Fe-DOMINATED BOGDANOVITE, $Au_5CuFe_2(Te,Pb)_2$, FROM CEMENTATION ZONE OF THE AGINSKY GOLD-TELLURIDE DEPOSIT, KAMCHATKA PENINSULA, RUSSIA

Ernst M. Spiridonov

Lomonosov Moscow State University, Moscow, mineral@geol.msu.ru

Fe-dominated bogdanovite, $Au_5CuFe_2(Te,Pb)_2$, a specific supergene mineral, occurs in the weathering profile (in cementation zone) of the Aginsky gold-telluride deposit, Kamchatka Peninsula, Russia. Bogdanovite has been formed as a result of replacement of hypogene kostovite, krennerite, sylvanite, altaite, nagyagite, bornite, and chalcopyrite. The mineral is associated with Fe-Pb and Fe-Cu-Pb tellurites. In the oxidized zone, bogdanovite is replaced by fine-grained segregations of gold, balyakinite, and plumbotellurite. The composition of Fe-dominated bogdanovite (average of four point analyses) is as follows, wt %: 60.35 Au, 2.19 Ag, 4.63 Cu, 9.33 Fe, 9.99 Te, 12.83 Pb, 0.07 Se; total is 99.39. Formula is as follows: $Au_{4.33}Ag_{0.29}Cu_{1.03}Fe_{2.36}Te_{1.11}Pb_{0.87}Se_{0.01}$. Bogdanovite has a metallic type of conductivity and relatively high microhardness $VHN_{20} = 290 - 354$ kg/mm^2, average 321 kg/mm^2 (n = 14). The mineral is anisotropic, biaxial. It is extremely specific in reflected light. Color bireflectance varying from grey and light violet to bright golden and red, and strong color anisotropy are characteristic features. Reflectance ranges from 2 to 43% in visible light. Change of reflectance sign at 670 nm is typical. According to optical parameters, the symmetry of bogdanovite is not higher than orthorhombic. According to X-ray diffraction data, bogdanovite is interstitial superstructure of the Me_4X type derived from face-centered lattice of gold. Parameter of the primitive pseudocubic subcell is 4.087 Å. Color images of Fe-dominated bogdanovite are first shown that will assist for corrected application of term bogdanovite.

2 figures, 13 references.

Keywords: bogdanovite, gold-telluride deposit, Kamchatka.

Currently, 41 mineral species of gold are known; seventeen of them were identified in weathering profile. The newly formed gold minerals are: gold of high fineness; Cu-bearing gold group minerals; sooty tellurides; gold tellurides, selenides, and sulfides including petzite, $AuAg_3Te_2$, sylvanite, $AuAgTe_4$, mutmannite, $AuAgTe_2$, petrovskaite AuAg(S,Se); and plumbo- and stibioplumbotellurides, bilibinskite, $Au_5Cu_3(Te,Pb)_5$, Sb-rich bilibinskite, $Au_6Cu_2(Te,Pb,Sb,Bi)_5$, Cu-rich bogdanovite $Au_5Cu_3(Te,Pb)_2$, Fe-rich bogdanovite $Au_5CuFe_2(Te,Pb)_2$, bezsmertnovite $Au_4Cu(Te,Pb)$; and oxides $AuSbO_3$ and $AuTeO_3$ (Sindeeva, 1959; Petrovskaya, 1973; Nesterenko *et al.*, 1984; Spiridonov and Chvileva, 1979, 1982, 1985; Chvileva *et al.*, 1988; Nekrasov, 1991).

Aginsky deposit

The Aginsky epithermal volcanic-related vein type low-sulfidation gold-telluride deposit (Shchepot'ev *et al.*, 1989; Naumova, 1996) located in the Central-Kamchatka structure is controlled by the Tertiary arc volcanic rocks. By geomorphology, the deposit is a sufficiently high mountain. Ore veins are composed of multiple crustified crusts of chalcedony-like quartz, which cement fragments of altered volcanic and terrigenous rocks. Altered wall-rocks are hydromica and dickite argillic and silicified rocks (Naumova, 1996). Sulfides (pyrite, chalcopyrite, bornite-chalcopyrite intergrowths, and fahlores including goldfieldite), tellurides (altaite, tellurobismuthite, rucklidgeite, sylvanite, krennerite, kostovite, petzite, hessite, and nagyagite), and native gold are ore minerals. Their fine segregations are irregular distributed in chalcedony-like quartz forming gold-rich clusters up to a few decimeters across (Sakharova *et al.*, 1984).

