

POST-MINE MINERALISATION IN THE CONISTON COPPER MINES

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Exploration of old underground mine workings commonly reveals deposits of minerals on the walls of old workings which quite clearly have formed since the workings were excavated: in many instances these deposits are still forming today. The term 'post-mine' is generally applied to these. A great variety of mineral species may occur in this situation.

The elements which form these minerals are derived from both the mineralised bodies and the wall-rocks in which they occur by the action of groundwater percolating through the old workings. Surface waters, derived almost entirely from rainwater, almost invariably contain some dissolved carbon dioxide and oxygen. This is quite capable of reacting with a number of minerals and removing elements in solution. When, as is usually the case, mineral deposits contain comparatively unstable sulphide minerals such as pyrite or marcasite, the reaction with groundwater produces an abundance of sulphurous and sulphuric acid thus enabling further chemical attack on minerals through which this very reactive groundwater passes. Very high levels of acidity may develop, particularly in pyrite- or marcasite-rich deposits. Many of the metallic elements present in a deposit may thus be taken into solution.

Mineralogists and ore-geologists use the term 'supergene' to describe these near-surface processes and the minerals produced by them. (The term 'hypogene' or 'primary' is used for the original mineralising process and the minerals so formed.) Although it is common to hear 'secondary' used as a synonym for 'supergene' this is not recommended as a great variety of 'secondary' processes occur quite unconnected with the near-surface environment.

Near the surface, especially above the water table where abundant oxygen or carbon dioxide is present in interstices in rocks, deposition of the dissolved elements commonly occurs to produce minerals typical of this 'supergene' environment. This process occurs naturally near the outcrop of mineral deposits. Mine workings, by introducing oxygen and carbon dioxide and by enhancing the flow of groundwater through a deposit effectively provide an artificial environment for these processes, often at depths well below the water table. It is in just this situation that the mine explorer encounters the products of 'post-mine supergene mineralisation'.

The nature of the minerals formed in such an environment depends on a number of factors including the composition of the available 'hypogene' minerals, the solubility products and stability fields of the chemical compounds involved, the abundance of free oxygen and carbon dioxide and the nature of groundwater flow patterns. The topic is thus highly complex when studied in detail.

For the mine explorer at Coniston it is worth commenting on those 'post-mine' minerals which are known to be present. Most conspicuous, but not necessarily most abundant, in old copper mines are copper-bearing minerals. Almost all such copper minerals are brightly coloured, usually in shades of blue or green. One of the most common green copper minerals is malachite ($\text{Cu}_2\text{CO}_3(\text{OH})_2$) and this is certainly present in parts of the Coniston workings. However, the sulphate brochantite ($\text{Cu}_4\text{SO}_4(\text{OH})_6$) is also common and is frequently misidentified as malachite

(Young and Johnson, 1985). The oxidation of abundant pyrite in the Coniston veins has produced sulphate rich groundwaters which in many circumstances will favour the formation of brochantite rather than malachite. A simple acid test will help to distinguish malachite which will fizz readily in dilute (10%) hydrochloric acid. Although there are several other obviously "malachite-green" copper minerals which may occur in such environments none has so far been recorded from Coniston.

To many people the best known blue copper mineral is azurite ($\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$). This is typically a vivid blue mineral though when crystallised it is commonly a very dark blue indeed. It is in general a much less common mineral than malachite and seems to be particularly scarce at Coniston, indeed despite many years familiarity with Coniston minerals I have yet to see a specimen despite claims of its presence in several descriptions of the area. Azurite has been confirmed at only a handful of localities in the Lake District.

A selection of blue 'post-mine' encrustations from Paddy End when examined by x-ray diffraction techniques proved to consist of either langite ($\text{Cu}_4\text{SO}_4(\text{OH})_6 \cdot 2\text{H}_2\text{O}$) or posnjakite ($\text{Cu}_4\text{SO}_4(\text{OH})_6 \cdot \text{H}_2\text{O}$): in places both minerals were present in the same small sample (Young and Johnson, 1985). Small specimens of these minerals may be seen on the dumps at Paddy End. It is likely that much of the material commonly referred to as 'azurite' from Coniston consists of one or perhaps both of these minerals.

Pale, turquoise-blue encrustations from Paddy End include material which gave an x-ray pattern close to chalcoalumite ($\text{CuAl}_4(\text{SO}_4)(\text{OH})_{12} \cdot 3\text{H}_2\text{O}$) though its identity could not be determined precisely. Chrysocolla ($\text{Cu}_x\text{Al}_y\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$) may also be present as a constituent of vivid deep blue to turquoise-blue rather enamel-like encrustations at Paddy End. Whereas it has not been possible to confirm the presence of this mineral here it is an important constituent, along with malachite, of the natural supergene assemblage present in the vein outcrop at Black Scar Workings west of Levers Water (Young, 1987).

Bright rose-pink crusts locally attract interest at Coniston. Samples of these so far studied consist of erythrite ($\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$), either alone or perhaps more commonly as an intergrowth in post-mine calcite coatings. The cobalt has been derived either from discrete cobalt minerals in the ore or present as traces within the other sulphides (Russell, 1925). In this context it is worth noting that when found on the Paddy End dump the closely associated sulphide has always proved to be tennantite ($\text{Cu}_3\text{FeAs}_4\text{S}_{13}$). The occurrence of any sulphide associated with erythrite in the workings is worth investigating as the nature of the primary cobalt, and associated nickel, assemblages have never been investigated *in situ*.

White or colourless encrustations are less conspicuous in the workings but probably as numerous. Post-mine calcite, as thin coatings of 'flow-stone' do occur but are probably not abundant, reflecting the general low calcite content in the primary veins. Common in parts of the Coniston workings is gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) as crusts of rather pearly crystals of the variety known as selenite. Gypsum is a common post-mine mineral in many mines in which sulphate-rich groundwaters are abundant.

Earthy yellow to brown coatings are very common in most abandoned mines including Coniston. Commonly ignored or simply dismissed as 'limonite' (not a true mineral but rather a field term for unspecified earthy iron oxides) these deposits may include a variety of iron oxide and basic iron

sulphates including members of the jarosite group and similar minerals. The writer is not aware of any work done on these minerals at Coniston.

A variety of 'supergene' minerals of 'post-mine' origin are thus known at Coniston. Many more almost certainly remain to be identified.

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References

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