Penrhyn Quarry

[SH 620 650]

Introduction

Penrhyn Quarry (Figure 5.47) is a renowned geological site for the famous boudinaged dolerite dykes which traverse the Cambrian slates. These dykes are strongly mineralized, particularly in the neck zones of the boudins, and an 'Alpine-type' vein assemblage, notable for large, specular hematite crystals, is overprinted by chalcocite mineralization with associated chrysocolla. The origin of the chalcocite is equivocal, as chalcocite is typically a supergene copper mineral.

Description

Penrhyn Quarry (Figure 5.48) works slates of Lower Cambrian age, which have been intruded by a series of basic dykes of mainly Lower Palaeozoic age, although cross-cutting Tertiary dykes have also been reported (Williams and Ramsay, 1968). The Lower Palaeozoic dykes have been altered during regional metamorphism and were strongly boudinaged during Acadian compressive deformation, which was particularly intense in this area, lying within the so-called 'Cambrian Slate-belt' of Wales (Scott, 1992). The dykes are pervasively mineralized with the development of ladder-vein systems, which represent syn-deformational, infilled fractures at the neck zones of the boudins.

These veins are restricted to the dykes; the slates are generally non-mineralized, apart from occasional bands of well-formed pyrite cubes of diagenetic to low-grade metamorphic origin.

Within the veins, four mineral assemblages may be discerned, namely: rock-forming minerals; calcite and ferroan carbonates; chalcocite mineralization; and supergene mineralization. Initial veining, showing certain resemblances to the 'Alpine-type' veining seen elsewhere in North Wales (e.g. the Manod Quarry GCR site), consists of quartz accompanied by abundant chlorite, with lesser amounts of pink albite and platy, specular hematite which forms crystal rosettes up to 30 mm across (Bevins, 1994). The dolerite dykes are strongly chloritized adjacent to these veins. At the nearby Dinorwic slate quarry, similar mineralization is accompanied by abundant epidote, and the dyke rocks are epidotized (Bevins and Mason, 1998). In places, these veins have undergone post-emplacement deformation. Subsequent carbonate mineralization resulted in the crystallization of siderite, which forms brown, rhombohedral crystals and is overgrown by scalenohedral calcite. This assemblage shows no evidence for deformation.

Copper mineralization occurs in analogous settings at other slate quarries in the Dinorwic area, but is particularly well-developed at Penrhyn Quarry. It comprises massive chalcocite (up to several centimetres across), which fills voids and cracks in both earlier assemblages. Bornite has also been reported as a component of the copper mineralization (Bevins, 1994), but is extremely rare. In polished section, alteration along cracks in the chalcocite to covellite is a frequent feature, but the most obvious alteration product is chrysocolla. This forms typically sky-blue to greenish-blue, massive replacements of chalcocite, with occasional botryoidal developments lining fractures. Malachite is also present, but in much lesser amounts. There is also a report of the vanadium-copper supergene mineral calciovolborthite from this area (Bevins, 1994), but the occurrence, represented by a single specimen in a private mineral collection, requires verification.

Interpretation

The varied mineral assemblages hosted by fractures within the boudinaged basic dykes at Penrhyn Quarry are indicative of a multi-phase history of localized fracturing associated with fluid migration. The earliest assemblage, comprising quartz-chlorite-albite-specular hematite (with, additionally, epidote at similar localities nearby), represents the initial, syn-deformational, ladder-vein development as those dykes aligned at a high angle to the maximum (north-west-southeast) compressive stress field were boudinaged. Deformation of this early assemblage clearly indicates

that it formed during incremental deformation, so that those phases which crystallized earliest were subsequently deformed as the compressive process continued.

This early assemblage bears some resemblances to the 'Alpine-type' vein mineralization which is particularly common in the Ffestiniog–Porthmadog belt. The key difference is the presence of specular hematite, although hematite of a similar habit is of frequent occurrence in the analogous Alpine Fissures of the Alps. However, the Penrhyn veins were formed in different lithologics and at a deeper structural level to those of the Ffestiniog–Porthmadog area, so such a difference is perhaps not particularly significant in genetic terms. What both occurrences share is that the mineral assemblages are interpreted as having been derived locally with relatively restricted circulation of mineralizing fluids.

The carbonate mineralization is of uncertain origin and is again restricted to the dykes. The delicate, undamaged calcite scalenohedra overgrowing siderite are perhaps suggestive that this assemblage post-dates the Acadian compression. However, there is nothing similar in the Immediate district to compare with this phase of mineralization; hence its exact genesis remains unclear.

