Dolyhir Quarry

[SO 245 579]

Introduction

Quarrying at Dolyhir (Figure 5.69) dates back over many years, the chief products being road aggregates, produced mainly from Precambrian rocks, and agricultural lime, produced from limestones of Wenlock age. Mineralization in this area has been documented in the past. Murchison (1839) noted occurrences of copper ores at Stanner and Old Radnor, while· Lewis (1967) referred to small-scale mining for lead at Hanter Hill, to the south-east of Dolyhir. According to Hall (1993), no sign can now be seen of old workings in the district. Malachite specimens have long been known from the nearby Old Radnor Quarry (Bevins and Sharpe, 1982; Bevins, 1994), while Parnell and Eakin (1989) reported minor tennantite-barite-chalcopyrite mineralization in the Old Radnor district.

The significance of the mineralization described here was first noted in the early to mid-1990s (D.I. Green, pers. comm.) and was sampled intensively and studied in the period 1996 to 1997 (D.I. Green, unpublished data; Bevins and Mason, 1997). Since that time, quarrying has removed the most sulphide-rich exposures. However, it is likely that further mineralized outcrops will be exposed during future quarrying activities.

Description

At Dolyhir Quarry, elastic and volcaniclastic rocks of Neoproterozoic age, belonging to the Longmyndian Supergroup (Pauley, 1990), are unconformably overlain by algal-reef limestones of Wenlock age (Figure 5.70). The Neoproterozoic rocks constitute part of the Old Radnor Inlier, and outcrop within the major lineament of the Church Stretton Fault System. The inlier is approximately 3 x 1 km in extent and is aligned, as is the fault system, in a northeast-south-west direction.

Rocks belonging to the Longmyndian Supergroup exposed in Dolyhir Quarry comprise the Yat Wood Formation and the Strinds Formation. The Yat Wood Formation comprises at least 90 m of greenish-grey to grey laminated siltstones and mudstones with interbedded fine-grained sandstones. The Strinds Formation, at least 600 m thick, comprises sandstones and occasional conglomerates. Both formations are predominantly volcaniclastic (Pauley, 1990) and are interpreted as having been derived from volcanic activity associated with a magmatic arc. Tilting of the Neoproterozoic rocks, largely to the north-west, and the occurrence of metamorphic segregation quartz veins, themselves heavily fractured, within the sequence, represents pre-Silurian deformation and metamorphism.

Quartz pebbles, probably derived from the metamorphic veins, accompany numerous clasts of Longmyndian rocks within the basal conglomerate developed at the Precambrian–Wenlock unconformity. The overlying Dolyhir Limestone Formation was a localized development which formed on an elevated tract of the Silurian seabed (see Woodcock, 1993). The Dolyhir Limestone Formation is an algal-reef deposit with an abundant calcareous algal, coral and shelly fauna. The reef limestones pass upwards into brown and grey nodular shales; the top of the limestone is highly irregular, with shale-filled hollows in between dome-like reef structures. The nodules in the shales are commonly septarian, containing cracks lined with quartz', calcite and, rarely, barite.

The Precambrian basement is cut by a number of igneous dykes, post-dating the folding, and ranging from a few tens of centimetres to nearly 20 m wide. These have received little attention from previous authors, although one of them is likely to be the 'trap' referred to by Murchison (1839) as a 'dyke about 16 ft in width'. The main dykes have been observed cutting through both the Yat Wood and Strinds formations in a roughly east-west direction, and are doleritic in composition but with pervasive and locally intense late magmatic hydrothermal alteration (epidotization and chloritization). The largest dyke, which is 15–20 m wide, is the freshest and has been traced for over 400 m across the quarry. The thinner dykes are more altered, so much so that most of the original constituents have been replaced. The pre-Wenlock erosion surface affects dykes and sediments alike: the absolute age of the dykes is, however, unknown.

The pattern of fracturing exposed in the quarry is complex. Both Longmyndian and Wenlock strata are cut by faults which are predominantly strike-slip in nature, and trend north–south to NNE–SSW and north-west-south-east to NNW–SSE. The whole structure of the Old Radnor Inlier has been described as a strike-slip duplex (Pauley, 1990). This has been attributed to sinistral strike-slip movements along the Church Stretton Lineament. The date of this faulting is clearly post-Wenlock; whether it occurred during Acadian, Variscan or even later movements remains to be established.

