Life and Minerals: the Machów mine (Poland)

Enero 2019

The History of Life cannot be told whatsoever without telling the History of the minerals that lead to its origin and play on its evolution. Life is a geological phenomenon, after all. Emerged from certain geochemical conditions and in a/some geological setting/s we need yet to completely understand. As a geological agent, Life alters and modify the geochemistry of the systems in which it is involved, transforming minerals and creating, on occasions, vast structures. Now, we are agents of this geological change, transforming minerals and structures, but we are not alone in that endeavor. During the History of Life, bacteria were very good also transforming minerals for their benefit.

It is the case of the Machów sulfur mine, in Poland. This is a classic deposit (I think that now is not available and the open pit is flooded) well known by mineral collectors because its beautiful specimens of crystallized celestite (SrSO4) and native sulfur.

Celestite and sulfur. Machów mine, Poland. 3 cm FOV

The story of these minerals began c. 14 million years ago, when an ecological catastrophe took place: the Badenian (Middle Miocene) salinity crisis. Tectonic movements closed the oceanic gateways of large water masses, resulting in the formation of hypersaline waters and the deposition of millions of tons of gypsum and halite when these masses were dried by a climatic change.

The big masses of gypsum are exactly like what we would consider an oxygen tank or simply fresh air for a particular type of organisms: the sulfate-reducing bacteria. These organisms do not need air to breathe: they use sulfate respiration instead oxygen, following this overall reaction:

$$SO_4^{2-}- + \text{organic matter} --\rightarrow HS^- + OH^- + CO2$$

The sulfate reducing bacteria eat organic matter present in the sediments or provided by other bacteria (like methanogenic

bacteria), using sulfate as final electron acceptor, resulting in the transformation of the sulfate from gypsum in a mixture of sulfides and carbonates (limestone). The overall process is:

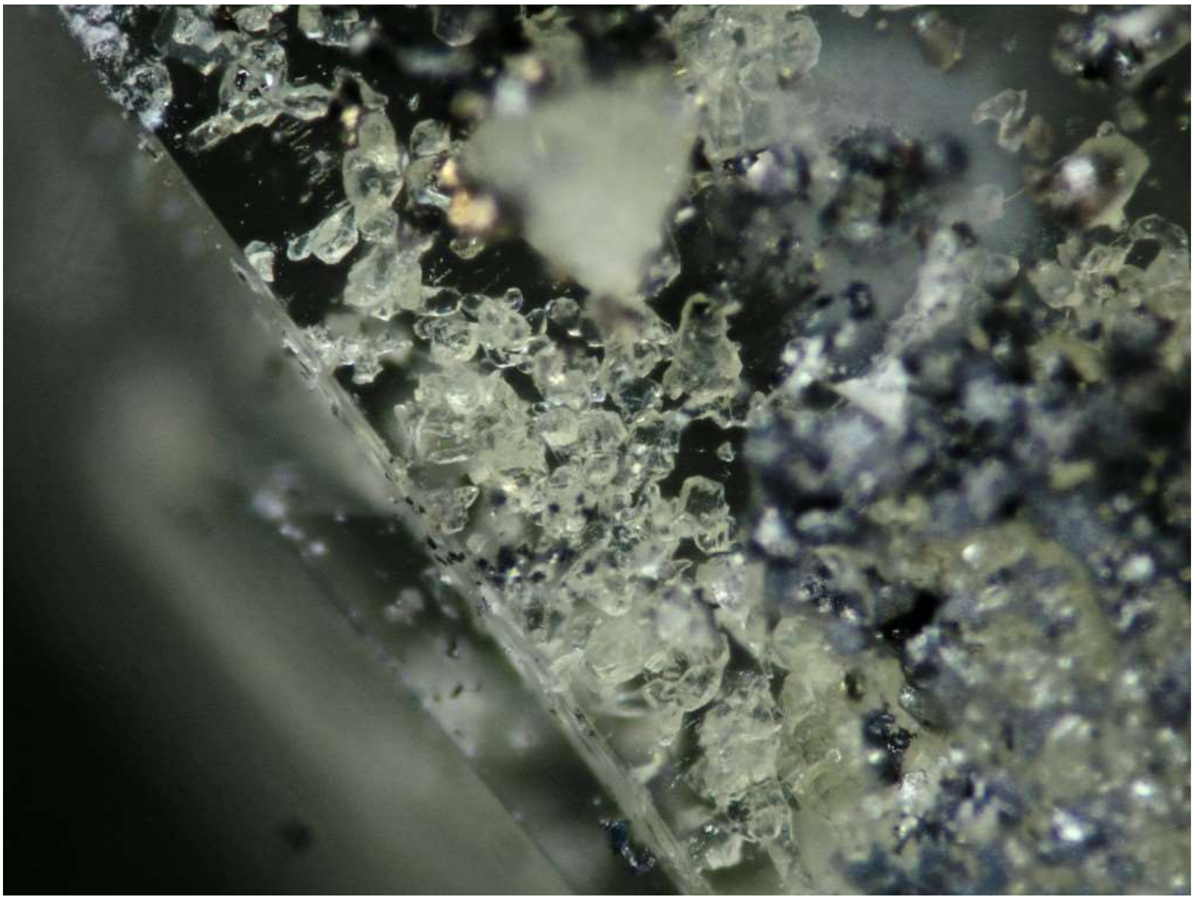
primary gypsum –> sulfide + limestone (CaCO3)

