Ecton Copper Mines, Derbyshire

[SK 099 579]

Introduction

The copper ore deposits at Ecton, with nearby Mixon, form the western extremity of the South Pennine Orefield (see (Figure 4.28) for location map). The Ecton orefield occupies the western edge of the Derbyshire Dome, which lies the extreme southern end of the Pennine Hills (Pattrick and Polya, 1993). The Ecton mines penetrate copper deposits within folded Dinantian limestones, namely the Milldale Limestone and Ecton Limestone formations (Critchley, 1979), which form the NNW–SSE-trending Ecton Anticline at the northern end of the Manifold Valley gorge, in east Staffordshire. Namurian mudstones and sandstones unconformably overlie the limestones, which now form an inlier of high relief, surrounded by low-relief Namurian terrain (Aitkenhead *et al.,* 1985).

The mineralization at Ecton is unique in being the only deposit substantially mined for copper in the Carboniferous Limestone of England. Records suggest that Ecton was mined during the Roman occupation of Britain *(c.* 50 BC) (Dunham, 1983) and periodically since then. The most significant ore yields were produced during the 18th and early 19th centuries (Kirkham and Ford, 1967). Mining operations ceased in 1891 (Robey and Porter, 1972), but throughout the most prolific mining period mining records state that Ecton yielded a number of copper-bearing ores including (in order of abundance) chalcopyrite, bornite, chalcocite, cuprite, tenorite, malachite and azurite (Sarjeant, 1956; Kirkham and Ford, 1967). Of these minerals, chalcopyrite was the most abundant and exploited sulphide, followed by lesser amounts of galena (Masheder and Rankin, 1988). Pyrite also figured as one of the dominant hypogene sulphides, although was never exploited as an ore. Calcite is evident as the major gangue mineral, together with barite and minor fluorite (Pattrick and Polya, 1993), and hydrocarbons also occur (Ewbank *et al.,* 1993, 1995). It is estimated that between 100 000 and 150 000 tons of ore in total were extracted from the Ecton mines, with grades of around 15% copper (Robey and Porter, 1970) during the most prolific mining period. Associations are frequently made with the mining area of Mixon, several kilometres west of Ecton, where mineralization occupies a similar geological setting. The Mixon mines, although covering a smaller area, were also known for the high quality of their copper and lead ores, albeit occurring in lesser quantities (Robey and Porter, 1970).

The predominance of copper over lead and zinc sulphides in the Ecton and Mixon areas is atypical of the South Pennine Orefield as a whole, where lead-zinc-fluorite-barite mineralization dominates. The South Pennine Orefield has been described as a classic carbonate-hosted Mississippi Valley-type deposit by Mostaghel (1985b), and as a fluoritic subtype of the Mississippi Valley-type lead-zinc deposits by Dunham (1983). In contrast, Masheder and Rankin (1988) proposed that the predominance of copper over lead and zinc sulphides at Ecton may indicate a different origin to that assumed for the South Pennine Orefield.

Description

The Ecton orebody is thought to be bell-shaped, increasing in volume with depth and dominated by vein-style mineralization in the form of vertical pipe-like void-infilling and metasomatic replacement bodies (Ixer and Vaughan, 1993). The mining works at Ecton focused mainly on the irregular pipe-like bodies within the uppermost 300 m of the Asbian and Brigantian limestone sequences, which underlie the now eroded basal Namurian Edale Shales aquiclude (Pattrick and Polya, 1993). The mineralization within these pipe-like bodies is suggested to have occurred as the result of open-cavity filling (Masheder and Rankin, 1988), and the Ecton Pipe is the largest, with a vertical extent of several hundred metres. Copper ores were found to be most prolific in the lower levels of the orebody, and the worked lead ores, principally galena and barite stringers, were generally found to exist as discrete deposits in the higher Namurian sandstones in the immediate vicinity of the larger pipes (Kirkham and Ford, 1967; Masheder and Rankin, 1988). Secondary enrichment of the copper ores is considered to be the likely cause of both the higher grade of ore in the upper levels of the deposit, which yielded around 15% copper between the years 1776 and 1817 (compared to poorer-grade ore in the lower levels), and the existence of galena and sphalerite as alteration products in the upper orebody. As the chief ore of copper, chalcopyrite was frequently found associated with calcite, fluorite and barite, where calcite was the predominant gangue mineral existing in the form of large (> 10 cm) transparent crystals lining cavity walls within the main Ecton Pipe (Masheder and Rankin, 1988). Particularly characteristic of the location is the occurrence of chalcopyrite as small crystals (1 mm or less) within massive grey sparry calcite.

