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GEOCHEMISTRY

Genetic Features of Supergene Modified Gold in Weathering Crusts

A. F. Khazov and D. V. Petrovskii†

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The phenomenon of the formation of in situ (authigenic) native gold in mine dumps, alluvial placers, and oxidation zones of auriferous ore deposits was discovered in the first half of the 20th century [1–3]. However, this fact had a negligible impact on the theory of ore formation or the practice of prediction, prospecting, and assessment of gold deposits. The scale of authigenic gold mineralization in nature remains unclear and debatable thus far. According to [4, 5], the role of rearrangement and secondary concentration of gold is exaggerated unreasonably. However, other researchers [6, 7] believe that the secondary gold is a widespread mineral that dominates in some weathering crusts and placers. The genetic classification of gold in such deposits also remains a controversial issue. According to modern concepts, the oxidation zone of ore deposits contains three types of gold particles: (1) primary particles with all features of native mineralization, (2) residual particles subjected to intense dissolution and purification (leaching of admixtures), and (3) "supergene" (newly formed) particles related to the chemogenic redeposition of the preliminarily dissolved primary gold [5, 8, 9]. Estimation of proportions between genetic types of gold particles depends on the individual experience and attitude of researchers [5, 9].

Analysis of the available materials shows that the main problem in assessment of the role of secondary gold mineralization lies in the determination of specific features of transitional forms of native gold. The classification mentioned above suggests that supergene transformation of primary gold is an irregular process. At first, gold is only dissolved leading to the development of relict gold particles. The gold is precipitated subsequently from aqueous solutions. Our investigations of the auriferous weathering crust in the Polar Urals have provided new insight into processes of the modification of primary gold mineralization in the course of supergenesis.

We studied the auriferous weathering crust in the Katalamba deposit confined to the Mesozoic–Cenozoic erosional-tectonic depression [10]. Walls of the depression enclose Riphean and Early Ordovician rocks that are stable during weathering. The depression floor includes Late Riphean carbonate and volcanosedimentary rocks. Supergene rocks and auriferous ores are developed in intensely fractured and crushed rock zones dipping at 55°–60° NW. The tectonic zone is more than 2 km long and 250 m wide. The mineralized zone is 400–100 m long and 80–150 m wide.

The auriferous weathering crust is developed after volcanic–terrigenous–carbonate rocks subjected to regional metamorphism (greenschist facies of the medium and lower grades). The protoliths often bear signs of considerable hydrothermal-metasomatic alteration (bleaching, sericitization, silicification, and primary gold–sulfide mineralization). The weathering profile includes the following zones (from bottom to top) [11]: (1) slightly altered massive or disintegrated parental rocks that are transformed into eluvium in some places (sapropelites, zone A); (2) gray to variegated structural (primarily, loamy) products of the disintegration of parental rocks (lithomarge, zone B); and (3) deep red and intensely ferruginated (ocherous) structureless loams with lumps and concretions of oxyhydroxides of iron and less common manganese (lateritized lithomarge, zone C).

Zonal distribution of clay minerals (chlorite, montmorillonite, dioctahedral mica, and kaolinite) is an important property of supergene transformations. The weathering profile shows that the chlorite–sericite

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†Deceased.

Institute of Geology, Komi Scientific Center, Ural Division, Russian Academy of Sciences, Pervomaiskaya ul. 54, Syktyvkar, 167000 Russia
e-mail: akhazov@geo.komisc.ru

assemblage is replaced upward in the section by the kaolinite–sericite and hydrogoethite–kaolinite–sericite assemblages. The most sensitive indicator of zonality is represented by kaolinite, the content of which rises steadily from the bottom to the top of the weathering crust. Zonality of the weathering profile is also suggested by the increase in the content of disordered polytypes of muscovite (1M) and kaolinite (IITp) from bottom to top.

The weathering crust usually contains fine gold particles. However, their dimension is appreciably larger relative to particles in native deposits and smaller relative to particles in alluvial placers, including the Bol'shaya Katalamba placer. The intermediate dimension of gold particles in the weathering crust can be explained by the authigenic coarsening of primary particles in supergene conditions, on the one hand, and by the hydraulic differentiation of particles in the water flow, on the other hand [12].

