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Heron Renewable Energy Plant
Immingham
North-East Lincolnshire

Geophysical Survey

October 2009

Report No. 1996

CLIENT

Headland Archaeology Ltd.

Heron Renewable Energy Plant
Immingham
North-East Lincolnshire

Geophysical Survey of the proposed laydown area

Summary

A geophysical (magnetometer) survey covering 20 hectares of a proposed laydown area was carried out near South Killingholme, south of Immingham, in order to facilitate the development of the Heron Renewable Energy Plant. Numerous broad, linear and curvilinear anomalies have been identified throughout the survey area. However, these are interpreted as being due to former creeks or palaeochannels or by spreads of alluvial material in this former marshy, littoral, environment. No anomalies of probable archaeological potential have been identified by this survey. The detection of magnetic anomalies in another part of the site that have proved on excavation to be caused by archaeological features demonstrates that it is possible to identify archaeological features and deposits in this alluviated environment. Numerous other surveys in the vicinity over the last decade have produced similar results. Therefore, on the basis of the geophysical survey this site is considered to have a low to medium archaeological potential. Nevertheless it should be noted that the depth of alluvium could mask the relatively weak magnetic responses from archaeological features and that consequently the presence of undetected archaeological features cannot be completely dismissed.

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Report Information

Client:	Headland Archaeology Ltd
Report Type:	Geophysical survey
Location:	South Killingholme, near Immingham
County:	North-East Lincolnshire
Grid Reference:	TA 175 175
Period(s) of activity represented:	
Report Number:	1996
Project Number:	3484
Site Code:	IHR09
Planning Application No.:	n/a
Museum Accession No.:	-
Date of fieldwork:	September/October 2009
Date of report:	October 2009
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Fieldwork:	Alex Harrison BSc Ian Wilkins BSc MSc
Report:	Alistair Webb
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Research:	n/a
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1 Introduction

Archaeological Services WYAS was commissioned by Simon Stronach of Headland Archaeology (UK) Ltd on behalf of their clients Drax Power Limited to carry out a program of non-intrusive geophysical evaluation (magnetometer survey) over the proposed laydown area of the proposed Heron Renewable Energy Plant, South Killingholme, near Immingham (see Fig. 1). The survey covered approximately 20 hectares.

The geophysical survey was undertaken to inform an Environmental Impact Assessment and allow the relevant County Council to make an informed decision on any planning application.

Site location, topography and land use

The survey area covered six contiguous fields (see Fig. 2 – A to F), centred at TA 175 175, north-west and south-east of Marsh Lane, and a narrow adjoining strip to the west (see Fig. 2). A railway line marks the site boundary to the north-east with field boundaries/drains demarcating the site limits to all other sides.

The land was flat at below 10m above Ordnance Datum. The three fields to the north of Marsh Lane had been harrowed and the fields to the south were under permanent pasture.

Geology and soils

The solid geology comprises Burnham Chalk overlain with superficial deposits of marine and estuarine alluvium. The soils comprise deep, stoneless, mainly calacareous clays that are classified in the Newchurch 2 soil association.

2 Archaeological background

Numerous geophysical surveys and trial trench evaluations have been undertaken in the last decade in advance of the development of the land between East Halton, North and South Killingholme and the Humber Estuary. Many of these have identified pockets of settlement dating from the Iron Age to the early post-Roman period, predominantly slightly further inland than the site under evaluation here, such as on the site now occupied by the gas power station and the oil refineries, but also on more marginal land closer to the estuary. In these locations evidence of settlement have been found sometimes on small ‘islands’ that were slightly elevated above the former salt marshes.

3 Aims, Methodology and Presentation

The general aim of the geophysical survey was to obtain information that would evaluate the archaeological potential of the proposed laydown area. This information would then enable further evaluation and/or mitigation measures to be designed as appropriate.

Specifically the aims were:

- To interpret any geophysical anomalies identified by the survey and thereby
- To determine (so far as is possible) the presence and extent or absence of buried archaeological remains in the area that will be directly impacted by the construction and operation of the renewable energy plant.

These aims were to be achieved by undertaking detailed magnetometer survey across the whole of the proposed laydown area.

All the survey areas were set out and tied-in to existing boundaries and structures using a Trimble theodolite and superimposed onto a digital Ordnance Survey map base supplied by the client.

Magnetometer survey

For the survey Bartington Grad601 instruments were used to take readings at 0.25m intervals on zig-zag traverses 1m apart within 20m by 20m grids so that 1600 readings were recorded in each grid. These readings were stored in the memory of the instrument and later downloaded to computer for processing and interpretation. Geoplot 3 (Geoscan Research) software was used to process and present the data. Further details are given in Appendix 1. Detailed survey allows the visualisation of weaker anomalies that may not have been readily identifiable by magnetometer (magnetic) scanning.

Reporting

A general site location plan, incorporating the 1:50000 Ordnance Survey mapping is shown in Figure 1. Figure 2 and Figure 3 show nearby survey results and cropmark detail respectively. The processed greyscale data, the 'raw' XY trace plot data and interpretation figures are presented at a scale of 1:1000 in Figures 4 to 18 inclusive.

Further technical information on the equipment used, data processing and survey methodologies are given in Appendix 1 and Appendix 2. Appendix 3 describes the composition and location of the site archive.

The survey methodology, report and any recommendations comply with guidelines outlined by English Heritage (David *et al* 2008) and by the IfA (Gaffney, Gater and Ovenden 2002). All figures reproduced from Ordnance Survey mapping are with the permission of the controller of Her Majesty's Stationery Office (© Crown copyright – OS Licence No. 100023320).

