STRATASCAN

Geophysical Survey Report

Enderby, Leicestershire

for

University of Leicester Archaeological Services

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J2664

Simon Haddrell BEng (Hons) AMBCS PIFA

Document Title:	**Geophysical Survey Report Enderby, Leicestershire**
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Stratascan Job No:	**2664**
Techniques:	**Magnetic susceptibility Detailed magnetic survey (gradiometry)**
National Grid Ref:	**SK 525 014**

Plate 1 – Facing west across Area 6

Field Team:	**Adam Cooper BA (Hons) MSc, Andrew Murphy, Dominic Murphy, Glenn Rose, Richard Fleming, Matt Gillot**
Project Manager:	**Simon Stowe BSc. (Hons)**
Report written by:	**Simon Haddrell BEng(Hons) AMBCS PIFA**
CAD illustration by:	**Simon Haddrell BEng(Hons) AMBCS PIFA Robbie Austrums**
Checked by:	**Peter Barker C.Eng MICE MCIWEM MIFA**

Stratascan Ltd.
Vineyard House
Upper Hook Road
Upton upon Severn
WR8 0SA

Tel: 01684 592266
Fax: 01684 594142
Email: ppb@stratascan.co.uk
www.stratascan.co.uk

LIST OF FIGURES

1 SUMMARY OF RESULTS

The survey undertaken at Enderby, Leicestershire has identified two areas of probable archaeology. The first area, in the north west of the site, is in the form of several linear features in a perpendicular formation with two possible thermoremenant features in the same area. These features may represent an area of former. The second area of probable archaeology is in the south east; this feature has been interpreted as a possible former enclosure with several, possibly associated, cut features in close proximity. A group of possible cut features can be seen in the north of the site. Several other areas around the site contain possible ridge and furrow, cut features and / or embankments of possible archaeological origins.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned by University of Leicester Archaeological Services to undertake a geophysical survey of an area outlined for development.

2.2 Site location

The site is located near Enderby at OS ref. SK 525 014. The M1 forms the eastern boundary with the M69 traversing through the centre of the survey area. Leicester Lane is to the south and Beggers Lane to the West. Leicester is located to the north and east of the site.

2.3 Description of site

The survey area is approximately 320 hectares. Magnetic susceptibility was carried on the entire survey area followed by Targeted Magnetic survey on 49 hectares of the survey area. The land is mainly used as pastoral farmland. Other areas are grassy but not in use as farmland, although do contain public footpaths. The topography is mainly flat with some gentle slopes on some parts of the site.

2.4 Geology and soils

The underlying geology is Triassic Mudstones (British Geological Survey South Sheet, Fourth Edition Solid, 2001).

The overlying soils are known as Brockhurst 2. These consist of slowly permeable seasonally waterlogged reddish fine loamy over clayey soils (Soil Survey of England and Wales, Sheet 4 Eastern England).

2.5 Site history and archaeological potential

No specific details were available to Stratascan.

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 53 days from 9th November 2009 to 19th February 2010. Weather conditions during the survey were varied throughout the survey.

3.2 Grid locations

The location of the survey grids has been plotted in Figure 3 together with the referencing information. Grids were set out using 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.

3.3 Description of techniques and equipment configurations

3.3.1 Magnetic Susceptibility

Alteration of iron minerals in topsoil through biological activity and burning can enhance the magnetic susceptibility (MS) of that soil. Measuring the MS of a soil can therefore give a measure of past human activity and can be used to target the more intensive and higher resolution techniques of Magnetometry and Resistivity.

Measurements of MS were carried out using a field coil which provides a rapid scan and has the benefit of allowing "insitu" readings to be taken. The equipment used on this contract was an MS2 Magnetic Susceptibility meter manufactured by Bartington Instruments Ltd. A field coil known as an MS2D was used to take field readings. This assessed the top 200mm or so of topsoil. To overcome the problem of ground contact all readings were taken 4 or 5 times and an average taken. All obvious localised "spikes" were ignored.

3.3.2 Magnetometer

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

Magnetic susceptibility
The magnetic susceptibility survey was carried out on a 20 m grid with readings being taken at the node points.

