

GEOPHYSICAL SURVEY REPORT

STRATASCAN™



Project name:
Willington Quarry, Derbyshire

Client:
University of Leicester Archaeological Services

March 2015

Job ref:
J8042

Report author:
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Techniques:

**Detailed magnetic survey –
Gradiometry**

Survey date:

19th February 2015

Site centred at:

SK 278 268

Post code:

DE65 6HA

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1 SUMMARY OF RESULTS

A detailed gradiometry survey was conducted over approximately 4.7 hectares of grassland. Former enclosures and pits have been identified as evidence of former settlement activity, along with areas of ridge and furrow cultivation, which supports information from the desk-based assessment. The settlement is likely to extend to the west where the data is masked by a large area of made ground. A linear anomaly and areas of pitting may be of archaeological or natural origin. The remaining features are natural or modern in origin and include areas of magnetic variation, evidence of modern ploughing, an underground service, disturbance from nearby ferrous objects and magnetic spikes that are likely to be modern rubbish.

2 INTRODUCTION

2.1 *Background synopsis*

Stratascan were commissioned to undertake a geophysical survey of an area outlined as part of a quarry extension. This survey forms part of an archaeological investigation being undertaken by University of Leicester Archaeological Services.

2.2 *Site location*

The site is located near Willington, Derbyshire and is centred at OS ref. SK 278 268.

2.3 *Description of site*

The survey area is approximately 4.7 hectares of grassland, lying on a floodplain with the River Trent to the south and Dove to the northwest. The site is generally flat with slight undulations, and is unobstructed apart from an electric fence which divides the southern area.

2.4 *Geology and soils*

The underlying geology in the north of the site is mudstone and siltstone of Radcliffe Member with Tarporley Siltstone Formation – siltstone, mudstone and sandstone in the southern areas. (British Geological Survey website). Superficial deposits of silt and gravel of Hemington Member are present across the site (British Geological Survey website).

The overlying soils across the majority of the site are known as Fladbury 2, which are typical pe-lo-alluvial gley soils, with an area of Wharfe soils in the southeast of the site, which are typical brown alluvial soils. The Fladbury 2 soils consist of stoneless clayey soils, whilst the Wharfe soils consist of deep stoneless permeable fine loamy soils (Soil Survey of England and Wales, Sheet 3 Midland and Western England).

2.5 **Site history and archaeological potential**

Extract from "An Archaeological Desk-Based Assessment for Willington Quarry Derbyshire: Trent Extension 2014" (University of Leicester Archaeological Services, 2014):

"The site lies within an area rich in prehistoric archaeology. Archaeological work undertaken in the current quarry since the 1990s to the present has revealed a number of areas of prehistoric evidence including areas of Neolithic and Bronze Age occupation, the remains of a Bronze Age barrow, and four Bronze Age burnt mounds.

The area lies close to the line of the Roman road known as Ryknield Street, the remains of which have been revealed in some areas, along with evidence of Roman occupation.

Anglo-Saxon remains have been discovered nearby and medieval field systems (ridge and furrow) are visible across the site, particularly in the northern area.

Therefore, there is moderate to high potential for prehistoric remains to be discovered during any quarrying on the site. A mound, interpreted as a prehistoric round mound has been identified within the area. There is also moderate potential for Roman remains to be discovered"

2.6 **Survey objectives**

The objective of the survey was to locate any features of possible archaeological origin in order that they may be assessed prior to development.

2.7 **Survey methods**

This report and all fieldwork have been conducted in accordance with both the English Heritage guidelines outlined in the document: *Geophysical Survey in Archaeological Field Evaluation, 2008* and with the Institute for Archaeologists document *Standard and Guidance for Archaeological Geophysical Survey*.

Due to the moderate to high potential for prehistoric and Roman remains to be discovered, detailed magnetic survey (gradiometry) was used as an efficient and effective method of locating archaeological anomalies. More information regarding this technique is included in Appendix A.