A number of the strike-slip fractures are mineralized with calcite and traces of chalcopyrite. However, a few fractures show a much more complex history of mineralization. The Longmyndian strata, exposed in the lower, northern parts of the quarry, are cut by thin (< 15 m) veins locally carrying white to yellow (rarely blue) crystalline barite, barytocalcite, witherite and chalcopyrite. Also present are rare proustite and luzonite (T.F. Cotterell, pers. comm.). Recently, Green *et al.* (2005c) have reported the occurrence of the rare carbonate mineral ewaldite from Dolyhir Quarry, forming yellow-brown hexagonal pyramidal crystals with pinacoid terminations, associated with core-bit twins of harmotome. This represents the first British occurrence of ewaldite, and only the fourth worldwide. Recently the occurrence of paralstonite, associated with alstonite and barytocalcite has been determined, forming chalky, finely crystalline, white coatings on harmotome in fractures in Longmyndian strata in the northern face on the upper level of the quarry (Cotterell and Dean, 2007). Inclusions of tennantite and galena occur within massive barite, whilst nodular luzonite with covellite and chalcocite form within massive calcite with coarse, crystalline barite overgrowths. Rare proustite and enargite have also been recorded (T.F. Cotterell, pers. comm.).

In the northern and eastern parts of the quarry, exposures of realgar mineralization have been uncovered at times: these consist of thin films of scarlet realgar occupying narrow fractures in dark-grey Yat Wood Formation mudstone, with very occasional millimetre-sized euhedral crystals occurring in rare wider veinlets, the crystals overgrowing euhedral chalcopyrite (T.F. Cotterell, pers. comm.). Finally, in an area in the upper, south-western part of the quarry; now worked away, veins in grits belonging to the Strinds Formation carried chalcopyrite, accompanied by quartz and hydrocarbon and altered to massive chalcocite and bornite, these both coated in places with fibrous malachite and well-crystallized azurite.

Mineralization is also strongly developed in the limestones of Wenlock age which are exposed in the western part of the quarry, although the most mineralized part of the principal vein, trending north-west-south-east and carrying solid sulphide up to 0.5 m in width, has now been quarried away. It has, however, been intensively sampled and studied, with reference material lodged in the National Museum of Wales and Manchester Museum. This vein was thickest at the top of the limestone; in the overlying shales it pinched out dramatically. The vein assemblage consists of tennantite, intergrown with galena, chalcopyrite and an undetermined member of the enargite group, associated with bladed, white barite plus scalenohedral calcite. Primary greenockite occurs as bright-yellow cleavage sections within the other intergrown sulphides and is locally altered to the rare cadmium carbohate otavite (D.I. Green, pers. comm.). The generally fine-grained sulphide intergrowths also contain pyrite and sphalerite, the latter species being very rare (R.A. Ixer, pers. comm.).

Secondary alteration of the complex sulphide assemblage described above has resulted in the formation of a diverse, arsenate-sulphate-carbonate-dominated suite of supergene minerals which includes some minerals as yet to be characterized. The assemblage is dominated by malachite and azurite, with rarer tyrolite, which all form extensive crystalline coatings on the limestone vein walls. Associated with these minerals, cuprite, olivenite, dundasite and chrysocolla have been recorded (D.I. Green, pers. comm.). The massive sulphide contains cavities lined with oxidation products, including well-crystallized anglesite, azurite, cerussite, mimetite and beudantite, associated with a number of as yet undetermined species (D.I. Green, pers. comm.). Near the top of the vein exposure, and close to the overburden, heavily oxidized sulphidic material, collected in the early to mid-1990s, has been shown to contain a suite of micro-crystalline minerals including lanarkite, elyite, linarite, caledonite, beudantite and leadhillite (D.I. Green, pers. comm.). Wulfenite has also been recorded (Di Green, pers. comm.) but is extremely rare.

Further supergene mineralization occurs on minor joint-planes within the overlying shales, and comprises fibrous malachite and azurite, which often replaces fossil debris. Within this setting, azurite also occurs as daisy-like, radiating aggregates on joints, and as relatively massive developments, associated with gossanous limonite.

Interpretation

It is clear that the vein mineralization at Dolyhir Quarry, with the exception of metamorphic quartz in the Longmyndian rocks, is closely related to tectonic activity within the north-west–south-east part of the strike-slip duplex described above. The mineralization is only locally intense, but the apparent confinement of the richest sulphide-barite body to the upper part of the limestone sequence suggests that the ascending hydrothermal fluids were ponded at that point due to the presence of the overlying, relatively impermeable shales. The shales would not only act as a cap due to their impermeability but their relatively plastic nature, in comparison to the underlying brittle limestone, would also inhibit the formation of large open fractures during faulting.

In other mineralized areas of the quarry, the mineralization is weak but persistent. This also supports the contention that fluids, passing through the Old Radnor Inlier, only deposited significant amounts of ore minerals where they were ponded in open fractures. It also implies that further Pb-Cu-As-dominated sulphide bodies might be expected in fractures near the top of the Dolyhir Limestone elsewhere in the inlier.