Outcropped ore is significantly oxidized and leached. Vein quartz contains clusters of limomite and malachite, tellurite, plumbotellurite, mackayite, balyakinite (Spiridonov, 1980), other supergene tellurites, fine-scalloped supergene gold, and chlorargyrite. Between primary ore and oxidized zone, there is cementation zone, where most hypogene tellurides, bornite and part of chalcopyrite are replaced by aggregates of Fe-Pb and Fe-Cu-Pb tellurites and various gold plumbotellurides.

Fe-dominated bogdanovite from the Aginsky deposit

Bogdanovite occurs along cleavage of krennerite and sylvanite, relicts of which were observed in its segregations. Relicts of kostovite, altaite, and nagyagite in bogdanovite are extremely rare. These poor stable minerals are completely replaced. Bogdanovite partially replaced hypogene bornite and chalcopyrite. Cu-dominated bogdanovite is associated with bilibinskite and Fe-Cu-Pb tellurites, bezsmertnovite, and Cu-bearing gold. Fe-dominated bogdanovite is associated with Fe-Pb tellurides (Fig. 1); between these minerals there are compromise growth surfaces.

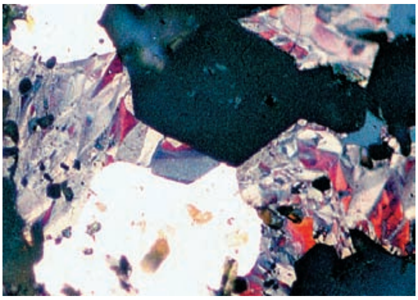
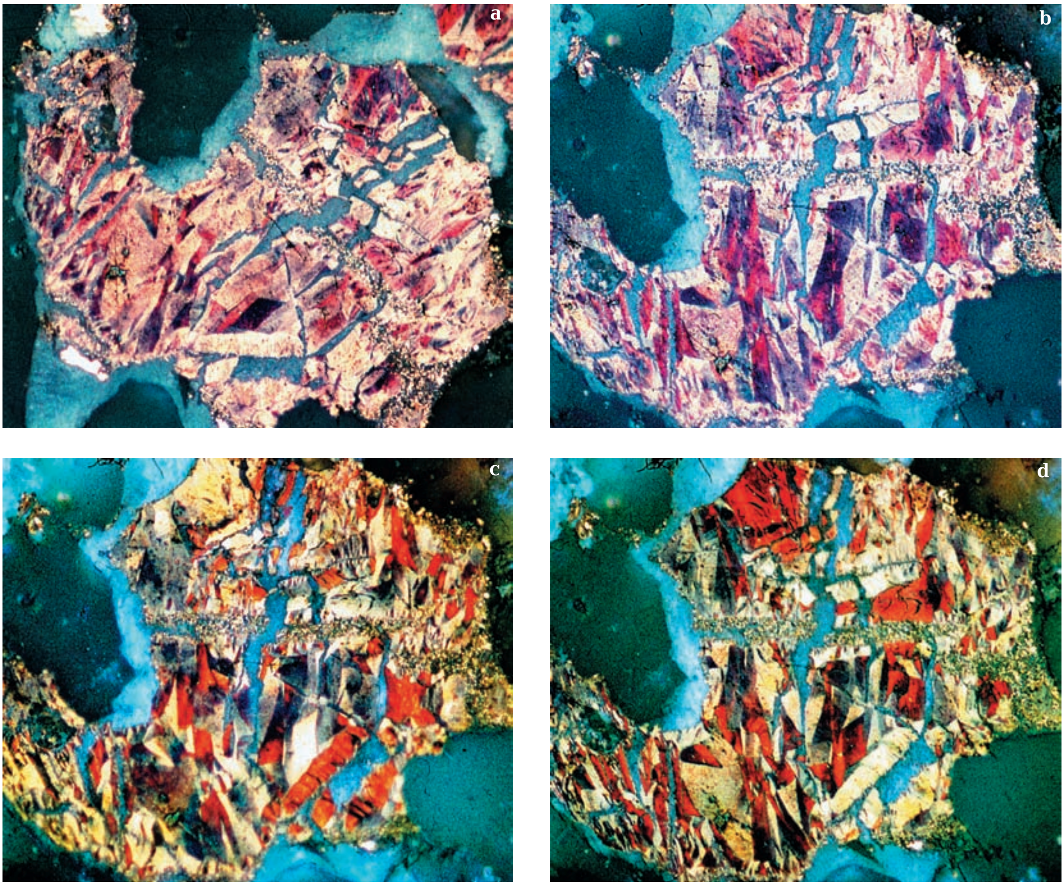


