

**Land east of Lydney Road
Yorkley
Gloucestershire**

MAGNETOMETER SURVEY REPORT

for

Cotswold Archaeology

Kerry Donaldson & David Sabin

October 2015

Ref. no. 632

ARCHAEOLOGICAL SURVEYS LTD

**Land east of Lydney Road
Yorkley
Gloucestershire**

Magnetometer Survey Report

for

Cotswold Archaeology

Fieldwork by David Sabin (Hons) MCIfA

Report by Kerry Donaldson BSc (Hons)

Report checked by David Sabin

Primary archive location - Archaeological Surveys Ltd, Yatesbury, Wiltshire

Survey date – 1st October 2015

Ordnance Survey Grid Reference – **SO 63750 06850**



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SUMMARY

A geophysical survey was carried out by Archaeological Surveys Ltd, at the request of Cotswold Archaeology, on a single pasture field at Yorkley, Gloucestershire. The magnetometer survey located a number of strongly magnetic discrete anomalies within the northern part of the site. Several of these anomalies are clustered, with some forming the corners of a possible square feature with external dimensions of 10.5m. Many of the anomalies appear to be conjoined, forming short irregular linear, and "U" shaped features in places. Some of the anomalies are more isolated. Many of the groups of discrete responses are associated with zones of magnetic debris. These anomalies may well indicate industrial processes, waste material or possible magnetically thermoremnant features. The strength of the anomalies at over 100nT may indicate an association with iron working.

1 INTRODUCTION

1.1 *Survey background*

- 1.1.1 Archaeological Surveys Ltd was commissioned by Cotswold Archaeology to undertake a magnetometer survey of an area of land at Yorkley, Gloucestershire. An outline planning application has been lodged with the Forest of Dean District Council (P1059/15/OUT). The application proposes a residential development and additional car parking for the adjacent primary school. The survey forms part of an archaeological assessment of the site.
- 1.1.2 The geophysical survey was carried out in accordance with a Written Scheme of Investigation (WSI) produced by Archaeological Surveys (2015) and issued by Cotswold Archaeology to Charles Parry, Archaeologist for Gloucestershire County Council, prior to commencing the fieldwork.

1.2 *Survey objectives and techniques*

- 1.2.1 The objective of the survey was to use magnetometry to locate geophysical anomalies that may be archaeological in origin so that they may be assessed prior to development of the site. The methodology is considered an efficient and effective approach to archaeological prospection.
- 1.2.2 The survey and report generally follow the recommendations set out by: English Heritage (2008) *Geophysical survey in archaeological field evaluation*; and Institute for Archaeologists (2002) *The use of Geophysical Techniques in Archaeological Evaluations*. The work has been carried out to the Chartered Institute for Archaeologists (2014) *Standard and Guidance for Archaeological Geophysical Survey*.

1.3 *Site location, description and survey conditions*

- 1.3.1 The site lies on the southern edge of Yorkley within the parish of West Dean in Gloucestershire. It is centred on Ordnance Survey National Grid Reference (OS NGR) SO 63750 06850, see Figures 01 and 02.
- 1.3.2 The geophysical survey covers approximately 3.5ha within a single pasture field. The application boundary does not include the south eastern part of the site, but the whole field was surveyed in order to maximise the information gathered to help with context and interpretation. The area is generally flat or gently sloping but elevated with land sloping down to the west, east and south.



Plate 1: Survey area looking to the north

- 1.3.3 The ground conditions across the site were generally considered to be favourable for the collection of magnetometry data. A small strip along the western side of the field could not be surveyed due to the presence of bales, manure and farm machinery. Weather conditions during the survey were fine.

1.4 *Site history and archaeological potential*

- 1.4.1 The site lies within an area associated with coal extraction from the late medieval period, post-medieval period and 19th century. A former coal shaft, associated with the Bailey Hill Colliery, is located immediately to the north of the site. Pennant Sandstone quarries are also recorded in the vicinity.
- 1.4.2 To the south east there are a number of archaeological sites and findspots. These include the location of a number of prehistoric work flints, the majority dating to the Mesolithic period, the site of a Roman coin hoard, adjacent to a

Roman road under 1km away, and three medieval or post-medieval charcoal burning platforms, 1.2km away.

- 1.4.3 Although there are no recorded archaeological sites or findspots directly within the site, the location of coal and stone extraction nearby may indicate that there are further associated features. The prehistoric activity within the wider vicinity may indicate that there is some potential for the site to contain previously unrecorded cut features.

