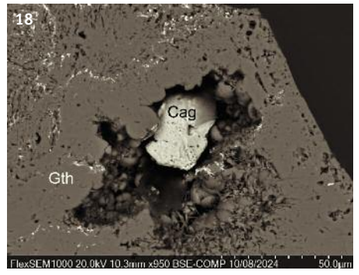


18. Crystal of Br-rich **chlorargyrite** (Cag) in **goethite** (Gth). **Zone 3**, level +235 m. SEM/BSE image: Anatoly V. Kasatkin.

phosphates (bayldonite, gartrellite, duftite, pyromorphite, fluorpyromorphite, fluorapatite), acanthite, arsenopyrite, baryte, and wulfenite are also present in this association.

Perite, $PbBiO_2Cl$ occurs as inclusions (up to 10 µm in size) in cerussite from **Zone 3** (level +235 m) in association with goethite, malachite, and numerous arsenates and phosphates. The chemical composition of this mineral is (wt.%) PbO 48.31, Bi_2O_3 45.90, Cl 6.49, Cl=O –1.47, total 99.23. The empirical formula calculated on the basis of 3 anions is $Pb_{1.08}Bi_{0.98}O_{2.09}Cl_{0.91}$. Slightly overestimated Pb contents compared to Bi is caused by host cerussite.

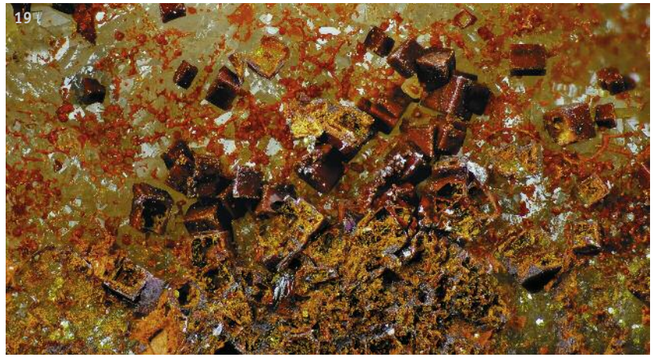
Chlorargyrite, AgCl is extremely rare in **Zone 3** (level +235 m), where it fills fractures in limonite as rough cubic and cuboctahedral crystals (up to 30 µm in size) (*Fig.* 18) in association with malachite, cerussite, wulfenite, various arsenates (bayldonite, duftite, mimetite, segnitite) and phosphates (pyromorphite, phosphohedyphane). This mineral is a Br-rich variety embolite. Its chemical composition is (wt.%) Ag 67.02, Cl 11.93, Br 19.11, I 0.75, total 98.91, corresponding to the empirical formula (calculated on the sum of all atoms equal to 2), $Ag_{1.03}Cl_{0.56}Br_{0.40}I_{0.01}$.

Oxides and Hydroxides

Minerals of these chemical classes (goethite and quartz above all) constitute the main volume of the oxidized ores in the Phosphatno-Arsenatnaya vein.

Supergene **hematite, Fe_2O_3** occurs as fine coatings and powdery brick-red crusts that are common throughout all three zones (*Figs.* 16, 23). In **Zone 1**, it is frequently intergrown with dominant goethite in the gossan.

Goethite, FeOOH is the major supergene mineral of the oxidized ores at the Murzinskoe deposit, and the Phosphatno-Arsenatnaya vein in particular. It is pervasive and predominantly occurs as a hydrated variety comprising limonite aggregates. In **Zone 1**, goethite is the most important constituent of the gossan. At mid-



19. Brown cubes representing **goethite** pseudomorphs after pyrite. FOV: 0.3 cm. **Zone 2**, level +245 m. Specimen: Anatoly V. Kasatkin. Photo: Maria D. Milshina.

20. Orange crusts of **goethite** on green **segnitite**. FOV: 0.5 cm. **Zone 3**, level +235 m. Specimen: Anatoly V. Kasatkin. Photo: Maria D. Milshina.

dle and lower levels, quartz veins at some sites (up to 1 m long) are brown, orange, and reddish brown due to dense clusters of limonite. Goethite also occurs as fine-radial crusts and clusters (up to 5 cm in size), as well as dark brown and brown-black spherulites (up to 2 cm in size). Some specimens with goethite (limonite) are pseudomorphs after cubic pyrite crystals (up to 3 mm in size) (*Fig.* 19) and were collected in **Zones 2** and **3**. In most cases, goethite is one of the earliest supergene minerals that crystallized before (or contemporaneously with) carbonates (malachite, azurite). However, in **Zone 3**, we also observed late goethite overprinting segnitite and other arsenates (*Fig.* 20).

Quartz, SiO_2 is the major gangue mineral of Phosphatno-Arsenatnaya vein. Blocks of the earliest massive grayish white quartz, which in some places are filled with sulfide inclusions are observed, later massive beige quartz are cemented by druse quartz which represents the last generation of quartz (*Fig.* 8). The latest generation of quartz is observed as druses of long-prismatic, transparent and colorless, crystals (up to 1 x 0.2 cm in size) and opaque milky-white crystals up to 5 x 1 cm in size. In the oxidized ores, quartz is also common. It is one of the main constituents of the gossan in **Zone 1**; in **Zones 2** and **3**, it forms massive pods, veinlets, and aggregates together with limonite and malachite. In the oxidized ores, the vast majority of quartz is relict, however, supergene quartz is observed in **Zones 2** and **3**. Colorless transparent quartz crystals, and fine-crystalline crusts, overgrow malachite clusters,