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STRATASCAN



Geophysical Survey Report

Roman Fort near Cardigan

for

Cambria Archaeology

April 2008

J2457

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Roman Fort Near Cardigan**

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Techniques: **Detailed magnetic survey (gradiometry)**

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1 SUMMARY OF RESULTS

The gradiometer survey undertaken on 4.3ha of land near Cardigan revealed no evidence of a Roman Fort. Some positive and negative linear anomalies were identified which indicate cut features such as ditches and earthwork features such as earthen banks of possible archaeological origin. Linear positive and negative responses in Area 1 are possibly related to former field boundaries.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned by Cambria Archaeology to undertake a geophysical survey in an area of a suspected Roman Fort.

2.2 Site location

The site is located near Cardigan, Ceredigion, Wales at OS ref SN 1720 4665.

2.3 Description of site

The survey area is 4.3ha of sloping pasture land set over two fields.



Plate 1: Looking South West across Area 1



Plate 2: Looking North East across Area 2

The underlying geology is Caradoc & Ashgill (British Geological Survey South Sheet, Fourth Edition Solid, 2001). The overlying soils are known as Denbigh 1 which are typical Palaeozoic salty mudstone and siltstone. These consist of well drained fine loamy and fine silty soils over rock (Soil Survey of England and Wales, Sheet 2 Wales 1983).

2.4 Site history and archaeological potential

This site is the possible location of a Roman Fort where it was initially thought Roman finds had been recorded. More recently it has been clarified that these finds have not come from the suspected fort fields but from further towards the river.

2.5 Survey objectives

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

2.6 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 4 days from 25th March to 29th March 2008. Weather conditions during the survey were dry and sunny.

3.2 Grid locations

The location of the survey grids has been plotted in Figure 2 together with the referencing information. Grids were set out using a Leica 705auto Total Station and referenced to suitable topographic features around the perimeter of the site.

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. '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 shows the basic processing carried out on all processed gradiometer data used in this report:

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

2. *Zero mean grid* (sets the background mean of each grid to zero and is useful for removing grid edge discontinuities)

Geoplot parameters:

Threshold = 0.25 std. dev.

3. *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

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 (Figure 3) and trace plots (Figures 4 & 5), together with a greyscale plot of the processed data (Figure 6). Magnetic anomalies have been identified and plotted onto the 'Abstraction and Interpretation of Anomalies' drawing for the site (Figure 7).

4 RESULTS

The magnetometer survey identified a number of geophysical anomalies across the site, some of which may relate to archaeological activity. These anomalies have been abstracted into the following categories:

- Discrete positive response – possible pit
- Positive area and linear anomalies – cut features of possible archaeological origin
- Negative area and linear anomalies – earthwork features of possible archaeological origin
- Linear area of disturbance associated with overhead cables
- Moderate strength dipolar anomaly
- Area of magnetic disturbance associated with nearby fences or modern interference
- Bipolar anomaly associated with pylons
- Strong positive anomaly with associated negative return – ferrous object

Discrete positive response – possible pit

There are several small positive anomalies across the survey area. These may indicate cut features, perhaps pits of a possible archaeological origin.

Positive linear and area anomalies – cut feature of possible archaeological origin

The gradiometer data has revealed a large number of positive linear and area anomalies within the survey area. Such features are generally representative of in filled cut features such as ditches. To the north of the centre of Area 2 the linear anomalies are likely to relate to former field boundaries. In Area 1 many of these responses are at relatively low amplitudes of between 0nT – 4nT. Many of the positive anomalies appear to be associated with negative linear anomalies.

Negative linear and area anomaly – earthwork feature of possible archaeological origin

In Area 1 some isolated linear negative anomalies are observed. These represent banks or earthworks of possible archaeological origin. Most of the negative area anomalies identified throughout the survey area are adjacent to positive anomalies, which suggest that they are associated with each other, suggesting the presence of some form of bank and ditch arrangement. The linear area anomaly identified in Area 2 is likely to relate to a former field boundary.

