Geophysical Survey of an Early Lead Smelting Site at Hagg Farm, Fremington, Swaledale, North Yorkshire

1.0 Introduction

A small fluxgate gradiometer survey was conducted over a probable early lead smelting site at Hagg Farm, Fremington, Swaledale, North Yorkshire on the 24th July 2013. The site had previously been identified from a spread of lead slag by members of the Swaledale and Arkengarthdale Archaeological Group (SWAAG). The Group propose to excavate the site, in collaboration with members of the Northern Mine Research Society, during August 2013.

2.0 Background

Industrial sites by their nature can be difficult to geophysically survey. Smelting sites in particular can present numerous problems, for example the undulating topography can present practical surveying difficulties, whilst the responses from spreads of slag and other debris can often mask underlying anomalies. Nevertheless, it is always worthwhile attempting such surveys. Previous geophysical surveys over lead smelting sites in the Yorkshire Dales: Grassington Low Mill (Roe *et al* 1999), Marrick Cupola Mill (Vernon 2005), Dacre (Vernon *et al* 1999), Grinton (Vernon 2005), whilst never providing a complete understanding of the sites, have to varying degrees, added to the knowledge of the site. It was hoped from the geophysical survey at Fremington to at least define the site limits and perhaps identify geophysical anomalies produced by structures associated with the smelting process.

3.0 Location and Topography

The Hagg Farm smelting site lies approximately two kilometres due east of Reeth, on the north side of Swaledale (SE 05946 99141) at a height of about 335m AOD. (See Figure 1). The area where the slag was noted consists of undulating rough pasture with a steep slope on the western side. At the top of the slope there is a gritstone wall, that contains occasional pieces of slag and partially vitrified burnt stone. The wall is aligned roughly north-south. To the west of the wall the ground is relatively flat and there is a suggestion of ridge and furrow in this field.

4.0 Geophysical Survey and Data Processing

The survey was conducted with a Geoscan FM 36 Fluxgate Gradiometer and consisted of six 10m x 10m gradiometer grids (Figure 2 - grids 1 to 6) that were tied in with a base line established by SWAAG on the east side of the wall. Most of the survey was over the area of the slag spread and the steep slope. The survey was extended to the west of the wall. No readings were recorded between the west side of the base line and the west side of the wall.

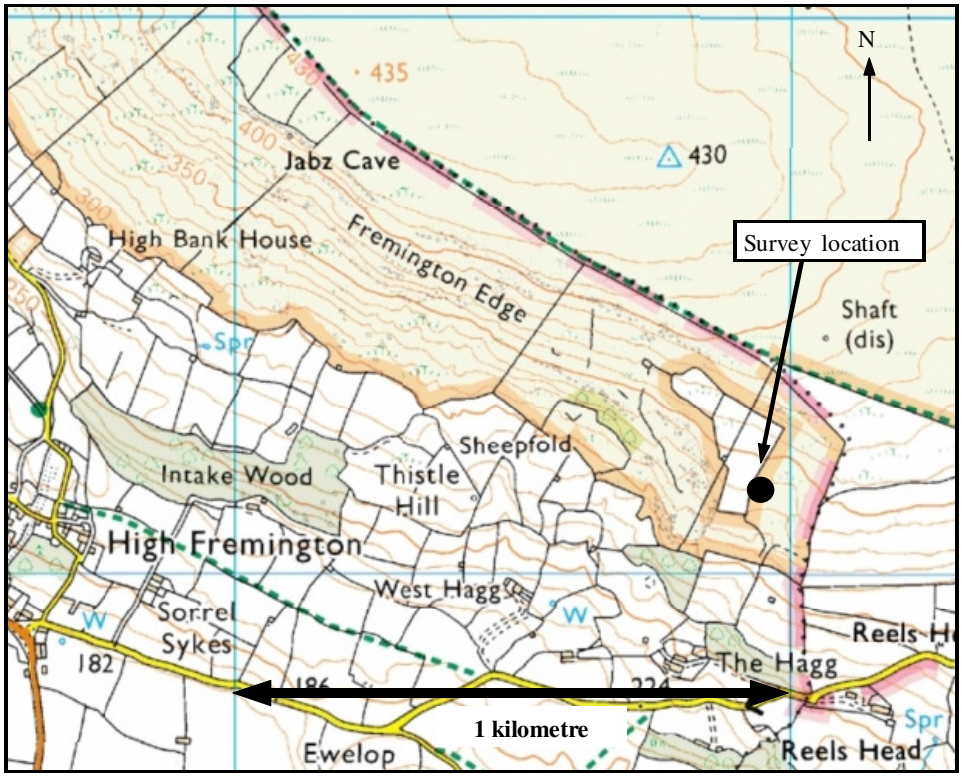


Figure 1. Hagg Farm: Survey location

Figure 2. Hagg Farm: Geophysical survey grids
(Numbered in the order that they were surveyed)

See Appendix 1 for a brief description of the geophysical technique employed.

