GEOPHYSICAL SURVEY REPORT

Project

ARCHAEOLOGICAL MAGNETIC GRADIOMETRY SURVEY

Location

Pen Caer Lan Farm, Seven Sisters, NPT

Client

Lighthouse Development Consulting

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Lighthouse Development Consulting

Project Geophysicist: Jordan Mertes BSc MSc PhD FGS

Reviewer: Christian Bird BSc FGS

Job Reference: 8654

Date: December 2023

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1 EXECUTIVE SUMMARY

This report presents the results of a geophysical survey conducted at the proposed site of a solar energy development at Pen Caer Lan Farm, Seven Sisters, Wales. The survey was conducted between the 17th and 18th of October 2023. This report provides a detailed account of the survey findings.

Planning is being sought to use the site as a solar farm. A high-resolution magnetic gradiometry survey was conducted across all accessible parts to identify any features that may be of archaeological significance and thus inform any decisions regarding the site's future development.

The total area surveyed measures roughly 11 ha.

Anomalous geophysical features of interest have been digitised and presented as summary archaeological interpretation plots.

No sites that are likely to represent archaeological significance features have been identified.

2 INTRODUCTION

This report presents the results of a geophysical survey conducted at the proposed site of a solar energy development at Pen Caer Lan Farm, Seven Sisters, Wales (see Plate 1). The survey was conducted between the 17th and 18th of October 2023. This report provides a detailed account of the survey findings.

Planning is being sought to develop a solar farm at the site. A high-resolution magnetic gradiometry survey was conducted across all accessible parts to identify any features of archaeological significance and thus inform any decisions regarding the site's future development.

2.1 Site Description

The location of the site is shown in Plate 1. Plate 2 shows the extent of the survey area. Initially, the site included the area outlined in red in Plate 2; however, due to poor ground conditions (and in consultation with the Client), the survey was reduced in scope to the 6.8 ha area highlighted in green. The 19 ha area highlighted in orange was included as a secondary area, and the objective was to survey as much of this area as possible. Pen Caer Lan Farm comprises rough pasture and is centred on OSGB grid coordinate 280597N 208558E. Multiple obstructions were encountered within both the primary (green) and secondary (orange) sites. These include ditches, stone walls, dense shrubs and steep slopes. Plate 3 shows the final total area surveyed. The area surveyed measured 11 ha.

