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DEPT. OF PRODUCTION AND MECHANICAL ENGINEERING

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# WETWANG SLACK, EAST YORKSHIRE

# SLAG REPORT

## SITE SUMMARY

The excavations at Wetwang Slack are the continuation of the Garton Slack Project. The excavations in the Slack uncovered Iron Age/Romano British Cemetries and field systems, and a farmstead of Iron Age/Romano British Date was investigated on the adjacent Wold. The majority of the slag derived from the farmstead site.

## INTRODUCTION

The manufacture of iron artefacts from the ore was a two stage operation. Firstly, the iron was extracted from the ore by the smelting process, and secondly, the artefacts were manufactured or repaired in the smithing process. Both processes generated waste or slags as by-products, these have been divided into the non-diagnostic and the diagnostic residues. The former may have derived from any pyrotechnological process, and comprise Fuel Ash Slag and Hearth (or Furnace) Lining. The diagnostic residues are those that can be ascribed to the smelting or smithing process; the commonest form being the silicate slags.

## The Residues from Wetwang Slack

A total of 8.3kgs of residue were recovered, and were divided into six categories, (Table 1). No evidence for iron smelting was present, and all the diagnostic slag derived from the smithing process.

The full slag listing is given in Appendix 1.

TABLE 1 CLASSIFICATION OF WETWANG SLACK RESIDUES

| | |
|---|---|
| NON-DIAGNOSTIC RESIDUES | Kgs |
| Fuel Ash Slag | 0.030 |
| Hearth Lining | 0.030 |
| DIAGNOSTIC RESIDUES | |
| Smithing Slag | 6.795 |
| Hearth Bottoms | 0.560 |
| OTHER | |
| Marcasite/Pyrites Nodules | 0.815 |

The only significant deposit of diagnostic slag occurred in Area XI (Table 2), the farmstead. The remainder represents a very low background level of residual/disturbed material such as is present on many archaeological sites. The majority of the smithing slag was recovered from a single section of ditch 501 (4.280 Kg of smithing slag and a single hearth bottom weighing 0.250 Kg). This was close to a four-post structure that enclosed an area of burning. It is, therefore, possible that it was the smithy of the farmstead, and the waste slag was deposited in the nearby ditch. A sample of this slag is being analysed.

Context 05 ( also a ditch) produced 0.350 kgs of smithing slag and a single hearth bottom weighing 0.210 Kgs. The remaining smithing slag present on Area XI was probably residual from the main area of activity. It is also of interest that the majority of marcasite/pyrite nodules derived from this area.

TABLE 2 WETWANG SLACK RESIDUE DISTRIBUTION BY AREA

(WEIGHT IN Kg)

| | AREAS | | | | | |
|---|---|---|---|---|---|---|
| | VI | VII | IX | XI | XII | XIII |
| Smithing Slag | | | | 6.795 | | |
| Hearth Bottom | | | 0.100 | 0.460 | | |
| Hearth Lining | | | 0.030 | | | |
| Fuel Ash Slag | | | | 0.025 | | 0.030 |
| Cinder | 0.030 | 0.020 | | 0.030 | | |
| Marcasite | | | | 0.595 | 0.220 | |

ANALYSES OF SLAG SAMPLE FROM DITCH 501 (SAMPLE CODE WWS501)

The sample had a typical smithing slag morphology, it was randomly shaped, had an agglomerated appearance, and stone fragments were incorporated in the slag. It weighed 120gm and measured 60mm in diameter and 35mm in depth. In section the slag texture ranged from fine grained to coarsely vesicular, and there was evidence of 'stone' inclusions throughout the section. The central area of the section was mounted and polished to a lum finish.

The ironworking silicate slags are discussed in detail elsewhere, (McDonnell Forthcoming). They usually consist of three phases, firstly free iron oxide, (normally FeO), secondly iron silicate (normally fayalite $2FeOSiO_2$), and thirdly a glassy phase containing a range of oxides. The texture, form, and relationship of the three phases (determined under the metallurgical microscope), are indicative of the conditions under which the slag formed. Chemical analyses of the sample and of individual phases (determined on the Scanning Electron Microscope with attached Link energy dispersive system), also provides data for interpreting the slags. Assimilation of the data from both methods of analysis can be used to distinguish iron smelting slags from smithing slags.

The slags from Wetwang Slack were identified as smithing slags on morphological criteria and, therefore, the purpose of the analyses is to characterise this slag type, and determine its chemical and mineral composition.

The optical study confirmed that the slag was vesicular, and contained foreign matter, (as observed in the cross-section). Finely dispersed small (0.1mm) metallic inclusions were also present. The mineral texture comprised coarse globular dendrites of iron oxide (FeOx), and broken silicate laths in a glassy matrix. The variation in the phase percentages is given in Table 3. The texture and phase percentages indicate a heterogeneous composition, and non-equilibrium cooling conditions, for example the silicate laths generally imply a rapid cool, yet the large globular iron oxide dendrites suggest a slow cool.

