Dolgellau Gold-Belt

Introduction

Gold is present as an economically significant component of a major series of quartz veins that outcrop in a curved belt of ground to the west and north of Dolgellau, flanking the Harlech Dome. This geographically well-constrained metallogenic province (Figure 5.17) is known as the 'Dolgellau Gold-belt'. The first documented discovery of gold in this part of Wales was in 1843 (Dean, 1845), in contrast to the demonstrably earlier Roman workings at the Dolaucothi Mine GCR site. However, the Romans were active militarily in the Dolgellau Gold-belt area, and a major Roman road, Sam Helen, passes close to a number of gold localities and crosses rivers in which alluvial gold has long been panned (Crew and Musson, 1996).

Initial gold-mining attempts in the early 1850s were met with public scepticism, but following a significant discovery at Clogau Mine, the area experienced a major gold rush, and by 1862 virtually every vein outcrop was being explored, with highly variable results (Hall, 1990). Activity continued apace throughout the latter half of the 19th century and into the early 20th century, during which period 18 mines yielded approximately 4 tons of gold (Hall, 1990), the majority of production coming from the Clogau and Gwynfynydd mines, near Bontddu and Ganllwyd respectively. Production peaked in 1904, when Clogau Mine produced a record 18 417 oz of gold. The area saw a renaissance in 1931, following Britain's abandonment of the gold standard, but mining again declined with the outbreak of the Second World War. More recently, intermittent operations have been centred on the Clogau and Gwynfynydd mines, the gold being entirely used in specialist, provenanced jewellery. Currently, although the mines are all closed,the area is being re-appraised by an exploration company.

The rocks of the Dolgellau Gold-belt comprise marine shallow-water elastic to deeper basinal hemipelagic sedimentary rocks of Middle to Upper Cambrian age, based on Allen *et al.* (1981), and Allen and Jackson (1985). The area underwent uplift, with local folding, at the end of Cambrian times, prior to the Rhobell Fawr volcanism in early Tremadoc times. The igneous activity, in an island-arc setting (Kokelaar, 1977, 1979), was triggered by south-easterly subduction of ocean floor to the north-west of Wales (Dewey, 1969). The Rhobell Fawr volcanic episode resulted in the subaerial eruption of a thick pile of basic lavas, and these, together with associated autoclastic breccias, lie unconformably upon the eroded Cambrian palaeosurface. Contemporaneous intrusive magmatic phases resulted in the emplacement of a series of dioritic to doleritic dykes and laccoliths (with associated porphyry-type mineralization) and numerous sill-like minor intrusions (Allen and Jackson, 1985). Many of the intrusive rocks have undergone intense hydrothermal alteration to a quartz-calcite-sericite-chlorite-dominated assemblage that gives them a typical green-grey colour (so-called 'greenstones'). The final phase of intrusion resulted in the emplacement of a group of thin basaltic dykes that, in some cases, occupy fissures that have later been re-activated to host gold-belt-type veins.

Following the Rhobell Fawr volcanic phase, the area again underwent uplift and local folding, with movement being centred on the rising Harlech Dome, a basement-controlled crustal block of north–south orientation. This resulted in mélange development on its northern flanks during Arenig to Llanvirn times (Smith, 1987). The folds produced during the pre- and post-Rhobell Fawr episodes trend north–south, an anomalous orientation in the Welsh Caledonides where the pervasive structural trend is north-east-south-west. However, end-Caledonian (Acadian) compression related to the final closure of the Iapetus Ocean (see Woodcock and Soper, 2006) accentuated these earlier structures and imposed more typical NNE–SSW- to NE–SW-trending folds on the Ordovician cover in the east of the area (Allen and Jackson, 1985).

