ARCHAEOLOGICAL
SERVICES
WYAS

Lynemouth Windfarm
Northumberland

Geophysical Survey

March 2006

Report No. 1508

Headland Archaeology

Lynemouth Windfarm

Northumberland

Geophysical Survey

Contents

Summary

Geophysical (magnetometer) surveys carried out at the proposed locations of sixteen wind turbines near Lynemouth have not revealed any anomalies thought to be indicative of archaeological activity although former field boundaries and a trackway and evidence of ridge and furrow ploughing has been identified. On the basis of the geophysical survey the archaeological potential of the areas surveyed is considered to be low.

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1. Introduction and Archaeological Background

1.1 Archaeological Services WYAS was commissioned by Mark Roberts of Headland Archaeology on behalf of their client Scottish Power to carry out a geophysical (magnetometer) survey at the proposed site of a windfarm south-west of Lynemouth, Northumberland (see Fig. 1). The survey was carried out at sixteen different sites around the junction of the A1089 and A1068 where it is proposed to locate the turbines; each site covered an area of 1 hectare centred approximately on the proposed turbine position. Geographically the locations extended from Site 12 in the west (NZ 2650 9045) to Site 15 in the north (NZ 2820 9085) and from Site 8 in the east (NZ 2870 8995) to Site 16 in the south at NZ 2750 8935 (see Fig. 2).

1.2 Topographically the site was relatively flat at about 25 metres Above Ordnance Datum with a shallow valley for Haydon Letch roughly bisecting the site (see Fig. 2). Six turbine locations were to the west of the stream and ten to the east. The ground cover was a mixture of low growing brassicas, stubble and permanent pasture. No problems were encountered during the survey although snowfall during the survey allied with the clay soils resulted in the ground conditions being extremely heavy underfoot. The survey was carried out between March 7th and 17th 2006.

1.3 The drift geology across the site comprises boulder clay with the overlying soils being classified in the Foggathorpe 1 soil association. These soils are characterised as seasonally waterlogged clays and fine loams, often with no stones.

1.4 No information on the known archaeology either within the site boundaries or in the immediate vicinity was available at the time of survey. Fieldwalking was carried out immediately prior to the geophysical survey at four locations where the ground conditions were favourable. It is understood that no significant finds or clusters of finds have been recovered in the limited fieldwalking undertaken to date (Roberts pers. com).

2. Methodology and Presentation

2.1 The general aims of the survey were to obtain information that would contribute to an evaluation of the archaeological significance of the proposed scheme that would enable further evaluation and/or mitigation measures to be designed.

2.2 More specific aims were:-

- To determine the presence or absence of buried archaeological remains in the defined survey areas;
- To clarify the extent and layout of any remains;
- To provide information about the nature and possible interpretation of any geophysical anomalies identified by the survey.

These aims were to be achieved by undertaking detailed magnetometer survey in 1 hectare blocks centred on the proposed turbine location. At the two locations where the turbine is to be sited close to an existing boundary the survey area was moved so that the block no longer straddled the boundary whilst still encompassing the proposed turbine location.

2.3 Detailed survey employs the use of a sample trigger to automatically take readings at predetermined points, typically at 0.25m intervals, on traverses 1m apart. These readings are stored in the memory of the instrument and are later downloaded to computer for processing and interpretation. Further details are given in Appendix 1. Detailed survey allows the visualisation of weaker anomalies that may not be identifiable by cruder evaluation techniques such as magnetic scanning or magnetic susceptibility survey.

2.4 A Bartington Grad601 magnetic gradiometer was used during the survey with readings being taken at 0.25m intervals on zig-zag traverses 1m apart within 20m by 20m grids. The readings were stored in the memory of the instrument and later downloaded to computer for processing and interpretation using Geoplot 3 software.

2.5 The survey methodology, report and any recommendations comply with guidelines outlined by English Heritage (David 1995) and by the IFA (Gaffney, Gater and Ovenden 2002). All figures reproduced from Ordnance Survey mapping are done so with the permission of the controller of Her Majesty's Stationery Office. © Crown copyright.

2.6 A general site location plan, incorporating the 1:50000 Ordnance Survey mapping, is shown in Figure 1. Figure 2 shows the processed magnetometer data superimposed onto a digital map base at a scale of 1:10000. The processed (greyscale) and unprocessed (XY trace plot) data, together with accompanying interpretation diagrams, are presented in Figures 3 to 50 inclusive at a scale of 1:1000.

2.7 More detailed technical information on the equipment used, data processing and magnetic survey methodology is given in Appendix 1. Appendix 2 details the survey location information and Appendix 3 describes the composition and location of the site archive.

The figures in this report have been produced following analysis of the data in 'raw' and processed formats and over a range of different display levels. All figures are presented to most suitably display and interpret the data from this site based on the experience and knowledge of Archaeological Services staff.

3. Results and Discussion

3.1 No anomalies of probable archaeological origin were identified in any of the survey areas. However, numerous magnetic anomalies have been identified and these fall into four main categories described below.

Dipolar, isolated anomalies and areas of magnetic disturbance

3.2 Numerous isolated dipolar anomalies ('iron spikes' - see Appendix 1) have been identified across all parts of the site. These anomalies are indicative of ferrous objects or other magnetic material in the topsoil/subsoil and, although archaeological artefacts may cause them, they are more often caused by modern cultural debris that has been introduced into the topsoil often as a consequence of manuring. In this case there is no obvious clustering and consequently the anomalies are not considered to be archaeologically significant.

3.3 More extensive areas of magnetic (ferrous) disturbance have also been identified in several locations, particularly in Sites 10 and 11. This disturbance is probably caused by modern dumped ferrous material. At Site 11 the disturbance is at the junction of two former field boundaries and may be due to material imported to infill a boggy gateway.

Positive Linear Anomalies and Linear Trends

3.4 Former, infilled, field boundaries (see Fig. 2) are the cause of linear anomalies identified in Sites 1, 3, 4 and 11. In Site 3 the parallel linear anomalies are indicative of ditches either side of a trackway that is shown on the first edition Ordnance Survey map heading in a south-easterly direction from the former bridge over Haydon Letch (see Fig. 2). This track terminates at the intersection with the next field boundary to the south-east which has also been identified as a linear anomaly in Site 1 to the north. The parallel linear trend anomalies identified in Sites 1 and 4 aligned from north-east to south-west and in Site 3 from north-west to south-east are indicative of ridge and furrow ploughing. The anomalies are caused by the magnetic contrast between the infilled furrows and the former ridges. In Site 4 there is no evidence for the continuation of ploughing to the south-west of the trackway/boundary.

3.5 Linear trends in the data can also be seen at Sites 2, 10, 12, 14 and 15. It is thought that the linearity of these anomalies is more likely to be indicative of modern ploughing or land drains rather than ridge and furrow ploughing.

3.6 The parallel linear anomalies in Site 13 are also considered to have a modern origin relating to the inspection cover that is the cause of the magnetic disturbance at the south-western end of the linear anomalies.

Areas of Magnetic Enhancement/Variable Magnetic Background

3.7 Areas where the magnetic background is elevated above the normal prevailing background has resulted in a random pattern of discrete, positive anomalies causing the grey tone plot to have a mottled appearance. This effect is particularly noticeable in Sites 7, 9 and 16 but is noted to a lesser extent in all the other survey areas, particularly at the northern end of Site 8. The erratic, essentially random, nature of these anomalies probably points to a geological rather than an archaeological origin. These anomalies are thought to be due to concentrations of igneous and metamorphic rocks present in the boulder clay. The more broad areas of variation are probably also natural in origin being due to larger scale variation in the composition of the boulder clay and/or to changes in the depth and composition of the bedrock.

4. Conclusions

4.1 No anomalies thought to be indicative of archaeological activity have been identified at any of the sixteen proposed wind turbine locations and therefore, on the basis of the geophysical survey the archaeological potential of the areas surveyed is considered to be low.

4.2 However, the effects of compositional variation in the boulder clay and topsoil has been revealed and linear anomalies locating 19th century field boundaries and indicating the former practice of ridge and furrow ploughing have also been identified.

The results and subsequent interpretation of data from geophysical surveys should not be treated as an absolute representation of the underlying archaeological and non-archaeological remains. Confirmation of the presence or absence of archaeological remains can only be achieved by direct investigation of sub-surface deposits.

Bibliography

David, A., 1995. *Geophysical Survey in Archaeological Field Evaluation: Research and Professional Services Guidelines* No. 1. English Heritage

Gaffney, C., Gater, J. and Ovenden, S. 2002. *The Use of Geophysical Techniques in Archaeological Evaluations*. IFA Technical Paper No. 6

Acknowledgements

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Fieldwork

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E. Heapy BSc

A. Walsh BSc

Report

A. Webb

Graphics

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Figures

Appendices

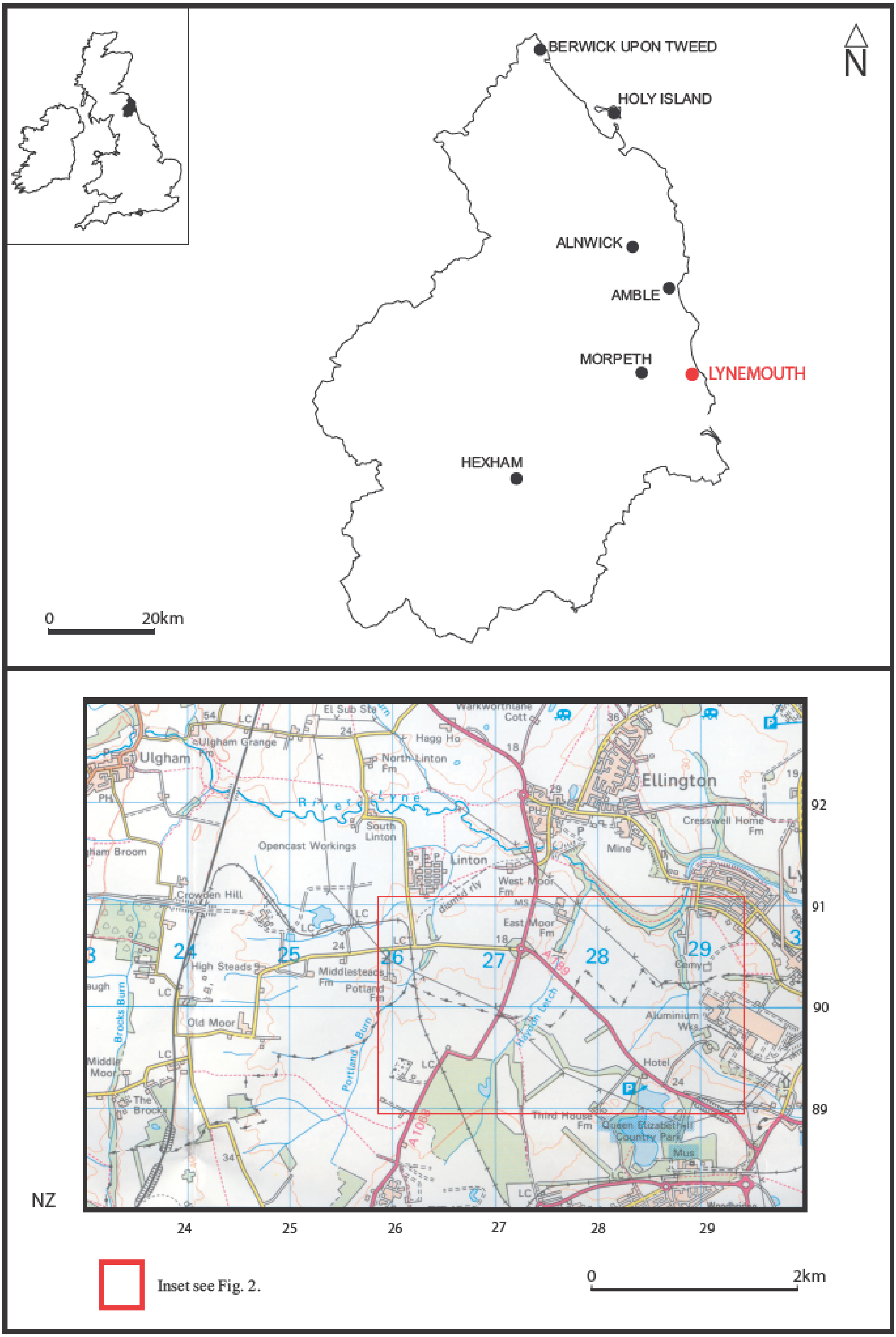

Fig. 1. Site location

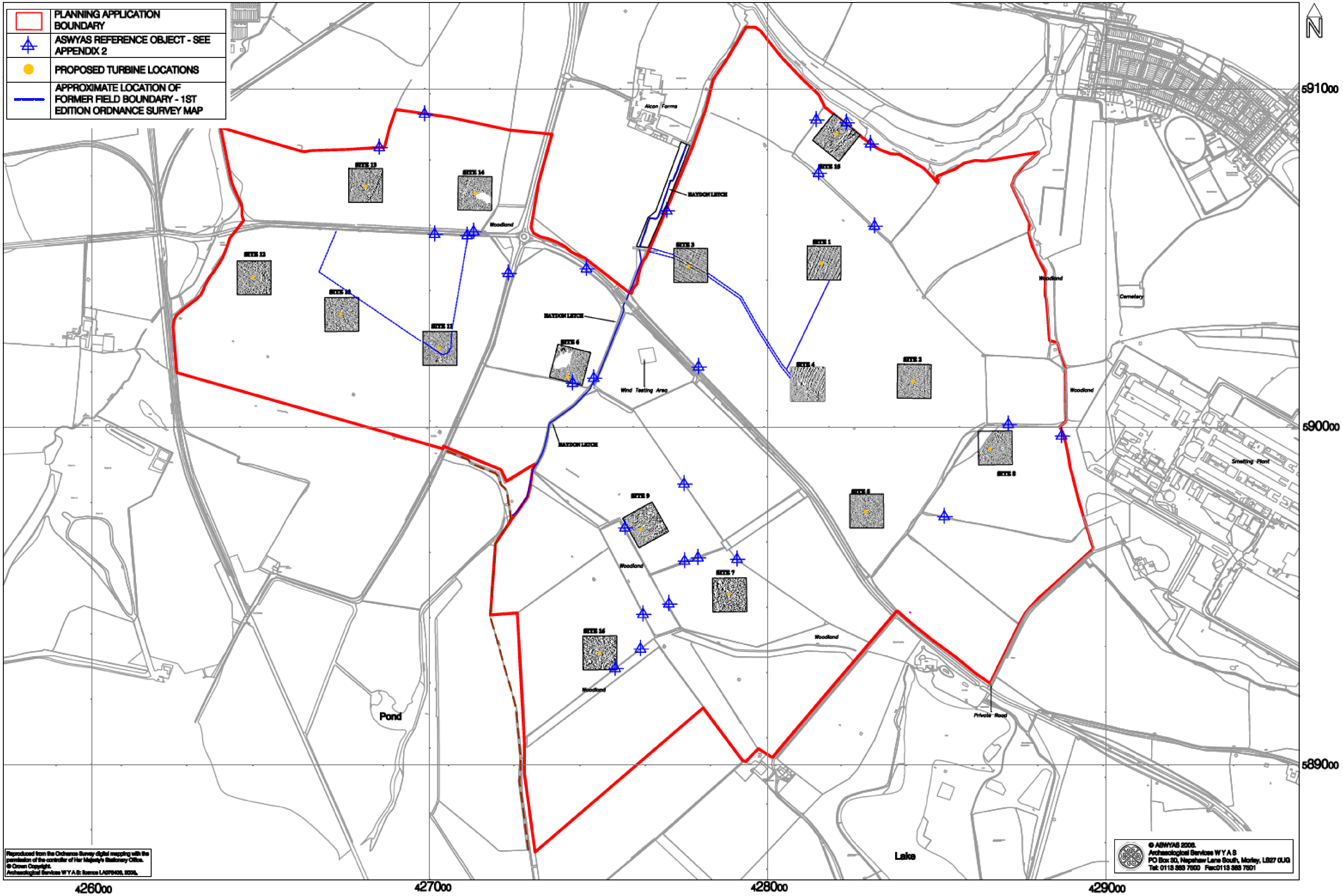

Fig. 2. Site location showing greyscale magnetometer data (1:10000 @ A3)

0 400m

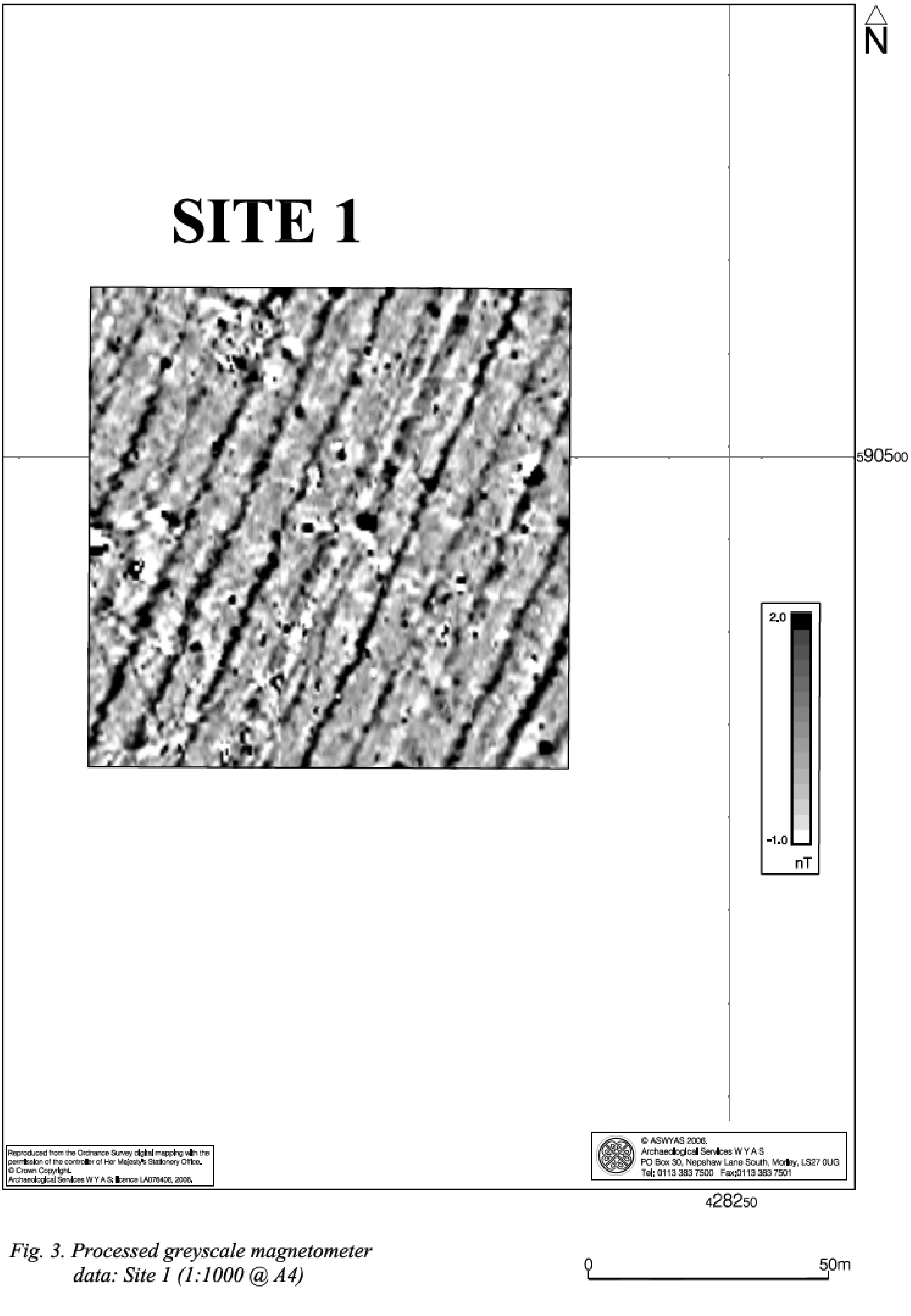

Fig. 3. Processed greyscale magnetometer data: Site 1 (1:1000 @ A4)

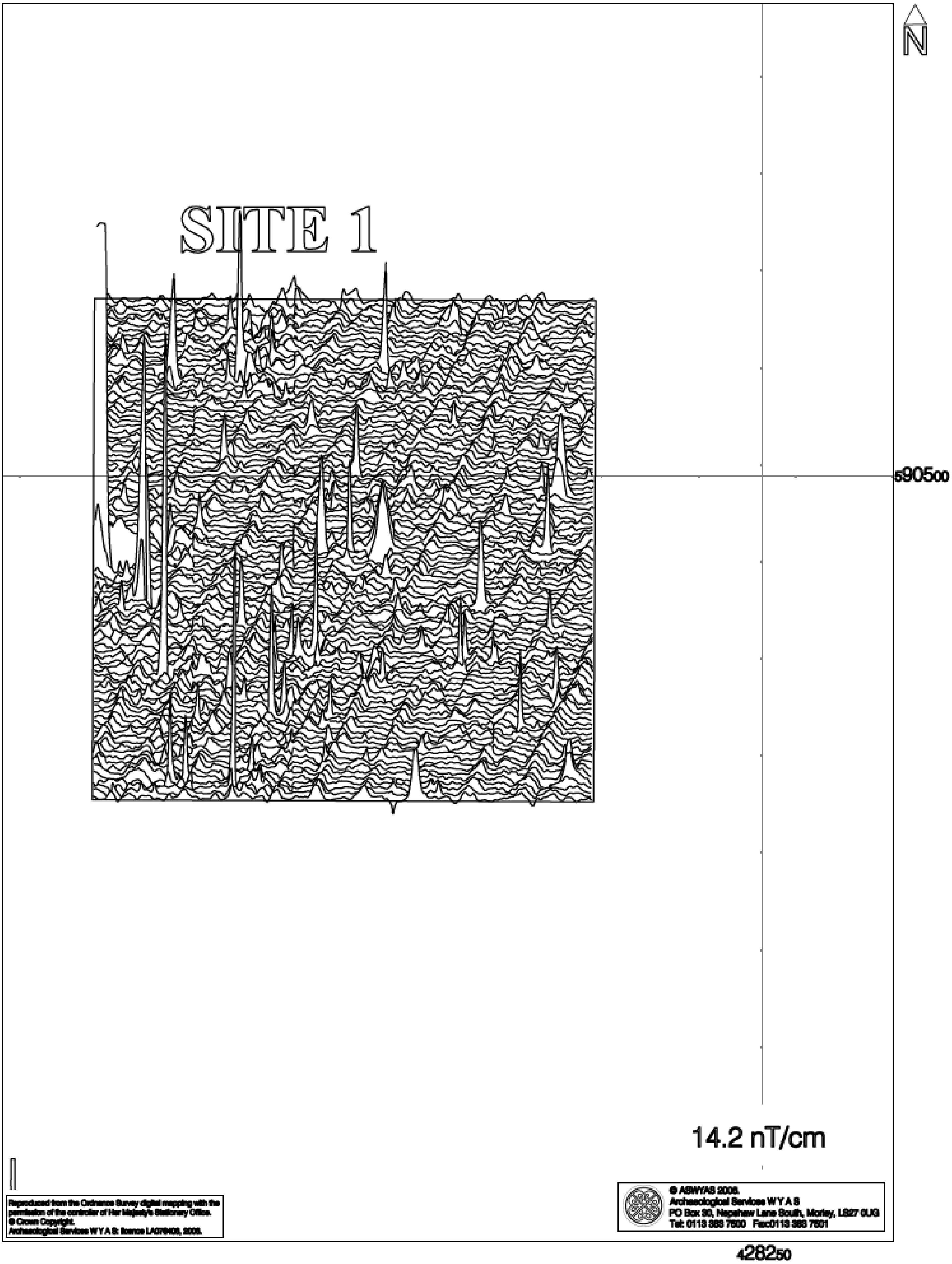

Fig. 4. XY trace plot of raw magnetometer data: Site 1 (1:1000 @ A4)