1.5 Geology and soils

- 1.5.1 The underlying solid geology across the site is Carboniferous sandstone from the Coleford Member (BGS, 2015). (BGS, 2015).
- 1.5.2 The overlying soil across the survey area is from the Withnell 1 association and is a typical brown podzol. It consists of a well drained, loamy soil over sandstone (Soil Survey of England and Wales, 1983).
- 1.5.3 Magnetometry survey carried out across similar soils has produced variable results. Leaching of ferrous minerals in podzolic soils can relate to very low magnetic susceptibility.

2 METHODOLOGY

2.1 Technical synopsis

- 2.1.1 Magnetometry survey records localised magnetic fields that can be associated with features formed by human activity. Magnetic susceptibility and magnetic thermoremnance are factors associated with the formation of localised fields. Additional details are set out below and within Appendix A.
- 2.1.2 Iron minerals within the soil may become altered by burning and the break down of biological material; effectively the magnetic susceptibility of the soil is increased, and the iron minerals become magnetic in the presence of the Earth's magnetic field. Accumulations of magnetically enhanced soils within features, such as pits and ditches, may produce magnetic anomalies that can be mapped by magnetic prospection.
- 2.1.3 Magnetic thermoremnance can occur when ferrous minerals have been heated to high temperatures such as in a kiln, hearth, oven etc. On cooling, a permanent magnetisation may be acquired due to the presence of the Earth's magnetic field. Certain natural processes associated with the formation of some igneous and metamorphic rock may also result in magnetic thermoremnance.
- 2.1.4 The localised variations in magnetism are measured as sub-units of the Tesla, which is a SI unit of magnetic flux density. These sub-units are nano Teslas (nT),

which are equivalent to 10^{-9} Tesla (T).

2.2 *Equipment configuration, data collection and survey detail*

- 2.2.1 The detailed magnetic survey was carried out using a SENSYS MAGNETO®MXPDA 5 channel cart-based system. The instrument has 5 fluxgate gradiometers spaced 0.5m apart with readings recorded at 20Hz. The gradiometers have a range of recording data between 0.1nT and 10,000nT. The system is linked to a Leica GS10 RTK GPS with data recorded by SENSYS MAGNETO®MXPDA software on a rugged computer.
- 2.2.2 Data are collected along a series of parallel survey tracks wherever possible. The length of each track is variable and relates to the size of the survey area and other factors including ground conditions. A visual display aids accurate placing of tracks and their separation.
- 2.2.3 Data are not collected within fixed grids and data points are considered to be random even though the data are collected in a systematic manner covering all accessible areas (Aspinall, Gaffney and Schmidt, 2009).

2.3 *Data processing and presentation*

- 2.3.1 Magnetic data collected by the MAGNETO®MXPDA cart-based system are initially prepared using SENSYS MAGNETO®DLMGPS software. Survey tracks are analysed and georeferenced raw data (UTM Z30N) are then exported in ASCII format for further analysis and display using TerraSurveyor.
- 2.3.2 The data are collected between limits of ± 10000 nT and clipped for display at ± 10 nT. Data are interpolated to a resolution of effectively 0.5m between tracks and 0.15m along each survey track. A zero median traverse function is required in order to remove fixed offset values present within the sensors which do not undergo a zeroing procedure in the field. The approach ensures that the gradiometer sensors are very accurately aligned and fixed to the vertical magnetic field and are not influenced by localised magnetic fields or disturbed by vibration. Although a zero median traverse algorithm can remove anomalies aligned with the survey tracks, in practice this rarely occurs due to the use of long traverses, high resolution measurement and variability within the magnetic susceptibility of long linear features.
- 2.3.3 Appendix C contains metadata concerning the survey and data attributes and is derived directly from TerraSurveyor. Reference should be made to Appendix B for further information on any processes, such as clipping, carried out on the data.
- 2.3.4 A TIF file is produced by TerraSurveyor software along with an associated world file (.TFW) that allows automatic georeferencing (OSGB36 datum) when using GIS or CAD software. The main form of data display used in the report is the minimally processed greyscale plot.

- 2.3.5 The raster images are combined with base mapping using ProgeCAD Professional 2014, creating DWG (2010) file formats. All images are externally referenced to the CAD drawing in order to maintain good graphical quality. The CAD plots are effectively georeferenced facilitating relocation of features using GPS, resection method, etc.
- 2.3.6 An abstraction and interpretation is also drawn and plotted for all geophysical anomalies located by the survey. Anomalies are abstracted using colour coded points, lines and polygons. All plots are scaled to landscape A3 for paper printing.
- 2.3.7 A brief summary of each anomaly, with an appropriate reference number, is set out in list form within the results (Section 3) to allow a rapid and objective assessment of features within the survey area.
- 2.3.8 A digital archive is produced with this report, see Appendix D below. The main archive is held at the offices of Archaeological Surveys Ltd.