The numerous quartz veins of the Dolgellau Gold-belt form branched and anastomozing zones of mineralization that generally trend in an east-west to ENE–WSW direction and persist over several kilometres of strike length. They vary in width from thin strings up to massive bodies of quartz several metres wide. The veins are generally discordant to bedding, and dips are variable, a feature that is partly due to later deformation. Typically, and especially where hosted by shales, the veins display multiple book-and-ribbon textures, indicative of repeated fissure opening, although massive pods of quartz and breccia cements also occur, particularly where the veins are hosted by competent greenstones or arenitic units. Frequent intra-vein partings, sometimes stylolitic in section, carry abundant sericite and chlorite. Veins are usually 'welded' to their walls, although gouging along some vein walls indicates re-activation of suitably orientated veins as loci for faults. Wall-rocks are variably altered, the most frequent additions being pyrite, arsenopyrite and sericite.

The veins consist of quartz with calcite, chlorite, sericite, sulphides (major pyrite, pyrrhotite, chalcopyrite, galena, sphalerite, arsenopyrite; and minor acanthite, bismuthinite, boulangerite, bournonite, cobaltite, cubanite, matildite, mackinawite, pyrargyrite and tetrahedrite), tellurides (aleksite, altaite, hedleyite, hessite, nagyagite, pllsenite, tellurobismuthite and tetradymite), electrum and gold (Forbes, 1867; Readwin, 1888; Gilbey, 1968; Naden, 1988; Bevins and Stanley, 1990; Bevins, 1994; Mason *et* al., 2002). The sulphides occur in massive, complex intergrowths enclosed by milky quartz. A generalized paragenetic sequence was described by Gilbey (1968), with initial pyrite-arsenopyrite being succeeded by chalcopyrite-pyrrhotite-pyrite; followed by sphalerite-galena-chalcopyrite-pyrite, with all stages accompanied by the gangue species. More recently, Mason *et al.* (2002) have reported a four-stage paragenetic sequence comprising early Fe-Co-As followed by localized bonanza-style Au-Ag-Bi-Te-Pb mineralization. Stage three is dominated by a Cu-Fe association, whilst the final stage is a Pb-Zn association.

Gold occurs in two generations: firstly as microscopic inclusions in pyrite/arsenopyrite/ cobaltite, and secondly as often coarse-grained visible masses associated variably with Bi, Ag and Pb tellurides, Ag-Sb minerals, and/or galena (Gilbey, 1968; Naden, 1988; Mason *et al.,* 2002). The main gold-telluride assemblage is extremely localized within the overall vein environments. Indeed a recurrent problem in mining for gold in this area has been that the bulk gold grade of the mineralization is usually sub-economic, the vast majority of the gold being restricted to localized high-grade 'bonanza-shoots'. For example, at Clogau Mine in 1867, over 500 oz of gold was produced from 'a section of vein six feet long, 4 ft 6 inches high and 9 inches wide' (Hall, 1990). This 'bonanza' was discovered by mining engineer Arthur Dean, who, with an early use of geological modelling, successfully targeted areas in which the veins passed from a greenstone host into black shale in his search for gold (Hall, 1990). However, the exact mechanism for the development of the localized gold 'bonanzas' is not totally understood, and is the subject of continuing research. Bottrell *et al.* (1988) concluded, from fluid-inclusion studies on samples from Clogau Mine, that the gold was precipitated when externally derived hydrothermal fluids reacted with the wall-rocks (and particularly graphitic horizons within the Clogau and Maentwrog formations), an argument first put forward by Gilbey (1968).

Within the gold-belt there also occurs a generation of veins which are distinctive in their banded, crustiform nature and carry a coarse-grained, mineralogically simple assemblage dominated by calcite (often pinkish), marcasite, sphalerite and galena. These veins are a late-stage feature, and cross-cut the gold-belt-type veins where they intersect them. They are of widespread occurrence, not only in the gold-belt, but also throughout the Snowdonia district.