2.8 **Processing, presentation and interpretation of results**

2.8.1 **Processing**

Processing is performed using specialist software. This can emphasise various aspects contained within the data but which are often not easily seen in the raw data. Basic processing of the magnetic data involves 'flattening' the background levels with respect to adjacent traverses and adjacent grids. Once the basic processing has flattened the background it is then

possible to carry out further processing which may include low pass filtering to reduce 'noise' in the data and hence emphasise the archaeological or man-made anomalies.

The following schedule shows the basic processing carried out on all minimally processed gradiometer data used in this report:

1. *Destripe* (Removes striping effects caused by zero-point discrepancies between different sensors and walking directions)
2. *Destagger* (Removes zigzag effects caused by inconsistent walking speeds on sloping, uneven or overgrown terrain)

2.8.2 Presentation of results and interpretation

The presentation of the data for each site involves a print-out of the minimally processed data both as a greyscale plot and a colour plot showing extreme magnetic values. Magnetic anomalies have been identified and plotted onto the 'Abstraction and Interpretation of Anomalies' drawing for the site.

3 RESULTS

The detailed magnetic gradiometer survey conducted at Willington Quarry, Derbyshire has identified a number of anomalies that have been characterised as being either of a *probable* or *possible* archaeological origin.

The difference between *probable* and *possible* archaeological origin is a confidence rating. Features identified within the dataset that form recognisable archaeological patterns or seem to be related to a deliberate historical act have been interpreted as being of a probable archaeological origin.

Features of possible archaeological origin tend to be more amorphous anomalies which may have similar magnetic attributes in terms of strength or polarity but are difficult to classify as being archaeological or natural.

The following list of numbered anomalies refers to numerical labels on the interpretation plots.

3.1 Probable Archaeology

- 1 A number of positive linear and rectilinear anomalies in Areas D and E. These are indicative of former cut features of archaeological origin, representing former enclosures and evidence of settlement activity.
- 2 Widely spaced parallel linear anomalies in Area E. These are related to ridge and furrow cultivation.

3.2 *Possible Archaeology*

- 3 A number of small, discrete positive anomalies in the south of the site, possibly associated with Anomaly 1. These are indicative of former cut features of archaeological origin, such as backfilled pits and may be of archaeological or natural origin.
- 4 A single positive linear anomaly in Area A. This is indicative of a former cut feature of possible archaeological or natural origin.
- 5 A number of small discrete positive anomalies in the Areas A and C. These are indicative of former cut features, such as backfilled pits, and may be of archaeological or natural origin.
- 6 A number of large, positive anomalies in Area E. These are of possible archaeological origin, however this cannot be determined with any degree of confidence and they are more likely to be of natural origin.

3.3 *Other Anomalies*

- 7 Large areas of amorphous magnetic variation in Areas B, C and E are likely to be natural in origin.
- 8 Strong, bipolar linear anomalies running across the site in Area A, B and C. These are likely to relate to modern underground services.
- 9 A large area of strong magnetic debris in Area D. This is likely to be related to an area of disturbed or made ground and is likely to be masking weaker archaeological anomalies beneath it.
- 10 Closely spaced parallel linear anomalies in Areas A and E. These are related to modern agricultural activity such as ploughing.
- 11 Areas of magnetic disturbance are the result of substantial nearby ferrous metal objects such as fences and underground services. These effects can mask weaker archaeological anomalies, but on this site have not affected a significant proportion of the area.
- 12 A number of magnetic 'spikes' (strong focussed values with associated antipolar response) indicate ferrous metal objects. These are likely to be modern rubbish.

4 CONCLUSION

The survey at Willington Quarry has identified a number of features of probable and possible archaeological origin. An area of enclosures and pits has been identified close to the river Trent. This is evidence of settlement in the area, supporting evidence provided by the desk-based assessment of the site. Areas of ridge and furrow cultivation have also been identified, providing evidence of medieval agricultural activity, again supporting the desk-based assessment. A linear anomaly, along with areas of pitting may be archaeological or natural in origin. A large area of made ground in the south of the site is likely to be masking weaker archaeological features associated with the settlement activity that has been identified.

The remaining features are natural or modern in origin and include areas of natural magnetic variation, a modern underground service, evidence of modern ploughing, magnetic disturbance from nearby ferrous metal objects and magnetic spikes that are likely to be modern rubbish.

