

Editorial

# Editorial for the Special Issue “Native Gold as a Specific Indicator Mineral for Gold Deposits”

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Native gold is the most common and significant industrial gold mineral. Pure native gold without impurities is rare. The main impurity in native gold is silver, which forms a continuous solid solution characterized by fineness from 0 to 1000‰. At some deposits, the fineness of native gold is high and varies over a narrow range, whereas at others, it is low and covers a wide range of values. Cu, Hg, and Pd concentrations vary from trace to high in native gold. These metals form solid solutions with gold (Au,Hg; Au,Pd) or intermetallic compounds (AuCu, Cu<sub>3</sub>Au). Other elements, including Pt, Rh, Ir, Fe, As, Sb, S, Se, Te, Bi, Ti, Cr, Ni, Co, Mn, W, Sn, U, Th, and He, and rare earth, alkaline, and alkaline earth elements are less common and, when detectable, occur in minor amounts (between 1 and 0.01%) in native gold. The chemical composition of native gold is one of the most important typomorphic features, allowing experts to predict possible original sources of metal for placers. The quantity of impurities in native gold varies drastically between different types of deposits and primarily depends on the physicochemical conditions of formation and the metallogenic features of gold-bearing provinces. The concentration levels and ratios of various elements in gold grains can provide a geochemical history of ore-forming events. In recent years, special attention has been paid to studying mineral inclusions in native gold and matrix minerals since they are critical informative features. Minerals intergrown with native gold can be the best parameter to identify different styles of mineralization.

This Special Issue is a continuation of three previous Special Issues [1–3]. It includes 16 articles focused on the typomorphic features of native gold from gold deposits in Russia, India, Chile, Scotland, and Canada. This Special Issue aims to identify and generalize the reasons for variations in the compositions of native gold.

The paper by Savva et al. [4] contains the results of a detailed comparative description of the typomorphic features of native gold from 14 gold deposits in the northeast of Russia. These gold deposits are grouped as follows: gold–arsenic–sulfide disseminations in black shale strata (Natalka, Degdekan, Karalveem, Maldyak), gold–quartz veins in granitoids (Dorozhnoye, Butarnoye, Shkolnoye, Maltan), and epithermal gold–silver adularia in volcanogenic strata (Kupol, Olcha, Kubaka, Burgali, Primorskoe, Dalnee). The typomorphic features of native gold, such as the content of impurities, variations in fineness, internal structure, and mineral associations, are reliable indicators for identifying the three different settings of gold deposits.

In the article by Anand and coauthors [5], the petrography, mineral chemistry, fluid inclusion, and sulfur isotopic compositions of gold mineralization associated with magnetite and apatite were used to understand the possible source of ore-bearing fluids. The authors conclude that this deposit can be classified as an iron–copper–gold oxide (IOCG) and iron oxide–apatite (IOA) type of deposit.

The paper by Fridovsky et al. [6] studied five orogenic gold deposits (Malo-Taryn, Badran, Khangalas, V’yun, and Shumnyi) in the central sector of the Yana-Kolyma metallogenic belt in northeast Russia. The native gold in quartz veins has a fineness of 800–900‰, and “invisible” gold is disseminated in arsenian pyrite-3 and arsenopyrite-1 in the ore zones of these deposits. They report new data on the microtextures, chemical composition, and



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stable sulfur isotopes of auriferous pyrite-3 and arsenopyrite-1 from proximal alterations in sediment-hosted (Malo-Taryn, Badran, Khangalas) and intrusion-hosted (V'yun, Shumniy) orogenic Au deposits. The analytical results indicate that subcrustal and metamorphic systems in the Late-Jurassic-to-Early Cretaceous Verkhoyansk-Kolyma orogeny were, probably, the primary source of S and Au and mineralizing fluids.

Mayorova et al. [7] investigated the typomorphic features of native gold from gold-sulfide-quartz and gold-arsenic-sulfide ore occurrences in the Manitanyrd region of the Polar Urals, Russia. These occurrences are localized in volcanogenic and volcanogenic-sedimentary Precambrian rocks. The isotope composition of sulfur in sulfides indicates a single deep magmatic source of sulfur in ore formation. The similarity of the geological-structural, mineralogical-geochemical, and isotope-geochemical features of the gold-sulfide-quartz and gold-arsenic-sulfide occurrences suggests their formation in a single hydrothermal system.