3 RESULTS

3.1 *General assessment of survey results*

- 3.1.1 The detailed magnetic survey was carried out over approximately 3.5ha within a single pasture field.
- 3.1.2 Magnetic anomalies located can be generally classified as positive responses of archaeological potential, positive and negative anomalies of an uncertain origin, linear anomalies of an agricultural origin, areas of magnetic debris and strong discrete dipolar anomalies relating to ferrous objects. Anomalies located within the survey area have been numbered and are described in 3.4 below.

3.2 *Statement of data quality*

- 3.2.1 Data are considered representative of the magnetic anomalies present within the site. There are no significant defects within the dataset. Anomalies related to cultivation and other linear anomalies imply that the soil magnetic susceptibility is sufficient for the location of features with archaeological potential.

3.3 *Data interpretation*

- 3.3.1 The list of sub-headings below attempts to define a number of separate categories that reflect the range and type of features located during the survey. A basic explanation of the characteristics of the magnetic anomalies is

set out for each category in order to justify interpretation, a basic key is indicated to allow cross referencing to the abstraction and interpretation plot. CAD layer names are included to aid reference to associated digital files (.dwg/.dxf). Sub-headings are then used to group anomalies with similar characteristics within the survey area.





Report sub-heading CAD layer names and plot colour	Description and origin of anomalies
<p>Anomalies with archaeological potential</p> <p>AS-ABST MAG POS DISCRETE ARCHAEOLOGY AS-ABST MAG POS ARCHAEOLOGY</p> 	<p>Anomalies have the characteristics (mainly morphological) of a range of archaeological features. Where they are very strong this may indicate intense burning or industrial processes and can be associated with magnetic debris. More diffuse responses can relate to accumulations or spreads of such material.</p>
<p>Anomalies with an uncertain origin</p> <p>AS-ABST MAG POS LINEAR UNCERTAIN AS-ABST MAG NEG LINEAR UNCERTAIN AS-ABST MAG POS DISCRETE UNCERTAIN</p> 	<p>The category applies to a range of anomalies where <u>there is not enough evidence to confidently suggest an origin</u>. Anomalies in this category <u>may well be related to archaeologically significant features, but equally relatively modern features, geological/pedological features and agricultural features should be considered</u>. Positive anomalies are indicative of magnetically enhanced soils that may form the fill of 'cut' features or may be produced by accumulation within layers or 'earthwork' features; soils subject to burning may also produce positive anomalies. Negative anomalies are produced by material of comparatively low magnetic susceptibility such as stone and subsoil.</p>
<p>Anomalies with an agricultural origin</p> <p>AS-ABST MAG AGRICULTURAL</p> 	<p>The anomalies are often linear and form a series of parallel responses or are parallel to extant land boundaries. Where the response is broad, former ridge and furrow is likely; narrow response is often related to modern ploughing.</p>
<p>Anomalies associated with magnetic debris</p> <p>AS-ABST MAG DEBRIS AS-ABST MAG STRONG DIPOLAR</p> 	<p>Magnetic debris often appears as areas containing many small dipolar anomalies that may range from weak to very strong in magnitude. It often occurs where there has been dumping or ground make-up and is related to magnetically thermoremnant materials such as brick or tile or other small fragments of ferrous material. This type of response is occasionally associated with kilns, furnace structures, or hearths and <u>may therefore be archaeologically significant</u>. It is also possible that the response may be caused by natural material such as certain gravels and fragments of igneous or metamorphic rock. Strong discrete dipolar anomalies are responses to ferrous objects within the topsoil.</p>

Table 1: List and description of interpretation categories

3.4 List of anomalies

Area centred on OS NGR 363750 206850, see Figures 03 & 04.

Anomalies of archaeological potential

(1) - A number of small clusters of strongly magnetic discrete anomalies, possibly forming the corners of a square 10.5m across. These responses are very strong at +50nT to +150nT, with surrounding negative halos of generally -10nT to -30nT,

which indicates possible industrial activity or thermoremnant features.

(2) - A group of strongly positive responses is located 40m to the north of anomalies (1) and have a similar magnitude, but some peak at over 500nT. Weakly magnetic debris appears to be associated. These again may indicate industrial activity, possibly iron working.

