

GEOPHYSICAL SURVEY REPORT

STRATASCAN™



Project name:
Bourton on the Water, Gloucestershire

Client:
CgMs Consulting Ltd

May 2014

Job ref:
J6592

Report author:
Thomas Richardson MSc AIFA

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Techniques:

Gradiometry

Earth Resistance

Ground Penetrating Radar

Survey date:

**24th and 26th March &
28th-30th April 2014**

Site centred at:

SP 160 208

Post code:

GL54 2BJ

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1 SUMMARY OF RESULTS

Detailed gradiometry, ground penetrating radar (GPR) and earth resistance surveys were conducted over approximately 1 hectare of grassland. The survey identified a Roman road and stoned area located by previous excavations. A probable former enclosure, a former field boundary and areas of ridge and furrow cultivation have also been identified. A number of possible archaeological anomalies, including features possibly relating to former structures, have been identified; however it is not possible to determine their origin with any degree of confidence. The remaining anomalies are of modern origin, relating to ferrous objects and fencing.

2 INTRODUCTION

2.1 *Background synopsis*

Stratascan were commissioned to undertake a geophysical survey of an area outlined for development. This survey forms part of an archaeological investigation being undertaken by CgMs Consulting Ltd.

2.2 *Site location*

The site is located to the west of Bourton on the Water, Gloucestershire at OS ref. SP 160 208.

2.3 *Description of site*

The survey area is approximately 1 hectare of grassland. The survey is generally flat with an area in the west obstructed by a breeze block structure.

2.4 *Geology and soils*

The underlying geology is Charmouth Mudstone Formation - Mudstone (British Geological Survey website). The drift geology is Head – Clay, Silt, Sand and Gravel (British Geological Survey website).

The overlying soils are known as Denchworth which are typical pelo-stagnogley soils. These consist of clayey soils with fine loamy over clayey soils (Soil Survey of England and Wales, Sheet 5 South West England).

2.5 *Site history and archaeological potential*

The site covers part of the scheduled monument of Bourton Bridge Roman Settlement (SM 31930). Previous excavations of the survey area have identified a Roman Road, also seen in aerial photographs, running across the north of the site and a number of structures, mostly in the south west of the site (Gloucestershire Archaeology 1977).

A section 42 Licence has been issued by English Heritage to carry out the works.

2.6 **Survey objectives**

The objective of the survey was to locate any features of possible archaeological origin.

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*.

Given that the site is relatively small (1ha) a multi-technique approach has been carried out. This generally allows a greater understanding of anomalies that may be viewed out of context with the wider landscape. Detailed magnetic survey, earth resistance survey and radar have been selected.

More information regarding these techniques is included in Appendix A.

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

2.8.1 *Processing*

Gradiometer

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)

Earth Resistance

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 through 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

Radar

Processing is performed using specialist software (Mala Rslicer). There are a wide range of filters available, the application of which will vary depending on the project. The most commonly used are:

Gain	Amplification to correct for weakening of signal with depth.
DC-Shift	Re-establishes oscillation of the radar pulse around the zero point)
Dewow / Ringdown Removal	Removes low frequency, down-trace instrument noise
Bandpass Filtering	Suppresses frequencies outside of the antenna's peak bandwidth thus reducing noise
Background Removal	Can remove ringing, instrument noise and minimize the near-surface 'coupling' effect
Migration	Collapses hyperbolic tails back towards the reflection source
Amplitude Envelope	Simplifies pulses for production of time-slice maps by summing peak values, regardless of polarity, over a given time-window.

2.8.2 Presentation of results and interpretation

Gradiometer

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.

Earth resistance

The presentation of the data for the site involves a grey scale plot of the processed data. Anomalies have been identified and plotted onto the 'Abstraction and Interpretation of Anomalies' drawing.

Radar

If a number of radargrams are collected over a grid, or in conjunction with GPS data, it is possible to reconstruct the entire dataset into a 3D volume. This can then be resampled to compile 'plan' maps (time slices) of response strength at increasing time offsets (typically converted to show approximate depth), thus simplifying the visualisation of how anomalies vary beneath the surface across a survey area. The close centred traverses of the Mala MIRA make for effective time slices, which are included at a number of depths.

3 RESULTS

The detailed survey conducted at Bourton on the Water 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 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.

Gradiometer

The detailed magnetic gradiometer survey conducted at Bourton on the Water has identified a number of anomalies. The list below refers to the number in Figure 06.