Sporadic occurrences of celestine (strontium sulphate) in calcite veinlets in the south-east mine-workings are also thought to be the product of secondary mineralization, together with the copper-zinc minerals aurichalcite, rosasite and rare chalcanthite (Ford and Sarjeant, 1964). Other reported secondary carbonate minerals include cerussite (lead carbonate) and smithsonite (zinc carbonate), and these are probably the result of oxidation of primary lead and zinc sulphides (Ixer and Vaughan, 1993). Associated gangue minerals include hydrozincite, limonite, 'wad' (manganese oxyhydroxides), pyrite and arsenopyrite (Ford and Sarjeant, 1964). Rust (1995a) described a wide range of supergene minerals from the dumps surrounding Waterbank Shaft [SK 102 576], which included rare species such as namuwite, ramsbeckite and schulenbergite, as well as two minerals which could not be matched to known species. One of these has subsequently been identified as the first British record of the rare lead sulphate selenate mineral olsacherite (Rust and Green, 2005).

Several fault-/joint-sets dominate the main South Pennine Orefield (Weaver, 1974; Quirk, 1988), and the same structural regime is observed in the Ecton orebody. The earliest and most common faults trend north-west-southeast and are 1–2 km-long straight vertical faults coinciding with master joints. These are often associated with pre-mineralization solution cavities, which are syn-sedimentary features (Pattrick and Polya, 1993). Minor fault-sets are normally sinuous and 2–5 km long, but reaching up to 8 km in some cases. These are wrench faults trending east-west or ENE–WSW, and often show horizontal slickensides on their wall-rocks with little vertical displacement. Most of the large rake deposits belong to this set. Other minor faults comprise a series of north-east-south-west extensional structures (Weaver, 1974; Quirk, 1988), which are probably of late Carboniferous age.

Some 12 mines with 70–80 associated shafts (Porter, 1970) penetrate the vein system to depths of at least 300 m (Kirkham and Ford, 1967). The principal NW–SE-trending veins can be observed along the ridge that forms the north-west-southeast axis of the Ecton Anticline and on the NE-facing hillside. The south-east plunge of the anticline allows best exposure of worked veins at the shafts and pits sunk into the northern region of the anticline. Principal worked E–W-trending veins can be observed to dip to the south within the limestone strata at the disused workings at Clayton Mine (see (Figure 4.29)), Stone Quarry Mine and Fly Mine, but the workings are overgrown. Other smaller exploited pipes trend ENE–WSW

A detailed description of the Ecton area, from which much of the following is drawn, is presented in Braithwaite (1991). Many of the lower mine-workings are now flooded at adit level. Several of the major adits remain in the south-west at the base of Ecton Hill, and continue to drain water from the old shafts. This is the case with respect to Deep Ecton Adit, Clayton Adit, Birches (Hurts) Adit, and the remains of Salts Level that are preserved, although the associated building works (which include old smelters, mills, smiths' forges, waterways and a tramway) are either ruined or have been demolished and mixed with tipped mine waste. Few of the original buildings remain and these are now mostly residential properties. The remains of a worked quarry (formerly known as 'Apes Tor Quarry' [SK 100 585]) are also visible on the western extent of Ecton Hill in dose proximity to the main adits. Above this quarry and halfway up the W-facing flank of Ecton Hill are the remains of the engine house, shafts, several adits and the spoil heap of Dutchman's Mine. These disused works are behind a stabilizing barrier of conifers, planted to prevent slope failure of the mine spoil. Inspection of this spoil heap reveals discarded lumps of blocky pink barite with distinctive spots of lustrous chalcopyrite and green malachite interspersed throughout orange-weathered, 'honeycomb'-texture limestone. Large red-brown grains of hematite are also evident in the spoil, together with veinlets of calcite and dark cubes of galena and lustrous grains of sphalerite.

There are a number of other ruined buildings and works associated with the Ecton mines, and many of these can be seen from public footpaths. Old shafts and trial pits however are frequently bacicfilled, and the remains of worked veins are only exposed at a few locations on the hill.

Interpretation

The copper-rich mineralization at Ecton, along with other significant lead-zinc-iron-rich deposits in the Pennines, Comubia, Cumbria and the Bristol Channel are the result of post-Carboniferous episodes of low-temperature hydrothermal activity, largely hosted by Lower Carboniferous carbonate rocks, so-called Mississippi Valley-type (Pattrick and Polya, 1993).

