ESSAY REVIEW

Ecton Copper Deposits, Staffordshire

The recent publication of *Ecton Copper Mines under the Dukes of Devonshire 1760-1790* by Lindsey Porter (2004) has yet again raised the difficult question of the nature of this famous copper ore deposit, as well as throwing light on many related matters.

Four years ago the writer reviewed the geological settings of the mineral deposits throughout northeast Staffordshire (Ford, 2000) and summarized the state of knowledge of these deposits, which have been under water since mining ceased in 1856 at Ecton Mine and in 1889 at Clayton Mine. Each of these two mines worked a "pipe" of copper, lead and zinc minerals, in effect a vertical, roughly cylindrical ore-body. The term pipe is used at Ecton with a completely different meaning from its use in the rest of the South Pennine Orefield. In the latter a pipe is generally defined as an elongate orebody roughly parallel to the stratification and usually nearly horizontal, often centred on palaeokarstic features, or formed along the contacts of limestone with either dolomites or lavas. At Ecton, the pipes have a more or less vertical cross-cutting relationship to complexly folded strata, with no palaeokarst, dolomites or lavas involved. As no description of the deposits based on direct observation by a geologist is known, reliance has long been placed on the somewhat vague and incomplete accounts from the late 18th to middle 19th century.

Lindsey Porter's excellent book contains chapters on the geology and on contemporary visitors' accounts, with quotations from several writers including Banks (1767), Harpur (c.1767-1770), Efford (1769), Hatchet (1796), and Mawe (1802). While these were largely concerned with the experiences of the visitors, with mining methods or the minerals found, they included some observations on the geological setting - in the days before geology was established as a science. Taking these observations together with the much later contribution by Joseph Watson (1860), Porter has been able to deduce somewhat more about the nature of the deposits than my conclusions in 2000.

In short, Ecton Mine's "irregularly cylindrical" ore-body was worked over a vertical height of about 1400 feet (420 m), down to 300 m below river level, and the Clayton orebody was worked over a similar depth some 250 m to the south. Neither bottomed the stratigraphic sequence of Carboniferous Limestone beds. Most of the ores were hosted in the Ecton Limestones-with-Shales, but it seems likely that the workings penetrated the Milldale Limestones beneath.

The pipes were in or close to the ill-defined axis of the Ecton anticline (Prentice, 1952; Aitkenhead et al, 1985), though the 18th century writers did not recognize it as such. Indeed, an unsigned and undated section (shown as Figure 2.1 in Porter's book) shows the structure of the hill as a monocline facing east, though no evidence for such a structure is known. The anticline plunges northwards, so that the apparently regular sequence of limestone divisions dipping at about 20° south, as shown on some mid 19th century diagrams, is contrary to modern geological analysis. Instead, the incompetent nature of the mass of thin limestones with intervening shales overlying more massive limestones appears to have resulted in concertina-like and often discordant folding of the former on both flanks of the anticline. If these folded beds are regarded as lying on each side of a tight upfold, the pipes may in fact lie mostly within the Ecton Limestones-with-Shales, particularly with the tightly compressed core of the fold. The folded limestones are well seen in Apes Tor at the northern end of Ecton Hill, where they display north-south axes resulting from east-west compression. Equivalents to the Apes Tor folds are also visible in the presently accessible adits where the anticlines are generally some 10-20 m wide and high (Critchley, 1979). Critchley's diagram of the folds seen along Clayton adit (reproduced as Figure 5 in Ford, 2000) show that the western flank is almost flat-lying with tight upright folds only in the vicinity of the pipes. Some of these tight folds are visible in the walls of the Clayton Engine Chamber and are illustrated in photographs in Porter (2004) and Ford (2000).

In the only detailed discussion of the folds found so far, Watson (1860) referred to the anticlines as huckle saddles and the synclines as trough saddles. He noted the presence of double saddles. He also said that ores were present in saddle joints, i.e. axial fractures in both anticlines and synclines and also along the bedding forming "wings" on each side. While Watson provided a good description and a diagram, he unfortunately cited no specific localities, and it is not known whether he ever saw such structures in the Ecton pipe, as that began to fill with water four years before his paper was published. Saddles were, however, found in the Clayton and Good Hope Mines at Ecton, though no full description of their mineralization features is available. A saddle has also been found in Royledge Mine, some 5 km to the west; Watson may have projected ideas from these other examples to formulate a general idea for all the Ecton mines, but his paper is not clear on this matter. Lindsey Porter has suggested that if the axial joints in anticlines and synclines, i.e. huckle and trough joints, were aligned in the stack of eight groups of folds (see below) they would provide linked lines of weakness for the movement of mineralizing fluids.

