Bryn-Coch and Capel Hermon

[SH 744 246], [SH 748 253]

Introduction

The existence of low-grade, disseminated mineralization in the Coed y Brenin area had been remarked upon by Ramsay (1881), but it was nearly a century later, following a systematic and detailed modern exploration programme, that drill targets were established. The drilling, often through thick drift, proved a zone of potentially ore-grade copper mineralization, comprising about 200 million tons grading at 0.3% Cu, with accessory molybdenum and low-grade gold (Rice and Sharp, 1976). Such an orebody could only be worked by open-pit methods, and the economic grade of the deposit, coupled with strict planning regulations in this area, lying as it does within the Snowdonia National Park, make it unlikely that the deposit will ever be exploited commercially.

These closely adjacent GCR sites (Figure 5.11) provide the best opportunity to study the essential aspects of the Coed y Brenin porphyry copper mineralization. Despite its large size, this mineral deposit is poorly exposed, and these forestry road cuttings represent the best examples of porphyry copper mineralization in Great Britain, a deposit that is unusually old (early Ordovician) in global terms. Bryn-Coch is in fact a marginal area to the main Coed y Brenin orebody as defined by Riofinex in the 1970s (Rice and Sharp, 1976), but is of similar grade. At Capel Hermon, the mineralization has been extensively altered by supergene processes, while at Bryn-Coch it may be examined in its unweathered state. The Capel Hermon site was cleared of fallen talus through the courtesy of Forest Enterprise in 1998 and exposure was vastly improved (Figure 5.12). During this clearing operation, the occurrence of the rare copper arsenate tyrolite was noted and subsequently confirmed by X-ray diffraction analysis (authors' unpublished data and also Armstrong *et al.,* 2003).

Description

Low-grade, disseminated copper sulphide mineralization pervades altered microtonalite belonging to the Afon Wen Intrusive Complex of Tremadoc age (Allen *et al.,* 1976). The intrusive complex is related to the nearby Rhobell Fawr subaerial volcano, which was active in Tremadoc times (Kokelaar, 1979). This episode of calc-alkaline volcanism is expressed at surface predominantly by flow-brecciated, basaltic to andesitic lavas and tuffs, as at the *Rhobell Fawr* GCR site (Stephenson *et al.,* 1999). Much of the Rhobell Fawr volcanic sequence has been removed by post-Tremadoc erosion, but the associated intrusions are distributed widely in the Cambrian strata in the Harlech Dome region, particularly around its southern and eastern flanks, in the broad tract of ground referred to as the 'Dolgellau Gold-belt' (see elsewhere in this chapter).

The Afon Wen Intrusive Complex is a N–S-trending suite of intrusions of intermediate composition reaching up to 500 m in total thickness. The complex is generally hosted in a concordant manner within sedimentary rocks of the Upper Cambrian Ffestiniog Flags Formation, but the presence of a discordant, lower section, possibly representing a feeder passing through the Maentwrog and Clogau formations, was indicated by Allen and Jackson (1985). Xenoliths and raft-like masses of sediment are common, especially towards the eastern margin of the complex, where the contact consists of interfingered intrusive and sedimentary rocks. The western contact is steeply dipping and relatively sharp, a feature taken by Rice and Sharp (1976) to indicate 'forceful emplacement'.

Three principal types of intrusive igneous rocks, all hornblende-bearing diorites, were identified within the Afon Wen Intrusive Complex and described by Rice and Sharp (1976) following the Riofinex exploration programme. Further work by Allen and Jackson (1985) classified the rocks making up the complex as either quartz-microdiorite or microtonalite, both porphyritic in places. Rice and Sharp (1976) considered their 'older diorite' to be the most significant component of the complex in terms of its copper content. However, in the field these rocks are difficult to distinguish, due to the degree of alteration and, as with the other Cambrian-hosted intrusions in the area, they are commonly referred to as 'greenstones'.