Magnetometer
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

Magnetic Susceptibility
The MS2D coil assesses the average MS of the soil within a hemisphere of radius 200mm. This equates to a volume of some 0.016m^3 and maximum depth of 200mm. As readings are only at 20m centres this results in a very coarse resolution but adequate to pick up trends in MS variations.

Magnetometer
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

Magnetic susceptibility
The readings are logged manually on site, and then transferred to the office where they are entered into a computer and grey scale plots are produced.

Magnetometer
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.

3.5 Processing, presentation of results and interpretation

3.5.1 Processing

Magnetic susceptibility
No processing of the data has been undertaken. *Surfer* 8 is used to generate a colour plot of the data.

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. 'Despiking' is also performed to remove the anomalies resulting from small iron objects often found on agricultural land. 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 show the basic processing carried out on all minimally 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

In addition to this the processed gradiometer data has also had the following processes carried out.

1. *Despike* (useful for display and allows further processing functions to be carried out more effectively by removing extreme data values)

   Geoplot parameters:
   X radius = 1, y radius = 1, threshold = 3 std. dev.
   Spike replacement = mean

3.5.2 Presentation of results and interpretation

The presentation of the data for each site involves a print-out of the raw data both as greyscale (Figures 3,7,11,15,19,23 & 27) and colour plots (Figures 4,8,12,16,20,24 & 28), together with a greyscale plot of the processed data (Figures 5,9,13,17,21,25 & 29). 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 & 30).

4 RESULTS

4.1 Magnetic susceptibility

The survey has identified several areas of enhanced readings. An area in the south along the boundary with the M69, an area in the north close to the motorway service station, an area to the north and south of New House Farm and an area to the west and north west of the survey area. Three areas around Warren Farm have also shown areas of enhancement. An area of low magnetic susceptibility has been targeted in the east of the site.

4.2 Detailed gradiometry

The abstracted anomalies have been divided into varying types. The types have then been tabulated and assessed as to the level of activity in each area according to the following table. Possible archaeological features have been highlighted in blue.

Level of activity	
-	None
*	Minimal
**	Moderate
***	Significant

Area / Description	1	2	3	4	5	6	7
Discrete positive anomaly – possible pit	**	*	*	*	*	*	*
Positive linear anomaly - cut features of a possible archaeological origin.	*	*	*	-	***	**	*
Positive area anomaly- cut features of a possible archaeological origin.	*	-	*	*	-	-	-
Weak positive area anomaly - cut features of a possible archaeological origin.	-	***	-	-	*	-	-
Negative linear anomaly – former embankment of a possible archaeological origin	-	-	*	-	*	-	-
Negative area anomaly – former embankment of a possible archaeological origin	-	-	-	-	-	-	-
Weak negative area anomaly – former embankment of a possible archaeological origin	-	-	-	-	-	-	-
Moderately strong positive and negative anomaly – possible thermoremenant feature	-	-	-	-	*	-	-
Ridge and furrow	-	-	-	-	-	-	-
Bipolar anomaly of an unknown origin	-	-	-	**	-	-	-
Positive anomaly with associated negative response – ferrous object	*	*	*	**	*	*	*
Magnetic disturbance associated with pipe	-	-	-	-	*	-	-
Agricultural mark	*	*	*	-	-	-	-
Magnetic disturbance associated with nearby metallic objects	-	-	-	*	-	*	-
Magnetic debris	*	-	-	**	*	-	-
Area of magnetic variations possible geological / pedological response	-	**	-	-	-	-	-
Linear anomaly possibly relating to land drains	-	-	-	-	-	-	*

