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GEOCHEMISTRY

First Finding of Nisbite and Aurostibite in the Eastern Transbaikal Region

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Antimonides of Ni (nisbite $NiSb_2$) and Au (aurostibite $AuSb_2$) are genetically interesting rare minerals that appear at a very low activity of sulfide S and As [1, 2, 5, 7–9, 14]. Since aurostibite is not subjected to cyanidation and amalgamation [7 and others], the abundance of this mineral forces engineers to change the ore dressing technology.

Nisbite was identified in a hydrothermal uranium deposit of the Red Lake Formation, Canada [10]. The low activity of S in this area was related to the very high oxidative potential of alkaline-ultraacid (sodic) ore-bearing hydrothermal solutions. In Russia, nisbite was detected in the Festival'noe copper–tin deposit (Khabarovsk region) and the Zolotaya Gora gold deposit (the Urals) [8]. In the Zolotaya Gora gold deposit, nisbite occurs among native antimony in association with cuprostibite Cu_2Sb, zlatogorite $CuNiSb_2$, galena, ullmannite (Ni,Fe,Co)(Sb,As)S, seinajokite $FeSb_2$, gudmundite FeSbS, and native lead.

Aurostibite is developed in many hydrothermal (telethermal, plutonic, and less common volcanic) gold–antimony deposits in Yakutia, South Africa, Australia, Czechia, Finland, Kazakhstan, Uzbekistan, Bolivia, and France [1–3, 5, 7, 9, 11–15]. Aurostibite, a reaction mineral, makes up replacement rims in the native gold and its complete pseudomorphs. This mineral is a product of superposition of late (often epigenetic) antimony mineralization (with native antimony) upon the older gold mineralization.

We discovered nisbite and aurostibite in the Au-bearing carbonate–quartz–sulfide veins of the Darasun deposit. The minerals were identified with optical and electron microscopic methods. Their chemical analyses were performed with a Cameca SX-46 microprobe (I.A. Bryzgalov, analyst). SEM images were obtained in the Microprobe Analysis Laboratory of the Department of Petrology, Geological Faculty, Moscow State University.

Orebodies of the Darasun deposit are often characterized by the superposition of mineral aggregates of the preore boron (tourmaline) and molybdenum, gold–bismuth, antimony, and postore quartz–calcite stages. Mineral aggregates of the preore stages are confined to minor intrusions of distinctly porphyritic (spidery) monzonites and granosyenites of the ore-bearing Jurassic Amudzhikan Complex. In the Dukat deposit, mineral aggregates of the gold–bismuth stage are universally developed as azonal formations relative to the intrusions. In the economic Central, Eastern, and Northern sectors of the deposit, where ores are located among diverse granitoids and other felsic rocks, the ore is mainly composed of pyrite, arsenopyrite, galena, and sphalerite. In the Western sector, where the ores are confined to gabbroids and amphibolites, chalcopyrite is the major mineral and pyrrhotite is widespread. Mineral aggregates of the antimony stage are primarily developed in the Central and Eastern sectors, where lead sulfoantimonides and antimonite are abundant. The antimony mineralization is less developed in the Western sector, where the ores contain rare nisbite and aurostibite segregations. Nickel antimonides (breithauptite and willyamite) were identified here in [6].

The Pirrotinovaya and Pyataya Elektricheskaya gold ore veins include antimonides of Ni and Au. In addition to the major chalcopyrite and monoclinic pyrrhotite Fe_7S_8, pyrite, arsenopyrite, sphalerite, ikunolite, cosalite, hedleyite $Bi_{14}Te_6$, tsumoite Bi_2Te_2, pilsenite Bi_4Te_3, tetradymite Bi_2Te_2S, tellurojoseite (joseite B) Bi_4Te_2S, and native gold also occur in the ores. Nickel antimonides are confined to thin sinuous carbonate veinlets that crosscut pyrrhotite, chalcopyrite, and sphalerite. Nisbite is developed in aggregates of breithauptite NiSb with ullmannite NiSbS or willyamite (Ni,Co)SbS, which replace edges of chalcopyrite grains at their contact with carbonates. Sulfoantimonides (ullmannite and willyamite) are older minerals. They are crosscut by curvilinear microveinlets of antimonide

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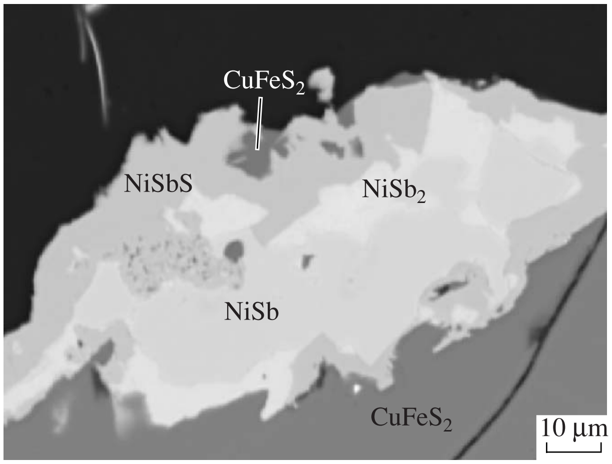

Fig. 1. Reflected electron image of an intergrowth of breithauptite (NiSb), nisbite ($NiSb_2$), and ullmannite (NiSbS) at the contact of chalcopyrite ($CuFeS_2$) and carbonate (black). The field is 150 μm wide.

