fig. 2. Scheme of geological structure of the Kyvvozh region, modified and simplified after materials of an unpublished report on a GDP-200 objct of sheets Q-39-XXXV and XXXVI (Kyvvozh area) of the Karpinsky Russian Geological Research Institute. (1) Lower Permian rocks: clay, siltstone, marl, interlayers of sandstone and limestone, dolomite, limestone; (2) Lower-Middle Carboniferous rocks: clay, claystone, marl, limestone, dolomite; (3) Upper Devonian rocks: clay, intercalation of limestone and clay, siltstone, sandstone, limestone, claystone; (4–6) Middle Riphean rocks: (4) metasandstone, intercalation of metasandstone and metasiltstone, intercalation of silty shales and phyllitic shales of the Lunvozh Formation; (5) quartzite sandstones, metasandstone, metasiltstone, silty shales, shales of the Pok'yu Formation; (6) shales and metasandstones of the Pizhma Formation; (7) dikes of dolerites of the Kanin–Timan subvolcanic dolerite complex; (8) dike of gabbrodolerites of the Central Timan gabbrodolerite complex; (9) faults; (10) (a) Au-bearing placers and (b) placer occurrences; (11) average Au content (wt %): (a) Au; (b) Ag; (c) other trace elements (indicated above the diagram).

The igneous rocks of the Vol–Vym Uplifts are subdivided on two complexes: the Late Riphean Central Timan gabbrodolerite and Middle Devonian Kanin–Timan dolerite. The Central Timan Complex includes a small dike of gabbrodolerites, which is exposed in the middle reaches of the Lunvozh Creek. The rocks of the Kanin–Timan Complex include longitudinally oriented dolerite dikes, which intrude the rocks of the Pizhma, Pok'yu, and Lunvozh formations.

There are abundant faults of various orientations. The largest NW-trending faults are characterized by intense foliated rocks with zones of disseminated and stringer-disseminated sulfide mineralization (pyritization zones). There are also the features of weathering mantles known in adjacent territories, in particular, Devonian bauxites.

The Quaternary sediments, which host the studied gold placers, formed from the Middle Neopleistocene to the Holocene. Their thickness typically does not exceed a few meters, but is significantly higher at the foot of the slope. It contains moraine sediments, which occur in depressions of pre-Quaternary relief, in river valleys. The moraines are composed of loams, variously grained sands, boulders, and pebbles of various degree of roundness. The coarse-clastic material is lithologically heterogeneous and includes sandstones, limestones, dolomites, quartzites, basaltic porphyrites, quartz–epidote rocks, and siliceous–clayey shales, which are close in textures and composition to the Uralian and Timan rocks. At the same time, there are alien rocks for the regions, e.g., granites, biotite gneisses, and other rocks known at remote territories, which most likely provided the clastic material. The fluvioglacial sediments consisting of loams, sands, and pebblestones are closely related to moraines.

Alluvial sediments, which compose the above floodplain terraces of different levels and floodplains and riverbeds of rivers and creeks, ubiquitously occur. The material of local rocks is dominant. The residual and talus deposits occur on flat water drainage uplifts and slopes. There are lacustrine–alluvial deposits, which include sequences of silty clays and sands with fine peat interlayers.

The main gold-bearing placers are confined to the valleys of Srednii Kyvvozh, Kyvvozh, and Dimtem'el creeks. The Srednii Kyvvozh placer includes the floodplain–riverbed terrace deposits and is extended for 3 km at a width of 10–40 m. A productive gold-bearing bed is confined to a near-bottom part of alluvium and is composed of pebble–rubble–clayey deposits with a small amount of boulders. The thickness of the bed is 0.5–1.5 cm. The distribution of gold has a stream character with several streams up to 15 m. The Kyvvozh placer is located in the middle reaches of the Kyvvozh Creek. The length of the placer is 1.7 km, and the width is up to 80 m. A productive bed is located in the near-bottom part of the floodplain–riverbed alluvium. The main part of the bed is composed of pebble–rubble and clayey–gravel–pebble deposits with several angular–rounded boulders. Similarly to the Srednii Kyvvozh placer, the distribution of gold is stream. The Dimtem'el placer is located northward of the Kyvvozh placers in the lower reaches of the eponymous creek and is extended at a distance of 9.6 km at an average width of 46 m. Gold is mostly focused in the near-bottom sandy–gravel–pebble deposits.

Primary rocks, which compose the bottom of gold placers and are exposed in the creek bed, form shale druses, which are transversely oriented to the stream in most cases and filled by sandy–clayey material locally with native gold.

MATERIALS AND METHODS

The alluvial deposits of the Srednii Kyvvozh, Kyvvozh, Dimtem'el, and Levy Kyvvozh creeks and Pok'yu River were sampled for heavy concentrates during the field works. The samples were collected from the modern riverbed, floodplain, and clastic bottom (shale druses). The sample volume varied from 0.01 to 0.1 m^3. The samples were washed to gray heavy concentrate and treated with bromoform to extract the heavy fraction. The latter was further studied with quantitative mineralogical analysis and sampling of gold monofractions. In total, 169 heavy concentrate samples were analyzed. The visual identification of minerals was confirmed by X-ray diffraction methods. About 1700 gold particles were studied. Their size, morphology, and the degree of roundness were estimated on an MSB-9 optical binocular microscope. The peculiarities of microrelief, internal structure, and the composition of gold particles with mineral inclusions were studied on a TESCAN VEGA 3 LMN scanning electron microscope (SEM) equipped with an INCA X-MAX energy-dispersive spectrometer (EDS) (Oxford Instruments) at an accelerating voltage of 20 kV, a vacuum of 0.05 Pa, and a beam size of 2 μm. The exposition time was 500 000 pulses. The samples for SEM-EDS studies were prepared following a standard method. For study of morphology, the native gold particles were placed on metallic disks covered with double-size conducting scotch tape. To study the internal structure and composition of native gold, the particles were mounted on plastic disks covered with double-size scotch tape, which were filled with epoxy resin and further polished. The samples were covered with carbon.

RESULTS

Mineral Composition of Heavy Fraction of Alluvial Deposits

A heavy fraction of alluvial deposits of the Kyvvozh region includes 33 minerals (Fig. 3) with dominant garnet and ilmenite, subordinate constantly present zircon, epidote, leucoxene, goethite, kianite, rutile, staurolite, magnetite, hematite, and amphiboles. Titanite, apatite, anatase, corundum, spinel, chromite, tourmaline, micaceous minerals, chlorite and chloritoid, cassiterite, monazite, and marthite are sporadic minerals. Some samples contain single grains of cinnabar, perovskite, and olivine.

Native gold was found in most heavy concentrate samples. Its content widely varies, reaching 350 mg/m^3. The highest amount of gold (including large) was identified in goethite- and pyrite-bearing mineral assemblages of the Srednii Kyvvozh and Kyvvozh creeks, which wash out the zones of disseminate sulfide mineralization of the Riphean sequences. In some samples, native gold is associated with single grains of platinum group minerals, in particular, isoferroplati-

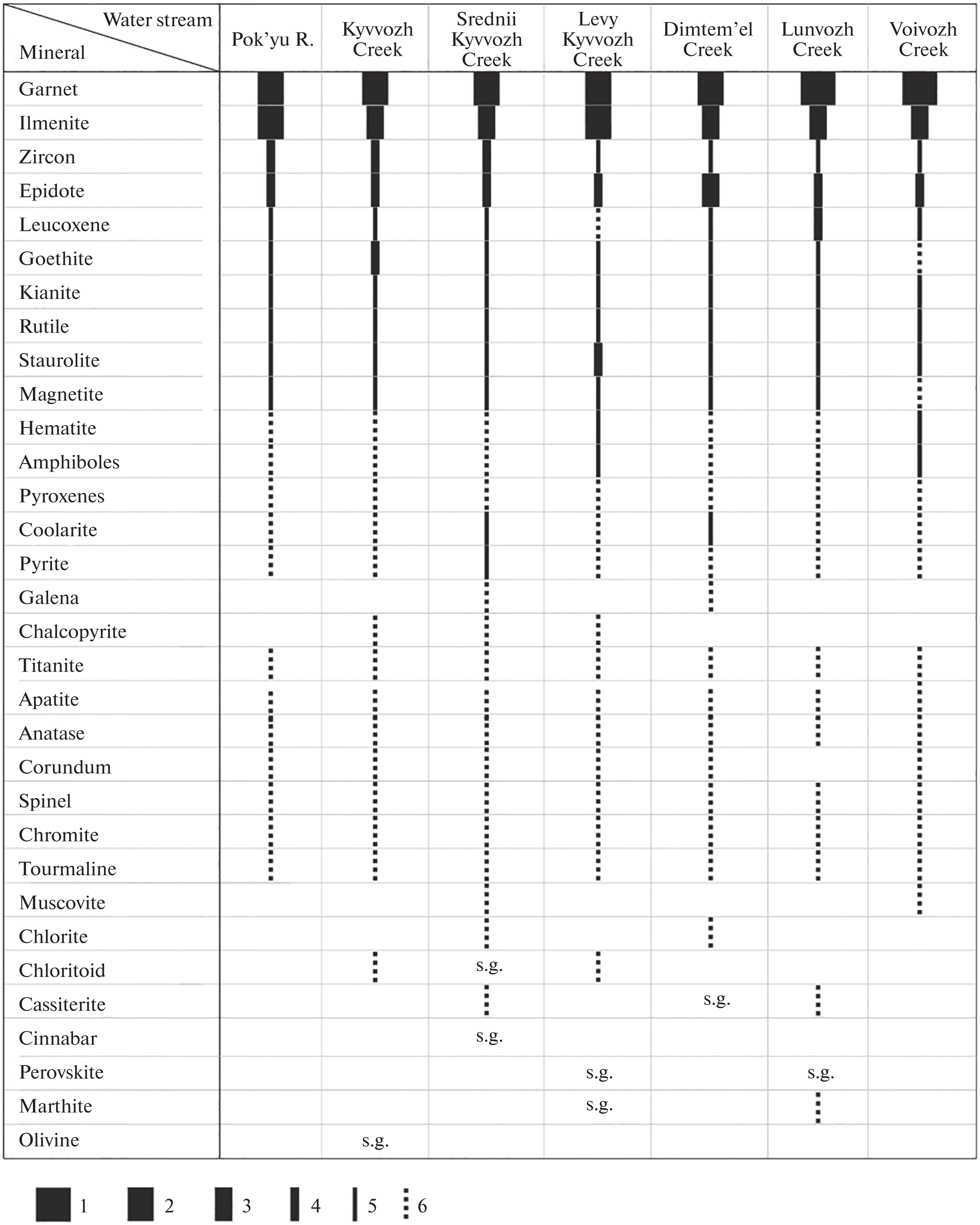

Fig. 3. Average content of minerals of heavy fraction from alluvial deposits of the Kyvvozh region (rel %): (1) >50; (2) 25–50; (3) 10–25; (4) 5–10; (5) 1–5; (6) <1; s.g., single grains.

