Dolaucothi Mine

[SN 663 403]

Introduction

Dolaucothi Mine (Figure 5.49) is unique in the metallogenesis of Wales. In an area otherwise mineralized only by Pb-Zn-Cu-Ag veins typical of the Central Wales Orefield, the Dolaucothi deposit comprises major stratabound pyrite-arsenopyrite-gold mineralization hosted by black pyritic shales and a network of flat-lying and vertical quartz veins, the whole package deformed into a series of tight isoclinal folds. The deposit is situated along the axis of the dome-shaped Cothi Anticline, a parasitic fold on the north-western flank of the major Tywi Anticline (Anne's and Roberts, 1989). Exposures in and around the old open-pits and the accessible underground workings graphically illustrate the complexity of this enigmatic ore deposit.

At surface, the Dolaucothi workings consist of a system of open pits occupying an ovate area extending over 1 km in length (Figure 5.50).

These are now accepted as largely being the work of the Romans, a number of ancient features being supportive of this assertion. For example, a long leat from the Afon Cothi runs over 10 km to arrive at a series of holding tanks above the open pits on Allt Cwmhenog (Hall, 1993; Annels and Burnham, 1995). It has been estimated that this was capable of providing the opencast workings with around 2.5 million gallons of water per day. This water demand has led many authors (for example Hall, 1993) to conclude that it must have been brought in for sluicing away the oxidized part of the deposit, in which pyrite and arsenopyrite would have been weathered to a gossanous clay, the gold previously locked up within their crystals thus being liberated and freely extracted by a system of sluices and gold catchers, such as turves or fleeces. This is reinforced by the existence of the two 'Roman Adits', two hand-driven tunnels running into the lower parts of the main opencast, and through which it is suggested the debris was sluiced and the gold was caught. Such mining methods were used by the Romans and were described, in fact, by Pliny, in his '*Natural History*', published in AD 77. The Roman age of the workings has been further indicated by a radiocarbon age obtained on a part of a wooden drainage wheel found preserved in mud when old workings were broken into during the 1930s. Analysis gave a calibrated age of 90 ± 70 BC (see Annels and Burnham, 1995).

The open pits are substantial in scale. An estimated 4 million tons of rock, of which 0.5 million were auriferous, were extracted, according to James Mitchell (see Hall, 1993), who worked the mine from 1905 to 1910. Mitchell also estimated that these operations had previously yielded 1 million oz of gold. A more conservative but still impressive estimate, given by Annels and Burnham (1995), was that from the Ogofau surface pit alone, 0.5 million tons of rock had been extracted, a third of which was ore, yielding 830 kg of gold (assuming a bulk gold grade of 5 g/t).

Serious interest in the mine revived in the 19th century, perhaps prompted by the discovery of a particle of gold in quartz by an officer of the British Geological Survey in 1844 (see Smyth, 1846). The mine was then intermittently worked through to 1939. Particular interest was taken in the site when Britain abandoned the Gold Standard in the early 1930s. However, the biggest problem that the operators had was that nobody in Britain would smelt the auriferous concentrates produced at the mine because of their high arsenic content. They therefore had to be shipped overseas. Initially, test batches went to Hamburg, but as the political climate in Europe changed during the late 1930s this became impossible and the ore had to be sent to Seattle at an intolerable cost. This alone would have brought about the mine's closure if the outbreak of war had not. Despite all the difficulties, the mine still yielded 1388 oz of gold from 16 862 tons of ore in 1938, the high tonnage of ore reportedly including much peripheral material fed through the mill between batches of ore-grade rock (Hall, 1993). During these later years of activity; the mine, which was romantically worked under the name 'Roman Deep', reached a depth of 140 m below surface (Annels and Burnham, 1995).

There is very little detailed published work on the Dolaucothi deposit. Early studies considered aspects of the mineralogy of the deposit, in particular the occurrence of cookeite (Brammall *et al.,* 1937). Steed *et al.* (1976) presented the results of an extensive geochemical and biogeochemical prospecting programme, which indicated an anomalous area displaced from the strike extension of the ore zone, which they considered to represent an additional area of gold mineralization. The most detailed study to date, however, is that by Annels and Roberts (1989), who undertook a detailed structural investigation of the mineral deposit and considered genetic models for the mineralization.

More recently, the site has been run jointly by Cardiff University and the National Trust, who use it jointly as a teaching and tourism centre. Further exploration of the mineralization by Cardiff University, including diamond drilling, has indicated the existence of strike extensions of mineralization up to 1 km to the north-east of the mine area.

