Abstract

The Late Cretaceous Sakdrisi gold and copper deposit is exploited by RMG and located in the Bolnisi mining district, in Georgia, 50 km southwest from the capital Tbilisi. It is believed to be the world's oldest gold mine, with mining activity dated back to the Bronze Age. The Bolnisi district is part of the Somkheto-Karabakh island arc of the Lesser Caucasus, which marks the transition between the Turkish Eastern Pontides to the west and the Iranian Zagros mountains to the East. The five mineralized blocks that compose Sakdrisi (Sak-I to Sak-V) are aligned along a NE-oriented fault. The deposit is poorly constrained, and this work presents a detailed multidisciplinary study of the Sak-IV and V open pits and their surroundings, in an attempt to provide a genetic model.

The mineralization at the Sak-IV open pit consists of a deep stockwork of multistage banded Au- Cu-bearing quartz-carbonate veins in rocks affected by pervasive quartz-sericite-pyrite alteration, with quartz-, kandite- and siderite-dominated proximal alteration haloes. Locally, spacing between the veins is reduced, and breccia-like textures are reported. The northern parts of this stockwork incorporate polymetallic Zn-Pb mineralization. It is overlain by some thicker chalcopyrite-pyrite-quartz veins with minor sphalerite, in strongly chloritized country rocks. Finally, to the south, the host tuff is heavily silicified, and gets progressively rich in barite and oxidized towards the surface. In this area, weathering and oxidation of the primary chalcopyrite and pyrite resulted in rocks exhibiting a vuggy texture. The whole mineralization was overthrusted by a thick barren ignimbrite in a southward motion, a process that protected the ore both from weathering and erosion.

Ubiquitous relicts of amorphous silica, and alternations of cryptocrystalline and crystalline quartz in the veins from the Sak-IV open pit suggest that repeated rapid changes in the depositional regime took place. This was certainly caused by repeated events of seismic reactivation or hydraulic fracking of the veins, possibly linked with boiling. This process is further supported by the macroscopic textures of these multi-stage veins, and by the straightforward crosscutting relationships between the different vein stages.

By contrast, the mineralization at the Sak-V open pit is very different: its northeastern extremity is occupied by a deep red gossan-like zone, mainly exploited for gold, whereas the bottom part of the pit is occupied by a strongly chloritized zone (similar to the Sak-IV chloritized zone) crosscut by a stockwork of quartz-poor massive chalcopyrite and pyrite veins. Finally, the top parts that are massively altered to kandite and strongly silicified host a stockwork of sphalerite-barite veins that eventually merge at the top to form a massive body.

The temperatures of the mineralizing fluids were estimated both by fluid inclusion microthermometry and sulfur isotope geothermometry, and range between 272 to 296°C in the Sak-IV open pit and between 216 to 270°C in the Sak-V open pit. Combined with the microprobe analyses on sphalerite crystals (in equilibrium with pyrite), that highlighted their average low (> 1) FeS mol%, these temperatures indicate that the mineralizing fluids at Sakdrisi had an intermediate- to high-sulfidation state (Einaudi et al., 2003). This result consistent with a mineralogy that is dominated by chalcopyrite, pyrite and quasi-stoichiometric sphalerite.

Sulfur isotope analyses on sulfides from Sakdrisi show that they mostly range between -2 and 1.7 ‰ $\delta^{34}S$, whereas the values for the barite, that range between 15.2 and 18.3 ‰, are shifted towards smaller $\delta^{34}S$ values than those of the Late Cretaceous seawater sulfates. This dataset suggests that most of the sulfur at Sakdrisi is of magmatic origin, and that sulfide-sulfate fractionation or isotopic equilibration processes took place.

Reequilibration processes may also have affected the carbonates from Sakdrisi, since the $\delta^{18}O$ and $\delta^{13}C$ values retrieved from different stages of carbonate precipitation are mostly depending on the localization of the sample in the open pit. The two carbonate precipitation events that are described in the present study, and that include siderite and dolomite, systematically post-date earlier sulfide assemblages, and are interpreted as the result of the descent of CO_2-rich steam-heated shallow groundwaters due to the 1) interstage and 2) final waning of the hydrothermal activity.

Finally, we report textures in the host tuff that we interpret either as block-and-ash flows or hyaloclastites, which are formed in very different environments, so that we strongly encourage further investigations by specialists.

A comparison with the neighbor Madneuli mine suggests that Sakdrisi could be a hybrid deposit formed at the transition between an epithermal environment at depth (Sak-IV) and an environment that is closer to the seafloor, and more akin to the VMS-related one (Sak-V).