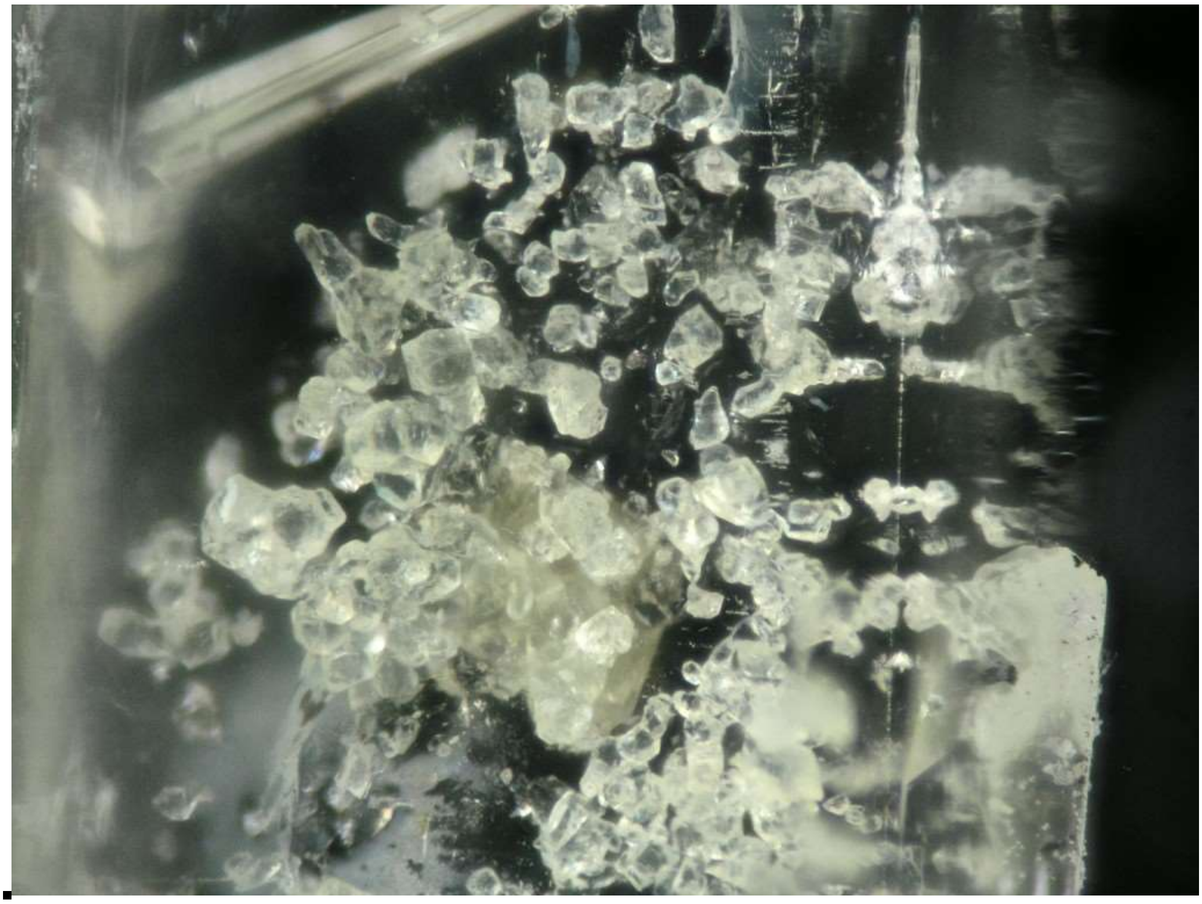
Partial oxidation of the sulfide lead to the precipitation of sulfur, mixed with the carbonates. The transformation of gypsum-rich rock in limestone provoked the contraction of the rock, creating a lot of fissures and cavities where fluid enriched in sulfide accumulates and suffer partial oxidation, leading to the crystallization of sulfur. The scale of the process is enormous. The bacterial ecosystem created in Tarnobrzeg one of the biggest high-grade elementary sulfur deposit in Europe, from which up to 5 million tons of sulfur were extracted annually since the beginning of sulfur mining in 1956.

