12: Minor Metals

12.1 Arsenic

Arsenic was one of a number of contaminants affecting copper and tin production in Cornwall and Devon. In the case of tin, where alluvial tin deposits were worked the arsenic had already been eliminated through weathering and leaching as part of the process of natural erosion and was not usually a problem. *In situ* tin lodes, however, were often contaminated with arsenic and as production from this source increased from about the 15th century the arsenic along with other contaminants (including iron pyrites, FeS^2 and zinc sulphide, ZnS) had to be removed by calcining the ore prior to smelting. A similar problem was attached to the exploitation of sulphide copper ores from the 18th century onwards, as mining progressed below the weathered secondary ores close to surface, and it became necessary also to roast the ores to remove these contaminants by burning them off as gases. Burning houses or reverberatory claciners used for this purpose were recorded by the anonymous writer of 1671; although no structures remain from this period, later examples from the 19th century survive at some mines in both Devon and Cornwall. Prior to the early 19th century this process was carried out without any attempt to recover the arsenic, which was lost to the atmosphere. Mine owners in Cornwall and West Devon were slow to recognise the economic potential in recovering arsenic in the form of the arsenious oxide (As_2O_3) but, once accepted, most large mines engaged in the practice and by the 1870s some mines were realising a significant income from arsenic sales.

The uses for arsenic compounds were, by the mid-19th century, manifold and the substance had a number of uses. It was added to molten lead in the manufacture of shot to produce a spherical shape and arsenical oxides were used in certain chemical processes as well as uses in the preparation of pigments for paint and wallpaper. It was also a powerful poison employed in the preparation of sheep dip and other insecticides, such as crop dusts and sprays. The most important application for the latter in the late 19th to early 20th century was the control of Colorado beetle in North American potato crops but the most well-known use, the control of boll weevil infestation in cotton plants in the 1920s, came too late to draw on English arsenic production (Burt 1988, 15-18).

Levels of arsenic contamination in copper ores from other mines in England was perhaps not as great as that in Devon and Cornwall but it was, never the less still a problem, which had to be eliminated. At Alderley Edge this was acheived as part of the acid leaching process and the arsenic was removed as waste along with the sand (Carlon & Dibben 2012, 74). Arsenic does not appear to have been recovered at these or any other copper mine in England outside Devon and Cornwall. A small quantity was recovered from tungsten-bearing ores at the Carrock Fell Mine, in what is now Cumbria, and it was worked as the primary produce in Scotland at the Talnotry Mine near Newton Stewart, in Dumfries and Galloway (Pickin 2013).

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12.1.1 The geological background

In England the presence of significant amounts of arsenic in copper and tin is associated with mineralisation linked to the Cornubian granite emplacement in Devon and Cornwall. Although arsenic is present in some ores in Cheshire (Alderley Edge) and the north-west, in what is now known as Cumbria, it might have been regarded as a contaminant but it was not present in sufficient quantities to justify its recovery with the exception of a small quantity produced by the Carrock Mine in the early 20th century. The principal ore of arsenic is arsenopyrite or arsenical pyrites (FeAsS) also known as 'mispickel' or 'white mundic' found in close association with copper and tin ores (Scrivener *et al* 1997, 19). The geology of arsenic production is therefore firmly linked to that of tin and copper mining in Cornwall and Devon, addressed in the Resource Assessment for those metals.

12.1.2 Historical background

The first arsenic refinery in Cornwall was set up near Perranwell in 1817 to recover arsenic from mine waste. This was followed in 1835 by a second plant, again treating mine waste, near Bissoe-bridge after which mine owners realised that what they were burning off as a contaminant was of value, and some began to erect flues to condense and collect the arsenic from their roasting hearths (Earl 1983, 12).

By the late 1860s mines in Devon and Cornwall were working arsenopyrite specifically for the arsenic content, with sulphur (for sulphuric acid production) as a significant by-product. Within ten years production of arsenopyrite ores had risen to nearly 15 thousand tons per annum. Thereafter it fluctuated wildly but was still at over 12 thousand tons of ore per annum in the last years of the century (Burt et al 1984, xxv-xxvi).

The majority of the arsenic produced in Devon and Cornwall came, however, from the treatment of tin and copper ores. Its production provided a significant supplementary income for many mines but only in the case of Devon Great Consols, after 1884, did it become the dominant source of income (Burt 1988, 23, Table 5). Although some arsenic production continued into the mid-20th century it was a very much reduced levels (Earl 1983, 26).

12.1.3 The technology of arsenic production

Arsenical ores were seldom sold in their raw state and needed concentration at or near the source to convert them into a commercial product. Earl (1983) provides a detailed account of the processes used in arsenic recovery and refining, which might be used in the interpretation of

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surviving features, particularly those found on the later sites from the end of the third quarter of the 19th century.