Kondratieva and coauthors [8] studied the typomorphism of native gold in the Aldan-Stanovoya gold-bearing province, Aldan Shield, Russia. Denudation processes and gold placer formations affected the morphological and geochemical properties of primary ores' native gold and eluvial deposits' supergene gold in this area.

Murzin and coauthors [9] investigated the mineralogy and sulfur isotope geochemistry in sulfides from one Au-PGE deposit, Ozernoe, at the Dzelyatyshor wehrlite-pyroxenite massif, Polar Urals, Russia. They concluded that the variations of sulfur isotopic composition in pyrite, chalcopyrite, and bornite indicated that a deep-seated magmatic basic melt was the source of the ore-forming fluid, ore components, and sulfur during Au-Pd ore formation.

Palyanova et al. [10] studied the composition and structure of uncommon Pd,Hg-rich placer gold from watercourses draining the Itchayvayam mafic-ultramafic complex, Kamchatka, Russia. Their paper contains a review and a considerable amount of data on the composition of minerals in the Au-Pd-Hg system and the formation conditions of the Pd,Hg-bearing gold and Au-bearing potarite in other regions across the world. These authors discussed the genesis of Pd,Hg-rich gold and concluded that meteoric waters or low-temperature hydrotherms rich in Pd and Hg could lead to replacing Pd,Hg-poor gold with Pd,Hg-rich gold.

The review by Palyanova et al. [11] summarized the available information on the palladian gold of several compositions and types of isomorphic impurities (Ag, Cu, Hg). The authors concluded that palladian gold more frequently corresponds to the Au-Pd-Ag, Au-Pd-Ag-Cu and Au-Pd-Ag-Cu-Hg systems and less often to Au-Pd, Au-Pd-Hg, Au-Pd-Cu, Au-Pd-Ag-Hg. They also concluded that palladian gold belongs with deposits where the main components of ores are PGE, Cr, Cu, Ni, V, and Ti. They propose classifying the types of deposits based on the fineness, content, and set of impurities in palladian gold and minerals intergrown with it.

Several articles focus on the typomorphic features and sources of native gold placer deposits [12–19]. Becerra et al. [12] studied the morphology, composition, and mineral inclusions in native gold from terraced placers in the Pureo Area (Southern Chile). The authors suggest two possible primary sources of the placer gold: Paleozoic-Triassic metamorphic rocks or hydrothermal deposits associated with Cenozoic intrusive activity. Their results have implications for exploring new placer deposits and gold-bearing hypogene deposits of the southern Chile Coastal Cordillera.

Nikiforova [13] studied the internal structures, chemical composition, and microinclusions of placer gold from the southeast Siberian platform in great detail. The author documented two stages of ore formation: the first in the Precambrian and the second in the Mesozoic. The internal structures typical of endogenous and exogenous conditions can be used for forecasting ore sources and types of gold deposits of the Siberian platform.

Lalomov and coauthors [14] studied the transformation of placer gold from the Sykhoi Log placer deposits in the Bodaibo gold-bearing district, Siberia, Russia. Weathering crusts developed along the zones of disjunctive dislocations near the Sukhoi Log gold deposit.

The morphology, chemical signatures, structure, and inclusions of placer gold from four different locations led to the conclusion that weathering rims develop mainly from chemical reactions with infiltrating fluid.

The article by Zmodik and coauthors [15] studied the morphology, composition, intergrowths, and microinclusions of native gold from the alluvial deposits of the Kamenny stream Ozerninsky area, Western Transbaikalia, Russia. The Kamenny placer is of particular interest due to finding gold-brannerite nuggets, unique both in size and in weight (from 1–2 g to 200 g), of various microtextures, and with mineralogical and geochemical features. The nuggets also contain hematite ( $\pm$ magnetite), W-bearing rutile, barite, less often muscovite, quartz, siderite, goethite, nano- and micro-inclusions of uraninite, native Pb or Pb oxide, petzite, tellurobismuthite, altaite, and single grains of chalcopyrite. Four types of placer gold were documented, and possible primary sources were postulated.

Okrugin and Gerasimov [16] studied palladian gold and platinum minerals in placers of diamonds and precious metals, widespread in the Anabar River basin on the northeastern part of the Siberian Platform, Russia. The composition of palladian gold, ferroan platinum, and other associated minerals and their microstructural relationships indicate a paragenetic connection between native gold and platinum group minerals. The authors conclude that the primary sources of the placers of the Anabar River basin are alkaline-ultrabasic massifs and carbonatites.

