GEOPHYSICAL SURVEY REPORT

STRATASCAN™

SUMO Group Member

Project name:

Hartlebury Castle

Client:

Hartlebury Castle Preservation Trust

May 2014

Job ref:

J6898

Report author:

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GEOPHYSICAL SURVEY REPORT

Project name:
Hartlebury Castle
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Job ref:
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Techniques:
Detailed magnetic survey – Gradiometry

Survey date:
27 May 2014

Site centred at:
SO 837 712

Post code:
DY11 7XX

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1 SUMMARY OF RESULTS

A detailed gradiometry and earth resistance survey was conducted over approximately 0.2 hectares of parkland. No archaeological features were visible within the gradiometry survey data, although two areas of possible archaeological interest have been identified from the resistivity survey. These possibly relate to a former driveway located to the west of the survey area and an area of post-medieval quarrying located to the east.

Other features identified are likely modern or natural in origin, including services, magnetic disturbance and a small area of natural variation.

2 INTRODUCTION

2.1 *Background synopsis*

Stratascan were commissioned to undertake a geophysical survey of an area to contribute towards a Conservation Management plan. This survey forms part of an archaeological investigation being undertaken by Hartlebury Castle Preservation Trust. The Trust in partnership with Worcestershire County Council and Museums Worcestershire, are submitting a bid to the Heritage Lottery Fund to help preserve the Castle and the Registered Historic Parkland

2.2 *Site location*

The site is located near Hartlebury, east of Stourport-On-Severn at OS ref. SO 837 712. The survey area sits to east of the stable block of the castle.

2.3 *Description of site*

The survey area is approximately 0.2 hectares of parkland with a gentle slope down towards the manor house to the west of the survey area. The area is overgrown with several large trees around the edge leading to some of the survey area being unsurveyable. There is also a guard fence around a small tree in the centre of the eastern edge of the survey area.

2.4 *Geology and soils*

The underlying geology belongs to the Bromsgrove Sandstone Formation, a Triassic fluvial deposit (British Geological Survey website). The drift geology is not recorded (British Geological Survey website).

The overlying soils are known as Bromsgrove which are typical well drained, loamy soils. These consist of reddish, fine loamy soils associated with slight seasonal waterlogging and deep lenses in places (Soil Survey of England and Wales, Sheet 3 Midland and Western England).

2.5 Site history and archaeological potential

The following is taken from the desk-based assessment (DBA) provided by Worcestershire Archive & Archaeology Service (Cornah and Robson-Glyde 2014):

"The archaeological and historical importance of the Castle and Park at Hartlebury has long been thought to stretch from the 9th century AD into the present day, and its association with the Bishop of Worcester has been well documented. Although nothing has yet been seen in terms of the early settlement of the site, there is considerable potential for deposits and structures associated with it in the form of buried archaeological features. The buildings have an aspect of survival from the medieval period, and features such as the moat and ponds, are likely to have their origins at this time. These were set within a well documented park that once extended beyond the known historical bounds."

The DBA also documents the possible presence of areas of post-medieval quarrying, civil war fortification ditches and driveways/avenues related to the park within, or in close proximity to, the survey area.

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 to inform the Conservation Management plan.

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.*

Detailed magnetic survey (gradiometry) was used alongside earth resistance survey as efficient and effective methods of locating archaeological anomalies. Although sandstone geology can offer variable responses, the combination of gradiometry and earth resistance survey ensures that the majority of archaeological features that may be present (ditches, earthworks, tracks & masonry remains) can be identified. More information regarding these techniques is included in Appendices A - D.

2.8 Processing, presentation and interpretation of results

2.8.1 Gradiometry 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 Resistivity Processing

The processing was carried out using specialist software known as *Geoplot 3* and involved the 'despiking' of high contact resistance readings and the passing of the data though a high pass filter. This has the effect of removing the larger variations in the data often associated with geological features. The net effect is aimed at enhancing the archaeological or man-made anomalies contained in the data.

The following schedule shows the processing carried out on the processed resistance plots.

Despike *X radius = 1*

Y radius = 1

Spike replacement

High pass filter *X radius = 10*

Y radius = 10

Weighting = Gaussian

Low pass filter *X radius = 10*

Y radius = 1

Weighting = Gaussian

An interpolation process was applied to the processed data using the following parameters.

Interpolation *x2 linear x & y*

2.8.3 Presentation of results and interpretation

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

3 RESULTS

The detailed magnetic gradiometer and earth resistance survey conducted at Hartlebury Castle has identified a small number of anomalies that have been characterised as being of *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 and lettered anomalies refers to numerical labels on the interpretation plots.