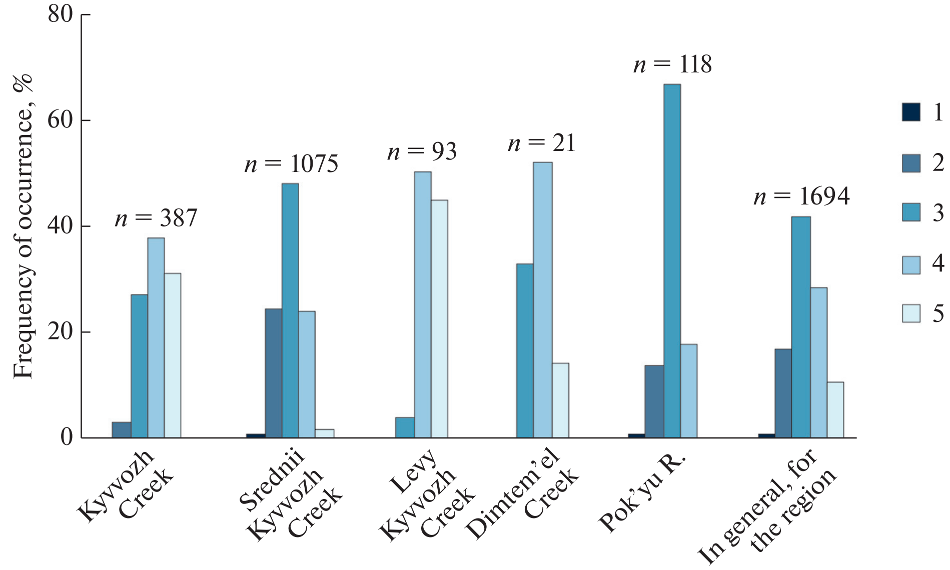

Fig. 4. Histogram of occurrence of gold by granulometric classes in the Kyvvozh region: (1) 1.0–2.0 mm; (2) 0.5–1.0 mm; (3) 0.25–0.5 mm; (4) 0.1–0.25 mm; (5) <0.1 m; *n*, grain number.

num, tetraferroplatinum, and Os–Ir–Ru alloys, which were previously found in alluvium of the Kyvvozh and Chernaya Kedva rivers (Makeev et al., 1996).

Native Gold

Native gold is mostly homogeneous yellow, reddish yellow, and, rarely, straw yellow. The surface of gold particles is often covered by crusts of black and reddish brown Mn and Fe oxyhydroxide (todorokite, pyrolusite, and lepidocrockite).

Granulometry

The size of gold particles in the studied heavy concentrate samples varies from 0.05 to 2.0 mm (Fig. 4). Small gold (0.25–1.0 mm) with a dominant size of 0.25–0.50 mm is the most abundant (59%). Very small gold (0.10–0.25 mm) is less abundant (29%). It is mostly observed in heavy concentrate samples of the Kyvvozh, Levy Kyvvozh, and Dimtem'el creeks. The amount of fine gold (<0.1 mm) does not typically exceed 11%, except for in the Kyvvozh and Levy Kyvvozh creeks, where its content is higher. The largest gold grains up to 2.0 mm in size were found in samples of the Srednii Kyvvozh Creek and the Pok'yu River. Their amount does not exceed 1%.

Note that native gold of the Srednii Kyvvozh placer was previously characterized during experimental industrial works as large (>0.5 mm) with nuggets up to 2 cm weighing up to 24 g (Dudar, 1996; Makeev and Dudar, 2003).

Morphology

Most native gold of the Kyvvozh region has platy, tabular, and lumpy morphology (Fig. 5). The platy and tabular particles include angular–rounded, rounded, elongated, flattened–tabular, subisometric, and rare scaly particles, as well as the particles of complex morphology (e.g., rare spherical and rod particles). According to flatness, the native gold particles are subdivided into moderately (73%) and strongly (22%) flattened and subisometric (5%) ones, excluding the Pok'yu area, with strongly dominant flattened (64%) and subordinate moderately flattened (36%) forms. It is important that many gold particles underwent recurrent deformations, which probably originated after their rounding in a water stream and include envelope folding, curves, crumpling, and complex contours similar to ruptures.

In the degree of roundness, native gold is subdivided on unrounded, weakly rounded, semirounded, and well and perfectly rounded (Fig. 6). The unrounded gold is rare and occurs in all areas except for the Pok'yu area. In spite of its rare occurrence in the riverbed alluvium, its large amount was detected in heavy concentrates after the placer exploration (Fig. 7). The gold particles have complex, often, branching form without any features of rounding. The particle surface has a complex surface with angular unevenness, knobs, holes, and imprints.

Weakly rounded gold occurs in all areas and is a few in numbers ranging from 4% (Levy Kyvvozh) to 23% (Srednii Kyvvozh), being 19%, on average in all areas. The gold grains exhibit preserved primary ore forms (Fig. 5i). They are mostly angular, with weakly crum-

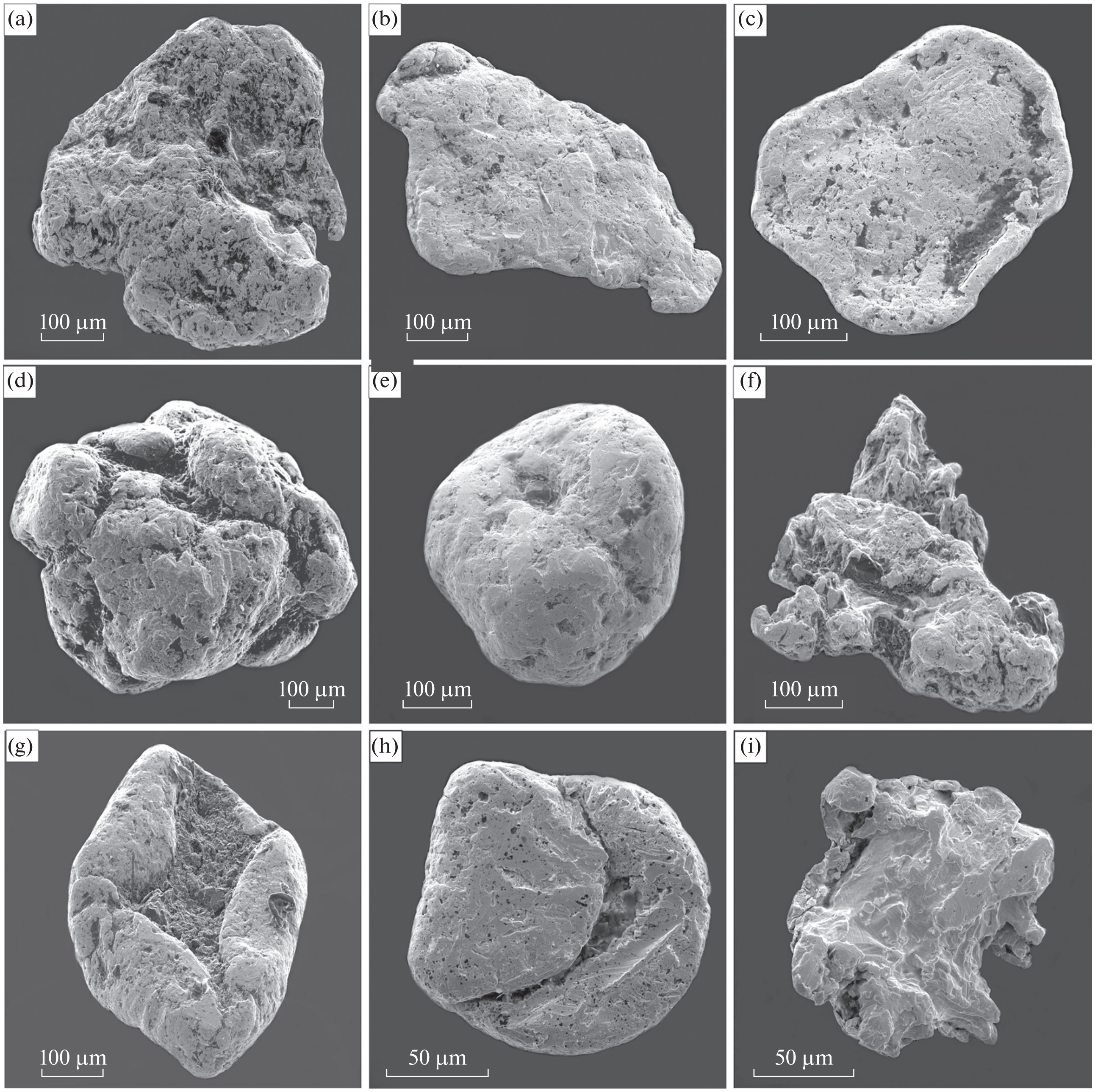

Fig. 5. Morphology and roundness of typical grain particles: (a, b) well-rounded platy and elongated-platy; (c) well-rounded platy with an end roll; (d) lumpy semirounded; (e) perfectly rounded spherical; (f) complex semirounded; (g, h) well-rounded platy with envelope crumpling; (i) complex weakly rounded. Here and in Figs. 7, 8, secondary electron images.

pled edges, as a rule, of complex anhedral growth morphology. There are local small areas with rolls. Gold of this group has the lower average values of flatness and the high preservation of imprints of ore minerals and compromise growth surfaces. The amount of roundness in a particle contour is 5 to 25%.

The semirounded gold is widely abundant in the studied region and the frequency of its occurrence is 45%. This gold is dominant at the Kyvvozh and Sredni Kyvvozh areas. In the upper reaches of Srednii Kyvvozh Creek, the occurrence of semirounded gold is higher than in an economic placer, which is located downstream, where its roundness is higher. In the Levy Kyvvozh area, the semirounded gold occurs approximately in equal proportion with well-rounded gold. The semirounded gold has an angular–rounded morphology with angular and fully smoothed ledges on the surface (Fig. 5f). It can contain extended areas

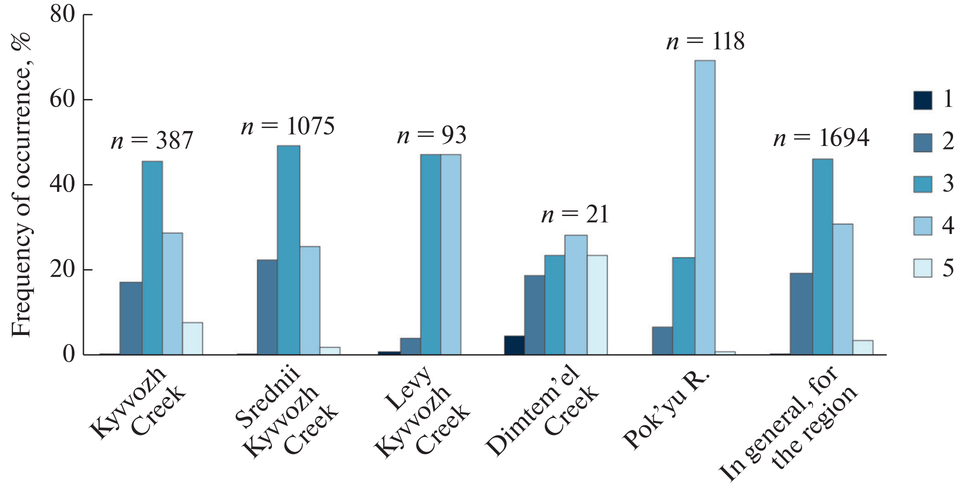

Fig. 6. Histograms of occurrence of gold by the degree of roundness in areas of the Kyvvozh region. (1) Unrounded; (2) weakly rounded; (3) semirounded; (4) well rounded; (5) perfectly rounded; *n*, grain number.