Alteration of the various rocks of the Afon Wen Intrusive Complex, which is of the propylitic-phyllic-type, has resulted in the development of rocks consisting of relict phenocrysts of plagioclase and amphibole, often wholly pseudomorphed. The plagioclase crystals are usually replaced by albite, chlorite, sericite, calcite and quartz, while the amphibole crystals are replaced typically by chlorite, epidote, calcite, tremolite, sericite, quartz and titanite. The fine-grained, green-grey groundmass consists of a mosaic intergrowth of feldspar, quartz, calcite, chlorite and epidote (Allen and Jackson, 1985). The maximum intensity of copper mineralization occurs along the western edge of the phyllic zone, as identified by Rice and Sharp (1976), which constitutes the inner part of the porphyry copper system. Here, alteration is dominated by relatively high contents of sericite-quartz-carbonate compared relative to the contents of chlorite and epidote, which are more characteristic of the outer propylitic zone of such systems.

Commonly, porphyry copper bodies show a zonation pattern, with a copper-rich centre and a peripheral zone of intense pyritization, and Coed y Brenin conforms to this pattern. Away from the Bryn-Coch and Capel Hermon GCR site, exposures of pyritized intrusive rocks and sedimentary rocks of the Ffestiniog Flags Formation are common along the forest roads, and a fine example occurs on the road leading up to the Moel Hafod-Owen GCR site.

The unweathered primary mineralization of the Coed y Brenin porphyry copper deposit, as exposed at Bryn-Coch, consists of pyrite, accompanied by chalcopyrite, both of which occur as thin veinlets (< 1 mm wide) and as fine disseminations in the host rock. Thin quartz-carbonate veins, generally no more than 1–2 cm in width, occur along joints in the host rock but are laterally impersistent. These carry, in addition to pyrite and- chalcopyrite, minor quantities of molybdenite (Rice and Sharp, 1976), and, in the exposure at Capel Hermon, lesser quantities of bornite and tennantite (Armstrong *et al.,* 2003). Molybdenite also occurs as thin, dark-grey, metallic smears on otherwise unmineralized joint-planes, and molybdenum concentrations are in the range 30–50 ppm. Gold is present at low levels (*c.* 0.1 ppm) and its paragenesis is uncertain. All of these ore mineral occurrences are typical of porphyry copper mineralization. Secondary malachite and covellite are locally conspicuous at Bryn-Coch, but are more abundant at Capel Hermon, where a layer enriched in supergene malachite can be seen at the base of the soil profile. In the Capel Hermon exposure, rare azurite and tyrolite (Armstrong *et al.,* 2003) also occur, the latter forming silky blue fans of lath-like micro-crystals to *c. 1* mm, being an alteration product of tennantite.

Interpretation

The Coed y Brenin deposit, although often cited as the best example of porphyry copper mineralization in the British Isles sector of the Caledonian–Appalachian orogen (e.g. Rice, 1993), is problematic in that in some aspects it does not fit readily into current classification schemes for this important global type of ore deposit. In its setting, ore mineralogy and ore mineral textures, Coed y Brenin is typical of the porphyry copper style of mineralization. However, aspects of alteration assemblages, fluid-inclusion character, host-rock geochemistry and isotopic compositions of the sulphides and alteration phases sometimes conflict, perhaps due to the age of the deposit and the variety of processes that have affected the deposit since its formation. An example of this disparity relates to the K-Ar data obtained from micas in the deposit (Allen and Jackson, 1985), which yield two age populations, namely 409 ± 7 Ma and 374 ± 5 Ma. These ages are too young to be compatible with the geological age of the deposit obtained direct from geological constraints, and therefore must represent later resetting events, during which argon-loss occurred from the micas. A mineral deposit in which such resetting has occurred is likely to have been affected by events resulting in increased temperatures and/or stress, and it is clearly possible that such events could also cause overprinting of other aspects of the deposit.

