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PRODUCTION ENGINEERING DIVISION

ASTON UNIVERSITY

ASTON TRIANGLE

BIRMINGHAM B47ET

FARTHINGSTONE SLAG REPORT

Ironworking slag was recovered from the primary ditch-fill, and was probably contained within the rampart construction. This suggests that the slag derived from an early period in the occupation of the site, possibly Fifth or Sixth Centuries B.C..

Slag Morphology

A sample of the slag was retained with other finds in the Museum. It consisted of a single large lump and several smaller pieces, (also several pieces of burnt stone and fired clay). All the lumps of slag showed the characteristic ropey texture of tap or flowed slag. The large piece had been accessioned by the Museum and could only be sectioned at an extremity, and no fracture surface could be prepared.

Mineral Texture

A flowed spur was sectioned and prepared in the usual manner. The polished section showed an uncharacteristic micro-structure. At low power (X100), the structure appeared to be a glassy phase containing about 15% of a mineral that was not recognisable, and had no crystal form, there were also a few spheroidal vessicles present. At higher magnification (X400), the glassy phase resolved into a very fine lath crystaline structure and a glassy phase in which the large sized mineral had crystalised. The structure indicated that the slag had cooled very rapidly, the extreme fineness of the structure was due, in part, to the section being from a spur.

Chemical and Mineral Analyses

X-Ray Diffraction Analysis (using Cobalt radiation), of the polished specimen produced a pattern of strong Fayalite peaks and a single Quartz peak, no iron oxide was present, Table 1.

TABLE I X-RAY DIFFRACTION PATTERN (d-spacings, relative peak intensities in brackets)

Farthingstone slag	Quartz	Fayalite
3.57		3.55 (80)
3.38 (100)	3.34 (100)	
2.83		2.83 (90)
2.57		2.57 (70)
2.51		2.50 (100)
1.78		1.77 (90)

The specimen was analysed on the Scanning Electron Microscope with an attached Link Analysis System. Bulk analyses using a raster scan at magnifications of about 200 times were successfully obtained, but individual spot analyses of the crystalline and glass phases could not be obtained without impinging on the other phase due to the fineness of the structure. Bulk analyses of three different areas of the sample are shown in Table II. The results show high alumina and silica contents and a low iron oxide content. A theoretical mineral assemblage calculated from the analyses gives the major minerals present as Ferrosilite ($2FeO.2SiO_2$), Orthoclase ($KAlO_2.3SiO_2$), Hercynite ($FeO.Al_2O_3$),and Quartz (SiO_2). The major component is Ferrosilite which is fayalite saturated with silica.

the x-ray diffraction shows that saturation did not occur and thus the excess silica and aluminium component was retained in the glass. This is in agreement with the mineral texture which results from rapid cooling, and hence impeeding the diffusion of oxides.

TABLE II FARTHINGSTONE BULK ANALYSES (WEIGHT % OXIDE)

	BULK1	BULK2	BULK3
Na	0.0	0.5	0.0
Mg	0.0	0.4	0.1
Al	9.1	8.9	8.9
Si	43.5	43.7	45.0
P	1.3	1.8	1.7
S	0.1	0.1	0.2
K	1.6	1.7	1.8
Ca	0.5	0.5	0.6
Ti	0.6	0.5	0.5
V	0.1	0.0	0.0
Cr	0.1	0.1	0.1
Mn	0.1	0.0	0.0
Fe	41.2	42.1	42.6
Co	0.0	0.1	0.1
TOTAL	98.2	100.4	101.6

It is not possible to determine the ore source from the chemical analysis (eg S.Fells 1983). It is also probable that several ore sources were exploited, eg ironstones and glacial deposits. The analysis would indicate an ore low in alkali metals (potassium and calcium), and high in alumina, although the alumina content could derive from reaction between the slag and the clay furnace lining. The ore also contained a low percentage of manganese.

The larger phase/inclusion observed in the optical study were also analysed (Table III). These show the inclusion to be predominantly iron oxide, probably in the form of Magnetite (Fe_3O_4) rather than Wustite (FeO), containing aluminium silicates (eg Hercynite), and Ulvite, ($2FeO.TiO_2$). The presence of Magnetite indicates insufficient reducing conditions during smelting, or, more probably, some oxidation during tapping.

TABLE III FARTHINGSTONE. ANALYSES OF INCLUSION/PHASE (WEIGHT % OXIDE)

	INCLUSION 1	2	3
Na	0.5	0.2	0.1
Mg	0.4	0.0	0.0
Al	9.8	7.8	7.2
Si	1.4	1.6	1.9
P	0.0	0.0	0.2
S	0.0	0.0	0.1
K	0.0	0.2	0.1
Ca	0.0	0.1	0.0
Ti	4.8	4.1	2.8
V	1.9	0.9	0.1
Cr	3.5	0.1	0.0
Mn	0.0	0.0	0.0
Fe	72.3 (77.0)*	81.4 (86.6)*	79.7 (85.0)*
Co	0.2	0.1	0.4
TOTAL	94.8 (99.5)	96.5 (101.7)	92.6 (97.9)

* EXCESS FeO as Fe_3O_4

CONCLUSION

The slag retained from the excavation is smelting slag deriving from a tapping furnace. It is therefore the earliest evidence for tapping furnaces in Britain. The slag has an uncharacteristic mineral texture, which with the discrepancy between the observed and calculated mineral compositions indicate very fast cooling. This results in part from the limitations of sampling.

Reference

S. Fells 1983 The Structure and Constitution of Ferrous Process Slags. PhD Thesis Aston University

G. McDonnell
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