The Trewhiddle Tungsten Bloom – *an initial report by*

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Introduction

The recent find of a large and particularly heavy metal lump by D Coombe, from Trewhiddle Farm near St Austell, sparked considerable interest in its origin and purpose; in particular once it had been identified as comprising considerable amounts of tungsten metal. Following on from initial analyses by Brian Earl, and an in-depth investigation by the BBC in co-operation with the Natural History Museum in London in October 2004, it became apparent that this is a rare example of early tungsten metal, and that it may hold clues about the early history of tungsten production or tungsten research in southwest Britain.

The aim of this first report is to characterise the material based on a few small samples removed in autumn 2004 from the side of the ingot, and the data provided by the Natural History Museum in London.

Macroscopic

The find is of dark to rusty colour, has a rough surface and is irregularly egg-shaped with a maximum length of around 20 cm ***(fig 1).***

The quality of the surfaces varies slightly from more smooth and consolidated to rather rough and porous, almost fragmented (see the top surface in ***fig 2*** as compared to the side surfaces). This gives the find the feel of a worked piece rather than appearing as an un-treated waste product.

Fig. 1: *Side view of the Trewhiddle bloom, showing area of previous cutting attempts.*

The weight of the find is approximately 17 kg, its volume was determined to about 1.7 litres, resulting in an apparent density of 10 g/ccm. Upon sectioning, a shiny metallic interior became visible, with large areas of dark inclusions ***(fig 2).***

Fig. 2: *Side view of the Trewhiddle bloom, showing the surface freshly exposed from this study.*

Initial assessment, and questions

The initial assays had identified the composition as being predominantly of metallic tungsten, leading to speculations that this piece may represent an early attempt to produce tungsten metal. One of the problems deriving from this assessment, though, lies in the fact that metallic tungsten has a density of around 19 g/ccm, as opposed to the 10 g/ccm measured for this object, and the rather high temperature necessary to melt tungsten, of around 3,300 C. Another fundamental question is that of the likely date of this object, which was found as a surface find with no supporting dating evidence.
To address the first two questions, a series of polished sections were produced from the slivers of metal removed during the initial investigation.

Chemical composition

One of the polished fragments was subjected to XRF analysis, using the Institute of Archaeology's SPECTRO XLab 2000 Pro and the 'alloy' methods. This indicates that the sample is comprised of about 40 to 45 wt% tungsten, c. 30 wt% tin, and c. 25 wt% iron. The main other component identified is silicon, probably present as silicon dioxide, at a few percent by weight. Of the trace elements, phosphorous is present at just above half of one percent, while sulphur, chromium and manganese are present at less than 0.1 percent. However, visual inspection of the sample clearly shows that it contains different parts and regions, most likely of different chemical composition, so that the values given here are not likely to be representative of the whole object.

Microscopic investigation

The metallic part shows a number of different phases, differentiated by their grey shades and hardness ***(figs. 3 and 4).***