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.

4 Results

The anomalies identified during the survey can be classified into three categories.

Linear, dipolar anomalies

These anomalies are caused by buried pipes. One pipe runs along the north-eastern edge of Field F and a second runs west/east across the northern half of Field B and along the northern edge of Field C.

Areas of magnetic disturbance

Individual dipolar 'iron spike' anomalies are prevalent across all parts of the site. Although these could be caused by archaeological artefacts unless there is other information or evidence to suppose an archaeological interpretation they are usually assumed to be due to modern ferrous rubbish either on the ground surface or in the plough soil. On this site there are several clusters of 'spike' responses but in all instances there is evidence to support a modern interpretation. The data from the westernmost quarter of Field A has a speckled appearance due to the frequency and extent of the ferrous responses. However, this area was until recently separated from the remainder of the field and was used for allotments (Dinsdale pers. com.). Other clusters can be seen along the field boundaries, particularly adjacent to the drains that divide the fields. It is assumed that the clustering is due to the accumulation of ferrous material in the drains that is then spread around the field edges when the drains are periodically cleaned out.

Areas of magnetic enhancement

Numerous broad, linear and curvilinear anomalies with no discernible pattern can be seen across all parts of the site. These anomalies are particularly densely clustered and extensive in Field A and Field B and least prevalent in Field C. Despite the linearity of some of these anomalies none is interpreted as having a potential archaeological origin. Rather these anomalies are interpreted as being caused by natural variation in the soils and superficial geology due to the intermittent and periodic inundation of this littoral environment before the salt marshes were drained and reclaimed over the last 250 years. Evidence for the former state of the land is reflected in place names such as Marsh Lane and Marsh Farm.

5 Discussion and Conclusions

No anomalies of any archaeological potential have been identified by the magnetometer survey. Although it is acknowledged that recent flooding of the site may have resulted in archaeological horizons being potentially buried too deeply under alluvium to enable them to be identified by magnetometer survey it is considered more likely that this particular area is just too close to the former estuary edge to have been occupied in prehistoric or later periods.

Indeed possible evidence of Romano-British settlement has been identified on another part of the site which is approximately 0.4km further inland than the area currently under survey.

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.

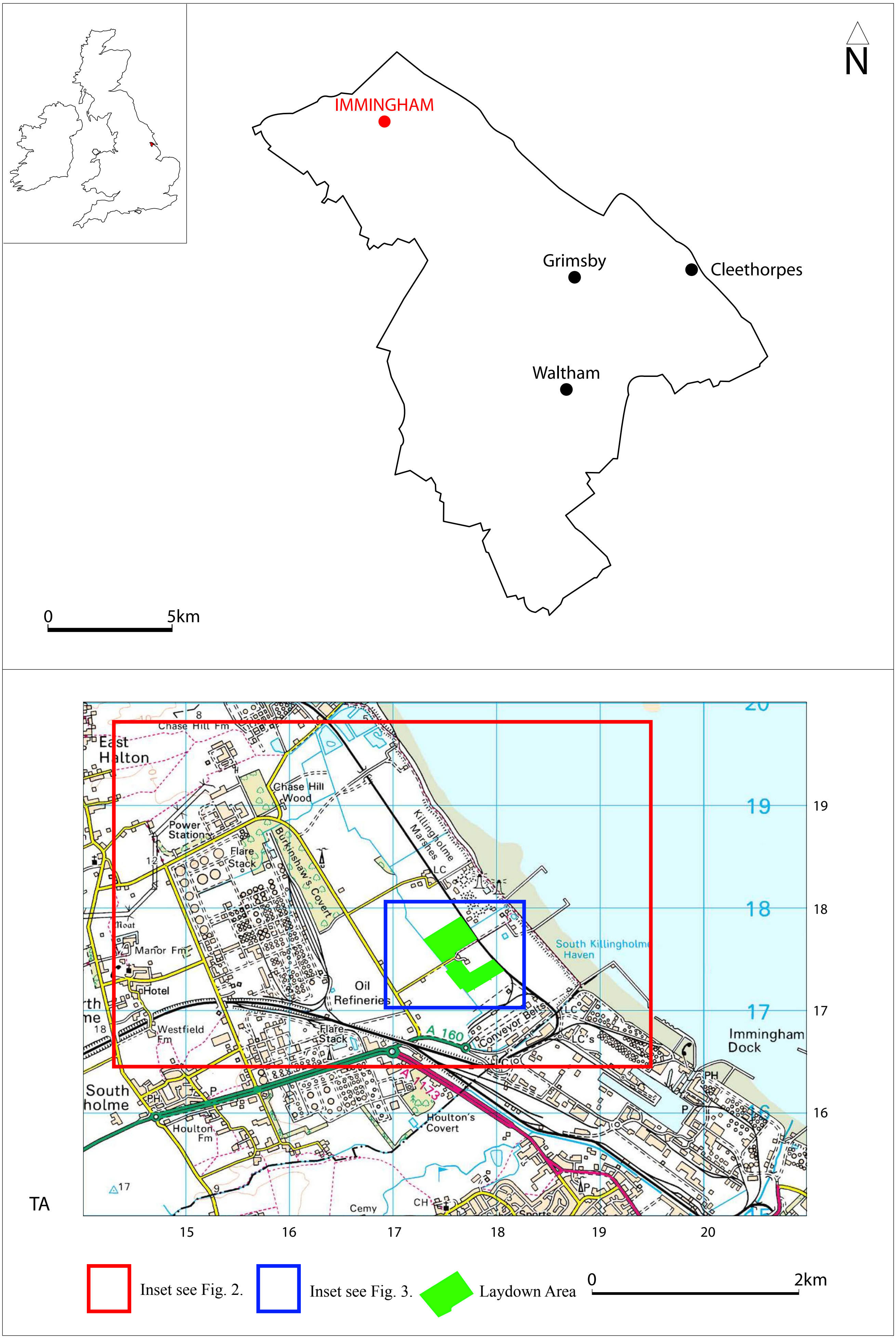

Fig. 1. Site location

Fig. 2. Site location showing previous geophysical surveys in the vicinity (1:12500 @ A3)