Farther to the north-east again, drainage geochemical surveys by the British Geological Survey have indicated that similar mineralization may occur intermittently along the trend of the Cothi Anticline. A structurally and stratigraphically similar area, the Rhiwnant Dome, has been identified by the British Geological Survey 25 km to the north-east of Dolaucothi, where significant, anomalous levels of gold and arsenic have been found in stream sediments (Brown, 1993). The potential for further occurrences of this type of mineralization along a marked structural trend, coupled with the amount of mineralization worked historically, emphasizes that the Dolaucothi area represents an important metallogenic province of Wales.

Description

The Dolaucothi stratabound gold-arsenopyrite-pyrite deposit is hosted by Ashgill-age black-shales and grey siltstones belonging to the Yr Allt Formation which outcrop in the core of the dome-shaped Cothi Anticline, parasitic on the north-western flank of the major, probably basement-controlled, Tywi Anticline (Annels and Roberts, 1989). The host strata are overlain by turbidites of the Cwmere Formation (Llandovery), which include a prominent massive conglomeratic horizon. In the vicinity of the mine, the strata are deformed by a complex series of tight to isoclinal folds, often sheared and overthrust along their axes. A pervasive axial planar cleavage has been developed in the more argillic units.

The gold mineralization occurs both in sulphidic bands within the black shales and in a series of shale-hosted quartz veins. In the mine area, the shales carry a series of sulphidic formations up to 1.5 m in thickness, which tend to exhibit a marked thinning both to the northeast and south-west of the mine. These are dominated by pyrite, which occurs in a number of modes, comprising clusters of framboids, disseminations of small euhedral crystals, and occasional bands of coarse cubic crystals. Arsenopyrite is an important component of the shale-hosted mineralization. It occurs as porphyroblasts and forms euhedral laths and rhombic crystals up to 20 mm in size, which often enclose pyrite. Gold occurs as minute (<< 1 mm) grains included in, or lining microfractures in, arsenopyrite (see Annels and Roberts, 1989).

Auriferous sulphide concentrations also occur near the walls of massive, white quartz veins, which form a network of thick horizontal 'reefs' connected by thin vertical 'feeders'. Additionally, podiform quartz bodies occur along subvertical reverse-movement shear zones developed above fold axes. The principal quartz vein, upon which the majority of 20th century mining activity was concentrated, is an apparently concordant 'reef' referred to as the 'Roman Lode'. This body, up to 6 m in thickness, has been traced along a strike length of 250 m, and followed down-dip to the south-west in excess of 140 m below surface. Although currently inaccessible, the structure of the Roman Lode is well described in the literature and recorded in old photographs (see for example Hall, 1993). In section, the Roman Lode typically shows a corrugated hangingwall separated from the wall-rock by up to 10 cm of clay-gouge. The footwall consists of shale impregnated with pyrite and arsenopyrite, both of which are auriferous. Steeply discordant 'leader' veins descend from the Roman Lode footwall into the wall-rocks.

The lode and associated veins both consist of locally vuggy milky quartz, with subordinate amounts of ferroan dolomite and 'hydro-muscovite', more recently characterized as 2M1 illite (Annels and Roberts, 1989). The Li-bearing chlorite-group mineral cookeite is locally common, and its presence has been cited by Brammall *et al.* (1937) as evidence for a magmatic input to the fluids responsible for the mineralization. In the Roman Lode and associated veins, gold is present within patches of auriferous pyrite (with associated arsenopyrite), which in the case of the Roman Lode occur with increasing frequency towards the footwall.

The Au-As mineralization in all modes is cut locally by small Pb-Zn-Cu-bearing quartz-carbonate-sulphide veins with minor remobili-zation of gold (Annels and Roberts, 1989), which resemble those of the Central Wales A1- and A2-type mineralization. Further Central Wales-style Pb-Zn-Cu mineralization occurs at Dolaucothi along two transverse normal faults, known as the 'Clochdy Gwenno Fault' and the 'Lead Lode Fault'.

Although secondary minerals arc not obvious at the site, both pyrite and arsenopyrite have weathered in places to yellow ochres. Greenish scorodite locally forms thin coatings on arsenopyrite. Gypsum Is common as a post-mining crystalline efflorescence on the mine walls, a common feature in almost all underground driveages where pyrite occurs.

Interpretation

The origin of the Dolaucothi pyrite-arsenopyrite-gold deposit is controversial. It was initially assumed to be a classic saddle-reef system, and in the 1930s a magmatic source for the mineralization was considered most likely (Brammall *et* al., 1937). More recently, the possibility that Dolaucothi was formed by exhalative activity on the early Silurian seafloor was considered by Annels and Roberts (1989). In the same paper, the authors cited sulphur isotope data that consistently favour an epigenetic (though not necessarily direct magmatic) hydrothermal origin, thereby, in their view, ruling out the exhalative hypothesis. The preferred model favours a mineralized thrust (the Roman Lode) and associated extensional shear-gash veins (the steeply discordant footwall 'leaders). In this model, the pyrite- and arsenopyrite-bearing shales represent alteration by replacement of receptive lithologies. The model places the hydrothermal fluid migration and mineralization within the context of the Acadian deformation, suggesting that it occurred at an early stage of this compressive event. During this early stage, prograde metamorphism of the basement rocks below the area resulted in the leaching, by circulating fluids, of gold, arsenic and other elements from intrusive and extrusive igneous rocks. The resultant overpressured hydro-thermal fluids then escaped to higher crustal levels during successive phases of uplift and accompanying tectonism.