The grain size composition of gold particles in the weathering crust (0.08–1.5 mm) is a function of the hyperbolic distribution law (Fig. 1). The variation is primarily characterized by a jumpwise coarsening of individual gold particles in the course of transition from the lower (grus–rubble) part of the lithomarge to the upper loamy part. Measurements of grain size distribution revealed that the weathering profile is characterized by both coarsening and isometrization trends. These facts are consistent with the appearance of well-developed and uneroded gold monocrystals in the crust [13].

The results of crystallographic analysis (Fig. 2) showed that the majority of equant gold particles have dodecahedral habitus represented by the combination of two simple forms (rhombododecahedron and octahedron). Octahedral faces developed at the site of dodecahedral apices are characterized by lesser dimensions. Some crystals include additional cubic faces. The complete formula of habitus is as follows: $\{210\} \geqslant \{111\} > \{100\}$. This formula differs cardinally from that for gold particles from native gold deposits characterized by octahedral or cubic octahedral faces [5].

The dodecahedral faces of gold monocrystals often show typical striation (Fig. 3a), which is similar to microstep sculptures commonly attributed to the self-oscillating growth regime. Some octahedral faces include striations oriented at right angles to each other. They are likely to indicate the trend of temporal replacement of the octahedral habitus by the cubic one. In gold particles from the weathering crust, the growth sculpture is supplemented with obvious forms of etching (Fig. 3b), dissolution, and regeneration (Fig. 3c). These properties testify to the alternation of periods of growth and dissolution in the ontogeny of gold particles.

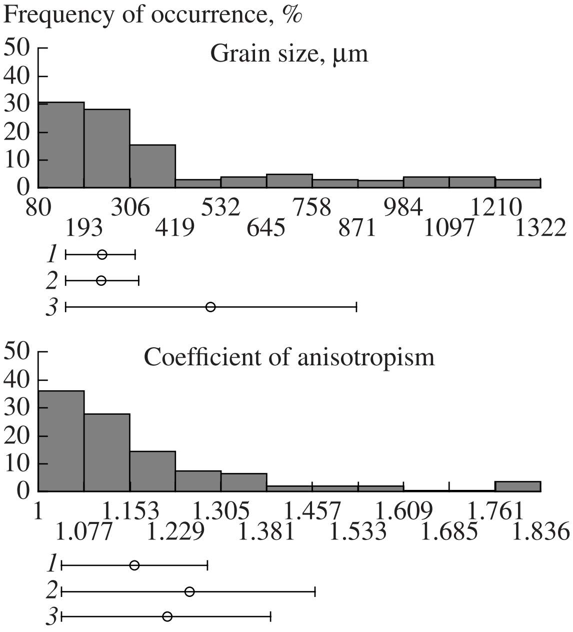

Fig. 1. Distribution of gold particles in terms of grain size and morphology in the profile of the auriferous weathering crust. Horizontal lines beneath bar charts show size variation ranges of gold particles along the weathering profile ($\bar{X} \pm S_{\bar{x}}$). Zones: (1) A, (2) B (lower part), (3) C (upper part). The coefficient of anisotropism was determined as the ratio of plane projection of the gold particle perimeter to the length of the circumference with $r = 1/2$ of the grain diameter.

Native gold particles studied in our work are characterized by the presence of both xenomineral inclusions, which are obviously inherited from primary gold particles, and authigenic supergene particles [13]. The xenomineral inclusions are represented by quartz, feldspars, and chlorites; the authigenic particles, by intermetallides (Sn_3Au–Sn_2Au_2), ferromanganese oxyhydroxides, and neogenic gold developed as a friable microcrust (Fig. 4).

Gold particles from the weathering crust are commonly very pure (fineness 950–1000‰). In terms of this criterion, the fineness of gold particles is 90–100‰ higher than that of particles from native occurrences and 60–65‰ higher than that of particles from alluvial placers in the Polar Urals. Purification of the entire volume of gold particles in the weathering crust is combined with their coarsening and isometrization [14].