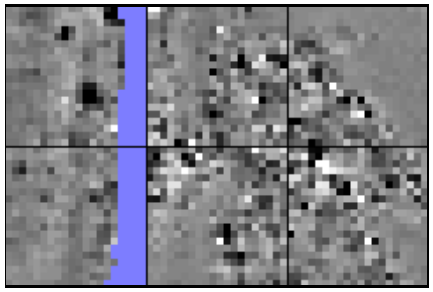
The survey data was dumped from the instruments to the computer using Geoplot v3. Finally data processing was carried out with Geoplot v3.

5.0 Gradiometer Data and Recorded Features.

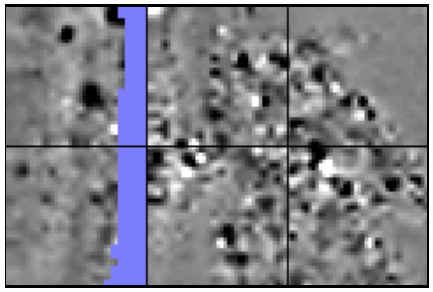
For the majority of geophysical surveys over archaeological sites, fluxgate gradiometer data usually ranges between -5 and +5nT. However, for industrial sites, the data range may expand considerably, particularly those associated with iron smelting / working. Concentrations of hammerscale produced by forging processes for example, can generate readings in excess of 2000nT. However, iron is relatively rare on lead processing sites, unless it is a component of the ore or the underlying rock, and this survey is no exception. No readings were noted above 40nT.

Figure 3 (a to d) shows the geophysical data clipped to various ranges. The raw data is shown relative to its standard deviation (data relative to mean value) in 3(a). The same data is shown interpolated in 3(b). Interpolation is the only processing that has been conducted on the data. This basically involves introducing additional data values as means between the recorded values. This has a smoothing effect on the data and can assist in spotting more subtle anomalies during interpretation. Figures 3 (c and d) shows the data clipped to various ranges. By clipping data, values that fall outside the clipped range will produce a white (negative data) or black (positive data) response. Thus on Figure 3 (c) and (d) any black anomaly will have a value greater than 30nT and 15nT, respectively. By examining different clipping ranges, it is possible to gradually identify different features in the survey.

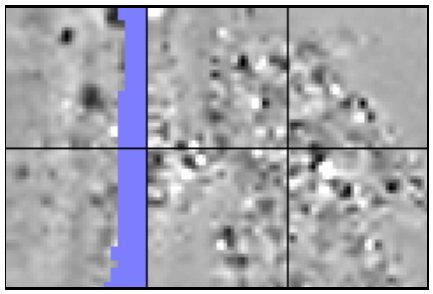
Figure 3 (d) is an interpretation of the data. The survey is dominated by a large pseudo-horseshoe shaped anomaly; a cluster of variable high data, identified as A with two linear limbs C located in the four eastern grids of the survey. This anomaly was noted during the survey and roughly corresponds to a pseudo-circular parch mark on the ground. This is interpretated as being produced by the remains of a lead-smelting bale, the higher values probably being generated by burnt stone, rather than slag. The surrounding gritstone, which was probably used for the construction of the bale, generally has a ferruginous cement, which was probably modified to a more magnetic form of iron during the smelting process. Trending away from the bale in a south-east direction is a linear anomaly (B) that is curtailed at its southern end by a curved anomaly. It is suggested that this may be a channel running from the bale. The higher values to the north and south of it possibly generated by lead slag. There are two further spreads of higher value anomalies, D and E, on the south-west side of anomalies A to C that may represent slag spreads. The extent of anomaly D suggests that it may pre-date the wall. Linear anomaly F is possibly related to agricultural activity e.g. Ridge and Furrow.



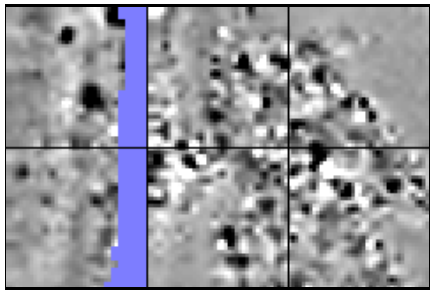
a) Raw (Unprocessed data)
Standard Deviation –3 (white) to +3 (black)



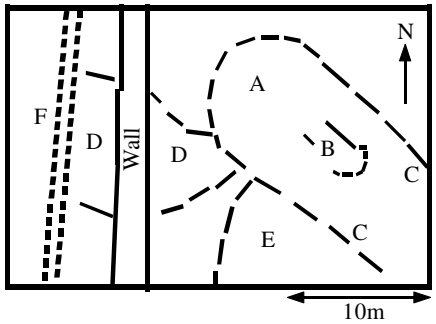
b) Interpolated data
Standard Deviation –3 (white) to +3 (black)



c) Interpolated data
Clipped –15 (white) to +30 (black)



d) Interpolated data
Clipped –10 (white) to +15 (black)



e) Interpretation (See Text)

Figure 3. Hagg Farm: Geophysical data and interpretation.