Fluid-inclusion research by Shepherd and Allen (1985) has shown that sulphide-bearing quartz veins within the porphyry copper deposit were deposited from low-salinity (mean = 8 wt% NaCl equivalent), hot (160°–280°C) fluids, but data from minor quartz veinlets and fractured quartz phenocrysts led Shepherd and Allen (1985) to conclude that the initial Cu-Mo mineralization was deposited from relatively high-temperature, saline fluids. The effects of this initial high-temperature mineralization were subsequently overprinted by retrograde phyllic alteration as the intrusions cooled and the surrounding meteoric convective system collapsed inwards.

Conventionally, a magmatic fluid input is to be expected as an integral part of the process leading to porphyry copper deposit formation. In the case of Coed y Brenin, recent research (Miller *et al.,* 1992), involving a study of oxygen isotope distributions in quartz, has suggested that this may not be the case: $\delta^{18}O$ values from quartz veins within the deposit show a narrow range of values between +10.3‰ and +13.2‰ (SMOW), while combined oxygen and fluid-inclusion data indicate an original $\delta^{18}O$ for the mineralizing fluid of –3.5‰ to 0.0‰ (SMOW). These values, close to those that would be expected for meteoric hydrothermal waters, led Miller *et al.* (1992) to conclude that 'there is clearly no evidence for the involvement of magmatic fluids' in the porphyry copper mineralization.

However, caution is necessary in the selection of mineral samples for isotopic and fluid-inclusion studies, and in particular the paragenetic position of the sample selected should be established without doubt (Mason, 1997). This is a critical factor with quartz veins in a province such as the Dolgellau Gold-belt, which has been subjected to multiple phases of mineralization, regional metamorphism and deformation. In addition to the porphyry-type mineralization, the Coed y Brenin area is rich in gold-belt veins (this volume), which have recently been shown to be of pre-Acadian age (Mason *et al.,* 1999), and which occur on all scales, from veinlets through to massive quartz sulphide lodes, such as that mined at Dolfrwynog. In addition, there are widespread white quartz-filled gashes which formed at an early stage in the metamorphism and deformation of both intrusive rocks and gold-belt veins, the so-called 'Late-Quartz Veins' of Platten and Dominy (1999), which also locally contain carbonates, sericite, epidote and sulphides. To identify quartz veins which can be confidently associated genetically with the porphyry copper mineralization, rather than with later events, is a difficult problem, which is well illustrated at these two sites.

Data which perhaps better reflect the characteristics of the fluids responsible for the Cu-Mo mineralization were obtained from sulphur isotope analysis in samples of chalcopyrite, pyrite and molybdenite, minerals genetically associated with the porphyry copper mineralization (Miller *et al.,* 1991). Values of $\delta^{34}S$ from these minerals have a range from +1.1‰ to +9.7‰, which are broadly similar to those from sulphides in the Dolgellau Gold-belt veins of –2.5‰ to +11.0‰ (Bottrell and Spiro, 1988). The sulphur isotope data obtained by Miller *et al.* (1991) were interpreted as representing the mixing of fluids containing light igneous and heavy sedimentary sulphur. This would be expected in a hydrothermal system in which permeable elastic sediments were intruded by high-level magmas; the resultant convective cell or cells would allow both late magmatic and abundant meteoric waters to mix and circulate through the sediments and intrusives, mobilizing and re-distributing metalliferous minerals into concentrated ore-zones.