Gas pyrochromatography data are particularly important for the genetic diagnosis of gold particles [15]. We analyzed a bulk monomineral sample of native gold, the pyrolysate of which contained the following components (μg/g): H_2 4.07, N_2 6.41, CO 11.24, CO_2 132.14, H_2O 929, CH_4 3.63, CH_4 2.55, C_2H_6 0.48, (C_3H_6 + C_3H_8) 3.42, C_4H_8 0.17, *iso*-C_4H_{10} 0.08, and C_4H_{10} 0.03. In terms of the composition and propor-

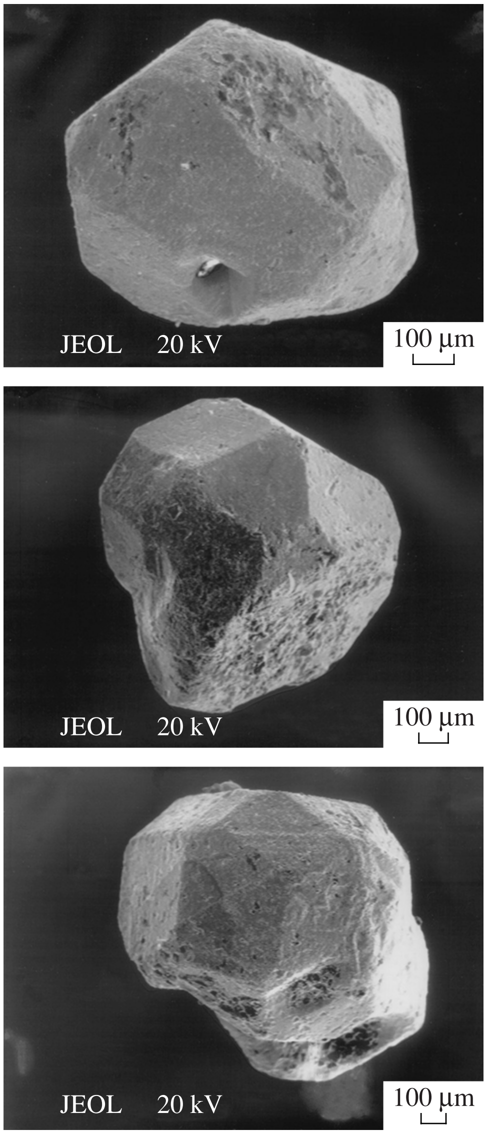

Fig. 2. Typical habitus of idiomorphic gold particles.

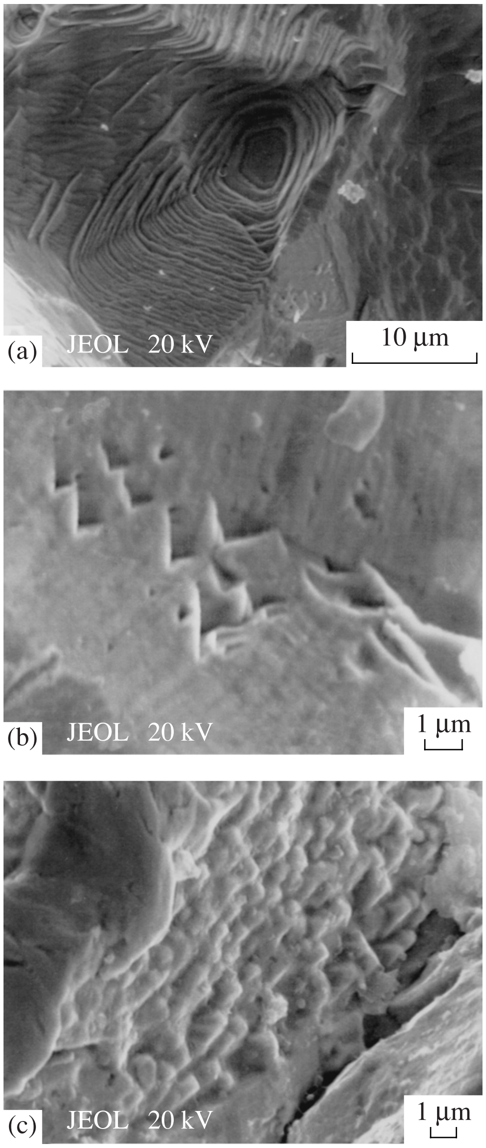

Fig. 3. Sculptures of (a) growth, (b) etching, and (c) dissolution and regeneration on dodecahedral faces of gold microcrystals.