The emplacement of the gold-belt veins has, until recently, been assigned to a post-Caledonian (early Devonian) mineralizing event, based largely on K-Ar ages of 410 ± 13 Ma to 390 ± 12 Ma obtained from wall-rock micas (Allen and Jackson, 1985). The interpretation of the K-Ar data was influenced by the inference that the gold-belt veins were emplaced after end-Silurian deformation because the veins cut across the trends of axial traces and cleavage.

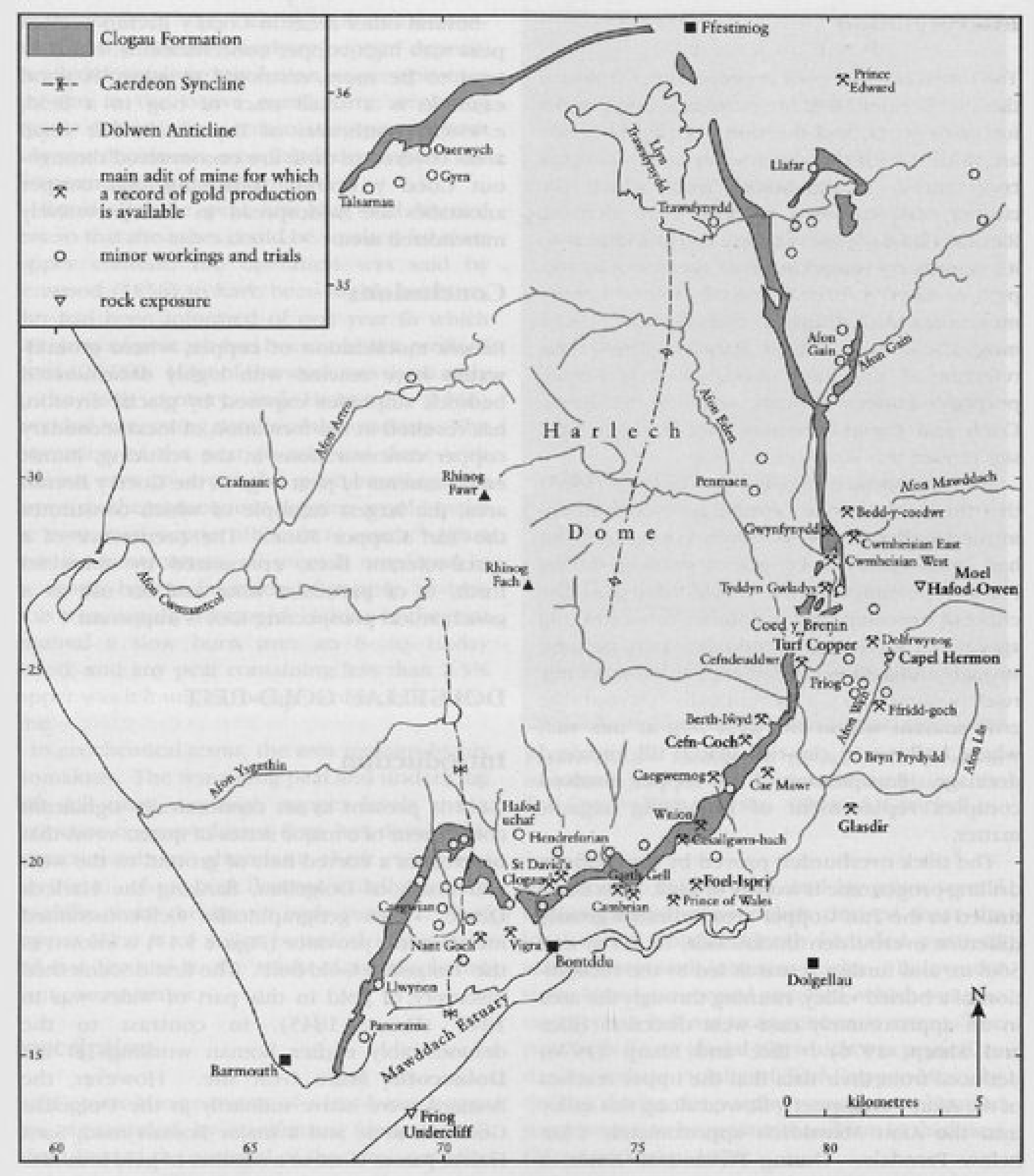
Data obtained from fluid inclusions and isotopes of sulphur, oxygen and hydrogen (Bottrell and Spiro, 1988; Bottrell *et al.,* 1988, 1990; summarized by Shepherd and Bottrell, 1993) pointed towards a metamorphic origin for the mineralizing fluids of the gold-belt. An estimate of the P-T conditions of formation of the gold-belt veins (Bottrell *et al.,* 1988) was given as 1.8 ± 0.3 kbar at 320° C. The mineralizing fluids, it was proposed, were produced during deep groundwater permeation during the final stages of uplift of the Harlech Dome.