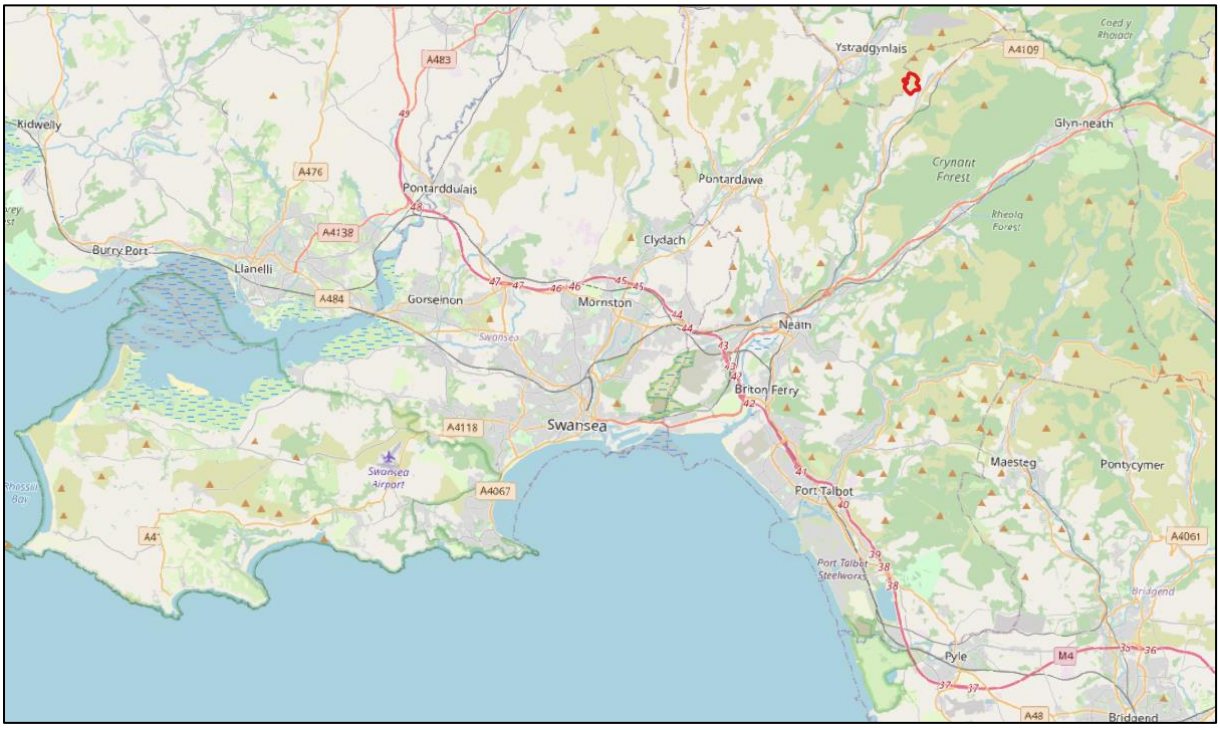


Plate 1: *Site Location*

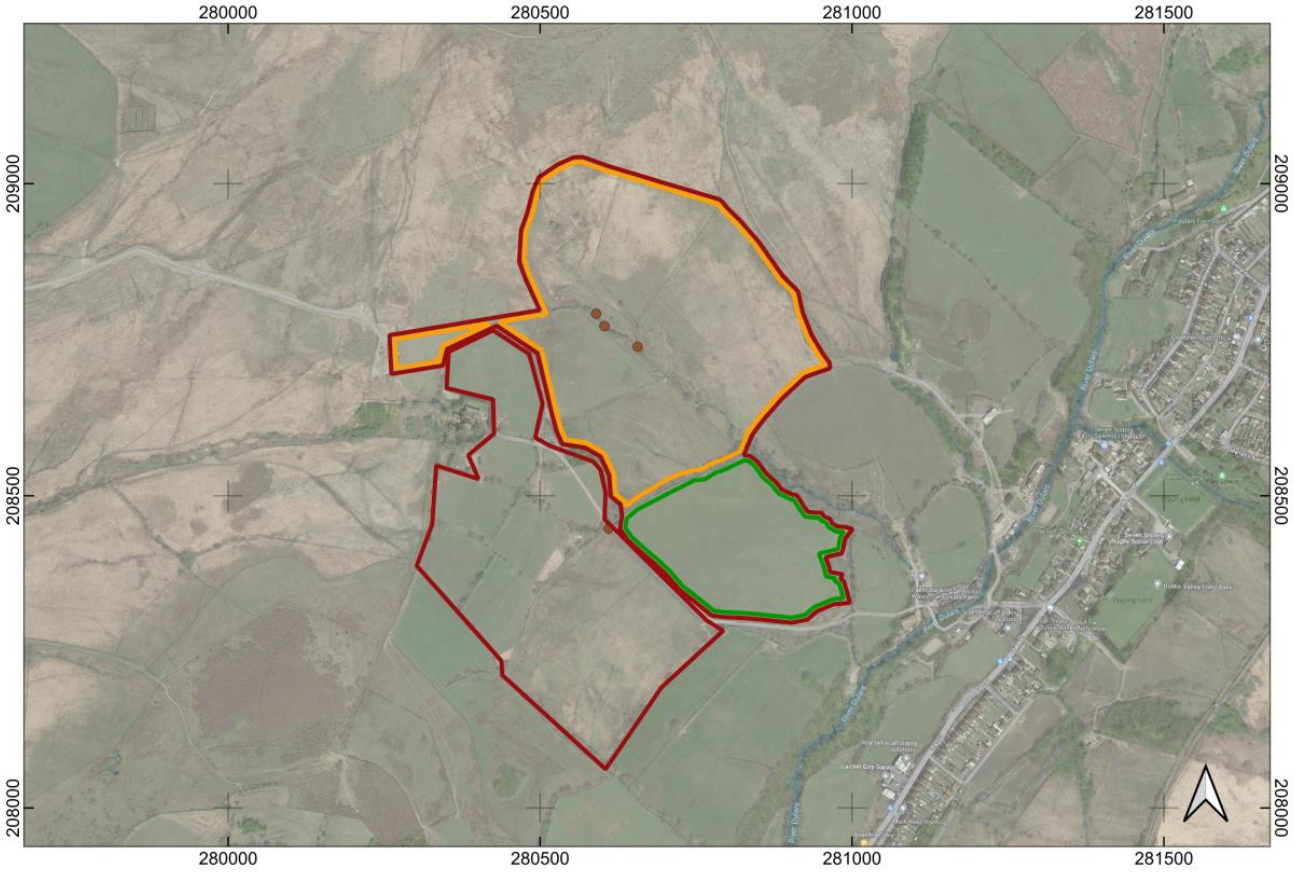


Plate 2: *Detail of the survey area.*

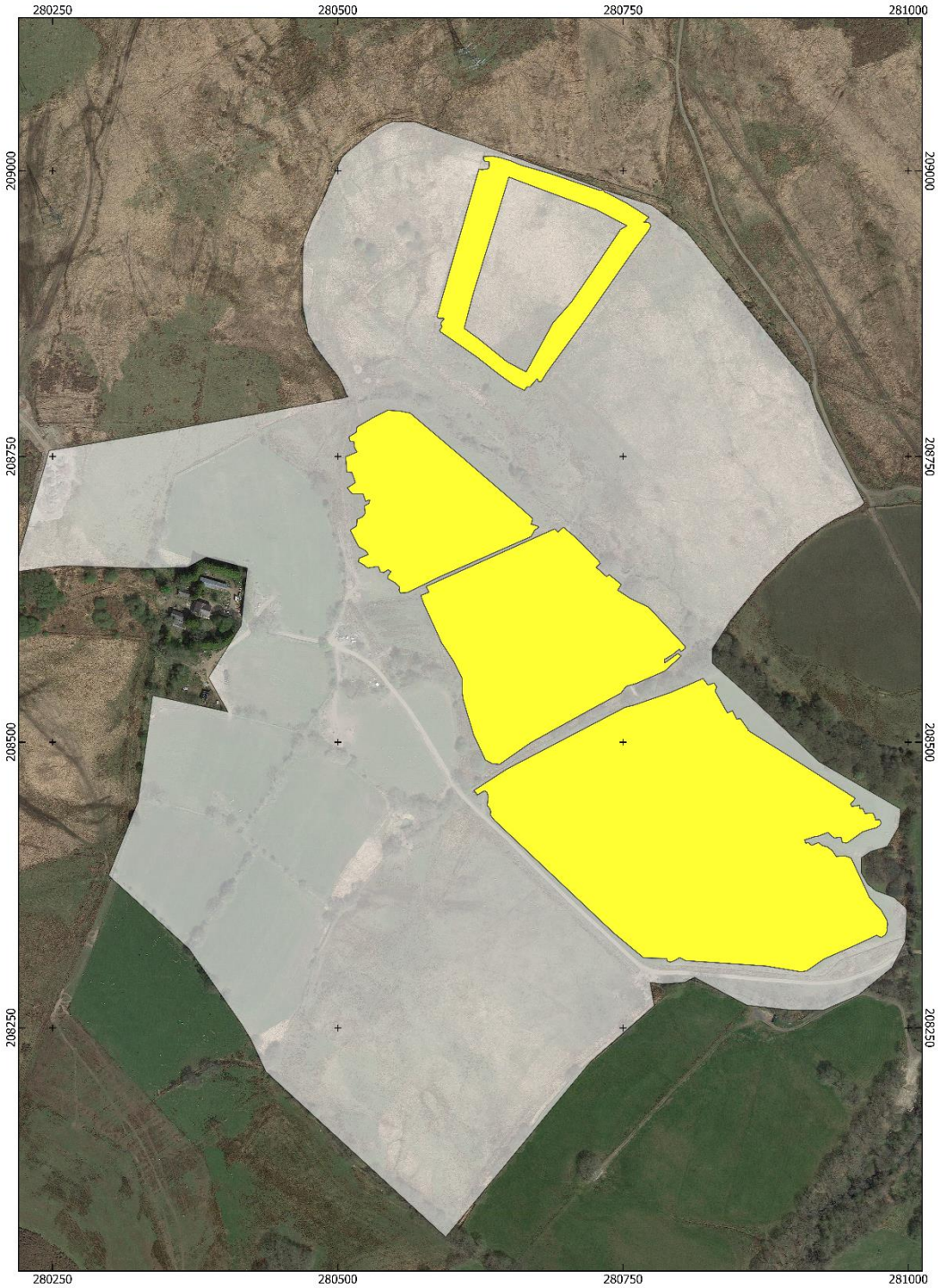


Plate 3: *Final coverage achieved by the geophysical survey at Pen Caer Lan (yellow).*

2.2 Geological setting

The British Geological Survey (BGS) map indicates that Quaternary 'Devensian Till' superficial deposits mantle the north and eastern areas of Pen Caer Lan Farm. These tills are described as *'unsorted sediment with gravel in a fine mud matrix'.* Bedrock in the area is mapped as the South Wales Middle Coal Measures Formation and is primarily comprised of mudstones, siltstones and sandstones. There are remains of past mining activities across the site. Data from the Coal Authority shows suspected mine adits (brown dots in Plate 4) and the areas classified as 'high risk' regarding possible development (hatched areas Plate 4).