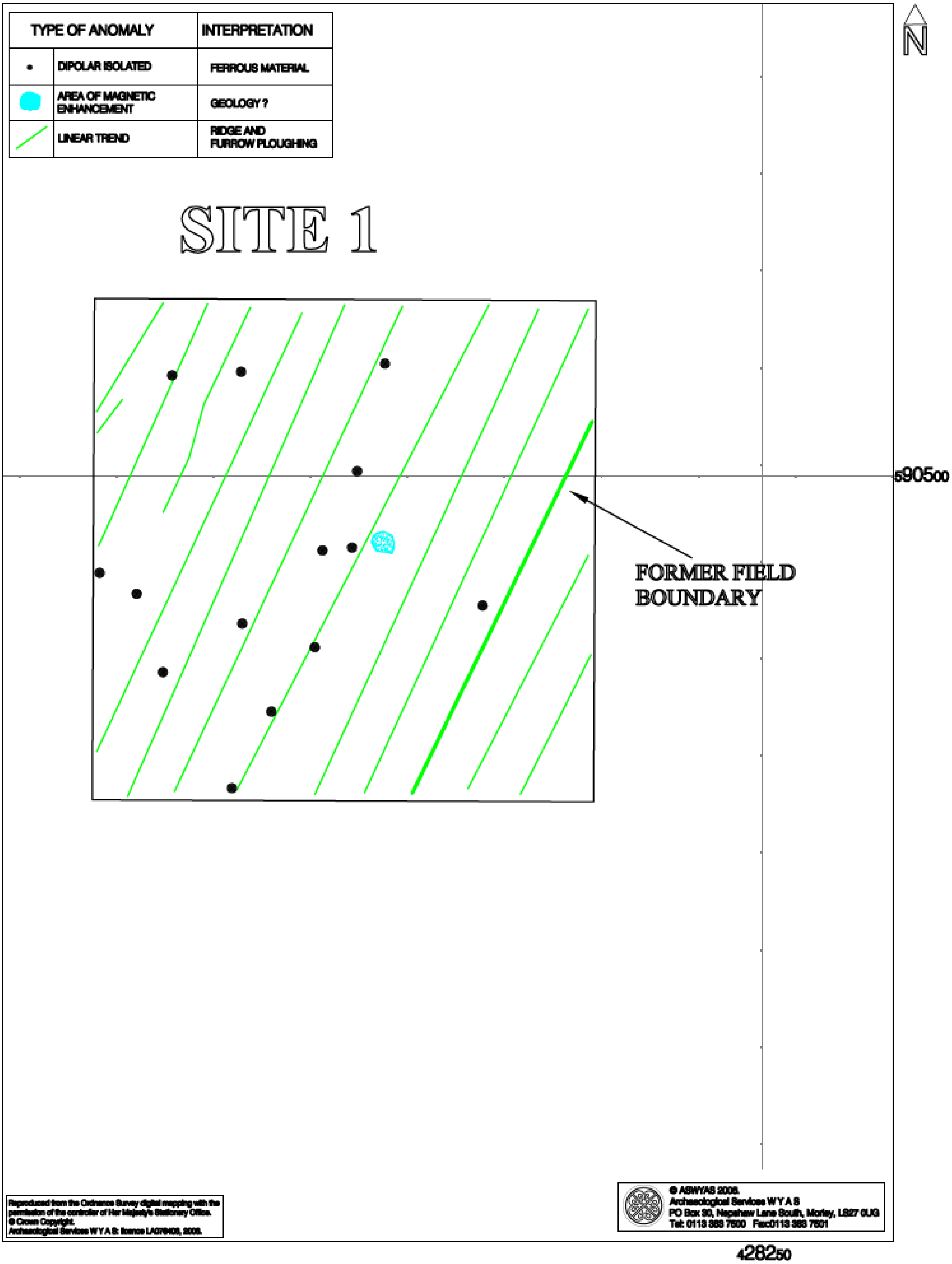

Fig. 5. Interpretation of magnetometer data: Site 1 (1:1000 @ A4)

0 50m

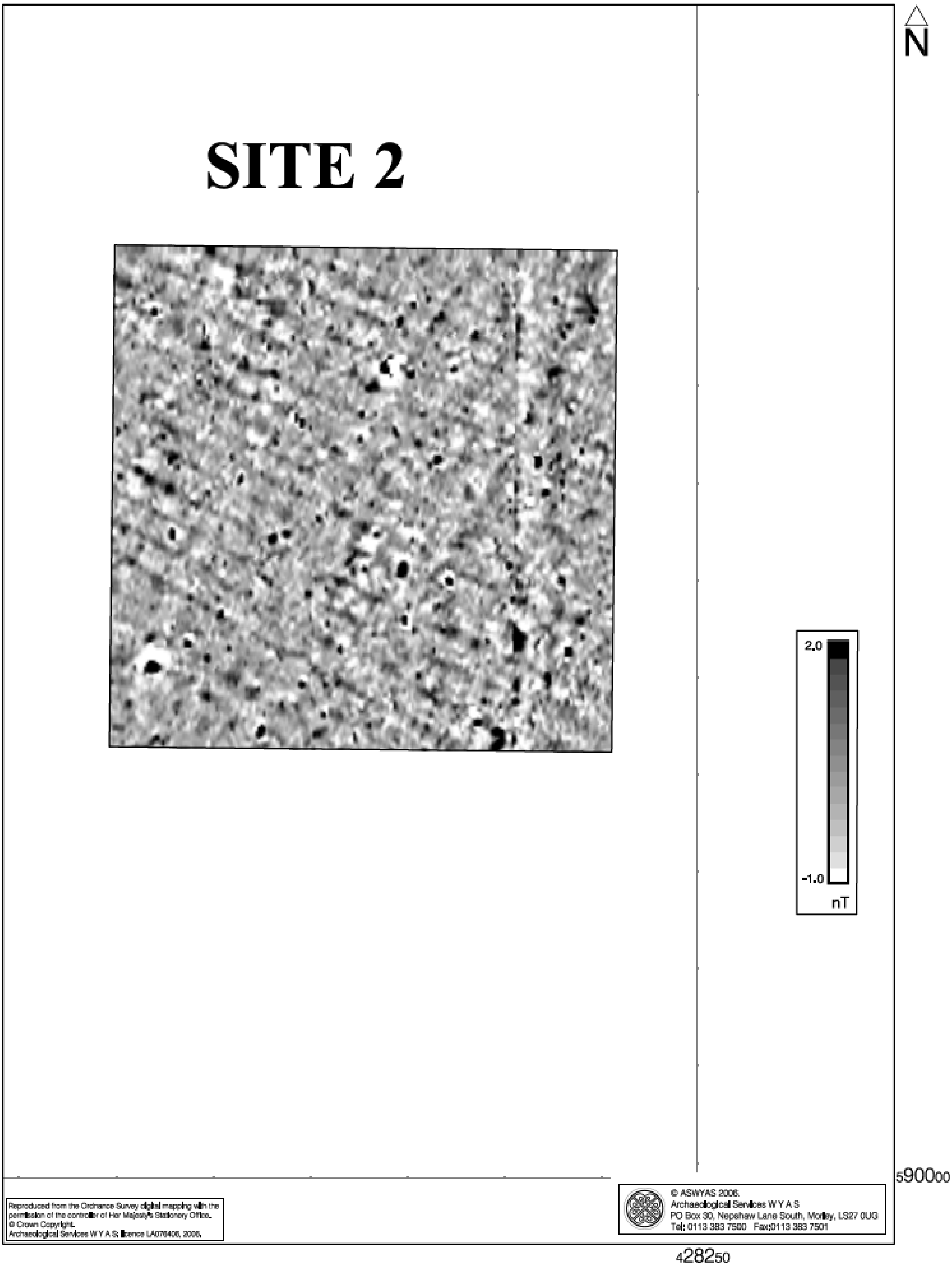

Fig. 6. Processed greyscale magnetometer data: Site 2 (1:1000 @ A4)

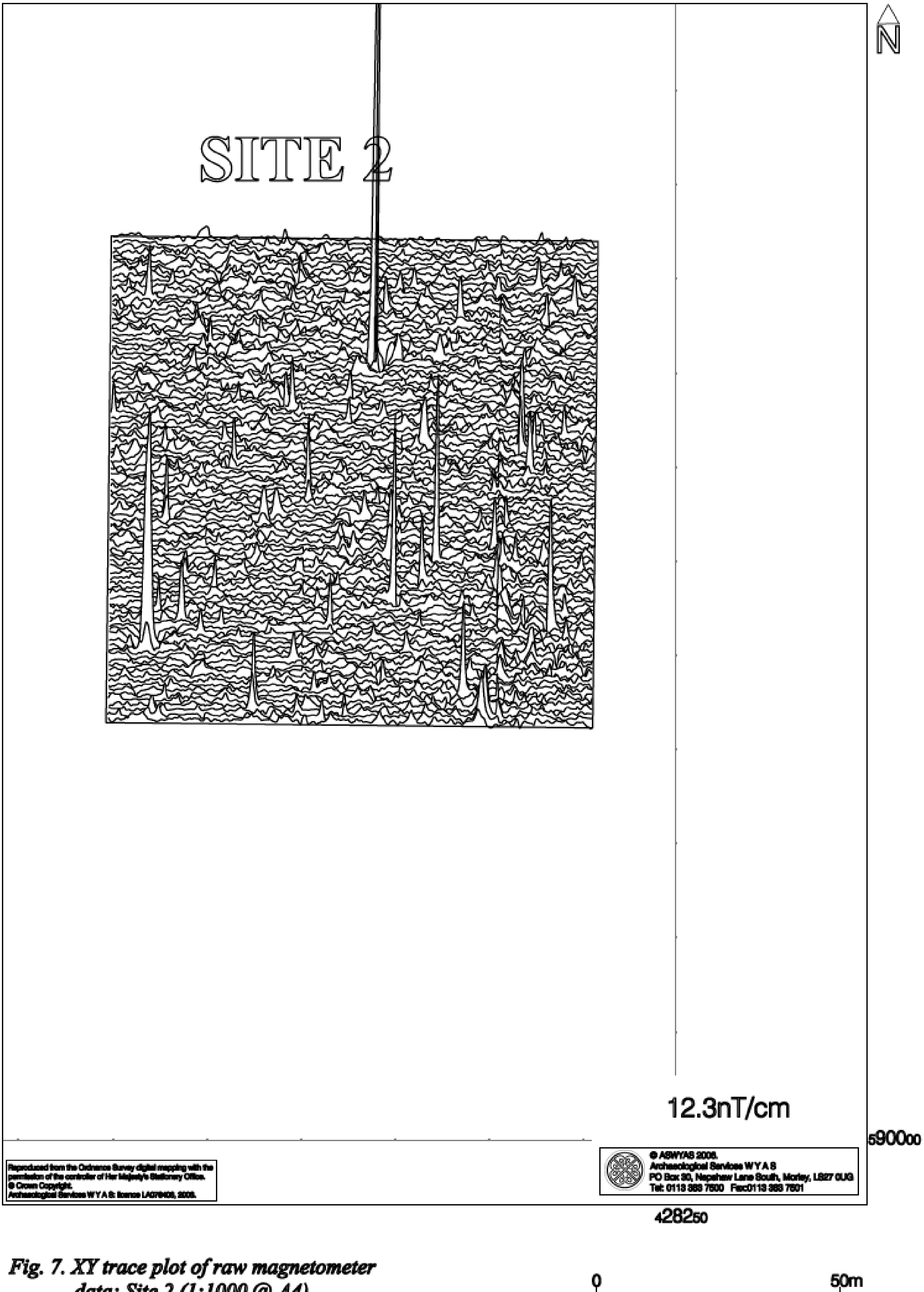

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Fig. 7. XY trace plot of raw magnetometer data: Site 2 (1:1000 @ A4)

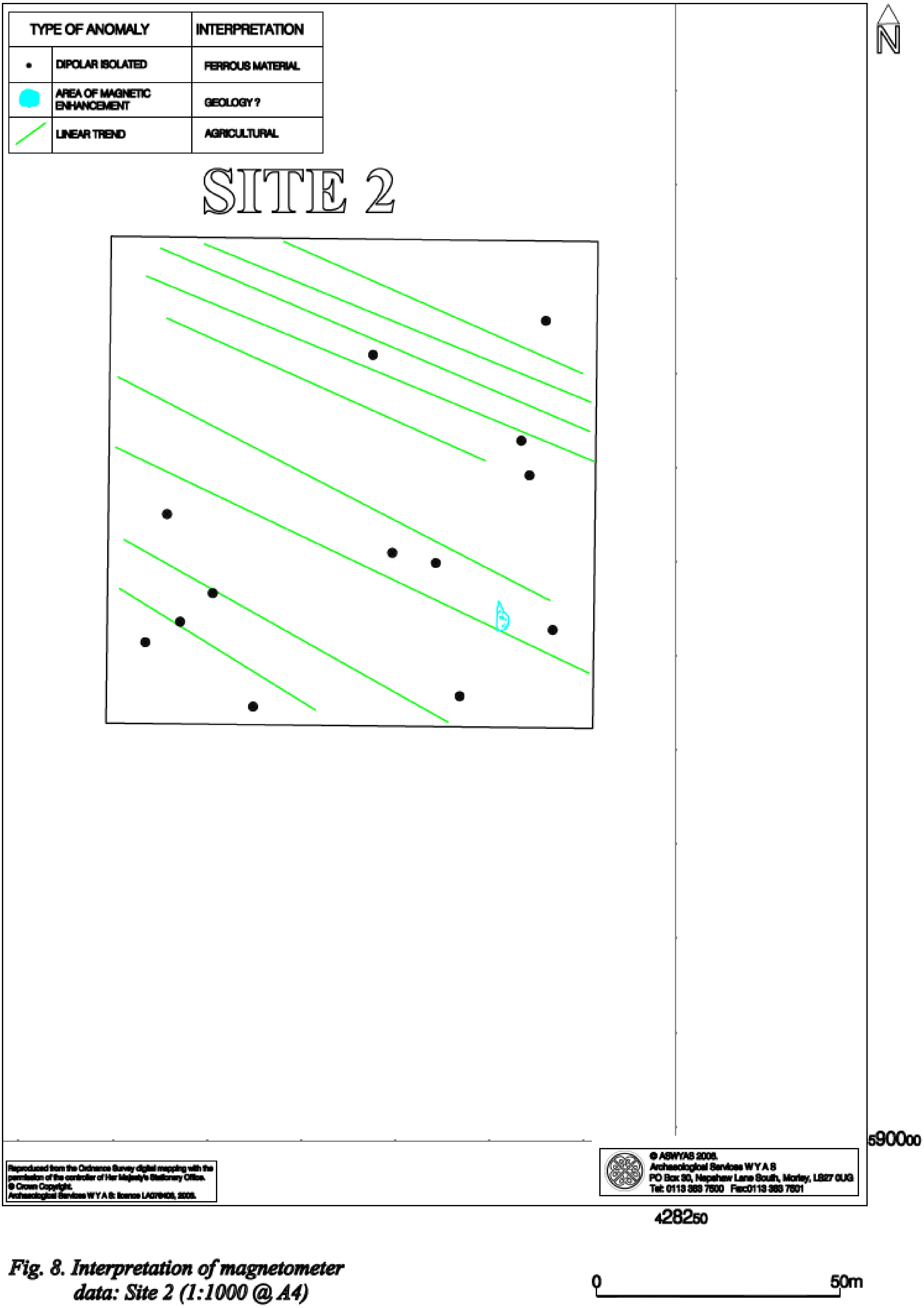

Fig. 8. Interpretation of magnetometer data: Site 2 (1:1000 @ A4)

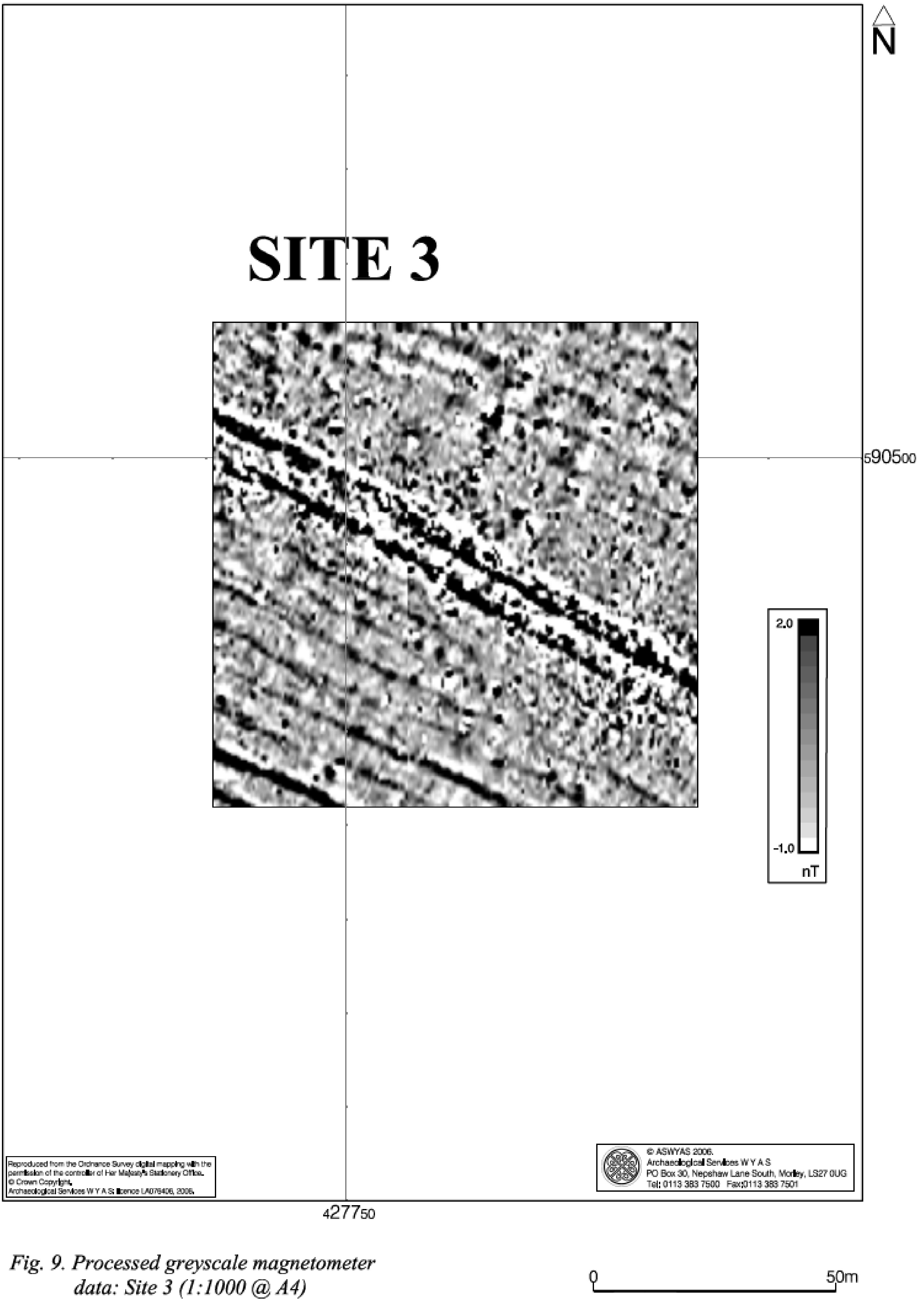

Fig. 9. Processed greyscale magnetometer data: Site 3 (1:1000 @ A4)

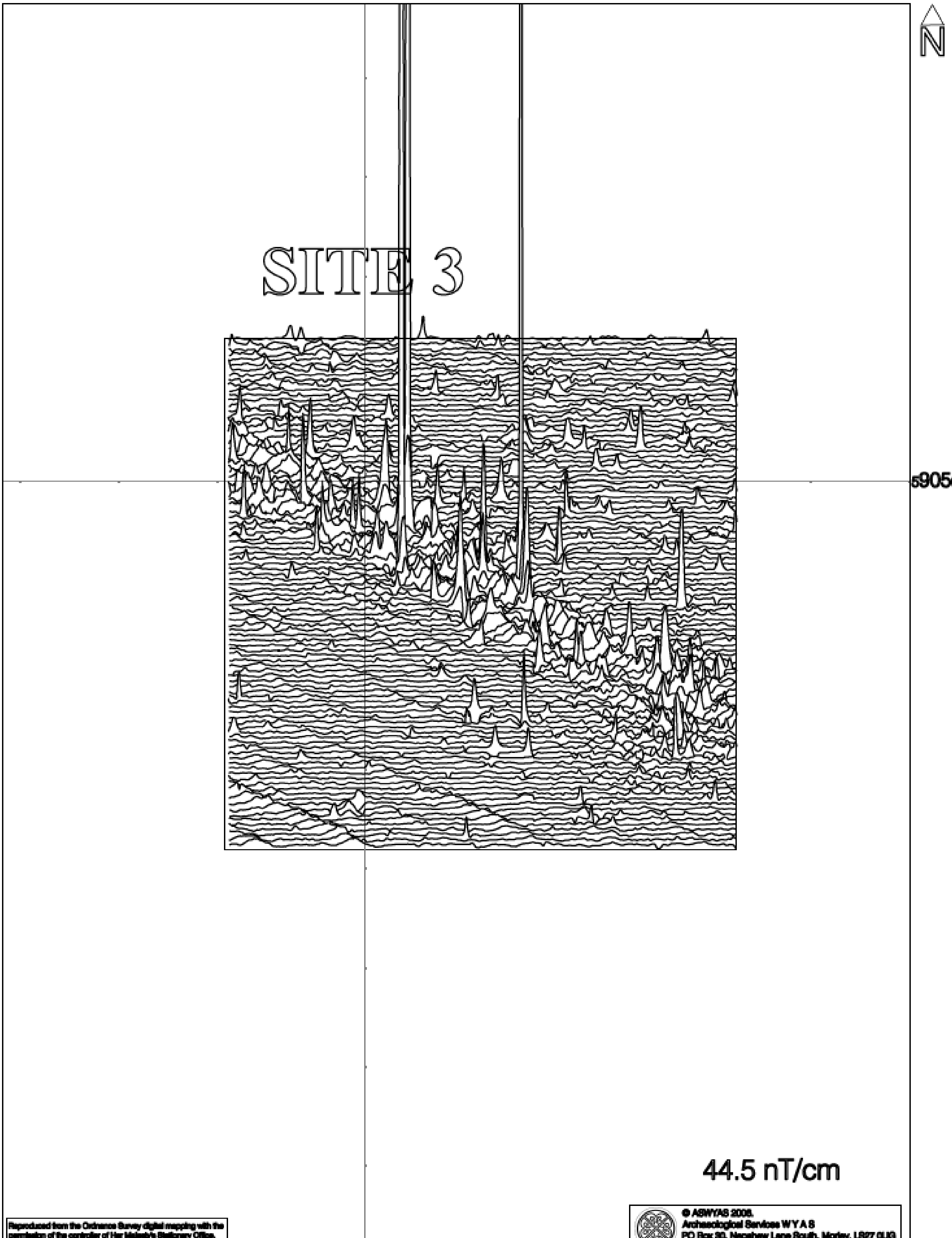

Fig. 10. XY trace plot of raw magnetometer data: Site 3 (1:1000 @ A4)

0 50m

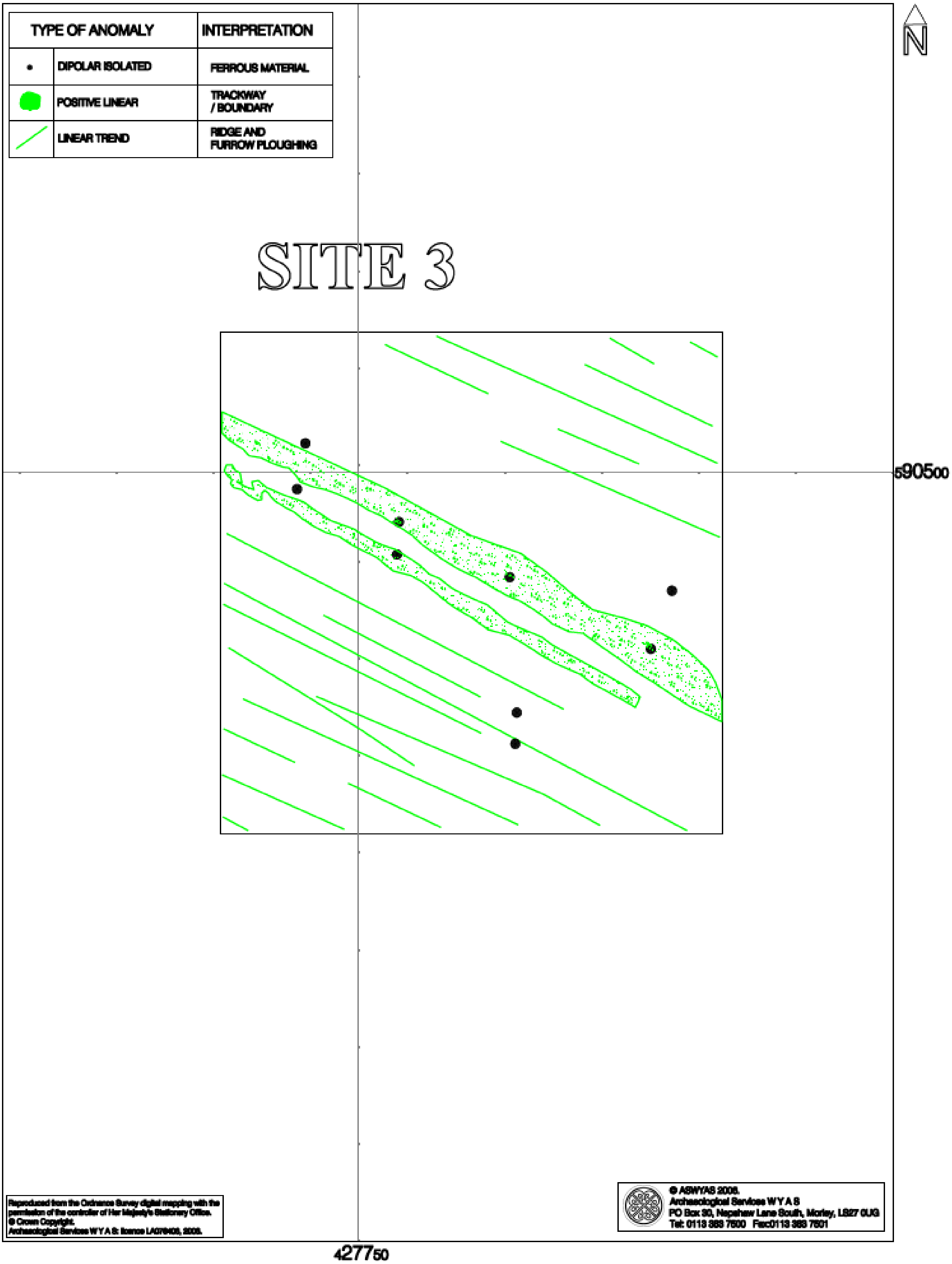

Fig. 11. Interpretation of magnetometer data: Site 3 (1:1000 @ A4)