Linear area of disturbance associated with overhead cables

A linear area of disturbance is observed on a roughly north south orientation in Area 1. This response follows the line of an overhead cable and is likely to be associated with disturbance from the cable.

Moderate strength dipolar anomaly

Several dipolar anomalies are evident across the survey area. These consist of moderate strength positive anomalies with associated negative responses. These anomalies are of uncertain origin but may be associated with ferrous objects buried at depth.

Area of magnetic disturbance associated with nearby fences or modern interference

Large areas of magnetic disturbance are observed running along the perimeter of the survey area. These anomalies are probably caused by metal fencing and modern interference. They may obscure the presence of faint anomalies of possible archaeological origin.

Bipolar anomaly associated with pylons

Two bipolar anomalies are observed in Area 1, these are caused by wooden electricity pylons.

Strong positive anomaly with associated negative return – ferrous object

A number of strong positive anomalies with associated negative returns can be seen across the site. These anomalies are typical of near surface ferrous objects.

5 CONCLUSION

The gradiometer survey identified a number of positive and negative anomalies which represent cut features such as ditches and earthwork features of possible archaeological origin. However, there is little evidence for a Roman Fort. The anomalies which have been observed are at relatively low amplitudes and are not synonymous with the sort of response expected from a Roman Fort site. Some of these anomalies may simply be caused by geological/pedological variation. It is likely that a number of the linear anomalies are related to former field boundaries, particularly in Area 2.

Individual magnetic anomalies were observed across the survey area, some of which are high amplitude, others of which are weaker and more discrete. These are probably related to ferrous objects of modern origin, although it is possible that some of these may be associated with metal objects from previous occupation.

6 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 2 Wales*.

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.

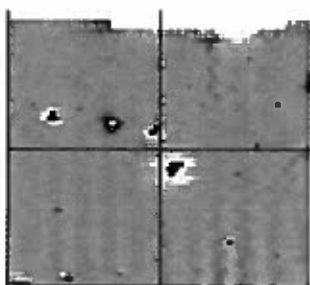
APPENDIX B – Glossary of magnetic anomalies

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

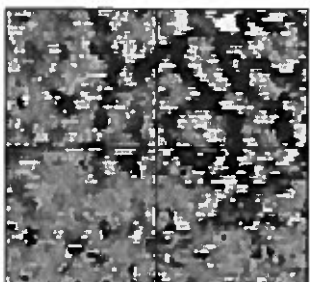


This consists of a single positive anomaly with an associated negative response. There should be no separation between the two polarities of response. These responses will be created by a single feature. The interpretation of the anomaly will depend on the magnitude of the magnetic measurements. A very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

Positive anomaly with associated negative response

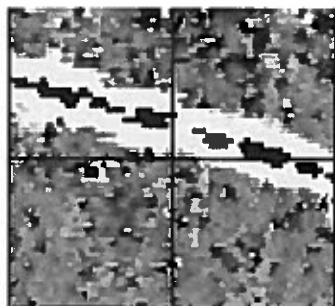
See bipolar and dipolar.

Positive linear



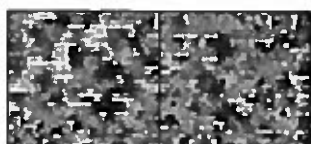
A linear response which is entirely positive in polarity. These are usually related to infilled cut features where the fill material is magnetically enhanced compared to the surrounding matrix. They can be caused by ditches of an archaeological origin, but also former field boundaries, ploughing activity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

Positive linear anomaly with associated negative response



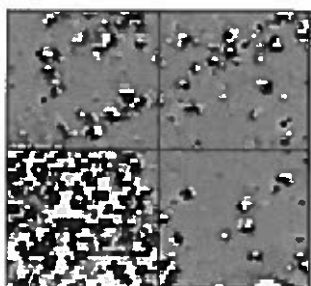
A positive linear anomaly which has a negative anomaly located adjacently. This will be caused by a single feature. In the example shown this is likely to be a single length of wire/cable probably relating to a modern service. Magnetically weaker responses may relate to earthwork style features and field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