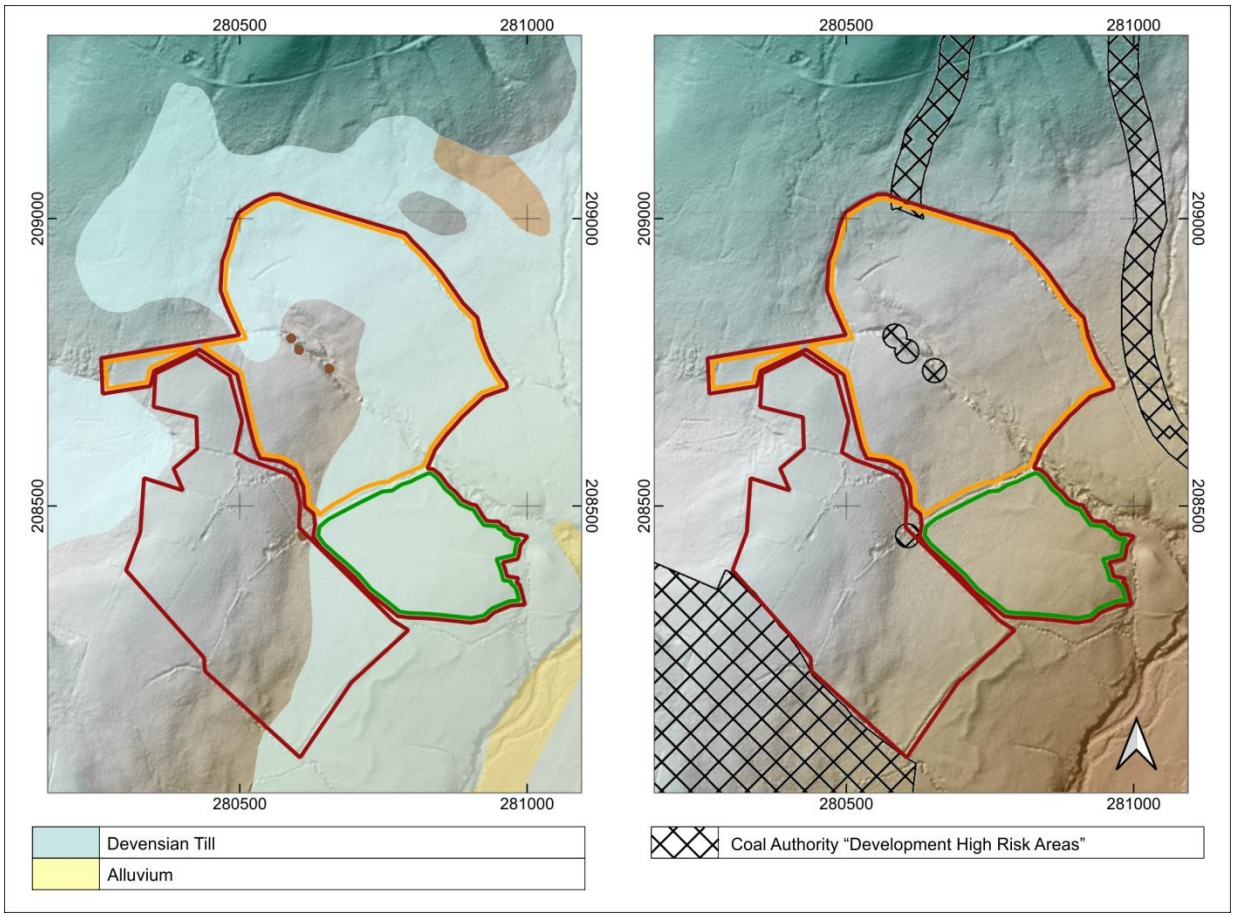


Plate 4: *Superficial geology (left) and Coal Authority "Development High Risk" overlay (right) of Pen Caer Lan and the surrounding area.*

2.3 Survey objectives

The primary objectives of the geophysical survey are to locate and describe any detectable archaeological features present. The survey will provide a standalone document and facilitate any subsequent fieldwork phase by indicating the detected features' location, character, extent, and potential significance.

The geophysical survey results will also inform any subsequent archaeological assessment and, ultimately, the design layout. Therefore, it is being conducted before other archaeological evaluations.

2.4 Quality control

The geophysical data were collected in line with standard operating procedures outlined by the instrument manufacturer and TerraDat company policy. All services and reports are undertaken to the highest standards to BS 5930:2015 (site investigation) and meet the standard required by The Chartered Institute for Archaeologists' Standard and Guidance for Archaeological Geophysical Survey (2014).

On completion of the survey, the data were downloaded from the survey instrument onto a computer and backed up appropriately. The acquired data set was initially checked for errors that may be caused by instrument noise, low batteries, positional discrepancies, etc., and any field notes were either written up or incorporated in the initial data processing stage. The data set was then processed using standard processing routines. Once processed, the resulting plots are subject to peer review to ensure the integrity of the interpretation. Our quality control standards are BS EN ISO 9001:2015 certified.

3 SURVEY DESCRIPTION

The survey was conducted using magnetic gradiometry. The results are presented in the form of interpreted data plans indicating the location and physical characteristics of identified anomalous features together with a text description.

3.1 Topographic survey/grid layout

The SENSYS MAGNETO MXV3 data acquisition is controlled by proprietary software MONMX, which provides a real-time graphical display of ground coverage based on the RTK-GPS positioning system mounted on the trailer. Survey traverses are acquired to provide as little overlap between traverses as possible while minimising any gaps between the traverses. Survey traverses are driven as straight as is reasonably practicable until the entire site is covered, after which 'headland' files are acquired at the site boundaries to ensure maximum coverage.

3.2 Magnetic survey

Magnetic surveys are designed to exploit the subtle deviation in the Earth's magnetic field caused by objects/materials of variable magnetic properties in the subsurface. These properties include ferromagnetism, remnant magnetism, and magnetic susceptibility. In an archaeological setting, these tend to be buried ferrous objects, burnt materials, or the disturbance or accumulation of naturally occurring ferrous minerals within the soil**.** The **r**ecorded data value is the magnetic gradient (the difference in the magnetic field strength recorded by two vertically separated fluxgate magnetometers).

A plan image showing the variation in the magnetic gradient of the site survey area is produced. Based on the recorded magnetic variation, it is possible to identify buried archaeological features such as walls, hearths, kilns, ditches, and pits.

3.2.1 Magnetic survey – field activity

The magnetic gradiometry data were acquired using a multi-sensor array (8 fluxgate gradiometer probes installed at 0.5 m sensor separation) mounted on a specialist modular (Sensys Magneto MXV3; Plate 3). Network-corrected RTK GPS provides real-time GPS positioning. The trailer is towed across the survey area behind an ATV (Plate 5) at speeds of <15 km/h. This system allows for the acquisition of 0.5 m across-track resolution gradiometry data within a 3.5 m wide swathe. The data were acquired at a rate of 200 Hz, nominally providing data at 0.025 m intervals along each traverse. This approach enhances resolution (double that of a conventional hand-held instrument in both x and y directions) and acquisition rate; However, a trade-off can be a poorer signal-to-noise ratio.

Plate 5: *John Deer Gator and Sensys Magneto MXV3 (Library Photo).*

3.2.2 Magnetic survey - data processing

The gradiometry data were acquired using SENSYS proprietary software MONMX, which produces a data file for each acquired survey line. These files are compiled in DLMGPS, which associates each gradiometry data point with a GPS coordinate, calculated based on the location of each sensor within the array, thus creating a single swathe of gradiometry data up to 3.5m wide. The software applies a constant median filter to normalise the data within each swathe; the data are then exported as raw ASCII files.