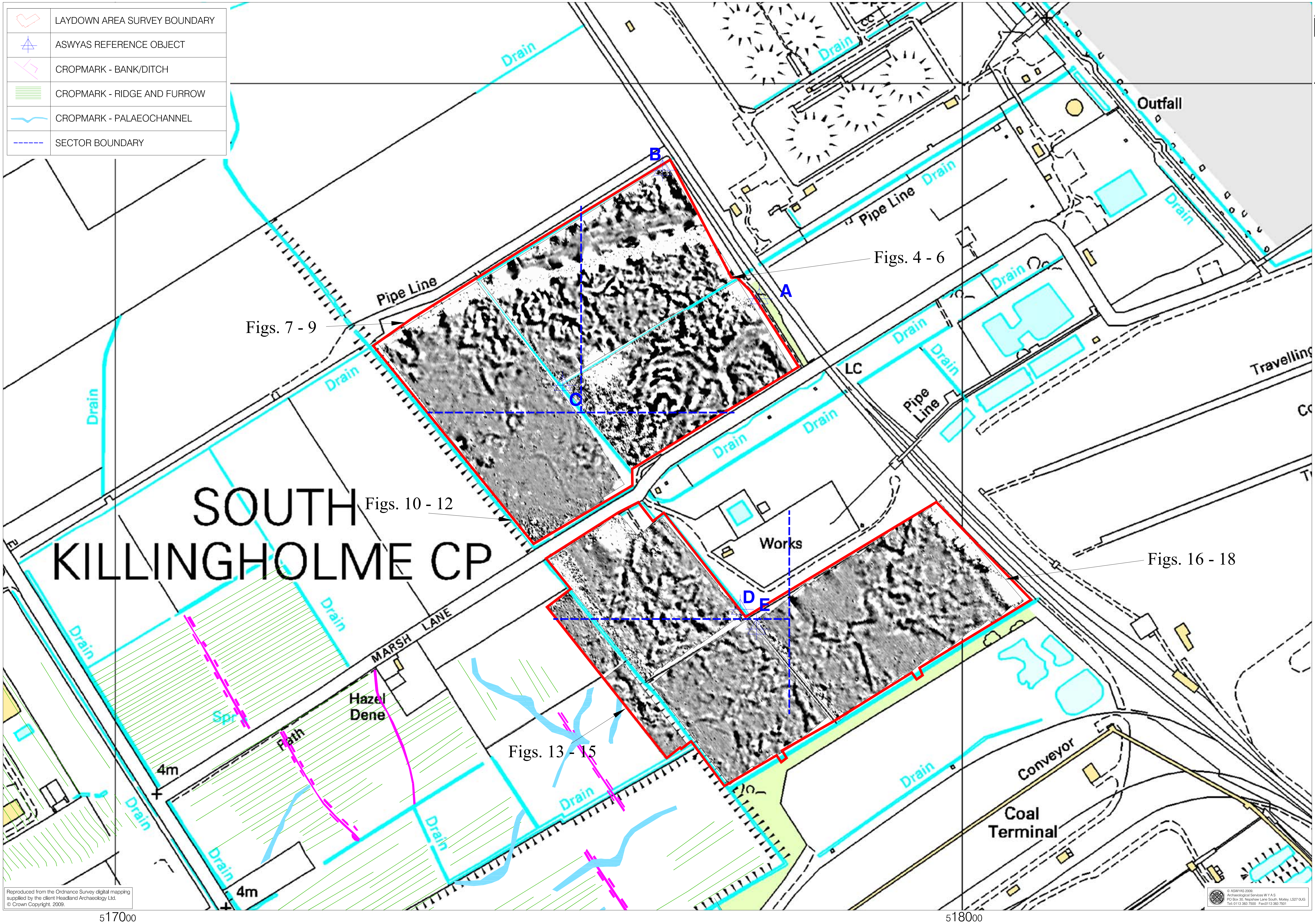

Fig. 3. Processed greyscale magnetometer data, cropmark detail and sector divisions (1:4000 @ A3)

