Coed y Brenin Porphyry Copper System

The Coed y Brenin disseminated copper deposit, with its associated breccia pipes, constitutes the best-known example of a porphyry copper system within the British Caledonides and is one of the oldest known examples of this class of deposit worldwide. Various styles of mineralization occur at different structural levels within the system, from mesothermal disseminated Cu-Mo-Au occurring mainly in intrusive rocks, up to high-level, epithermal Au-As-Sb-enriched assemblages occurring in breccia pipes emplaced in the overlying sedimentary succession. It has now been shown that these deposits are all linked genetically.

The Coed y Brenin porphyry copper system lies within the Dolgellau Gold-belt, and comprises the area in, and to the north of, the NE–SW-trending, fault-controlled Afon Wen valley, which is situated approximately 8 km to the NNE of Dolgellau (Figure 5.11). Copper has long been mined in the area, from the numerous 'gold-belt'-type veins (this volume) that are present, and which occasionally carry workable quantities of chalcopyrite, with local, rich concentrations of gold. Alluvial gold has historically been won from the gravels of the Afon Wen (Hall, 1990), while the most important copper producer in the first half of the 19th century was a group of workings situated about the hamlet of Capel Hermon, known as the 'Dolfrwynog Mine'. Several rich pockets of gold were discovered at this site in the 1850s (Hall, 1990), but mining had ceased by the end of the 1860s. However, by this time, the much bigger Glasdir copper deposit was being opened up. At the time, Glasdir was regarded as a 'lode' deposit, and it produced significant quantities of copper and gold in the late 19th and early 20th centuries.

The first allusion to the presence of a much larger disseminated copper deposit in Coed y Brenin came from the observations of Ramsay (1866), who investigated strongly enhanced copper levels in a peat deposit known as the 'Turf Copper' Mine, situated between the valleys of the Afon Wen and Afon Mawddach. This site is unique in the British Isles, in that copper-rich peat was exploited by stripping, burning in a kiln and smelting of the ashes thereby obtained. Operations were chiefly conducted in the early 19th century and were highly profitable at times. The richest 'ore' contained leaves and acorns that had been replaced by native copper (Henwood, 1856).

Long before the advent of systematic geochemical surveying, this major copper anomaly had attracted the attention of prospectors, and Ramsay (1866) remarked that there had been a great deal of exploration in the vicinity for the 'great lode, or bunch', from which the copper salts had supposedly been leached. However, he concluded that such a lode probably did not exist: rather, the copper had been derived from 'the minute quantities of the sulphide that are more-or-less diffused through the mass of the hill that overlooks the Thrf Copper Mine'. Some years later, Hunt (1887) also noted the presence of disseminated copper-bearing minerals in the rocks of the area. The significance of their observations was not, however, followed up for almost 80 years, until Riofinex Ltd, attracted by these old reports, commenced an intensive exploration programme in the area from the mid-1960s to the early 1970s.

The results of the Riofinex Ltd exploration project, which included detailed geological, geochemical and geophysical surveys, leading to a diamond-drilling programme, were presented by Rice and Sharp (1976). These investigations had proved the existence of pervasive, disseminated, copper mineralization in a host microdiorite laccolith with associated metasomatic alteration. The conclusion of Rice and Sharp (1976) was that this mineralization was similar in type to that found in Tertiary 'porphyry coppers', but with only the phyllic and propylitic alteration zones being observed, the potassic zone being absent. The copper was reported by Rice and Sharp (1976) to occur as fine-grained chalcopyrite blebs in hairline fractures and disseminations, concentrated in two broad zones in which the copper grade exceeded 0.2%, and in which recoverable molybdenum and gold were also present. The copper-rich zones are surrounded by a halo of disseminated and vein pyrite mineralization. Rare secondary copper minerals, principally malachite, were also recorded. However, due to a combination of environmental and economic factors, the deposit has remained unworked.