The ASCII files output from DLMGPS were further processed using TerraDat proprietary software MagMerge (Plate 6) to remove any poor-quality data (sensor drop-outs/data spikes, etc/overlapping data.) and apply 50Hz and rolling median filters. The 50Hz filter removes artefacts principally associated with electrical power lines, while the median filter equalises the background data across the swathes within a dataset, removing any apparent striping between them. Plate 7 shows an example of raw data alongside filtered data. Table 1 details the processing steps that are applied to the ASCII data;

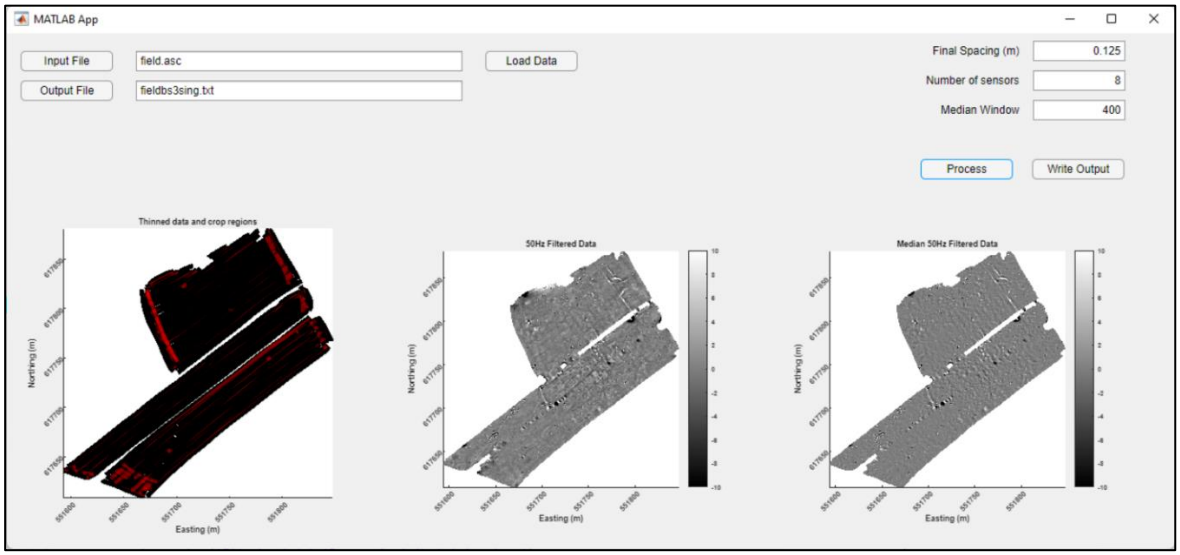


Plate 6: *TerraDat proprietary software MagMerge*

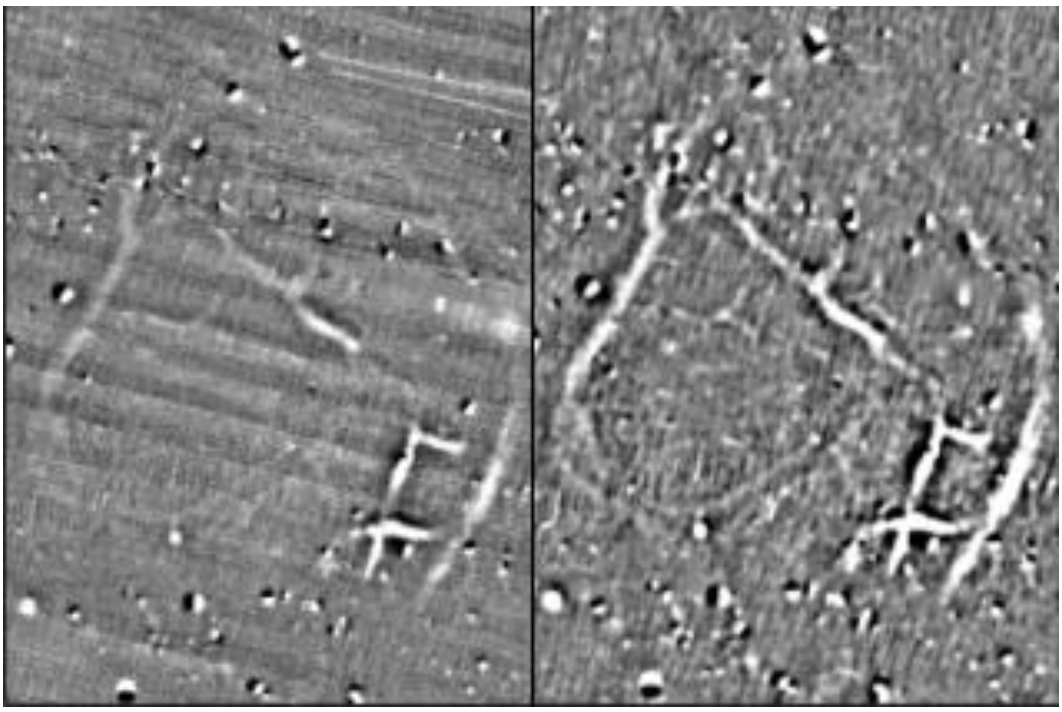


Plate 7: *Raw data (left) and filtered data (right)*

Processing Step	Description
Raw data input	Raw data (.asc) file is imported, and X,Y,Z,gradient,Time_stamp,sensor columns are retained. All other columns are removed.
Truncate Time_Stamp	Alphanumeric Time_stamp variable is truncated to the last digits (e.g. L1_20221007-095821_GZ.prm becomes 95821) to create unique IDs for each line.
Create line_number	Variable 'line_number' (i.e. 1 to #lines) is created by identifying all unique 'Time_stamp' values.
Rolling median	The median filter is calculated per line, per sensor, on values within -/+20nT and removed from the gradient to create a new 'GM' column. The rolling median filter has a window length of 400 data points centred on the input value. Therefore, the first and last 200 data points do not have sufficient information to calculate the median. In these cases, the first value calculated is applied back to the start of the line, and the last value calculated is filled forward to the end of the line. In practical terms, the median window length is equivalent to 10m of data acquisition.
Filter 50Hz Noise	50Hz noise from electrical utilities is removed through wavelet analysis, signal decomposition, and a 50Hz Bandstop filter. Both methods yield similar results. Multiple combinations of median and 50Hz filters are created (i.e. G50, G50M, G50BS and G50BSM) for comparison.
Calculate Mean Spacing	Mean along-track spacing is calculated.
Thin data	Data are thinned to specified output resolution using the calculated mean spacing
Crop overlapping data	Calculate bounding polygons around each line of data. Remove data located within reverse-ordered overlapping polygons.
Display Data	Plot thinned data and cropped areas, plot 50Hz filtered data, plot median filtered data.
Write output file	Write output file containing thinned data with X,Y,Z, gradient,Time_stamp,sensor,Gm,G50,G50M,linenum,G50BS,G50BSM.
Write output GPS	Write output X,Y,Z gps file using centre (actual GPS) data.

***Table 1**: Processing steps applied to the raw magnetic gradiometry data.*

The magnetic gradiometry data is output as raw and filtered 'XYZ' files in .CSV format. The height data from the GPS is also output as an approximately 3m x 0.125m resolution DTM of the Site. These files are gridded in Oasis Montaj, using minimum curvature gridding and a grid cell size of 0.125m. Once the data is gridded and an appropriate colour scale applied, the data is exported as high-resolution GeoTiff images (900 DPI) before being imported into the open-source GIS software qGIS. Features of interest are then digitised to produce summary archaeological interpretation plans. These are integrated with the DTM to allow consideration of any identified archaeological features within the site's topography. Final figures are drafted in CorelDraw.