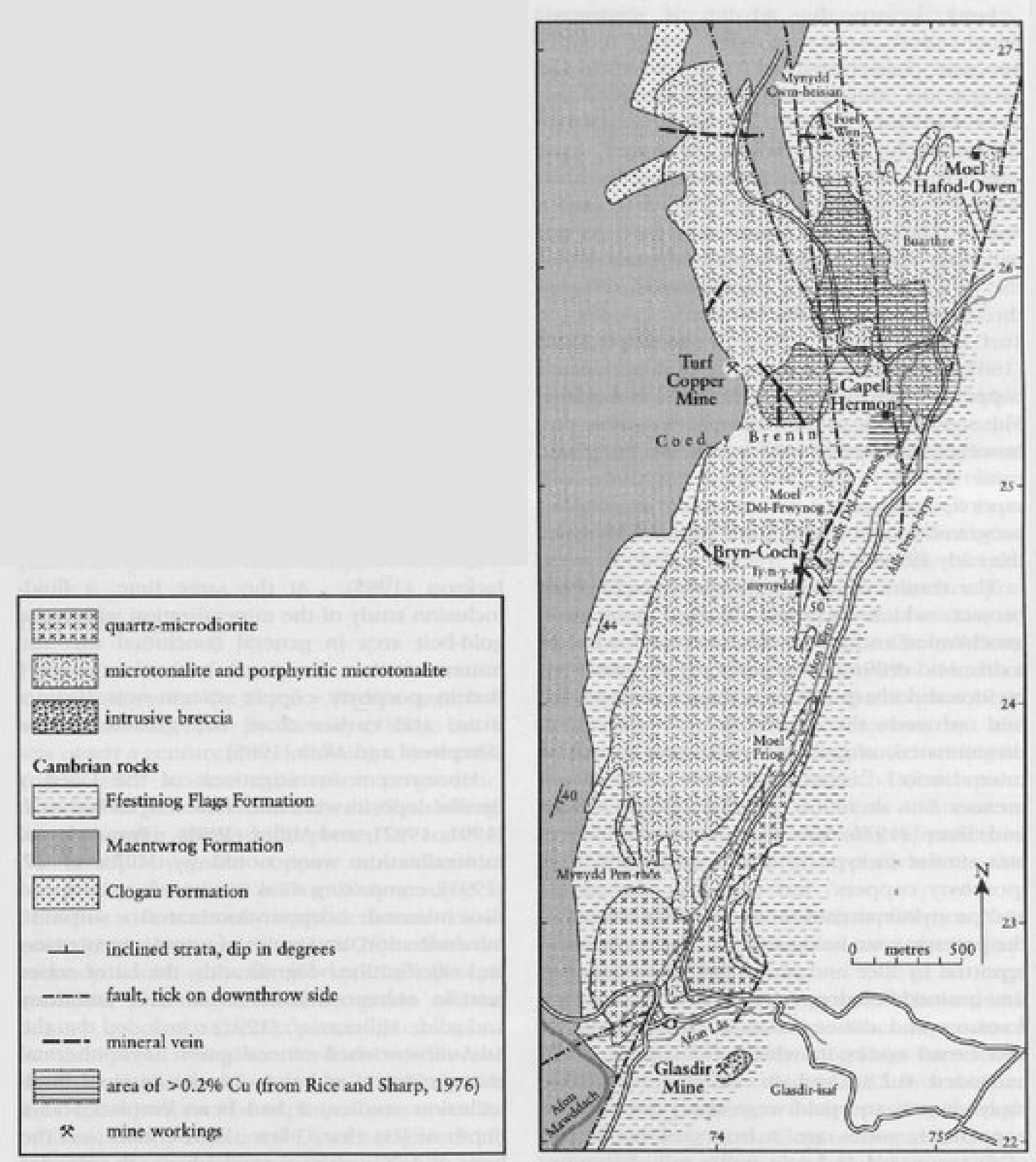
In other parts of the world, zones of supergene enrichment often occur in the upper parts of porphyry copper deposits and carry particularly valuable ore-grades. At Coed y Brenin this zone is missing, and Allen and Jackson (1985) suggested that it was presumably eroded away during Pleistocene glacial activity. This assertion is strongly supported by the occurrence of rare nuggets (up to *c.* 2 cm) of intergrown native copper and cuprite, among the other placer minerals, in the drift-derived alluvium of the Afon Wen, downstream from the porphyry copper deposit U.S. Mason, unpublished data). Post-Pleistocene supergene processes have superficially affected the deposit in places, such as at the Bryn-Coch and Capel Hermon GCR site, where malachite is present; conditions were clearly less favourable for azurite crystallization. The alteration of tennantite to tyrolite is remarkably similar in style to the supergene mineralization at the Dolyhir Quarry GCR site (this chapter), although at Coed y Brenin the supergene assemblage is much simpler.