Reading between the lines of Efford's, Hatchet's and Harpur's writings, Porter has deduced that there were eight arrangements or groups of saddles in the depths of Ecton pipe, each having been mined out to leave a succession of voids stacked on one another. The voids were recorded as "vaults", giving the

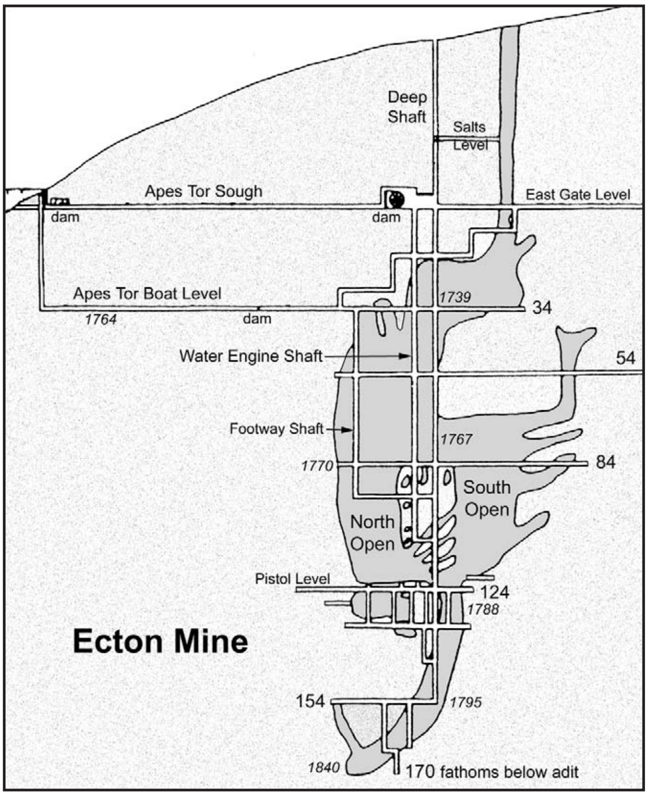

***Figure 1**. Diagrammatic section of the Ecton pipe, redrawn after a mid-19th century prospectus; numbers in the larger font indicate depths in fathoms below adit level at the Apes Tor Sough, and numbers in the smaller italic font indicate dates of the advancing workings.*

misleading impression of natural caverns. Some saddles were said to be capped by "pipes" of the traditional Peak District type, but details are unknown. The "stacked voids" do not agree with the arrangement of "opens" in a mid-19th century prospectus diagram (Fig. 1). Only those parts of the mines at or above adit level, i.e. above the level of the River Manifold, are still accessible and details of the folding in some adits were admirably described by Critchley (1979), some of whose diagrams were reproduced in Ford (2000). The details of folds in other adits remain undescribed.

The pipe was noted to have been squinted in places, i.e. offset by faulting ("squatted", according to Watson, 1860), and the mineralized pipe was lost at the lowest levels perhaps by the same type of offsetting. Double saddles were mentioned in mid-19th century reports in the *Mining Journal*, apparently due to folds crossing at right-angles, though this seems strange in the tectonic regime of east-west compression. In the pipes the ores were found in large and small masses between limestone blocks of similar size, sometimes with clay admixtures. Structures known as "lums" were apparently similar aggregations of limestone blocks with much clay: a presumed example is visible today in the adit of the nearby Dale Mine that was worked for lead.

Clayton Mine was apparently of similar nature, but it was worked by a different company of adventurers (= shareholders) and no 18th century archives are known to have survived. A few mid-19th century diagrams were attached to company prospecti. Both the detailed nature of the deposit and the history of mining are poorly documented.

Though mining peaked with the Duke's activities of the late 18th century, there was a long history of previous mining. Indeed the discovery of an antler pick and hammer stones in old high level workings indicates that mining took place in Bronze Age times (Barnatt & Thomas, 1998). Specimens of copper ore collected in the 1690s are in the Woodwardian Collection of the Sedgwick Museum, Cambridge. The somewhat patchy early 18th century history was summarized by Barnatt (2002)

The overall impression gained is that the orebodies were large masses of mineralized crush-breccia developed in tight folds in the incompetent Ecton Limestones-with-Shales. Ore-fluid movement is likely to have been largely lateral, with an upward component, out of the Cheshire basin, as discussed by Ford (2000). There were several other pipes in the area (Ford, 2000; Porter & Robey, 2000) but none was exploited to anything like the same extent and none has been studied in modern times, and it may well be that there are further ore-deposits comparable with Ecton which have never been found.