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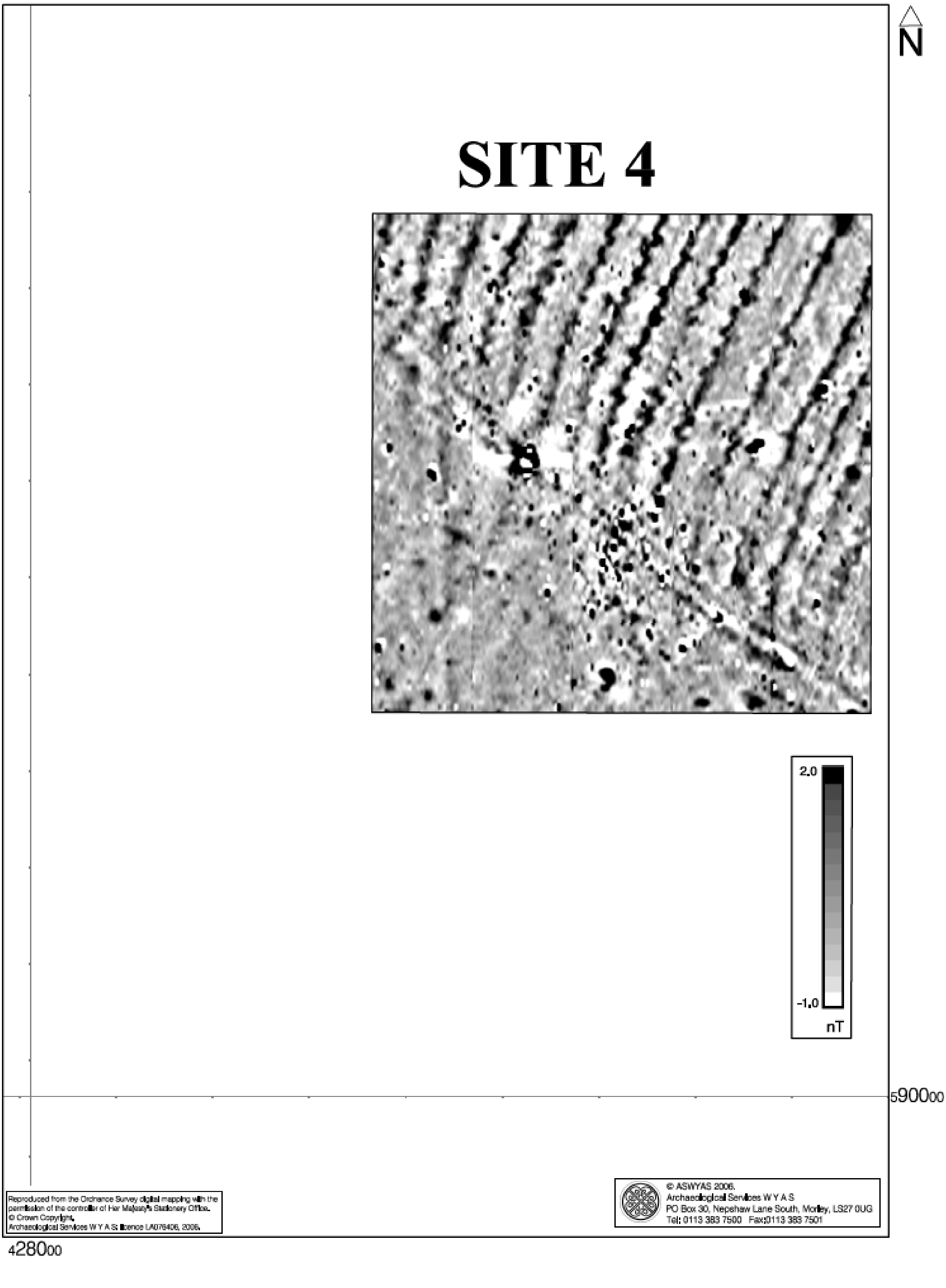

Fig. 12. Processed greyscale magnetometer data: Site 4 (1:1000 @ A4)

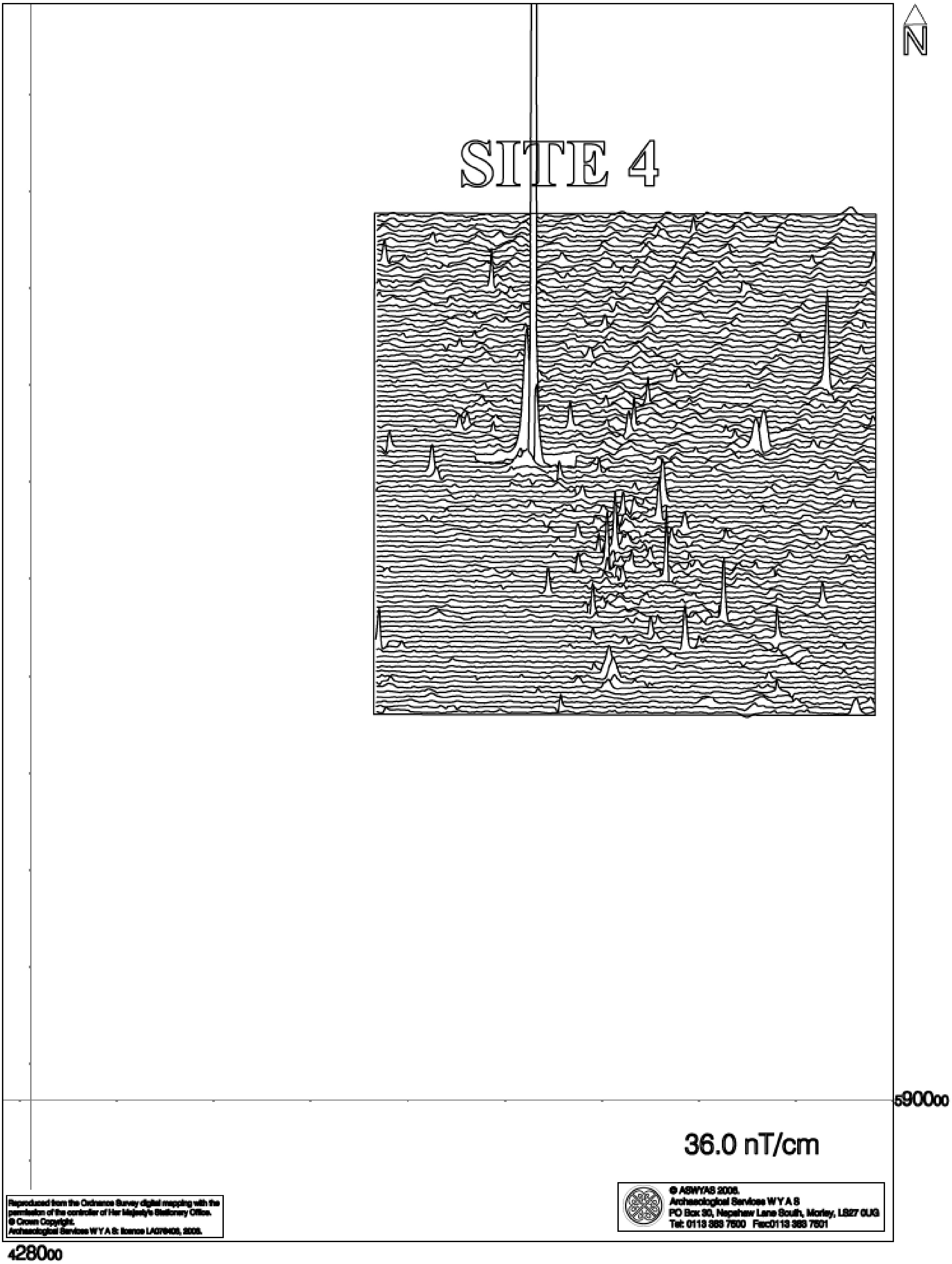

Fig. 13. XY trace plot of raw magnetometer data: Site 4 (1:1000 @ A4)

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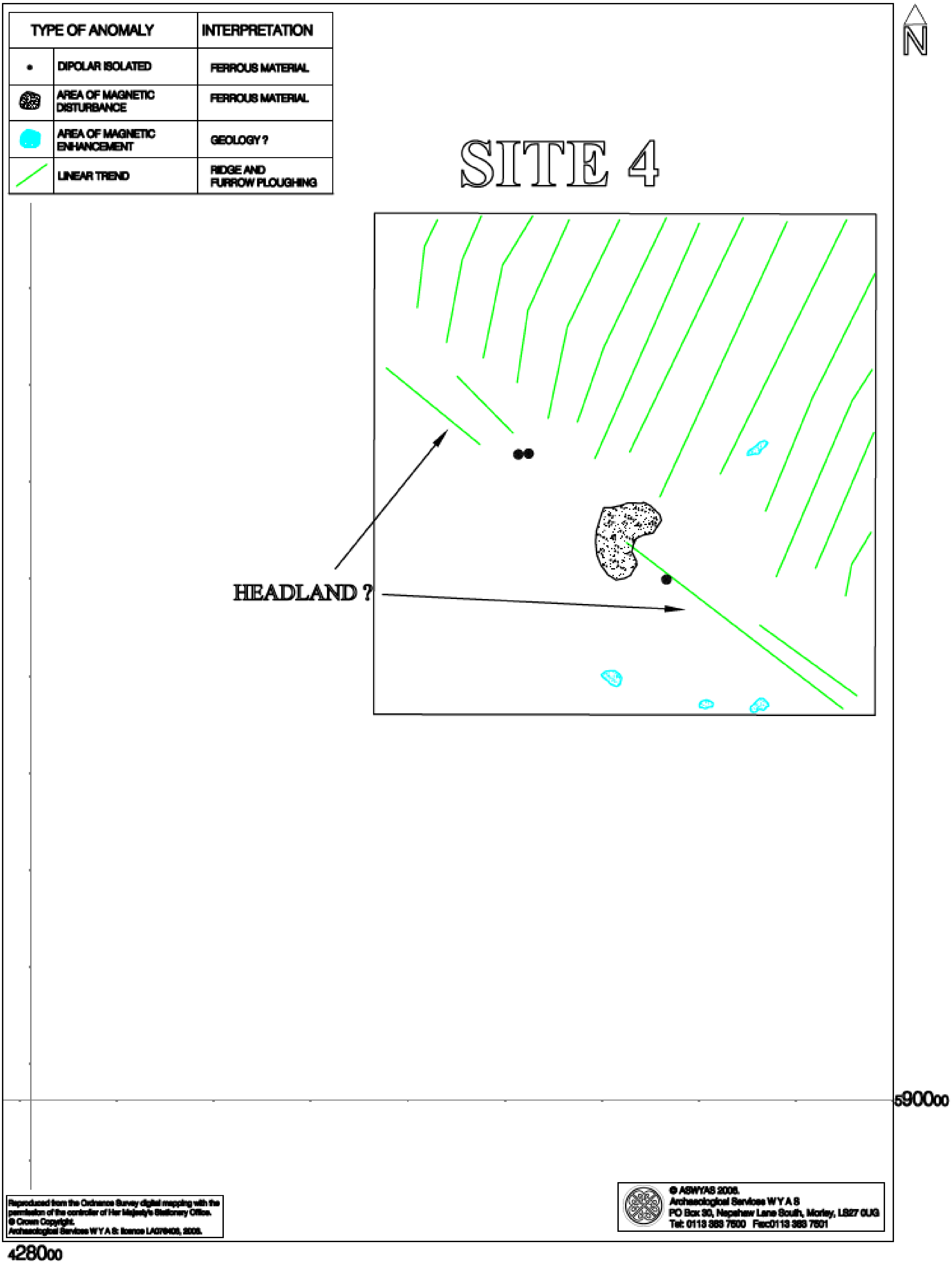

Fig. 14. Interpretation of magnetometer data: Site 4 (1:1000 @ A4)

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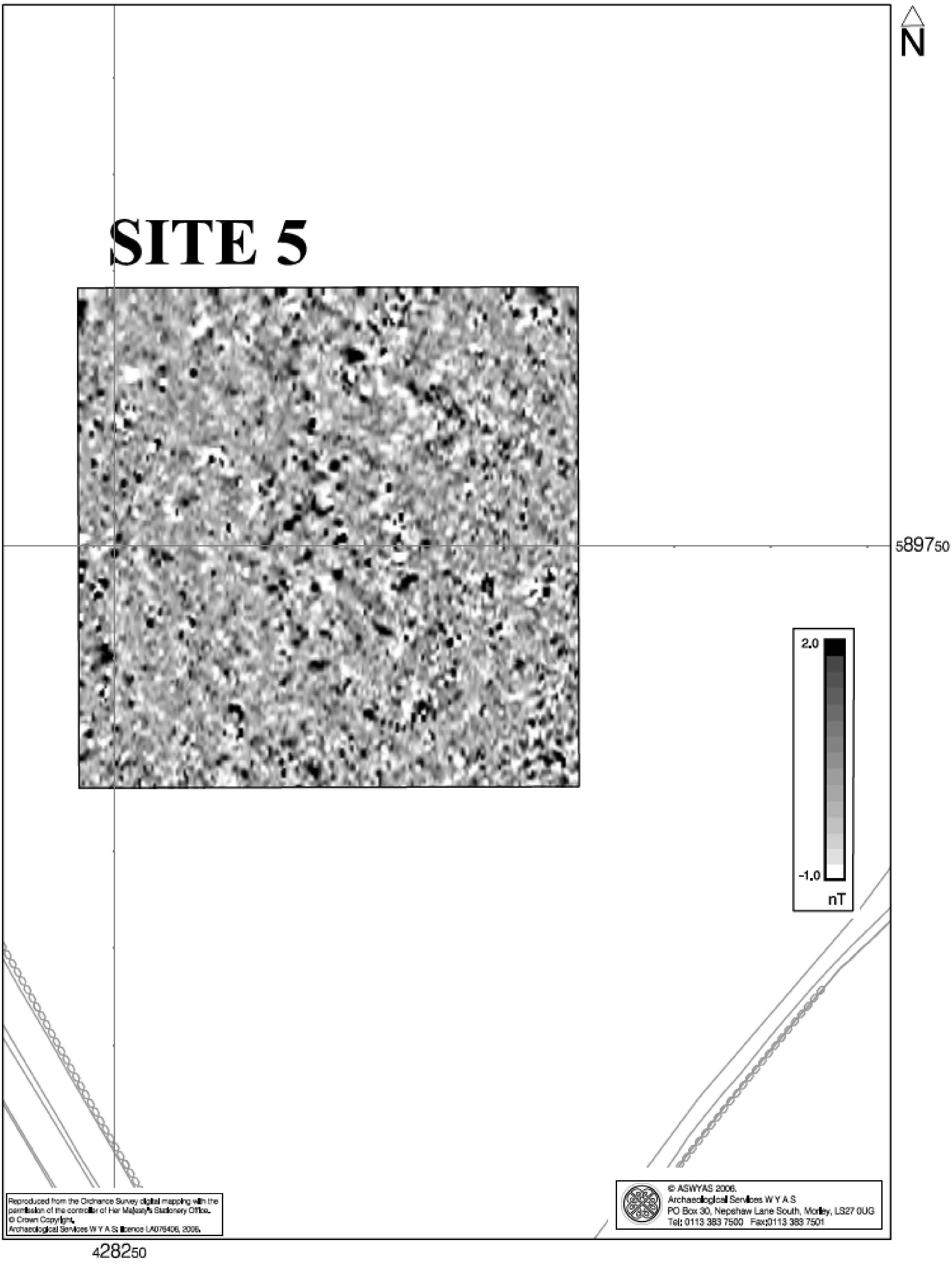

Fig. 15. Processed greyscale magnetometer data: Site 5 (1:1000 @ A4)

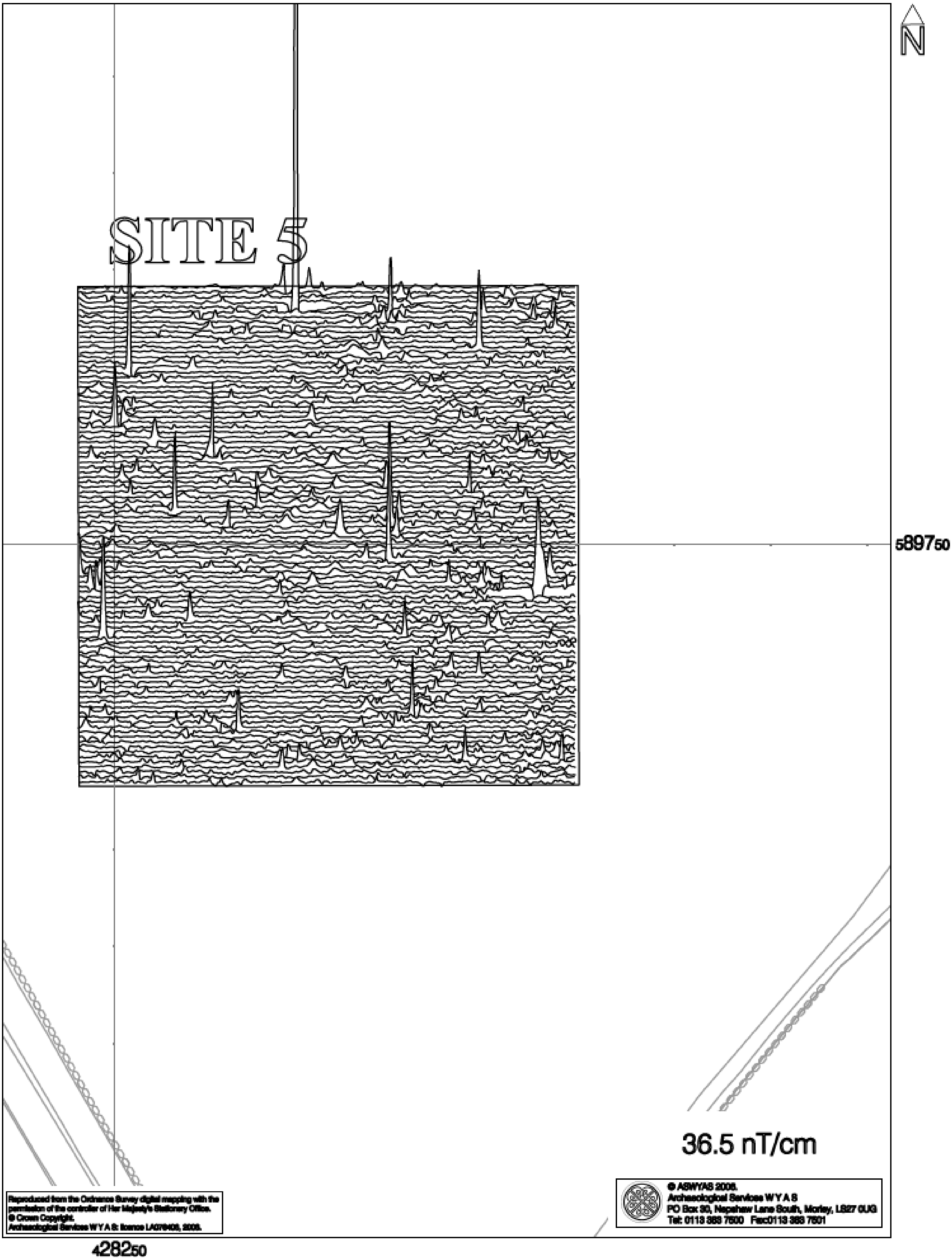

Fig. 16. XY trace plot of raw magnetometer data: Site 5 (1:1000 @ A4)

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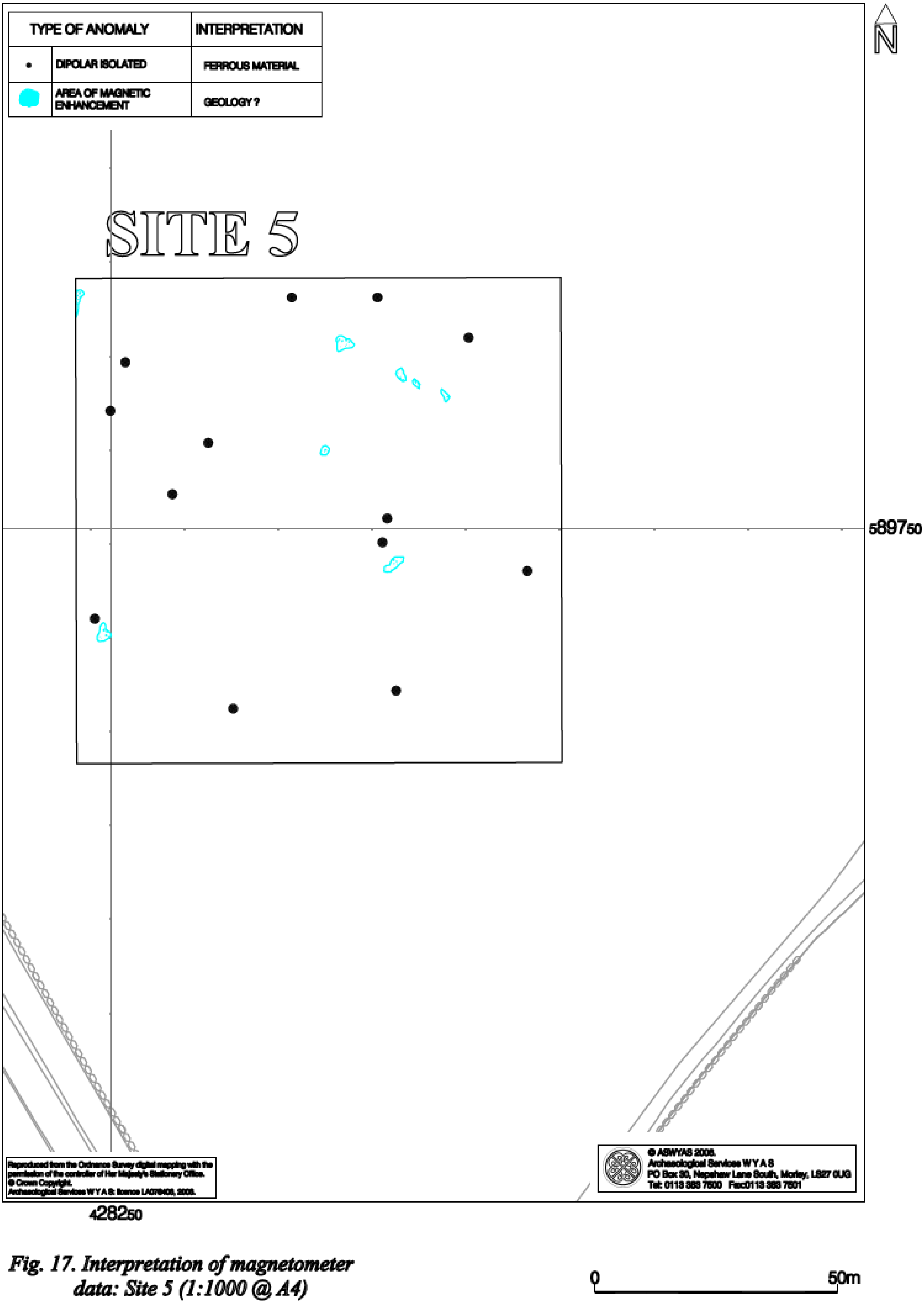
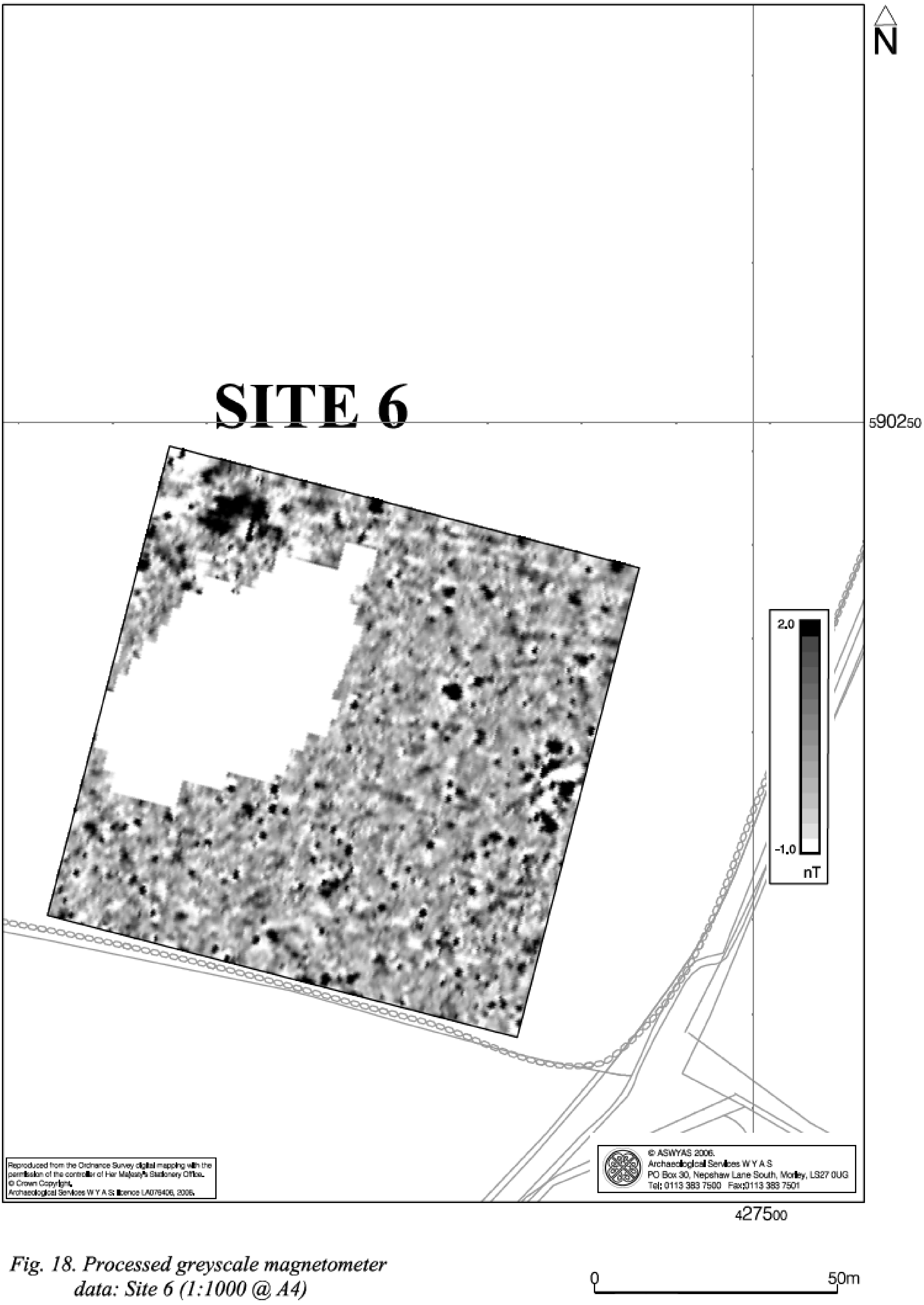