5 REFERENCES

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APPENDIX A – METHODOLOGY & SURVEY EQUIPMENT

Grid locations

The location of the survey grids has been plotted together with the referencing information. Grids were set out using a Leica 705auto Total Station and referenced to suitable topographic features around the perimeter of the site or a Leica Smart Rover RTK GPS.

An RTK GPS (Real-time Kinematic Global Positioning System) can locate a point on the ground to a far greater accuracy than a standard GPS unit. A standard GPS suffers from errors created by satellite orbit errors, clock errors and atmospheric interference, resulting in an accuracy of 5m-10m. An RTK system uses a single base station receiver and a number of mobile units. The base station re-broadcasts the phase of the carrier it measured, and the mobile units compare their own phase measurements with those they received from the base station. A SmartNet RTK GPS uses Ordnance Survey's network of over 100 fixed base stations to give an accuracy of around 0.01m.

Survey equipment and gradiometer configuration

Although the changes in the magnetic field resulting from differing features in the soil are usually weak, changes as small as 0.2 nanoTeslas (nT) in an overall field strength of 48,000nT, can be accurately detected using an appropriate instrument.

The mapping of the anomaly in a systematic manner will allow an estimate of the type of material present beneath the surface. Strong magnetic anomalies will be generated by buried iron-based objects or by kilns or hearths. More subtle anomalies such as pits and ditches can be seen if they contain more humic material which is normally rich in magnetic iron oxides when compared with the subsoil.

To illustrate this point, the cutting and subsequent silting or backfilling of a ditch may result in a larger volume of weakly magnetic material being accumulated in the trench compared to the undisturbed subsoil. A weak magnetic anomaly should therefore appear in plan along the line of the ditch.

The magnetic survey was carried out using a dual sensor Grad601-2 Magnetic Gradiometer manufactured by Bartington Instruments Ltd. The instrument consists of two fluxgates very accurately aligned to nullify the effects of the Earth's magnetic field. Readings relate to the difference in localised magnetic anomalies compared with the general magnetic background. The Grad601-2 consists of two high stability fluxgate gradiometers suspended on a single frame. Each gradiometer has a 1m separation between the sensing elements so enhancing the response to weak anomalies.

Sampling interval

Readings were taken at 0.25m centres along traverses 1m apart. This equates to 3600 sampling points in a full 30m x 30m grid.

Depth of scan and resolution

The Grad 601-2 has a typical depth of penetration of 0.5m to 1.0m, though strongly magnetic objects may be visible at greater depths. The collection of data at 0.25m centres provides an optimum methodology for the task balancing cost and time with resolution.

Data capture

The readings are logged consecutively into the data logger which in turn is daily down-loaded into a portable computer whilst on site. At the end of each site survey, data is transferred to the office for processing and presentation.

APPENDIX B – BASIC PRINCIPLES OF MAGNETIC SURVEY

Detailed magnetic survey can be used to effectively define areas of past human activity by mapping spatial variation and contrast in the magnetic properties of soil, subsoil and bedrock.

Weakly magnetic iron minerals are always present within the soil and areas of enhancement relate to increases in *magnetic susceptibility* and permanently magnetised *thermoremanent* material.

Magnetic susceptibility relates to the induced magnetism of a material when in the presence of a magnetic field. This magnetism can be considered as effectively permanent as it exists within the Earth's magnetic field. Magnetic susceptibility can become enhanced due to burning and complex biological or fermentation processes.

Thermoremanence is a permanent magnetism acquired by iron minerals that, after heating to a specific temperature known as the Curie Point, are effectively demagnetised followed by re-magnetisation by the Earth's magnetic field on cooling. Thermoremanent archaeological features can include hearths and kilns and material such as brick and tile may be magnetised through the same process.