0 100m

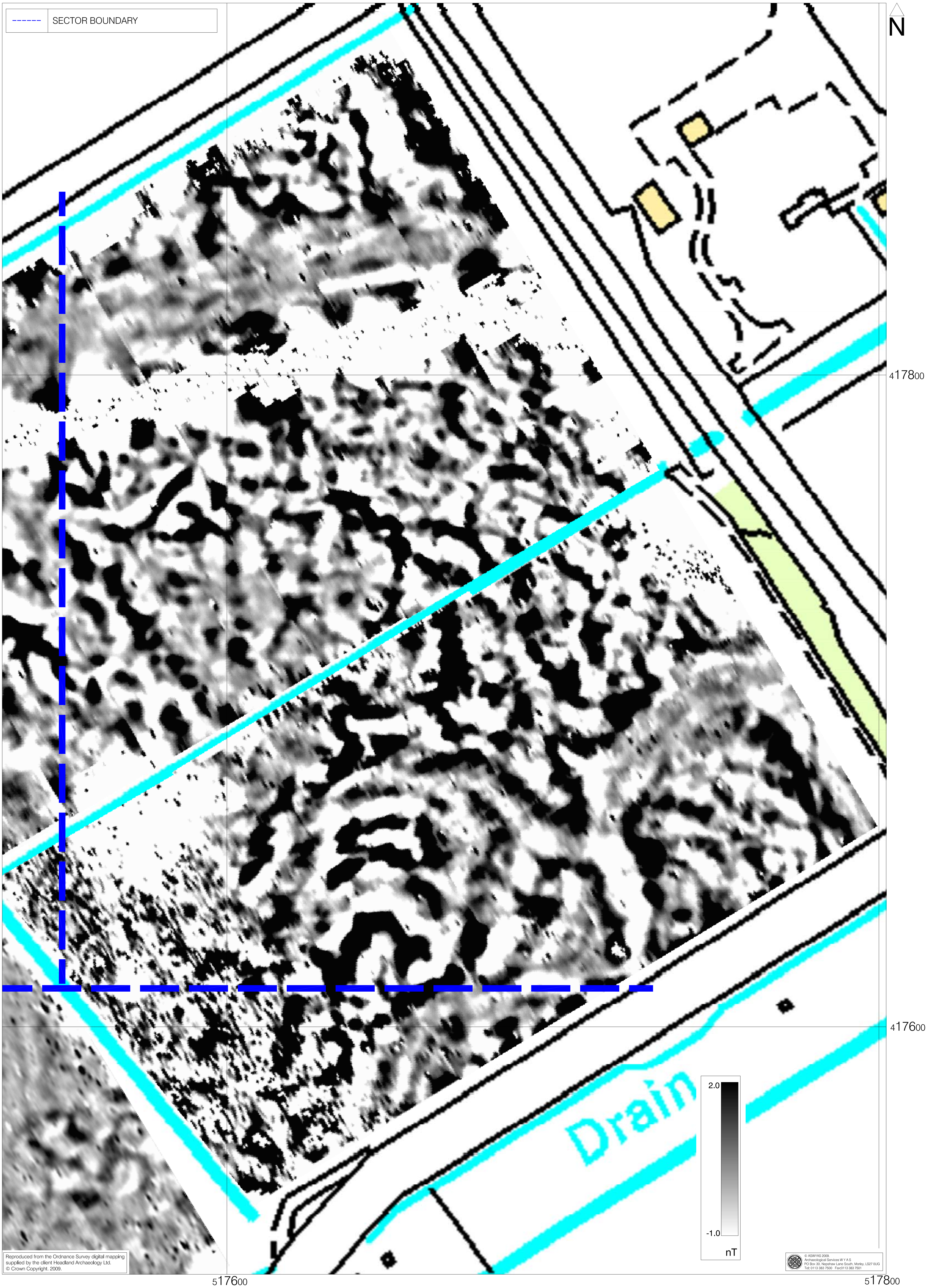

Fig. 4. Processed greyscale magnetometer data; Field A and Field B, east (1:1000 @ A4)