3.1 Probable Archaeology

- 1** A negative linear anomaly with associated positive responses. This is indicative of a raised surface with a ditch either side, and is likely to be related to the Roman road identified by previous excavations.
- 2** Widely spaced curving linear anomalies across the site. These are indicative of ridge and furrow cultivation. Two phases of activity can be seen in the west of the site.

3.2 **Possible Archaeology**

No possible archaeology has been identified within the survey area.

3.3 **Other Anomalies**

- 3 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.
- 4 A number of magnetic 'spikes' (strong focussed values with associated antipolar response) indicate ferrous metal objects. These are likely to be modern rubbish.

Earth Resistance

The earth resistance survey conducted at has identified a number of anomalies. The list below refers to the number in Figure 08.

3.4 **Probable Archaeology**

- A A linear high resistance anomaly. This is indicative of an area of compacted ground, likely to relate to the Roman road identified by previous excavations.
- B A sub-circular area of high resistance. This is likely to be related to the area of stones identified by previous excavations.
- C Widely spaced curving linear anomalies across the site. These are indicative of ridge and furrow cultivation.
- D A moderately high resistance area anomaly in the east of the site. This is indicative of an area of compacted ground and is probably related to GPR anomaly 6.

3.5 **Possible Archaeology**

- E Areas of high resistance anomalies across the site. These are indicative of compacted ground and may be of archaeological origin.
- F Boundary between general areas of high resistance in the north east of the site and lower resistance in the south west. This suggests the possibility of more archaeological activity in the north east of the site.

3.6 **Other Anomalies**

No other anomalies have been identified within the survey area.

Radar

The GPR survey conducted at Bourton on the Water has identified a number of anomalies. The list below refers to the number in Figure 13.

3.7 **Probable Archaeology**

- 5 A linear anomaly at a depth of 0.55m in the north of the site. This is likely to relate to the Roman road identified by previous excavations.
- 6 Curvi-linear anomalies at a depth of 0.55m in the east of the site. These are likely to be related to a former enclosure or field boundaries and relate to earth resistance anomaly D.
- 7 A linear anomaly at a depth of 0.1m. This is likely to be related to a former field boundary not present on available mapping.
- 8 Widely spaced curving linear anomalies across the east of the site. These are indicative of ridge and furrow cultivation.

3.8 **Possible Archaeology**

- 9 Anomalies at a depth of 0.45m in the west of the site. These may be related to former buildings, such as those identified by previous excavations, or be of natural origin.
- 10 A number of linear anomalies at 0.65m in the west of the site. These may be related to structural remains, but it is also possible that they are caused by ridge and furrow cultivation or be of natural origin.
- 11 An area of high energy at a depth of 0.55m. This may be of archaeological origin, however interpretation is difficult as only part of the anomaly is covered by the survey area.

3.9 **Other Anomalies**

No other anomalies have been identified within the survey area.

4 CONCLUSION

The survey at Bourton on the Water has identified a number of anomalies of archaeological origin. The Roman road identified by previous excavations and aerial photography can be seen extending across the north of the field. A stoned area identified by the excavations has also been identified. A former field boundary and a number of linear features relating to a former enclosure are present, however it is unlikely that they are contemporary with each other as they are seen at different depths. A number of phases of ridge and furrow cultivation can be seen across the site, suggesting that the area has been used as agricultural land since the medieval period.

A number of possible archaeological anomalies, including features possibly relating to former structures, have been identified; however it is not possible to determine their origin with any degree of confidence. The remaining anomalies are of modern origin, relating to ferrous objects and fencing.

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.

Gradiometer

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.

Earth Resistance

Survey equipment and configuration

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 1.0m centres along traverses 1.0m apart. This equates to 400 sampling points in a full 20m x 20 grid. All traverses were surveyed in a "zigzag" mode.

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 job, data is transferred to the office for processing and presentation.

Radar

Survey equipment and configuration

The Mala MIRA is a fully integrated system comprising an array of 400MHz antennas, an odometer wheel, battery and rugged laptop for system control and data-capture. The antennas are configured to collect 8 parallel lines of data, 0.08m apart, with each swathe of the machine. The acquisition software uses the integrated odometer to trigger the system, whilst recording a stream of 3D positional information from a separate robotic total station. The data are recorded in digital format and can be processed to produce depth slice maps, 2D sections or 3D cubes.

Sampling interval

Readings were taken at 0.08m intervals with traverse intervals of 0.08m. All survey traverse positioning was carried out using a Trimble S6 Robotic Total Station.

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.