Description \ Area	8	9	10	11	12	13	14
Discrete positive anomaly – possible pit	*	*	*	-	*	**	-
Positive linear anomaly - cut features of a possible archaeological origin.	-	*	-	-	-	-	-
Positive area anomaly- cut features of a possible archaeological origin.	-	-	-	-	-	-	-
Weak positive area anomaly - cut features of a possible archaeological origin.	-	-	*	-	-	*	-
Negative linear anomaly – former embankment of a possible archaeological origin	-	-	-	-	-	-	-
Negative area anomaly – former embankment of a possible archaeological origin	-	-	-	-	-	-	-
Weak negative area anomaly – former embankment of a possible archaeological origin	-	-	-	-	-	-	-
Moderately strong positive and negative anomaly – possible thermoremenant feature	-	-	-	-	-	-	-
Ridge and furrow	***	***	-	-	***	***	-
Bipolar anomaly of an unknown origin	-	-	-	-	-	*	-
Positive anomaly with associated negative response – ferrous object	*	*	*	*	*	*	**
Magnetic disturbance associated with pipe	*	*	-	-	-	-	-
Agricultural mark	-	-	***	***	-	-	-
Magnetic disturbance associated with nearby metallic objects	-	-	-	-	-	-	*
Magnetic debris	-	-	-	-	-	-	-
Area of magnetic variations possible geological / pedological response	-	-	-	-	-	-	-
Linear anomaly possibly relating to land drains	-	-	*	-	-	*	*

Description \ Area	15	16	17	18	19	20	21
Discrete positive anomaly – possible pit	-	-	*	*	*	*	*
Positive linear anomaly - cut features of a possible archaeological origin.	-	-	*	*	*	-	**
Positive area anomaly- cut features of a possible archaeological origin.	-	-	-	*	-	-	**
Weak positive area anomaly - cut features of a possible archaeological origin.	-	-	-	-	-	-	*
Negative linear anomaly – former embankment of a possible archaeological origin	-	-	-	*	-	-	-
Negative area anomaly – former embankment of a possible archaeological origin	-	-	-	-	*	-	-
Weak negative area anomaly – former embankment of a possible archaeological origin	-	-	-	-	-	-	-
Ridge and furrow	-	-	-	-	-	-	-
Moderately strong positive and negative anomaly – possible thermoremanent feature	-	-	-	-	-	-	*
Bipolar anomaly of an unknown origin	-	-	-	*	-	-	-
Positive anomaly with associated negative response – ferrous object	*	*	*	*	*	*	*
Magnetic disturbance associated with pipe	-	**	*	-	-	-	*
Agricultural mark	*	-	-	-	**	-	-
Magnetic disturbance associated with nearby metallic objects	*	*	-	*	*	*	*
Magnetic debris	-	-	-	-	-	-	**
Area of magnetic variations possible geological / pedological response	-	-	-	-	-	-	-
Linear anomaly possibly relating to land drains	*	-	-	*	*	*	*

5 DISCUSSIONS

Possible archaeological features, in varying levels of probability, have been identified across the majority of the site. Most areas contain a small number of cut features, embankments and/or possible pits with the exception of Areas 2, 5, 6 & 21.

Area 2

Area two contains a series of weak positive area anomalies, representing cuts of a possible archaeological origin. These features may be a series of manmade pits and can also be observed, to a lesser extent, in Areas 1 and 4.

Plate 2 – Possible former enclosures in Area 5

Area 5

This area contains a number of positive linear anomalies, interpreted as cut features of a possible archaeological origin, in the south west of the field. These features appear to form a series of connected perpendicular lines forming possible former enclosures. Two moderately strong bipolar anomalies, representing possible thermoremanent features, in close proximity to the cut features can be observed in the data. This area also contains several discrete positive anomalies, representing pits of a possible archaeological origin, in the south west of the field.

Area 6

Even though the features do not form any recognisable shapes or formations, this field contains more possible cut features than most other fields on this site. These features may be archaeological in origin or alternatively these features may be associated with the local geology / pedology. A number of discrete positive anomalies, representing possible pits, are also scattered around the field.