TABLE 3. SAMPLE WWS501 VOLUMETRIC PHASE PERCENTAGES

| AREA | SILICATE % | GLASS % | FeOx % |
|---|---|---|---|
| 1 | 65 | 20 | 15 |
| 2 | 60 | 20 | 20 |
| 3 | 55 | 20 | 25 |
| 4 | 50 | 30 | 20 |
| 5 | 40 | 30 | 30 |

The chemical analyses of five different areas of the mounted specimen, (Table 4, B1-5), show consistent high FeO percentages, which accords with the excess iron oxide phase present in the volumetric study. The alumina content is high with respect to the other alkali oxides, (lime and potassium oxide). The phosphorus pentoxide content is low. Analyses B2-4 total less than 100%, due to the presence of higher iron oxides, magnetite ($Fe_3O_4$) rather than wustite (FeO)in the dendritic free iron oxide.

The phase analyses identify the silicate as fayalite containing some lime. The iron oxide analysis (FEOX), does not total 100%, identifying the dendrite as either magnetite or low elemental wustite, (which is non-stoichiometric). The glass phase contains the expected oxides, e.g. aluminium, calcium, and potassium.

The elemental and volumetric analyses shows the slag to contain excess iron oxide, but the optical study identified the presence of silica, (stone) inclusions. If the slag had been fully liquid for a long period of time, the silica and free iron oxide would have reacted together to form fayalite. Therefore, the presence of both silica and free iron oxide indicates incomplete mixing, short periods of liquidity, and rapid cooling. This mechanism could be present in the smithing hearth but not in the smelting furnace.

## CONCLUSIONS

The residue evidence shows low background levels across all areas except Area XI, the farmstead, in which there is slag evidence for a smithy and a possible asociated structure. This type of smithy was not 'full-time' but would have been used as required.

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## References

McDonnell J.G. (Forthcoming), 'The Slags From Amersham Mantles Green' in 'Excavations at Amersham Mantles Green' by P.A. Yeoman. Records of Buckinghamshire.

TABLE 4 SAMPLE WWS501 BULK AND PHASE ANALYSES

( Weight Percent Oxide, Fe as FeO )

| | B1 | B2 | B3 | B4 | B5 | SIL | GLASS | FEOX |
|---|---|---|---|---|---|---|---|---|
| Na | 0.0 | N.D | 0.1 | N.D | N.D | N.D | 0.4 | 0.5 |
| Mg | 0.3 | 0.2 | 0.5 | 0.1 | 0.3 | 0.2 | N.D | 0.1 |
| Al | 6.3 | 5.9 | 7.3 | 7.2 | 6.0 | 0.4 | 14.5 | 0.6 |
| Si | 22.2 | 20.9 | 20.4 | 18.1 | 18.6 | 29.1 | 34.6 | 0.7 |
| P | N.D | N.D | N.D | 0.2 | N.D | N.D | 1.2 | N.D |
| S | 0.7 | 0.8 | 0.6 | 0.4 | 0.3 | N.D | 0.8 | N.D |
| K | 1.2 | 0.8 | 0.9 | 0.2 | 0.1 | N.D | 6.6 | 0.1 |
| Ca | 2.6 | 1.7 | 1.9 | 0.6 | 0.9 | 1.5 | 13.0 | N.D |
| Ti | 0.1 | 0.2 | 0.2 | 0.4 | 0.4 | 0.1 | 0.4 | 0.3 |
| V | N.D | N.D | N.D | N.D | N.D | N.D | 0.1 | 0.1 |
| Cr | 0.1 | N.D | N.D | N.D | N.D | 0.1 | N.D | N.D |
| Mn | N.D | N.D | N.D | N.D | N.D | N.D | N.D | N.D |
| Fe | 66.7 | 66.7 | 64.9 | 64.9 | 68.6 | 67.7 | 27.6 | 94.5 |
| Co | 0.4 | 0.5 | 0.4 | 0.2 | N.D | 0.3 | N.D | 0.3 |
| Ni | 0.1 | 0.3 | 0.1 | N.D | 0.2 | 0.2 | N.D | 0.3 |
| | 100.7 | 98.0 | 97.3 | 92.3 | 95.4 | 99.6 | 99.2 | 97.5 |