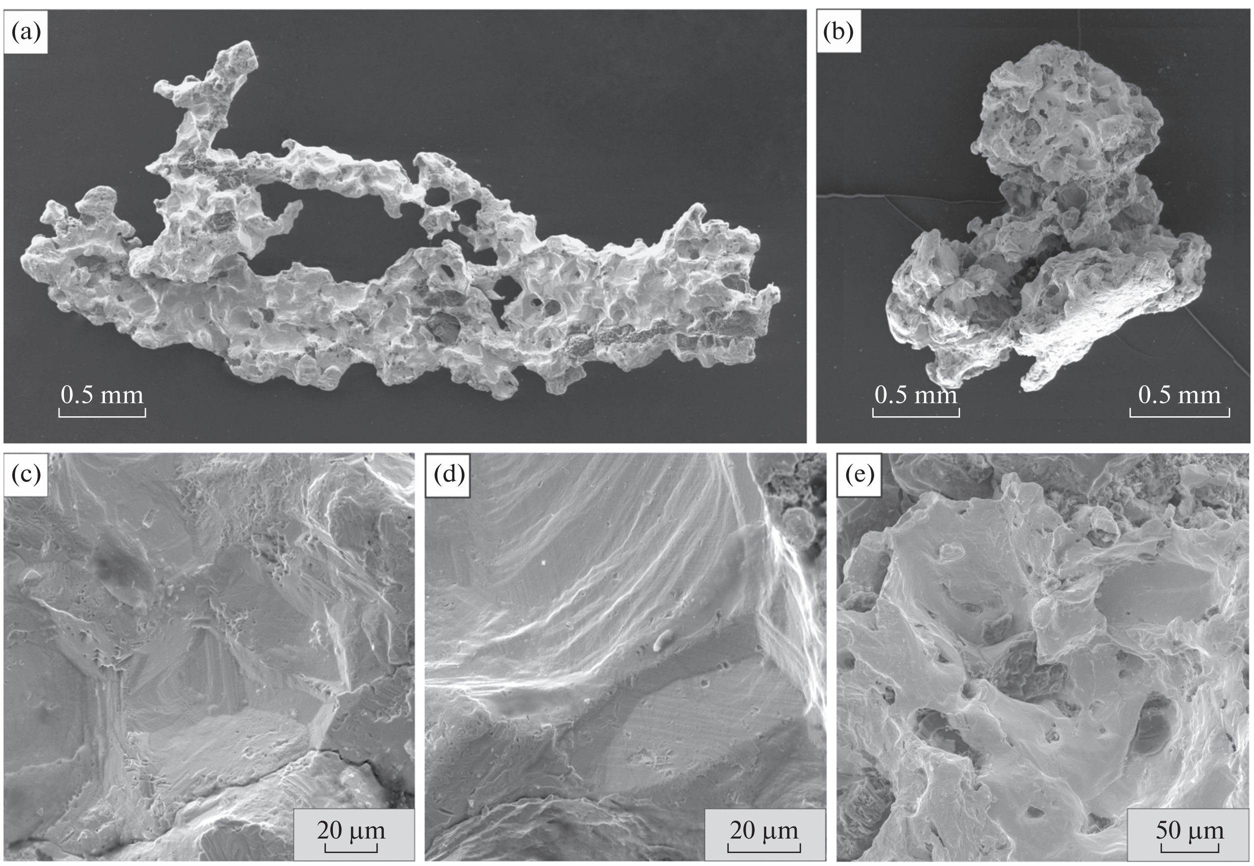

Fig. 7. (a, b) Unrounded complex gold grain and (c–e) its typical surface.

with overgrows and rolls, and the particles with complex morphology can be lumpy (Fig. 5d). The degree of the roundness in the particle contours is 25–50%.

Well-rounded gold often occurs (30%), but exhibits uneven distribution in areas. In the Pok'yu area, it is dominant (69%), in contrast to other areas: from 26% (Srednii Kyvvozh) to 47% (Levy Kyvvozh). Gold mostly includes flattened particles with rolls along the margins (Figs. 5a–5c, 5g, 5h). The lumpy, scaly, ellipsoidal, and dumbbell forms with almost or fully

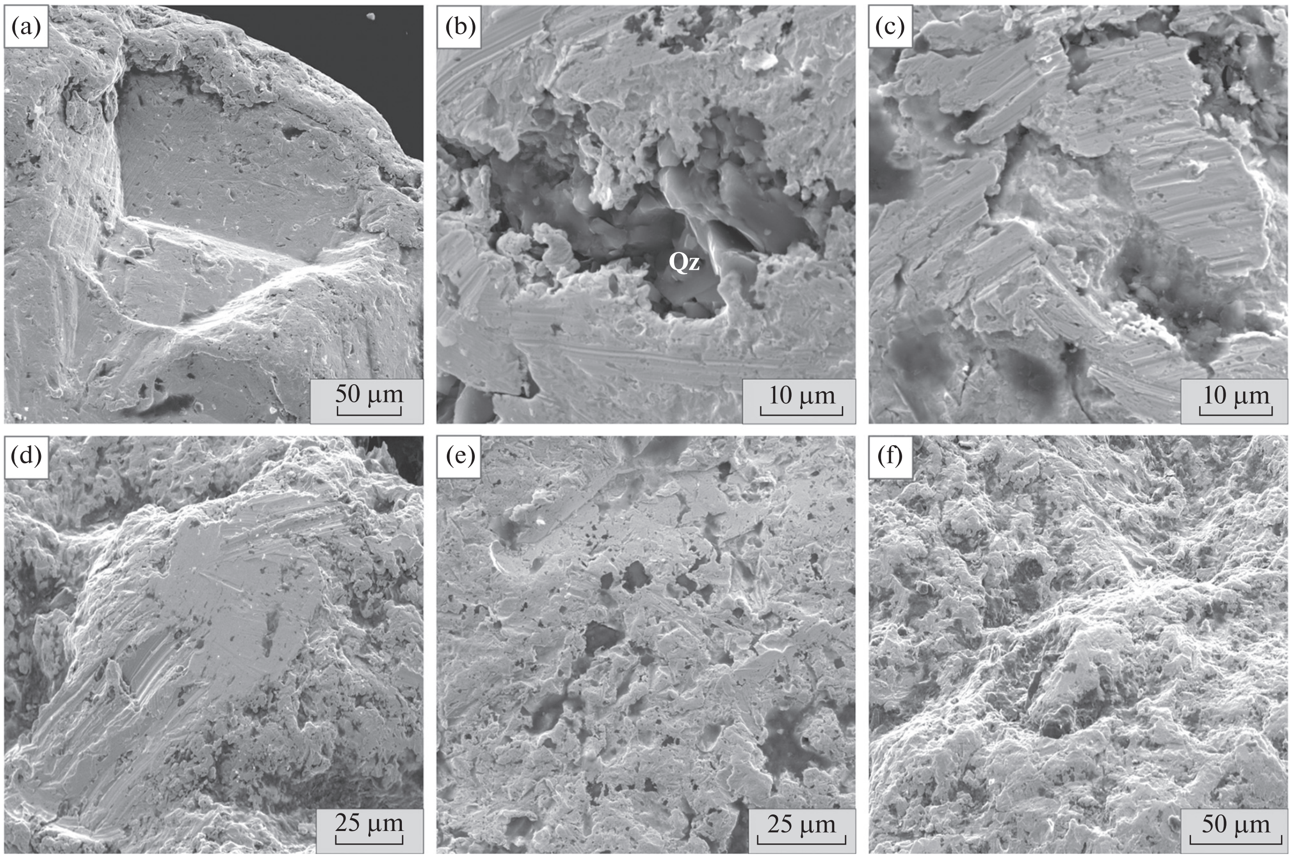

Fig. 8. Peculiarities of microrelief of gold particles; (a) angular and stepwise imprints of minerals–intergrowths; (b) cavern with quartz particles (Qz) and newly formed spongy gold; (c, d) slickenlines and scratches; (e, f) pit and pit–knobby relief.

smoothed ledges are less abundant. The degree of roundness in the contours of the gold particles is 25–50%.

Perfectly rounded gold is rare (4%). It has even contours, areas with rolls, and a strongly smoothed surface (Fig. 5e). The degree of roundness of this gold is >90%.

The surface of variously rounded particles is pit and pit–knobby. There are caverns with newly formed (supergene) spongy gold. The areas unaffected by rounding are smoother and locally contain angular or stepwise imprints of minerals intergrown with gold. In our opinion, slickelines, which indicate recurrent deformations of the gold particles mentioned above, are most interesting.

Internal structure and chemical composition

The placer gold particles have a heterogenous internal structure with rims, blocks, and veinlet zones, which significantly differ in chemical composition. The Ag content of central relatively homogeneous areas of gold grains widely varies reaching 41.9 wt % (Table 1). The gold with 0.4–4.1 wt % Ag occurs most frequently. A maximum Ag content is typical of gold from the Srednii Kyvvozh area. In rare cases, gold from Srednii Kyvvozh, Kyvvozh, and Levy Kyvvozh areas contains 0.4–10.7 Cu, 0.4–1.9 Pd, and 2.2–4.3 Hg wt %. Only Ag was detected in gold from the Dimtem'el and Pok'yu areas.

The fineness of gold varies from 579 to 1000‰. High-fineness gold (951–999‰) most often occurs in all areas (Fig. 9). The upper reaches of the Srednii Kyvvozh Creek and the Levy Kyvvozh and Pok'yu areas contain very high-fineness gold without Ag and other trace elements.

The most gold particles are rimmed by high-fineness gold (Fig. 10). These rims can be continuous or discontinuous and are characterized by the presence of numerous small relatively isometric zones of slit branching pores, as well as on the surface of gold grains. The width of the rims is typically 5–15 μm, locally, 30–70 μm. There are particles in which primary gold is preserved only in form of small relics. The traces in rims are absent in most cases. Nonetheless, the Ag content can locally be as high as 3.3 wt %. One Srednii Kyvvozh gold particle contains 2.2 wt % Hg. The fineness of rims varies from 910 to 1000‰ (Fig. 11).