In those studies, it was inferred that the emplacement of the gold-belt veins post-dated the timing of peak metamorphism. The metamorphic peak was put at 420–400 Ma, quoting Fitch *et al.* (1969). However, with regard to the timing of peak metamorphic P-T conditions, it has been argued by Bevins and Rowbotham (1983), and Robinson and Bevins (1986) that the metamorphism of the Lower Palaeozoic strata in parts of the Welsh Caledonides was directly related to depth of burial, the metamorphic grade increasing downwards through the stratigraphical column. Indeed, the values for conditions of formation of the gold-belt veins quoted above (Bottrell *et al.,* 1988) could represent the lowermost greenschist metamorphic conditions that would have affected the Cambrian rocks of the area. However, in the Dolgellau Gold-belt, with its polyphase history of uplift throughout the Lower Palaeozoic, the point in time when burial depth (and hence metamorphic grade) reached a maximum is not known. It cannot, however, be assumed that burial metamorphism peaked coincidentally with the Acadian deformation and strain-related metamorphism to which the K-Ar data of Fitch *et al.* (1969) pertain. Additionally, the K-Ar isotope systems upon which this age range was based would, in all likelihood, have been reset by the Acadian deformation, thereby losing the isotopic signatures of earlier metamorphic processes.

The problem of K-Ar resetting in micas during tectonic disturbance also applies to the model ages of the gold-belt veins presented by Allen and Jackson (1985). In fact, isotopic data discussed by Bottrell *et al.* (1990) suggested that isotopic disequilibrium between quartz and calcite in the gold-belt veins was the product of a widespread resetting event after the formation of the veins. Additionally, it was suggested by Fitches (1987) that the relationship of the veins to fold axes does not necessarily mean that they post-dated the Acadian deformation. Given that the main folds within the Dolgellau gold-belt were likely to have been initiated in the phases of uplift associated with the Rhobell Fawr volcanic episode, veins cutting across their axes could in fact have been pre-tectonic with respect to the Acadian deformation. This would make them analogous with the quartz-sulphide veins developed during Caradoc times in the vicinity of the Snowdon Caldera (Reedman *et al.,* 1985), seen for example at the Lliwedd Mine and Llanberis Mine GCR sites. Indeed, recent work has re-appraised structural evidence superbly exposed at the Friog Undercliff GCR site and concluded that the gold-belt veins are, in fact, pre-tectonic in age (Mason *et al.,* 1999).

Three GCR sites have been selected to represent the mineralization of the Dolgellau Gold-belt, namely Foel-Ispri Mine, where the sulphide mineralogy of the gold-belt may be readily studied, Cefn-Coch Mine, a site which demonstrates the variations in vein textures according to the nature of their host lithology, and Friog Undercliff, where wave-cut-platform and cliff-base exposures provide a vast, naturally polished section with critical evidence for constraining the age of the gold-belt veins.

References



(Figure 5.17) Map of the Harlech Dome region, showing the locations of the principal gold mines and the Dolgellau Gold-belt GCR sites. After Institute of Geological Sciences 1:50 000 Sheet 135, Harlech (1982).