Lindsey Porter's book gives a detailed account of this major mining enterprise in the late 18th century (much enlarged from Porter & Robey, 2000). Nominally conducted by successive Dukes of Devonshire, who were happy to receive the profits and spend them on various projects such as buildings in Buxton and at Chatsworth, the actual management was left to the agents, a few of whom Porter reveals to have been rather less than honest. The enterprise involved up to 300 miners, plus some of their wives, the latter mostly on surface ore-dressing, as well as their children. In an otherwise sparsely populated agricultural region, such a work-force drew in many immigrants, and it needed considerable back-up of housing, food and beer. Porter's analysis of thousands of documents in the Duke of Devonshire's archives at Chatsworth House has revealed the complexity of operations.

Most of the smelting was done at Whiston some 15 km to the southwest and this required teams of pack-horses and mules to transport the ore; these in turn required fodder, and tons of hay were required in winter to alternate with pasturage in summer, doubtless a considerable boost to local agricultural revenues. The Duke's agents minimized costs by building dedicated roadways to avoid paying tolls on turnpikes. Coal for the smelting furnaces was obtained from the Duke's own collieries near Whiston. Some coal was brought back to Ecton on the return journeys, for use in a steam winding engine, in smithies, lime burning, domestic heating and a limited amount of smelting of both copper and lead. Vast quantities of timber were needed both within the mine and for buildings outside, and woodlands were all but stripped for miles around. Great quantities of nails were obtained from forges in the Belper area. Machinery and other metal equipment also had to be brought in, sometimes necessitating teams of horses for heavy loads. Fluorspar was shipped in from the Matlock area for use as a flux in the smelting process. Clay was brought in from the Pocket Deposits (Brassington Formation) at Newhaven for use in water-proofing ponds and for lining furnaces; bricks were imported for building furnaces; the list goes on.

While copper was the main product, considerable quantities of lead ore were raised. As Ecton was outside the main orefield, it had no Barmaster and no lead records were made. Zinc ore was obtained too, but its use in brass-manufacture was largely a 19th century phenomenon and the 18th century miners took little note of it. The marketing of these different ores was a complex business, and several clerks were employed dealing with wages, merchants, supplies and shipping. It is their records which have provided such a mine of information on what was one of the largest mining operations in Europe in its day.

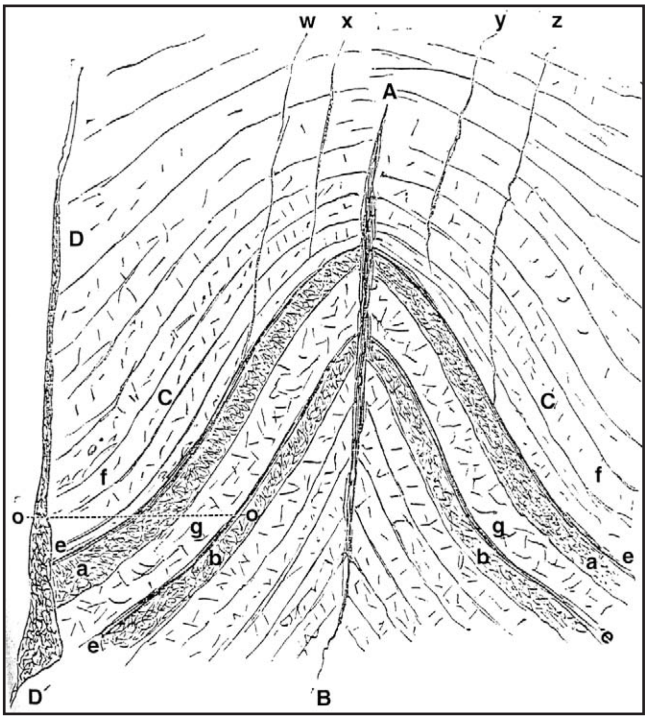

***Figure 2**. Joseph Watson's 1860 diagram of a saddle (reproduced from Porter, 2004, page 21). A is the crown or huckle of a saddle; A-B is the saddle joint; C and C are the wings; D-D is a trough joint, usually more productive of ore than a saddle joint; w, x, y and z mark fissures, which ran up to a pipe vein; f and f are troughs rich in ore, particularly at a and a; e and e are soft decomposed limestone, taken to be guides to ore; o-o marked a cross-cut to reach the wings and troughs.*

In recent years part of Ecton Mine has been developed as an educational resource by Geoff Cox, and it is to be hoped that this arrangement will continue after his recent death. It is also to be hoped that someday a research grant will make it possible to pump out the flooded workings and see those geological details which have been hidden for nearly two centuries.

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