Table 1. Chemical composition of typical gold particles of the Kyvvozh region

No.	Sample no.	Analytical area	Element content, wt %						K_h	Fineness, ‰
			Au	Ag	Cu	Pd	Hg	Total		
Srednii Kyvvozh Creek										
1	201202	Center	99.85	–	–	–	–	99.85	1.00	1000
2		Rim	99.75	–	–	–	–	99.75		1000
3	203201/1	Center	99.08	0.89	0.52	–	–	100.49	1.00	986
4		Margin	99.53	–	–	–	–	99.53		1000
5		Dark area	83.57	16.13	–	–	–	99.70		838
6	600302	Center	90.92	9.20	–	–	–	100.12	1.10	908
7		Rim	99.63	–	–	–	–	99.63		1000
8		Veinlet	89.69	9.36	–	–	–	99.05		906
9	600202	Center	98.54	3.23	–	–	–	101.77	1.01	968
10		Rim	99.13	–	–	–	–	99.13		1000
11	600203/2	Center	89.52	10.61	–	–	–	100.35	1.12	894
12		Rim	100.48	–	–	–	–	100.48		1000
13	60002/3	Center	57.75	41.92	–	–	–	99.67	1.73	579
14		Rim	99.91	0.88	–	–	–	100.79		991
15	YuG-1v/2	Matrix	92.80	3.05	3.48	–	–	99.33	1.07	934
16		Lamella	90.66	0.59	9.41	–	–	100.66		901
17		Rim	98.94	–	–	–	–	98.94		1000
18	YuG-3/2	Center	82.28	17.50	–	–	–	99.78	1.21	825
19		Rim	99.72	–	–	–	–	99.72		1000
20	2902k-SKY-18/29	Center	92.84	6.89	–	–	–	99.73	1.07	931
21		Rim	99.80	–	–	–	–	99.80		1000
22		Veinlet	55.45	44.33	–	–	–	99.78		556
23	YuG-14b/1	Center	98.14	1.58	–	–	–	99.72	1.02	984
24		Rim	100.56	–	–	–	–	100.56		1000
25	2902-SKY-18/12	Center	97.99	2.26	–	–	–	100.25	1.02	977
26		Rim	99.70	–	–	–	–	99.70		1000
27		Veinlet	49.77	50.68	–	–	–	100.45		495
28	6078K-5	Center	75.85	24.79	–	–	–	100.64	1.30	754
29		Rim	98.68	–	–	–	–	98.68		1000
30	6078M-2	Center	82.12	14.43	–	–	4.03	100.58	1.22	816
31		Rim	100.52	–	–	–	–	100.52		1000
32	6079K-3	Center	91.69	8.81	–	–	–	100.50	1.08	912
33		Rim	98.82	1.94	–	–	–	100.77		981
34	5427/3	Center	85.66	11.67	–	–	4.32	101.65	1.17	843
35		Rim	100.4	–	–	–	–	100.4		1000
36	5427/4	Center	97.27	2.51	–	–	–	99.78	1.02	975
37		Rim	99.0	–	–	–	–	99.00		1000
38		Veinlet	48.54	52.6	–	–	–	101.14		480
39	5428/9	Center	88.48	0.40	10.71	–	–	99.58	1.14	888
40		Rim	100.46	–	–	–	–	100.46		1000

Table 1. (Contd.)

No.	Sample no.	Analytical area	Element content, wt %						K_h	Fineness, ‰
			Au	Ag	Cu	Pd	Hg	Total		
41	601601/5	Center	99.05	0.91	–	–	–	99.96	1.00	991
42		Margin	99.24	–	–	–	–	99.24		1000
43	601601/6	Center	77.21	20.54	–	–	3.81	101.57	1.25	760
44		Rim	96.64	3.54	–	–	–	100.18		965
45	601601/7	Center	95.31	2.04	2.81	–	–	100.16	1.05	952
46		Rim	100.17	–	–	–	–	100.17		1000
Kyvvozh Creek										
47	2907Ap-KYV-18/4	Center	96.11	3.81	–	–	–	99.92	1.05	962
48		Rim	100.65	–	–	–	–	100.65		1000
49		Veinlet	87.77	12.59	–	–	–	100.36		875
50	2907a-KYV-18/14	Center	69.26	31.87	–	–	–	101.13	1.44	685
51		Rim	99.50	–	–	–	–	99.50		1000
52	2909v-3	Center	100.21	0.84	–	–	–	101.05	1.00	992
53		Rim	100.19	–	–	–	–	100.19		1000
54		Veinlet	94.89	5.19	–	–	–	100.08		948
55	2909v-4	Center	99.72	1.17	–	–	–	100.89	1.01	988
56		Rim	100.32	–	–	–	–	100.32		1000
57		Veinlet	28.58	71.28	–	–	2.85	102.72		278
58	2912a-5	Center	99.55	1.84	–	–	–	101.39	1.00	982
59		Rim	99.93	–	–	–	–	99.93		1000
60		Veinlet	81.49	19.02	–	–	–	100.52		811
61	2954-7	Center	99.17	0.64	–	–	–	99.81	1.01	994
62		Rim	100.43	–	–	–	–	100.43		1000
63	2955-1	Center	99.96	0.78	–	–	–	100.74	1.00	992
64		Rim	99.92	–	–	–	–	99.92		1000
65		Veinlet	48.13	53.05	–	–	–	101.18		476
66	510-01-7	Center	92.64	5.84	0.48	–	–	98.96	1.08	936
67		Rim	99.61	–	–	–	–	100.14		1000
Levy Kyvvozh Creek										
68	2940Ka-4	Center	98.95	1.47	–	–	–	100.42	1.01	985
69		Rim	99.71	–	–	–	–	99.71		1000
70	2940Ka-7	Center	96.62	4.16	–	–	–	100.78	1.02	959
71		Rim	99.01	–	–	–	–	99.01		1000
72	2941b-1	Matrix	81.34	17.33	0.69	–	–	99.36	1.23	819
73		Lamella	77.65	–	21.92	–	–	99.57		780
74		Rim	100.01	–	–	–	–	100.01		1000
75	2941b-2	Center	98.06	0.51	2.29	–	–	100.86	1.01	972
76		Rim	99.51	–	–	–	–	99.51		1000
77	2941g-3	Center	97.38	0.88	0.38	1.89	–	100.53	1.01	969
78		Rim	97.88	–	–	1.06	–	98.93		989

Table 1. (Contd.)

No.	Sample no.	Analytical area	Element content, wt %						K_h	Fineness, ‰
			Au	Ag	Cu	Pd	Hg	Total		
79	2941g-4	Center	91.30	5.77	2.71	–	–	99.78	1.09	915
80		Rim	99.74	–	–	–	–	99.74		1000
81	2941g-6	Center	97.92	3.38	–	–	–	101.30	1.02	967
82		Rim	99.47	0.37	–	–	–	99.84		996
83	2941v-19-3	Center	70.44	29.44	–	–	–	99.88	1.42	705
84		Margin	100.34	–	–	–	–	100.34		1000
85		Veinlet	87.95	12.02	–	–	–	99.97		880
86	2941v-19-6	Center	87.56	12.29	–	–	–	99.85	1.14	877
87		Margin	99.84	–	–	–	–	99.84		1000
Dimtem'el Creek										
88	2919g-DIM-18/3	Center	82.90	17.08	–	–	–	99.98	1.20	829
89		Rim	99.56	–	–	–	–	99.56		1000
90	2919g-DIM-18/1	Center	95.66	6.02	–	–	–	101.68	1.04	941
91		Rim	99.91	–	–	–	–	99.91		1000
92	2918b-DIM-18/1	Center	99.73	1.37	–	–	–	101.10	0.99	986
93		Rim	98.31	–	–	–	–	98.31		1000
94		Veinlet	58.42	42.10	–	–	–	100.52		581
95	2919g-DIM-18/6	Center	91.94	7.32	–	–	–	99.26	1.09	926
96		Rim	100.57	–	–	–	–	100.57		1000
97	2919D-1	Center	88.28	11.80	–	–	–	100.08	1.15	882
98		Rim	101.17	0.45	–	–	–	101.62		996
Pok'yu River										
99	205303/1	Center	72.91	27.14	–	–	–	100.05	1.36	729
100		Rim	99.38	0.65	–	–	–	100.04		994
101	204701/3	Center	85.71	14.40	–	–	–	100.11	1.15	856
102		Rim	98.86	–	–	–	–	98.86		1000
103	205601	Center	93.66	6.33	–	–	–	99.98	1.06	937
104		Rim	99.19	0.80	–	–	–	99.99		992
105	204704/19	Center	92.65	8.29	–	–	–	100.94	1.07	918
106		Rim	99.47	–	–	–	–	99.47		1000
107	204704/10K	Center	98.73	1.05	–	–	–	99.78	1.01	989
108		Rim	99.93	–	–	–	–	99.93		1000
109		Veinlet	66.92	32.81	–	–	–	99.73		671

Here and in Tables 2–4, a dash indicates an element not detected; K_h is a coefficient of heterogeneity calculated as ratio of Au content in the rim and the central part.

Gold particles with very high-fineness rims are dominant. Table 1 shows the coefficients of heterogeneity, which characterize the ratios of Ag content of rims and central parts of gold grains, which are used in some works (Silaev et al., 1987; Lalomov et al., 2016). For the Kyvvozh gold, this ratio is 1.0–1.2 in most cases, locally reaching 1.4–1.7 (at a relatively low Ag content in the central parts). Note also the absence of a clear positive correlation between the content of rare Ag in the rims and the central parts of the gold grains (Fig. 12).

Gold from the Kyvvozh area rarely has a blocky (granular) structure in comparison with other areas. The blocks have different sizes and form (Fig. 13). An

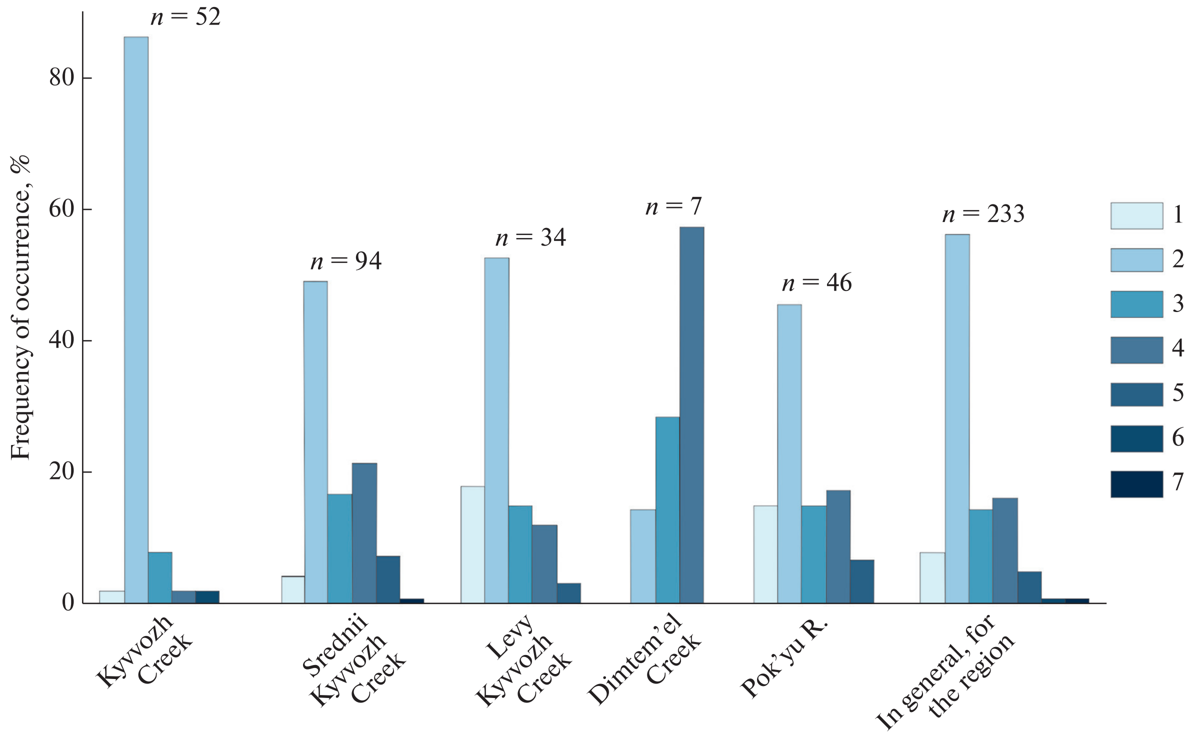

Fig. 9. Histogram of fineness of the central part of gold grains (‰): (1) 1000; (2) 951–999; (3) 900–950; (4) 800–900; (5) 700–800; (6) 600–700; (7) 500–600; *n*, number of particles.

important feature is related to the presence of veinlet low-fineness zones up to 50 μm wide without sharp internal boundaries at the periphery of blocks. The Ag content of these zones is typically 35–40 wt %. In the Kyvvozh area, one gold particle hosts a veinlet with 71.3 wt % Ag and 2.9 wt % Cu, whereas another contains 43.1 wt % Ag and 0.4 wt % Pd. The veinlets with a high Ag content correspond to electrum and kustelite in composition. Figure 13d shows a typical distribution of Au and Ag content along the profile in one of the intersections of a blocky gold particle. As can be seen, it has a complex contrasting character. It is interesting that the low-fineness veinlet zones at the boundaries of the blocks are often replaced by the narrower very-high-fineness zones free of Ag and other traces, whereas they are locally detached each from other. These high-fineness zones can be conjugated with external high-fineness rims.