The paper by Gerasimov [17] focuses on the typomorphism of native gold from two modern placer occurrences, “Billyah” and “Nebaibyt”, in the Anabar Region northeast of the Siberian platform, Russia. The results of this study indicate that the native gold in these modern placers comes from two different sources: paleo-placers and nearby “primary” ores.

The paper by Chapman et al. [18] is devoted to the alluvial gold from six localities south of Loch Tay in central Scotland. The compositional features and inclusions in native gold were interpreted to represent two broad geographical groupings. This paper demonstrates that research on gold composition and microinclusions can contribute to exploration campaigns.

Chapman et al. [19] reported the results of studying detrital gold from 160 localities of nine different deposit types in British Columbia. They documented that different deposits have specific compositional characteristics of native gold and specific suites of mineral inclusions. Their data demonstrate that mineral inclusion assemblages in gold particles provide far more information than the fineness of native gold. The authors developed compositional templates for identifying diagnostic signatures of native gold from different types of deposits, including orogenic, low-sulfidation epithermal, and alkalic porphyry settings.

A new Special Issue of *Minerals*, “Native Gold as a Specific Indicator Mineral for Gold Deposits, volume 2” [20], is planned. Three previous Special Issues [1–3] were printed as books [21–23]. This new Special Issue aims to further develop effective criteria for forecasting and searching for gold deposits beyond the scope of this Special Issue.

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## References

1. Special Issue “Experimental and Thermodynamical Modeling of Ore-Forming Processes in Magmatic and Hydrothermal Systems”. Available online: [https://www.mdpi.com/journal/minerals/special\\_issues/Experimental\\_Thermodynamical\\_Modeling](https://www.mdpi.com/journal/minerals/special_issues/Experimental_Thermodynamical_Modeling) (accessed on 13 December 2018).
2. Special Issue “Mineralogy of Noble Metals and “Invisible” Speciations of These Elements in Natural Systems”. Available online: [https://www.mdpi.com/journal/minerals/special\\_issues/noble\\_metals](https://www.mdpi.com/journal/minerals/special_issues/noble_metals) (accessed on 26 February 2020).
3. Special Issue “Mineralogy of Noble Metals and “Invisible” Speciations of These Elements in Natural Systems, Volume II”. Available online: [https://www.mdpi.com/journal/minerals/special\\_issues/noble\\_metals\\_volume\\_ii](https://www.mdpi.com/journal/minerals/special_issues/noble_metals_volume_ii) (accessed on 28 July 2021).
4. Savva, N.E.; Kravtsova, R.G.; Anisimova, G.S.; Palyanova, G.A. Typomorphism of Native Gold (Geological-Industrial Types of Gold Deposits in the North-East of Russia). *Minerals* **2022**, *12*, 561. [CrossRef]