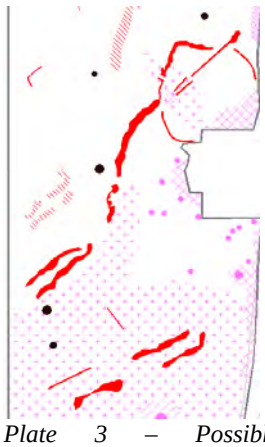


Plate 3 – Possible enclosure in Area 21

Area 21

This area contains positive linear anomalies, representing cut features of probable archaeological origins, forming a probable enclosure. The features may also be associated with the linear feature traversing the area in a north east – south west direction in the same area. These anomalies may represent a former boundary. Two parallel cut features, interpreted as cut features of a possible archaeological origin, are evident in the south of the field. A moderately strong bipolar anomaly, representing a possible thermoremanent feature, is apparent in the south east of the area. The south of the field contains a significant amount of magnetic debris which may be masking weak archaeological features.

6 CONCLUSION

The magnetic susceptibility survey undertaken at Enderby, Leicestershire has, correlated well with detailed gradiometry. Plate 4 shows the areas of probable archaeology overlain on the magnetic susceptibility results. The magnetic susceptibility readings are also elevated from pipelines and agricultural activity in other areas.

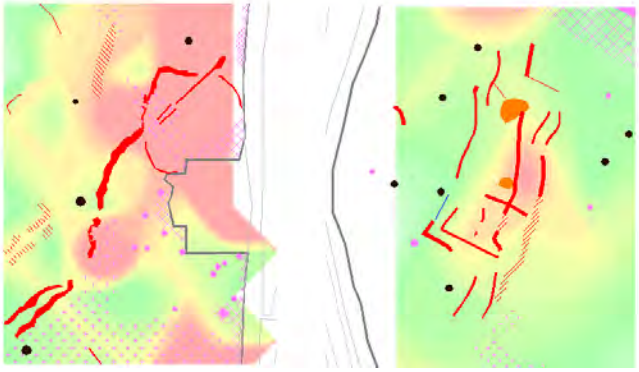


Plate 4 – Correlation between magnetic susceptibility and detailed gradiometry

The detailed gradiometer has found evidence for archaeological features, the most notable are in Areas 5 and 21. The features in Area 5 are mainly perpendicular to each other and may form a former enclosure. The Anomalies in Area 21 are also typical of an enclosure, with a possible former field boundary intersecting the feature. Area 6 contains a number of possible cut features; however they are weak and lack any recognisable shapes for formations, therefore may be of an alternative origin. Possible archaeological pits can be seen across all the fields surveyed with the exception of Area 11, 14, 15 & 16. Thermoremanent features can be seen in Areas 5, 19 & 21, the most notable of which are in Area 5 in close proximity to, and possible associated with, a series of cut features. Possible former ridge and furrow can be seen in Area 10 and 11.

Agricultural marks can be seen in Areas 1,2,3,8,9,12,13,15 & 19. Strong magnetic disturbance and debris in Areas 1,5,6,8,9,16,17,20 & 21 may be masking weak archaeological features. Particular care should be taken around Areas 5 and 21 as these elevated readings are in close proximity to the probable archaeology.

Area 4, 13 & 18 contain several bipolar anomalies which are of an uncertain origin, these features may warrant further investigations to determine the cause.

7 REFERENCES

British Geological Survey, 2001. *Geological Survey Ten Mile Map, South Sheet, Fourth Edition (Solid)*. British Geological Society.

Soil Survey of England and Wales, 1983. *Soils of England and Wales, Sheet 5 Southwest
England*.

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 *thermoremnant* 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.

Thermoremnance 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. Thermoremnant archaeological features can include hearths and kilns and material such as brick and tile may be magnetised through the same process.

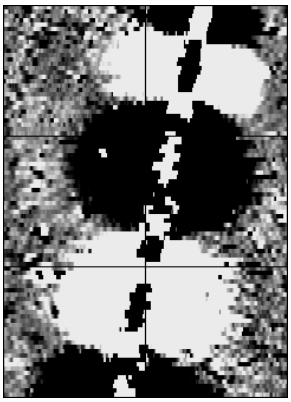
Silting and deliberate infilling of ditches and pits with magnetically enhanced soil creates a relative contrast against the much lower levels of magnetism within the subsoil into which the feature is cut. Systematic mapping of magnetic anomalies will produce linear and discrete areas of enhancement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