(3) - A broadly linear positive response with stronger, discrete responses at its north western end extends between anomalies (2) and a patch of magnetic debris which contains other strongly magnetic responses.

(4) - A number of discrete positive responses appear to form a line to the north of (2).

(5) - Four discrete positive responses are in a line towards the western edge of the survey area. They are remote from the majority of the responses, but appear also to relate to possible industrial activity or thermoremnant features.

Anomalies with an uncertain origin

(6) - A narrow, negative linear anomaly appears to extend parallel with anomalies (4) and between anomalies (1) and (2). Its origin is uncertain, but an association with adjacent features is possible.

(7) - The survey area contains a number of positive linear, curvilinear and rectilinear anomalies. It is not possible to determine if they relate to cut features or ground disturbance, or if they relate to natural features.

(8) - A small number of weakly positive discrete anomalies have been located. They have a response of 2-6nT, and while they may relate to pit-like features, a natural origin is possible.

Anomalies with an agricultural origin

(9) - A series of linear anomalies, parallel with the eastern and western field boundaries relates to agricultural activity. Only the trend has been shown, not all the anomalies have been abstracted.

Anomalies associated with magnetic debris

(10) - Large patches of magnetic debris are located in the northern part of the survey area. They are generally within the vicinity of the strong, discrete positive responses and other large, strong, dipolar anomalies and appear to have an association with industrial activity.

(11) - Strong, discrete, dipolar anomalies are responses to ferrous and other magnetically thermoremnant objects with the topsoil.

4 CONCLUSION

- 4.1.1 The magnetometry results have revealed that the northern half of the site contains a large number of very strongly magnetic discrete responses, many with a diameter of 1-1.5m. Many of them appear conjoined, some forming linear, "U" shaped or "V" shaped responses. Although some are more isolated, the majority are clustered and most are associated with spreads of weakly magnetic debris. The strength of the anomalies indicates that they may be associated with iron working or other industrial activities.
- 4.1.2 Other weakly positive linear and discrete anomalies have also been located within the rest of the site, but these lack a coherent form and it is possible that they relate to natural features within the underlying soils and geology.

5 REFERENCES

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

Appendix A – basic principles of magnetic survey

Iron minerals are always present to some degree within the topsoil and enhancement associated with human activity is related to increases in the level of magnetic susceptibility and thermoremanent material.

Magnetic susceptibility is an induced magnetism within a material when it is in the presence of a magnetic field. This can be thought of as effectively permanent due to the presence of the Earth's magnetic field.

Thermoremanent magnetism occurs when ferrous material is heated beyond a specific temperature known as the Curie Point. Demagnetisation occurs at this temperature with re-magnetisation by the Earth's magnetic field upon cooling.

Enhancement of magnetic susceptibility can occur in areas subject to burning and complex fermentation processes on biological material; these are frequently associated with human settlement. Thermoremanent features include ovens, hearths, and kilns. In addition thermoremanent material such as tile and brick may also be associated with human activity and settlement.

Silting and deliberate infilling of ditches and pits with magnetically enhanced soil can create an area of enhancement compared with surrounding soils and subsoils into which the feature is cut. Mapping enhanced areas will produce linear and discrete anomalies allowing an assessment and characterisation of hidden subsurface features.

It should be noted that areas of negative enhancement can be produced from material having lower magnetic properties compared to the topsoil. This is common for many sedimentary bedrocks and subsoils which were often used in the construction of banks and walls etc. Mapping these 'negative' anomalies may also reveal archaeological features.

Magnetic survey or magnetometry can be carried out using a fluxgate gradiometer and may be referred to as gradiometry. The SENSYS gradiometer is a passive instrument consisting of two fluxgate sensors mounted vertically 65cm apart. The instrument is carried about 10-20cm above the ground surface and the upper sensor measures the Earth's magnetic field as does the lower sensor but this is influenced to a greater degree by any localised buried field. The difference between the two sensors will relate to the strength the magnetic field created by the buried feature.

There are a number of factors that may affect the magnetic survey and these include soil type, local geology and previous human activity. Situations arise where magnetic disturbance associated with modern services, metal fencing, dumped waste material etc., obscures low magnitude fields associated with archaeological features.

Appendix B – data processing notes

Clipping

Minimum and maximum values are set and replace data outside of the range with those values. Extreme values are removed improving colour or greyscale contrast associated with data values that may be archaeologically significant. It has been found that clipping data to ranges between $\pm 5nT$ and $\pm 3nT$ often improves the appearance of features associated with archaeology. Different ranges are applied to data in order to determine the most suitable for anomaly abstraction and display.