The dominant sulphide minerals within the Dolyhir Quarry assemblage are tennantite, galena and chalcopyrite. While none of these are rare species worldwide, the paucity of sphalerite is an unusual feature, particularly with regard to Wales and the Welsh Borderland where, both in the Central Wales Orefield (see GCR site reports, this chapter), and south-west Shropshire (see Snailbeach Mine GCR site report, Chapter 4), sphalerite accompanies galena in abundance. However, in both of the latter areas, arsenic is rare or absent from epigenetic vein deposits. The lack of sphalerite at Dolyhir Quarry may explain why, very unusually, primary greenockite occurs as a component of the sulphide assemblage. In most Pb-Zn ore deposits, cadmium is present as a significant minor element in sphalerite.

Nickel is present at low (100–150 ppm) levels, as is silver (75–125 ppm) and mercury (up to 12 ppm), whilst bismuth was not detected. Most of the zinc present in the Dolyhir Quarry mineralization must occur in another sulphide phase, the likely candidate being tennantite, a mineral known for its tendency to have a variable composition incorporating a number of metals.

The level of 0.95 wt% Zn in a sample in which sphalerite had not been detected implies that most of the zinc present in the Dolyhir Quarry mineralization must occur in another sulphide phase, which in this case is tennantite.

The primary mineralization at Dolyhir Quarry is highly anomalous in regional terms, and it is difficult to identify any comparable deposit in Great Britain. Perhaps one of the most similar deposits is at the Clevedon Shore GCR site, on the southern side of the Bristol Channel, 15 km to the north-west of the Mendip Orefield (Ixer *et al.,* 1993). Here, tennantite- and enargite-group minerals accompany the typical MVT assemblage of the Mendip Orefield, dominated by galena, sphalerite, barite and calcite. Furthermore, cadmium levels in sphalerite are markedly elevated, reaching 8.46 wt% in some samples.

Despite the unusual mineralogy, however, the geological setting of the mineralization at Dolyhir Quarry has some characteristics with Mississippi Valley-type affinities, namely that the mineralization was deposited from fluids which rose through an uplifted block of Precambrian basement capped by Palaeozoic reef carbonate sedimentary rocks, and that weak mineralization in the Precambrian strata contrasts with locally important sulphide deposits at the top of the limestone sequence, where the overlying shales acted as a barrier to the hydrothermal fluids and effectively capped the mineral deposit. The nature and source of the mineralizing fluids currently remains undetermined; the Mesozoic Severn Basin, with a thick sedimentary fill, including Triassic evaporites, has been suggested as a source area (D.I. Green, pers. comm.).