Positive point/area



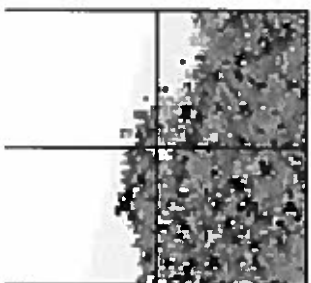
These are generally spatially small responses, perhaps covering just 3 or 4 reading nodes. They are entirely positive in polarity. Similar to positive linear anomalies they are generally caused by infilled cut features. These include pits of an archaeological origin, possible tree bowls or other naturally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

Magnetic debris



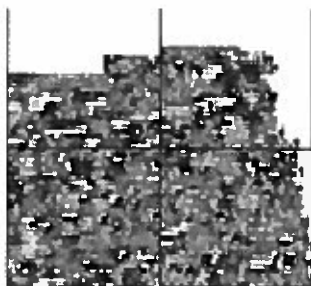
Magnetic debris consists of numerous dipolar responses spread over an area. If the amplitude of response is low ($\pm 3\text{nT}$) then the origin is likely to represent general ground disturbance with no clear cause, it may be related to something as simple as an area of dug or mixed earth. A stronger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

Magnetic disturbance



Magnetic disturbance is high amplitude and can be composed of either a bipolar anomaly, or a single polarity response. It is essentially associated with magnetic interference from modern ferrous structures such as fencing, vehicles or buildings, and as a result is commonly found around the perimeter of a site near to boundary fences.

Negative linear

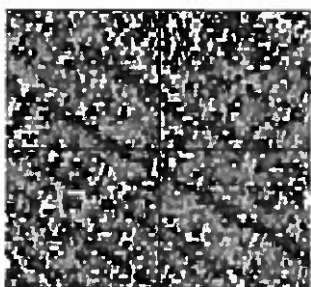


A linear response which is entirely negative in polarity. These are generally caused by earthen banks where material with a lower magnetic magnitude relative the background top soil is built up. See also ploughing activity.

Negative point/area

Opposite to positive point anomalies these responses may be caused by raised areas or earthen banks. These could be of an archaeological origin or may have a natural origin.

Ploughing activity



Ploughing activity can often be visualised by a series of parallel linear anomalies. These can be of either positive polarity or negative polarity depending on site specifics. It can be difficult to distinguish between ancient ploughing and more modern ploughing, clues such as the separation of each linear, straightness, strength of response and cross cutting relationships can be used to aid this, although none of these can be guaranteed to differentiate between different phases of activity.

Polarity

Term used to describe the measurement of the magnetic response. An anomaly can have a positive polarity (values above 0nT) and/or a negative polarity (values below 0nT).

Strength of response

The amplitude of a magnetic response is an important factor in assigning an interpretation to a particular anomaly. For example a positive anomaly covering a 10m² area may have values up to around 3000nT, in which case it is likely to be caused by modern magnetic interference. However, the same size and shaped anomaly but with values up to only 4nT may have a natural origin. 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.