SLAG LISTING   WETWANG SLACK (WEIGHT IN GRAMMES)

| CONTEXT | FEATURE | SMITH | HB | HL | FAS | CIN | OTHER | TYPE |
|---|---|---|---|---|---|---|---|---|
| * TOTAL FOR AREA | | 6 | | | | | | |
| VG | 517 | 0 | 0 | 0 | 0 | 30 | 0 | |
| ** Subtotal ** | | | | | | | | |
| | | 0 | 0 | 0 | 0 | 30 | 0 | |
| * TOTAL FOR AREA | | 7 | | | | | | |
| WR | 523 | 0 | 0 | 0 | 0 | 20 | 0 | |
| ** Subtotal ** | | | | | | | | |
| | | 0 | 0 | 0 | 0 | 20 | 0 | |
| * TOTAL FOR AREA | | 9 | | | | | | |
| AJ | 18 | 0 | 0 | 30 | 0 | 0 | 0 | |
| GZ | 149 | 0 | 100 | 0 | 0 | 0 | 0 | |
| ** Subtotal ** | | | | | | | | |
| | | 0 | 100 | 30 | 0 | 0 | 0 | |
| * TOTAL FOR AREA | | 11 | | | | | | |
| BC | 5 | 100 | 0 | 0 | 0 | 0 | 0 | |
| BK | 10 | 0 | 0 | 0 | 0 | 0 | 5 | PYRITE |
| BY | 12 | 20 | 0 | 0 | 0 | 0 | 0 | |
| CB | 14 | 100 | 0 | 0 | 0 | 0 | 0 | |
| CN | 5 | 90 | 0 | 0 | 0 | 0 | 0 | |
| CN | 20 | 10 | 0 | 0 | 0 | 0 | 0 | |
| DL | 13 | 0 | 0 | 0 | 20 | 0 | 0 | |
| DV | 11 | 0 | 0 | 0 | 0 | 0 | 30 | PYRITE |
| EA | 21 | 145 | 0 | 0 | 0 | 0 | 20 | PYRITE |
| EI | 5 | 350 | 210 | 0 | 0 | 10 | 310 | |
| JN | 50 | 50 | 0 | 0 | 0 | 0 | 0 | |
| JT | 7 | 0 | 0 | 0 | 0 | 0 | 140 | PYRITE |
| KG | 5 | 0 | 0 | 0 | 0 | 0 | 50 | PYRITE? |
| ON | 501 | 0 | 0 | 0 | 0 | 0 | 40 | PYRITE |
| OS | 503 | 180 | 0 | 0 | 0 | 0 | 0 | |
| PR | 509 | 70 | 0 | 0 | 0 | 0 | 0 | |
| PT | 502 | 30 | 0 | 0 | 0 | 0 | 0 | |
| QG | 513 | 170 | 0 | 0 | 0 | 0 | 0 | |
| RF | 507 | 200 | 0 | 0 | 0 | 0 | 0 | |
| RL | 501 | 4000 | 0 | 0 | 0 | 0 | 0 | |
| RT | 532 | 10 | 0 | 0 | 0 | 0 | 0 | |
| SH | 501 | 250 | 0 | 0 | 0 | 0 | 0 | |
| ST | 528 | 130 | 0 | 0 | 0 | 0 | 0 | |
| SU | 513 | 20 | 0 | 0 | 5 | 0 | 0 | |
| TK | 0 | 400 | 0 | 0 | 0 | 0 | 0 | |
| TU | 507 | 0 | 0 | 0 | 0 | 20 | 0 | |
| UC | 501 | 30 | 250 | 0 | 0 | 0 | 0 | |
| VA | 534 | 350 | 0 | 0 | 0 | 0 | 0 | |
| VJ | 547 | 10 | 0 | 0 | 0 | 0 | 0 | |
| VR | 506 | 80 | 0 | 0 | 0 | 0 | 0 | |
| ** Subtotal ** | | | | | | | | |
| | | 6795 | 460 | 0 | 25 | 30 | 595 | |

SLAG LISTING   WETWANG SLACK (WEIGHT IN GRAMMES)

| CONTEXT | FEATURE | SMITH | HB | HL | FAS | CIN | OTHER | TYPE |
|---|---|---|---|---|---|---|---|---|
| * TOTAL FOR AREA | | 12 | | | | | | |
| BO | 100 | 0 | 0 | 0 | 0 | 0 | 5 | FERUG PEBB |
| BX | 112 | 0 | 0 | 0 | 0 | 0 | 5 | ? |
| CK | 169 | 0 | 0 | 0 | 0 | 0 | 210 | PYRITE |
| ** Subtotal ** | | | | | | | | |
| | | 0 | 0 | 0 | 0 | 0 | 220 | |
| * TOTAL FOR AREA | | 13 | | | | | | |
| AT | 85 | 0 | 0 | 0 | 5 | 0 | 0 | |
| ** Subtotal ** | | | | | | | | |
| | | 0 | 0 | 0 | 5 | 0 | 0 | |
| ** Total ** | | | | | | | | |
| | | 6795 | 560 | 30 | 30 | 80 | 815 | |

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