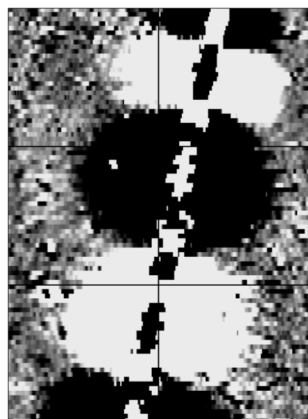
Silting and deliberate infilling of ditches and pits with magnetically enhanced soil creates a relative contrast against the much lower levels of magnetism within the subsoil into which the feature is cut. Systematic mapping of magnetic anomalies will produce linear and discrete areas of enhancement allowing assessment and characterisation of subsurface features. Material such as subsoil and non-magnetic bedrock used to create former earthworks and walls may be mapped as areas of lower enhancement compared to surrounding soils.

Magnetic survey is carried out using a fluxgate gradiometer which is a passive instrument consisting of two sensors mounted vertically 1m apart. The instrument is carried about 30cm above the ground surface and the top sensor measures the Earth's magnetic field whilst the lower sensor measures the same field but is also more affected by any localised buried field. The difference between the two sensors will relate to the strength of a magnetic field created by a buried feature, if no field is present the difference will be close to zero as the magnetic field measured by both sensors will be the same.

Factors affecting the magnetic survey may include soil type, local geology, previous human activity, disturbance from modern services etc.

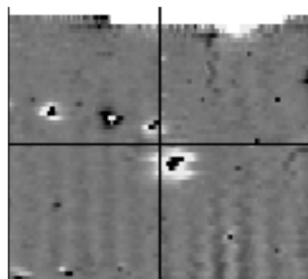
APPENDIX C – GLOSSARY OF MAGNETIC ANOMALIES

Bipolar



A bipolar anomaly is one that is composed of both a positive response and a negative response. It can be made up of any number of positive responses and negative responses. For example a pipeline consisting of alternating positive and negative anomalies is said to be bipolar. See also dipolar which has only one area of each polarity. The interpretation of the anomaly will depend on the magnitude of the magnetic field strength. A weak response may be caused by a clay field drain while a strong response will probably be caused by a metallic service.

Dipolar

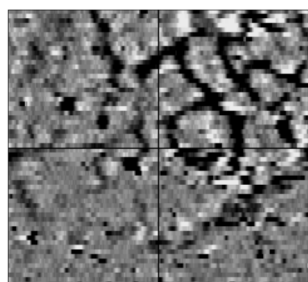


This consists of a single positive anomaly with an associated negative response. There should be no separation between the two polarities of response. These responses will be created by a single feature. The interpretation of the anomaly will depend on the magnitude of the magnetic measurements. A very strong anomaly is likely to be caused by a ferrous object.

Positive anomaly with associated negative response

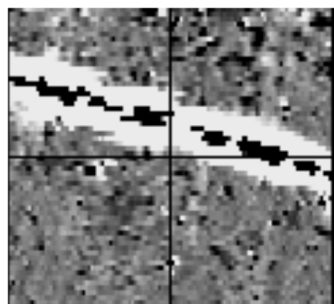
See bipolar and dipolar.

Positive linear



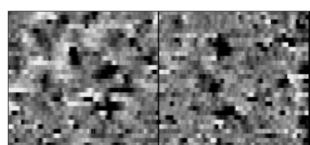
A linear response which is entirely positive in polarity. These are usually related to in-filled cut features where the fill material is magnetically enhanced compared to the surrounding matrix. They can be caused by ditches of an archaeological origin, but also former field boundaries, ploughing activity and some may even have a natural origin.

Positive linear anomaly with associated negative response



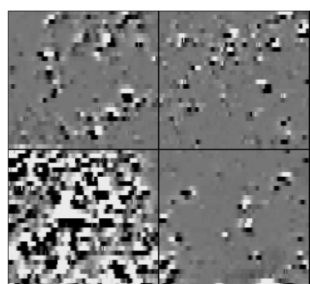
A positive linear anomaly which has a negative anomaly located adjacently. This will be caused by a single feature. In the example shown this is likely to be a single length of wire/cable probably relating to a modern service. Magnetically weaker responses may relate to earthwork style features and field boundaries.