Fig. 17. Interpretation of magnetometer data: Site 5 (1:1000 @ A4)



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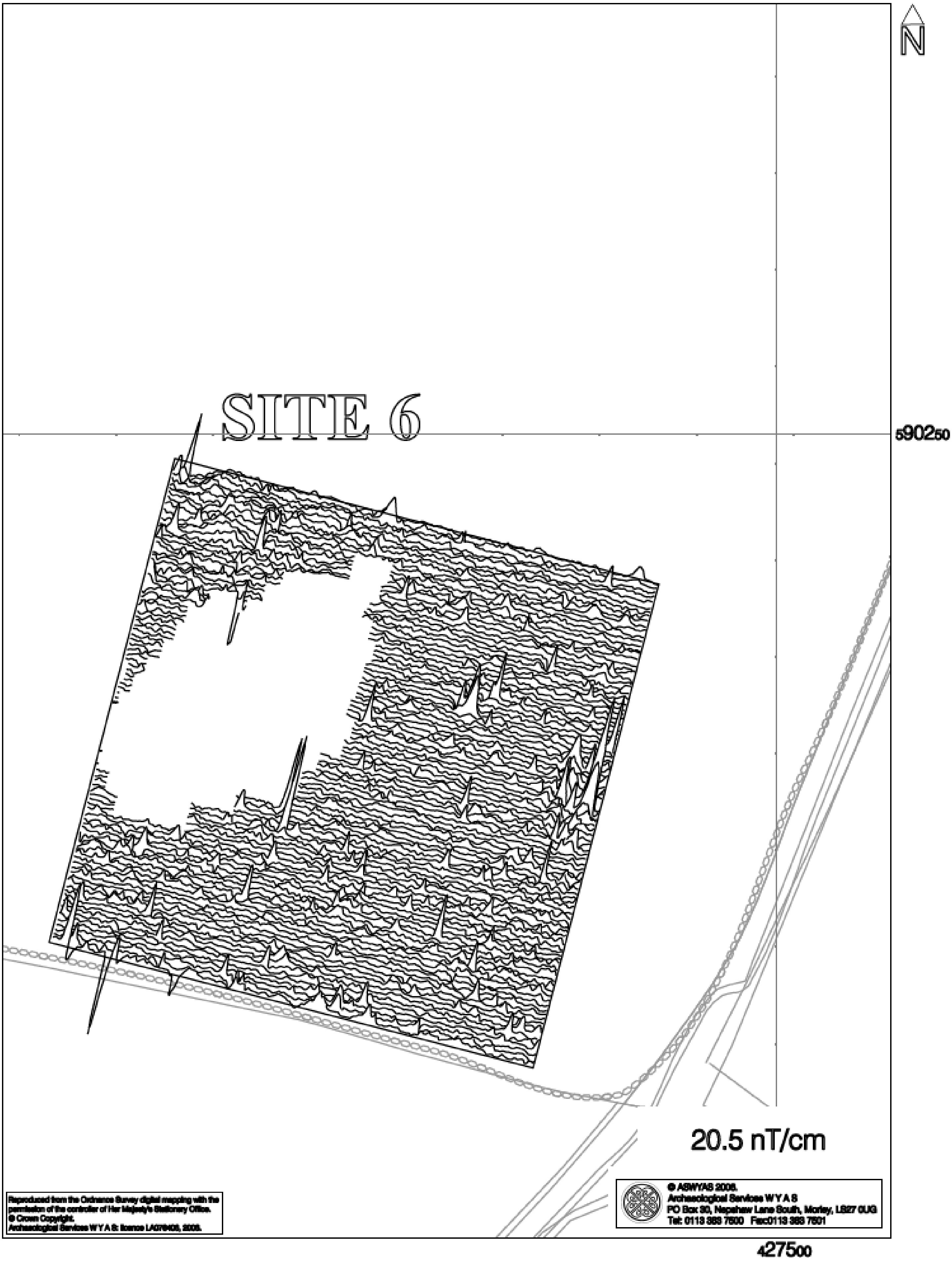

Fig. 19. XY trace plot of raw magnetometer data: Site 6 (1:1000 @ A4)

Fig. 20. Interpretation of magnetometer data: Site 6 (1:1000 @ A4)

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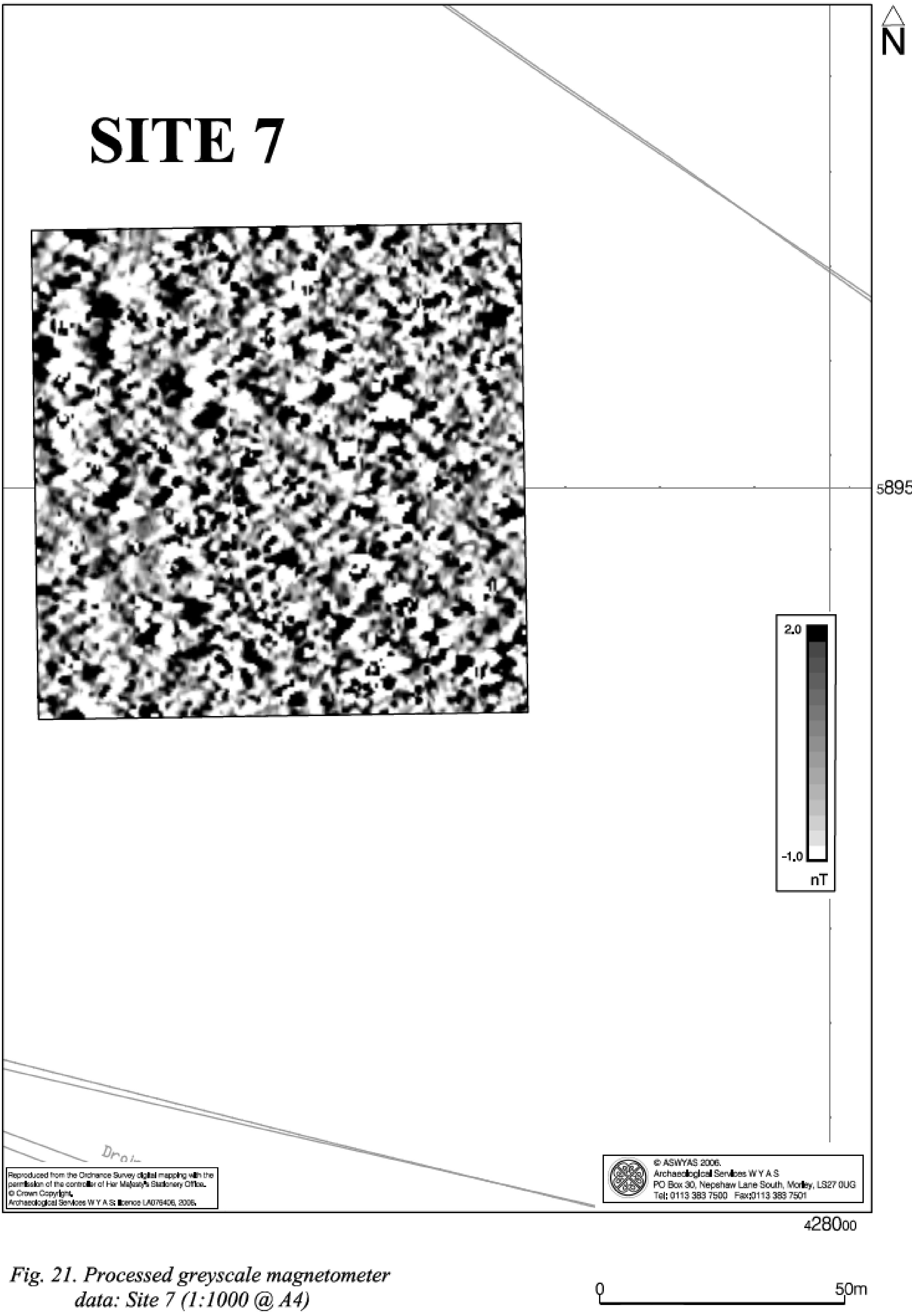

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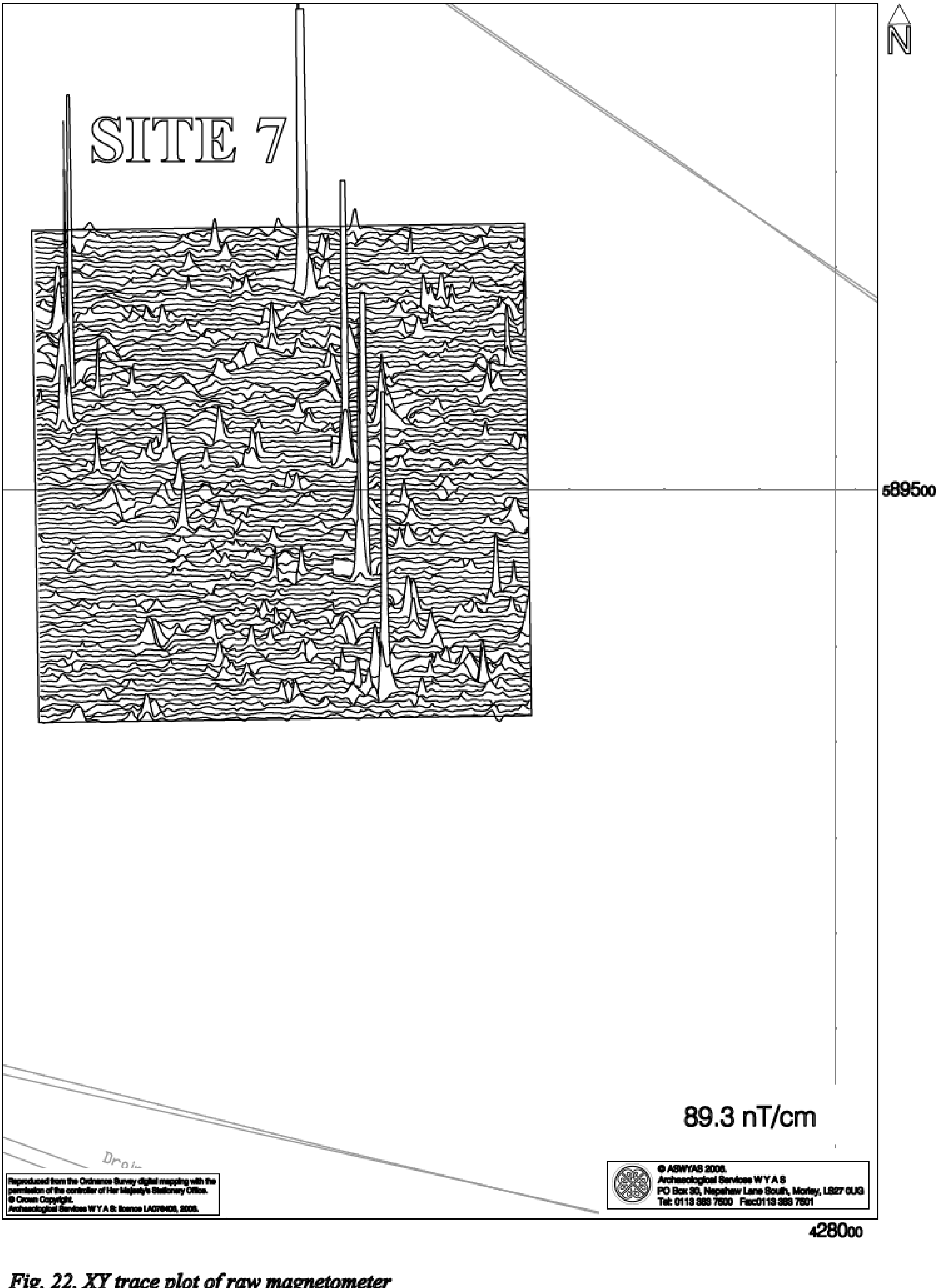

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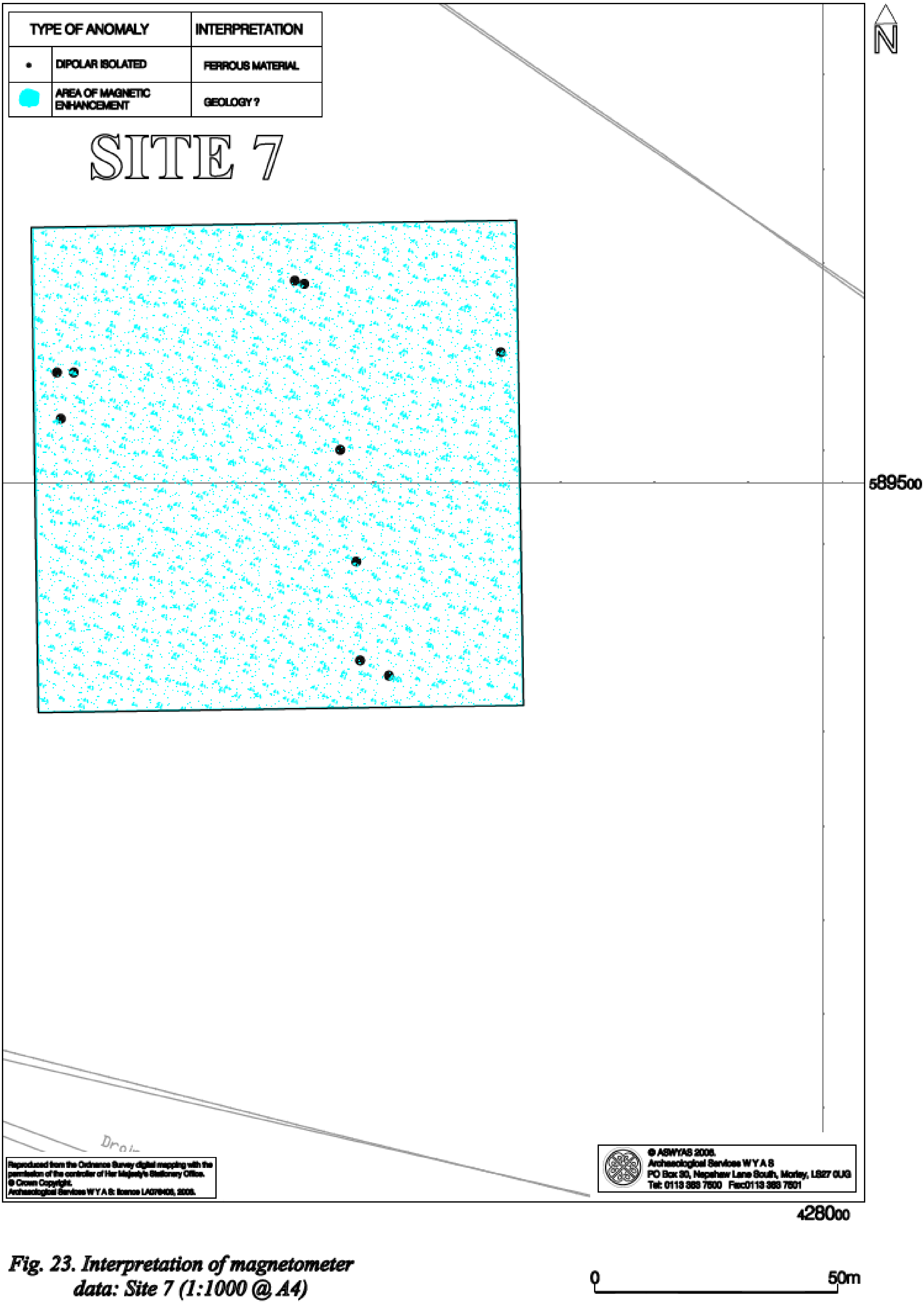

Fig. 23. Interpretation of magnetometer data: Site 7 (1:1000 @ A4)

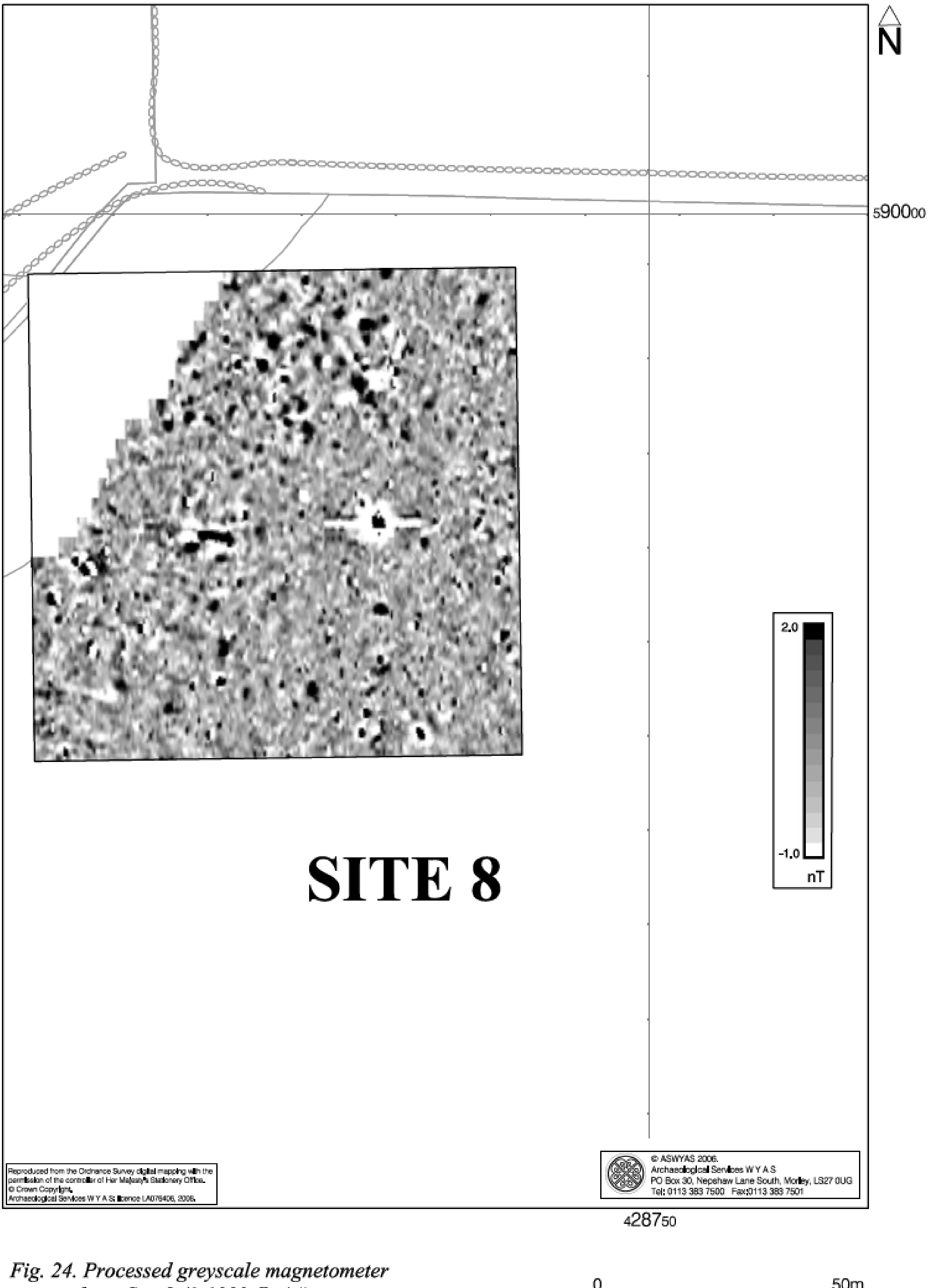

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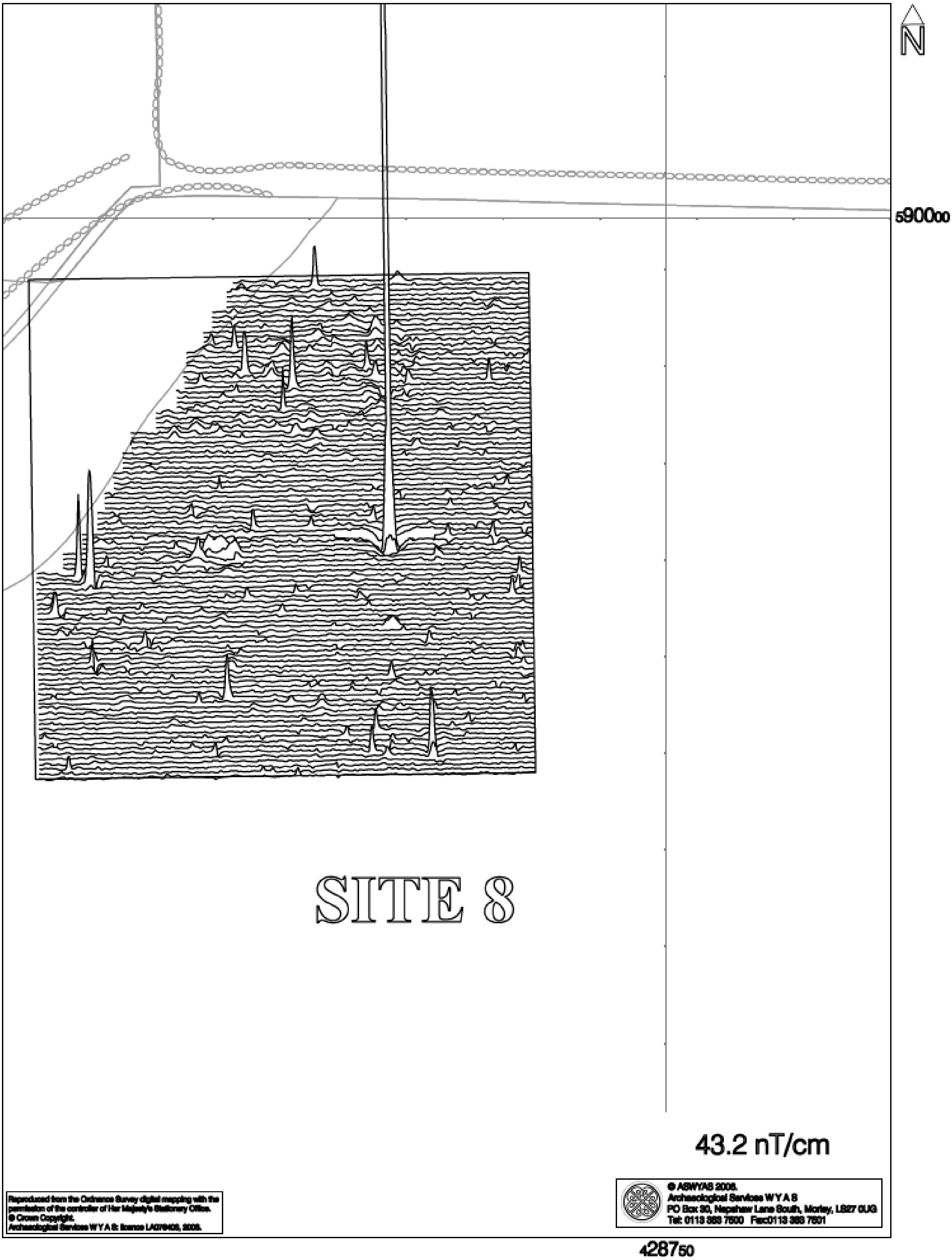
Fig. 24. Processed greyscale magnetometer data: Site 8 (1:1000 @ A4)



