Friog Undercliff

[SH 610 119]

Description

The coastal section running south from the southern end of the beach at Fairbourne, termed the Triog Undercliff', features numerous veins occurring within E-dipping Middle to Upper Cambrian strata on wave-cut platforms and in the water-worn cliff-bases (Figure 5.21). The section comprises, from north to south, pyritic shales and sandstones (Maentwrog Formation), black carbonaceous shales (Clogau Formation), and rhythmically layered semi-distal turbidites with manganiferous segregations (Gamlan Formation). The sedimentary sequence has been intruded by minor sills, generally < 0.5 m in width. These belong to the regional gold-belt suite of intermediate to basic intrusives ('greenstones), all of which have been pervasively hydrothermally altered, with replacement of the primary igneous assemblage by a secondary assemblage of calcite-chlorite-white mica-quartz.

Veins, ranging from millimetre-scale stringers to massive quartz-carbonate ribs > 2 m in width, occur abundantly throughout the section (Figure 5.22). Textures vary from simple ribs of inclusion-free quartz-carbonate to complex ribbon-rock zones in which multiple veins are separated by thin screens of sheared wall-rock. Quartz and calcite (in places manganoan) are accompanied by abundant sericite and chlorite. Sulphides are patchy in occurrence and are frequently restricted to specific veins within the ribbon-rock zones, where they may constitute up to 20% of the vein content. Typically the sulphides are fine grained. Pyrrhotite is the most widespread species, while sphalerite and galena are locally common. Chalcopyrite, pyrite and arsenopyrite are. infrequent. Both the vein textures and mineralogy are typical of the Dolgellau Gold-belt (see Cefn-Coch Mine and Foel-Ispri Mine GCR site reports, this chapter). Old workings on some of the veins (Anna Maria and Barmouth Consols mines), visible in the cliffs, were driven in search of gold in the 1850s and 1860s (Hall, 1990).

End-Caledonian (Acadian) deformation has resulted in folding, boudinage and cleavage of the veins. Folding is best displayed by the thinner veins aligned at a high angle to cleavage, where trains of buckle folds are common, whereas the thicker veins aligned nearly parallel to cleavage display boudinage. In some of the thicker veins, new quartz has been precipitated in the boudin necks (Mason *et al.,* 1999). Cleavage, which is well developed in the argillaceous components of the host rocks, manifests itself in the vein quartz as groups of parallel fractures that are most prominent at fold crests. Locally, the sedimentary rocks have been deformed plastically around the larger, relatively competent veins. Within the veins, ribbons of included wall-rock have commonly been deformed into thin intra-vein partings of sericite and chlorite that, in profile, frequently display a stylolitic texture. In thin-section, vein quartz displays mosaic textures with strain shadows and other signatures of lattice deformation.

Interpretation

The discovery, in 1997, of the Friog veins and their deformation (Bevins and Mason, 1998) has been a critical factor in constraining the age of the gold-belt veins, previously believed to be post-tectonic with respect to the Acadian deformation. It has now been established that variably developed folding and boudinage of the gold-belt-type veins is a consistent feature in widely separated locations across the area (Mason *et al.,* 1999; Platten and Dominy, 1999). At Friog, the deformation is particularly well-displayed in contrast to that at other gold-belt sites, due to the quality of wave-cut-platform and water-worn exposures. Petrological textures indicative of deformation were formerly noted in vein quartz samples from elsewhere in the gold-belt (Shepherd and Bottrell, 1993), although the cause of the deformation was not discussed. The undeformed, post-tectonic veins that do occur in the Dolgellau Gold-belt form a distinctive regional set, composed of banded, crustiform calcite with marcasite, sphalerite and galena. They tend to have a north–south strike and they cut the earlier, deformed gold-belt veins (Gilbey, 1968; Mason *et al.,* 1999).

The earlier interpretation, that the gold-belt veins were emplaced after Acadian deformation, was based on the fact that the veins cut across the trends of axial traces of folds. An example often cited is at Clogau Mine, where the veins cut

across the axis of an anticline parasitic on the eastern limb of the major north–south Caerdeon Syncline. However, the major N–S-trending fold pattern has been shown (Allen and Jackson, 1985) to represent early folding along N–S-trending structural lines active before the Rhobell Fawr volcanism, and accentuated during further, including Acadian, episodes of deformation. Therefore, in places, the gold-belt veins cut across the axial traces of much earlier folds.