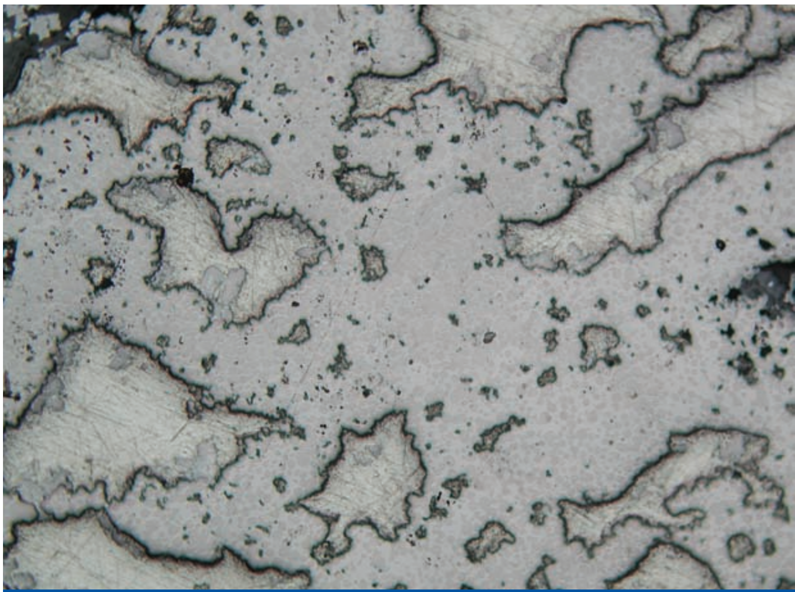

Fig 3: *Low-magnification overview of the metallic part of a sample from the Trewhiddle bloom. The silvery and rather scratched parts are metallic tin, often containing darker grey inclusions of tin-iron alloy (hard head). The matrix shows phases of different grey shades, as more clearly resolved in* ***fig. 4.***

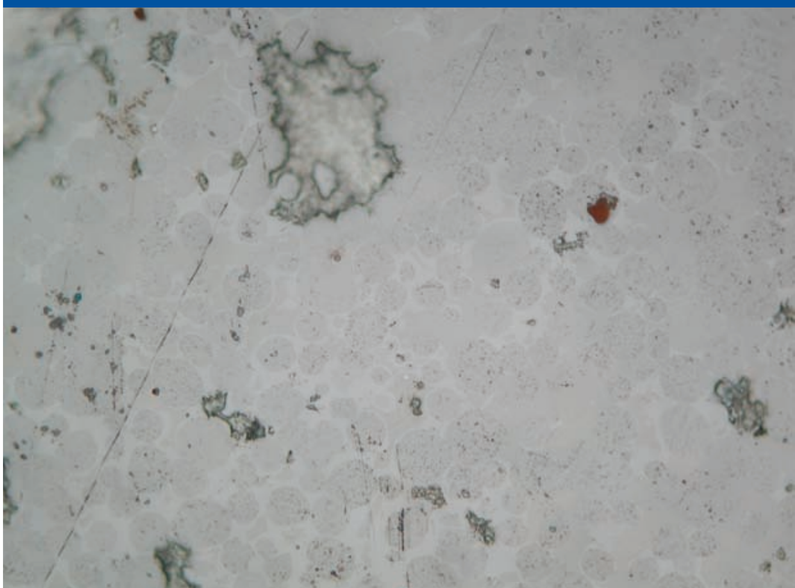

Fig 4: *Photomicrograph of the metallic matrix of the Trewhiddle bloom, with round particles of a hard and brittle phase (note the small dark specks), embedded in a slightly lighter matrix. In the lower right hand side, the matrix phase differs, having the same slightly darker grey shade as the round particles, but taking a better polish. Based on electron microprobe data from the Natural History Museum, the round particles are pure metallic tungsten, while the matrix phases are likely to be tungsten-iron alloys with and without phosphorous. Width of image c. 0.2 mm.*

The electron microprobe data from the Natural History Museum report almost pure tungsten for the round particles, with as little as 1/3 percent by weight of iron in it. The matrix phases appear to fall into two groups, one with about 63 wt% W, 34 wt% Fe and 3 wt% P, and another one with about 72 wt% W, 26 wt% Fe and 2 wt% P. The latter phase probably corresponds to the known phase W_6Fe_7 (theoretical iron content of c. 26 wt%), while the former may represent the known phase WFe_2, which has a theoretical iron content of around 38 wt%. These phases are all known to form during the smelting of impure tungsten ore; and indeed, the presence of iron (and other metals such as nickel, cobalt and so on) greatly facilitates the formation of tungsten metal and intermetallic phases.