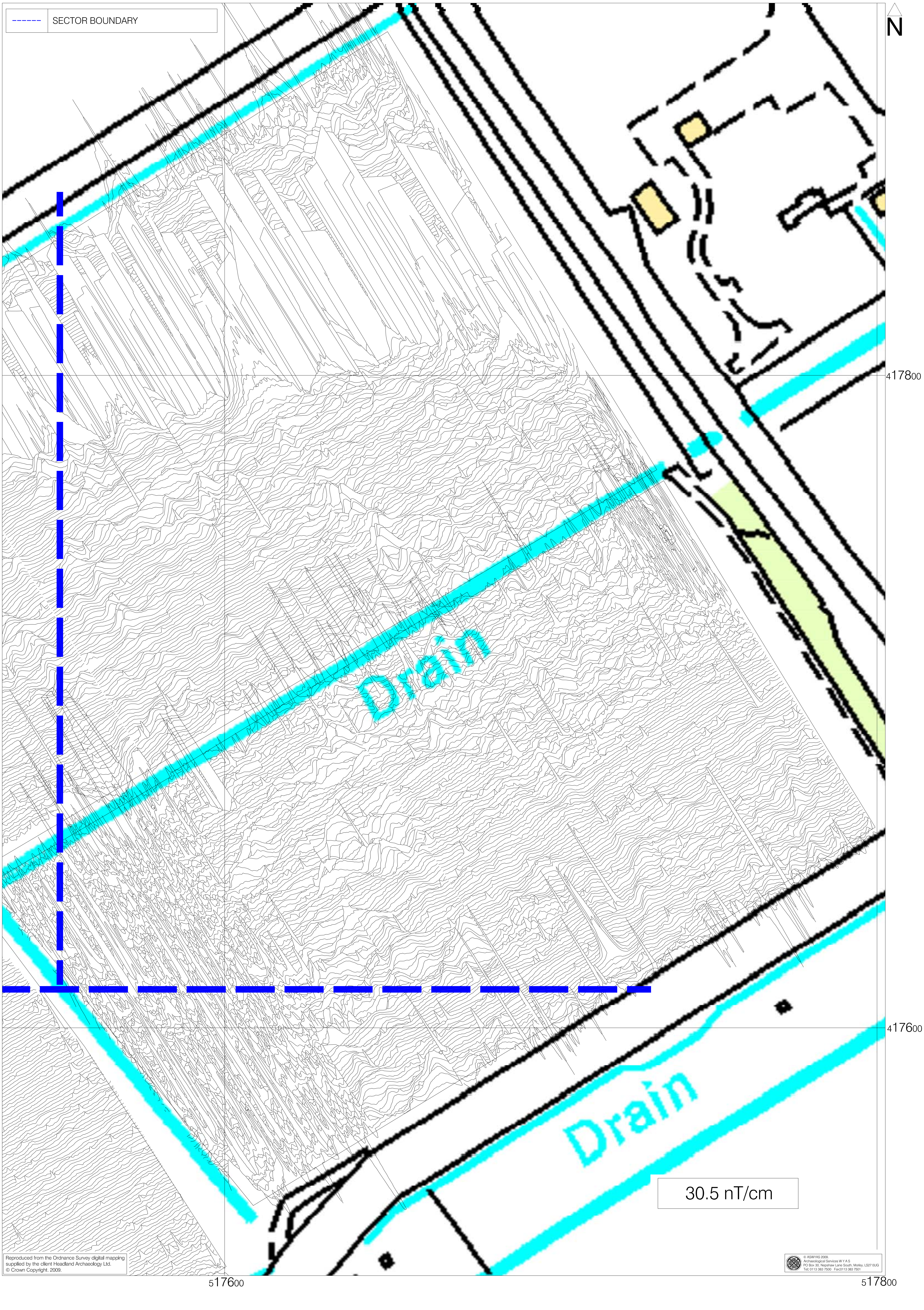

Fig. 5. XY trace plot of unprocessed magnetometer data; Field A and Field B, east (1:1000 @ A3)

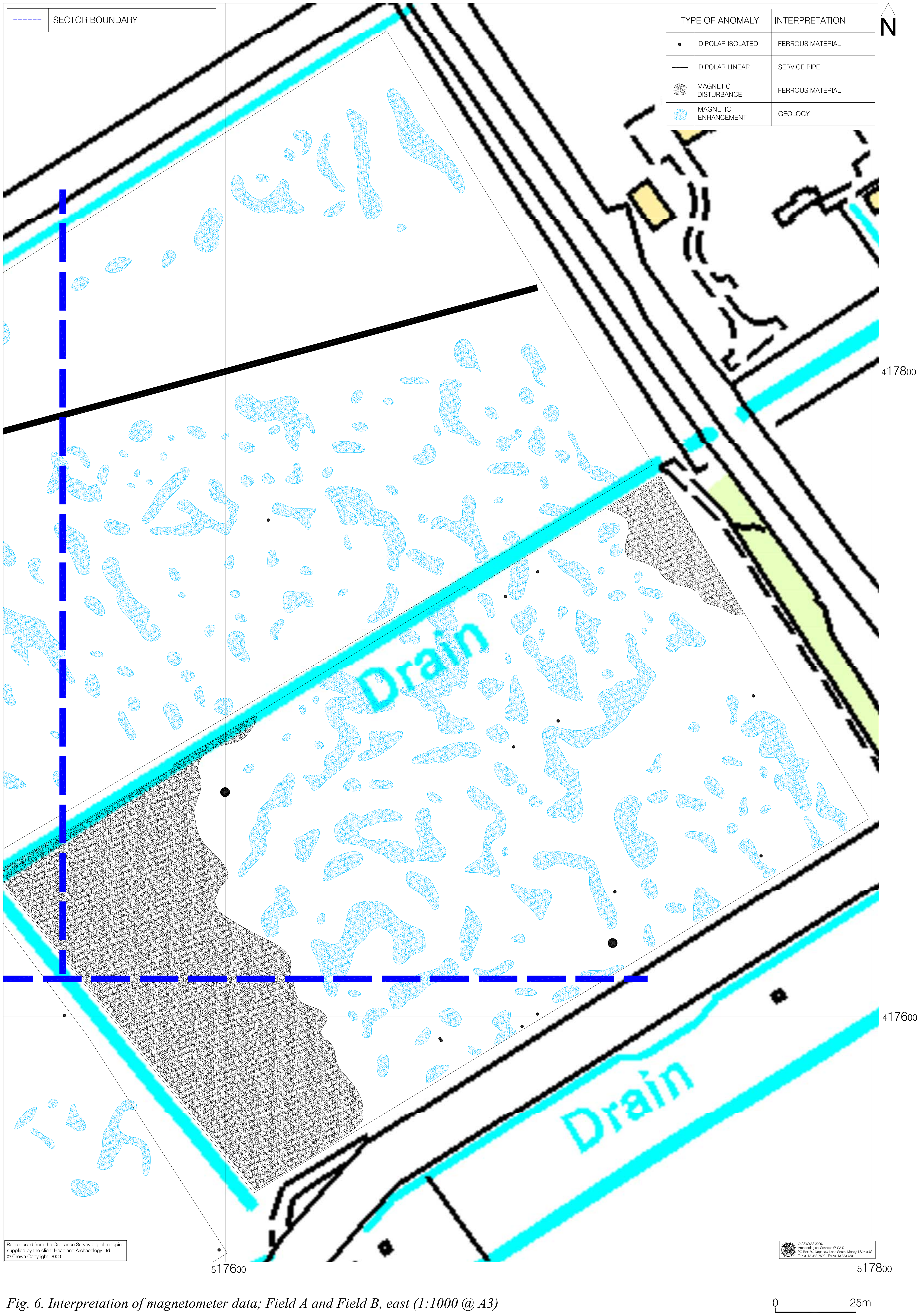

Fig. 6. Interpretation of magnetometer data; Field A and Field B, east (1:1000 @ A3)