6.0 Discussion

It has already been suggested that this site has been used for reprocessing lead slag (R. Smith, *pers. comm*) and the geophysical evidence may support this interpretation. Previous geophysical surveys at Grinton on the south side of Swaledale, for example where bales are known to exist from slag spreads, have sometimes produced a low range of values. Those bales, located on a prominent ridge, are represented by a linear spread (partially beaded) of geophysical anomalies,. This is consistent with the accepted concept of bale technology, i.e. little more than ephemeral bonfires. Typically they are sited at prominent locations to catch the prevailing wind (Murphy 1992, Murphy and Baldwin 2001). However, the Hagg Farm anomaly is in a partially sheltered location and appears to be a more robust feature, with definite structural components. It is more reminiscent of the Winterings bole, located in the Swaledale area, and first described by Raistrick (1928).

Kirkham (1971) published Raistrick's original survey (See Figure 4) which shows three courses of fallen stone overlying slag. The centre of the bale is composed of clay and scoria. More interestingly, Raistrick identified a second hollow area outside the bale which he suggested might be a 'pig bed' (for collecting and forming the molten lead), as well as noting two possible gaps in the side of the bale.

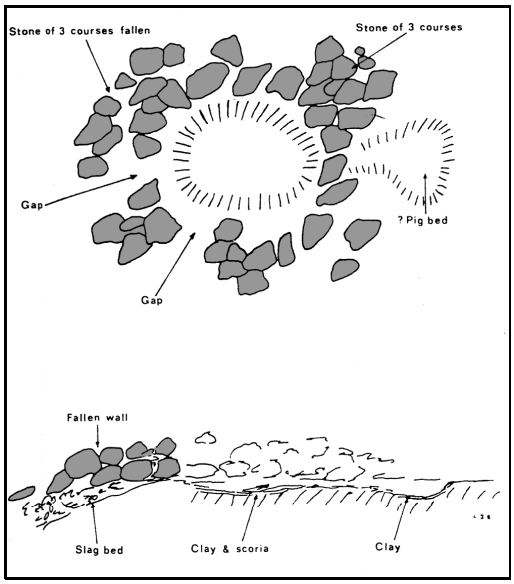


Figure 4.The Winterings Bole, Swaledale.
Arthur Raistrick's original record of the site.
(*Source: Modified from* Kirkham, N. 1971. p193)

By the time of publishing his work, Raistrick (1928) had firmed up his thoughts on how the bale might have been originally constructed (See Figure 5). The clay floor for example, became puddled clay, and the hollow outside the bale was for collecting molten lead, although the technique was still depicted as 'bonfire technology'

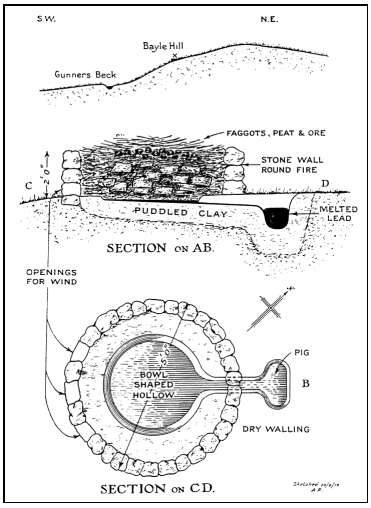


Figure 5.The Winterings Bole, Swaledale.
Arthur Raistrick's stylised illustration of the site.
(*Source*: Raistrick, 1928. Plate XIV)

Blanchland (1981), took Raistrick's interpretation one stage further and added two bellows to the rear of the bale, thus completing the concept that structure was more than just a simple bale, rather it was used for reprocessing lead slag - a blackworks oven?

Similar structures are recorded elsewhere in the Great Britain. Timberlake (2003) identified a 'bale' at Cwmystywyth, Central Wales with an external channel to collect molten lead.

There are therefore, several components of the Winterings boles that the geophysical data suggests may be present at Hagg Farm.

7.0 Conclusions

The geophysical survey identified anomalies that on 'face value' appear to be consistent with bale technology. There is still much to be found out about 'bale' technology and only the detailed excavation will reveal the true layout of this interesting site. If the site is for reprocessing lead slag then there may be additional features surrounding the bale, for example structures associated with bellows, that have been masked by slag anomalies.

Feedback on the excavation results would be most welcome, so that comparison can be made with the geophysical results.

Robert W. Vernon
26th July 2013

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Appendix 1

Geophysical Surveying Techniques

Fluxgate Gradiometer Survey

The instrument used is the Geoscan FM36 Fluxgate Gradiometer. Readings are recorded in nanoTesla (nT) the unit of Magnetic Flux Density.

Gradiometer magnetometers record localised variations in the earth's magnetic field which are produced by differences in underlying rock composition or the activities of man.

The fluxgate gradiometer has two sensors in a vertical staff. Any magnetic interference, for example solar activity, will affect both fluxgate sensors equally. However the sensor close to the ground will also record interference plus changes in the local magnetic field produced by buried features. By subtracting one signal from the other, the response from the buried object can be measured. The instrument has the advantage of being able to take continuous readings thereby allowing large areas to be surveyed quickly.