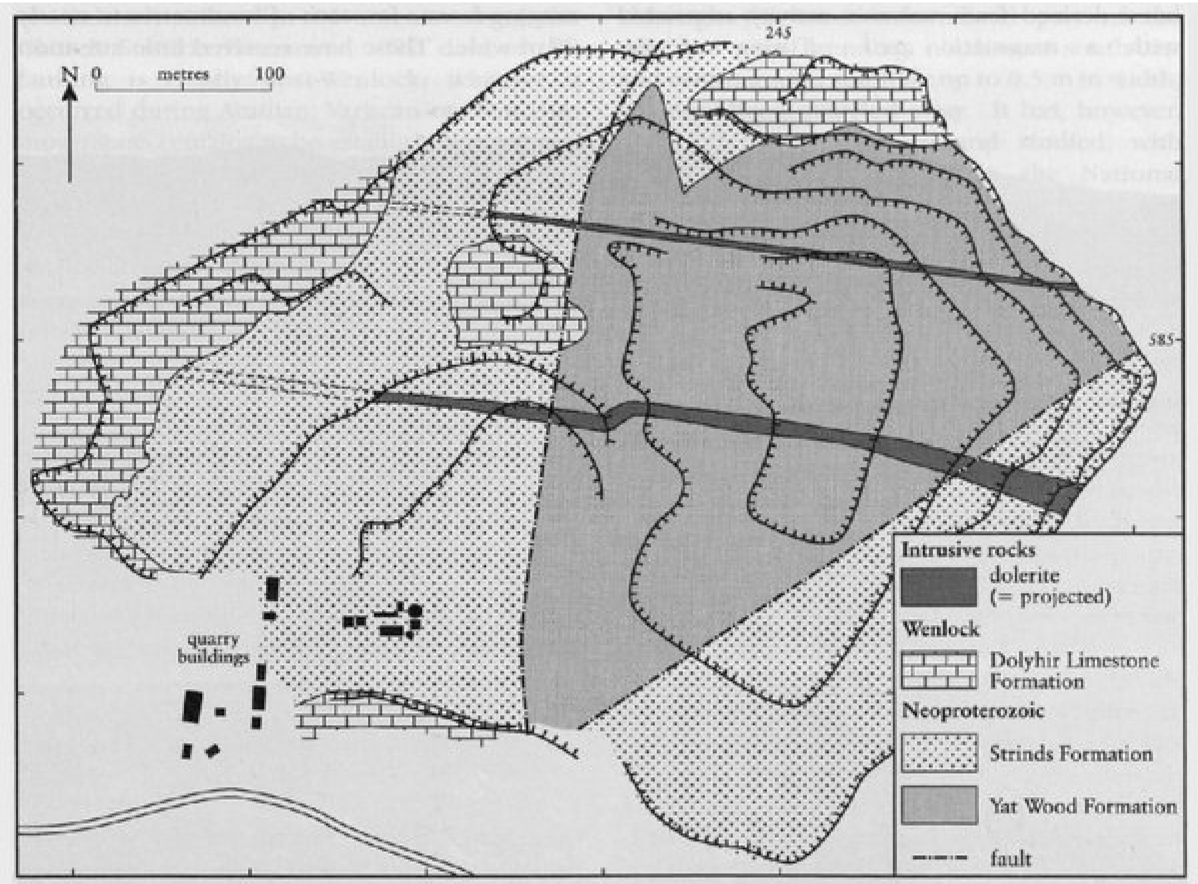
Supergene alteration at Dolyhir Quarry is widespread and occurs in several modes, which are comparable to other well-documented occurrences of secondary mineralization. Alteration of chalcopyrite, occurring in veins in Longmyndian rocks, to massive bornite and chalcocite overgrown by malachite and azurite, is remarkably similar to the pattern of mineralization observed in the Longmyndian succession in south-west Shropshire, for example at the Huglith (see Huglith Mine GCR site report, Chapter 4) and Westcott mines (Smith, 1922). In contrast, however, the supergene alteration of the mineralization occurring at the top of the Dolyhir Limestone Formation is far more complex. Near-surface alteration has resulted in the development of a suite of micro-crystalline minerals similar to the post-mining suite developed at many Central Wales Orefield sites, such as at the Frongoch Mine GCR site (Green *et al.,* 1996). At greater depths, patchy but locally intense alteration has produced azurite accompanied by an arsenate-sulphate assemblage, which is in some respects similar to that present at certain sites in South-west England, such as the Penberthy Croft GCR site (Camm and Merry, 1991). However, in view of the predominance of tyrolite at Dolyhir Quarry, a more reasonable comparison might be made with the localized underground tyrolite-dominated supergene assemblage at the Gwaithyrafon Mine in the Central Wales Orefield (Mason and Rust, 1995).

The abundance of azurite at Dolyhir Quarry is significant, since in both the Central Wales Orefield (see this chapter) and the Pb-Zn zone of south-west Shropshire (see Chapter 4), wherever chalcopyrite occurs in association with galena it is the secondary basic sulphate, linarite, which tends to form. At Dolyhir Quarry, however, the calcareous host lithologies would presumably have created a relatively alkaline geochemical environment in which secondary copper carbonates would be relatively stable. At Dolyhir Quarry, azurite is more abundant than malachite, which it overgrows. Stability data for malachite and azurite (Vink, 1986) show that malachite is stable at higher pH levels than azurite, and tends to form when acidic solutions, produced by oxidizing sulphides, are buffered by carbonate lithologies to well above pH 7. Discussing the restricted occurrence of azurite relative to malachite at the Great Orme Copper Mines GCR site, Ixer and Davies (1996), using the results of Vink (1986), suggested that azurite was the main copper secondary mineral to develop where there was insufficient carbonate available to create this buffering effect. The paragenetic sequence of minor malachite followed by major azurite at Dolyhir Quarry appears to reflect such a situation.

Conclusions

Mineralization intermittently exposed in Dolyhir Quarry is unique in Wales; the primary mineralization, of probable Mississippi Valley-type affinities, appears to have no equivalent elsewhere in Great Britain, while the secondary mineralization includes a number of minerals which are either of extreme rarity or, in a few cases, remain to be described as new mineral species. The research potential, both on-site and with the extensive sample suites collected recently, is considerable.

References



(Figure 5.69) Map of the Dolyhir Quarry GCR site. Based on Woodcock (1988), and unpublished mapping by T. Cotterell.

(Figure 5.70) Photograph of the Dolyhir Quarry GCR site. (Photo: T Cotterell.)