Centre for Archaeology Report

Analysis of Ingots from Lew Mill, Devon

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Summary

Three ingots were recovered at Lew Mill, on the edge of Dartmoor, Devon. Samples were taken from two of the ingots for analysis by energy dispersive spectrometry. The ingots were impure tin, containing about 7wt% lead. One of the ingots also contained 0.8wt% copper. The composition of the ingots is most consistent with finds of Roman date, according to the analytical data currently available.

Keywords

Lead/tin alloy, technology**,** Roman

Introduction

Three heavily corroded metal ingots were discovered by Tony Butland using a metal detector at Lew Mill, on the edge of Dartmoor, Devon. The ingots were found lying on top of one another at a depth of 0.36m, south of the lower bank of the Lew Mill leat (NGR: SX 46598615). A bronze palstave was recovered 90m away (NGR: SX 46688613) north of the river Lew (Marchand pers. comm).

All of the ingots were approximately rounded to oval in plan, with fairly flat upper surfaces and convex bottom surfaces. Ingot 1 was the largest, weighing 5286.5g. Ingot 2 was shallower and had a hole throughout its thickness, which was original rather than being post-burial damage, and weighed 1780.5g. Ingot 3 was the smallest, weighing 1442.5g.

A flake from one of the ingots was analysed by Chris Carey at Exeter University using Atomic Absorption Spectrometry (AAS). The sample was from the corroded surface of an ingot, and the dissolution of the flake during the sample preparation procedure was incomplete, so the results were approximate. Tin, lead and to a lesser extent copper were present in significant amounts. With the permission of the owner, two of the ingots were sampled and further analysed at the English Heritage Centre for Archaeology in order to determine their composition quantitatively.

Method

First the ingots were analysed using X-ray fluorescence (XRF) spectrometry. In this technique, the surface of the object is bombarded with X-rays, which are absorbed and cause atoms in that area of the object to emit secondary X-rays. The energies of the secondary X-rays are characteristic of the elements present and so the composition of the object can be determined. The advantage of XRF is that a semi-quantitative analysis can be obtained rapidly without sampling the object. However, as the corroded surface of the object is analysed, the composition is likely to differ from that of the original metal.

Small samples of uncorroded metal were then taken from ingots 1 and 3, using a fine drill. The samples were analysed using an energy dispersive spectrometer (EDS) attached to a scanning electron microscope (SEM). This analytical technique also uses secondary X-rays emitted by the sample to determine the composition and the results obtained are for the uncorroded metal.

Results

XRF

A series of pewter alloy standards were analysed using XRF and the results agreed well with the known compositions of these alloys (table 1 and figure 1).

Table 1: Results of XRF analyses of pewter alloys with known compositions.

Sample Composition	Measured Pb wt%	Measured Sn wt%
5wt% tin	93.6	6.4
21wt% tin	83.4	16.7
41wt% tin	56.8	43.2
81wt% tin	22.9	77.1
98wt% tin	5.3	94.7

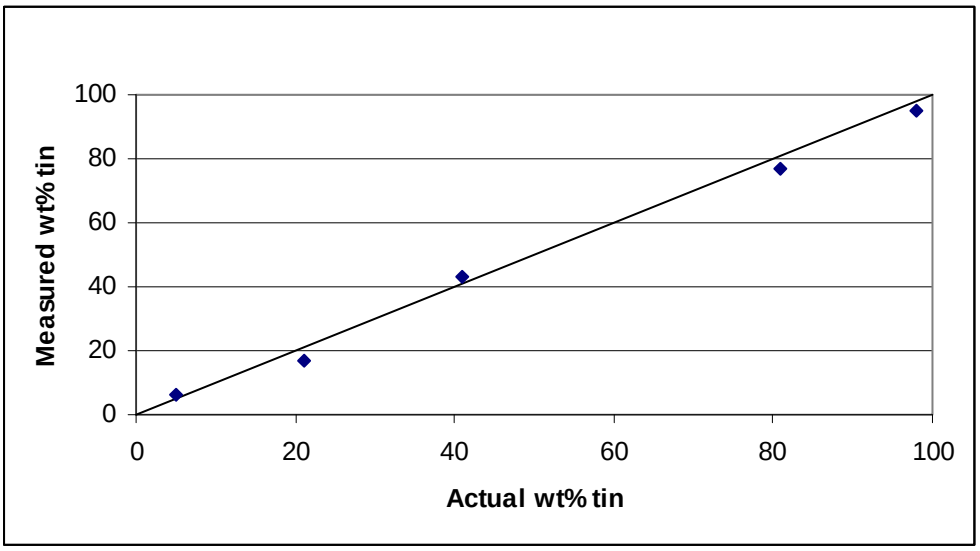

Figure 1: Measured wt% tin versus actual wt% tin in pewter standards for XRF analysis.

The corroded surfaces of ingots 1 and 3 were analysed. The results indicated that both ingots were comprised mainly of tin but contained appreciable amounts of lead, particularly in ingot 1. In excess of 1wt% copper was detected in the corroded surface of ingot 3 (table 2).