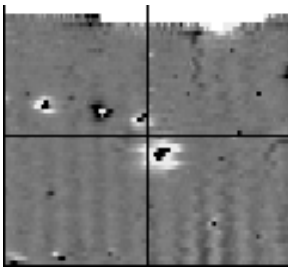
APPENDIX B – Glossary of magnetic anomalies

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

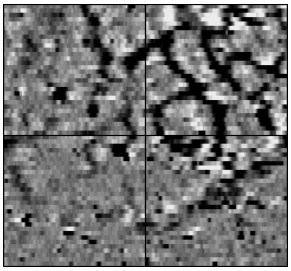


This consists of a single positive anomaly with an associated negative response. There should be no separation between the two polarities of response. These responses will be created by a single feature. The interpretation of the anomaly will depend on the magnitude of the magnetic measurements. A very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

Positive anomaly with associated negative response

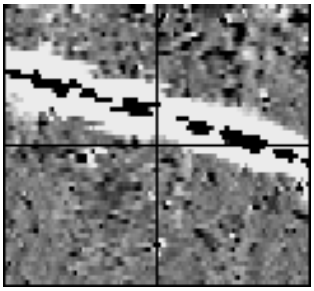
See bipolar and dipolar.

Positive linear



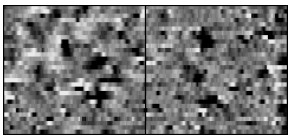
A linear response which is entirely positive in polarity. These are usually related to infilled cut features where the fill material is magnetically enhanced compared to the surrounding matrix. They can be caused by ditches of an archaeological origin, but also former field boundaries, ploughing activity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

Positive linear anomaly with associated negative response



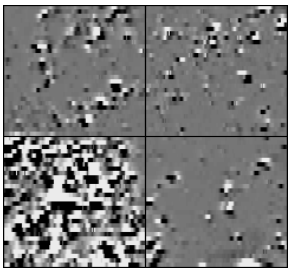
A positive linear anomaly which has a negative anomaly located adjacently. This will be caused by a single feature. In the example shown this is likely to be a single length of wire/cable probably relating to a modern service. Magnetically weaker responses may relate to earthwork style features and field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

Positive point/area



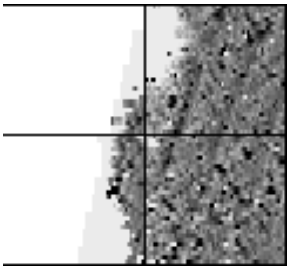
These are generally spatially small responses, perhaps covering just 3 or 4 reading nodes. They are entirely positive in polarity. Similar to positive linear anomalies they are generally caused by infilled cut features. These include pits of an archaeological origin, possible tree bowls or other naturally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

Magnetic debris



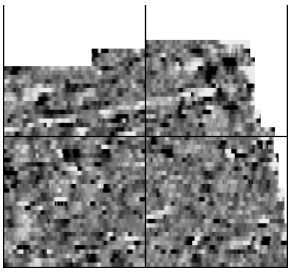
Magnetic debris consists of numerous dipolar responses spread over an area. If the amplitude of response is low (+/-3nT) then the origin is likely to represent general ground disturbance with no clear cause, it may be related to something as simple as an area of dug or mixed earth. A stronger anomaly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

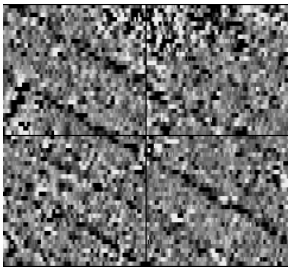


A linear response which is entirely negative in polarity. These are generally caused by earthen banks where material with a lower magnetic magnitude relative the background top soil is built up. See also ploughing activity.

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).

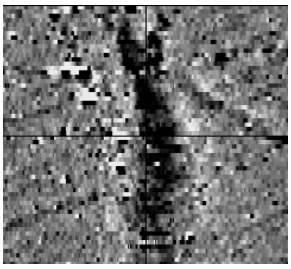
Strength of response

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 $10m^2$ 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. Trace plots are used to show the amplitude of response.

Thermoremnant 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.