Zero (destripe) Median/Mean Traverse

The median (or mean) of each traverse is calculated ignoring data outside a threshold value, the median (or mean) is then subtracted from the traverse. The process is used to equalise differences between the baseline value of gradiometer sensors.

High Pass Filtering

A mathematical process used to remove low frequency anomalies relating to survey tracks and modern agricultural features.

Appendix C – survey and data information

COMPOSITE
Filename: J632-mag-proc.xcp
Description: Imported as Composite from: J632-mag.asc
Instrument Type: Sensys DLMGPS
Units: nT
UTM Zone: 30U
Survey corner coordinates (X/Y): OSGB36
Northwest corner: 363662.828002726, 206974.196892288 m
Southeast corner: 363838.198002726, 206720.696892288 m
Collection Method: Randomised
Sensors: 5
Dummy Value: 32702

Source GPS Points: 1015800

Dimensions
Composite Size (readings): 1349 x 1950
Survey Size (meters): 175 m x 253 m
Grid Size: 175 m x 253 m
X Interval: 0.13 m
Y Interval: 0.13 m

Stats
Max: 11.05
Min: -11.00
Std Dev: 2.73
Mean: 0.05
Median: 0.00
Composite Area: 4.4456 ha
Surveyed Area: 3.1698 ha

PROGRAM
Name: TerraSurveyor
Version: 3.0.23.0

Processes: 1
1 Base Layer

GPS based Proce4
1 Base Layer.
2 Unit Conversion Layer (Lat/Long to OSGB36).
3 DeStripe Median Traverse:
4 Clip from -10.00 to 10.00 nT

Appendix D – digital archive

Archaeological Surveys Ltd hold the primary digital archive at their offices in Wiltshire. Data are backed-up onto an on-site data storage drive and at the earliest opportunity data are copied to CD ROM for storage on-site and off-site.

A copy of the report in PDF/A format will be supplied to the Gloucestershire Historic Environment Record, together with a DXF of the survey boundary. The report will also be uploaded to the Online Access to the Index of archaeological investigations (OASIS).

Archive contents:

Geophysical data - path: J632 Yorkley\Data\				
Path and Filename	Software	Description	Date	Creator
yorkley1\MX\ .prm .dgb .disp	Sensys MXPDA	Proprietary data formats representing magnetometer survey traverses logged to a PDA.	02/10/15	D.J.Sabin
yorkley1\MX\J632-mag.asc	Sensys DLMGPS	ASCII CSV (tab) file representing survey Area 1 in eastings, northings (UTM Z30N), magnetic measurement, traverse file and sensor number.	05/10/15	K.T.Donaldson
Mag\comps\J632-mag.xcp	TerraSurveyor 3.0.23.0	Composite data file derived from ASCII CSV.	05/10/15	K.T.Donaldson
Mag\comps\J632-mag-proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file (zmt and clipping to $\pm 10nT$).	05/10/15	K.T.Donaldson
Graphic data - path: J632 Yorkley\Data\				
Mag\graphics\ J632-mag-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a minimally processed greyscale plot clipped to $\pm 10nT$.	05/10/15	K.T.Donaldson
Mag\graphics\ J632-mag-proc.tfw	TerraSurveyor 3.0.23.0	World file for georeferencing TIF to OSGB36.	05/10/15	K.T.Donaldson
CAD data - path: J632 Yorkley\CAD\				
J632 version 1.dwg	ProgeCAD 2014	CAD file for creating plots of greyscales, abstraction, interpretation and mapping. Grid coordinates as OSGB. AutoCAD 2010 format.	01/10/15	K.T.Donaldson
Text data - path: J632 Yorkley\Documentation\				
J632 report.odt	OpenOffice.org 3.0.1 Writer	Report text as an Open Office document.	06/10/15	K.T.Donaldson

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Geophysical Survey Land east of Lydney Road Yorkley Gloucestershire

Map of survey area

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Licence number 100043739.