The early calciners were simple structures, either reverberatory or shaft furnaces, sometimes a modification of existing 'burning houses', linked to long flue systems in which the arsenious oxides would condense as soot of varying purity. From the 1830s onwards mechanisation of the process was introduced with the Brunton calciner, which allowed for continuous operation. The Brunton, patented by William Brunton in 1828 (Stewart 2005, 10), had a rotating convex circular hearth, powered by a waterwheel, over which the flames from two fireboxes were drawn. Ore was fed into the centre of the hearth and was roasted as it slowly rotated below cast iron coulters, which ploughed it towards the outer edge where the fully calcined ore was discharged (Earl 1983, 15-17). Bruntons were usually associated with long flue systems or labyrinths in which the purified arsenic collected. Less successful and less common was the rotating tubular calciner developed by Oxland and Hocking in the 1870s, known as the 'Oxland Tube' and the adaptation of other mechanised hearths, which could allow pyritic ores to self-combust. However, the rolling motion of the ore in Oxland Tubes created too much dust and this system was less successful; the Brunton was therefore the foremost process used. The last Brunton calciners were in use up until the 1950s but, by then, the separation of arsenic from tin and copper ores was effected by froth flotation (Earl 1983, 24-27). Devon Great Consols had both Bruntons (by at least 1866) and Oxland (by 1878) in use (Stewart 2005, 10-11).

Refineries, to which the arsenic-rich soot from the calciners was sent, were established either at the larger mines or as separate concerns, initially part of the works recovering arsenic from mine waste. The earlier refineries employed cast iron retorts, or 'kettles', to separate out the arsenious oxide from the soot (Earl 1983, 13-14) but these were later replaced by flat-bed reverberatory furnaces, using high grade fuel such as anthracite, again linked to long flues and labyrinths or condensing chambers (Earl 1983, 19). Refined arsenic was then ground to a powder and packed in barrels for transport. The grinding mill from the 1920s refinery at Devon Great Consols still survives.

12.1.4 The archaeology of arsenic production

The presence of arsenic in copper ores worked in Britain in prehistory may or may not be relevant to the production of arsenical copper and bronze, and there is some evidence to suggest it may have been a factor in the selection of copper ores from the south-west of England (Ixer & Pattrick nd), but it was not until the 19th century that arsenic bearing minerals were worked in their own right. It is therefore to the modern period, and to Cornwall and West Devon, that we look for the archaeological evidence for arsenic production.

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Among the best preserved burning houses in Devon or Cornwall is at the Atlas (or Albion) Mine, near Ilsington in Devon, Richardson (1992, 63). This has two burning chambers and an externally mounted stack, but it is unlikely to have produced arsenic commercially. A calciner of similar design, though with a single burning chamber survives at South Devon United mines at Mary Tavy and this example has had a long flue added as a means of deliberately collecting the arsenic (P Newman *pers comm*).

The flues, labyrinths or condensing chambers, and associated chimneys of arsenic calciners are dominant features on a number of tin and copper mines in Cornwall and West Devon, and some of the sites identified by Earl (1983) have been stabilised and conserved but some have been lost through neglect or deliberate clearance. The Brunton calciners and associated labyrinth and flues at Levant, in west Cornwall, were recorded prior to remedial work which resulted in the heavily contaminated site being covered over and the features are no longer accessible (Sharpe 1994). The similar surviving features at the nearby Botallack Mine in west Cornwall have, however, been conserved. They comprise the hearth for a Brunton calciner, flues, condensing chambers along with the remains of the stack, and these have been surveyed and interpreted by Pete Joseph (2010, 179-91, and 2012). Joseph had earlier prepared a survey and assessment of the calciner at Tolgus, in central Cornwall (2004).

In the Tamar Valley consolidation work on the surviving chimney at the Coombe Arsenic Works in East Cornwall was accompanied by a report on the watching brief (Buck 2006b). The arsenic works at Okel Tor, Calstock, were included in the assessment of that mine (Buck 1999). Archaeological assessments have also been carried out at Devon Great Consols (Buck 2002), including the arsenic works, and on the Gawton works (Buck 2006a), both on the Devon bank of the Tamar; the latter being carried out as part of the Tamar Valley Mining Heritage Project. The arsenic works at both Devon Great Consols and Gawton had been the subjects of earlier archaeological survey work (Dixon et al 1989; Pye & Dixon 1989; Pye & Weddell 1992).

Although the processes for the production of arsenic are well known for many individual calciners have been recorded in Devon and Cornwall, no overview, analysis or inventory of the surviving buildings is known, and a comprehensive study is overdue.

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