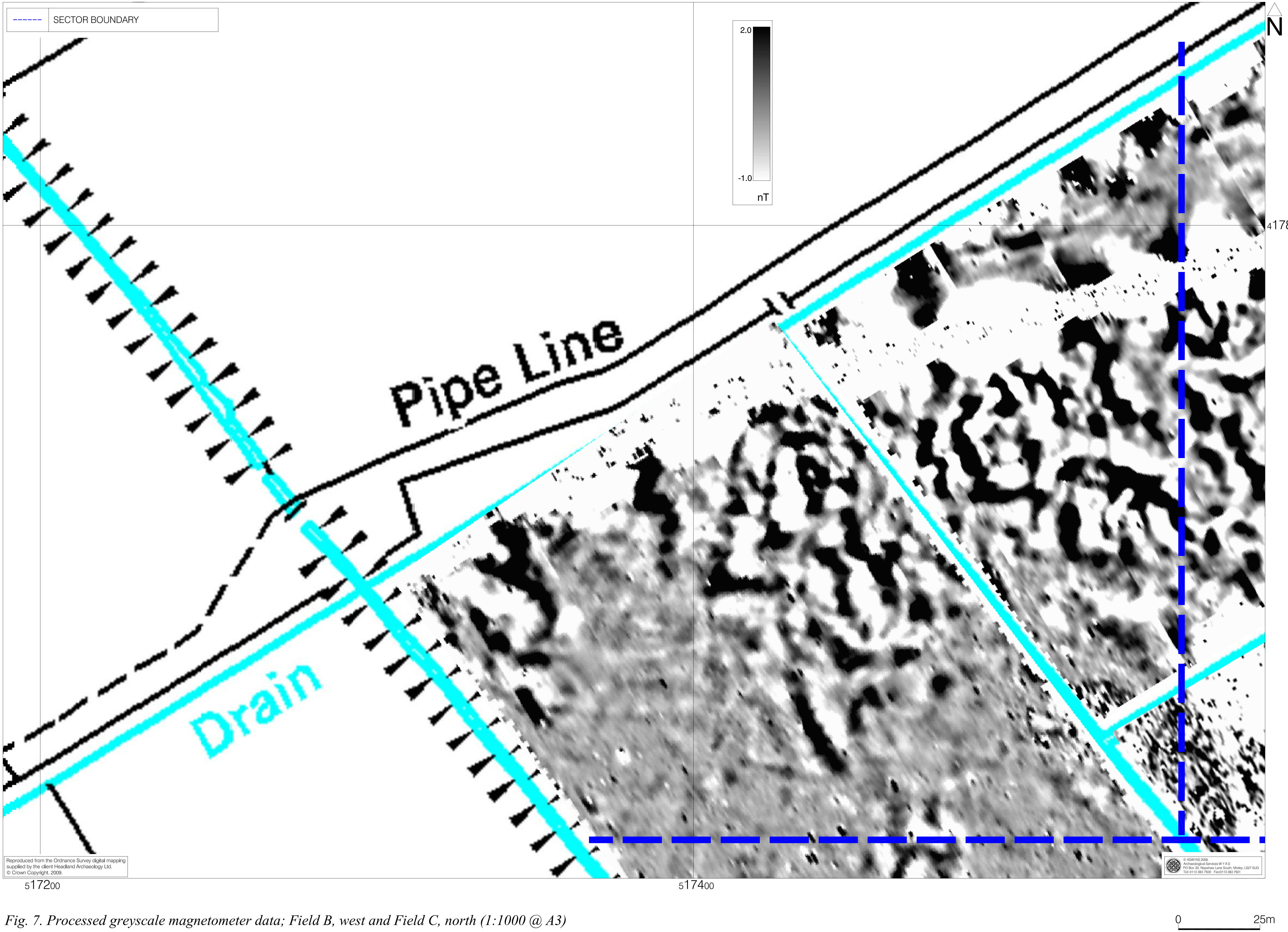

Fig. 7. Processed greyscale magnetometer data; Field B, west and Field C, north (1:1000 @ A3)