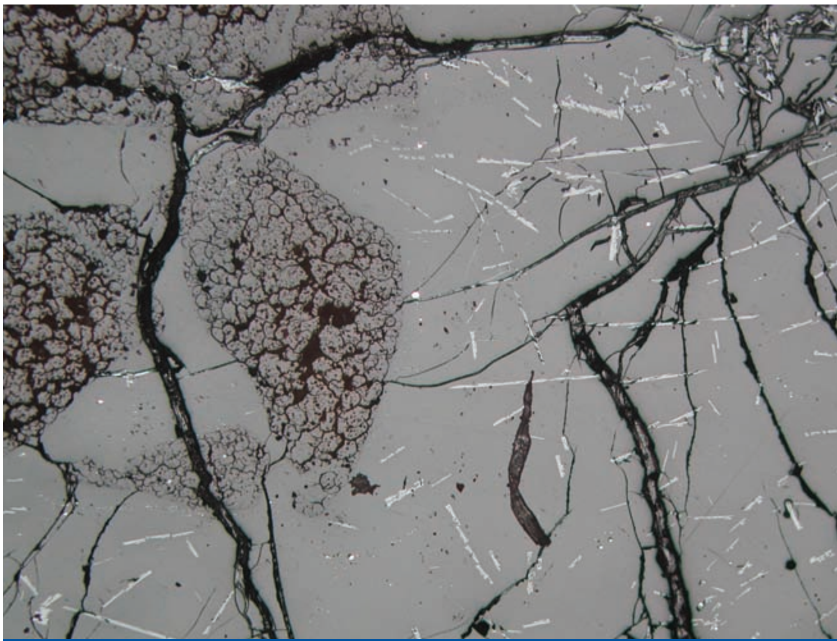

Fig. 5: *Photomicrograph of a slag inclusion from the Trewhiddle bloom. The cloudy areas at the left and upper left part of the image are silica (probably former quartz from the host rock), while the slag itself is predominantly glassy (grey area) with a scatter of bright needle-like crystals of metal oxide. Width of image c. 1 mm.*

Other parts of the samples show large inclusions of slag ***(fig. 5)*** and charcoal ***(fig 6)***; in particular the charcoal is dominating in the large dark inclusions already seen in the initial cut ***(see fig. 2)***.

The nature of the slag inclusions has not yet been studied in much detail; the presence of large clusters of pure silica and the overall glassy nature of the slag indicate that it is rich in silica, but may contain iron oxide and calcium oxide as well. It is hoped that the composition of this slag can be compared to published tin slag analyses, to test whether the Trewhiddle bloom originates from tin smelting, or has its own unique slag composition, and hence may be the result of a special smelting operation.

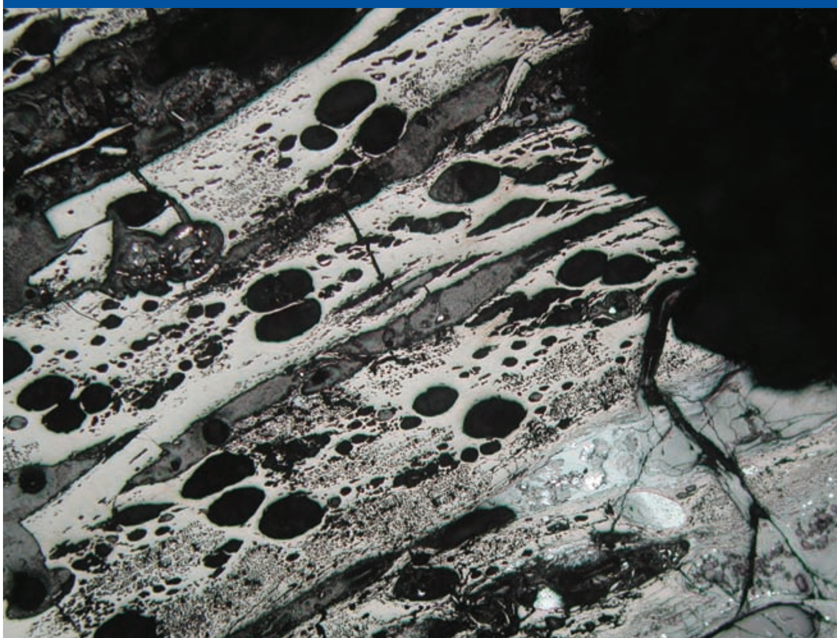

Fig. 6: *Charcoal inclusion in the Trewhiddle bloom. The cellular structure of the wood is well preserved, while the close association of the charcoal with the slag (lower right hand corner) confirms that the charcoal was in direct contact with the slag while the latter was still liquid.*