Fig. 1. Photomicrograph of Fe-dominated bogdanovite with bright color bireflectance, a pseudomorph after hypogene kostovite, krennerite, and altaite, filling interstices between crystals of quartz and hypogene gold (white-yellow) and intergrown with Fe-Pb tellurite (bluish gray). Reflected light, parallel polaroids. Image width 0.25 mm.

Fig. 2. Photomicrograph of segregations of Fe-dominated bogdanovite. a, b — bright color bireflectance, parallel polaroids; c, d — very strong color effects of anisotropy, crossed polaroids. Bogdanovite partially replaced balyakinite (sky blue) and tiny grains of gold of high fineness. Image width 0.35 mm.



Fe-dominated bogdanovite occurs as intergrowths of randomly oriented crystals, which are frequently split (Figs. 1, 2). Segregations are up to 1 mm in size; monoblocks are not more than 20 µm in size. Megascopally, it looks like bornite. It is well polished. Bogdanovite has a metallic type of conductivity and relatively high microhardness $VHN_{20} = 290-354$ kg/mm^2; mean value is 321 kg/mm^2 (n = 14); it is harder than gold.

In reflected light in light position, it is like bornite. In dark position, the mineral is uncommonly distinctive; the strong and contrast color effects of bireflectance and anisotropy are characteristic (Figs. 1, 2). The reflectance ranges from weak (2%) to medium (43%). In variable cross-sections, the mineral color ranges from grayish violet and magenta crimson to bright golden yellow and red. The measured values of reflectance in air are as follows, *Rg, Rp, Rm*, %: 15.6, 11.5, 13.9 (400 nm), 14.8, 9.5, 13.0 (420 nm), 14.2, 8.0, 12.8 (440 nm), 13.8, 6.7, 12.1 (460 nm), 13.8, 5.4, 11.6 (480 nm), — 15.6, 4.4, 11.7 (500 nm), 21.5, 3.4, 13.5 (520 nm), 28.3, 2.5, 16.3 (540 nm), 33.5, 2.2, 19.1 (560 nm), 36.4, 3.0, 21.0 (580 nm), 37.9, 5.9, 22.2 (600 nm), 38.3, 11.9, 22.6 (620 nm), 37.4, 21.0, 22.6

(640 nm), 35.8, 29.9, 22.5 (660 nm), 33.9, 36.9, 22.3 (680 nm), 31.7, 42.8, 22.0 (700 nm); analyst T.N. Chvileva, Institute of Mineralogy, Geochemistry, and Crystal Chemistry of Rere Elements, Moscow, Russia. The reflectances of Fe-dominated and Cu-dominated bogdanovite are similar. The section of curve *Rg* is similar to *R* section of gold. The mineral is biaxial. The reflectance sign changes at 670 nm. According to the most important color parameters, purity (color saturation, *p*) and hue (λ), bogdanovite (p = 52%, λ = 582 nm) is close to native gold (p = 48%, λ=577 nm). The color saturation of gold was suggested to be the highest of all known ore minerals (Nekrasov, 1991). According to optical parameters, the symmetry of bogdanovite is not higher than orthorhombic.

The composition of Fe-dominated bogdanovite (average of four point analyses) is as follows, wt. %: 60.35 Au, 2.19 Ag, 4.63 Cu, 9.33 Fe, 9.99 Te, 12.83 Pb, 0.07 Se; total is 99.39. Formula is as follows: $(Au_{4.33}Ag_{0.29}Cu_{0.38})_5(Cu_{0.65}Fe_{0.35})Fe_{2.01}(Te_{1.11}Pb_{0.87}Se_{0.01})_{1.99}$ that is close to $Au_5CuFe_2(Te,Pb)_2$.