4 RESULTS AND DISCUSSION

The final processed data quality is good. There is an issue with the persistence of subtle 'tank-tracking' (narrow longitudinal oscillations in background values between +/-1 nT) due to the slight bobbing motion of the cart and a few holes/gaps in the data where adjacent traverses have not overlapped correctly or due to obstructions/poor site conditions.

The data are presented as a series of grey-scaled plots exhibiting variations in the intensity of the magnetic gradient across the survey area. Both raw and processed magnetic data are used for the archaeological interpretation; therefore, both data types are displayed in the figures.

Anomalous geophysical features of interest have been digitised and presented as summary interpretation plots; Plate 8 presents a key to be used in conjunction with these plots.

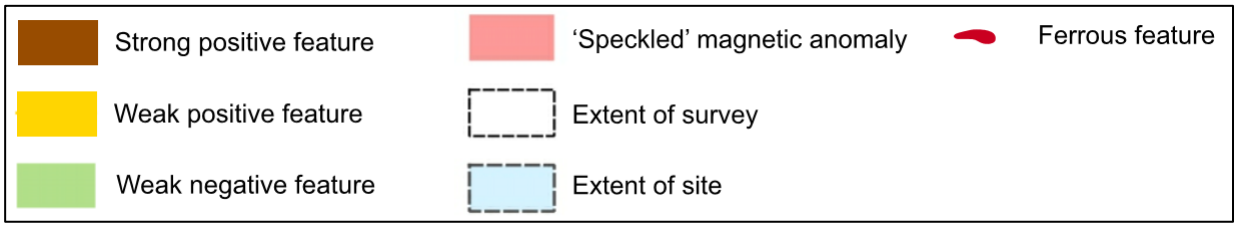


Plate 8: *Key to be used in conjunction with the interpretive plots*

4.1 List of figures

4.2 Magnetic gradiometry

Magnetic gradiometry (measurement of the vertical gradient of the Earth's magnetic field, using two sensors, one positioned above the other typically at 1.0m separation) developed from magnetometry (measurement of the Earth's magnetic field strength, using a single sensor) to free magnetic surveys from the constraint of requiring base-station measurements to compensate for diurnal variation in field strength.

The identified magnetic anomalies (i.e. areas with a magnetic gradient that deviates from that of the typical site background) may be due to the influence of one of three main magnetic properties: ferromagnetism (that exhibited by a magnetic object of ferrous metal), remnant magnetism (a permanent sympathetic magnetic field acquired during the cooling of a hot object, commonly seen in both fixed archaeological features such as hearths, as well as portable materials, such as ceramic building material [CBM]) and most importantly of all, magnetic susceptibility ([MS], a measure of the temporary sympathetic magnetic field generated by a body in an ambient field). Typically, weathering elevates the magnetic susceptibility, so soils have a higher MS than their parent rock. Anthropogenic processes (particularly heating) may also enhance MS. Thus, the fills of archaeological cut features typically show a higher magnetic susceptibility than the substrate into which they are cut (and thus appear as positive anomalies). There are exceptions to this sense of susceptibility contrast – for instance, where a cut feature is filled by stone with low magnetic susceptibility. For structures built of stone, there is typically a stronger contrast between the lower MS stonework and higher MS occupation deposits (meaning that stone walls, drains, etc., will usually show negative magnetic anomalies).