Positive point/area



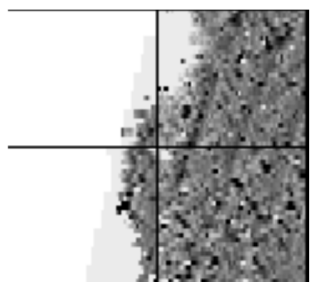
These are generally spatially small responses, perhaps covering just 3 or 4 reading nodes. They are entirely positive in polarity. Similar to positive linear anomalies they are generally caused by in-filled cut features. These include pits of an archaeological origin, possible tree bowls or other naturally occurring depressions in the ground.

Magnetic debris



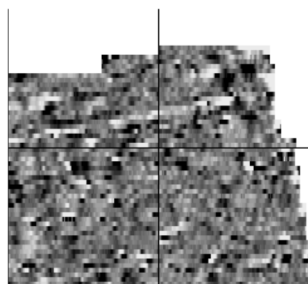
Magnetic debris consists of numerous dipolar responses spread over an area. If the amplitude of response is low ($\pm 3nT$) then the origin is likely to represent general ground disturbance with no clear cause, it may be related to something as simple as an area of dug or mixed earth. A stronger anomaly ($\pm 250nT$) is more indicative of a spread of ferrous debris. Moderately strong anomalies may be the result of a spread of thermoremanent material such as bricks or ash.

Magnetic disturbance



Magnetic disturbance is high amplitude and can be composed of either a bipolar anomaly, or a single polarity response. It is essentially associated with magnetic interference from modern ferrous structures such as fencing, vehicles or buildings, and as a result is commonly found around the perimeter of a site near to boundary fences.

Negative linear

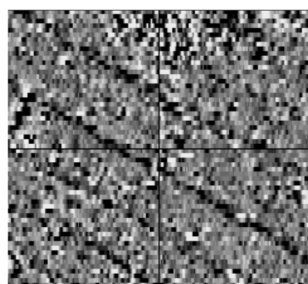


A linear response which is entirely negative in polarity. These are generally caused by earthen banks where material with a lower magnetic magnitude relative to the background top soil is built up. See also ploughing activity.

Negative point/area

Opposite to positive point anomalies these responses may be caused by raised areas or earthen banks. These could be of an archaeological origin or may have a natural origin.

Ploughing activity



Ploughing activity can often be visualised by a series of parallel linear anomalies. These can be of either positive polarity or negative polarity depending on site specifics. It can be difficult to distinguish between ancient ploughing and more modern ploughing. Clues such as the separation of each linear, straightness, strength of response and cross cutting relationships can be used to aid this, although none of these can be guaranteed to differentiate between different phases of activity.

Polarity

Term used to describe the measurement of the magnetic response. An anomaly can have a positive polarity (values above 0nT) and/or a negative polarity (values below 0nT).

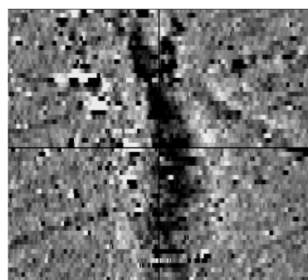
Strength of response

The amplitude of a magnetic response is an important factor in assigning an interpretation to a particular anomaly. For example a positive anomaly covering a 10m² area may have values up to around 3000nT, in which case it is likely to be caused by modern magnetic interference. However, the same size and shaped anomaly but with values up to only 4nT may have a natural origin. Colour plots are used to show the amplitude of response.

Thermoremanent response

A feature which has been subject to heat may result in it acquiring a magnetic field. This can be anything up to approximately +/-100 nT in value. These features include clay fired drains, brick, bonfires, kilns, hearths and even pottery. If the heat application has occurred in situ (e.g. a kiln) then the response is likely to be bipolar compared to if the heated objects have been disturbed and moved relative to each other, in which case they are more likely to take an irregular form and may display a debris style response (e.g. ash).

Weak background variations



Weakly magnetic wide scale variations within the data can sometimes be seen within sites. These usually have no specific structure but can often appear curvy and sinuous in form. They are likely to be the result of natural features, such as soil creep, dried up (or seasonal) streams. They can also be caused by changes in the underlying geology or soil type which may contain unpredictable distributions of magnetic minerals, and are usually apparent in several locations across a site.

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