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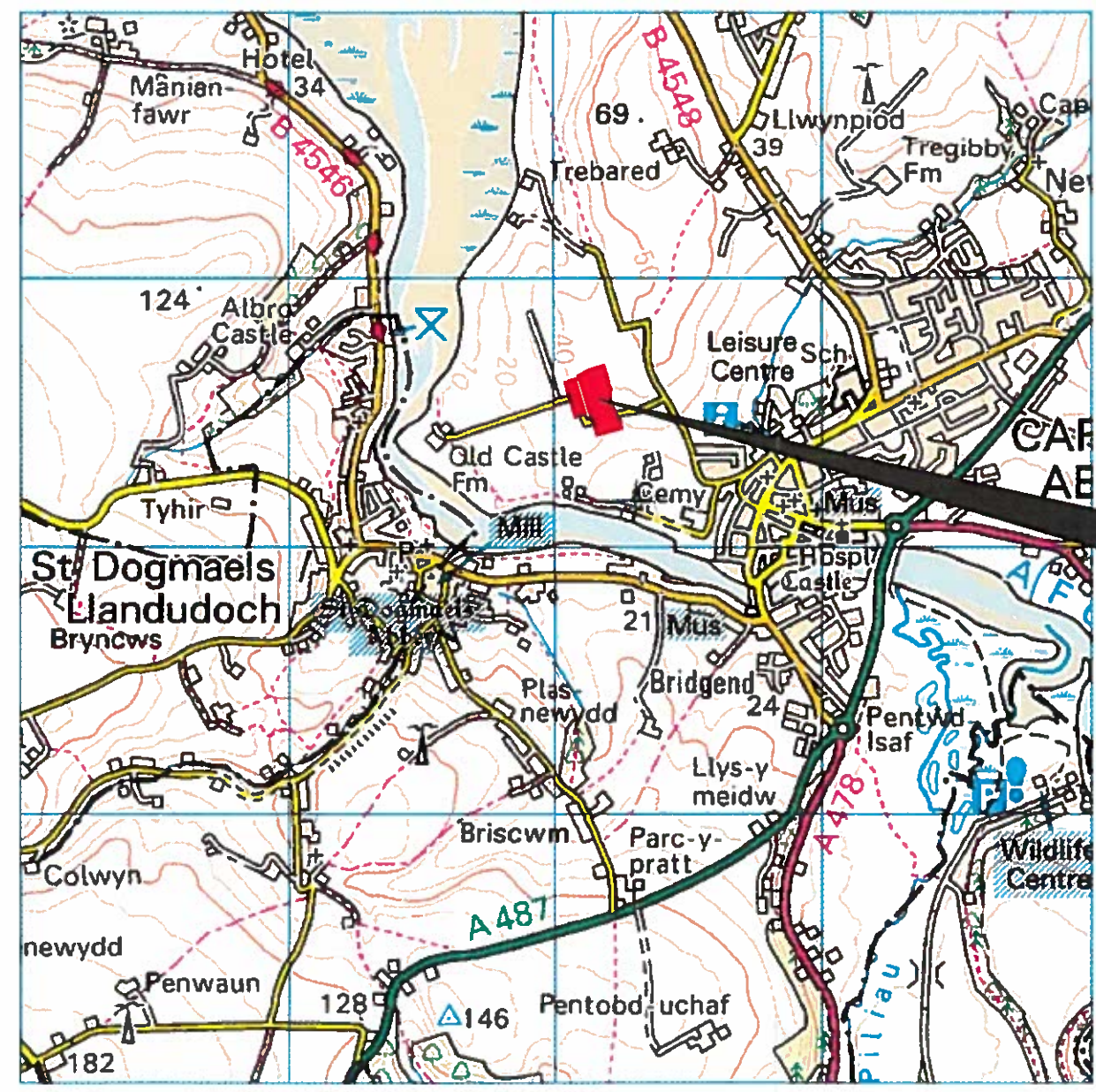
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19