Ferrous materials will usually strongly influence the magnetic gradient but of a limited spatial extent. These anomalies typically show strong negative and positive components (so a small iron object appears as a black/white dot on the plots). Accumulations of iron objects may generate a speckled appearance – typical, for instance, of the sites of former wire fences. The remnant magnetic fields of CBM may also produce speckled textures – brick rubble will appear similar to a spread of ferrous debris but with lower magnitude 'spikes'.

5 GEOPHYSICAL INTERPRETATION

There is very little in the way of interpretable features within the areas surveyed at Pen Caer Lan Farm. Those features that do exist are likely to be historical agricultural features. There is a feature comprised of a linear scattering of isolated high-amplitude features across the southern and central fields; however, this is located within a slight linear topographic depression and is likely to reflect the presence of an abandoned channel. In the northernmost of the three completely surveyed fields, there is a sub-rectangular scattering of weak positive anomalies with the (slight) potential to be archaeological in origin. In these instances, the isolated anomalies, despite a resemblance to archaeological pit features, are probably associated with slightly magnetic boulders within the boulder clay.

In the (very) partially surveyed NE field, a series of very strong parallel lineations are thought to represent historical agricultural lineations. These show an enhanced visibility in certain areas, and this is discussed further below.

5.1 Former field boundaries

The survey produced no evidence for removed former land divisions, in keeping with the available cartographic evidence.

5.2 Agricultural features

The field in the NE of the survey and the lower (eastern) parts of the western fields showed some evidence for agricultural lineations, probably associated with ploughing forming a part of pasture improvement.

5.3 Possible archaeological features

Although the survey lacked any certain geophysical evidence for archaeological features, some comment is required on three areas within the northeastern field (areas centred upon [280744, 208971] in the NE, [280661, 208817] in the southeast and [280692, 208857] close to the east side).

The first two ([1],[2]) correspond to areas where the agricultural lineation becomes locally of much higher amplitude. This effect can be attributed to disturbance of a subsoil with a higher

magnetic susceptibility (MS) than that of adjacent areas. Increased MS can be the result of human settlement activity but can also result from various natural causes.

In this instance, both the affected areas show discrete positive magnetic anomalies, each of relatively small size and none suggesting linear anomalies. This somewhat amorphous type of anomaly is most likely to be of natural origin, but the disturbance of a spread of anthropogenic material (burnt material or slag, for instance) cannot entirely be excluded.

The third of the anomalous areas [3] in the field does appear to show short lengths of linear magnetic anomaly and does not show the enhanced imaging of the agricultural lineation. This suggests that the anomaly represents a discrete source rather than the subsoil. The high amplitude of at least part of the complex of divergent linear anomalies suggests that either ferrous material may be present or may result from a lightning strike. However, as with the other two areas, an archaeological origin cannot entirely be excluded.

Disclaimer

This report represents an opinionated interpretation of the geophysical data. It is intended for guidance with follow-up invasive investigation. Features that do not produce measurable geophysical anomalies or are hidden by other features may remain undetected. Geophysical surveys complement invasive/destructive methods and provide a tool for investigating the subsurface; they do not produce data that can be taken to represent all of the ground conditions found within the surveyed area. Areas that have not been surveyed due to obstructed access or any other reason are excluded from the interpretation.

Figures

Title:
LOCATION OF GEOPHYSICAL SURVEYS

Project:
PEN CAER LAN FARM

TERRA DAT
down to earth geophysics
Tel: +44 (0) 2920 700127
Web:www.terradat.co.uk
Email: web@terradat.co.uk