One gold particle from the Srednii Kyvvozh area contains an evident exsolution structure of the Au–Cu solid solution (Fig. 14). The Cu and Ag content of the matrix is 2–3 wt %. The cuprous plates contain 8–9 wt % Cu and 0.5–0.6 wt % Ag corresponding to Au_3Cu. In addition to fine plates, there are also wider Cu-bearing aggregates. The gold particle with the exsolution structure from the Levy Kyvvozh area contains a higher Cu amount in cuprous plates (up to 21.9 wt %).

Mineral intergrowths and inclusions

The riverbed alluvium contains native gold with quartz inclusions and imprints of most likely pyrite crystals, micas, and Fe–Mg carbonates. The residual products of placer exploration contain gold–quartz intergrowths, as well as the sericite–quartz–goethite particles with native gold (Fig. 15).

The microinclusions in placer gold of the Kyvvozh, Pok'yu, Levy Kyvvozh, and Srednii Kyvvozh include quartz, muscovite, pyrite, chalcopyrite, galena, ankerite, microphases of the cobaltite–gersdorffite series, galenobismuthite, aurostibite, and native bismuth (Fig. 16). Note that the micromineral inclusions are most typical of blocky native gold.

Galena (locally, Bi-bearing) is the most abundant sulfide among the inclusions (Table 2). Some grains represent galenobismuthite with 54.4 wt % Bi and 0.4 wt % Se. Galena is intergrown with Sb-bearing minerals of the cobaltite–gersdorffite series (Table 3). In addition, aurostibite can occur individually or is intergrown with galena and contains nearly 1.2–3.1 wt % Bi (Table 4). In one case, we identified native bismuth. At the Levy Kyvvozh area, native gold particles also host monazite and a Pt selenide, which is most likely the first finding of sudovikovite ($PtSe_2$) in Timan. The main trace elements of sudovikovite include Pd and Te (Table 5). Tellurium was detected in this mineral for the first time in contrast to sudovikovite from metaso-

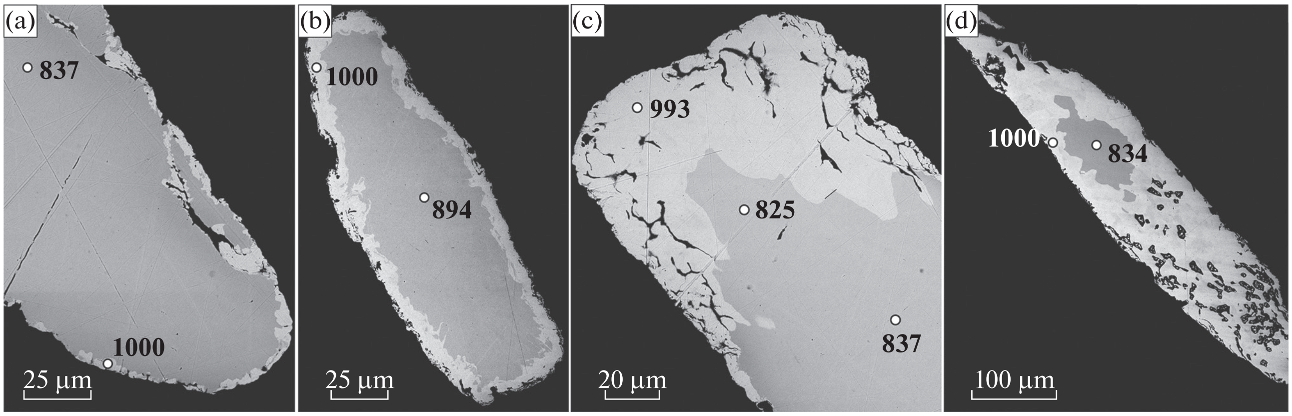

Fig. 10. Character and width of high-fineness rims (light) of gold particles: (a) uneven narrow; (b) massive; (c) wide uneven; (d) wide with relic of primary gold. Numbers indicate the fineness of native gold (‰). Here and in Figs. 13–16, BSE images.

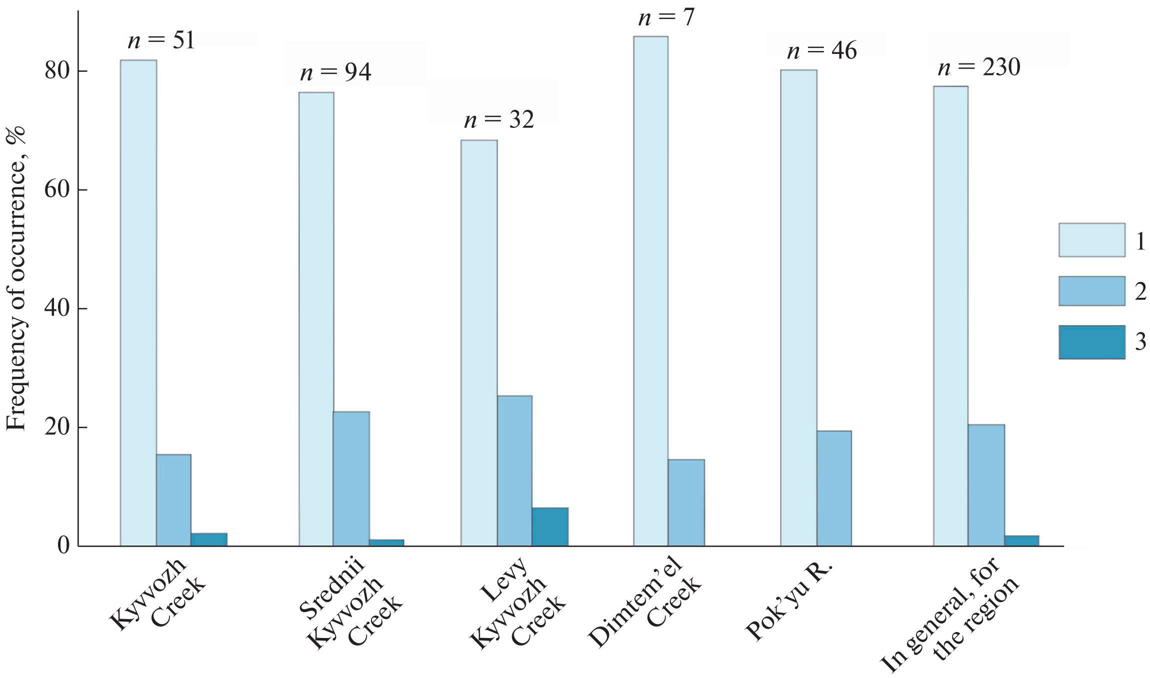

Fig. 11. Histogram of fineness of the rim of gold grains (‰): (1) 1000; (2) 951–999; (3) 900–950; n, number of gold grains.

matites of South Karelia, where it was discovered (Polekhovsky et al., 1997), allowing us to recognize a Te-bearing variety of this mineral.

DISCUSSION

The alluvial gold of the studied region is relatively homogeneous; however, it has specific spatial peculiarities, first of all, of structure and composition of trace elements. Relatively homogeneous Ag-bearing gold is most abundant (Fig. 2). Blocky native gold with low-fineness veinlets is less abundant in all areas. It is characterized by secondary deformations and various micromineral inclusions. The Ag-bearing gold from the Srednii Kyvvozh area locally contains Cu, whereas that from the Kyvvozh and Levy Kyvvozh areas contains Cu, Hg, and Pd. Most gold particles have high-fineness rims. Three gold types can be distinguished: the main homogeneous Ag-bearing gold (type I) and blocky gold with high-Ag veinlet zones (type II) and rare type III Ag-bearing gold with Cu and Pd (which are not always associated with each other). Mercury is detected in single cases in gold of various types.

No significant differences in the roundness and the composition of particles have been revealed for native gold from the upper reaches of the Srednii Kyvvozh

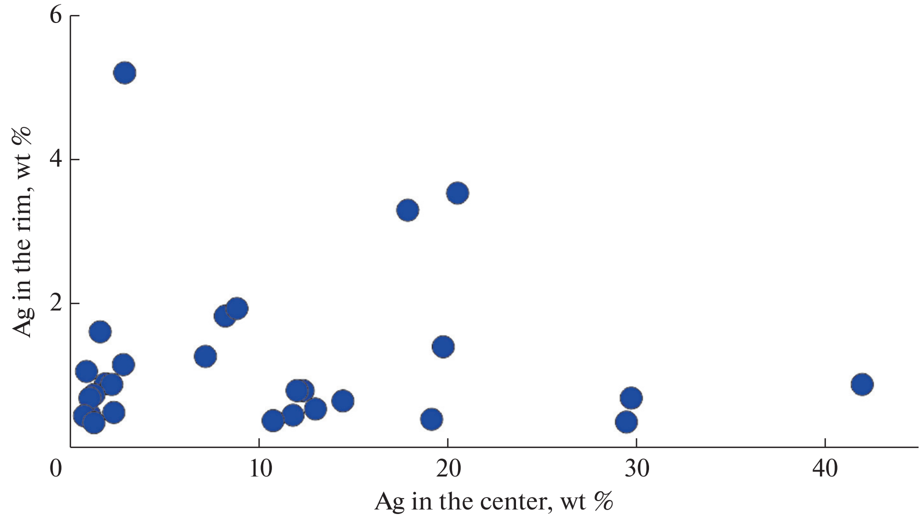

Fig. 12. Correlation of Ag content in the center and rim of gold particles.