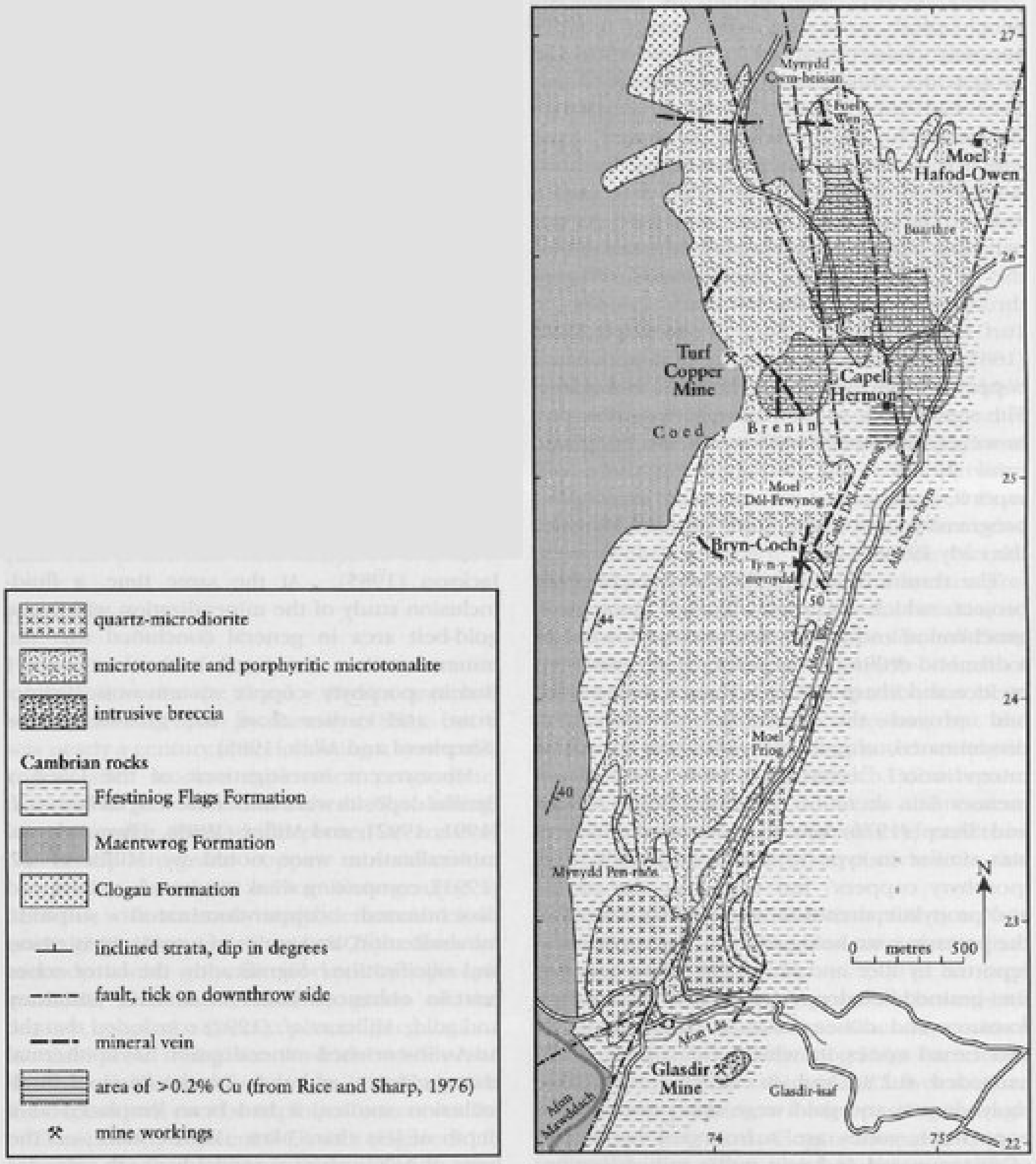
Allen *et al.* (1976) provided geochemical evidence that showed that all of the microdiorites in the Coed y Brenin area, which they grouped together as the 'Afon Wen Intrusive Complex', have high Cu contents. Geochemical data presented by Allen *et al.* (1976) indicated genesis of the magmas in an island-arc system, and that the intrusions could be correlated with the Rhobell Volcanic Group, of Tremadoc age. Further investigations by Allen *et al.* (1979) showed the extent of microdiorite-hosted copper mineralization to be greater than previously reported, not only to the north and south, but also over the discordant feeder to the intrusive complex.

The intensive research undertaken in the Coed y Brenin area during the 1970s also included a re-interpretation of the Glasdir deposit (Allen and Easterbrook, 1978). The 'lode' at Glasdir was described by Allen and Easterbrook (1978) as a disseminated sulphide deposit occurring at the margin of a breccia pipe intruded into the Upper Cambrian Ffestiniog Flags Formation, the ore-grade zone taking the form of a flattened, inverted cone. A number of other, similar but unmineralized, breccia pipes were also described from the area by Allen and Jackson (1985). At the same time, a fluid-inclusion study of the mineralization within the gold-belt area in general concluded that the mineralization associated with the Coed y Brenin porphyry copper system was distinct from, and earlier than, the gold-belt veins (Shepherd and Allen, 1985).

More-recent investigations of the Coed y Brenin deposits were undertaken by Miller *et al.* (1991, 1992), and Miller (1993). Two styles of mineralization were noted by Miller *et al.* (1991), comprising weak stockwork, veinlet and disseminated copper-dominated sulphide mineralization, and zones of intense pyritization and silicification. Significantly, the latter zones contain enhanced levels of arsenic, antimony and gold. Miller *et al.* (1992) concluded that the Au-As-Sb-enriched mineralization has epithermal characteristics, and that, on the basis of fluid-inclusion studies, it had been emplaced at a depth of less than 3 km. Furthermore, on the basis of 8^{18}O values, a model for both episodes of mineralization was proposed, involving the convective circulation of meteoric, as opposed to magmatic, waters.

Four GCR sites represent the disseminated, porphyry-type copper deposit, its genetically related mesothermal to epithermal representatives, and its geochemical effects (see (Figure 5.11)). The porphyry-type mineralization can be seen in its unweathered state at Bryn-Coch, while ore-grade mineralization that has undergone moderate supergene alteration is exposed at the closely adjacent Capel Hermon area; these two areas together comprise the Bryn-Coch and Capel Hermon GCR site. At the Glasdir Mine GCR site, copper mineralization occurs in a contemporary volcanic explosion breccia pipe, while at a high structural level, epithermal Au-As-Sb-enriched pyrite mineralization in a siliceous sinter-like environment is magnificently exposed at the Moel Hafod-Owen GCR site. Finally, the remobilization and reprecipitation of copper in the near-surface environment in Holocene times is demonstrated at the Turf Copper Mine GCR site. This network of sites is unique in the British Isles, and superbly demonstrates the range of primary and secondary mineral deposits associated with a porphyry copper deposit and its subsequent alteration.

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).