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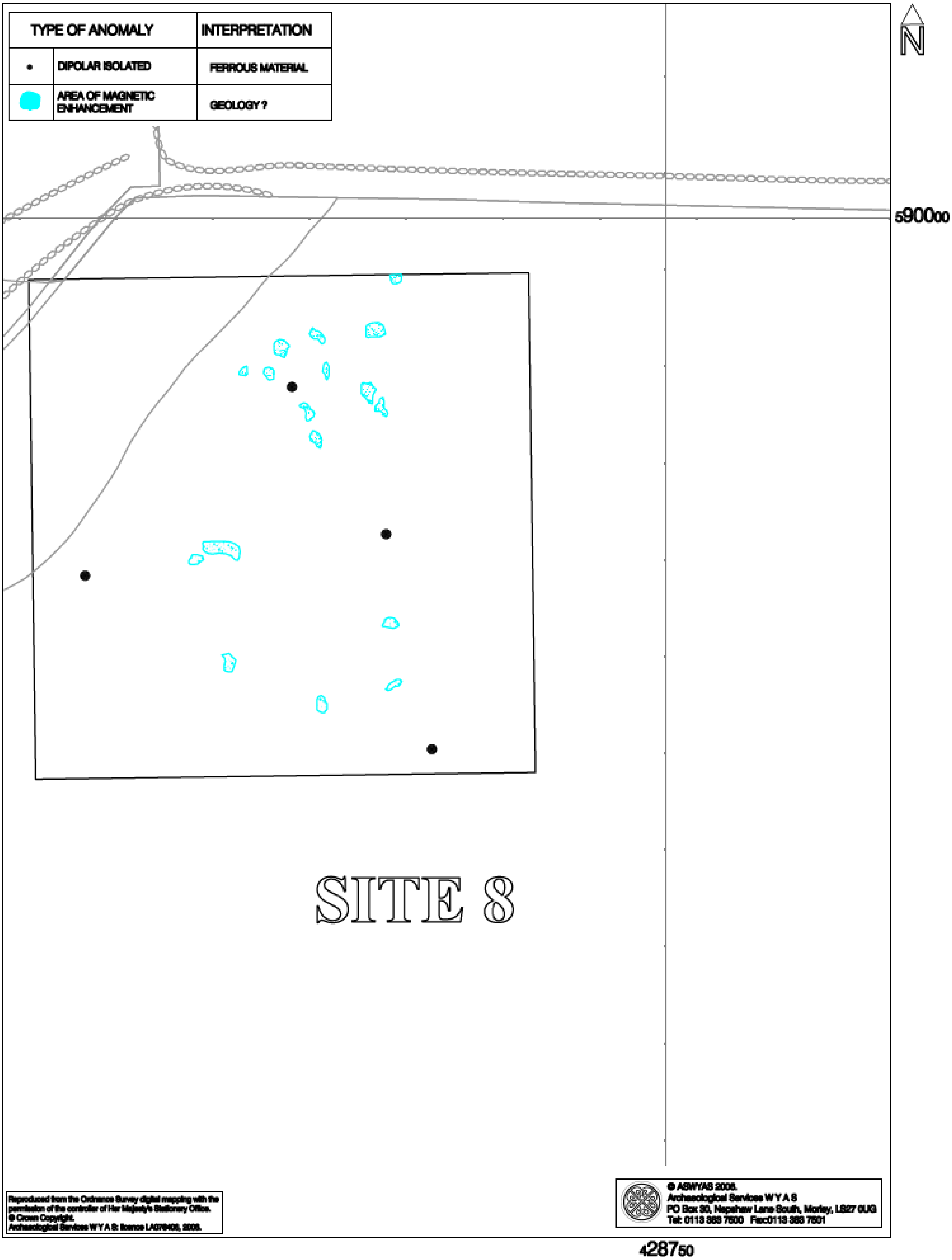

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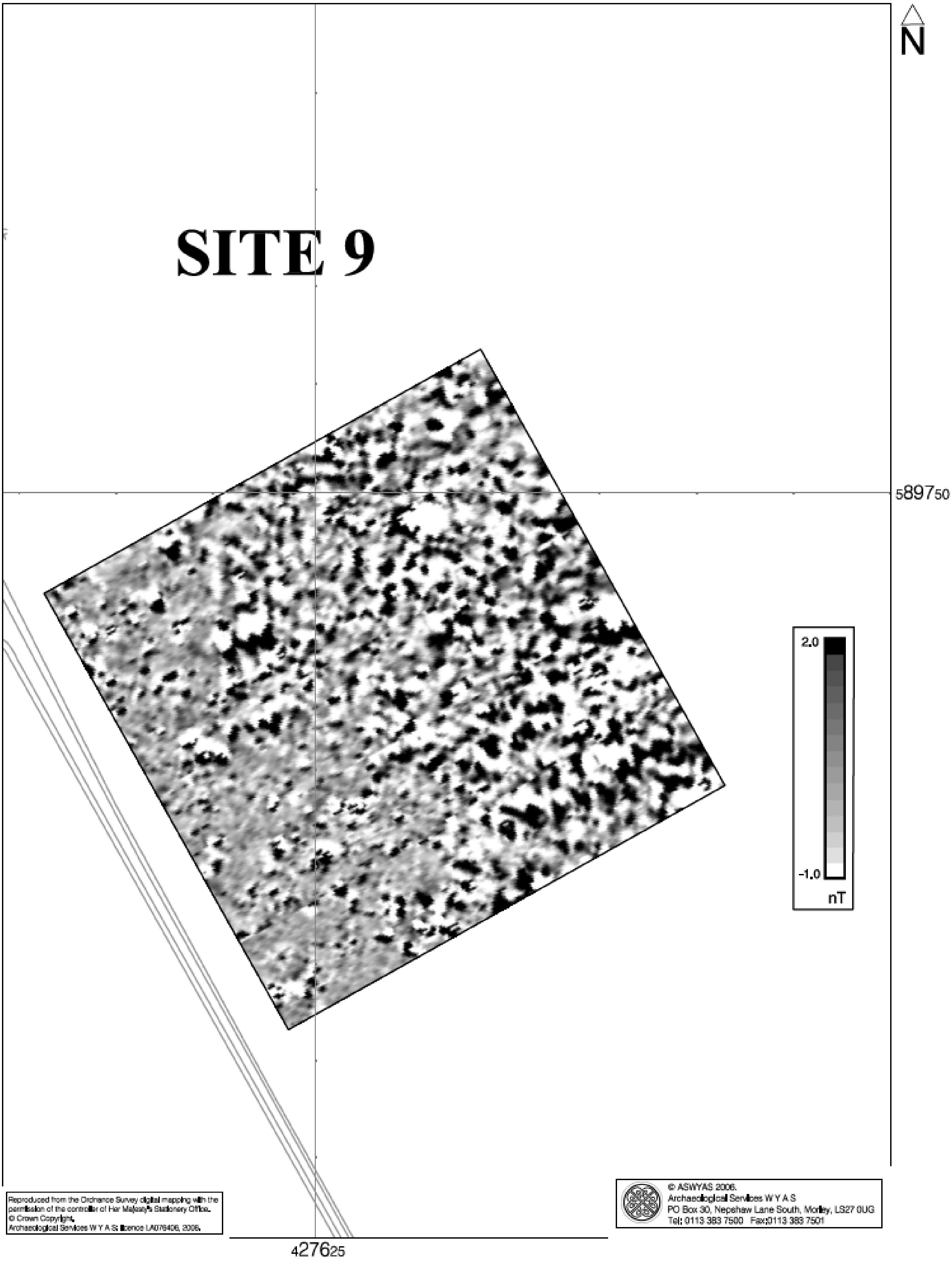

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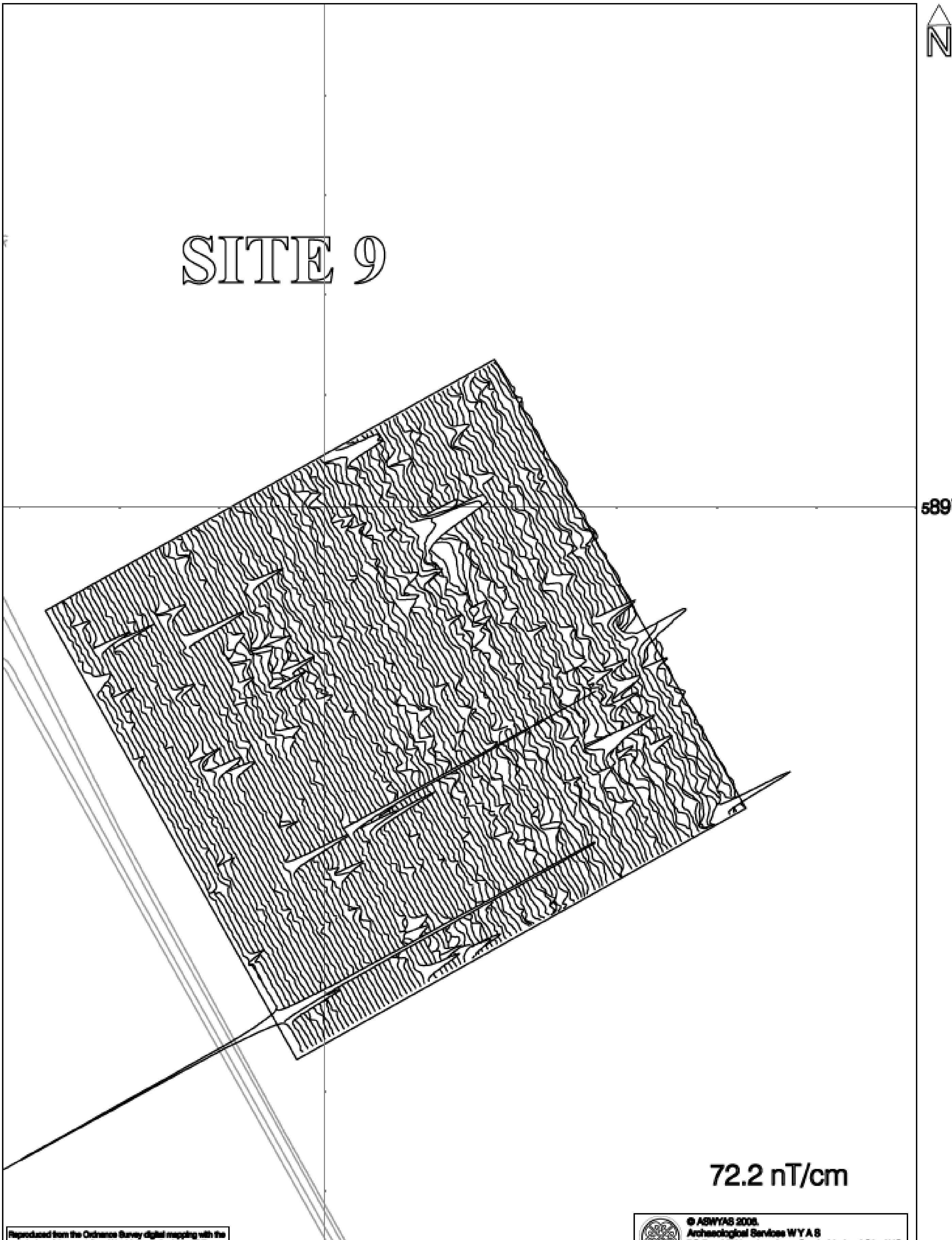
Fig. 27. Processed greyscale magnetometer data: Site 9 (1:1000 @ A4)



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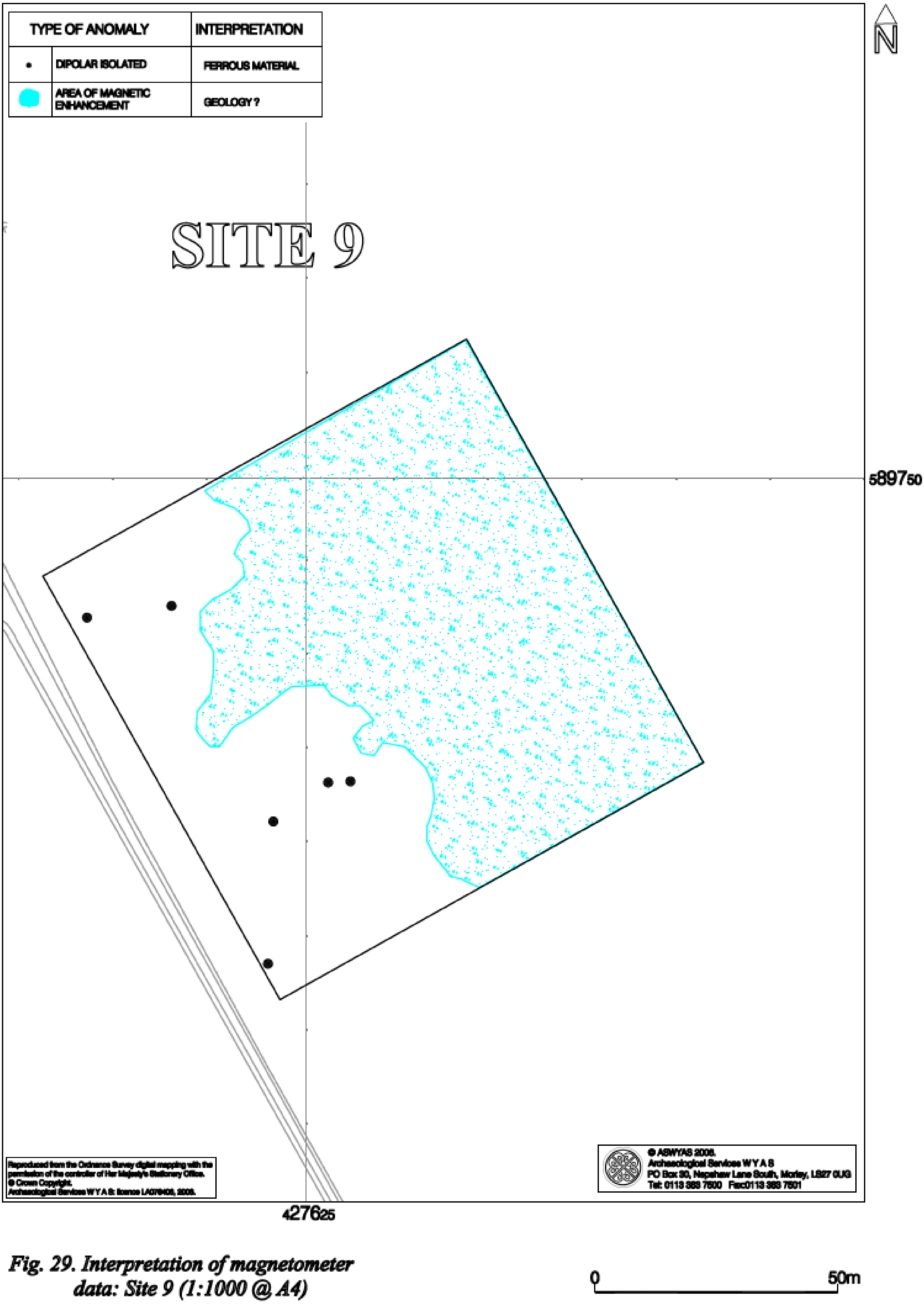

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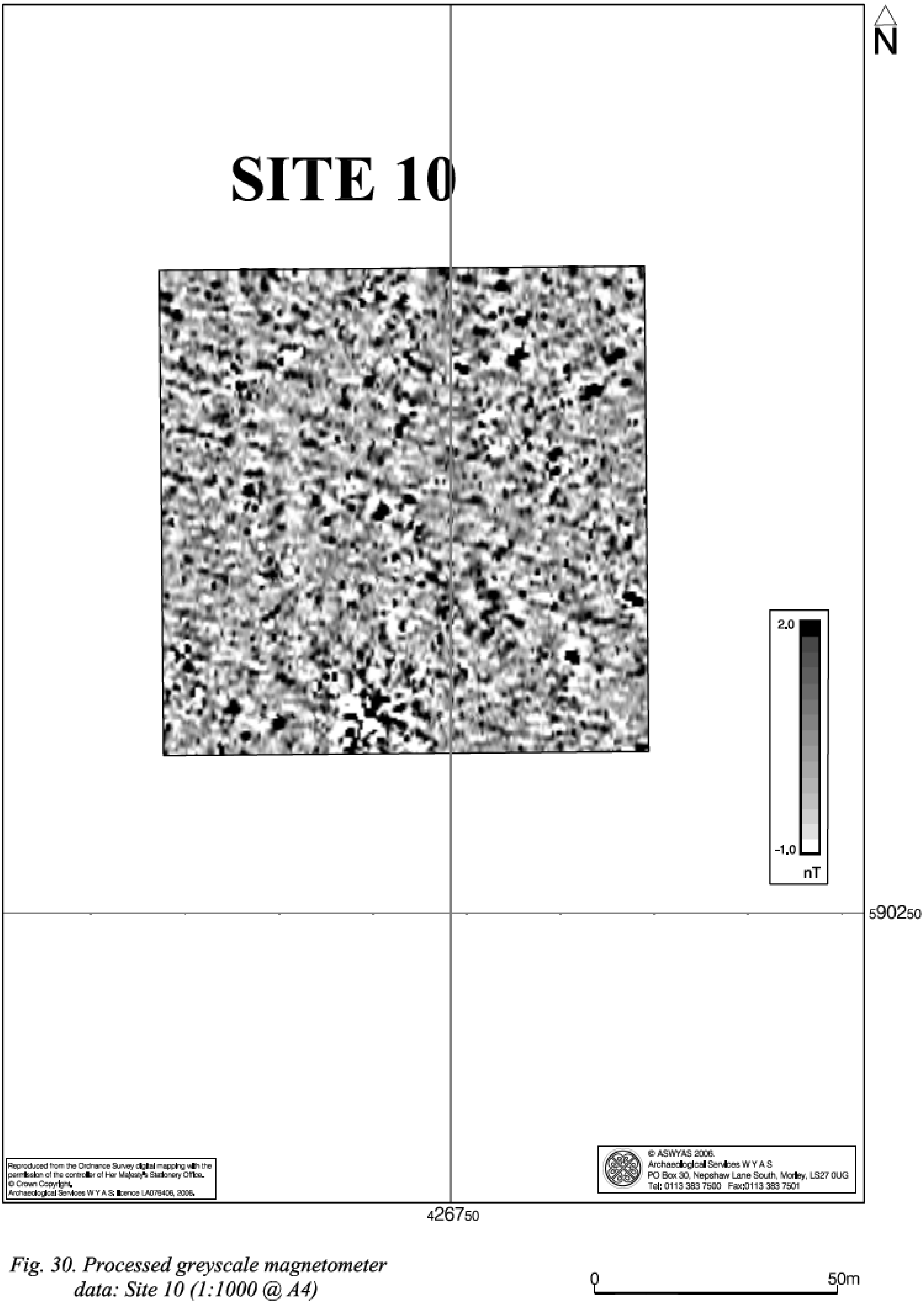

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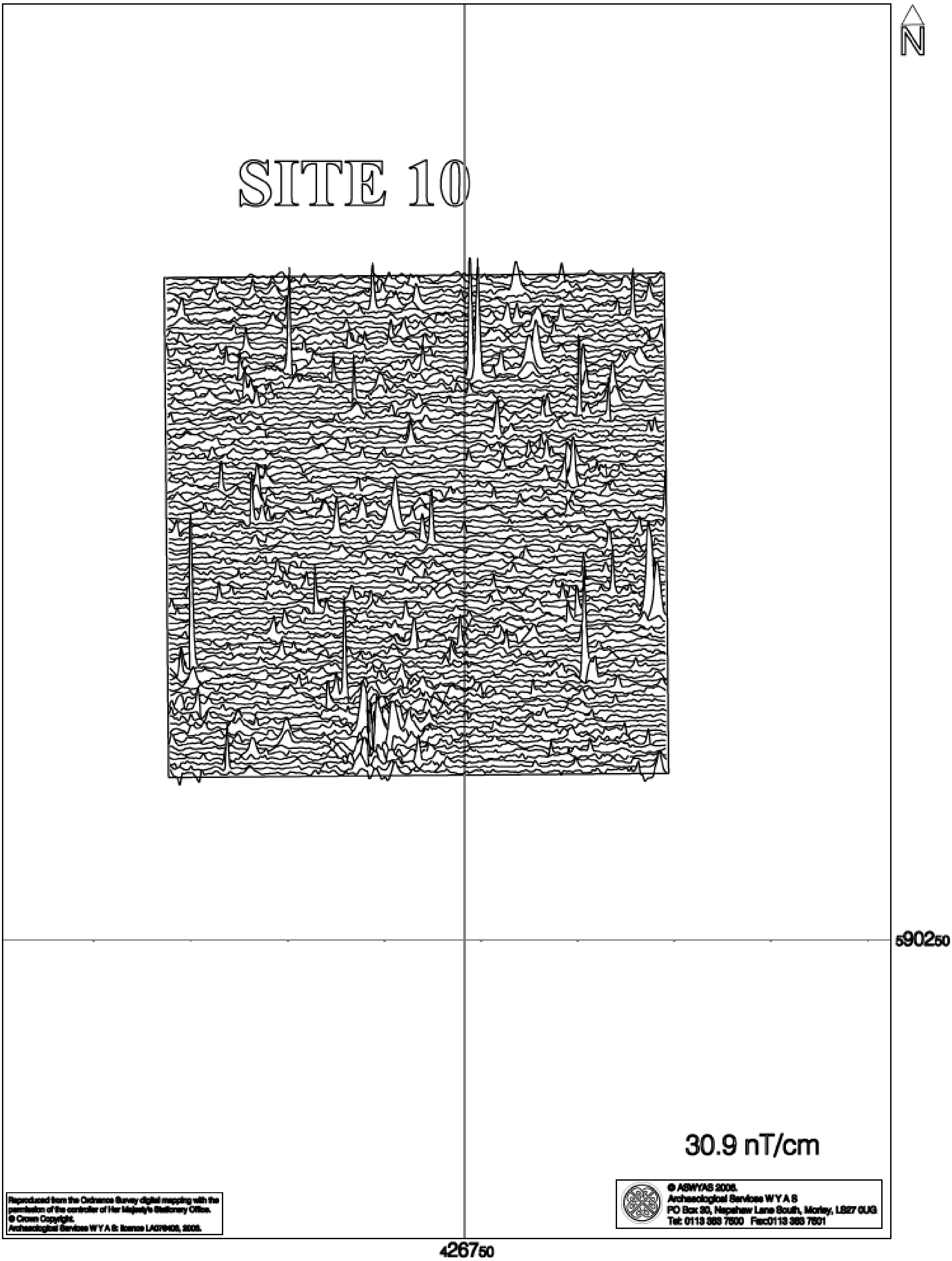

Fig. 31. XY trace plot of raw magnetometer data: Site 10 (1:1000 @ A4)

