Geophysical Survey Report

Lancaster University Turbines

for

Oxford Archaeology North

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1 SUMMARY OF RESULTS

Stratascan were commissioned by Oxford Archaeology North to undertake a magnetic gradiometer survey of an area outlined for development as a wind farm. The site comprises approximately 20.4ha of pasture beside the M6 motorway, opposite the Lancaster University, at OS ref. SD 490 575.

The survey results appear to be dominated by modern activity with construction related anomalies in the north and agricultural in the central region. The southern part of the survey shows more of potential archaeological interest with two possible enclosures and one possible thermoremanent feature which may represent a former kiln or other intense fire; these anomalies are all of unknown date and may warrant further investigation. A general scatter of possible pits may also be considered for sampling.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned by Oxford Archaeology North to undertake a geophysical survey of an area outlined for development as a wind farm. This survey forms part of an archaeological investigation being undertaken by Oxford Archaeology North.

2.2 Site location

The site is located beside the M6 motorway, opposite the Lancaster University, at OS ref. SD 490 575.

2.3 Description of site

The survey area comprises approximately 20.4ha of gently undulating pasture.

2.4 Geology and soils

The underlying geology is Namurian “Millstone Grit Series” (British Geological Survey South Sheet, Fourth Edition Solid, 2001); this is overlain by Quaternary boulder clay and morainic drift deposits (Institute of Geological Sciences, 1977).

The overlying soils are known as Brickfield 2 which are typical cambic stagnogley soils. These consist of slowly permeable seasonally waterlogged fine loamy soils (Soil Survey of England and Wales, Sheet 1 Northern England).
2.5 Site history and archaeological potential

A desk-based assessment prepared by Oxford Archaeology North (Blythe, 2009) was made available to Stratascan and provides the following information.

There is some evidence of Bronze Age activity in the locality of the survey area. A Bronze Age axe has been found approximately 50m outside the south-east end of the survey area at NGR SD 4928 5711. A log boat was discovered during works on Blea Tarn Reservoir approximately 600m north of the survey area. A flint scatter has been recorded at Galgate approximately 2km south-south-west of the survey area. There may therefore be a reasonable chance of Bronze Age activity within the area.

No evidence of Iron Age activity is known.

A Romano-British settlement has been excavated approximately 1km south-west of the survey area, and a Roman road is thought to have passed near to its eastern boundary.

Medieval remains in the region include an area of ridge-and-furrow approximately 500m south-east of the survey area and a medieval field system approximately 500m west of the southern tip of the survey area.

The area appears to have been enclosed between 1806 and 1841. Since that time, the area has seen some changes to field boundaries as well as the infilling of a few pits and ponds.

2.6 Survey objectives

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

2.7 Survey methods

Detailed magnetic survey (gradiometry) was used as an efficient and effective method of locating archaeological anomalies. More information regarding this technique is included in the Methodology section below.

3 METHODOLOGY

3.1 Date of fieldwork

The fieldwork was carried out over 7 days between the 5th and the 12th January. Weather conditions during the survey were cold, dry and sunny, with snow lying on the ground.
3.2 Grid locations

The location of the survey grids has been plotted in Figure 2 together with the referencing information.

The location of the survey grids is based on the Ordnance Survey National Grid, see Figure 2. The referencing and alignment of grids was achieved using a Leica DGPS System 500.

A DGPS (differential 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. Calculations to correct for these errors are performed at an accurately located base station. The base station then transmits the corrections which are received by DGPS consoles giving sub metre accuracy averaging around 0.5m error.

3.3 Survey equipment

Although the changes in the magnetic field resulting from differing features in the soil are usually weak, changes as small as 0.2 nanoTesla (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.
3.4 Sampling interval, depth of scan, resolution and data capture

3.4.1 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.

3.4.2 Depth of scan and resolution

The Grad 601 has a typical depth of penetration of 0.5m to 1.0m. This would be increased if strongly magnetic objects have been buried in the site. The collection of data at 0.5m centres provides an optimum methodology for the task balancing cost and time with resolution.

3.4.3 Data capture

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

3.5 Processing, presentation of results and interpretation

3.5.1 Processing

Processing is performed using specialist software known as Geoplot 3. 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 processed gradiometer data used in this report:

1. Zero mean traverse (sets the background mean of each traverse within a grid to zero and is useful for removing striping effects)

   Geoplot parameters:
   Least mean square fit = off
2. Destagger  
(shifts adjacent traverses to correct staggered anomalies produced during zigzag surveying)

*Geoplot parameters:*
various

3.5.2 Presentation of results and interpretation

The presentation of the data for each site involves a print-out of the raw data as greyscale (Figures 3, 7, 11, 15, 19 & 23), together with a colour plots showing strong values (Figures 4, 8, 12, 16, 20 & 24) and a greyscale plot of the processed data (Figures 5, 9, 13, 17, 21 & 25). Magnetic anomalies have been identified and plotted onto the 'Abstraction and Interpretation of Anomalies' drawing for the site (Figures 6, 10, 14, 18, 22 & 26).

4 RESULTS

*(Letters in bold refer to labels on interpretation plots).*

The results appear to be dominated by modern agricultural and ferrous anomalies, with only a few anomalies of potential archaeological interest, mainly towards the south of the survey.

The northern part of the survey contains a large number of strong responses. Some of these are linear (A) and represent modern pipes or cables, others are scattered (B) and probably indicate modern debris related to the construction of the meteorological station.

The central area is dominated by parallel straight linear anomalies (C) which are most likely to have been produced by ploughing. The area is currently under pasture so these anomalies represent past activity; however, the straightness and close spacing of the anomalies is consistent with modern agriculture and they are perhaps best interpreted as having a modern origin.

Towards the south of the central area is a moderate strength discrete bipolar anomaly (D) which may represent a thermoremanent feature, this could therefore be the site of an intense fire such as a furnace or kiln. A linear positive anomaly (E) across the thinnest section of the survey probably represents a former field boundary.

The southernmost quarter of the survey contains a greater number of potentially significant anomalies. Of particular interest are two sets of broad weak positive anomalies (F) which may represent small enclosures of unknown date. Parallel agricultural anomalies (G) associated with these appear slightly curved and which may indicate an older date than similar anomalies elsewhere. A set of curving linear anomalies (H) radiating from the field boundary may represent tracks emerging from a
former field entry point; however the form is also similar to some natural (geological or pedological) anomalies.

A number of positive discrete anomalies are found scattered over the entire survey. These may represent pits of potential archaeological significance. A scatter of strong bipolar anomalies represents iron objects; these are of possible archaeological significance, but are more likely to be modern.

5 CONCLUSION

The survey results appear to be dominated by modern activity with construction related anomalies in the north and agricultural in the central region. The southern part of the survey shows more of potential archaeological interest with two possible enclosures and one possible thermoremanent feature which may represent a former kiln or other intense fire; these anomalies are all of unknown date and may warrant further investigation. A general scatter of possible pits may also be worth sampling.

6 REFERENCES


APPENDIX A – 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 either 0.5 or 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 B – 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 infilled 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 infilled 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 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. Trace 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 insitu (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.