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# Editorial for Special Issue "Mineralogy of Noble Metals and 'Invisible' Speciations of These Elements in Natural Systems, Volume II"

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The articles published in the 2019 Special Issue "Mineralogy of Noble Metals and 'Invisible' Speciations of These Elements in Natural Systems" [1] do not cover all the stated problems of the specified topic, and hence, a second volume is being released. At present, a significant part of the reserves of gold and other noble metals consists of deposits of sulphide ores. Many sulphide ores are referred to as refractory ores by technologists. Knowledge of the mineralogy of these ores, including micro and nano minerals of noble metals, is a key factor in developing rational processing and enrichment schemes. The aim of this Special Issue is to facilitate new knowledge for solving fundamental and applied tasks.

The second volume Special Issue consists of one review on noble metal speciation in sulphide ores and eleven research articles on various other topics.

Vikentyev et al. [2] reviewed the distribution and speciation of noble metals in contrasting types of mineralisation from the Urals, one of the largest ore belts in the world. They describe the distribution and structural-chemical state of Au and Ag in sulphides from the late-magmatic to low-temperature hydrothermal, regarded as the indicators of the conditions of mineralisation and metamorphism of ores, with emphasis on the economically significant genetic types of ore deposits. This article is based on a large amount of new and existing information: mineralogical, electron microprobe, mass-spectrometric, and neutron activation. The ratio of forms of free and invisible gold in sulphides is discussed. Admixtures of metals and metalloids provide the increased crystal structure defects for the entry of noble metal impurities into sulphides by the mechanism of heterovalent isomorphism. The invisible gold is enlarged and passes into the visible state as native gold, Au-Ag tellurides, Au-Ag sulphides, and other minerals.

A number of articles [3–11] are devoted to the study of gold mineralization at different deposits and the characterization of the physicochemical conditions of its formation.

Jin and Sui [3] presented major and trace element analyses by electron microprobe and laser ablation inductively coupled plasma mass spectrometry on two types of tourmalines from the newly recognized intrusion-related Laodou gold deposit in the West Qinling Orogen of central China. Both tourmaline types fall into the alkali group and are classified under the schorl-dravite solid solution series. Chemical compositions and changes in tourmaline textures may provide evidence for changes in the processes related to the evolution of the hydrothermal system. In the Laodou gold deposit, type 1 tourmaline is a product of the late crystallization of the quartz diorite porphyry, whereas type 2 tourmaline coexists with Au-bearing arsenopyrite and is crystallized from the ore-forming fluids. The composition of tourmaline is largely controlled by fluid/rock ratios and chemical equilibria with coexisting phases in the hydrothermal system [3].

Kalinin and Kudryashov [4] investigated the Pellapahk Cu-Mo and Oleninskoe Au-Ag deposits in the western segment of the Russian Arctic in the Kolmozero–Voronya greenstone belt (Kola Peninsula). They regard these deposits as two parts of an Archean (2.83–2.82 Ga) porphyry-epithermal system, probably the oldest such deposit in the Fennoscandian Shield. The formation of the Oleninskoe Au-Ag deposit at the epithermal stage of the system is indicated by the spatial and genetic relationships with the sills of granite porphyry. The geological and structural characteristics of the Oleninskoe and the Pellapahk deposits, i.e., their location in a shear zone, the morphology and size of ore bodies, the scale of the deposits, and the intensity and zoning of rock alteration, are consistent with this model.

Kudrin et al. [5] studied disseminated gold–sulphide mineralization in metasomatites of the Khangalas deposit, Yana–Kolyma Metallogenic Belt (Northeast Russia). The textural and mineralogical-geochemical features, isotope-geochemical characteristics of gold-bearing sulphides from proximal metasomatites, and possible forms of Au in pyrite and arsenopyrite were investigated using electron microprobe, atomic absorption, LA-ICPMS trace element, isotope analysis, and computed microtomography. The gold content of sulphides and proximal metasomatites indicates that the Khangalas deposit has higher commercial potential than was previously indicated. Khangalas provides an exploration model useful in targeting similar gold deposits from the local to the regional scale.

Kondratieva et al. [6] studied tellurium mineralization from gold deposits of the Aldan shield (Southern Yakutia, Russia). Twenty-nine tellurium minerals, including 16 tellurides, 5 sulfotellurides, and 8 tellurates, have been identified from new results of this study and previously published results. The analysis of the composition of Te minerals in these gold deposits allowed identification of three mineral types: Au-Ag-Te, Au-Bi-Te, and mixed Au-Ag-Bi-Te. Tellurium minerals are developed in all known types of metasomatic formations represented by sericite-microcline metasomatites, beresites, gumbaites, jasperoids, and argillizites. The Au-Ag-Bi-Te minerals are the important sources of gold reserves in this district.