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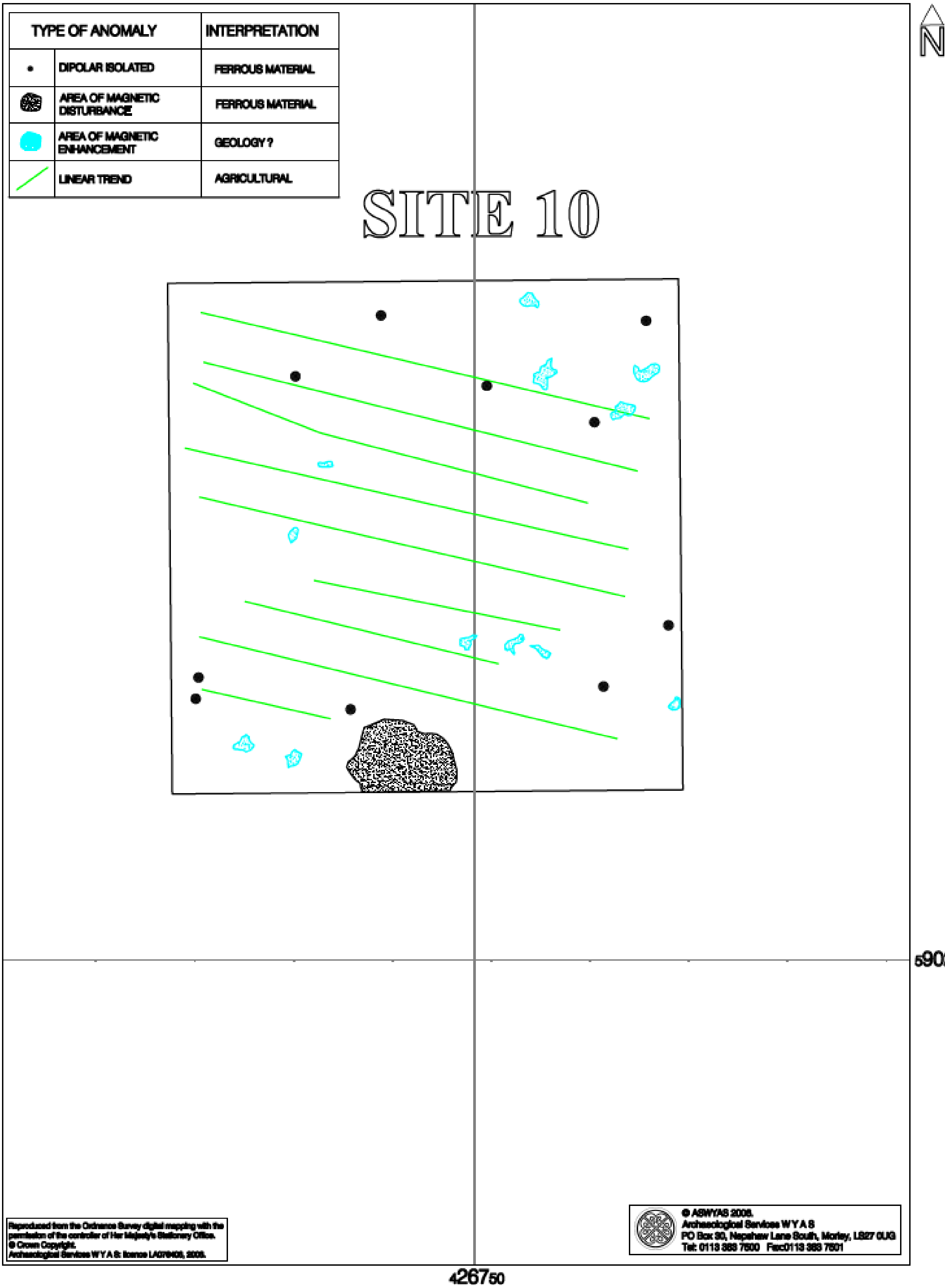

Fig. 32. Interpretation of magnetometer data: Site 10 (1:1000 @ A4)

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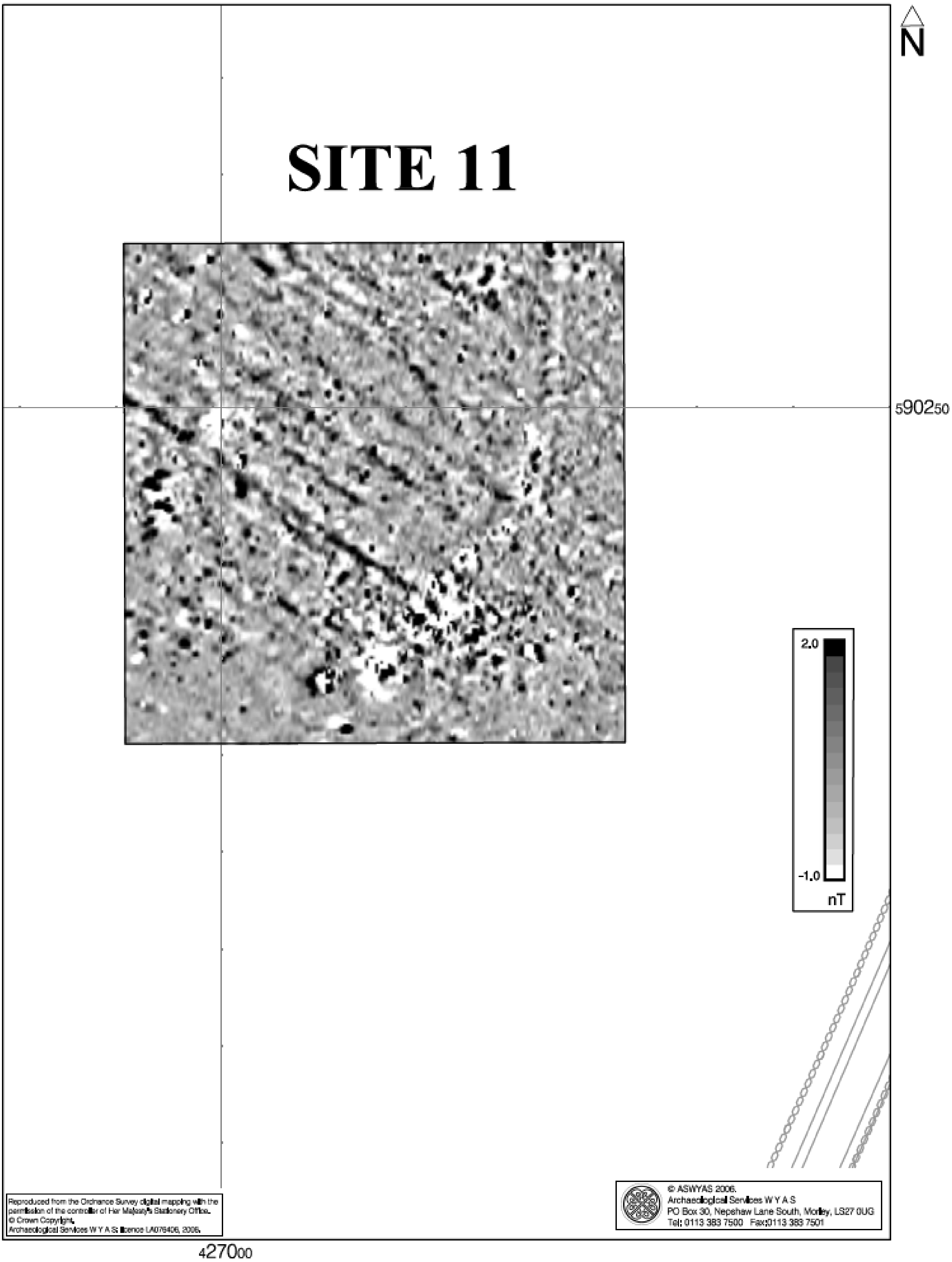

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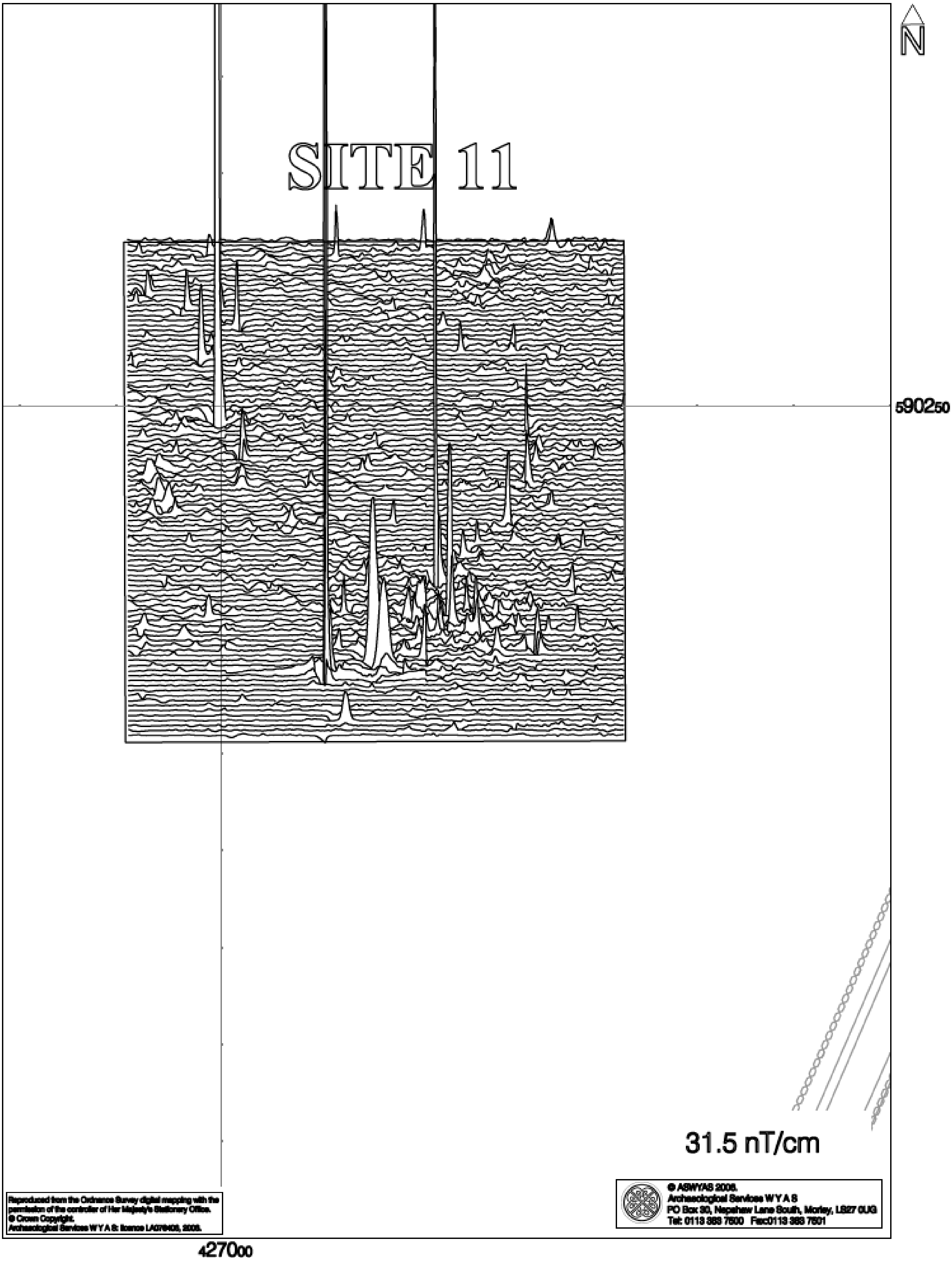

Fig. 34. XY trace plot of raw magnetometer data: Site 11 (1:1000 @ A4)

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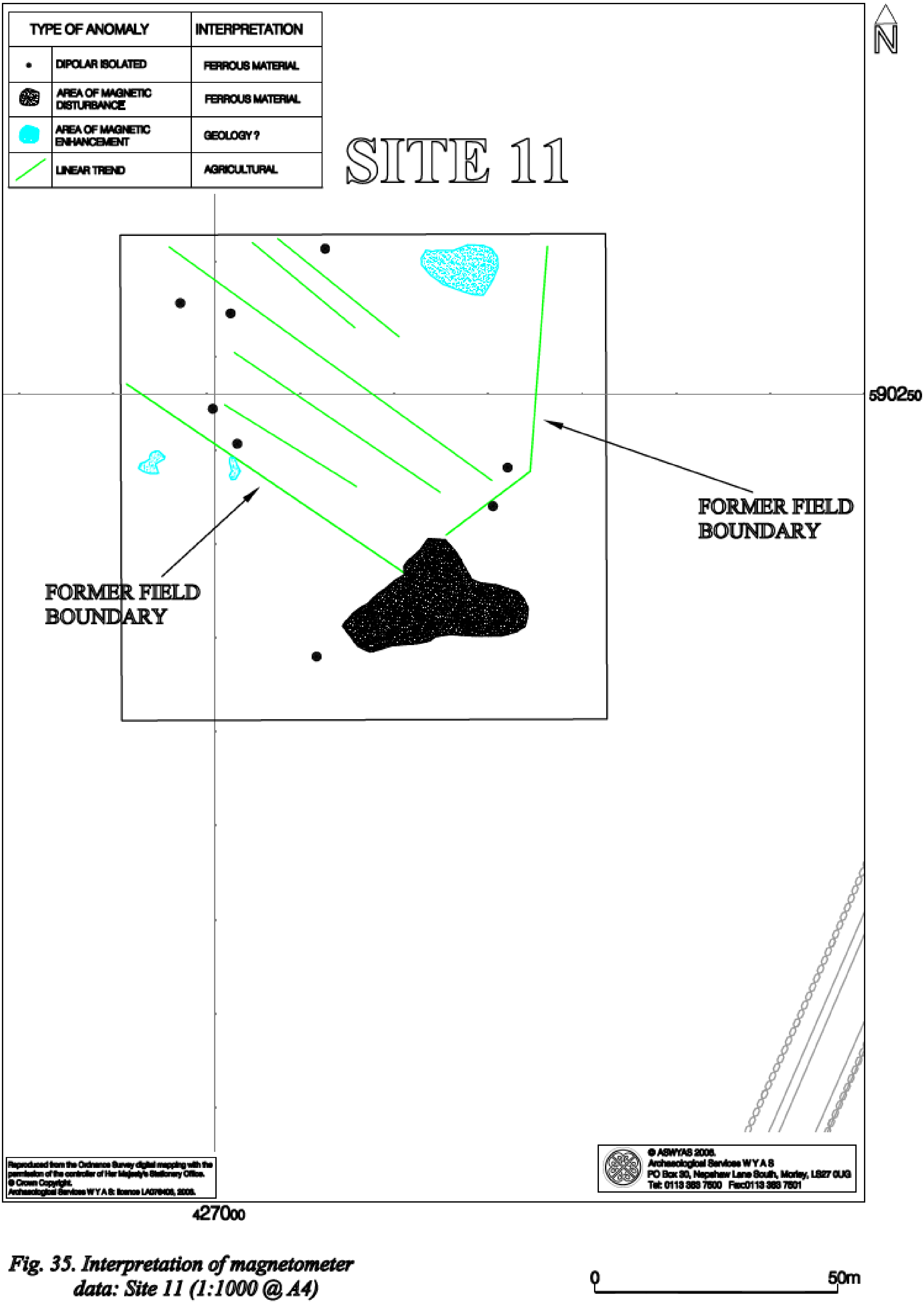
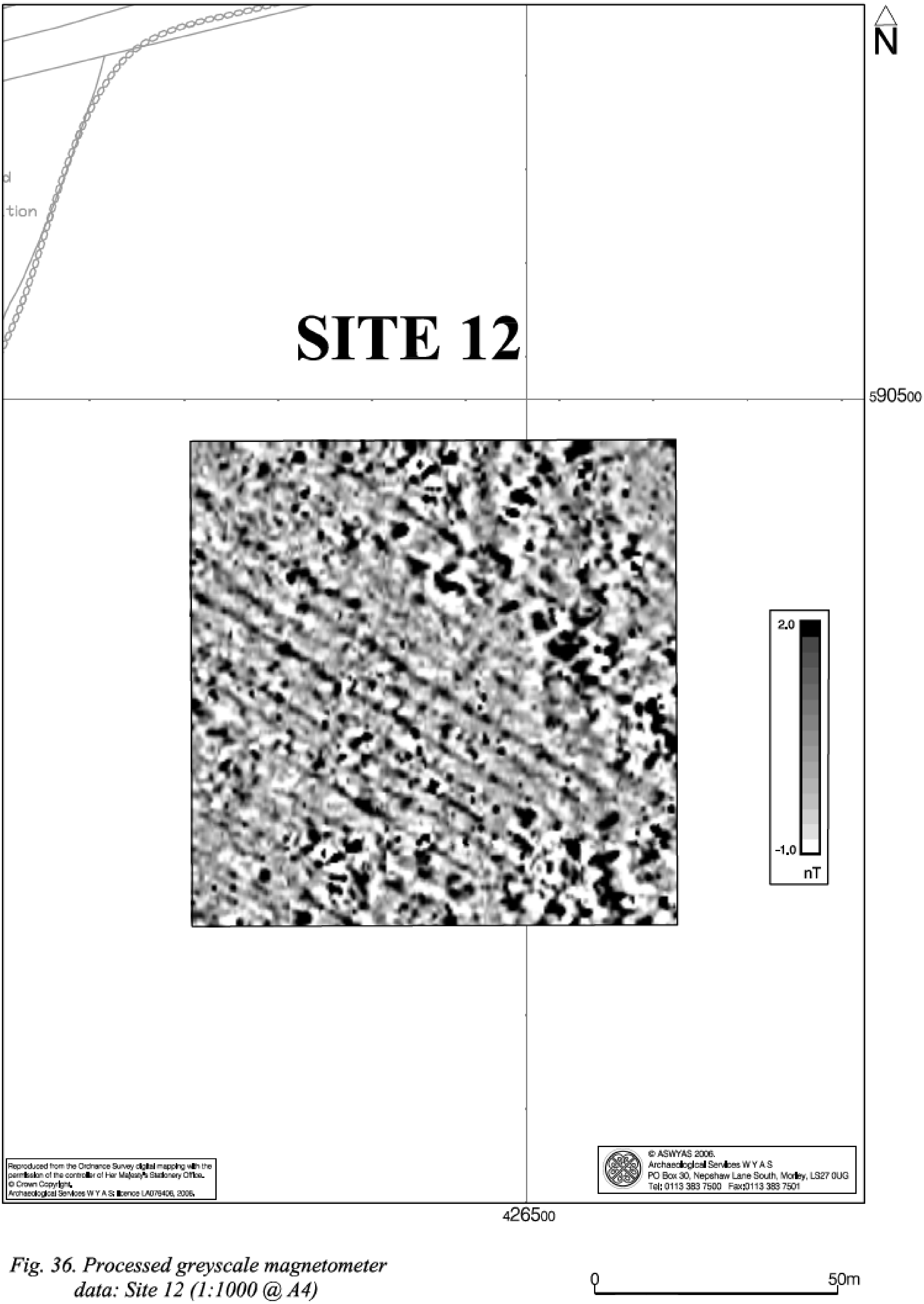


Fig. 35. Interpretation of magnetometer data: Site 11 (1:1000 @ A4)



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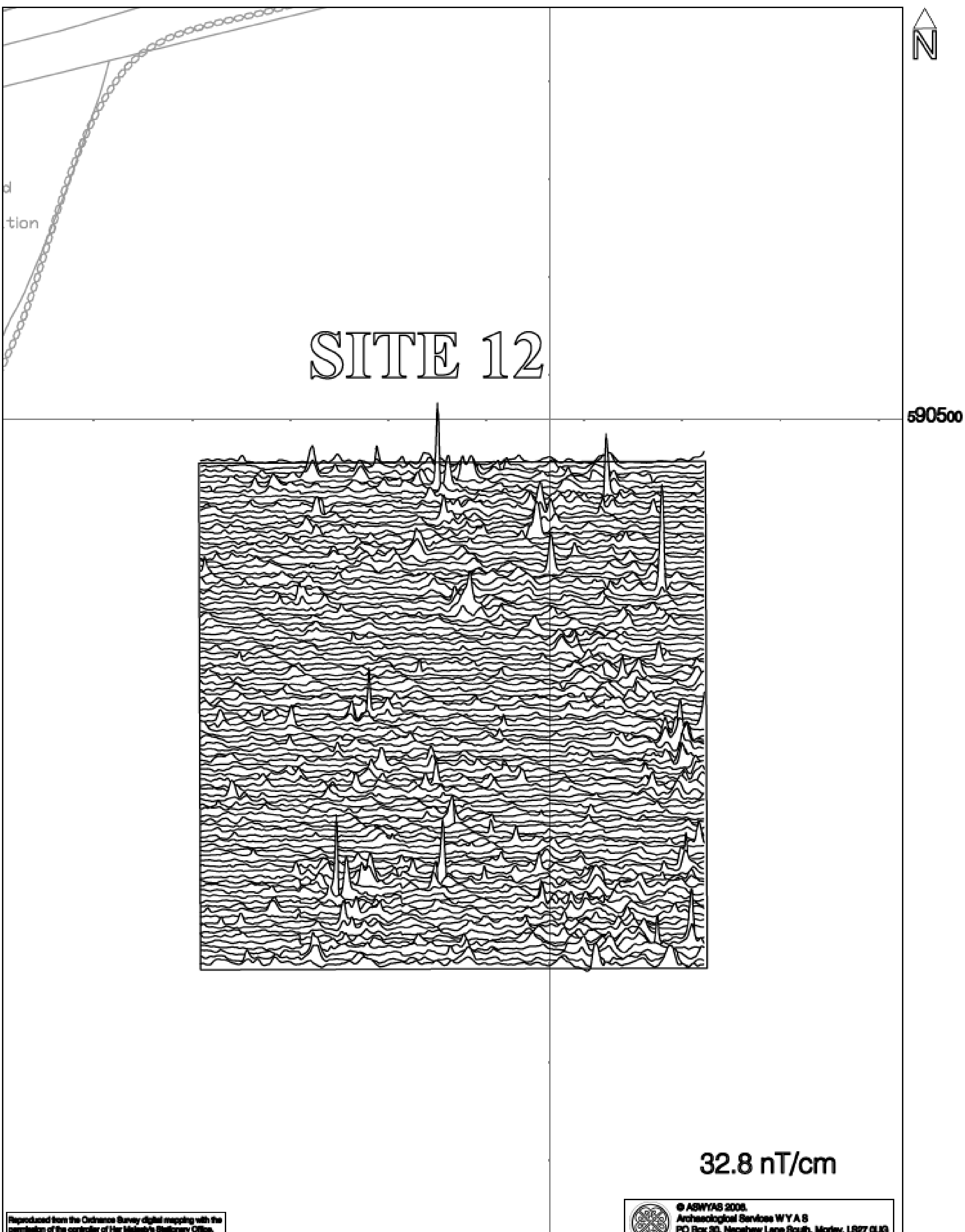

Fig. 37. XY trace plot of raw magnetometer data: Site 12 (1:1000 @ A4)

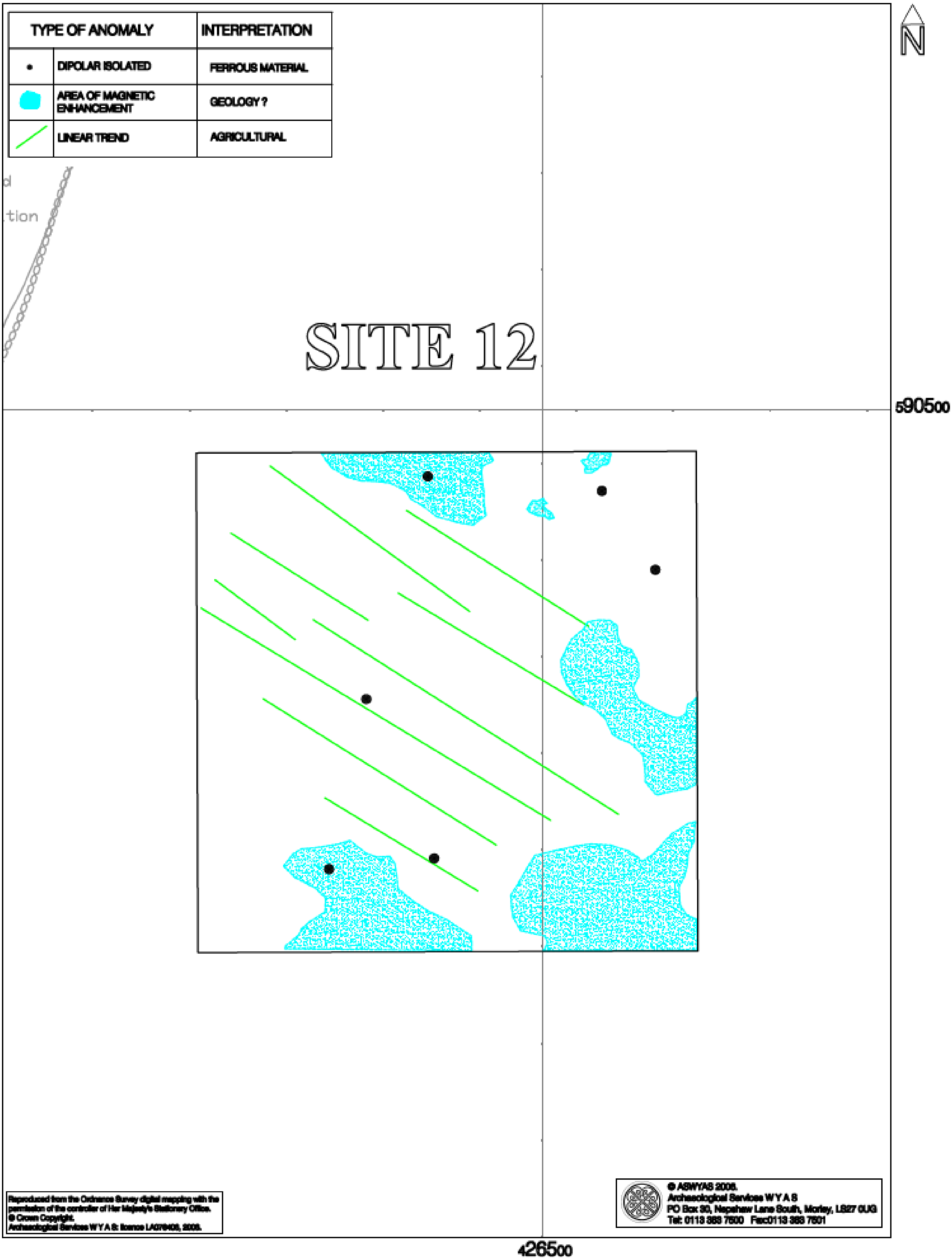

Fig. 38. Interpretation of magnetometer data: Site 12 (1:1000 @ A4)