The abundant chalcocite mineralization is of particular metallogenic interest. Chalcocite, the only major species present, is generally regarded as a secondary alteration product of primary chalcopyrite. However, detailed examination of mineralization at Penrhyn Quarry has failed to detect any chalcopyrite, both in hand specimen and polished section, while bornite is present only in trace amounts. Typically, as at the Dolyhir Quarry and Llechweddhelyg Mine GCR sites, supergene chalcocite contains numerous patches of bornite surrounding the remnant hypogene chalcopyrite. No such texture has been observed at Penrhyn Quarry, which raises the likelihood that the chalcocite may have an unusual primary genesis. This is re-inforced by the observation that supergene conversion of chalcopyrite to chalcocite in the nearby, pre-Acadian, Snowdonia copper veins is at most only superficial in nature.

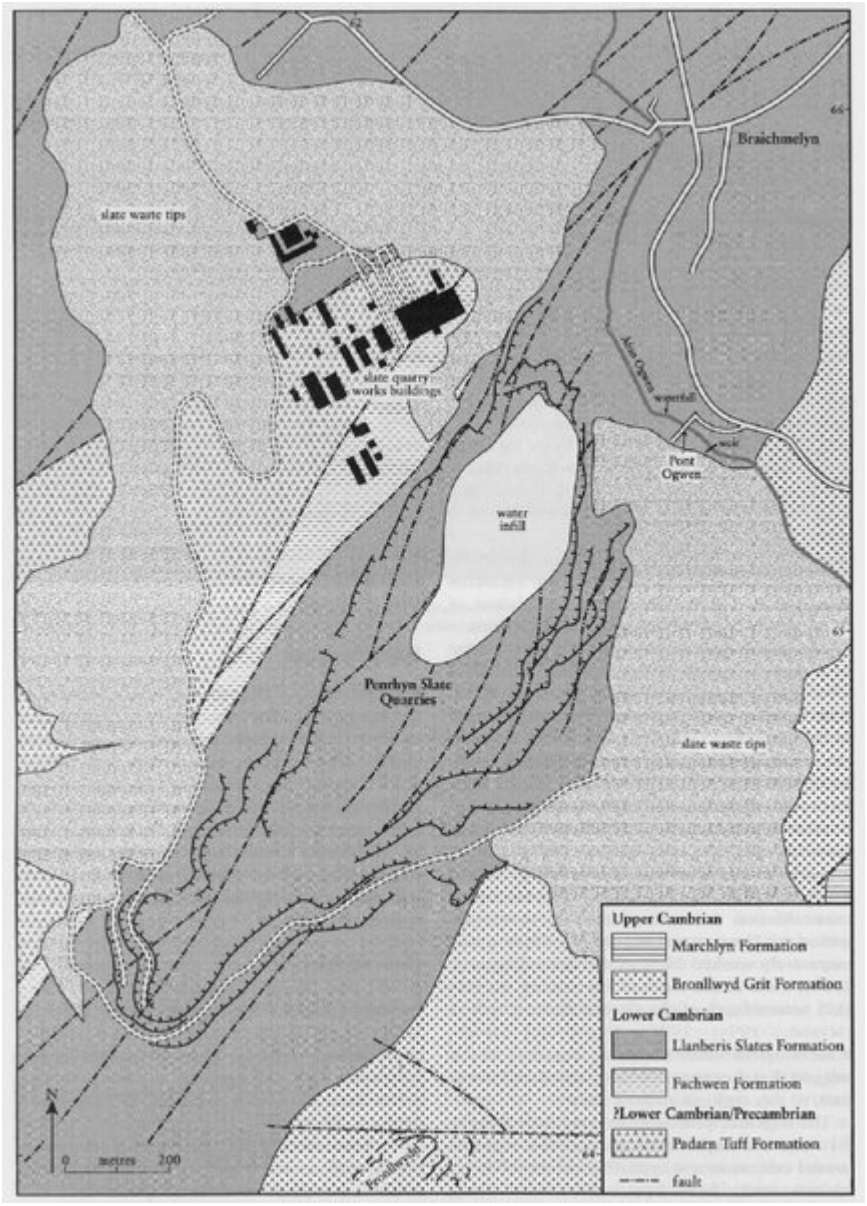
Alteration of primary chalcopyrite to malachite, chrysocolla and other minerals is of frequent occurrence through the Welsh Caledonides (e.g. at the Llechweddhelyg Mine GCR site). At Penrhyn Quarry, this type of supergene alteration has affected the chalcocite. The sequence of veining by covellite and replacement by chrysocolla and malachite is interpreted as being the product of prolonged oxidation of sulphides by groundwaters during deep weathering which affected the area in Tertiary times (Mason, 2004). The supergene alteration occurs at all levels of the quarry, over a considerable vertical distance, reflecting the fact that the pervasively fractured basic dykes acted as particularly permeable zones relative to the impermeable slates, and thus provided access for oxidizing groundwaters to the chalcocite. If this oxidation process took place during Tertiary times, then the implication is that the chalcocite had been deposited some time prior to this but after the Acadian deformation.

