Secondary minerals in minothems at Fragnè Mine (Turin, Italy)

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Introduction

Secondary minerals forming speleothems are called "cave minerals" and are the result of complex interactions between bedrock, circulating water, and sediments of various sources. A "speleothem" is a secondary mineral deposit formed in a cave (Moore, 1952) by a chemical reaction from a primary mineral in bedrock or detritus because of a unique set of conditions therein. In Carbone et al. (2016) the term "minothem" was defined considering the secondary mineral concretions forming in an artificial underground void, such as a mines. Minothems are the counterpart of speleothems in natural caves, and generally show the same morphologies. However, the petrographical and geological differences of the host rock can cause significant distinctions in mineralogy, color and shape of the minothems respect to speleothems (Carbone et al., 2016).

In this work we characterized and describe, for the first time, secondary minerals and related minothems forming at Fragnè mine. The sampling was performed together with speleologist from Liguria and Piedmont.

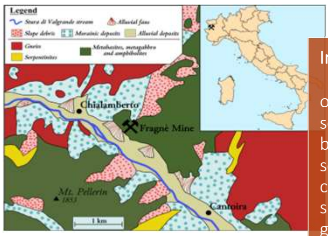

Figure 1. The Fragnè mine location.

The Fragnè mine

The Fragnè mine, Chialamberto (TO), Piedmont, Italy, is located in the Lanzo Valley (Fig.1). The site is abandoned and is characterized by active and intense Acid Mine Drainage (AMD) processes triggered by the supergenic interaction between sulfide-rich mineralizations and atmospheric agents. Acid Sulfate Waters (ASW) percolating inside the galleries drip through the mine roof and form numerous decorative dripstone features that coat the walls, ceilings, and floors of the mine, and grow out of muck piles creating minothems. The mine develops underground for about 5 km and had tunnels on 11 levels (http: //www.mineralipiemonte.it/), but lot of galleries are collapsed. The ore deposit consists of stratiform sulfide mineralizations characterized by the presence of lenticular twisted and folded bodies of massive pyrite and Cu-rich pyrite inside chloritoschists. Pyrite and Cu-rich pyrite are associated with minor amounts of chalcopyrite, sphalerite, bornite, pyrrhotite, and galena. All samples were taken in two low levels, currently the only viable ones (Santa Barbara, 899 m a.s.l., and Sobrero, 916 m a.s.l.). The first section of the entrance is flooded with waters characterized by AMD, with water levels depending on seasonal variation (Fig.2). All samples varying in color and representative of all types of minothems that occur inside the mine.

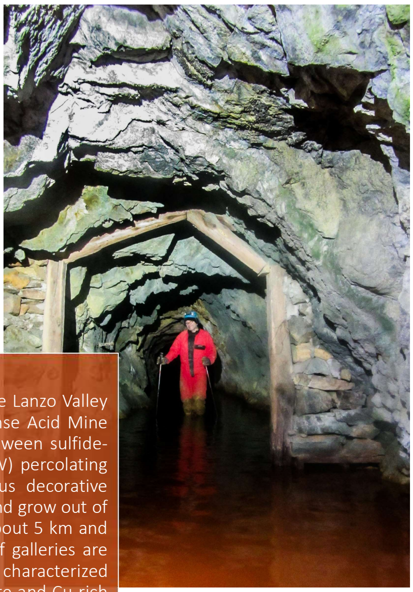

Figure 2. The first section of the entrance is flooded with waters characterized by AMD, with water levels depending on seasonal variation Photo by V. Balestra.

Results and discussions

The secondary minerals identified by XRPD are reported in Fig.3. All samples are characterized by mineral species that typically form in AMD environments: Fe-oxyhydroxides (mainly schwertmannite and goethite), but also sulfates such as gypsum, epsomite, hexahydrite, melanterite, jarosite, and ktenasite. The presence of chlorite, albite, quartz, and amphibole was attributable to the surrounding rocks and pyrite to ore mineralizations. Two types of poorly crystalline minerals were detected: allophane and schwertmannite.

The XRPD results showed that schwertmannite and goethite were the main minerals that occur in gelatinous (jelly) and hard minothems. Cross sections of jelly stalactites and hard stalactites were subjected to SEM investigations (Fig.4). All jelly stalactites and hard stalactites were characterized by concentric and rhythmic layers that develop around a large central channel. The inner zone was characterized by pin-cushion morphologies, globular masses surrounded by radial fiber aggregates typical of schwertmannite. Images at high magnifications allowed to identify abundant bacterial structures. The outer part was characterized by a compact zone with goethite grown in layers and with no signs of bacterial structures.

The presence of Fe-rich phases in all minothems shows that the AMD is still active at Fragnè Mine. The presence of gypsum, hexahydrate, and ktenasite further confirms the mobilization of chemical elements caused by acid drainage. In fact, the Mg and Ca rich-sulfates derive from the leaching of the minerals of the surrounding rocks, whereas Cu, Co and Zn come from the mineralized masses.

The evolution of schwertmannite versus goethite can be clearly observed in stalactites. The variation of mineralogical composition of Fe-rich minothems is probably due to the ageing of schwertmannite which, being a metastable phase, tends to transform into goethite, but it is not possible to exclude that goethite derives from pH variations only.

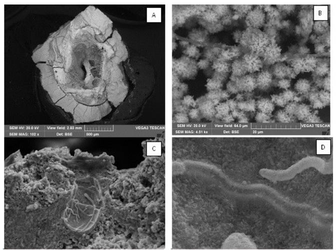

Figure 4. SEM images of representative Jelly stalactites.

Stalactite made of goethite and jarosite, Sobrero level

Gypsum crystalline crust, S. Barbara level

Column made of schwertmannite and poorly crystalline goethite, Sobrero level

Gypsum crust of needles, Sobrero level

Blister made of schwertmannite, Sobrero level

Gypsum crystalline crust, S. Barbara level

Pancake stalagmite made of poorly crystalline goethite, S. Barbara level

War club of schwertmannite and poorly crystalline goethite, Sobrero level

Stalactite made of schwertmannite and poorly crystalline goethite, covered with crystals, Sobrero level.

Soda straw of schwertmannite, S. Barbara level

Jelly stalactite made of allophane, Sobrero level

Hair of allophane, S. Barbara level

Crust of melanterite, S. Barbara level

Crust, S. Barbara level

Amorphous jellystone, Sobrero level

Jelly stalactite of schwertmannite and poorly crystalline goethite, Sobrero level

Figure 3. Secondary minerals and minothems in Fragnè mine. Photos by V. Balestra.

Conclusions

It is worth emphasizing that minothem Fe-oxy-hydroxide stalactites grow from the inside, i.e. the youngest layers surround the feeding channel, and these growing schwertmannite layers push the older (outer) more mature Fe-oxy-hydroxide layers outward. Also jelly stalactite tips are composed of younger schwertmannite. The external (older) layers, when the transformation is complete, are composed of goethite. This is in contrast with carbonate stalactites (speleothems), where the older layers are the ones surrounding the feeding channel, and water films degassing CO_2 form younger carbonate layers on their outside or at their tips. Because of these different mechanisms of formation, probably the use of "stalactite" (or jelly stalactite) in mines should be avoided, or substituted by "stalactite-like" minothems, in which "stalactite" only refers to the shape of the minothem.

References

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*Moore G. W. (1952), "Speleothem – a new cave term", National Speleological Society News, 10 (6): 2.