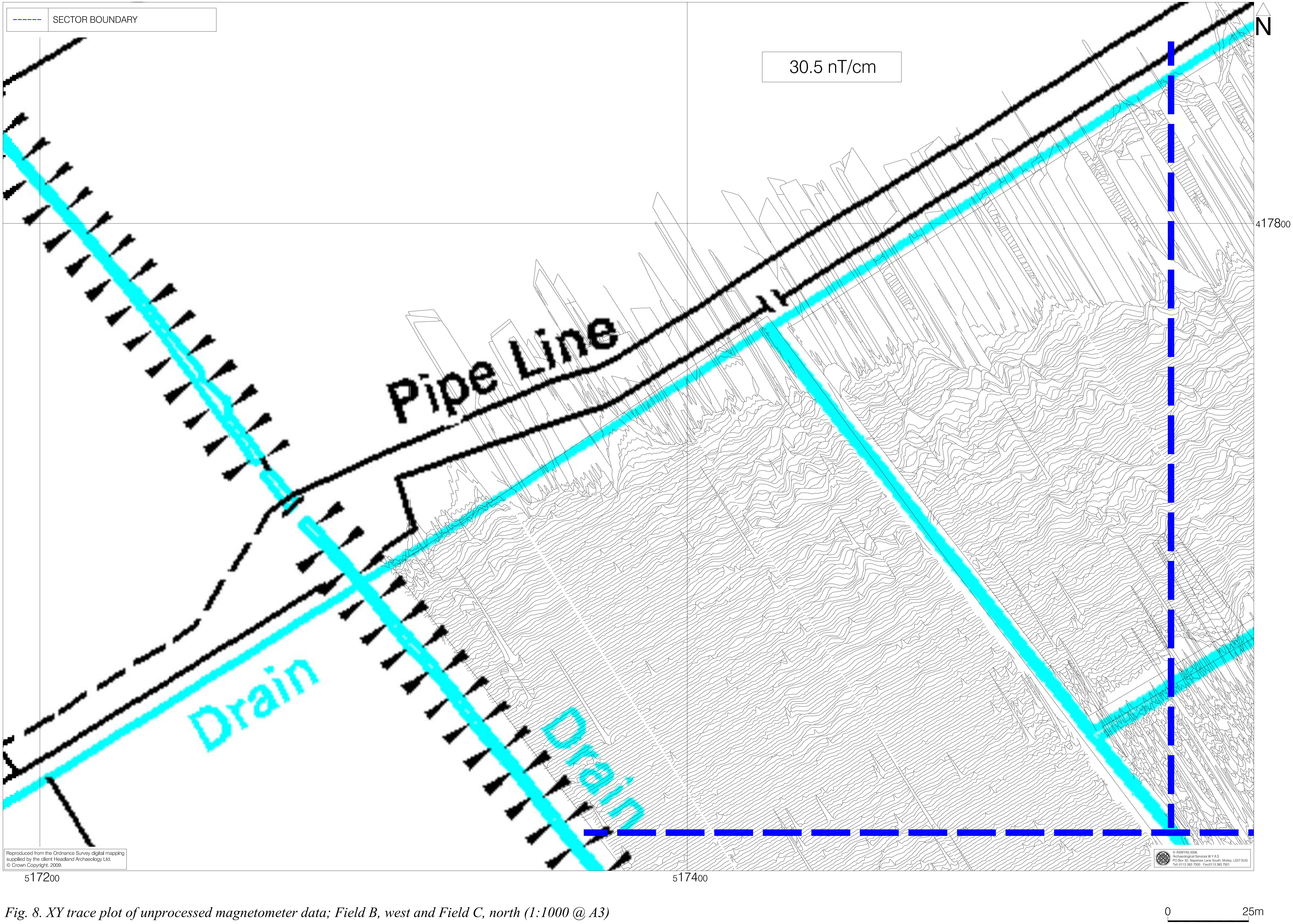

Fig. 8. XY trace plot of unprocessed magnetometer data; Field B, west and Field C, north (1:1000 @ A3)