GRADIOMETER SURVEY

*3.1 **Probable Archaeology***

No probable archaeology has been identified within the survey area.

*3.2 **Possible Archaeology***

No possible archaeology has been identified within the survey area.

*3.3 **Other Anomalies***

1 Two linear anomalies probably related to pipes, cables or other modern services.

2 Areas of magnetic disturbance associated with nearby metallic objects such as services or field boundaries. Some of the trees located in the proximity to the survey area are also surrounded by metallic protective fencing.

3 An area of strong magnetic debris, possibly disturbed or made ground. This may be related to the former driveway that runs parallel to the western border of the survey area.

EARTH RESISTANCE SURVEY

3.4 *Probable Archaeology*

No probable archaeology has been identified within the survey area.

3.5 *Possible Archaeology*

A Area of high resistance possibly indicative of compacted ground related to former driveway.

B Area of low resistance possibly indicative of landscaping related to post-medieval quarrying.

3.6 *Other Anomalies*

C Linear anomalies of low resistance showing disturbed ground or trenches indicating modern services.

D Area of low resistance probably of geological/pedological origin.

4 CONCLUSION

No archaeological features were identified from the gradiometry survey data; however a small area of strong magnetic debris, indicative of disturbed or made ground, is present in the south west of the survey area and may relate to a former driveway that runs parallel to the sites western border.

Other features identified are likely modern or origin, including two services, crossing the north and centre of the survey area and areas of magnetic disturbance relating to metallic fencing.

Two areas of possible archaeological interest have been identified within the earth resistance data. An area of high resistance in the western half of the site is possibly indicative of compacted ground relating to a former driveway, and correlates with the area of strong magnetic debris visible within the gradiometer survey data. In the east of the survey area an area of low resistance with a clear boundary running parallel with the top of the slope is visible. The orientation of this feature suggests that it is associated with landscaping, and it may be related to the adjoining area of post medieval quarrying present to the east of the site.

The modern services are also visible in the earth resistance data along with an area of low resistance visible in the south east of the site, and likely to be of geological or pedological origin.

5 REFERENCES

British Geological Survey South Sheet, 1977. *Geological Survey Ten Mile Map, South Sheet First Edition* (*Quaternary).* Institute of Geological Sciences.

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English Heritage, 2008. *Geophysical Survey in Archaeological Field Evaluation.*

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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.

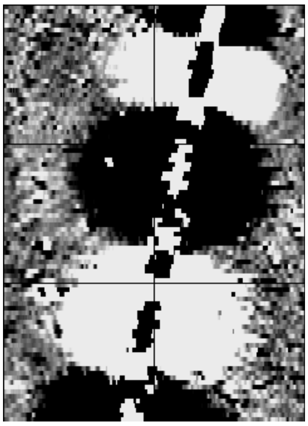
Silting and deliberate infilling of ditches and pits with magnetically enhanced soil creates a relative contrast against the much lower levels of magnetism within the subsoil into which the feature is cut. Systematic mapping of magnetic anomalies will produce linear and discrete areas of enhancement 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.

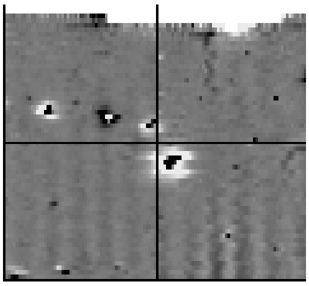
APPENDIX C – GLOSSARY OF MAGNETIC ANOMALIES

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

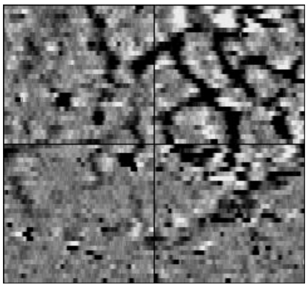


This consists of a single positive anomaly with an associated negative response. There should be no separation between the two polarities of response. These responses will be created by a single feature. The interpretation of the anomaly will depend on the magnitude of the magnetic measurements. A very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

Positive anomaly with associated negative response

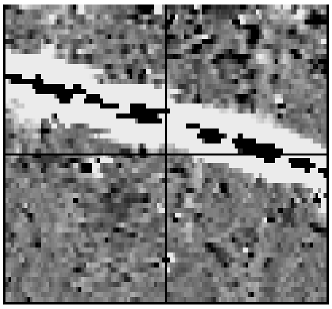
See bipolar and dipolar.