Scale: 1:3000 at A3
Drawn by/Ref: CB/8654/1
Date: 23/10/2023

FIGURE 1

280500 280750 281000

209000 208750 208500

280500 280750 281000

N

Title:
RAW MAGNETIC GRADIOMETRY - +/- 4 nT

Project:
PEN CAER LAN FARM

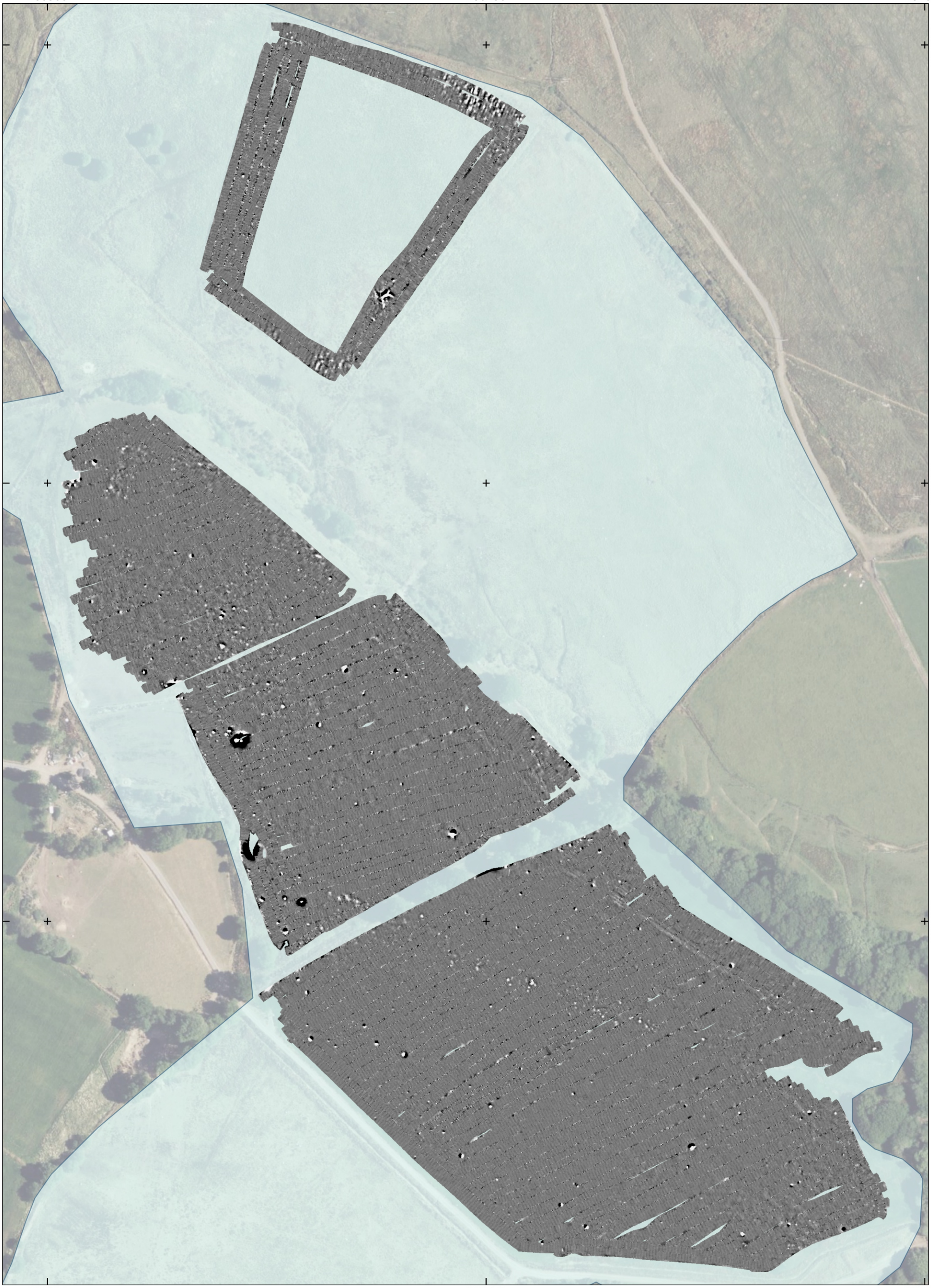
TERRA DAT
down to earth geophysics
Tel: +44 (0) 2920 700127
Web:www.terradat.co.uk
Email: web@terradat.co.uk

Scale: 1:2000 at A3
Drawn by/Ref: CB/8654/2
Date: 23/10/2023

FIGURE 2

280500 280750 281000

209000 208750 208500



280500 280750 281000

N

Title:
PROCESSED MAGNETIC GRADIOMETRY - +/- 4 nT

Project:
PEN CAER LAN FARM

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Email: web@terradat.co.uk

Scale:	1:2000 at A3
Drawn by/Ref:	CB/8654/3
Date:	23/10/2023

FIGURE 3

280500 280750 281000

209000 208750 208500

1 2 3

N

Strong positive feature
Weak positive feature
Weak negative feature
'Speckled' magnetic anomaly
Extent of survey
Extent of site
Ferrous feature

Title:
SUMMARY ARCHAEOLOGICAL INTERPRETATION

Project:
PEN CAER LAN FARM

TERRA DAT
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Tel: +44 (0) 2920 700127
Web:www.terradat.co.uk
Email: web@terradat.co.uk

Scale: 1:2000 at A3
Drawn by/Ref: CB/8654/4
Date: 23/10/2023

FIGURE 4

280500 280750 281000

209000 208750 208500

Topography

Low High

1 2 3

N

Strong positive feature

Weak positive feature

Weak negative feature

'Speckled' magnetic anomaly

Extent of survey

Extent of site

Ferrous feature

Title: **SUMMARY ARCHAEOLOGICAL INTERPRETATION WITH TOPOGRAPHY**

Project: **PEN CAER LAN FARM**

TERRA DAT down to earth geophysics

Tel: +44 (0) 2920 700127
Web:www.terradat.co.uk
Email: web@terradat.co.uk

Scale: 1:2000 at A3

Drawn by/Ref: CB/8654/5

Date: 23/10/2023

FIGURE 5

280500 280750 281000

209000 208750 208500

N

Strong positive feature

Weak positive feature

Weak negative feature

'Speckled' magnetic anomaly

Extent of survey

Extent of site

Ferrous feature

Title: **SUMMARY ARCHAEOLOGICAL INTERPRETATION WITH HISTORICAL OS MAP**

Project: **PEN CAER LAN FARM**

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Web:www.terradat.co.uk
Email: web@terradat.co.uk

Scale: 1:2000 at A3

Drawn by/Ref: CB/8654/6

Date: 23/10/2023

FIGURE 6