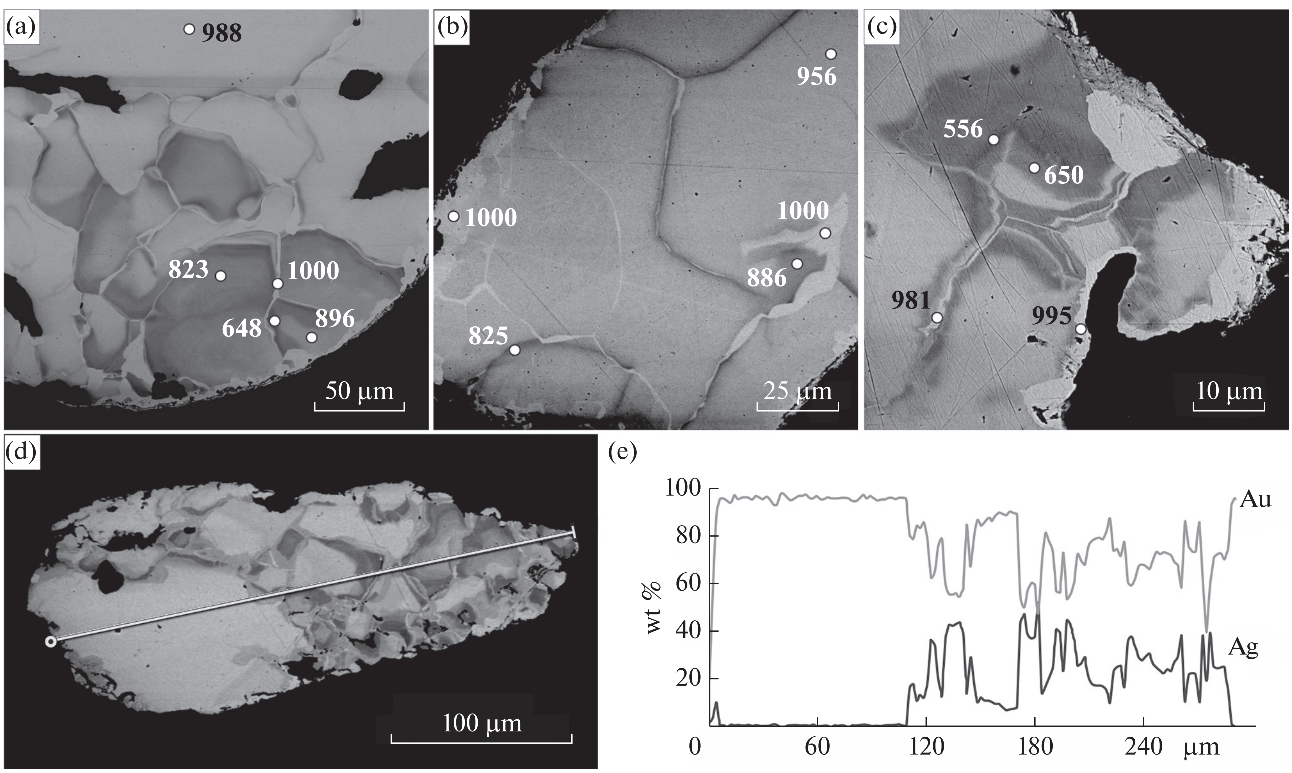

Fig. 13. Blocky structure of native gold: (a) blocks with different Ag content; (b, c) veinlet low-fineness zones along the block peripheries (dark) with overprinted narrow high-fineness zones (light); (d, e) blocky structure and Au and Ag distribution in a linear profile. Numbers indicate the fineness of native gold (‰).

Creek down the stream including the area of the economic placer (polygon) (Fig. 17). Low-fineness veinlets and inclusions of sulfides in native gold occur in both the upper (galena, cobaltite–gersdorffite) and the middle (pyrite, galena, cobaltite–gersdorffite) reaches of the polygon. Nonetheless, note that the Au content of the alluvial deposits of the polygon is the highest and the largest gold particles were found here. The zones with sulfide mineralization, where pyrite is associated with galena and chalcopyrite, are traced in the primary rocks.

The results of study of typomorphic features of gold from alluvial deposits of the Kyvvozh region allow us to make a decision as regards its possible primary

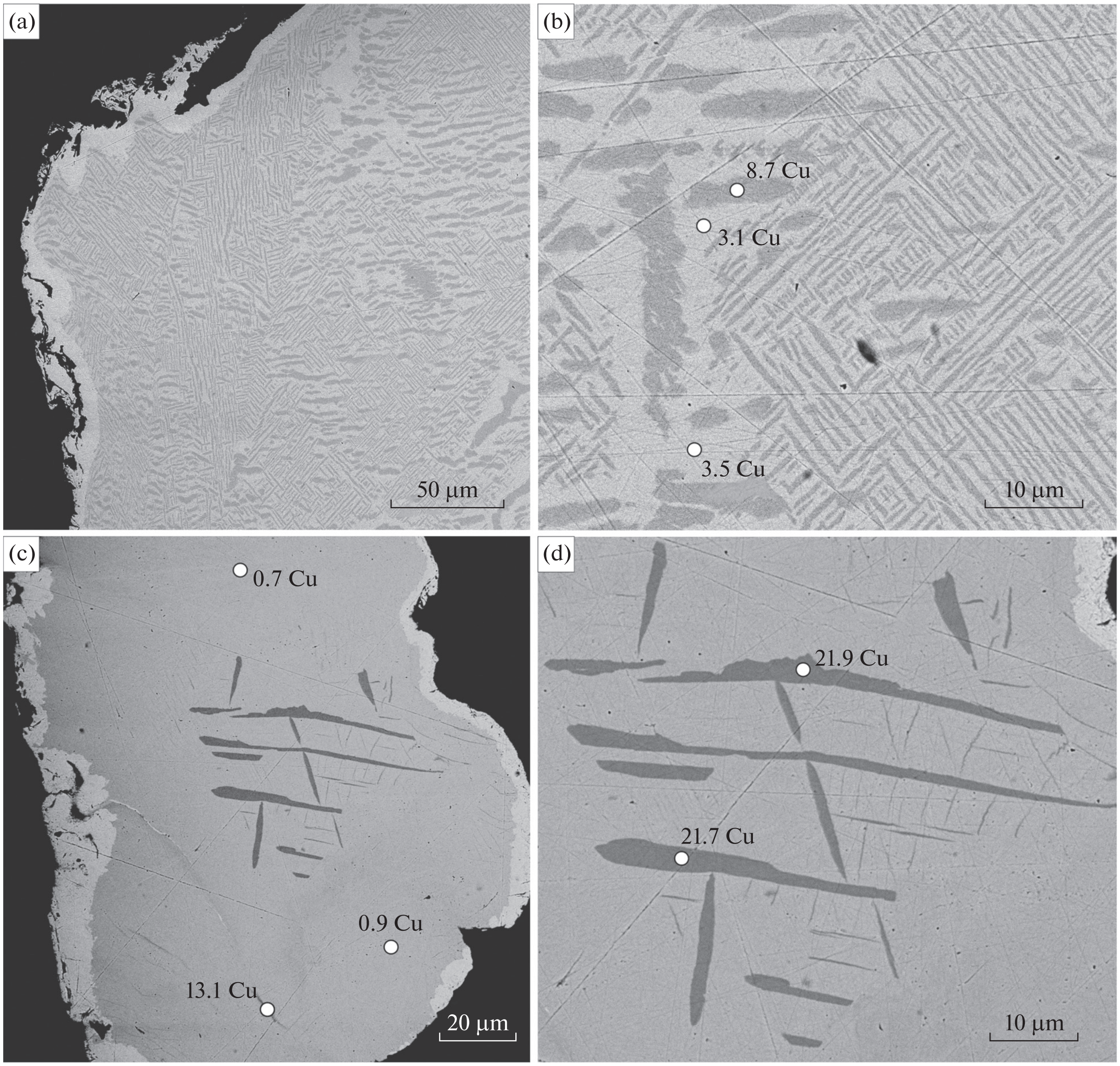

Fig. 14. Cu-bearing native gold with exsolution structure of Au–Cu solid solution from (a) Srednii Kyvvozh and (c) Levy Kyvvozh with (b, d) enlarged fragments. Numbers indicate the Cu content (wt %).

sources. The degree of transformations of primary morphology is known as an indicator of the distance of gold transportation from the primary source (Pertrovskaya, 1973; Shilo, 2002; Nikolaeva et al., 2015). The predominance of well-rounded and semirounded gold in all areas indicates its far transportation from primary sources. Because the gold particles exhibit no significant change in the degree of roundness from the upper reaches of the creeks down the stream, it is likely that they were added to the river alluvium along with material from drainage divide, slope, and terrace areas along the creeks. At the same time, findings of completely unrounded gold and small nuggets within the Srednii Kyvvozh and Kyvvozh placers indicates a proximity of primary sources, although it is necessary to keep in mind that gold could also be transported in rock clasts with its further liberation.

Secondary deformations of gold particles (curves, flattening, rolling, pits, ruptures, and slikenlines) can be explained not only by the transportation of gold in water streams and their collision with other particles, but also by their possible displacement and compression in talus deposits and shale druses, as well as the occurrence in the intermediate sedimentary reservoirs including ancient placers. The gold particles with ruptures and thus angular margins can erroneously be ascribed to weakly rounded or unrounded, which in fact is not true and is not an indicator of the nearest

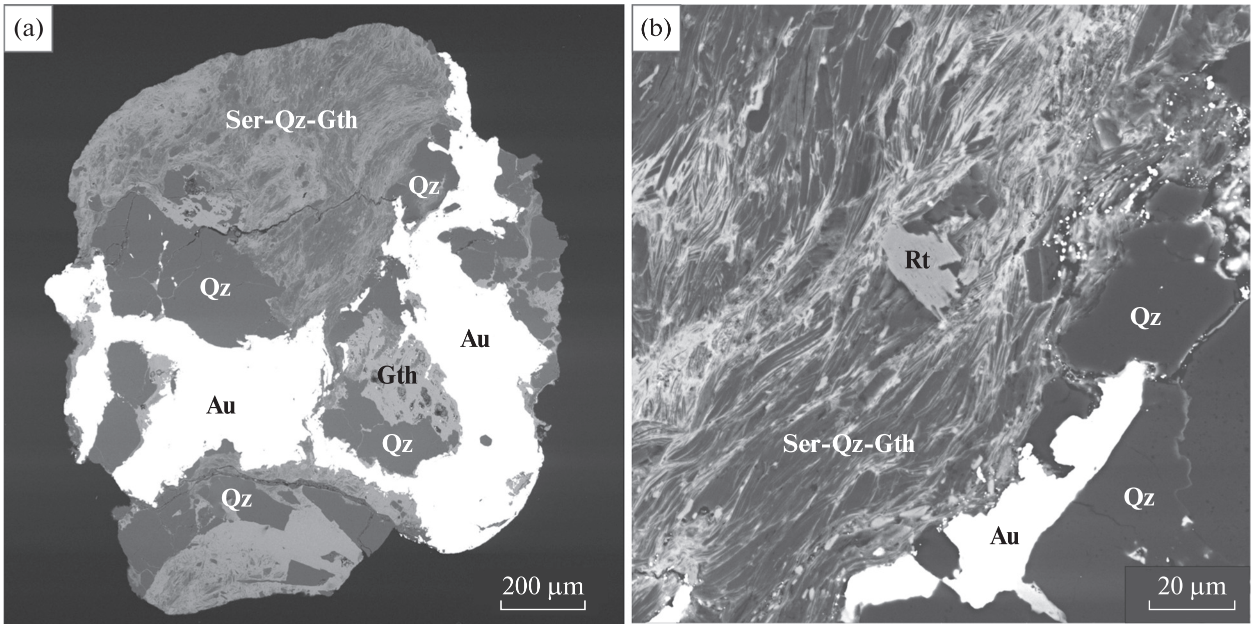

Fig. 15. Native gold in (a) sericite–quartz–goethite aggregate and (b) its enlarged fragment. Au, native gold; Gth, goethite; Ser-Qz-Gth, sericite–quartz–goethite aggregate; Rt, rutile, Oz, quartz.

source. Similar pseudo-ore native gold was previously found in the Devonian Ichet'yu paleoplacer, which is located in the Vol–Vym Uplift northward of the Kyvvozh region (Filippov and Nikiforova, 1998).