Table 2: XRF analyses of ingots 1 and 3.

Sample	Pb wt%	Sn wt%	Cu wt%
Ingot 3	8.8	89.9	1.4
	10.1	88.3	1.7
Ingot 1	20.6	79.4	0.1
	13.9	86.1	0.1

EDS

The pewter alloys used as standards for the qualitative XRF analysis were not suitable to use as standards for the quantitative EDS analysis, as they were found to be too heterogeneous. Instead more homogeneous solder standards were analysed using EDS and the results agreed well with the known compositions of these alloys (tables 3 and 4). An analysis is likely to be within 14% relative of the lead content, 10% relative of the tin content and 30% relative of the copper content. The detection limits are 0.1wt% for copper and lead, 0.3wt% for tin and about 0.5wt% for silver and gold.

Table 3: Known compositions of solder standards.

Standard	Pb wt%	Sn wt%	Cu wt%	Ag wt%	Au wt%
Solder 1	37.50	61.00	0.00	1.50	0.00
Solder 8	34.65	64.5	0.55	0.00	0.30

Table 4: Results of EDS analyses of solder standards.

Standard	Pb wt%	Sn wt%	Cu wt%	Ag wt%	Au wt%
Solder 1	34.95	64.10	bd	0.94	bd
	40.15	58.57	bd	1.22	bd
	37.12	61.47	bd	1.36	bd
Average	37.41	61.38	bd	1.17	bd
StDev	2.61	2.77	-	0.21	-
Solder 8	36.11	63.56	0.33	bd	bd
	35.16	64.38	0.46	bd	bd
	35.79	63.72	0.48	bd	bd
Average	35.69	63.89	0.42	bd	bd
StDev	0.48	0.43	0.08	-	-

bd = below detection limit

Severn different 0.05mm^2 areas of each sample of fresh metal from ingots 1 and 3 were analysed (table 5).

Table 5: EDS analyses of ingots 1 and 3, normalised.

Sample	Pb wt%	Sn wt%	Cu wt%
Ingot 3	3.75	95.51	0.74
	3.99	95.54	0.47
	15.55	83.80	0.65
	3.63	95.71	0.66
	15.3	84.17	0.54
	3.79	95.67	0.54
	2.90	95.23	1.87
Average	6.99	92.23	0.78
StDev	5.77	5.64	0.49
Ingot 1	8.37	91.54	bd
	6.32	93.64	bd
	7.45	92.50	bd
	6.59	93.34	bd
	7.54	92.39	bd
	5.41	94.59	bd
	8.78	91.20	bd
Average	7.21	92.74	bd
StDev	1.18	1.20	-

bd = below detection limit

Both ingots were comprised mainly of tin but contained around 7wt% of lead. Ingot 3 also contained about 0.8wt% copper. The composition of the ingots was variable, as shown by the analyses. The microstructure of the ingots consisted predominantly of

tin metal with distinct regions of lead distributed throughout. The copper detected in ingot 3 was in the lead regions rather than the tin.

Conclusions

The ingots are impure tin, containing some lead and, in ingot 3, small amounts of copper. Ingots with a plano-convex shape are often assumed to be of an early date but very few have actually been found in stratified contexts (Tylecote, 1990; Penhallurick, 1986, 225-236). Of the few tin or tin alloy objects, thought to be of Bronze Age or Iron Age date, that have been analysed, the majority are pure tin containing less than 1wt% of lead and only traces of copper (Tylecote, 1990, 50). The exceptions are rods from Auchtertyre, thought to be of Bronze Age date, which contained 21wt% lead. A very large proportion of tin and tin alloy finds from Britain date to the Roman period. Literature data shows that one of the Roman ingots from Battersea (Hughes, 1991) and a number of Roman objects from various sites contain levels of lead comparable with the Lew Mill ingots (Tylecote, 1990, 47 and 50; Beagrie, 1989) and some objects also contained small amounts of copper. For example, early Roman pewter objects in Britain have been found to be high-tin pewter, sometimes containing copper and 1-5wt% copper has been detected in Roman pewter spoons (Beagrie, 1989, 171 and 173). It is not clear whether the addition of lead and copper to the tin was intentional, although the relative frequency of high tin alloys suggests that it was, perhaps to modify the material properties of pure tin (Beagrie, 1989, 173; Tylecote, 1990).

Of ingots recovered in Devon, the 40 found at Bigbury Bay (Fox, 1995) were analysed and contained in excess of 98wt% of tin, very little lead and no copper. These ingots were a similar shape to the Lew Mill ingots and varied in size from 0.3kg to 13kg, with 8 weighing between 4 and 7kg and the majority less than 1.5kg. The date of these ingots is unknown.

In summary the size, shape and condition of these ingots suggests that they are of a relatively early date. Although a Bronze Age artefact was recovered near to where the ingots were found, the composition of the ingots is most consistent with finds of Roman date, according to the analytical data currently available.

References

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