● Survey location

Site centred on OS NGR
SO 63750 06850



Survey location

SCALE 1:25 000



SCALE TRUE AT A3

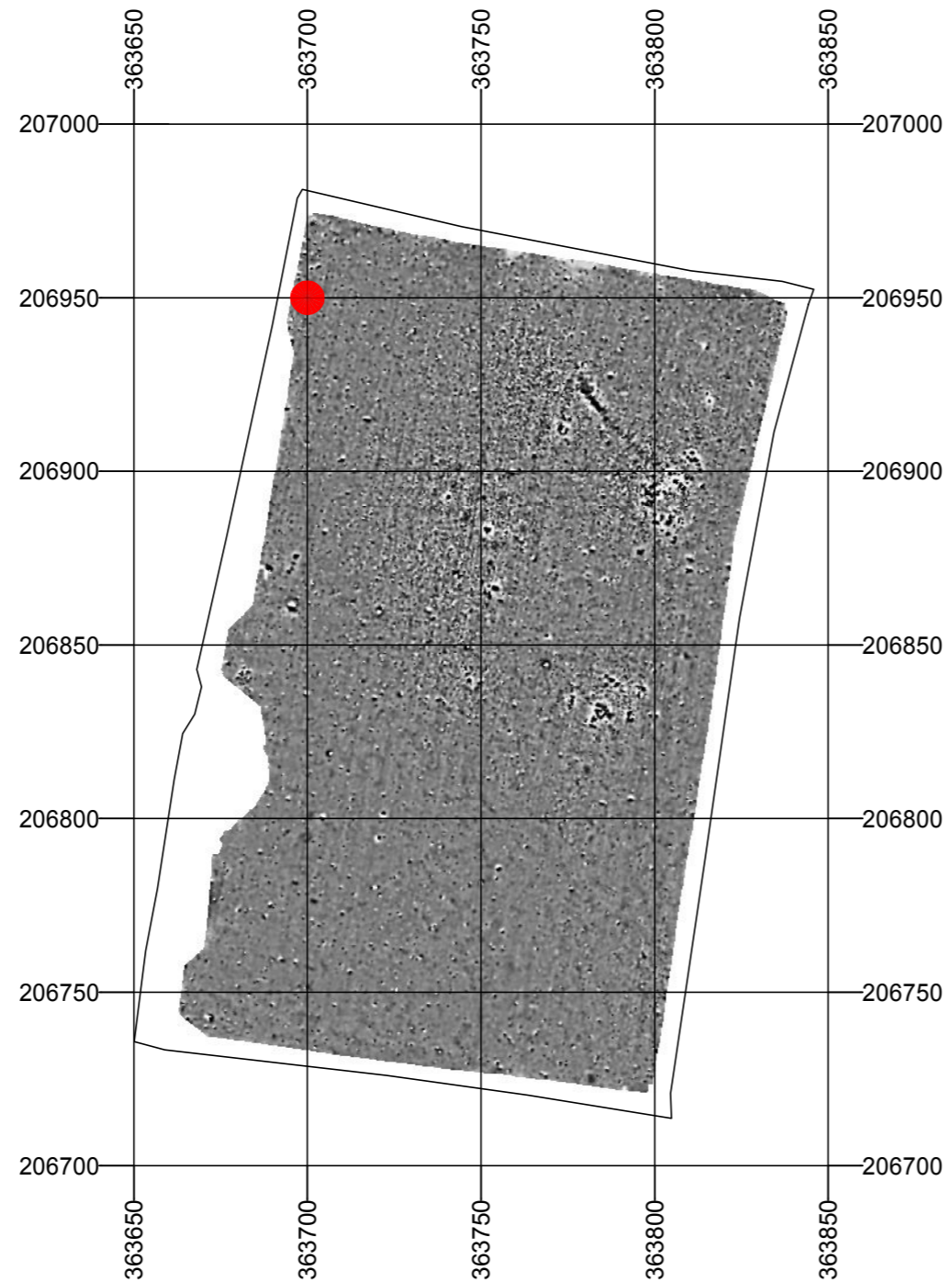
**Geophysical Survey
Land east of Lydney Road
Yorkley
Gloucestershire**

Referencing information

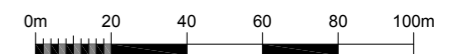
Referencing grid to OSGB36 datum at 50m intervals

Data collected at 20Hz and georeferenced to ETRS89 zone 30 with conversion to OSGB36 using OSTN02