The continuing supergene mobilization of copper is evident from the geochemistry of stream waters in the area (Rice and Sharp, 1976), and is well illustrated by the Turf Copper Mine GCR site, where copper in the native form has been precipitated in the near-surface environment in a peat bog, where the copper replaces organic matter.

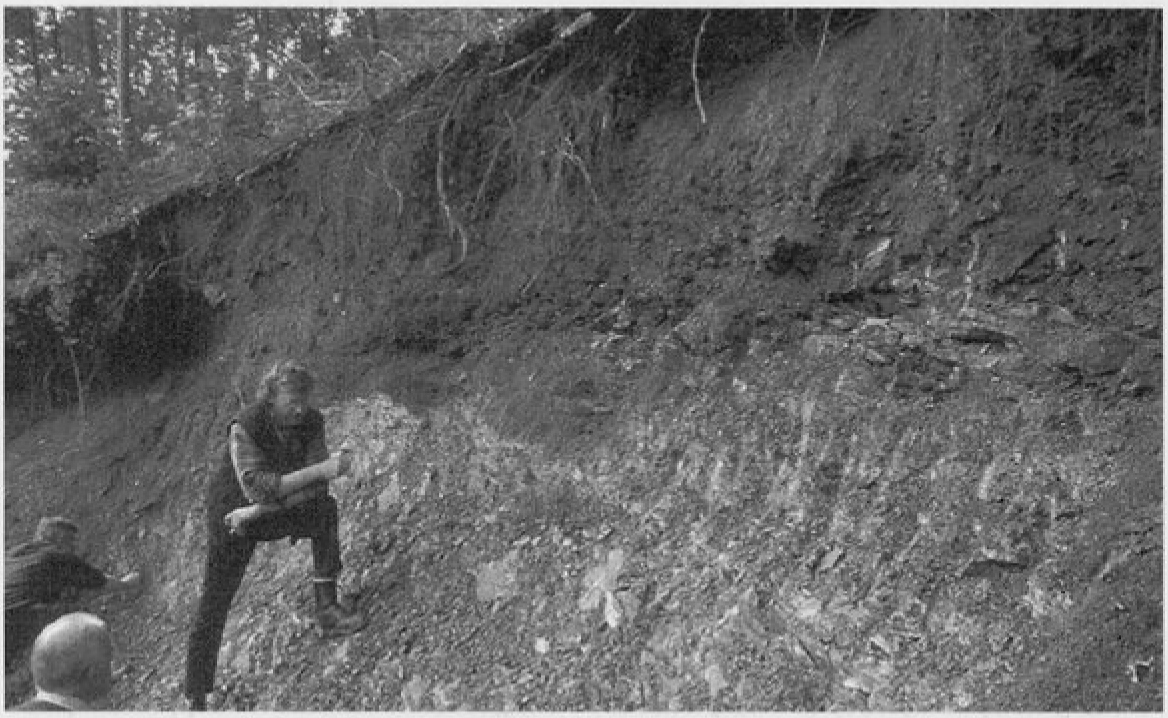
Conclusions

The Coed y Brenin porphyry copper deposit, excellently exposed at the Bryn-Coch and Capel Hermon GCR site, is of particular interest since it represents a relatively ancient example of this style of mineralization and is the finest example of such a deposit in Great Britain. As a result of its antiquity, the deposit has been affected by a variety of post-mineralization processes. These include the overprinting of primary assemblages, further episodes of mineralization, regional low-grade metamorphism and deformation.

References



(Figure 5.11) Map of the Coed y Brenin porphyry copper system, showing the localities of the Moe! Hafod-Owen, Thrf Copper Mine, Glasdir Mine, and Bryn-Coch and Cape Hermon GCR sites. After Allen et al. (1976).



(Figure 5.12) *Photograph of an exposure of mineralization in the Coed y Brenin porphyry copper system in a forestry track cutting near Capel Harmon, at Capel Hermon. (Photo: R.E. Bevins.)*