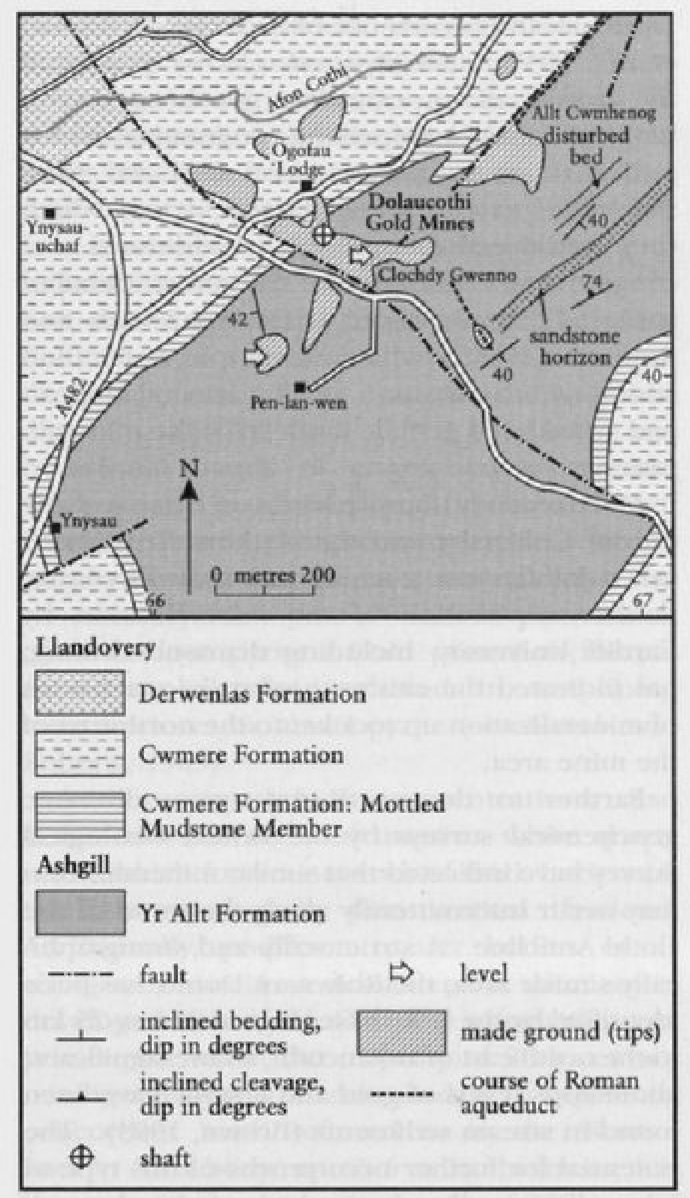
While several lines of evidence provide support for this model, this is a complex deposit. Therefore, it is anticipated that as further information is generated by ongoing research, the genetic model will continue to be modified, as has indeed been the case over the years at the even more complex Parys Mountain GCR site.

The relationship of the Dolaucothi Au-As mineralization to the more regionally widespread Central Wales-type base-metal vein mineralization (well developed at the nearby Nantymwyn GCR site) is well defined. Late cross-cutting normal faults, such as the Lead Lode, show dearly that the pyrite-arsenopyrite-gold mineralization was relatively early in the sequence of events.

Conclusions

The pyrite-arsenopyrite-gold mineralization occurring on a substantial scale at Dolaucothi Mine is unique in Wales. It clearly pre-dates the Central Wales Pb-Zn-Cu vein mineralization and, according to current models, was developed as a result of basement-derived hydrothermal fluids migrating up deep-seated fractures during the uplift which occurred at the onset of the Acadian deformation. Research continues actively at the site and it is anticipated that the models advocated for the genesis of this complex deposit will continue to be refined as more data are obtained.

References



(Figure 5.49) Map of the Dolaucothi Mine GCR site. After British Geological Survey 1:50 000 Sheet 212, Llandovery (2008).

(Figure 5.50) Aerial photograph of the Dolaucothi Mine GCR site. (Photo: © Crown copyright: Royal Commission on the Ancient and Historical Monuments of Wales.)