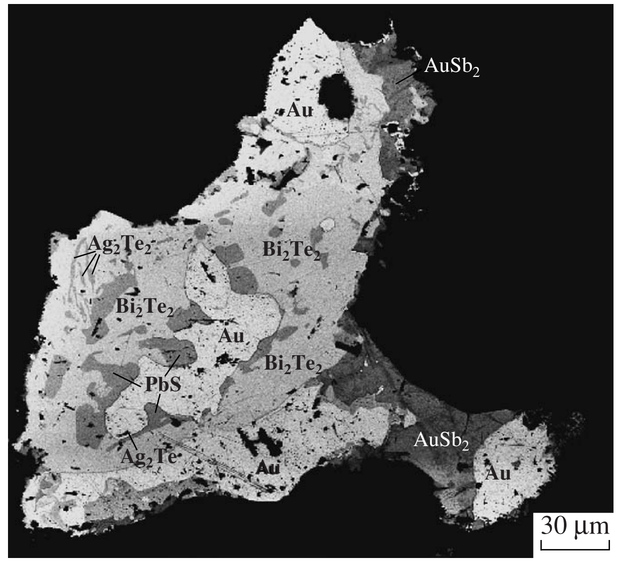

Fig. 2. Reflected electron image of the replacement rim of aurostibite ($AuSb_2$) in the native gold (Au). (Bi_2Te_2) Tsumoite; (Ag_2Te) hessite; (PbS) galena.

(breithauptite). The youngest microveinlets of diantimonide (nisbite) are developed along the contact of breithauptite with ullmannite or chalcopyrite (Fig. 1). These minerals are associated with tiny dyscrasite segregations.

Nickel antimonides, not larger than 0.1 mm in size, have a nearly stoichiometric composition. Ullmannite has the following composition (average of two analyses, wt %): Ni 25.64, Co 0.01, Cu 0.12, Fe 0.98, Sb 58.22, As 0.41, Bi 0.44, and S 15.22. The formula is $(Ni_{1.03}Fe_{0.04})_{0.97}(Sb_{1.01}As_{0.01})_{1.02}S_{1.01}$. Breithauptite has the following composition (average of six analyses, wt %): Ni 32.32, Co 0.01, Cu 0.28, Fe 0.22, Sb 67.48, As 0.06, Bi 0.04, and S 0.19. The formula is $(Ni_{0.97}Cu_{0.01}Fe_{0.01})_{0.99}(Sb_{1.00}S_{0.01})_{1.01}$. Nisbite has the following composition (average of two analyses, wt %): Ni 18.80, Co 0.04, Cu 0.03, Fe 0.05, Sb 79.67, As 0.38, Bi 0.13, and S 0.38. The formula is $Ni_{0.97}(Sb_{1.97}As_{0.02}S_{0.04})_{2.03}$.

The major portion of Ni is linked with ullmannite, breithauptite, and nisbite, whereas the major portion of Co is confined to willyamite. Ni and Co for these antimonides are likely to be derived from the older pyrrhotite. The wide distribution and compositional features of this mineral are related to the abundance of gabbroids and amphibolites in ore-hosting sequences of the Western sector in the Darasun deposit.

Aurostibite was identified in the Pirrotinovaya vein among aggregates of late minerals (galena, tsumoite Bi_2Te_2, and gold with hessite Ag_2Te veinlets) of the gold–bismuth stage (Fig. 2). The native gold (fineness 709–893) has a heterogeneous composition. Aurostibite makes up replacement rims in the native gold along its contact with quartz and carbonate. Aurostibite has the following composition (wt %): Au 45.44, Sb 53.52, Bi 1.08, and As 0.07; total 100.11. The contents of Ag, Cu, Hg, and Te are below the detection limits. The chemical formula is $Au_{1.02}(Sb_{1.95}Bi_{0.03})_{1.98}$. The Darasun aurostibite is distinguished from its counterpart in unmetamorphosed hydrothermal deposits by a higher Bi content.

In contrast to other sectors with lead sulfoantimonides and antimonite as the major antimonides and pyrite and galena as the major sulfides, the Western sector of the Darasun deposit is characterized by the development of nickel (and cobalt) antimonides associated with chalcopyrite and pyrrhotite as the major sulfides. This feature is related to a considerably lower activity of sulfur in the course of the formation of ores among basic rocks in the Western sector. This process is a typical manifestation of zonal ore deposition depending on the composition of host rocks.

Aurostibite could form in ores of the Western sector owing to the same reason under the influence of hydrothermal solutions of the antimony stage on gold ores.

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