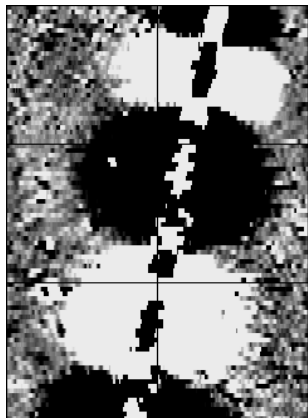
Silting and deliberate infilling of ditches and pits with magnetically enhanced soil creates a relative contrast against the much lower levels of magnetism within the subsoil into which the feature is cut. Systematic mapping of magnetic anomalies will produce linear and discrete areas of enhancement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

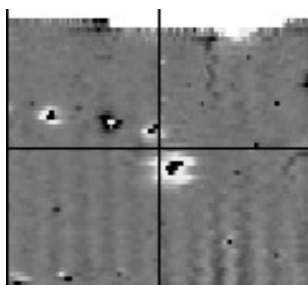
APPENDIX C – GLOSSARY OF MAGNETIC ANOMALIES

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

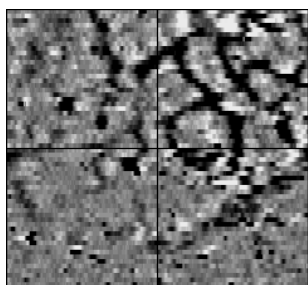


This consists of a single positive anomaly with an associated negative response. There should be no separation between the two polarities of response. These responses will be created by a single feature. The interpretation of the anomaly will depend on the magnitude of the magnetic measurements. A very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

Positive anomaly with associated negative response

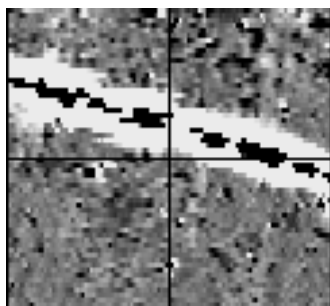
See bipolar and dipolar.

Positive linear



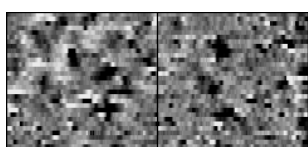
A linear response which is entirely positive in polarity. These are usually related to in-filled cut features where the fill material is magnetically enhanced compared to the surrounding matrix. They can be caused by ditches of an archaeological origin, but also former field boundaries, ploughing activity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

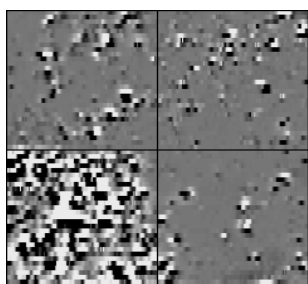
Positive point/area



depressions in the ground.

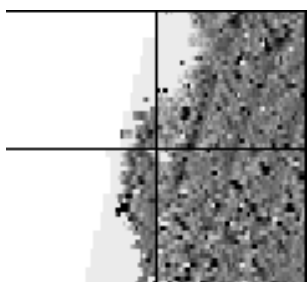
These are generally spatially small responses, perhaps covering just 3 or 4 reading nodes. They are entirely positive in polarity. Similar to positive linear anomalies they are generally caused by in-filled cut features. These include pits of an archaeological origin, possible tree bowls or other naturally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

Magnetic debris



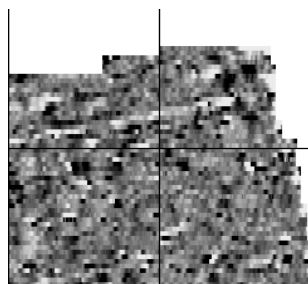
Magnetic debris consists of numerous dipolar responses spread over an area. If the amplitude of response is low ($\pm 3\text{nT}$) then the origin is likely to represent general ground disturbance with no clear cause, it may be related to something as simple as an area of dug or mixed earth. A stronger anomaly ($\pm 250\text{nT}$) 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

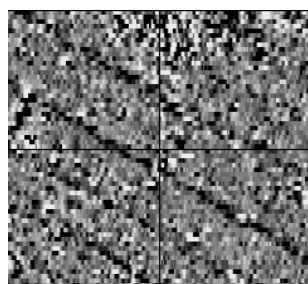


A linear response which is entirely negative in polarity. These are generally caused by earthen banks where material with a lower magnetic magnitude relative the background top soil is built up. See also ploughing activity.

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).

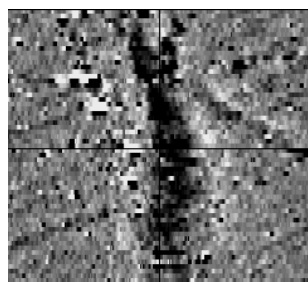
Strength of response

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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