Amendments		
Issue No.	Date	Description

Site centred on NGR SN 172 467

Client
CAMBRIA ARCHAEOLOGY

Project Title Job No. J2454
**GEOPHYSICAL SURVEY -
ROMAN FORT NEAR CARDIGAN**

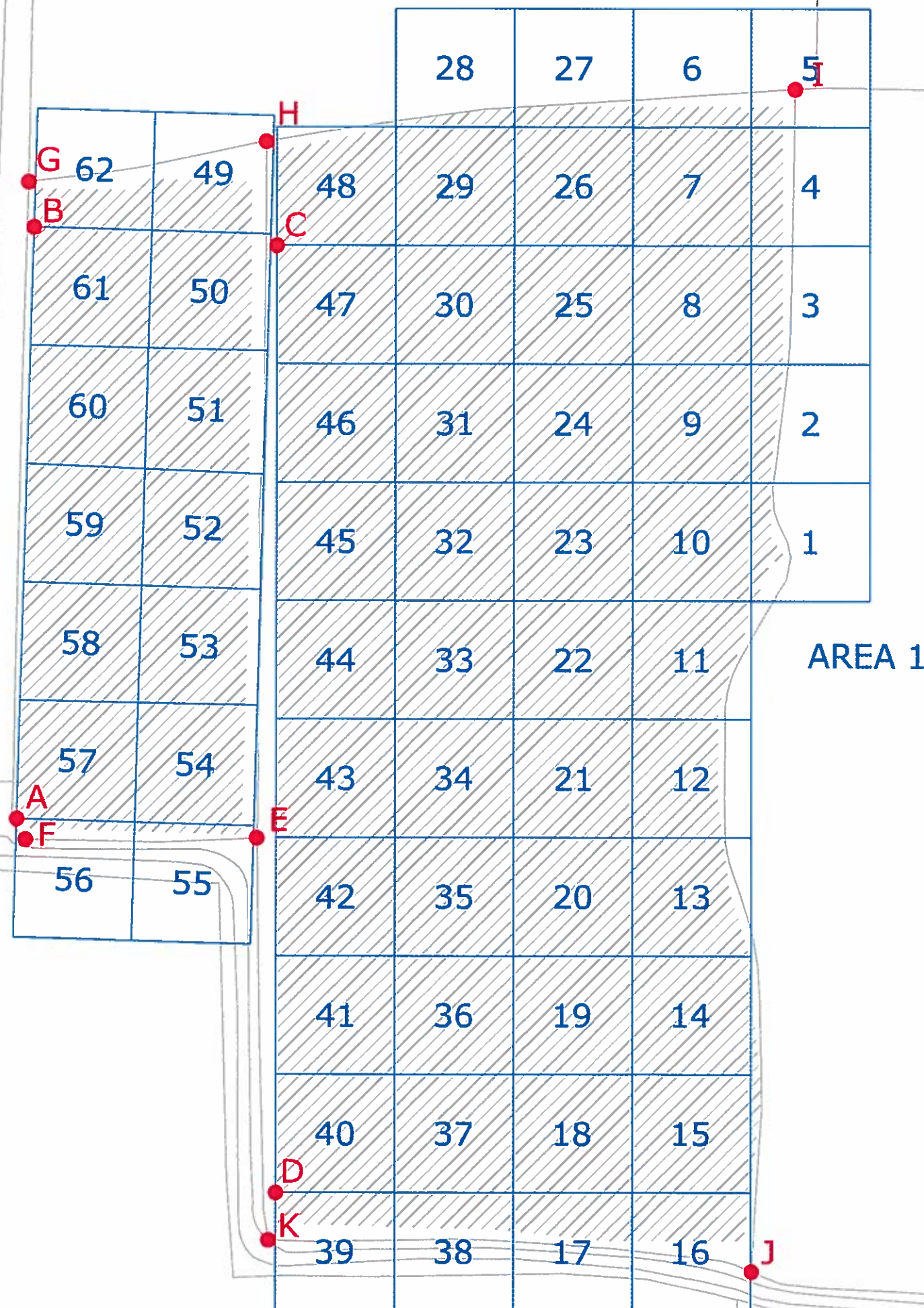
Subject
LOCATION PLAN OF SURVEY AREA

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AND ENGINEERING
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Scale
1:25 000
0m 500 1000m

Plot A3	Checked by SAS	Issue No. 01
Survey date APRIL 08	Drawn by CG	Figure No. 01