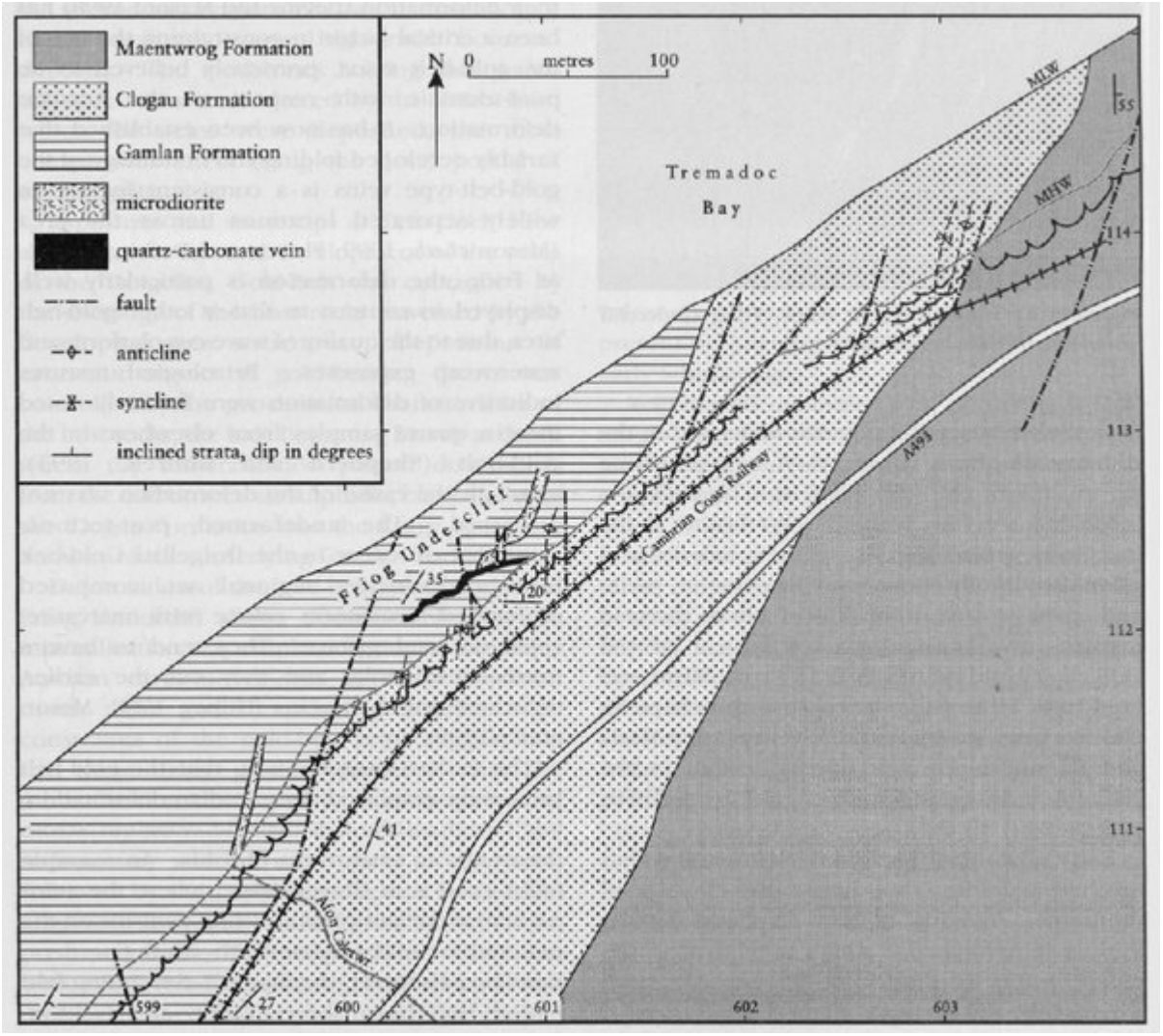
Conclusions

Gold has been extracted from quartz veins in the so-called Dolgellau Gold-belt for over 150 years. Abundant, sulphide-rich vein material at Foel-Ispri Mine shows that the gold-bearing quartz veins of the area principally contain arsenopyrite, pyrite, chalcopyrite, pyrrhotite, sphalerite and galena. The minerals typically form massive, complex intergrowths. Two generations of gold mineralization are present: one occurs as microscopic grains in early pyrite/arsenopyrite while the second was responsible for the formation of highly localized, coarse, high-grade 'bonanza' deposits. The mudstones hosting the quartz-sulphide veins were altered by the fluids from which the veins were deposited, the most conspicuous effect being the development of arsenopyrite.

Exposures and waste tips at Cefn-Coch Mine show that the textural development of the veins of the Dolgellau Gold-belt was controlled by the rheology of the host rocks traversed by the developing vein structures. Deposition of economic shoots of gold-bearing quartz was controlled by the geochemical characteristics of the host rocks, the lode becoming barren at depth where the mineralization passed downwards from the carbonaceous, sulphidic, black-shales of the Clogau Formation into the flaggy, quartzose arenites of the underlying Gamlan Formation.

Deformation of the gold-belt veins exposed at Friog Undercliff shows demonstrably that the mineralization was emplaced prior to the major Acadian earth-movements in early Devonian times. The post-Tremadoc, pre-Acadian age-constraints of the gold-belt veins suggest that the most likely genetic model is that the mineralization developed as a consequence of metamorphic and hydrothermal alteration of the sedimentary and intrusive rocks of the area, followed by fluid migration driven by residual magmatic heat-flow during post-Rhobell Fawr, pre-Arenig uplift. This interpretation is consistent with end-Tremadoc uplift of the Harlech Dome on basement-controlled fractures, which would have produced an extensional stress regime in the Cambrian cover rocks overlying the base ment of the dome. Under extension and the depressurizing caused by uplift and unloading, fluids would have risen through the Cambrian sedimentary rocks, creating hydraulic fracture-systems and depositing the gold-belt veins. Incremental uplift would have repeatedly re-activated the fractures hosting the gold-belt veins, with the addition of successive quartz-sulphide ribbons, and the development of the paragenetic sequence described for the area.

References



(Figure 5.21) Map of the Friog Undercliff GCR site. After Mason et al. (1999).

(Figure 5.22) Folded quartz veins, Friog Undercliff GCR site. (Photo: S. Campbell.)