The presence of high-fineness rims (including those completely Ag-free) of most gold particles indicates their intense transformation in the supergenesis zone, including, possibly, their occurrence in chemical weathering mantles. Note that the nature of rims can be diverse, including the removal of Ag from subsurface areas, as well as overgrowing of new gold (Nikolaeva, 1978; Murzin and Malyugin, 1987; Nikolaeva and Yablokova, 2007; Osovetsky, 2016; Nikiforova et al., 2020; Groen et al., 1990; Chapman et al., 2021; Lalomov et al., 2023). In spite of the visually sharp boundaries of the rims in the central parts of the studied gold grains, it can be suggested that the processes of Ag removal played the most important role. This is evident from the complex configuration of boundaries, which emphasizes the relict character of primary native gold, the presence of pores within the rims, and the absence of growth forms on the surface of gold particles. The variations in the width of the rims and the absence of correlation between the Ag content of the rim and the central part of the gold grains can be considered evidence of uneven supergene influence on gold. The formation of new gold on the surface of gold particles, which occur in alluvial deposits, was only observed as spongy microstructures in single cases.

Blocky gold with low-fineness veinlets, which is typical of strongly deformed particles, is noteworthy.

Table 2. Chemical composition of galena and galenobismuthite, wt %

S	Se	Pb	Bi	Total	Empirical formula
11.97	–	87.52	–	99.50	$Pb_{1.06}S_{0.94}$
13.94	–	85.15	–	99.09	$Pb_{0.97}S_{1.03}$
11.93	–	88.47	–	100.40	$Pb_{1.07}S_{0.93}$
13.91	–	83.91	2.74	100.56	$(Pb_{0.95}Bi_{0.03})_{0.98}S_{1.02}$
12.33	–	87.63	–	99.96	$Pb_{1.05}S_{0.95}$
12.39	–	88.06	–	100.45	$Pb_{1.05}S_{0.95}$
12.15	–	87.44	–	99.59	$Pb_{1.05}S_{0.95}$
11.99	–	87.92	–	99.91	$Pb_{1.06}S_{0.94}$
17.06	0.40	28.09	54.43	99.97	$Pb_{1.02}Bi_{1.95}(S_{3.99}Se_{0.04})_{4.03}$

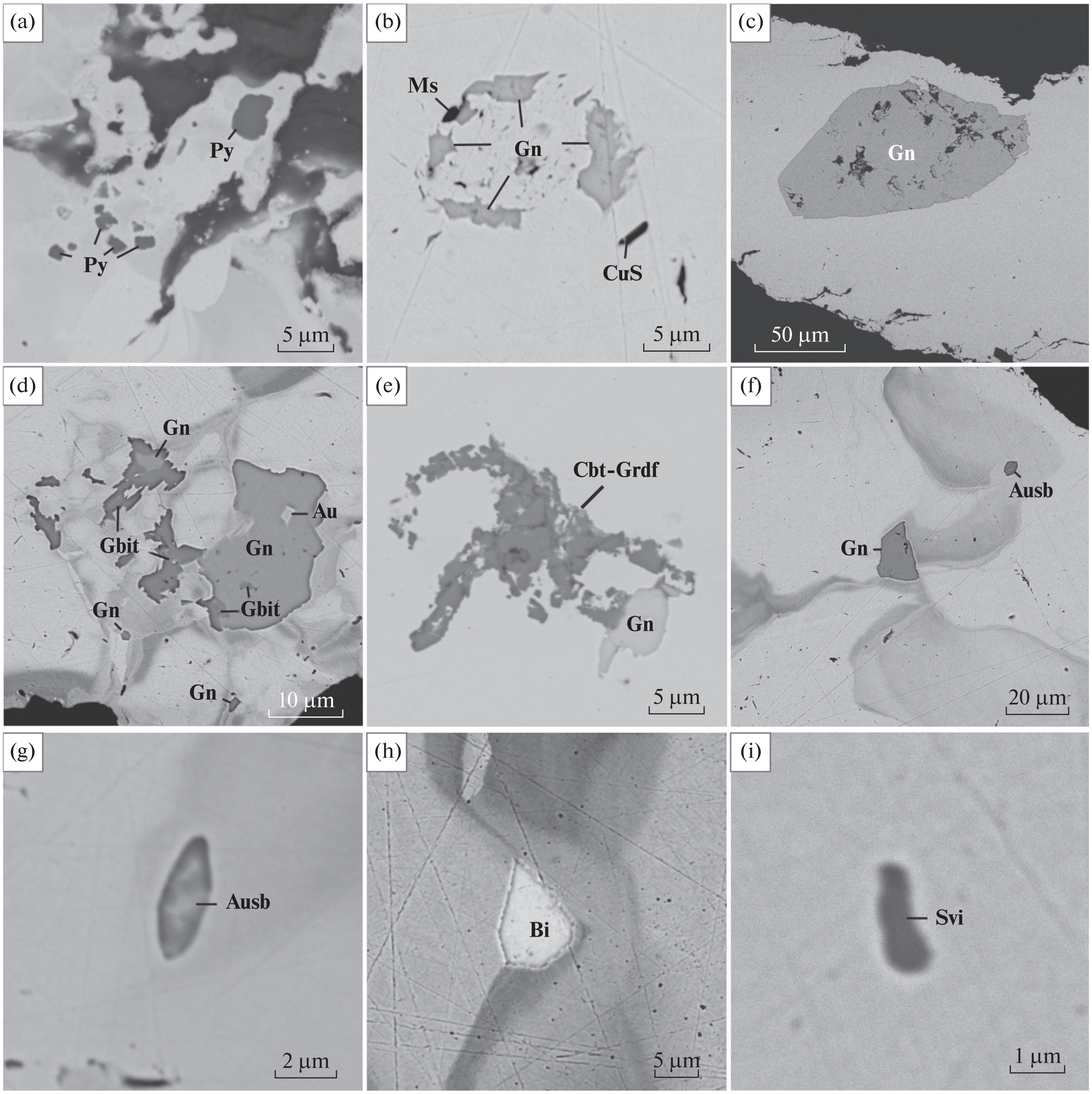

Fig. 16. Micromineral inclusions in native gold of the Kyvvozh region: sericite–quartz–goethite aggregate: Ausb, aurostibite; Bi, native bismuth; Cbt, cobaltite; CuS, covellite-like phase; Gbit, galenobismuthite; Cbt-Grdf, minerals of the cobaltite–gersdorffite series; Gn, galena; Ms, muscovite; Py, pyrite; Svi, sudovikovite.

Similar gold is abundant (Savva and Preis, 1990; Nikolaeva et al., 2015; Gerasimov, 2022). It is logical to assume for the Kyvvozh gold that the blocky structure and the formation of low-fineness veinlets are caused by the processes of solid-phase recrystallization (granulation) and mechanic diffusion of Ag toward the margins under influence of pressure simultaneously with deformation of gold particles. The formation of high-fineness veinlets at the boundaries of blocks adjacent to high-fineness external rims is related to simultaneous removal of Ag both from the subsurface and weakened internal interblock areas, when the particles occurred in supergene conditions. The possible deposition of late high-fineness gold along the fractures cannot fully be excluded.

Trace elements, as well as the mineral intergrowths and inclusions, are important for the identification of the genetic type of primary sources of alluvial gold (Petrovskaya, 1973; Murzin et al., 1981; Nesterenko, 1991; Nikolaeva and Yablokova, 2007; Naumov and

Table 3. Chemical composition of minerals of the cobaltite–gersdorffite series, wt %

S	Fe	Co	Sb	Ni	As	Total	Empirical formula
21.57	11.98	10.92	–	11.50	44.22	100.19	$(Fe_{0.35}Ni_{0.32}Co_{0.30})_{0.96}As_{0.95}S_{1.09}$
20.20	10.62	10.00	–	13.13	45.34	99.28	$(Ni_{0.37}Fe_{0.31}Co_{0.28})_{0.96}As_{1.00}S_{1.04}$
24.55	3.88	23.08	–	4.36	44.97	100.84	$(Co_{0.62}Ni_{0.12}Fe_{0.11})_{0.84}As_{0.95}S_{1.21}$
24.99	5.48	16.54	–	7.85	45.68	100.54	$(Co_{0.44}Ni_{0.21}Fe_{0.15})_{0.81}As_{0.96}S_{1.23}$
19.14	5.60	6.15	–	22.93	46.76	100.58	$(Ni_{0.65}Co_{0.17}Fe_{0.17})_{0.98}As_{1.03}S_{0.99}$
22.42	5.18	27.32	–	2.62	42.25	99.79	$(Co_{0.75}Fe_{0.15}Ni_{0.07})_{0.97}As_{0.91}S_{1.13}$
20.11	6.04	15.77	0.43	11.35	43.82	99.32	$(Co_{0.75}Fe_{0.15}Ni_{0.07})_{0.97}As_{0.91}S_{1.13}$
20.85	5.93	12.36	0.32	14.41	47.36	101.23	$(Co_{0.46}Ni_{0.33}Fe_{0.18})_{0.96}(As_{0.98}Sb_{0.01})_{0.99}S_{1.05}$
19.53	6.17	12.33	0.33	12.90	42.72	100.22	$(Ni_{0.38}Co_{0.36}Fe_{0.19})_{0.93}(As_{0.99}Sb_{0.01})_{1.00}S_{1.06}$

Table 4. Chemical composition of minerals of aurostibite, wt %

Sb	Au	Bi	Total	Empirical formula
40.23	55.96	–	96.18	$Au_{1.39}Sb_{1.61}$
39.89	57.76	2.34	99.99	$Au_{1.39}(Sb_{1.56}Bi_{0.05})_{1.61}$
39.69	58.14	1.97	99.81	$Au_{1.40}(Sb_{1.56}Bi_{0.04})_{1.60}$
38.14	59.44	2.36	99.94	$Au_{1.45}(Sb_{1.50}Bi_{0.05})_{1.55}$
36.98	60.17	2.71	99.85	$Au_{1.47}(Sb_{1.47}Bi_{0.06})_{1.53}$
39.89	56.34	2.81	99.04	$Au_{1.37}(Sb_{1.57}Bi_{0.06})_{1.63}$
43.06	54.43	3.07	100.56	$Au_{1.28}(Sb_{1.65}Bi_{0.07})_{1.72}$
35.80	61.71	1.21	98.71	$Au_{1.53}(Sb_{1.44}Bi_{0.03})_{1.47}$
40.53	56.21	2.59	99.33	$Au_{1.36}(Sb_{1.58}Bi_{0.06})_{1.64}$

Osovetsky, 2013; Nikolaeva et al., 2013; Gaskov, 2017; Leake et al., 1998; Chapman et al., 2000, 2011). The composition of placer gold of the Kyvvozh region, which contains only Ag in most cases, is typical of many gold–sulfide deposits. In addition to Ag, the placer gold of the Srednii Kyvvozh, Kyvvozh, and Levy Kyvvozh areas locally contains Cu and, in single cases, Pd. It is known that Cu is often observed in the composition of native gold. That with a high Cu content (>2–3 wt %) is most typical of deposits hosted in mafic rocks (Spiridonov and Pletnev, 2002). As to Pd, it is detected in native gold much more rarely than Cu. Nonetheless, Pd-bearing gold is known in a series of deposits, which are confined also to mafic and ultramafic rocks (Omang et al., 2015) and related to them (Murzin et al., 2021). It is also determined in gold grains (up to 0.85 wt % Pd and up to 2.23 wt % Pt) from massive sulfide ores hosted in felsic volcanic rocks of the rhyolite-basaltic association (Vikentiev, 2003). The findings of Cu- and Pd-bearing native gold in placers of the Kyvvozh region indicate its formation in relation to gabbroid dikes known in the region, which is consistent with previous ideas (Makeev et al., 1996). The presence of sporadic Hg in the Kyvvozh gold can be considered an indicator of endogenous character of faults, first of all, large NW-trending