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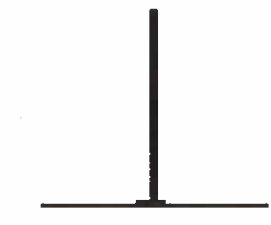

AREA 2

AREA 1





Amendments		
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-	-	-
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Area 1 Plotting parameters Maximum +3nT (black) Minimum -3nT (white)  -3SD +3SD	 +3nT -3nT
---	---

Area 2 Plotting parameters Maximum +3nT (black) Minimum -3nT (white)  -3SD +3SD	 +3nT -3nT
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Client	
CAMBRIA ARCHAEOLOGY	
Project Title	Job No. J2457
GEOPHYSICAL SURVEY - ROMAN FORT NEAR CARDIGAN	
Subject	
PLOT OF RAW GRADIOMETER DATA	

STRATASCAN™ GEOPHYSICS FOR ARCHAEOLOGY AND ENGINEERING VINEYARD HOUSE UPPER HOOK ROAD UPTON UPON SEVERN UK WR8 0SA T: +44 (0)1684 592266 F: +44 (0)1684 594142 E: info@stratascan.co.uk www.stratascan.co.uk	
	

Scale	0m 10 20 30 40 50m	
1:1250		
Plot	Checked by	Issue No.
A3	SAS	01
Survey date	Drawn by	Figure No.
APRIL 08	CG	03



AREA 2

AREA 1



Amendments		
Issue No.	Date	Description
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Client		
CAMBRIA ARCHAEOLOGY		
Project Title	Job No. J2457	
GEOPHYSICAL SURVEY - ROMAN FORT NEAR CARDIGAN		
Subject		
TRACE PLOT OF GRADIOMETER DATA SHOWING POSITIVE VALUES		
<div><div>STRATASCAN™</div><div>GEOPHYSICS FOR ARCHAEOLOGY AND ENGINEERING VINEYARD HOUSE UPPER HOOK ROAD UPTON UPON SEVERN UK WR8 0SA T: +44 (0)1684 592266 F: +44 (0)1684 594142 E: info@stratascan.co.uk www.stratascan.co.uk</div><div>REGISTERED IFA ORGANISATION</div></div>		
Scale 1:1250 <div><div></div><div>0m</div><div>10</div><div>20</div><div>30</div><div>40</div><div>50m</div></div>		
Plot A3	Checked by SAS	Issue No. 01
Survey date APRIL 08	Drawn by CG	Figure No. 04