Sidorov et al. [7] studied fluid inclusions from different types of quartz vein associations at the Maletoyvayam Deposit (Koryak Highland, Russia). This epithermal gold deposit contains unique ore mineralization with native gold, tellurides, selenides, and sulphoselenotellurides of Au, including maletoyvayamite, unnamed phases (AuSe, Au(Te,Se)), and oxidation products of Au-tellurides. The maletoyvayamite has not been reported anywhere else.

Fluid inclusions in quartz have salinities from 0.2 to 4.3 wt.% NaCl eq. (NaCl + KCl). The indicated temperature variations for quartz crystallization were 295–135 °C with pressures from 79 to 4 bar. These physicochemical characteristics of the Maletoyvayam ore deposit coincide with other high-sulphidation (HS)-type epithermal deposits. It can be speculated that Au–Cu–porphyry mineralization may be found at deeper horizons in the Maletoyvayam area.

Kolova et al. [8] investigated the features of Au-Ag-S-Se-Cl-Br mineralization at the epithermal Au-Ag Corrida deposit (Chukchi Peninsula, Russia) and estimated the physicochemical conditions of its formation on the basis of the study of fluid inclusions and thermodynamic modelling. This deposit is a new example of an epithermal deposit with significant quantities of Au–Ag chalcogenides (Se-acanthite, uytenbogaardtite, fischesserite, S-naumannite, and others) and Ag halides of the chlorargyrite-embolite-bromargyrite series. Fluid inclusions indicate that the ore-bearing quartz was formed at temperatures of 340 to 160°C from low salinity (3.55 to 0.18 wt. % NaCl eq.) fluids. Thermodynamic modelling suggests that mineralization formed under the following conditions: sulphur (log $fS_2$ from −6 to −27), selenium (log $fSe_2$ from −14 to −35), and oxygen (log $fO_2$ from −36 to −62).

Palyanova et al. [9] reported results of studies of the composition of native gold and minerals in intergrowth with it in two ore zones of the Chudnoe Au-Pd-REE deposit (Subpolar Urals, Russia). This deposit and some other Ural deposits (Baronskoe, Volkovskoe, Nesterovskoe, Ozernoe) are unique in the set of impurity elements in native gold (Ag, Cu, Pd, Hg) and variability of their concentrations. Despite the numerous results, the reasons for compositional changes in native gold and the presence of a wide set of impurity elements are not clear yet. The formation of native gold is probably related to fuchsitization and allanitization of rhyolites as well as to Na-, Si-, and K-metasomatism. The absence of carbonates and sulphides and the presence of palladium minerals, Cu and Pd in native gold, and Cr in fuchsite indicate a relationship between ore formation and mafic-ultramafic magmatism.

Silyanov et al. [10] studied the oxidized ores from the Olympiada deposit (Eastern Siberia, Russia). They obtained new data on the morphology and chemical composition of native gold and proposed a model of supergene redistribution of noble metals and other elements in the oxidation zone. They found that the supergene gold crystals (~1 μm), their aggregates, and their globules (100 nm to 1 μm) predominate in the upper oxidized zones, and spongiform gold occurs in the lower zone at the boundary with the bedrock.

Stepanov et al. [11] described the morphological features and composition of native gold and its relation to minerals in ore-bearing breccias with realgar-orpiment cement from the Vorontsovskoe gold deposit (Northern Urals, Russia). Despite a comprehensive study of this deposit, its genesis remains controversial. The general geological and geochemical patterns of the Turyinsk-Auerbakh metallogenic province [12] and the presence of small non-economic porphyry copper deposits suggest that the Vorontsovskoe deposit is an integral part of a large ore-magmatic system genetically associated with the formation of the Auerbakh intrusion.

Nikiforova [13] studied the typomorphism of placer gold and the mechanisms of its distribution in the east of the Siberian Platform. She developed a method for diagnosing the genotype of placer gold from its morphological characteristics (alluvial, aeolian, pseudo-ore). The diagnostic method and morphogenetic criteria for identifying the genesis of placers and different sources in the platform areas developed by Nikiforova [13] can be successfully used by production geological organizations for the exploration of placer gold deposits.

Simakin et al. [14] performed an experimental study of Pt solubility in a $CO$-$CO_2$ rich fluid at PT conditions close to the subsolidus conditions of upper crust ultramafic–mafic intrusions. They demonstrated that the solubility of Pt in a $CO$-$CO_2$ fluid at 50–200 MPa and 950 °C is 15–150 ppm, presumably in the form of $Pt_3(CO)_6^{2-}$. Their results demonstrate that the formation of carbonyl itself can be an important mechanism for the transport of Pt by fluid at the post-magmatic stage of layered ultramafic–mafic intrusions.

These studies contribute to our understanding of the behaviour of noble metals and the forms of occurrence in natural ore-forming systems.

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