● 363700 206950



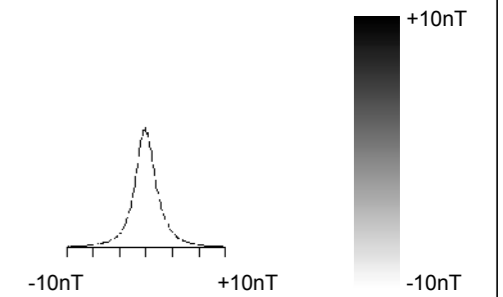
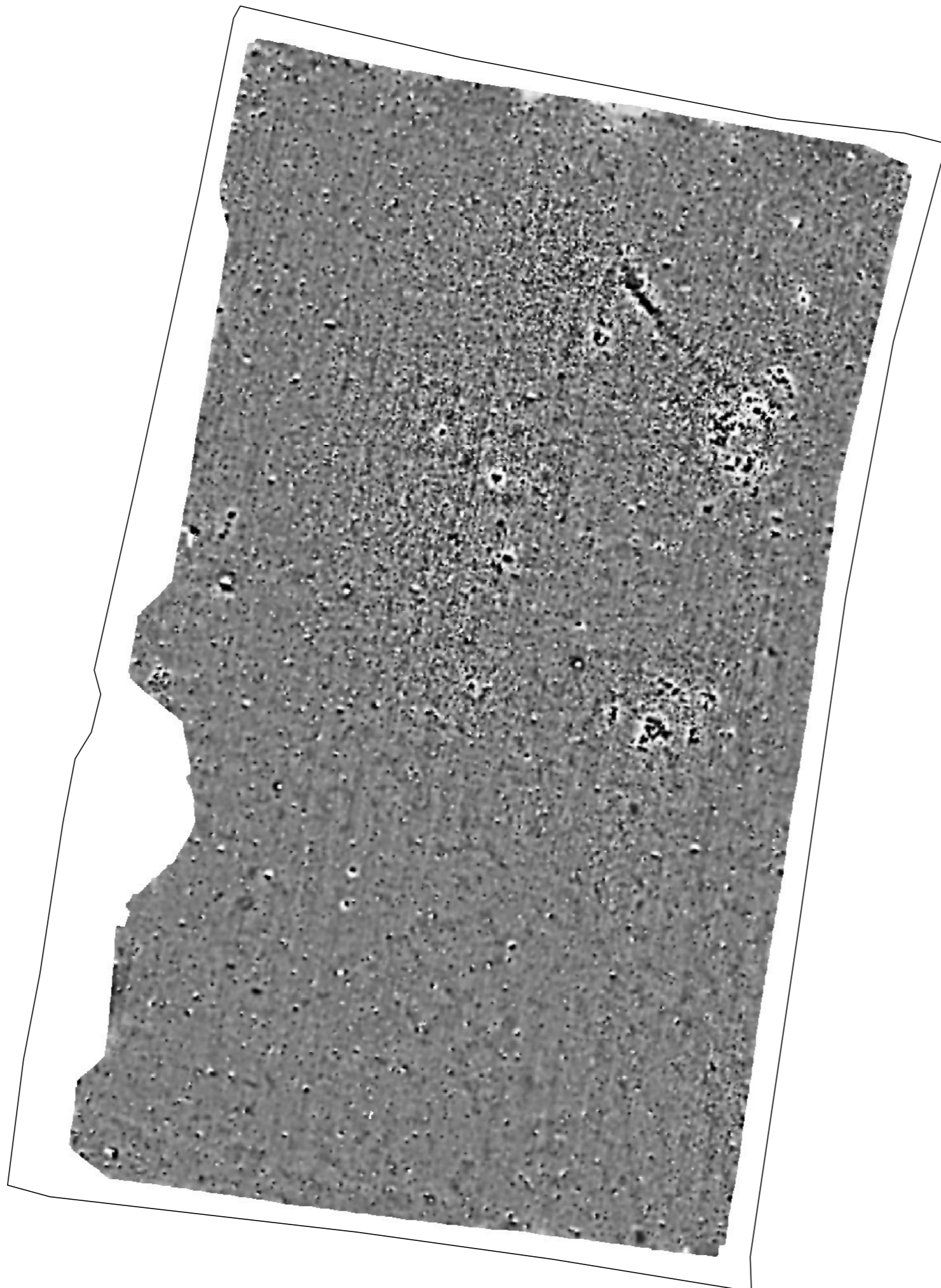
SCALE 1:2000