Fluid-inclusion studies have aided greatly in determining the age and source of the mineralizing fluids responsible for the Ecton mineralization. Masheder and Rankin (1988) obtained notably lower mean homogenization temperature data from primary and secondary inclusions within calcite and fluorite gangue from Ecton than those generated in previous studies from the South Pennine district (Rogers, 1977). Consequently, genetic models for this mineralized region have been refined, for example those models proposed by Dunham (1983), and Mostaghel and Ford (1986).

Basin dewatering has been one of the most popular models proposed to identify the source of the mineralizing fluids responsible for the Ecton ore deposits. Such a model involves the expulsion of metalliferous brines derived from surrounding sedimentary basins into ore structures within the Derbyshire Dome. Mostaghel and Ford (1986) suggested that eastward-moving fluids expelled from the Cheshire-Irish Sea Basin to the west of Ecton were responsible for the copper and associated mineralization in the area. Davidson (1966) speculated that the ores of Ecton and the South Pennine Orefield were telethermal, and deposited by interstitial brines derived diagenetically from evaporates, the brines being capable of concentrating metals from sediments through which they had migrated.

The presence of sulphate-rich groundwater in the sub-surface Carboniferous limestones beneath Nottinghamshire has been established by Downing (1967). Metals were transported in porewaters but only precipitated when mixed with brines, or sulphate and bacteriogenic sulphide. Further to this, Allen (1982) has suggested that sandstone-hosted stratabound copper deposits at the margins of Triassic basins in Cheshire and Staffordshire may be associated with the copper mineralization at Ecton.

As may be expected, in addition to a source of mineralizing fluids from the Cheshire Basin, sedimentary basins to the east of the Derbyshire Platform (probably related to the northern and southern North Sea basins) have also been considered as a source for mineralizing fluids responsible for the lead-zinc-fluorite mineralization present in the eastern and central parts of the South Pennine Orefield. Ford (1976) envisaged the North Sea Basin as a possible source for the Ecton mineralization, whilst a derivation from the basinal sediments of the Gainsborough, Edale and Widmerpool gulfs was considered possible by Rogers (1977), and Ineson and Ford (1982). However, Ixer and Townley (1979), in their description of the mineralogy and paragenesis of the South Pennine Orefield, concluded that the Ecton copper mineralization is anomalous and should not be considered to be part of the main orefield at all.

