MINERALS

A total of 104 minerals, including 72 supergene species (*Table* 1), were identified in specimens from the Phosphatno-Arsenatnaya vein. Of these, seven minerals were described for the first time in Russia, and 28 were reported for the first time at this deposit. All of these minerals are described in this chapter at varying levels of detail. Considering the specific nature of this publication, we have provided the most representative chemical compositions, unit cell parameters, and, in some cases, IR spectroscopic data. In addition, in keeping with the format of the *Mineralogical Almanac*, we have included a variety of photographs showcasing the most notable and fascinating specimens, enriching the mineral descriptions.

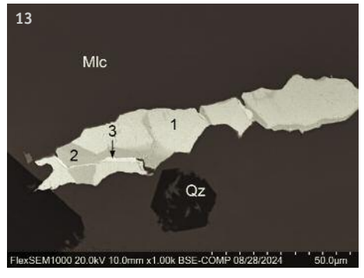
The minerals are organized by chemical classes. Isostructural minerals are grouped together in the chapter on "*Arsenates, phosphates, and vanadates (including those with other anion groups)*" within their respective supergroups, groups, and series.

Elements (native metals)

Bismuth, Bi occurs as very small (<10 μm) inclusions in azurite (**Zone 2**, level +245 m) associated with gartrellite, malachite, and segnitite. It is possible that we observe here the exceedingly rare case of native bismuth of supergene origin.

Gold, Au, occurs as an Ag-rich variety (electrum) that forms abundant disseminated anhedral grains and veinlets in the gossan of **Zone 1**. Commonly, gold is enclosed in limonite and less frequently, in relict quartz. Grain sizes range from 5 to 40 μm and veinlets reach lengths of up to 0.15 mm. Some veinlets are clearly zoned (*Fig.* 13), the chemical composition of gold ranges from ($Au_{0.85}Ag_{0.15}$) to ($Au_{0.60}Ag_{0.40}$), the darkest zones in the backscattered electron image (BSE) correspond to the mineral species **silver** with the composition ($Ag_{0.80}Au_{0.20}$). Pseudomalachite, iodargyrite, chalcopyrite, acanthite, covellite and chalcocite are also present in this assemblage. Supergene gold occurs as spongy aggregates up to 0.3 mm in size and is overgrowing azurite, limonite, and quartz (*Fig.* 14) together with bayldonite, gartrellite, covellite, malachite, pseudomalachite, segnitite, tennantite-(Zn), and chalcocite as observed in **Zone 2**. The chemical composition of this gold ranges from ($Au_{0.75}Ag_{0.25}$) to ($Au_{0.54}Ag_{0.46}$). In **Zone 3**, gold occurs as rare inclusions (up to 20 μm in size) in sphalerite and is associated with galena, cosalite, and supergene smithsonite, chalcocite, and cerussite. This gold is chemically pure or contains minor Ag (up to 0.10 *apfu*).

13. Zoned veinlet of electrum in malachite (Mlc) with quartz (Qz).
(1) **gold** ($Au_{0.60}Ag_{0.40}$),
(2) **silver** ($Ag_{0.80}Au_{0.20}$),
(3) **gold** ($Au_{0.85}Ag_{0.15}$).
Zone 1, level + 248 m.
SEM/BSE image: Anatoly V. Kasatkin.



14. Spongy **gold** (electrum)aggregates on quartz with **azurite**, **malachite**, and limonite. FOV: 0.1 cm.
Zone 2, level+245 m.
Specimen and photo:
Ekaterina V. Vorontsova.

Copper, Cu was observed at level +235 m (**Zone 3**) as grains (up to 1 mm in size) within so called "black" quartz (colored black by fine copper sulfides) together with minerals of the duftite-mottramite series, descloizite, goethite, and malachite. In our opinion, it is not coincidental that the occurrence of copper is related to the latest chromate-vanadate supergene association. This may reflect a local reducing environment at the lower level of the vein.

Sulfides, Sulfoarsenides, and Sulfotellurides

All minerals in these classes, except acanthite, covellite, and chalcocite, in the oxidized ores are relict. All minerals were identified in polished sections by their optical properties and chemical compositions.

Acanthite, Ag_2S is regularly observed during electron microprobe analysis (EMPA) of samples from **Zone 1** (level +248 m), it occurs as inclusions (up to 50 μm in size) in malachite and limonite associated with pseudomalachite, gold, silver, iodargyrite, chalcopyrite, covellite, and chalcocite. It is likely that acanthite is a supergene phase in this zone. Acanthite is occasionally observed in **Zone 2**.

Arsenopyrite, FeAsS is distributed locally. **In Zones 1** and **3**, it is very rare and occurs as euhedral grains up to 50 μm in size, whereas in **Zone 2** (+245 to +240 m), it forms gray crystals (up to 0.5 mm long) with rhombic cross-sections in quartz. Naturally, arsenate mineralization is the most extensive in the areas that contain this sulfoarsenide. Relict arsenopyrite in the oxidized ores is accompanied by arsenates (bayldonite, beudantite,