Positive linear



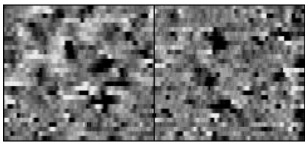
A linear response which is entirely positive in polarity. These are usually related to in-filled cut features where the fill material is magnetically enhanced compared to the surrounding matrix. They can be caused by ditches of an archaeological origin, but also former field boundaries, ploughing activity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

Positive linear anomaly with associated negative response



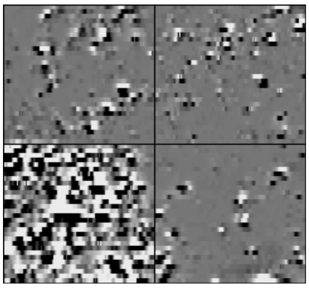
A positive linear anomaly which has a negative anomaly located adjacently. This will be caused by a single feature. In the example shown this is likely to be a single length of wire/cable probably relating to a modern service. Magnetically weaker responses may relate to earthwork style features and field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

Positive point/area



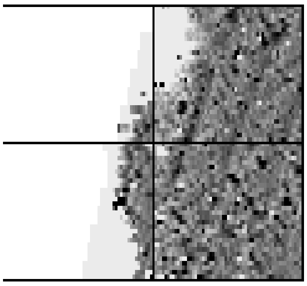
These are generally spatially small responses, perhaps covering just 3 or 4 reading nodes. They are entirely positive in polarity. Similar to positive linear anomalies they are generally caused by in-filled cut features. These include pits of an archaeological origin, possible tree bowls or other naturally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

Magnetic debris



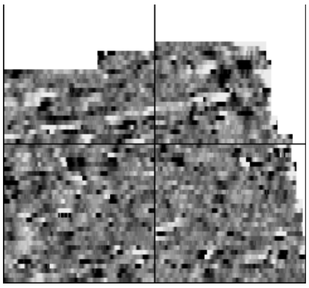
Magnetic debris consists of numerous dipolar responses spread over an area. If the amplitude of response is low (+/-3nT) then the origin is likely to represent general ground disturbance with no clear cause, it may be related to something as simple as an area of dug or mixed earth. A stronger anomaly (+/-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

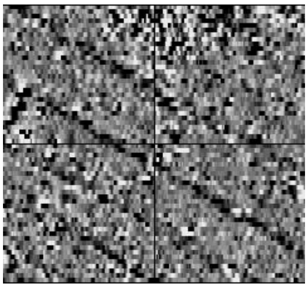


A linear response which is entirely negative in polarity. These are generally caused by earthen banks where material with a lower magnetic magnitude relative to the background top soil is built up. See also ploughing activity.

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).

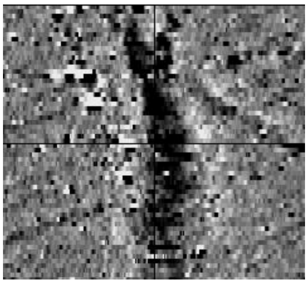
Strength of response

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 $10m^2$ 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.

APPENDIX D – RESISTIVITY: METHODOLOGY & SURVEY EQUIPMENT

Survey equipment and principle of methodology

This method relies on the relative inability of soils (and objects within the soil) to conduct an electrical current which is passed through them. As earth resistance is linked to moisture content, and therefore porosity, hard dense features such as rock will give a relatively high earth resistance response, while features such as a ditch which retains moisture give a relatively low response.

The resistance meter used was an RM15 manufactured by Geoscan Research incorporating a mobile Twin Probe Array. The Twin Probes are separated by 0.5m and the associated remote probes were positioned approximately 15m outside the grid. The instrument uses an automatic data logger which permits the data to be recorded as the survey progresses for later downloading to a computer for processing and presentation.

The resistance meter was used in conjunction with an MPX15 multiplexer to allow two adjacent readings to be taken at each instrument position.

Though the values being logged are actually resistances in ohms they are directly proportional to earth resistance (ohm-metres) as the same probe configuration was used through-out.

Sampling interval

Readings were taken at 1m centres along traverses 1m apart. This equates to 900 sampling points in a full 30m x 30m grid.

Depth of scan and resolution

The 0.5m probe spacing of a twin probe array has a typical depth of penetration of 0.5m to 1.0m. The collection of data at 0.5m centres with a 0.5m probe spacing provides an optimum resolution for the task.

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.

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