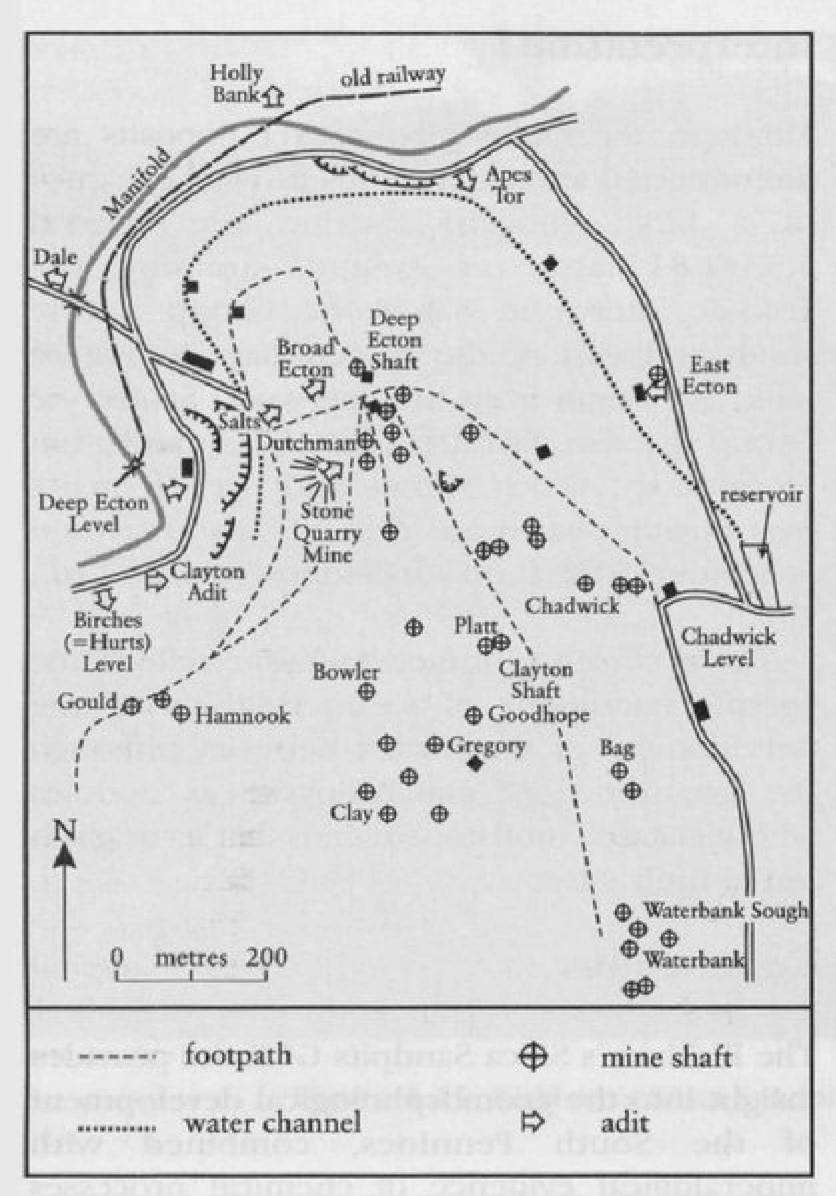
With this in mind, fluid-inclusion data obtained by Masheder and Rankin (1988) indicate that, irrespective of source, the lead-and zinc-rich fluids responsible for the mineralization in the South Pennines differed only slightly in their physico-chemical properties from the eastward-moving, copper-enriched fluids believed to be derived from the Cheshire Basin. The latter were also thought to be cooler, while K:Na ratio data suggest that the Ecton fluids were also more enriched in potassium than the lead-zinc-fluorite fluids that sourced the rest of the South Pennine Orefield. A possible explanation for the lower temperatures of the Ecton fluids is a shallower depth of origin within the Cheshire Basin, compared with the other more easterly sedimentary basins, rather than lower regional geothermal gradients (Masheder and Rankin, 1988). The higher potassium levels of the Ecton ore-fluids may be explained through the high abundance of evaporites in the Cheshire Basin than in other sedimentary basins elsewhere in the area (Masheder and Rankin, 1988). Potassium enrichments of ore fluids through interaction with evaporites is not a new concept and has been suggested by various authors to explain high K:Na ratios, and evidence from sulphur isotopic studies has indicated that sabkha-type fluids may be involved in ore formation. The abundance of calcite gangue is also consistent with the basinal brine model in explaining the Ecton ore genesis, based on fluid compositions of modern-day basinal brines (Carpenter *et al.,* 1974).

Conclusions

Based on the mineralization characteristics at Ecton, models of episodic basin dewatering, as proposed by Cathles and Smith (1983), can be applied to explain the copper mineralization at this site, where local basin evolution was responsible for controlling the flow of brines derived in this fashion (Pattrick and Polya, 1993). Periods of active rifting, thermal subsidence and basin inversion that were ongoing during late Carboniferous to early Permian times would have been conducive to fluid expulsion from rapidly buried sediments. Crustal extension, which occurred later in Permian times would have facilitated fluid movement, together with fault activity on basin margins (Pattrick and Polya, 1993). The Carboniferous Ecton Limestone and Milldale Limestone formations would have provided an ideal permeable aquifer within which to contain basinal fluids. Shale units within the limestones, as beneath Ecton and Mixon, would have acted as impermeable barriers but also as sources of sulphur.

The orebody at Ecton represents a unique type of copper mineralization, which shares a similar genetic model to the Pb-Zn mineralization of the South Pennine Orefield. Whereas the latter is classed as a typical carbonate-hosted Mississippi Valley-type deposit, Ecton may be classed as a copper subtype of this type of deposit. The most popular genetic theories for the formation of the Ecton orebody, like the South Pennine Orefield, incorporate a basinal brine model with respect to fluid derivation, and post-Carboniferous extensional tectonics as a mode of fluid migration prior to the mineralization. The literature suggests that although the majority of the South Pennine Orefield was sourced from fluids derived from basins to the east of the Derbyshire Platform, the Ecton mineral deposit brines were likely to have been sourced from a more westerly source that differed only slightly in terms of their chemical and physical properties from the South Pennine Orefield fluids. Marginal evaporitic fluids from the Cheshire Basin represent a possible fluid source for the Ecton mineralization, although a number of minor rift-basins present within the Carboniferous may also have provided a suitable source. Although much work has been conducted with respect to the larger economically important orefields in this area of Derbyshire, there still remains some lack of clarity with respect to the constraints on the genesis of the ore deposits at Ecton.

References



(Figure 4.28) Location map of Ecton Copper Mines.

(Figure 4.29) The remains of mineralization within Clayton Mine. (Photo: H. Townley, Natural England.)