tions of components in the gaseous phase, gold particles from the weathering crust are similar to particles in supergene loams of the lithomarge zone rather than particles associated with the primary gold–sulfide mineralization. Moreover, the gold particles are characterized by maximal concentrations of atmospheric gases (H_2, N_2) and minimal concentrations of H_2O and CO_2.

We believe that the native gold described above can be classified neither with the residual (relict), nor with the authigenic (chemogenic) genetic type. The gold particles studied are marked by several transitional properties that were inherited from the primary mineralization (e.g., primary inclusions), on the one hand, and from the significant modification of gold expressed as changes in the size and morphology of grains, the formation of dissolution sculptures, and the regeneration and growth of particles, on the other hand. It is evident that the nomenclature of genetic types of gold should contain a special taxon for native gold with the specific features described above. We propose to designate this type as supergene-modified gold.

The supergene-modified gold has the following typomorphic features: (1) the presence of primary xenomineral inclusions, (2) the development of dodecahedral crystals that are atypical for the primary endogenous gold, (3) the presence of fine sculptures of growth and dissolution on the grain surface combined with the absence of signs of plastic deformation and mechanical wear, (4) the presence of authigenic new segregations on the grain surface, (5) the strong statis-

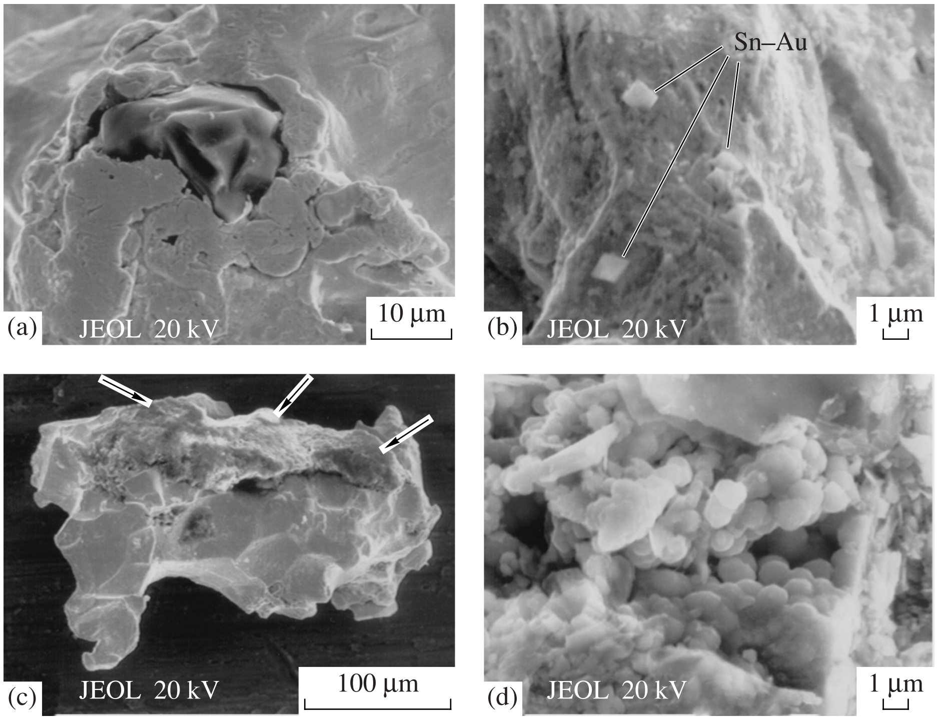

Fig. 4. Primary inclusions of (a) quartz, (b) neogenic intermetallides, (c) authigenic gold, and (d) iron oxyhydroxides in grain particles from the weathering crust.

tical trend of coarsening and isometrization of gold particles, and (6) very high fineness and compositional homogeneity of particles in the entire volume.

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