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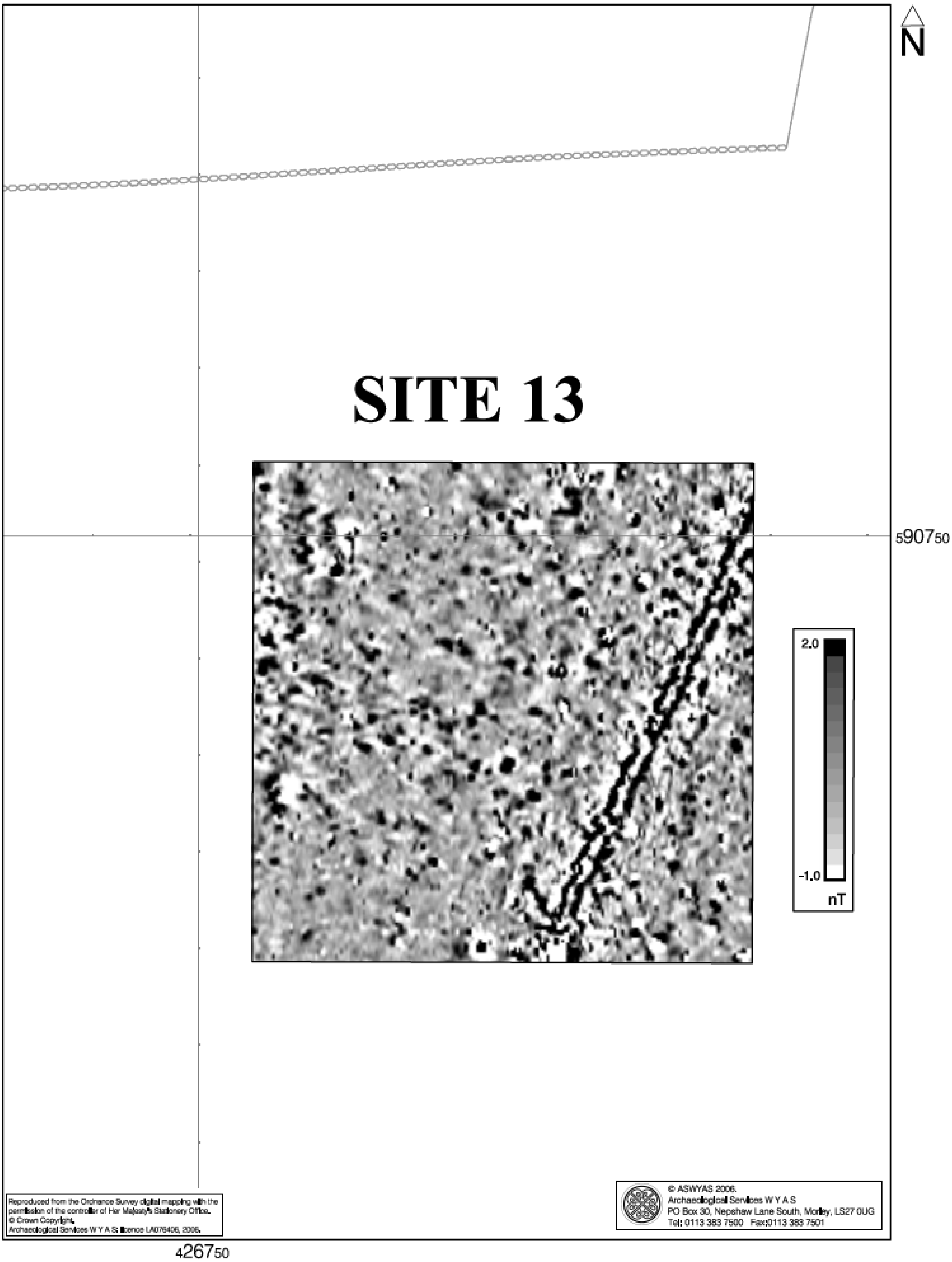

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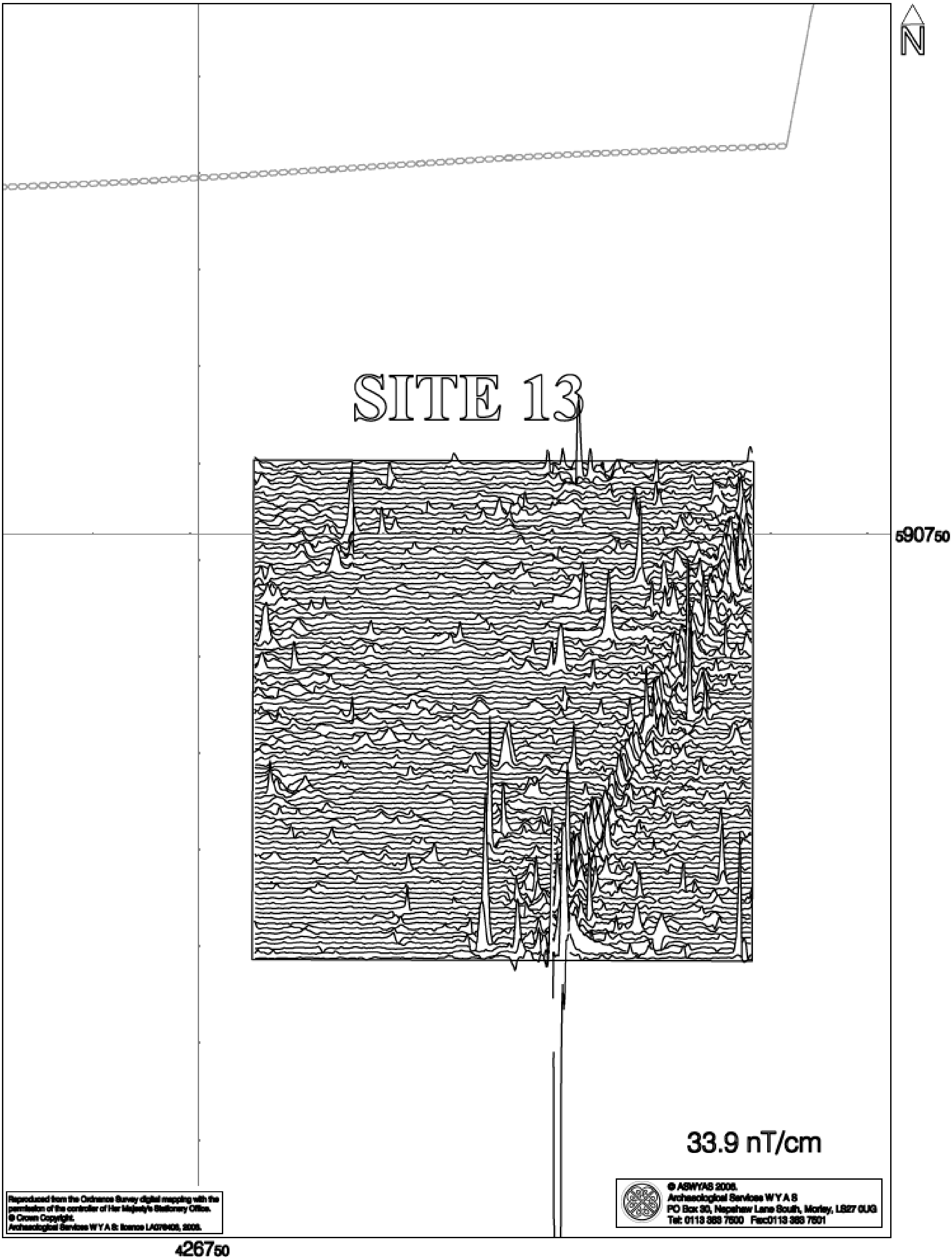


Fig. 40. XY trace plot of raw magnetometer data: Site 13 (1:1000 @ A4)

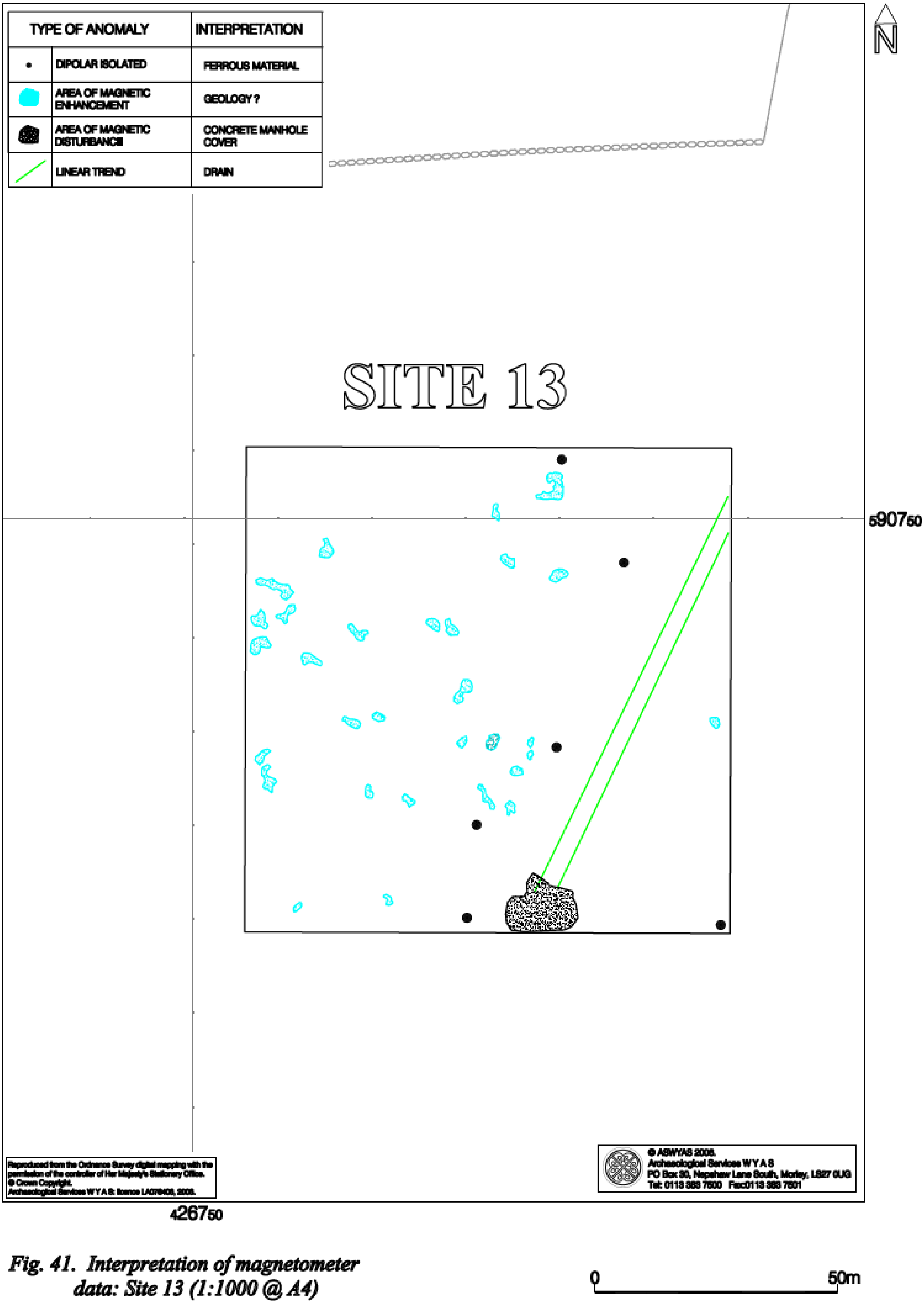
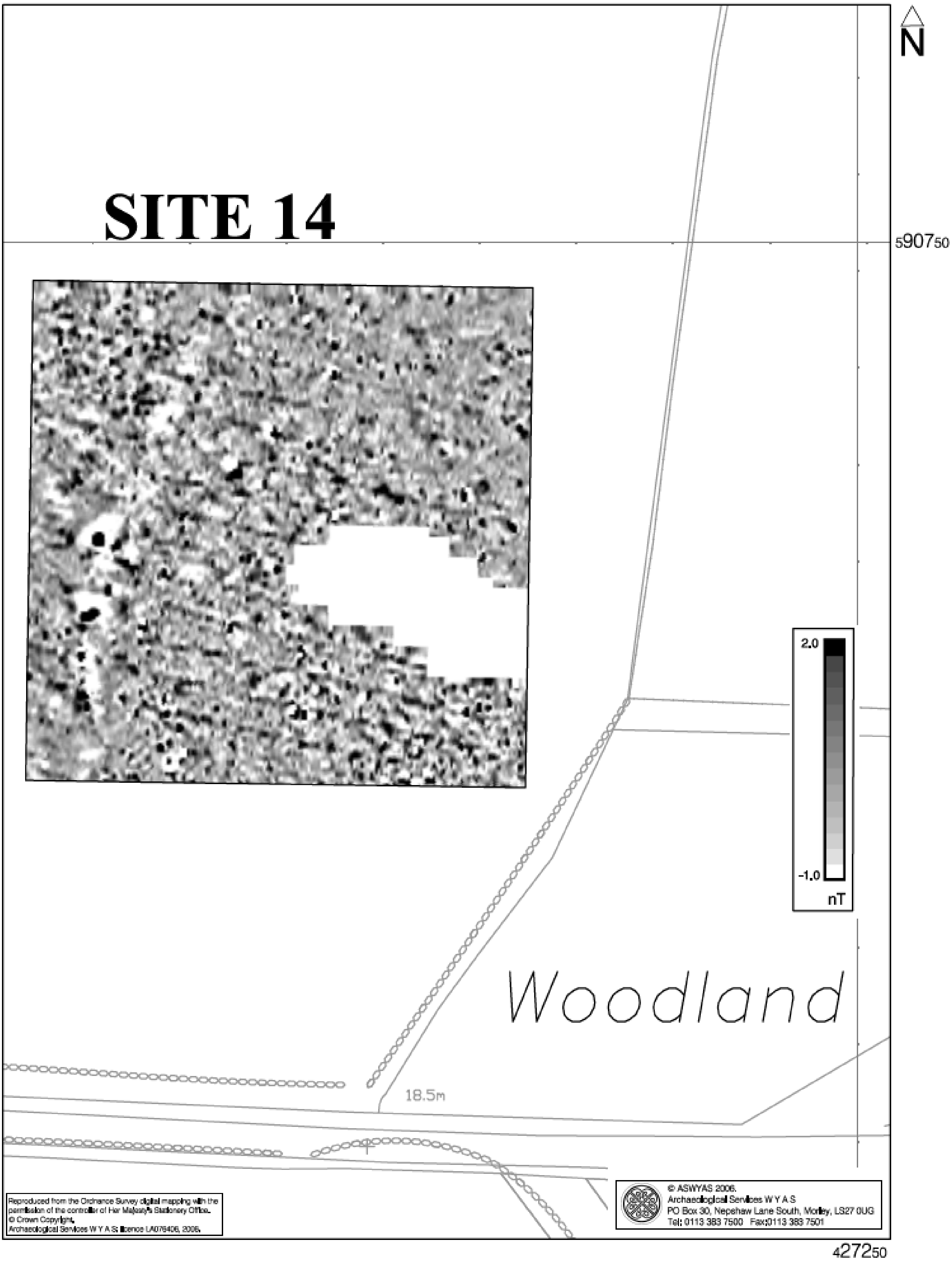


Fig. 41. Interpretation of magnetometer data: Site 13 (1:1000 @ A4)



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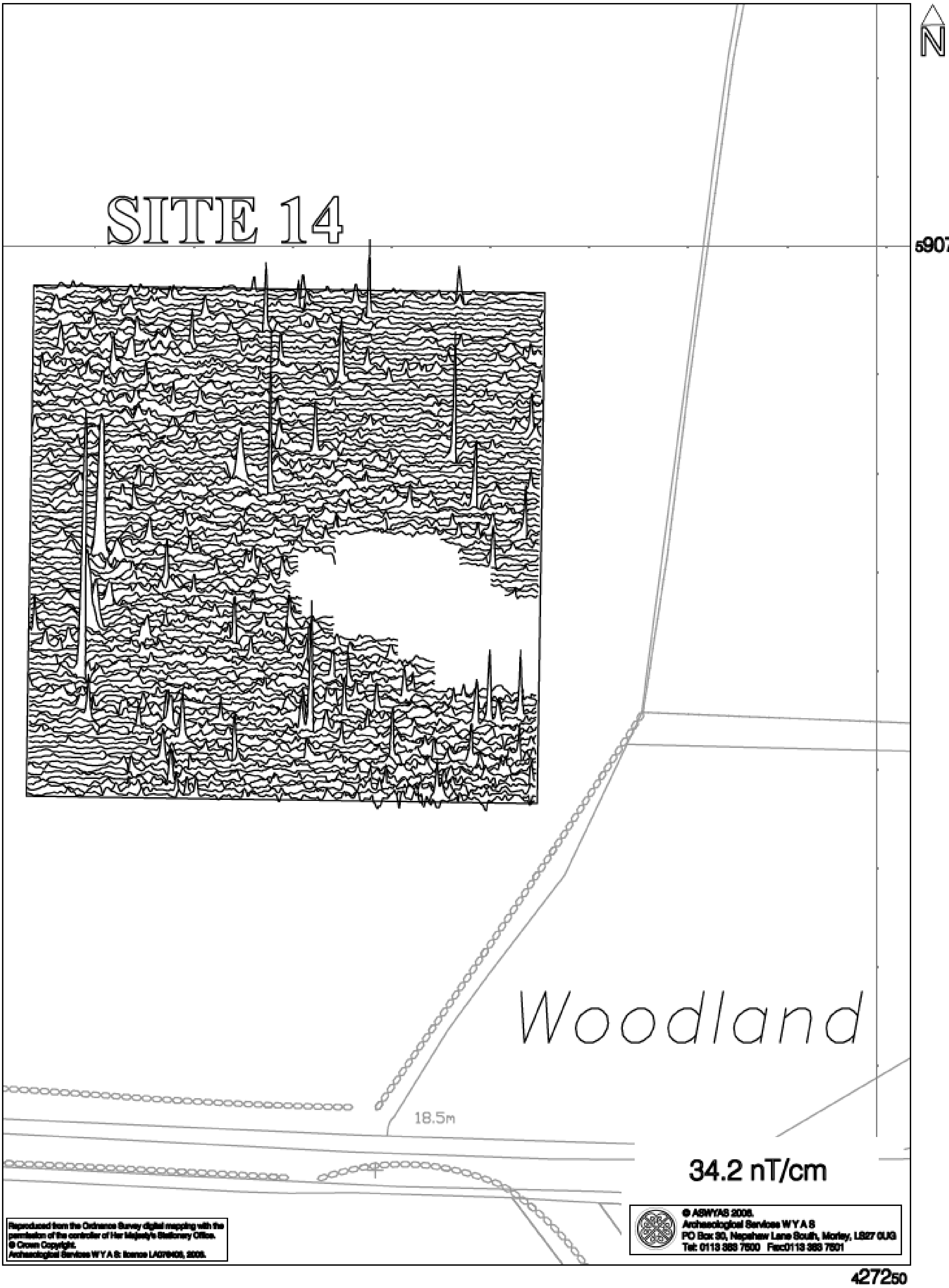

Fig. 43. XY trace plot of raw magnetometer data: Site 14 (1:1000 @ A4)

Fig. 44. Interpretation of magnetometer data: Site 14 (1:1000 @ A4)

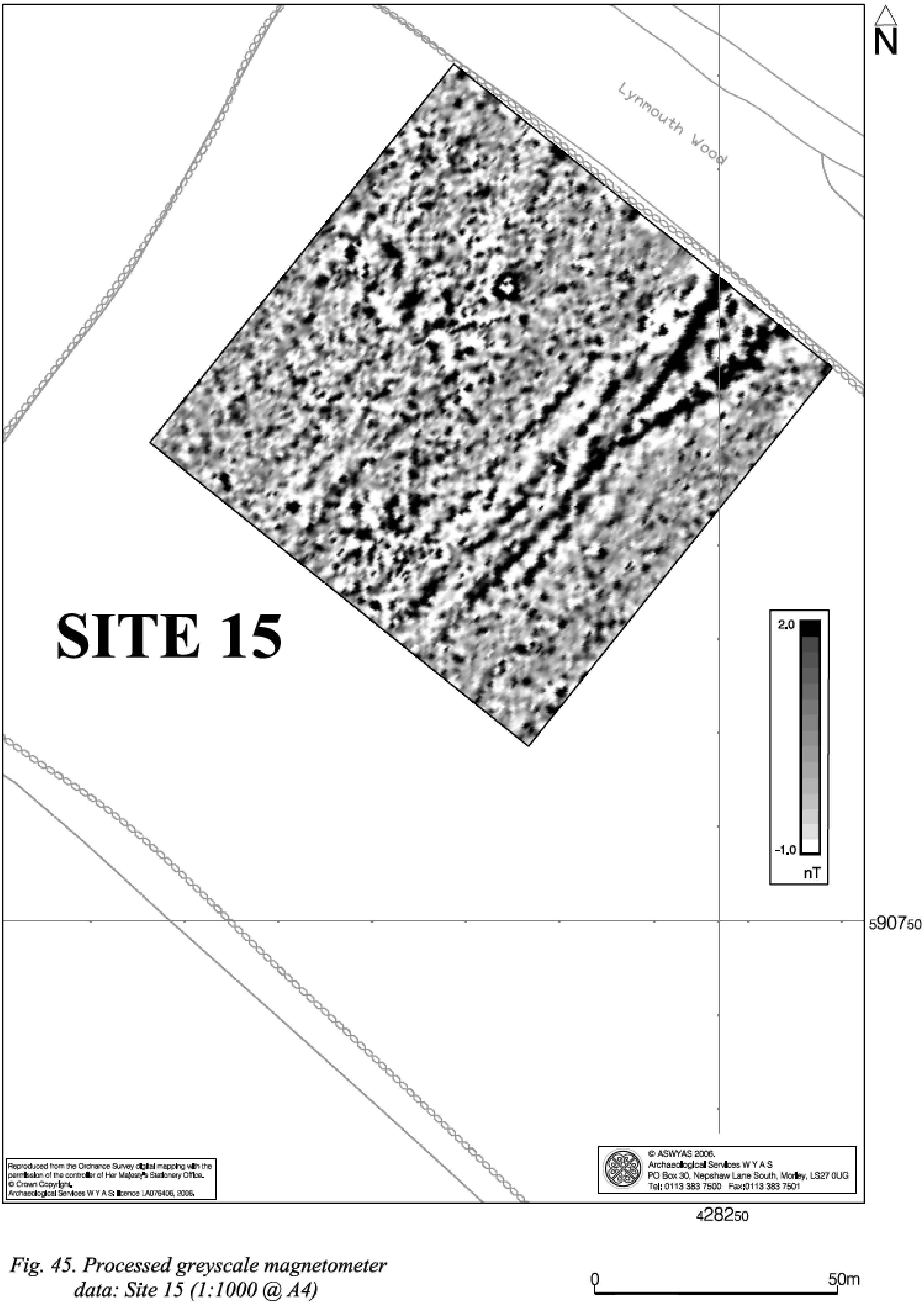

Fig. 45. Processed greyscale magnetometer data: Site 15 (1:1000 @ A4)

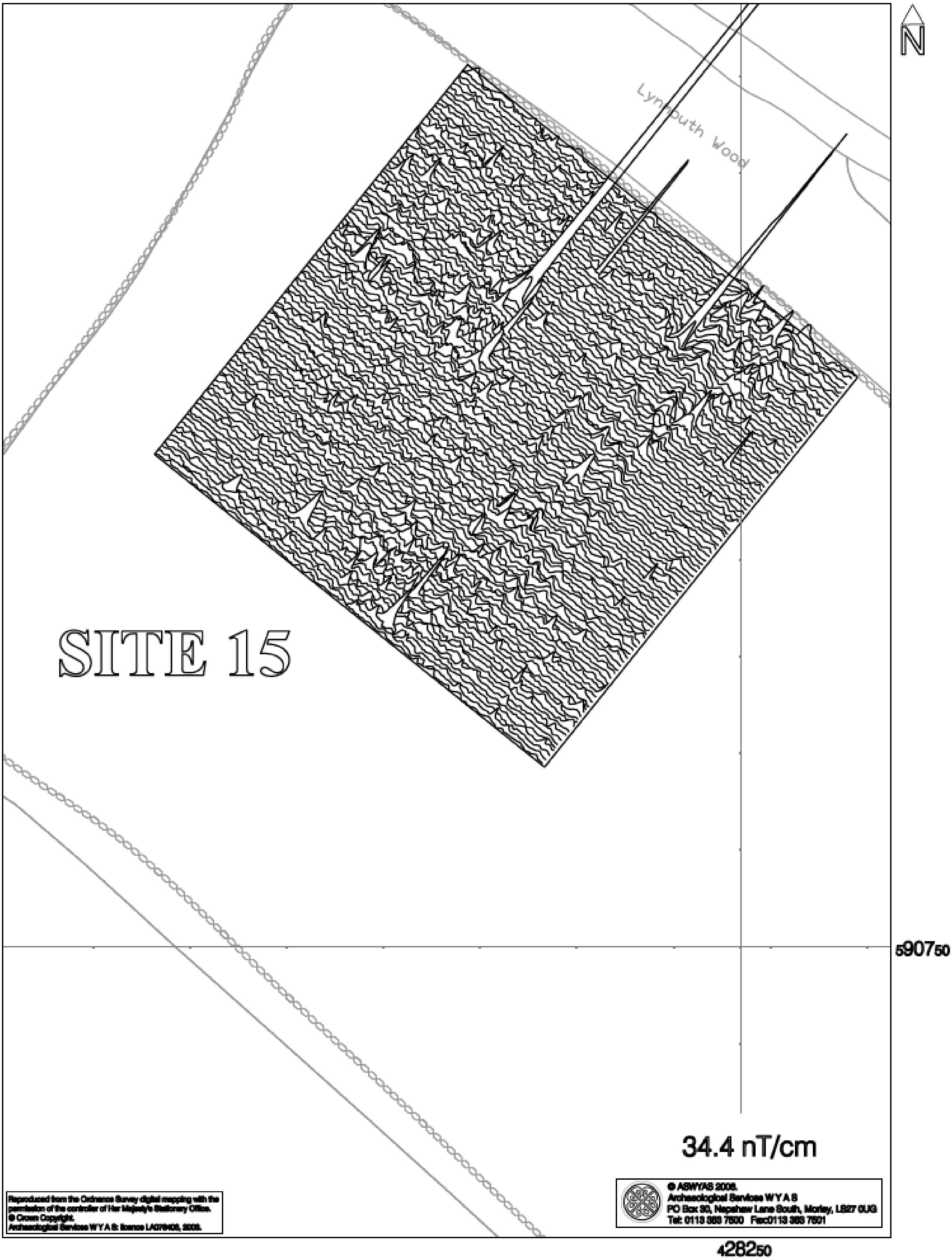

Fig. 46. XY trace plot of raw magnetometer data: Site 15 (1:1000 @ A4)