AREA 2

AREA 1



Amendments		
Issue No.	Date	Description

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Client
CAMBRIA ARCHAEOLOGY

Project Title
**GEOPHYSICAL SURVEY -
ROMAN FORT NEAR CARDIGAN**

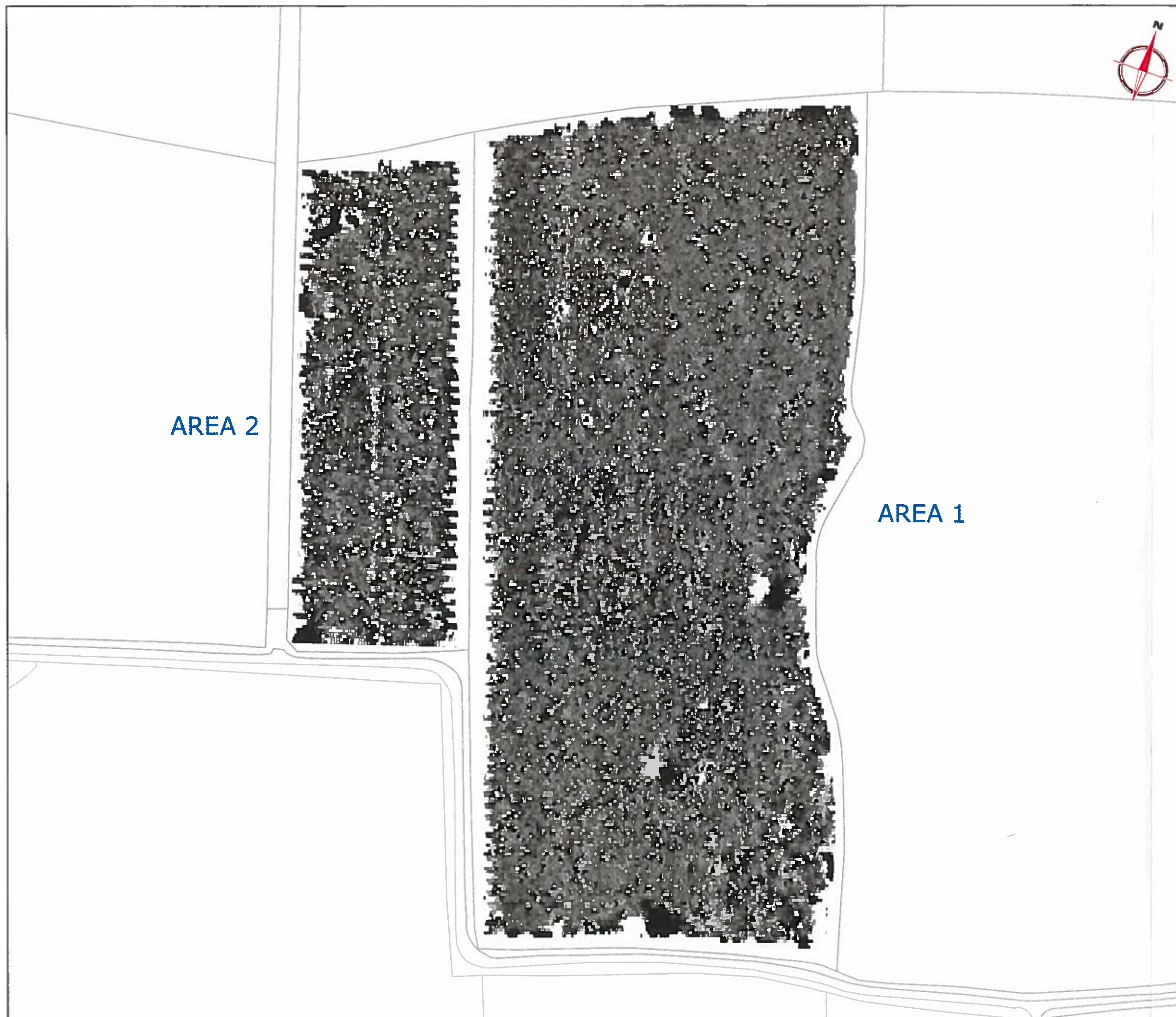
Job No. J2457

Subject
**TRACE PLOT OF GRADIOMETER DATA
SHOWING NEGATIVE VALUES**

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Scale
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Survey date APRIL 08	Drawn by CG	Figure No. 05



