Mineralization associated with Caradoc igneous activity in North Wales

A range of mineralization occurs in North Wales in direct association with volcanic, pyroclastic and intrusive rocks of Caradoc age (Reedman *et al.,* 1985; Howells *et al.,* 1991). Vein mineralization exposed in and around the Snowdon massif is linked to the development of a caldera which was associated with eruption of a thick volcanic sequence of bimodal acid-basic composition (Figure 5.23) and (Figure 5.24). Away from the caldera, a number of other, relatively minor mineral deposits occur in association with Caradoc volcanic rocks, although a major volcanogenic massive sulphide (VMS) deposit is present on Anglesey in a succession of probable early Silurian age.

Vein-hosted mineralization, occurring in and around the Snowdon Caldera of Caradoc age, has been mined historically, predominantly for copper but also locally for lead and arsenic (Bick, 1982). Four types of vein deposits occur in the area. The most important in economic terms is a major series of quartz-sulphide-bearing veins, developed in a setting that implies a genetic association with the caldera development (Reedman *et al.,* W85). This mineralization may be subdivided Into two classes, represented by two GCR sites. Firstly, within the caldera-fill, the veins carry pyrite, pyrrhotite, chalcopyrite, galena, sphalerite and bismuth minerals, as seen at the Lliwedd Mine GCR site. Secondly, within older Lower Palaeozoic sedimentary rocks peripheral to the caldera there is a belt of veins of similar mineralogy, but with far more abundant pyrrhotite as well as substantial arsenopyrite, represented by the Llanberis Mine GCR site.

Within the caldera, magnetite-hematite veins and breccia cements, with only minor sulphide content, represent a second type of mineralization. These veins carry minor scheelite and cassiterite, as seen at the Cwm Tregalan–Shadow Gully GCR site. Thirdly, an isolated but extremely unusual vein, outcropping to the west of the caldera at the margin of the Mynydd Mawr microgranite and tried at the Llyn Cwellyn Mine GCR site, contains fluorite and an associated quartz-carbonate-chalcopyrite-dominated assemblage which includes a number of rare, as yet undetermined, telluride minerals. The fourth type of vein mineralization consists of regional, probably Variscan, crustiform fissure- fill calcite-marcasite veins, although no site shows sufficient genetic importance to warrant GCR status.

The Snowdon Caldera developed in mid-Ordovician times (Howells *et al.,* 1991) within an ensialic back-arc setting (Kokelaar *et al.,* 1984). The products of extensive volcanic activity were deposited within a marine basin in which the predominant pattern of sedimentation involved the accumulation of fine- to coarse-grained siliciclastic sequences. Initial volcanism resulted in the deposition of the Llewelyn Volcanic Group (the '1st Eruptive Cycle' of Howells *et al.,* 1991), which crops out to the north and east of Snowdon. This consists of a number of localized acid to basic volcanic deposits, derived from a set of eruptive centres, with associated intrusive rocks, again with a wide compositional range. Welded ash-flow tuffs in the upper part of the sequence are interpreted as having been erupted subaerially to the north of the area, flowing southward to encounter a marine depositional environment (Howells and Leveridge, 1980: Howells *et al.,* 1985, 1991).

The Snowdon Volcanic Group (the '2nd Eruptive Cycle' of Howells *et al.,* 1991), with which the metalliferous mineralization is genetically linked, is separated from the Llewelyn Volcanic Group by a thick sequence of marine elastic sedimentary rocks. The coarsening of this sequence towards the top indicates a gradual shallowing of the sea immediately prior to the onset of volcanism. At the base of the volcanic sequence, basaltic pillow lavas and hyaloclastites are indicative of submarine eruption.

The Snowdon Volcanic Group is strongly bimodal, lacking the intermediate compositions present in the Llewelyn Volcanic Group. Associated intrusives include dolerites, rhyolites and microgranites, and the volcanic rocks are either acidic or basic. Early major acidic volcanism led to the eruption of the Lower Rhyolitic Tuff Formation. This comprises acidic ash-flow tuffs, rhyolite lavas, and marine sedimentary rocks including slumped or reworked tuffs. The sequence is interpreted (Reedman *et al.,* 1985) as the products of a massive eruptive event involving the production of approximately 60 km^3 of ash-flow tuffs and their ponding within a volcanotectonic depression termed the 'Lower Rhyolitic Tuff Caldera'. The caldera had an estimated surface area of 130 m^2 and was asymmetrical, with the greatest subsidence in the north, where almost 500 m of ash-flow tuffs accumulated. Subsidence, controlled by faulting, occurred primarily around the caldera margin and along a NE–SW-trending apical graben (Beavon, 1980). The lack of intercalated sedimentary rocks within the Lower Rhyolitic Tuff Formation indicates that it was deposited from effectively continuous volcanic activity.