X-ray powder diffraction pattern (Debaye powder pattern) was recorded for the sample which had been chemically analyzed. X-ray powder diffraction pattern of bogdanovite was corrected using special picture with NaCl (λFe*Kα*): 4.06 Å (0.5), 2.90 (0.5), 2.36 (10), 2.15 (1), 2.045 (6), 1.446 (6), 1.293 (0.5–1), 1.230 (8), 1.180 (3), 1.092 (2–3), 0.992 (2–3); analyst T.L. Evstigneeva, Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, Moscow. Russia. According to *d*-spacing and relation of intensities, X-ray diffraction pattern of bogdanovite is close to that of gold reported by Berry and Thompson (1962). It allows suggestion that the structure of bogdanovite is close face-centered cubic lattice of gold. In comparison with gold, X-ray diffraction pattern of bogdanovite contains additional reflections, which like the strongest reflections are indexed on the basis of primitive pseudocubic cell with a_0 = 4.087 Å. Only weak reflection 2.15 Å (1) is not indexed in this subcell. According to X-ray diffraction data, bogdanovite is interstitial superstructure of the Me_4X type derived from face-centered lattice of gold (Spiridonov, Chvileva, 1979).

Replacement products of bogdanovite from the Aginsky deposit

Like other bilibinskite group minerals, Fe-dominated bogdanovite is ephemerous. In oxidezed zone, they are extremely unstable and easily replaced by fine-grained aggregates of gold of high fineness, tellurite, balyakinite, radjite, choloalite, teynite, graemite, plumbotellurite, mackayite, and other tellurites, oxytellurites, and tellurates. Partially such replacement exhibits in the upper cementation zone (see Fig. 2).

Acknowledgments

This study was supported by the Russian Foundation for Basic Research (project no. 07–05–00057).

References

Berry L.G. and Thompson R.M. X-ray powder data for ore minerals: the Peacock atlas // Geol. Soc. Amer. Mem. New York. **1962**. V. 85. 281 p.

Chvileva T.N., Bezsmertnaya M.S., Spiridonov E.M. et al. Identification guide of ore minerals in reflected light. Handbook. Moscow: Nedra. **1988**. 505 p. (In Russian.)

Naumova O.A. Altered wall-rocks at Au-Ag deposits in the Central and Southern Kamchatka // PhD thesis. Moscow, TsNIGRI. **1996**. 23 p. (In Russian.)

Nekrasov I.Ya. Geochemistry, mineralogy, and origin of gold deposits. Moscow: Nauka. **1991**. 302 p. (In Russian.)

Nesterenko G.V., Kuznetsova A.I., Pal'chik N. A. et al. Petrovskaite, AuAg(S,Se), a new Se-beraing sulfide of gold and silver // Zap. VMO. **1984**. Pt. 113 (5). P. 602–607. (In Russian.)

Petrovskaya N.V. Native gold. Moscow: Nauka. **1973**. 347 p. (In Russian.)

Sakharova M.S., Lebedeva N.V., and Chubarov V.M. The first finding of rare Te minerals, goldfieldite, rucklidgeite, and native tellurium, in Kamchatka // Dokl. AN SSSR. **1984**. V. 278. P. 1217–1220. (In Russian.)

Shchepot'ev Yu.M., Vartanyan S.S., Oreshin V.Yu., and Guzman B.V. Gold deposits of island arcs of Pacific. Moscow: Nedra. **1989**. 244 p. (In Russian.)

Sindeeva N.D. Mineralogy, types of deposits, and major features of geochemistry of selenium and tellurium // **1959**. Moscow: AN SSSR Publ. (In Russian.)

Spiridonov E.M. Balyakinite, $CuTeO_3$, a new mineral from oxidized zone // Dokl. AN SSSR. **1980**. V. 253. P. 1448–1450. (In Russian.)

Spiridonov E.M. and Chvileva T.N. Bogdanovite, $Au_5(Cu,Fe)_3(Te,Pb)_2$, a new mineral from the group of intermetallic gold compounds // Bull. MSU Geol. **1979**. No 1. P. 44–52. (In Russian.)

Spiridonov E.M. and Chvileva T.N. Sb-rich bilibinskite (a second finding of bilibinskite) // Dokl. AN SSSR. **1982**. V. 265. P. 1243–1247. (In Russian.)

Spiridonov E.M. and Chvileva T.N. New data on mutmannite, $AuAgTe_2$ // Dokl. AN SSSR. **1985**. V. 280. P. 994–997. (In Russian.)