There appears to be no direct analogy to this occurrence of dyke-hosted chalcocite mineralization elsewhere in Great Britain. In other areas in or around the Welsh Caledonides where significant chalcocite is present, such as in south-west Shropshire (Smith, 1922), and the Dolyhir Quarry GCR site, there is almost always clear evidence that it formed due to the in-situ alteration of chalcopyrite. This is not the case at Penrhyn Quarry, and for the present, the genesis of the chalcocite mineralization remains unresolved.

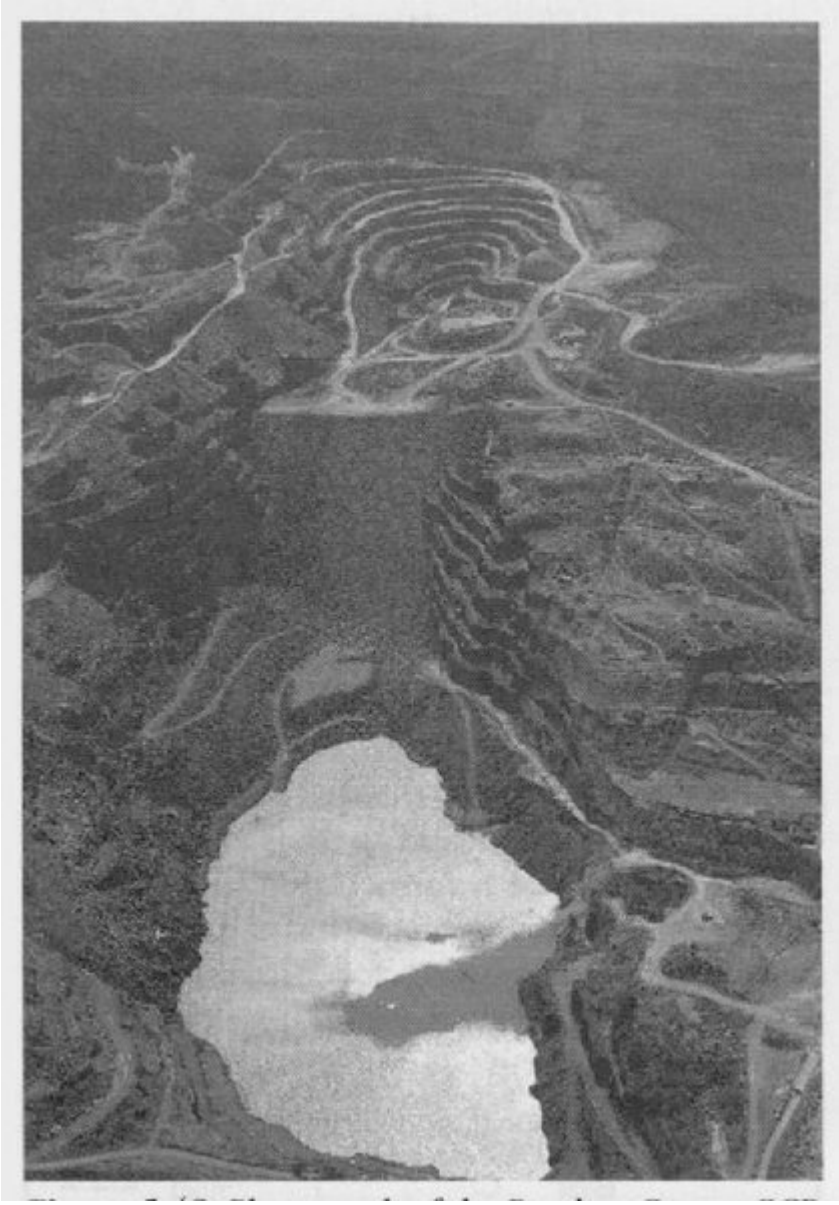
Conclusions

Mineralization associated with basic intrusions cutting slates at Penrhyn Quarry is multiphase and was controlled by the dominant geological structures. Quartz-chlorite-specular hematite-albite veins were deposited in the neck-zones of boudins as the dykes were subjected to compressive deformation. This was followed by carbonate mineralization, precipitating siderite and calcite, which was overprinted in turn by locally intense chalcocite mineralization, the genesis of which remains uncertain. The chalcocite has commonly been altered to chrysocolla.

References



(Figure 5.47) Map of the Penrhyn Quarry GCR site. After British Geological Survey 1:50 000 Sheet 106, Bangor (1985a).



(Figure 5.48) Photograph of the Penrhyn Quarry GCR site. (Photo: Crown copyright: Royal CoFigure