Table 5. Chemical composition of Te-bearing sudovikovite, wt %

Se	Pd	Te	Pt	Total	Empirical formula
44.65	2.11	4.34	49.66	100.76	$(Pt_{0.87}Pd_{0.07})_{0.94}(Se_{1.94}Te_{0.12})_{2.06}$
43.37	1.44	3.81	50.87	99.49	$(Pt_{0.92}Pd_{0.05})_{0.97}(Se_{1.93}Te_{0.10})_{2.03}$
42.33	1.94	4.25	51.54	100.06	$(Pt_{0.93}Pd_{0.06})_{0.99}(Se_{1.89}Te_{0.12})_{2.01}$
41.58	1.25	4.81	52.26	99.9	$(Pt_{0.96}Pd_{0.04})_{1.00}(Se_{1.87}Te_{0.13})_{2.00}$
43.42	1.47	3.92	51.63	100.44	$(Pt_{0.92}Pd_{0.05})_{0.97}(Se_{1.92}Te_{0.11})_{2.03}$

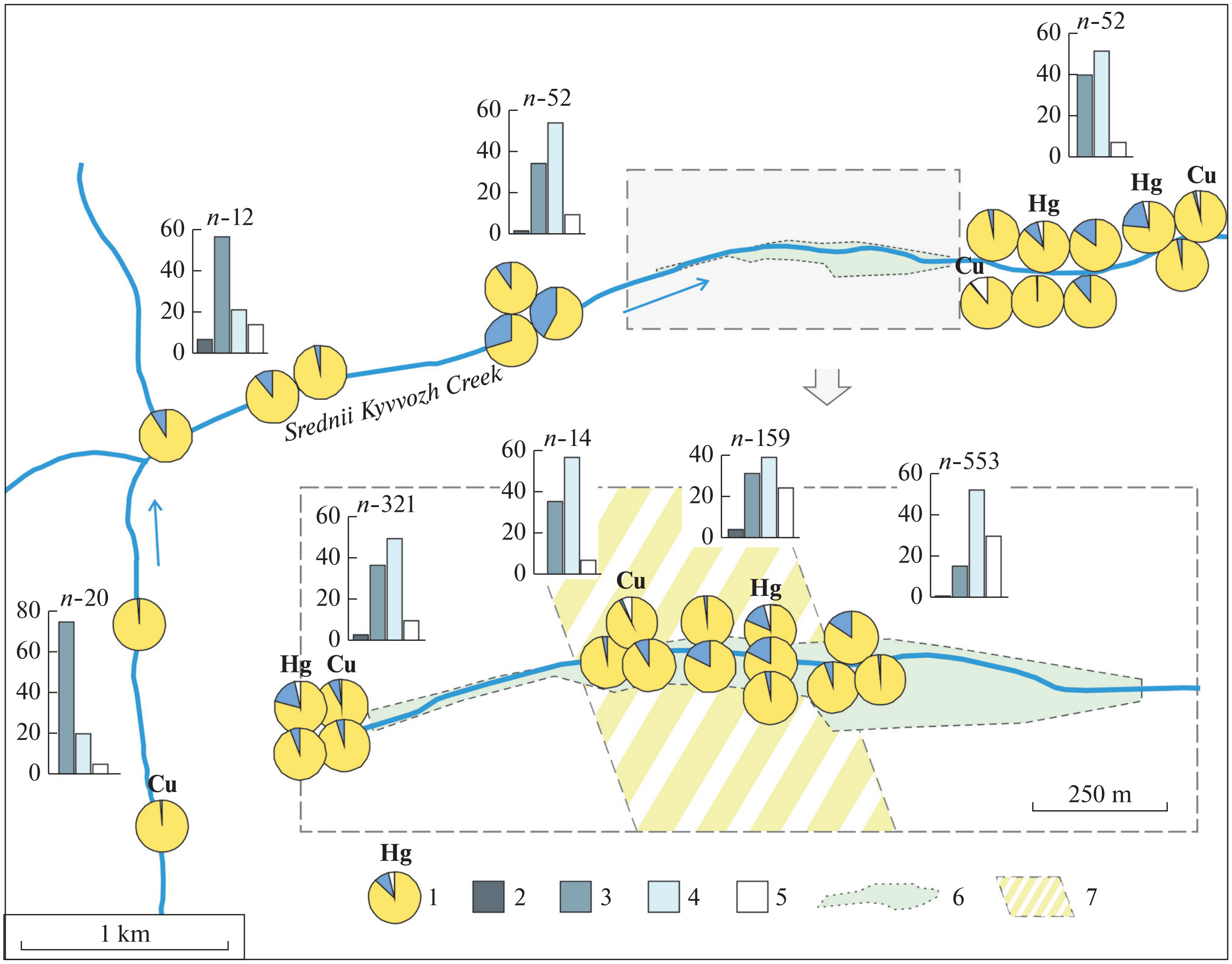

Fig. 17. Content of trace elements and the degree of roundness of gold from the alluvial deposits of the Srednii Kyvvozh area: (1) diagram of the gold composition: yellow sector—Au, blue sector—Ag, white sector—other trace elements (shown at the top of the diagrams); (2–5) histograms of the degree of gold roundness (%): perfectly rounded (2), well-rounded (3), semirounded (4), weakly rounded (5); (6) the contour of an industrial placer (mining site); (7) sulfide mienralization zone potentially promising for gold.

faults, involvement of fluids in ore formation, and the influence of mafic rocks. To some extent, this is supported by the findings of cinnabar in alluvial deposits. At the same time, Hg in native gold occurs in various hydrothermal deposits of the Urals, copper skarn and especially Carlin-type and massive sulfide, where the Hg content can reach 11–12 wt % (Vikentiev, 2003; Vikentiev et al., 2016).

The idea that the potential primary sources of placer gold of Central Timan are related to hydrothermal gold–sulfide occurrences, the formation of which is caused by processes of tectono-magmatic activation, especially in the Late Devonian, has been suggested by many researchers (Dudar, 1996; Kochetkov, 1996; Maiorova, 1996; *Timanskii*..., 2009). The intergrowths and mineral inclusions in gold described by us and other authors are direct evidence of its assemblage with quartz, muscovite, pyrite, chalcopyrite, galena, and carbonates in primary objects.

At the same time, the presence of gold particles of different degrees of roundness, secondary deformations, composition and content of trace elements, and various mineral inclusions in alluvial deposits indicates that the primary ore objects can differ from each other by geological setting and ore composition, as well as the distance from placers. Our placer gold with variously combined Cu, Pd, and Hg and microinclusions of Pd, Pt, Co, and Ni minerals indicates the genetic and spatial links of primary sources of this gold with basic magmatism and deep faults.

The zones of stringer-disseminated and disseminated sulfide (sulfide–quartz) mineralization in intensely foliated Riphean rocks of the Kyvvozh region can be considered potentially gold-bearing. One of the zones mentioned above is exposed during the exploration of the Srednii Kyvvozh placer (Fig. 17). This zone, which was studied before (Kuznetsov et al., 2014), is characterized by a predominance of pyrite and the presence of galena, chalcopyrite, gersdorffite, pyrrhotite, cobaltite, sphalerite, covellite, and Bi and Te minerals. They are also associated with rare-earth-element (REE) minerals (monazite and xenotime) and Ag–Se, Pb–Nb, Th–U, and Sr–Tb mineral phases. Two main stages of mineral formations are recognized: the early pyrite and late sphalerite–chalcopyrite–galena with REEs and rare-metal minerals. Unfortunately, no native gold has been found yet, but it is likely that it belongs to the late stage of mineral formation and has uneven distribution.

The finding of native gold in crushed samples of cataclastic sandstones at their contact with sericite–quartz–chlorite shales of the Lunvozh Group at the Srednii Kyvvozh area is interesting because of the problem of primary gold potential (Sokerin et al., 2023). Gold occurs as small particles of rounded–lumpy or complex morphology without traces of roundness. Their structure is characterized by a relatively homogeneous internal area and a compositionally contrasting low-fineness rim. The Ag content of the internal areas varies from 6 to 9 wt %. First, a gradual and, then, a sharp increase in Ag content up to 10–17 wt % are observed from the center to the margin of gold grains. The gold surface is locally overgrown by small aggregates of very high-fineness gold up to 5 μm thick, which appear as a late gold generation overgrowing low-fineness zones. The presence of this gold in sandstone samples is not a result of entrapment of gold from overlying loose sediments. Its formation is most likely caused by filtration of Au-bearing hydrothermal fluids along a tectonized contact of shales and sandstones.

The accumulation of gold in Quaternary deposits of the Kyvvozh region began due to pre-Quaternary erosion–denudation events (Dudar, 1996). The Au-bearing clastic material was transported from elevated areas and accumulated in negative relief forms including the valleys of current water streams (ancient paleovalleys). The neotectonic movements, which were responsible for the present-day geomorphology of the region, initiated the formation of new cuttings of river valleys, further erosion of primary gold-bearing occurrences, and the formation of residual–talus and alluvial deposits and Au-bearing placers with possible redeposition of gold from earlier placers—in particular, from the Devonian paleoplacers localized in quartz gravelites.

The typomorphic features of alluvial gold indicate that it was delivered to the alluvial deposits from various primary sources located at various distances (including proximal) from the placers. The results of these studies allow us to recognize the Srednii Kyvvozh zone of disseminated and stringer-disseminated sulfide mineralization, which is extended for a significant distance including the northward Kyvvozh area, as promising for primary gold. The drainage divide areas—especially, the main drainage divide of the Vol-Vym Uplift, which are poorly studied because of weak exposure—are also of interest.

CONCLUSIONS

Native gold from alluvial deposits of the Kyvvozh region, including Srednii Kyvvozh and Kyvvozh economic placers, is characterized by broadly varying morphology, roundness, structure, composition of trace elements, and other features. Moderately and well-rounded gold is dominant, and unrounded particles are rare. The size of gold grains widely varies, up to small nuggets. Many gold particles underwent recurrent deformations. The high-fineness rims are typical. In most cases, gold contains only Ag and, locally, also Cu, Pd, and Hg. There are frequent blocky–mosaic gold particles with low-fineness veinlet zones, which are traced along the periphery of blocks. The following minerals are intergrown with native gold and occur in it as inclusions: quartz, pyrite, ankerite, galena, and muscovite and, to a lesser extent, minerals of the cobaltite–gersdorffite series, galenobismuthite, native bismuth, and aurostibite, as well as sudovikovite, which is found for the first time in the region. Three gold types are recognized: main homogeneous Ag-bearing gold of type I and blocky gold with high-Ag veinlet zones of type II and rare gold of type III, which can contain Cu and Pd (not always accompanying each other) in addition to Ag. Mercury is observed in single cases in gold of different types.

The typomorphic features of placer gold indicate its complex exogenic evolution. The zones of sulfide mineralization in Riphean shale sequences are the most possible primary sources of gold. The placer gold with Cu, Pd, and Hg is related to gold–sulfide mineralization zones controlled by deep faults, which are derivatives of basic magmatism.

The Vol–Vym, Tsil'ma, and Chetlas uplifts of Central Timan deserve attention and continuation of prospecting works for primary gold. Poorly studied carbonaceous and C-bearing sericite–quartz silty shales and weathering mantle of the region are also of interest with respect to their gold potential.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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