0 50m

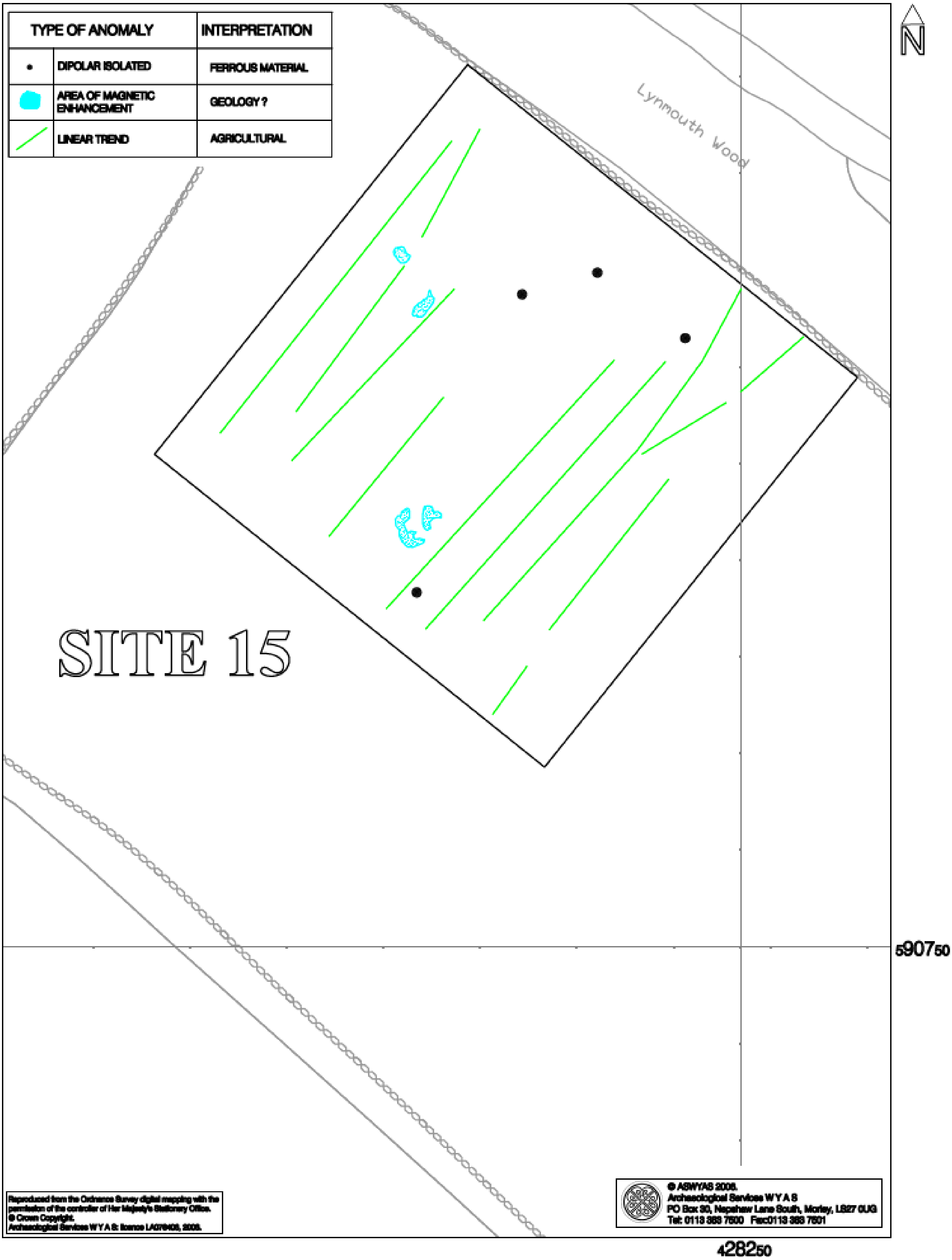

Fig. 47. Interpretation of magnetometer data: Site 15 (1:1000 @ A4)

0 50m

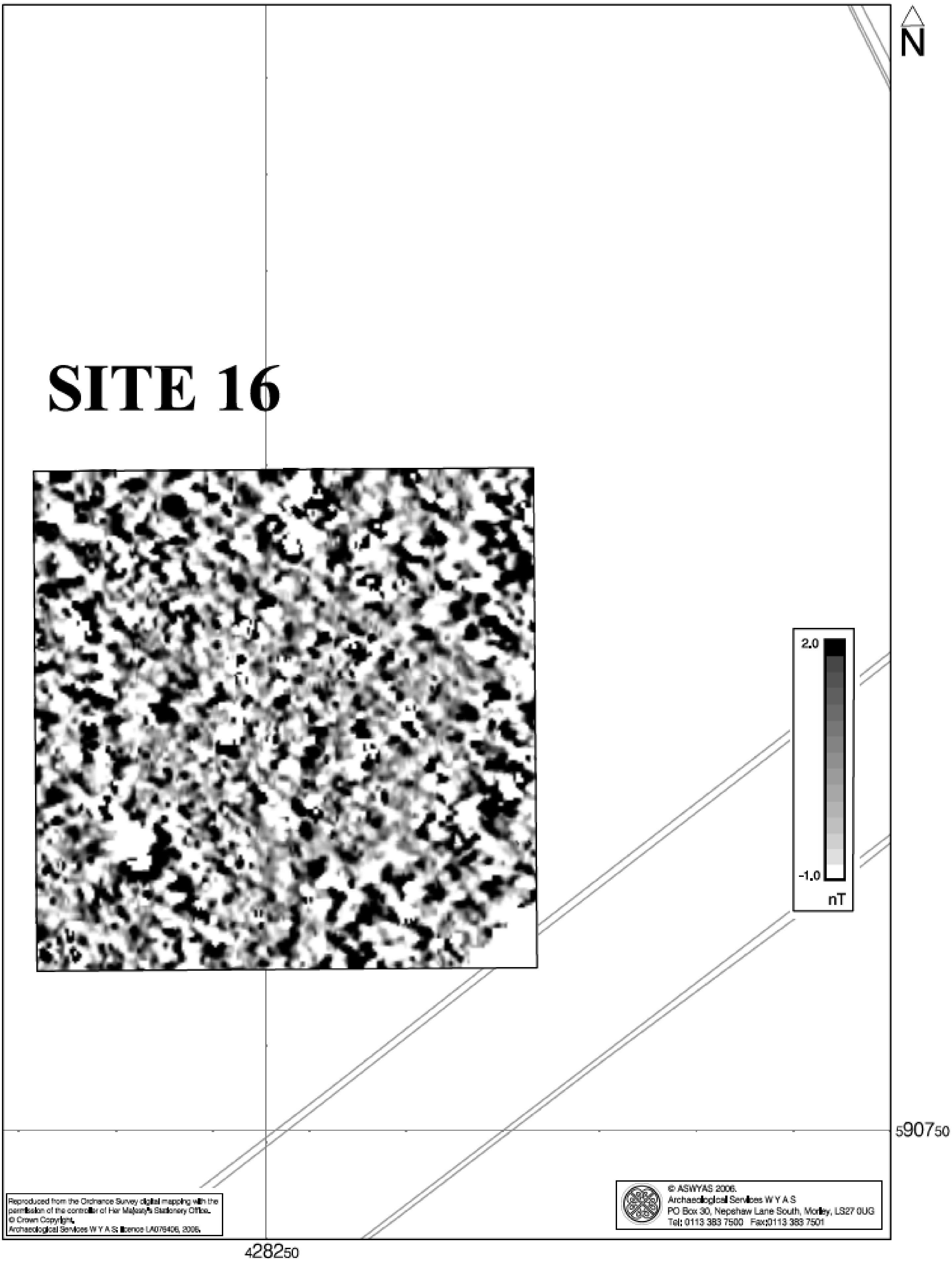

Fig. 48. Processed greyscale magnetometer data: Site 16 (1:1000 @ A4)

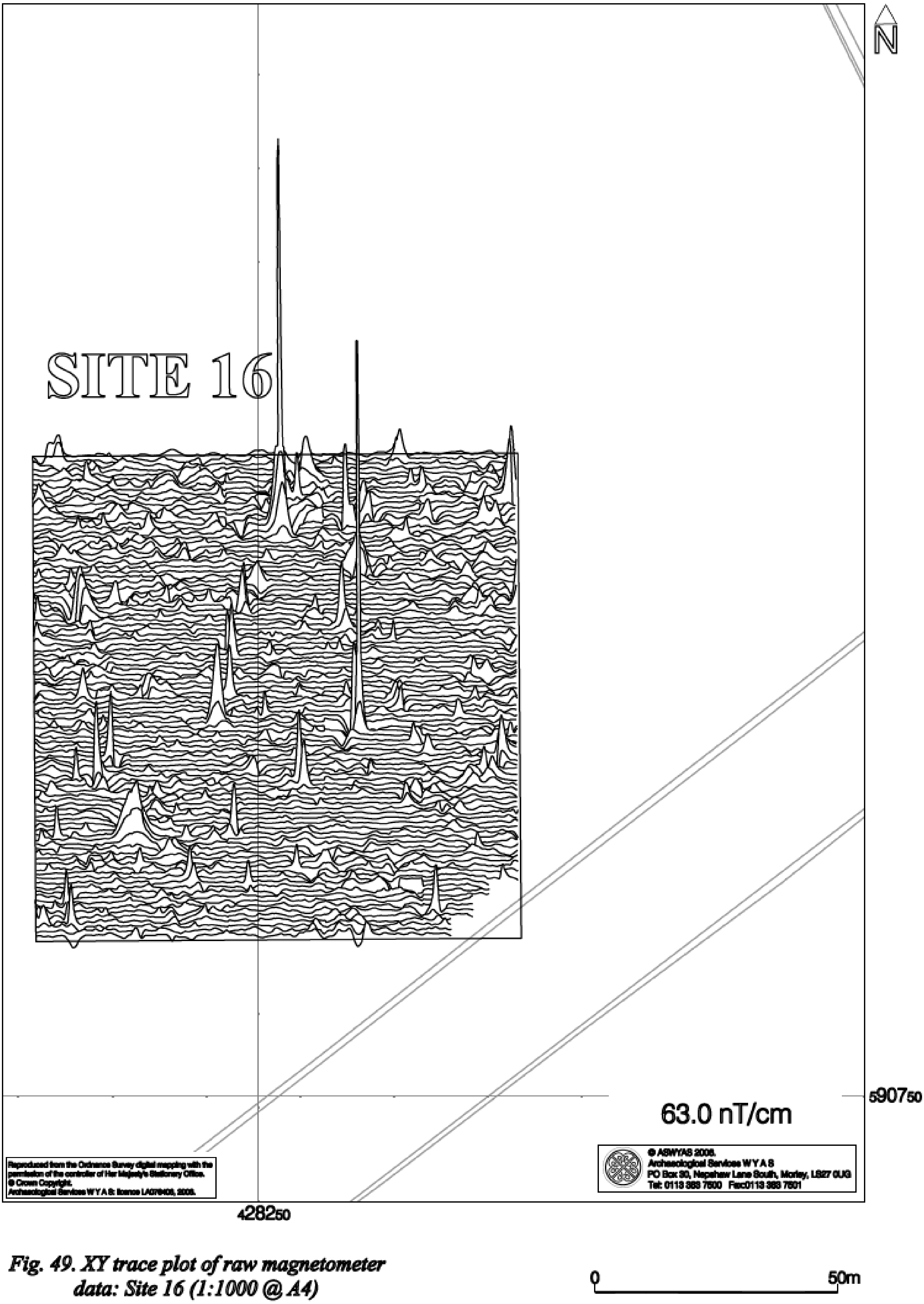

Fig. 49. XY trace plot of raw magnetometer data: Site 16 (1:1000 @ A4)

TYPE OF ANOMALY		INTERPRETATION
•	DIPOLAR ISOLATED	FERROUS MATERIAL
(cyan area)	AREA OF MAGNETIC ENHANCEMENT	GEOLOGY ?

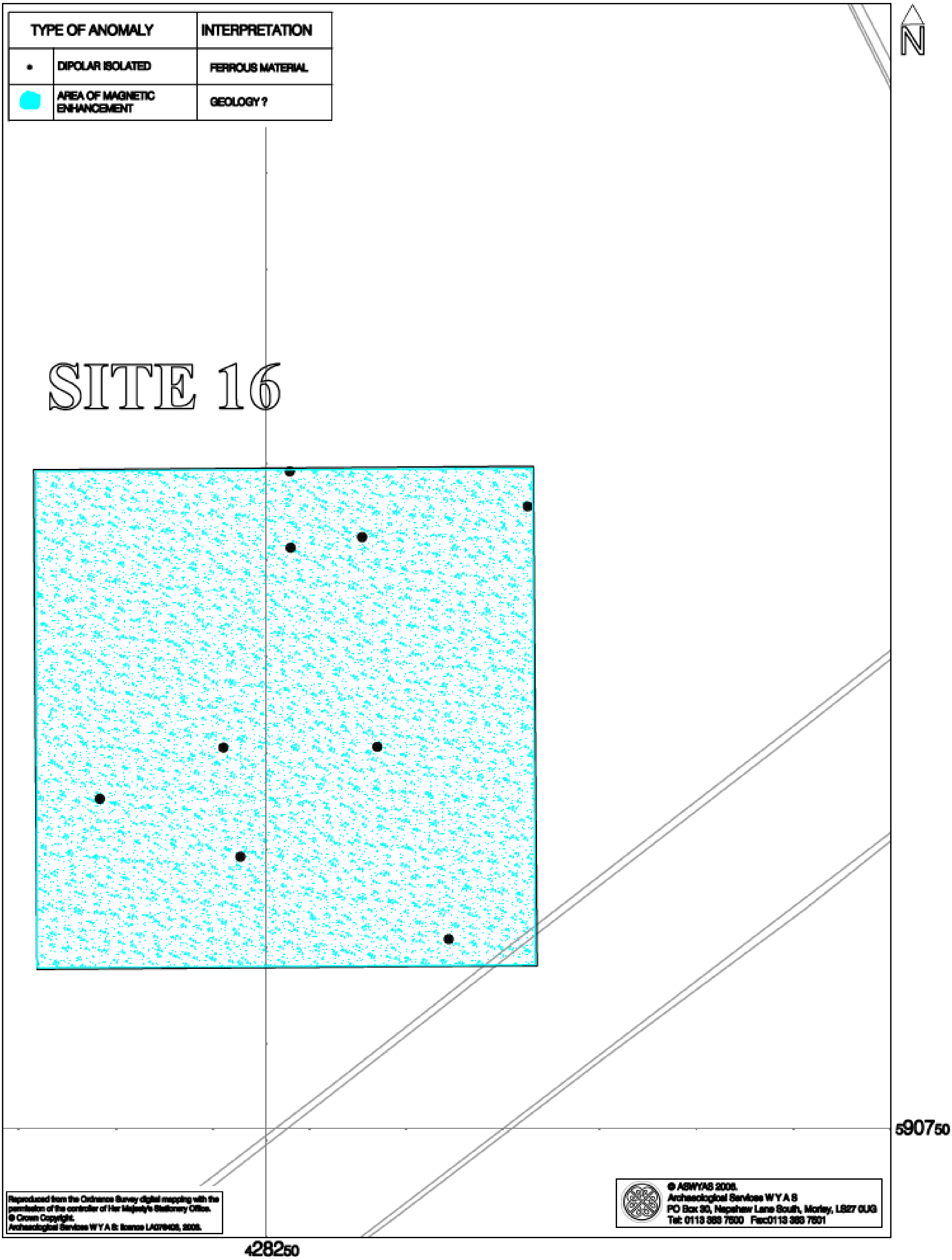

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Fig. 50. Interpretation of magnetometer data: Site 16 (1:1000 @ A4)

0 50m

Appendix 1

Magnetic Survey: Technical Information

Magnetic Susceptibility and Soil Magnetism

Iron makes up about 6% of the Earth's crust and is mostly present in soils and rocks as minerals such as maghaemite and haemetite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms so that by measuring the magnetic susceptibility of the topsoil, areas where human occupation or settlement has occurred can be identified by virtue of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of topsoils, subsoils and rocks into which these features have been cut, which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected. Less magnetic material such as masonry or plastic service pipes that intrude into the topsoil may give a negative magnetic response relative to the background level.

The magnetic susceptibility of a soil can also be enhanced by the application of heat. This effect can lead to the detection of features such as hearths, kilns or areas of burning.

Types of Magnetic Anomaly

In the majority of instances anomalies are termed ***'positive'***. This means that they have a positive magnetic value relative to the magnetic background on any given site. However some features can manifest themselves as ***'negative'*** anomalies that, conversely, means that the response is negative relative to the mean magnetic background. Such negative anomalies are often very faint and are commonly caused by modern, non-ferrous, features such as plastic water pipes. Infilled natural features may also appear as negative anomalies on some geological substrates.

Where it is not possible to give a probable cause of an observed anomaly a '?' is appended.

It should be noted that anomalies interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.

The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

Isolated dipolar anomalies (iron spikes)

These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic 'spiky' trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being present as a consequence of manuring.

Areas of magnetic disturbance

These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire fencing and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

Linear trend

This is usually a weak or broad linear anomaly of unknown cause or date. An agricultural origin, either ploughing or land drains is a common cause.

Areas of magnetic enhancement/positive isolated anomalies

Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response (sometimes only visible on an XY trace plot) on two or three successive traverses. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an 'iron spike' anomaly (see above). These anomalies can be caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

Linear and curvilinear anomalies

Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier ridge and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

Methodology: Magnetic Susceptibility Survey

There are two methods of measuring the magnetic susceptibility of a soil sample. The first involves the measurement of a given volume of soil, which will include any air and moisture that lies within the sample, and is termed volume specific susceptibility. This method results in a bulk value that it not necessarily fully representative of the constituent components of the sample. The second technique overcomes this potential problem by taking into account both the volume and mass of a sample and is termed mass specific susceptibility. However, mass specific readings cannot be taken in the field where the bulk properties of a soil are usually unknown and so volume specific readings must be taken. Whilst these values are not fully representative they do allow general comparisons across a site and give a broad indication of susceptibility changes. This is usually enough to assess the susceptibility of a site and evaluate whether enhancement has occurred.

Methodology: Gradiometer Survey

There are two main methods of using the fluxgate gradiometer for commercial evaluations. The first of these is referred to as ***magnetic scanning*** and requires the operator to visually identify anomalous responses on the instrument display panel whilst covering the site in widely spaced traverses, typically 10m apart. The instrument logger is not used and there is therefore no data collection. Once anomalous responses are identified they are marked in the field with bamboo canes and approximately located on a base plan. This method is usually employed as a means of selecting areas for detailed survey when only a percentage sample of the whole site is to be subject to detailed survey.

The disadvantages of magnetic scanning are that features that produce weak anomalies (less than 2nT) are unlikely to stand out from the magnetic background and so will be difficult to detect. The coarse sampling interval means that discrete features or linear features that are parallel or broadly oblique to the direction of traverse may not be detected. If linear features are suspected in a site then the traverse direction should be perpendicular (or as close as is possible within the physical constraints of the site) to the orientation of the suspected features. The possible drawbacks mentioned above mean that negative results from magnetic scanning should **always** be checked with at least a sample detailed magnetic survey (see below).

The second method is referred to as ***detailed survey*** and employs the use of a sample trigger to automatically take readings at predetermined points, typically at 0.5m or 0.25m intervals, on zig-zag traverses 1m apart. These readings are stored in the memory of the instrument and are later dumped to computer for processing and interpretation. Detailed survey allows the visualisation of weaker anomalies that may not have been detected by magnetic scanning.

During this survey a Bartington Grad601 magnetic gradiometer was used taking readings on the 0.1nT range, at 0.25m intervals on zig-zag traverses 1m apart within 20m by 20m square grids. The instrument was checked for electronic and mechanical drift at a common point and calibrated as necessary. The drift from zero was not logged.

Data Processing and Presentation

The detailed gradiometer data has been presented in this report in XY trace and greyscale formats. In the former format the data shown is 'raw' with no processing other than grid biasing having been done. The data in the greyscale images has been interpolated and selectively filtered to remove the effects of drift in instrument calibration and other artificial data constructs and to maximise the clarity and interpretability of the archaeological anomalies.

An XY plot presents the data logged on each traverse as a single line with each successive traverse incremented on the Y-axis to produce a 'stacked' plot. A hidden line algorithm has been employed to block out lines behind major 'spikes' and the data has been clipped. The main advantage of this display option is that the full range of data can be viewed, dependent on the clip, so that the 'shape' of individual anomalies can be discerned and potentially archaeological anomalies differentiated from 'iron spikes'. Geoplot 3 software was used to create the XY trace plots.

Geoplot 3 software was used to interpolate the data so that 1600 readings were obtained for each 20m by 20m grid. The same program was used to produce the greyscale images. All greyscale plots are displayed using a linear incremental scale.

Appendix 2

Survey Location Information

The site grid was laid out using a Geodimeter 600s total station theodolite and tied in to the corners of buildings and other permanent landscape features and to temporary reference points (survey marker stakes) that were established and left in place following completion of the fieldwork for accurate geo-referencing. The locations of the temporary reference points are shown on Figure 2 and the Ordnance Survey grid co-ordinates tabulated below. The internal accuracy of the survey grid relative to these markers is better than 0.05m. The survey grids were then superimposed onto a map base provided by the client as a 'best fit' to produce the displayed block locations. Overall there was a good correlation between the local survey and the digital map base and it is estimated that the average 'best fit' error is better than ±1.5m. However, it should be noted that Ordnance Survey co-ordinates for 1:2500 map data have an error of ±1.9m at 95% confidence. This potential error must be considered if co-ordinates are measured off for relocation purposes.

Station	Easting	Northing
A	427549.0854	589285.5675
B	427623.6261	589343.4653
C	427631.2590	589445.8424
D	427707.9245	589476.5349
E	427754.1881	589603.2472
F	427793.6884	589612.9569
G	427909.3573	589608.5144
H	427577.9581	589701.5051
I	427752.7448	589831.2756
J	428522.3750	589734.9252
K	428711.9682	590007.5135
L	428869.4178	589973.3954
M	427795.5223	590177.5583
N	427485.7293	590144.2958
O	427422.8799	590129.1693
P	427463.8529	590467.8756
Q	427232.7678	590454.3433

R	427130.1797	590577.7929
S	427111.0265	590566.1492
T	427014.8694	590570.0412
U	426851.1762	590826.7819
V	426985.0833	590925.3797
W	427701.2795	590639.4829
X	428316.1624	590593.9155
Y	428150.6069	590750.5762
Z	428304.2720	590837.6976
AA	428232.9008	590900.2091
AB	428143.6214	590908.3726

Archaeological Services WYAS cannot accept responsibility for errors of fact or opinion resulting from data supplied by a third party or for the removal of any of the survey reference points.

Appendix 3

Geophysical Archive

The geophysical archive comprises:-

- an archive disk containing compressed (WinZip 8) files of the raw data, report text (Word 2000), and graphics files (Adobe Illustrator, CorelDraw6 and AutoCAD 2000) files.
- a full copy of the report

At present the archive is held by Archaeological Services WYAS although it is anticipated that it may eventually be lodged with the Archaeology Data Service (ADS). Brief details will also be forwarded for inclusion on the English Heritage Geophysical Survey Database after the contents of the report are deemed to be in the public domain (i.e. available for consultation in the relevant Sites and Monument Record Office).