After a break in activity, caldera resurgence occurred with the eruption of the basic volcanic rocks which comprise the Bedded Pyroclastic Formation, consisting of basaltic lavas, hyaloclastites and basic tuffs with associated volcaniclastic rocks containing a shallow-water shelly marine fauna (Reedman *et al.,* 1985; Kokelaar, 1992). Rhyolite domes, representing waning acidic activity and indicating the availability of both acid and basic magmas to the system at this time, locally intruded the Bedded Pyroclastic Formation. Acidic activity finally returned with the eruption of the Upper Rhyolitic Tuff Formation. Following the final cessation of volcanism, the area returned to an environment of marine elastic sedimentation.

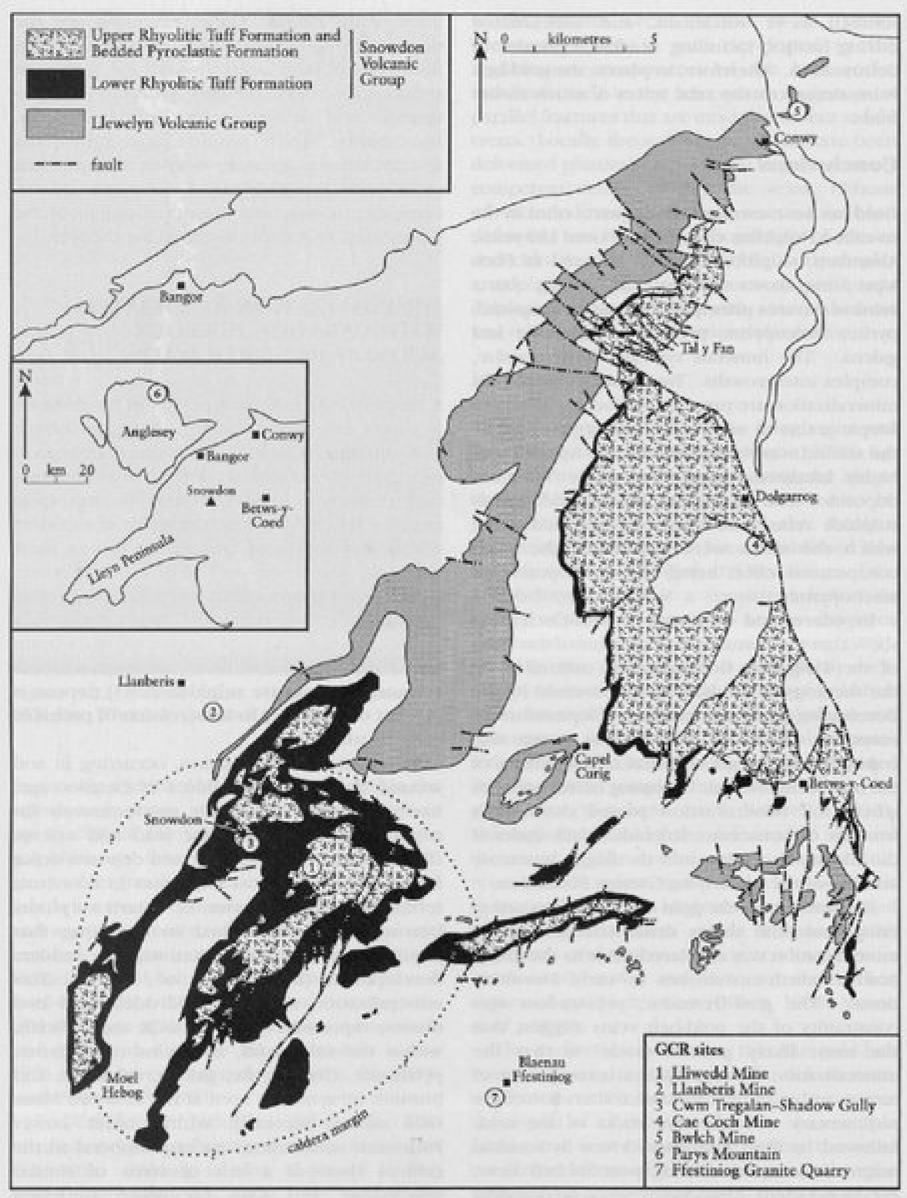
The various volcanic and sedimentary rocks underwent Acadian deformation in early to mid-Devonian times, and were folded along a northeast-south-west axial trend, with an associated axial planar cleavage. Metamorphism to lowermost greenschist facies occurred at some time prior to final deformation (Bevins and Robinson, 1988). In addition, with the exception of the crustiform fissure-fill veins, the mineralization was emplaced prior to Acadian deformation, as there is clear evidence for vein deformation (Fitches, 1987).