5. Anand, A.; Singh, S.; Gantait, A.; Srivastava, A.; Mayachar, G.K.; Kumar, M. Geological Constraints on the Genesis of Jagpura Au-Cu Deposit NW India: Implications from Magnetite-Apatite Mineral Chemistry, Fluid Inclusion and Sulfur Isotope Study. *Minerals* **2022**, *12*, 1345. [[CrossRef](#)]
6. Fridovsky, V.Y.; Polufuntikova, L.I.; Kudrin, M.V. Origin of Disseminated Gold-Sulfide Mineralization from Proximal Alteration in Orogenic Gold Deposits in the Central Sector of the Yana–Kolyma Metallogenic Belt, NE Russia. *Minerals* **2023**, *13*, 394. [[CrossRef](#)]
7. Mayorova, T.P.; Kuznetsov, S.K.; Efanova, L.I.; Sokerina, N.V. Gold–Sulfide Mineralization in the Manityrd Region, Polar Urals, Russia. *Minerals* **2023**, *13*, 747. [[CrossRef](#)]
8. Kondratieva, L.A.; Anisimova, G.S.; Kardashevskaya, V.N. Ore Mineralogy and Typomorphism of Native Gold of the Spokoininsky Cluster of the Aldan–Stanovoy Gold Province. *Minerals* **2023**, *13*, 543. [[CrossRef](#)]
9. Murzin, V.; Palyanova, G.; Mayorova, T.; Beliaeva, T. The Gold–Palladium Ozernoe Occurrence (Polar Urals, Russia): Mineralogy, Conditions of Formation, Sources of Ore Matter and Fluid. *Minerals* **2022**, *12*, 765. [[CrossRef](#)]
10. Palyanova, G.; Kutuyev, A.; Beliaeva, T.; Shilovskikh, V.; Zhegunov, P.; Zhitova, E.; Seryotkin, Y. Pd,Hg-Rich Gold and Compounds of the Au-Pd-Hg System at the Itchayvayam Mafic-Ultramafic Complex (Kamchatka, Russia) and Other Localities. *Minerals* **2023**, *13*, 549. [[CrossRef](#)]
11. Palyanova, G.A.; Zhegunov, P.S.; Beliaeva, T.V.; Murzin, V.V.; Borovikov, A.A.; Goryachev, N.A. Palladian Gold: Chemical Composition, Minerals in Association, and Physicochemical Conditions of Formation at Different Types of Gold Deposits. *Minerals* **2023**, *13*, 1019. [[CrossRef](#)]
12. Becerra, P.; Sanchez-Alfaro, P.; Piquer, J.; Plissart, G.; Garroz, B.; Kunstmann, D. Gold Provenance in Placers from Pureo Area, Southern Chile Coastal Cordillera, and Their Relationship with Paleozoic Metamorphic Rocks. *Minerals* **2022**, *12*, 1147. [[CrossRef](#)]
13. Nikiforova, Z. Internal Structures of Placer Gold as an Indicator of Endogenous and Exogenous Processes. *Minerals* **2023**, *13*, 68. [[CrossRef](#)]
14. Lalomov, A.; Grigorieva, A.; Kotov, A.; Ivanova, L. Typomorphic Features and Source of Native Gold from the Sykhoi Log Area Placer Deposits, Bodaibo Gold-Bearing District, Siberia, Russia. *Minerals* **2023**, *13*, 707. [[CrossRef](#)]
15. Zhmodik, S.M.; Airiyants, E.V.; Belyanin, D.K.; Damdinov, B.B.; Karmanov, N.S.; Kiseleva, O.N.; Kozlov, A.V.; Mironov, A.A.; Moroz, T.N.; Ponomarchuk, V.A. Native Gold and Unique Gold–Brannerite Nuggets from the Placer of the Kamenny Stream, Ozerninsky Ore Cluster (Western Transbaikalia, Russia) and Possible Sources. *Minerals* **2023**, *13*, 1149. [[CrossRef](#)]
16. Okrugin, A.; Gerasimov, B. Paragenetic Association of Platinum and Gold Minerals in Placers of the Anabar River in the Northeast of the Siberian Platform. *Minerals* **2023**, *13*, 96. [[CrossRef](#)]
17. Gerasimov, B. The Use of Typomorphic Features of Placer Gold of the Anabar Region for Determining Its Sources. *Minerals* **2023**, *13*, 480. [[CrossRef](#)]
18. Chapman, R.; Torvela, T.; Savastano, L. Insights into Regional Metallogeny from Detailed Compositional Studies of Alluvial Gold: An Example from the Loch Tay Area, Central Scotland. *Minerals* **2023**, *13*, 140. [[CrossRef](#)]
19. Chapman, R.; Mortensen, J.K.; Murphy, R. Compositional Signatures of Gold from Different Deposit Types in British Columbia, Canada. *Minerals* **2023**, *13*, 1072. [[CrossRef](#)]
20. Special Issue “Native Gold as a Specific Indicator Mineral for Gold Deposits, 2nd Edition”. Available online: [https://www.mdpi.com/journal/minerals/special\\_issues/A1D082156T](https://www.mdpi.com/journal/minerals/special_issues/A1D082156T) (accessed on 24 August 2023).
21. Palyanova, G. *Experimental and Thermodynamical Modeling of Ore-Forming Processes in Magmatic and Hydrothermal Systems*; MDPI: Basel, Switzerland, 2019; Available online: <https://www.mdpi.com/books/book/1081> (accessed on 30 August 2023).
22. Palyanova, G. *Mineralogy of Noble Metals and “Invisible” Speciations of These Elements in Natural Systems*; MDPI: Basel, Switzerland, 2020; Available online: <https://www.mdpi.com/books/book/2273> (accessed on 30 August 2023).
23. Palyanova, G. *Mineralogy of Noble Metals and “Invisible” Speciations of These Elements in Natural Systems, Volume II*; MDPI: Basel, Switzerland, 2021. Available online: <https://www.mdpi.com/books/book/4627> (accessed on 30 August 2023).

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