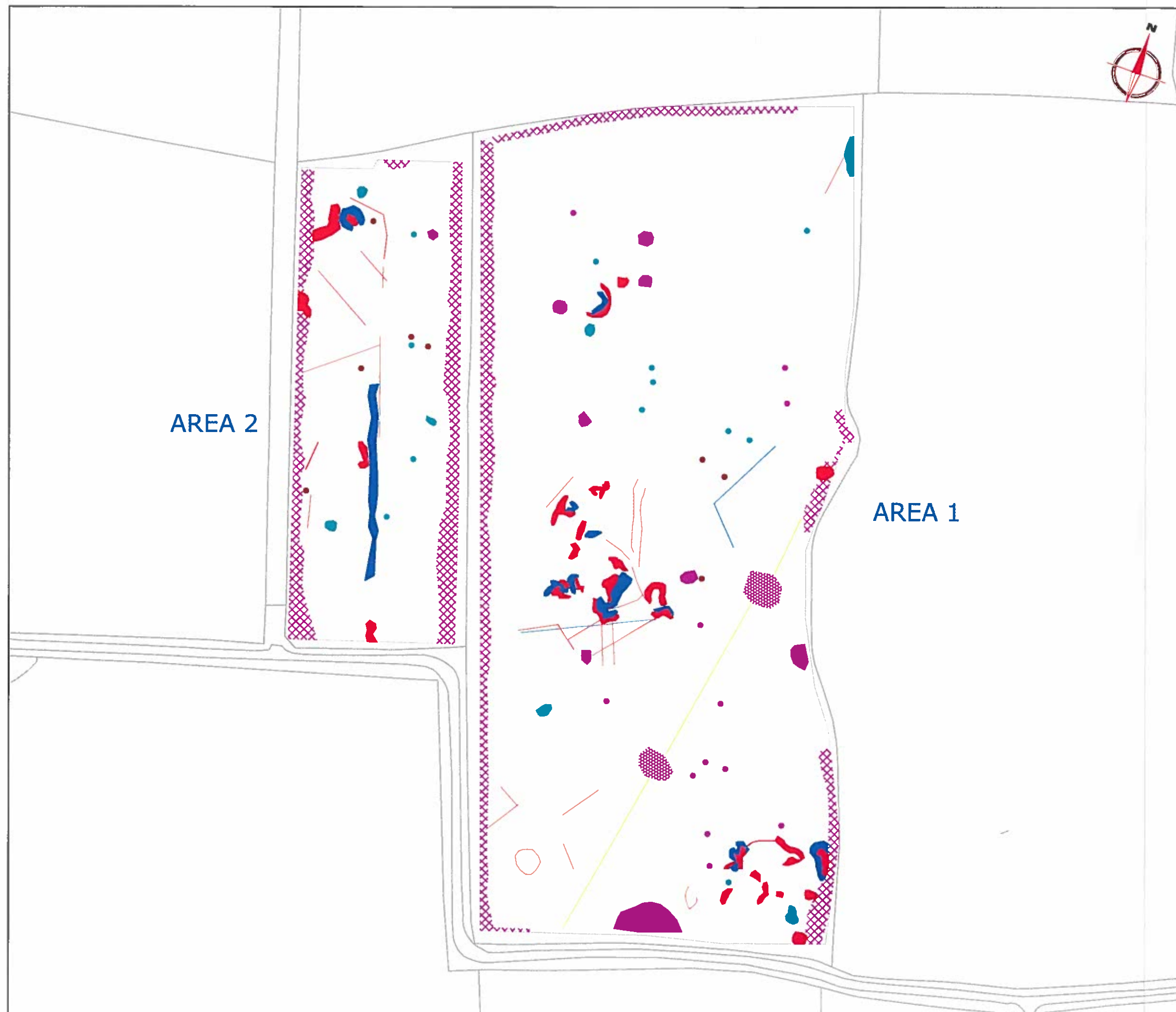
Amendments		
Issue No.	Date	Description
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Area 1 Plotting parameters Maximum +3nT (black) Minimum -3nT (white)	 -3SD +3SD	
Area 2 Plotting parameters Maximum +3nT (black) Minimum -3nT (white)	 -3SD +3SD	

Client CAMBRIA ARCHAEOLOGY	
Project Title GEOPHYSICAL SURVEY - ROMAN FORT NEAR CARIGAN	Job No. J2457
Subject PLOT OF PROCESSED GRADIOMETER DATA	

STRATASCAN™ GEOPHYSICS FOR ARCHAEOLOGY AND ENGINEERING VINEYARD HOUSE UPPER HOOK ROAD UPTON UPON SEVERN UK WR8 0SA T: +44 (0)1684 592266 F: +44 (0)1684 594142 E: info@stratascan.co.uk www.stratascan.co.uk		
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Scale 1:1250		
Plot A3	Checked by SAS	Issue No. 01
Survey date APRIL 08	Drawn by CG	Figure No. 06



Amendments		
Issue No.	Date	Description
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