To the north of Snowdonia, at the Bwlch Mine GCR site, near Llandudno, an unusual mineral deposit comprising thin veinlets containing sulphantimonide mineralization occurs in highly silicified, nodular ash-flow tuffs of the Llewelyn Volcanic Group. A number of rare antimony-bearing minerals are present.

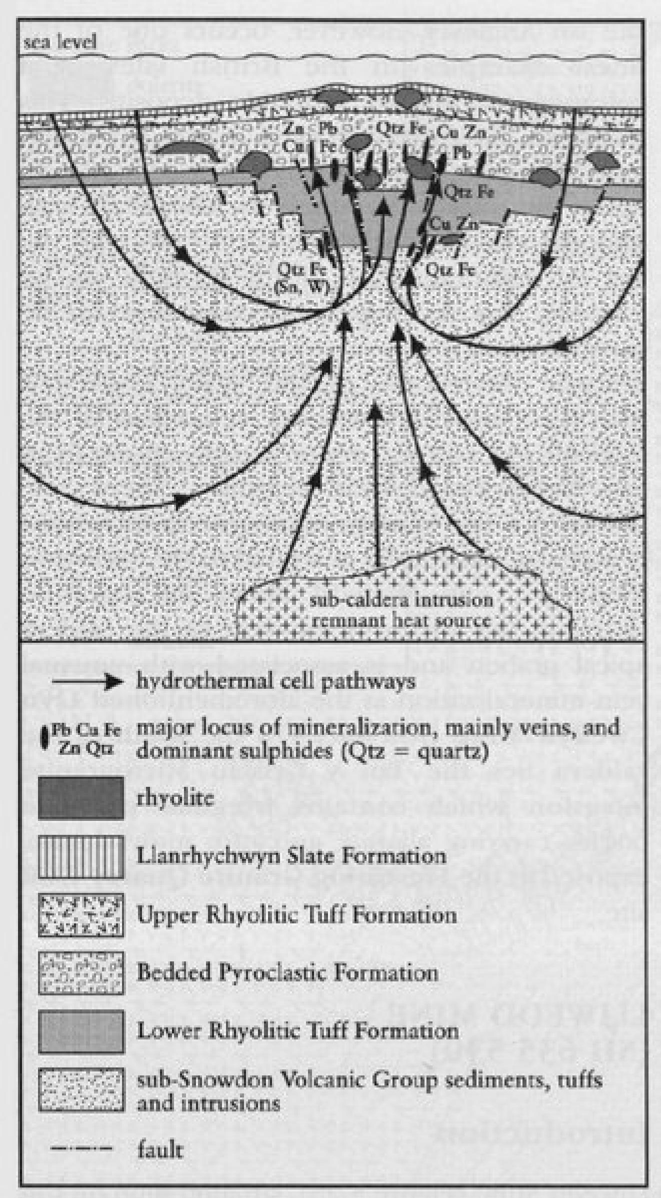
At the Cae Coch Mine GCR site a massive stratiform pyrite orebody occurring in black mudstones associated with basic lavas and tuffs is thought to represent contemporary volcanic exhalative mineralization, although an alternative syn-diagenetic fluid inhalation model has been proposed. At the Parys Mountain GCR site on Anglesey, however, occurs one of the finest examples in the British Isles of a volcanogenic massive sulphide deposit. This has been extensively worked, partly by underground mining and partly by opencast methods. Again the deposit is intimately associated with bimodal acid-basic volcanic rocks, although the age of mineralization, long thought to be Caradoc, has recently been considered to be early Silurian.

Large intrusions, of the scale associated with the Ordovician volcanic sequences of the English Lake District, are noticeably absent from the Welsh Caledonide region. There are, however, a few smaller microgranite intrusions present in Snowdonia, marginal to the Snowdon Caldera. The Mynydd Mawr microgranite intrusion lies to the north-west of the caldera apical graben and is associated with unusual vein mineralization at the aforementioned Llyn Cwellyn Mine GCR site. To the south of the caldera lies the Tan y Grisiau Microgranite intrusion which contains irregular pipe-like bodies carrying allanite and rare molybdenite, exposed at the Ffestiniog Granite Quarry GCR site.

References



(Figure 5.23) Map showing the distribution of the GCR sites in relation to mineralization associated with the main Snowdon Caldera. After Howells et al. (1991).



(Figure 5.24) Schematic cross-section through the hydrothermal cells responsible for the Snowdon mineralization. After Reedman et al. (1985).