ARCHAEOLOGY DATASHEET 103

Geophysical techniques for metalworking sites

Geophysical techniques have become a standard tool in archaeological fieldwork. This datasheet addresses both the recognition of metallurgical features within general surveys and the design of surveys to meet metallurgical purposes.

There is a clear distinction, both in the scale and type of remains, between metalworking on 'early' sites and later 'industrial' activity. In practice, this means some variation in approach between the examination of 'greenfield' and 'brownfield' sites.

The geophysical investigation of greenfield sites

The standard archaeogeophysical techniques can be employed quite straightforwardly in sites with a low level of metalworking activity, with some significant caveats. Thus, for most greenfield sites, the recognised standard approaches to geophysics, both for research and for assessment with the planning process, can be applied in the conventional way.

For sites with a low level of working non-ferrous metals, the metallurgical activity may not be distinguishable from domestic activity on the basis of geophysical data. For sites working ferrous materials and for sites with high levels of processing or production of non-ferrous metals, geophysical approaches may be extremely useful.

Magnetic gradiometry

Magnetic gradiometry is a powerful tool for the location, recognition and interpretation of metalworking sites and of metalworking features or deposits on other sites. Small primary metalworking features (bloomery and other small furnaces and hearths) may show as anomalies with a strong central positive component and an outer annular negative component. If the survey is of sufficient resolution then more subtle aspects of these features, for instance the orientation of bloomery furnace tapping channels, may sometime be determinable.

Care must be taken with the occurrence of other highly fired hearths/furnaces/kilns, such as limekilns, pottery kilns and even cereal-drying kilns, which may produce magnetic anomalies similar in form to those of metallurgical features. Even intense localised burning produced during tree-clearance may be mistaken for metallurgical activity. Certain discrimination between metalworking and other high temperature technologies or causes of burning is often not possible.

The strongest magnetic anomalies on early ironworking sites are commonly associated with locations of the roasting of iron ores, rather than of the iron smelting process itself. These anomalies may show a focus on a particular roasting hearth but commonly shows a areal distribution reflecting a spread of roasted ore detritus (the magnetic anomalies associated with the roasted ore being stronger than that of the hearth structure).

The residues from early metalworking were commonly deposited into adjacent ditches and changes in the magnetic character of ditches may indicate areas of disposal. This may be indicated by a change of amplitude of magnetic anomaly along the length of a ditch.

Slag deposits are usually identifiable through gradiometry in a straightforward manner. The caveat with slag deposits is that the variations in slag thickness (because of primary depositional variation, through subsequent reworking, by subsequent plough disturbance or simply because of surface topography) may cause substantial magnetic anomalies which may mask actual features which might be expected to show clear anomalies. Thus, for instance, bloomery furnaces surrounded by a slag mound may become invisible when compared with the anomalies due to plough damage to the mound. The problems of magnetic anomalies due to topography are particularly acute on more recent sites where substantial upstanding dumps and structures may be present.

As with ore-roasting, the occurrence in smithing residues of minerals with a high magnetic susceptibility will mean that they produce larger magnetic anomalies than equivalent amounts of iron smelting slags – unless the smelting slag deposits contain significant quantities of metallic iron.

One practical issue with magnetometer surveys of metalworking sites is that they often include areas of significant topographic relief (slag dumps, water management features, charging platforms...). These may not be suitable for the usual archaeogeophysical approach of using constant-speed walking of the magnetometer over a measured grid. Instead, the acquisition of individual datapoints using a hand-switch may be necessary (and the consequent decrease in speed of data acquisition and increase of cost allowed for).

Magnetic susceptibility

Magnetic susceptibility instruments have a very shallow depth of measurement and are therefore used for measuring the susceptibility of the deposit/material on which the probe rests. Direct measurement of magnetic susceptibility in the field has three main uses: firstly as a tool for prospecting for sites (although that usage seems to be declining as magnetic gradiometers become quicker to use), as a means of delimiting slag dumps and other residue spreads (magnetic gradiometry is often less useful as a tool for this purpose in situations) and finally as a means of working within excavations as a highly cost-effective proxy for examining the variation of residues, within an excavated surface or section.

One particular use for which this latter approach is used is as a proxy measurement for the distribution of hammerscale across a smithy floor: a technique for high resolution survey that is much more cost effective then the collection, processing and magnetic separation of multiple soil samples for hammerscale (although some sampling should still be undertaken to support the interpretation of the geophysical data).

Ground resistivity
Standard ground resistivity techniques can be applied to metallurgical sites, but the resolution usually prevents the identification of actual furnace or hearth structures. Current developments in tomography using induced polarisation (IP) techniques are showing one possible route towards 3d-imaging of metallurgical waste deposits.

The geophysical investigation of industrial and brownfield sites

For brownfield sites, the substantial thickness of levelling, demolition and abandonment deposits overlying *in situ* archaeological remains commonly presents a significant challenge. In addition, debris with strong magnetic properties, for instance brick and ferrous building materials, including rebar, may mask completely any magnetic effect from buried *in situ* structures. These issues may mean that conventional archaeogeophysical approaches are not appropriate. Instead, techniques more commonly used during geotechnical studies may be required. Decisions about how to survey a site may need to take into account 'prior knowledge' of the site and the results of any ground investigation.

Relevant geophysical techniques include resistivity profiling and tomography, electromagnetic techniques, ground penetrating radar (GPR), shallow seismic techniques and micogravity. The selection of appropriate techniques will depend on the circumstances of the individual site and its likely geophysical targets. There is no single technique, or suite of techniques, that can be regarded as a standard, in the way that specific resolutions of data acquisition by magnetic gradiometry and, to a lesser extent by ground resistivity, have become a recognised standard in greenfield archaeological site assessment.

A further complication with the interpretation of data from many such sites is that the metalworking processes largely occurred above ground level, so that hearths, furnaces and machines were commonly completely removed during subsequent demolition or alteration. In these cases, the surviving targets may be below-floor voids, flues, conduits and passages present. These targets are also commonly those of the geotechnical investigations too.

A close collaboration between geotechnical and archaeological investigations is therefore urged for such sites. The two approaches are commonly undertaken in parallel, but in isolation from each other; instead a greater dialogue between the two disciplines would lead to an enhancement in product from both. The archaeological investigation of brownfield sites is greatly aided by access to the geotechnical geophysical surveys – and the interpretation of the geotechnical survey is often greatly enhanced by the input of specialised archaeological understanding (including the rigorous documentary research and cartographic regression that is a standard part of the archaeological approach).

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