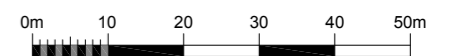
SCALE TRUE AT A3

**Geophysical Survey
Land east of Lydney Road
Yorkley
Gloucestershire**

**Greyscale plot of minimally
processed magnetometer data**











SCALE 1:1000

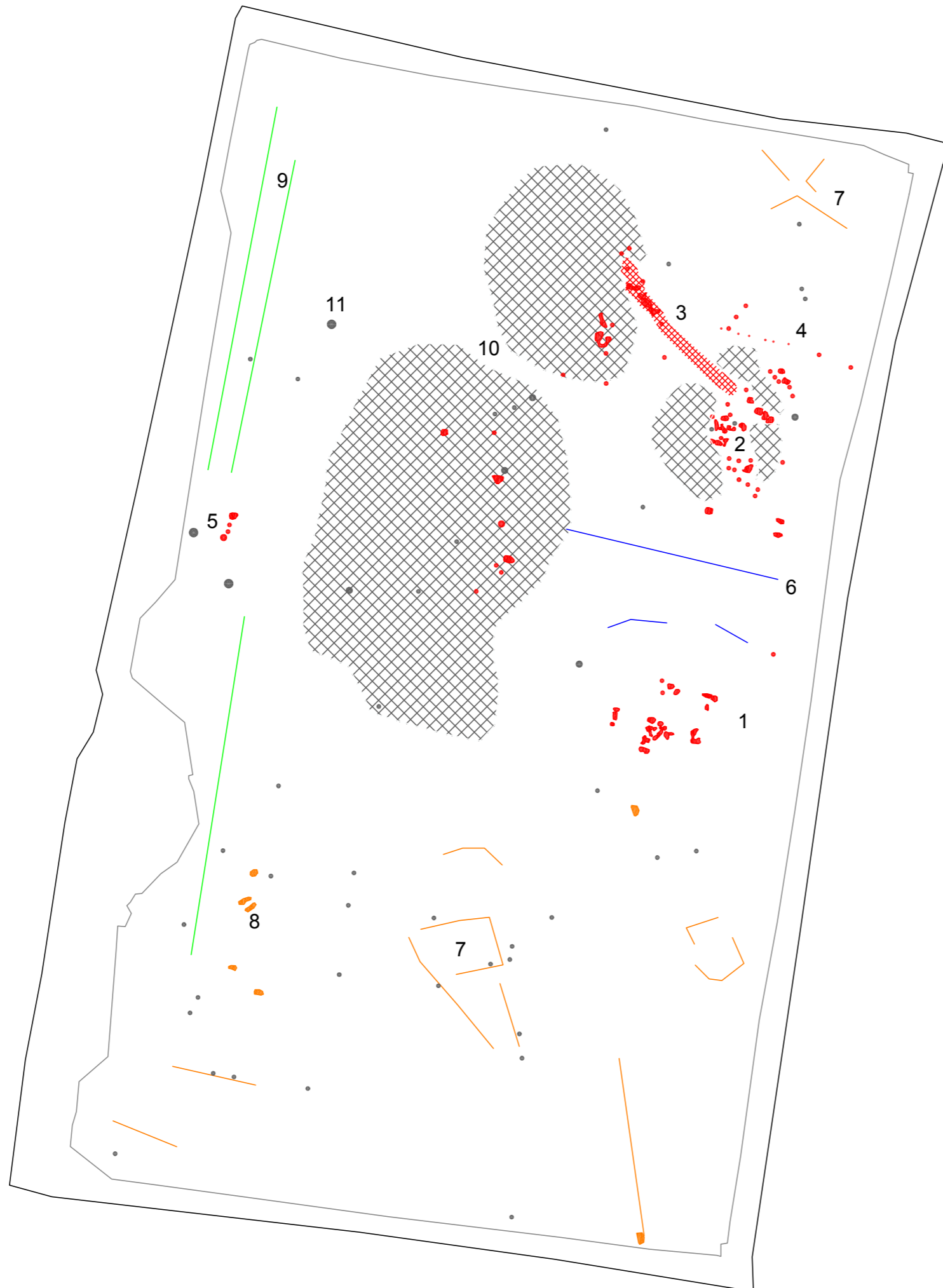


SCALE TRUE AT 43

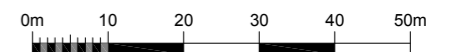
**Geophysical Survey
Land east of Lydney Road
Yorkley
Gloucestershire**

**Abstraction and interpretation of
magnetometer anomalies**

-  Positive linear anomaly - possible ditch-like feature
-  Negative linear anomaly - material of low magnetic susceptibility
-  Linear anomaly - of agricultural origin
-  Discrete positive response - industrial waste/thermoremnant feature of archaeological potential
-  Discrete positive response - possible pit-like feature
-  Positive anomaly - magnetically enhanced material of archaeological potential
-  Magnetic debris - spread of magnetically thermoremnant/ferrous material
-  Strong dipolar anomaly - ferrous object



SCALE 1:1000



SCALE TRUE AT A3