The use of charcoal as fuel for the smelting operation is interesting, and may help us to determine the approximate date of production for the bloom, either by radiocarbon dating, or by study of historical records and an understanding of the general use of charcoal and mineral coal / coke in Cornish metallurgy.

Preliminary interpretation

There is little doubt that the metal originates from a mixed tin - tungsten ore; the association between the two is too intimate and the amounts present too high. Tin and tungsten ores occur often together in nature, not least in Cornwall, and iron is a typical impurity in both ores. Even back in the 16th and 17th century, smelters in central Europe were aware of the occurrence of some unwanted material during tin smelting; they gave it the name of *wolfram* ('wolf spittle' in English), clearly on a negative note. However, it was not before the late 18th century (1783) that two brothers in Spain isolated and identified the new metal tungsten / wolfram. In the mid 19th century, the addition of tungsten to steel was patented first in Austria (which has large tungsten deposits of its own) and soon also in England. It is this period of metallurgical enquiry, experimentation and discovery in which we are interested in the context of the Trewhiddle bloom, as it may be an early witness of the Cornish attempts to elucidate the nature and potential use of this material which they produced inadvertently during tin smelting.

The first question therefore is whether this is a purposefully produced material, or whether it is just a waste of tungsten metal accumulated in the tin slag during repeated smelting and processing. At present, this is difficult to answer; however, there are some indications (primarily based on the investigation done by the Natural History Museum) of near-original ore minerals being present, both tungsten-iron oxides and tin oxide. If this is confirmed by further analyses, then there are good reasons to argue that this is unlikely tungsten accumulated over a period of time in a tin smelter, but is indeed the result of processing impure tungsten ore for the tungsten. The same goes for the presence of charcoal, which is – if present in larger quantities within the object – indicating direct smelting efforts, and not the accumulation of heavy tungsten metal, presumably at the bottom of a tin smelter. For further clarification, however, it is necessary to see how much charcoal there actually is in this piece. The overall low density of around 10 g/ccm (as compared to the expected 19 for tungsten and about 8 of tin metal, resulting in at least an average 13 or 14 so for a block of equal quantities of tin and tungsten) indicates that there is a significant amount of charcoal (or other very light material) trapped inside.

The second issue concerns the actual possibility of forming solid tungsten at a time when it was technically impossible to melt tungsten metal, or its alloys. Here, we have to resort to the known principle of solid state metal reduction, as e.g. routinely done in the bloomery process of early iron smelting; in this, the iron metal was also never liquid, but still formed a solid block or billet after sufficient forging. Chemically, tungsten ore is even easier to reduce to tungsten metal than iron ore to iron metal; the surrounding presence of tin and iron metal will have helped to agglomerate and separate the metal from any forming slag. The visually gained impression that this object underwent some hammering and consolidation would also point towards the intentional – probably experimental – production of this metal, and attempts to work or refine it.

In reference to the established term 'bloom' for the semi-finished product of solid-state direct iron smelting, I suggest to call also this find a bloom rather than an ingot; an ingot would be a trade item of acknowledged proportions and properties, which at present seems not to be what can be said about this unique and semi-finished find. Whether it was something which the local smelters did after the discovery of tungsten metal in Spain in 1783, or whether they tried to work, isolate and possibly develop this long-known un-identified by-product of tin smelting even before that, is at present impossible to say. For this, we would need a more reliable date of manufacture for this find, and / or insight into the activities of the tin smelters during the last century or so of their operation in this region. I certainly hope to contribute to this discussion with further research.