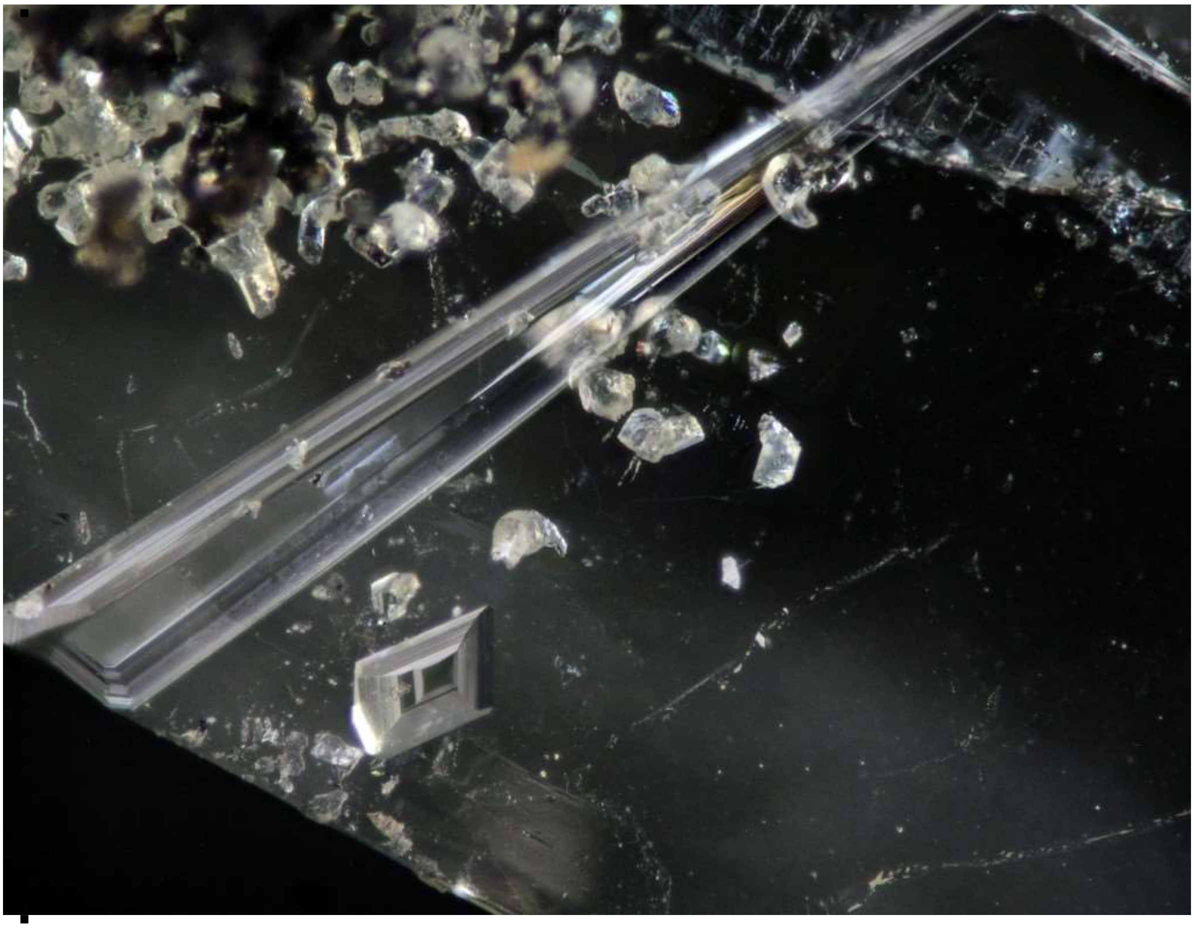
Sulfur crystals from Machów mine, Tarnobrzeg , Poland

The process of formation of sulfur is related with the origin of celestite: isotopic studies showed that the celestite is formed out of the residual sulfate not consumed by biological processing. Strontium mobilized precipitates first due to the lesser solubility of strontium sulfate, forming celestite crystals that are the usual accompanying mineral for the sulfur.

The celestite and sulfur occur intimately and the inclusions of sulfur crystals in celestite are very common.







Sulfur crystals included in celestite, recently analyzed by Raman spectroscopy

As you can see, Life could have a dramatic influence on the shape and composition of rocks and geological structures, the mineral transformations, origin of mineral deposits and the geochemistry. Life is a geological agent and its evolution cannot be separated from the evolution of the Earth as a whole system. That's why I think that anyone who wants to truly understand the nature, origins and evolution of Life, need to have at least a basic knowledge on Mineralogy and Geochemistry.

Celestite crystal and sulfur from Machów mine.

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