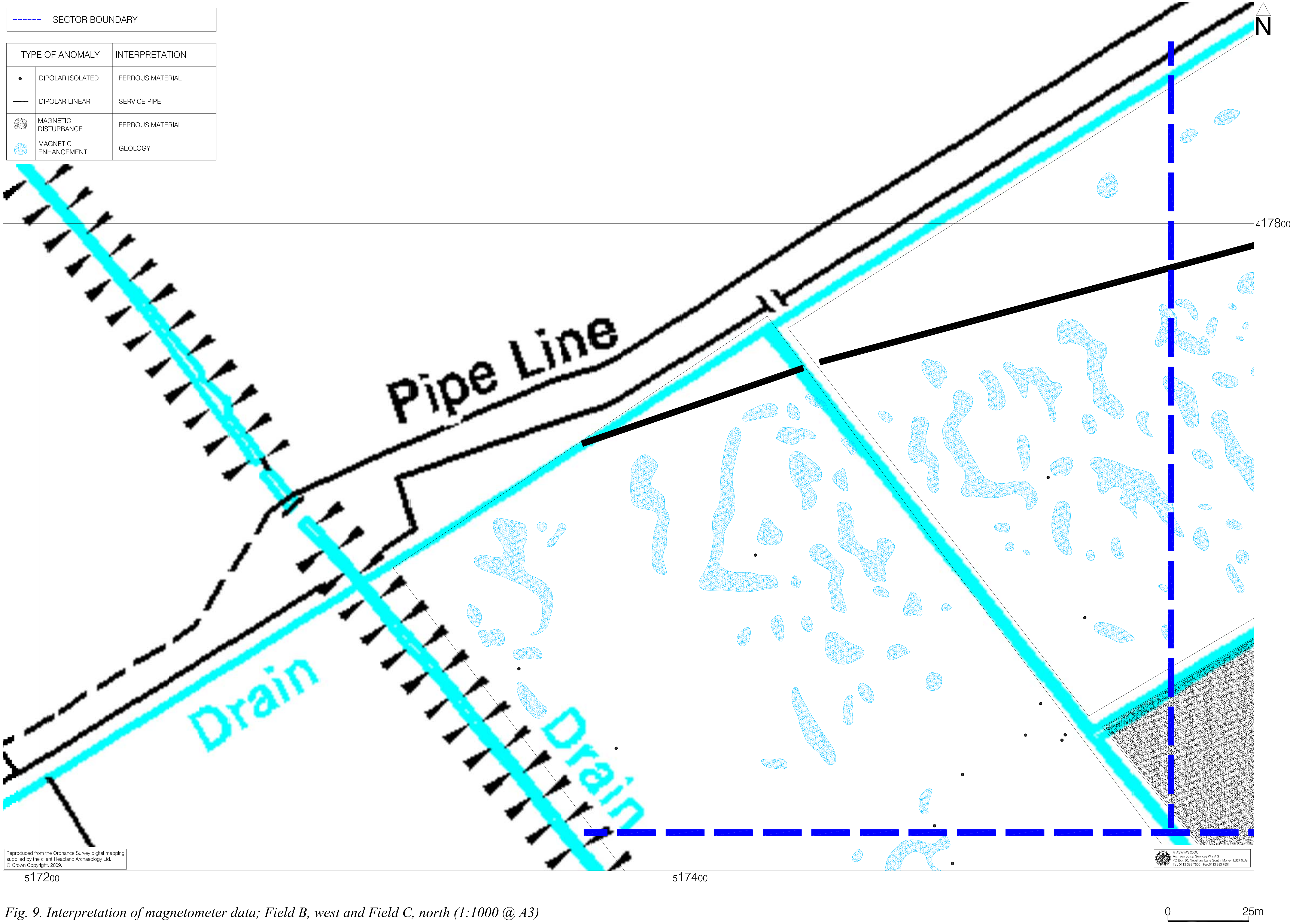

Fig. 9. Interpretation of magnetometer data; Field B, west and Field C, north (1:1000 @ A3)

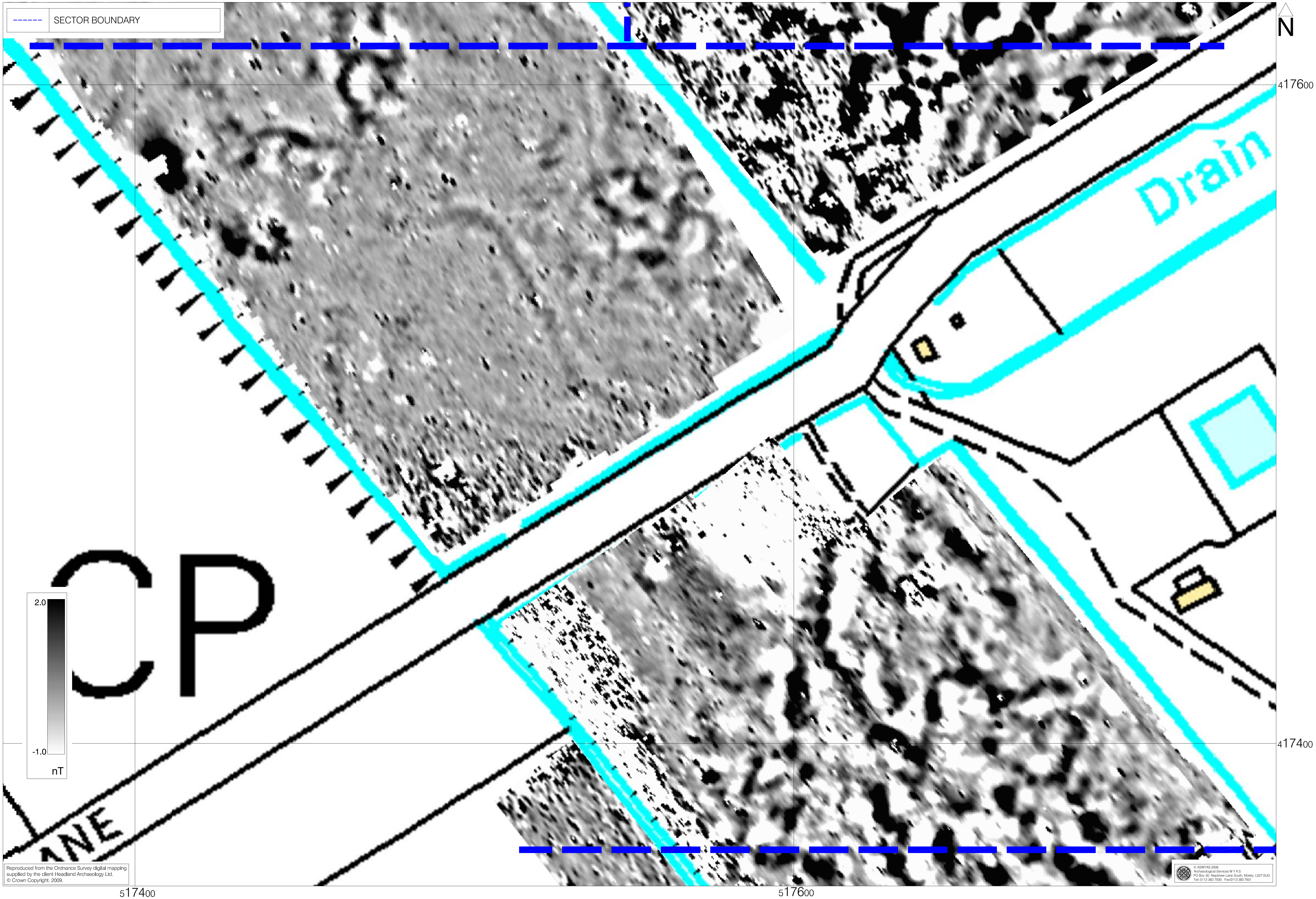

Fig. 10. Processed greyscale magnetometer data; Field C, south and Field D, north (1:1000 @ A3)

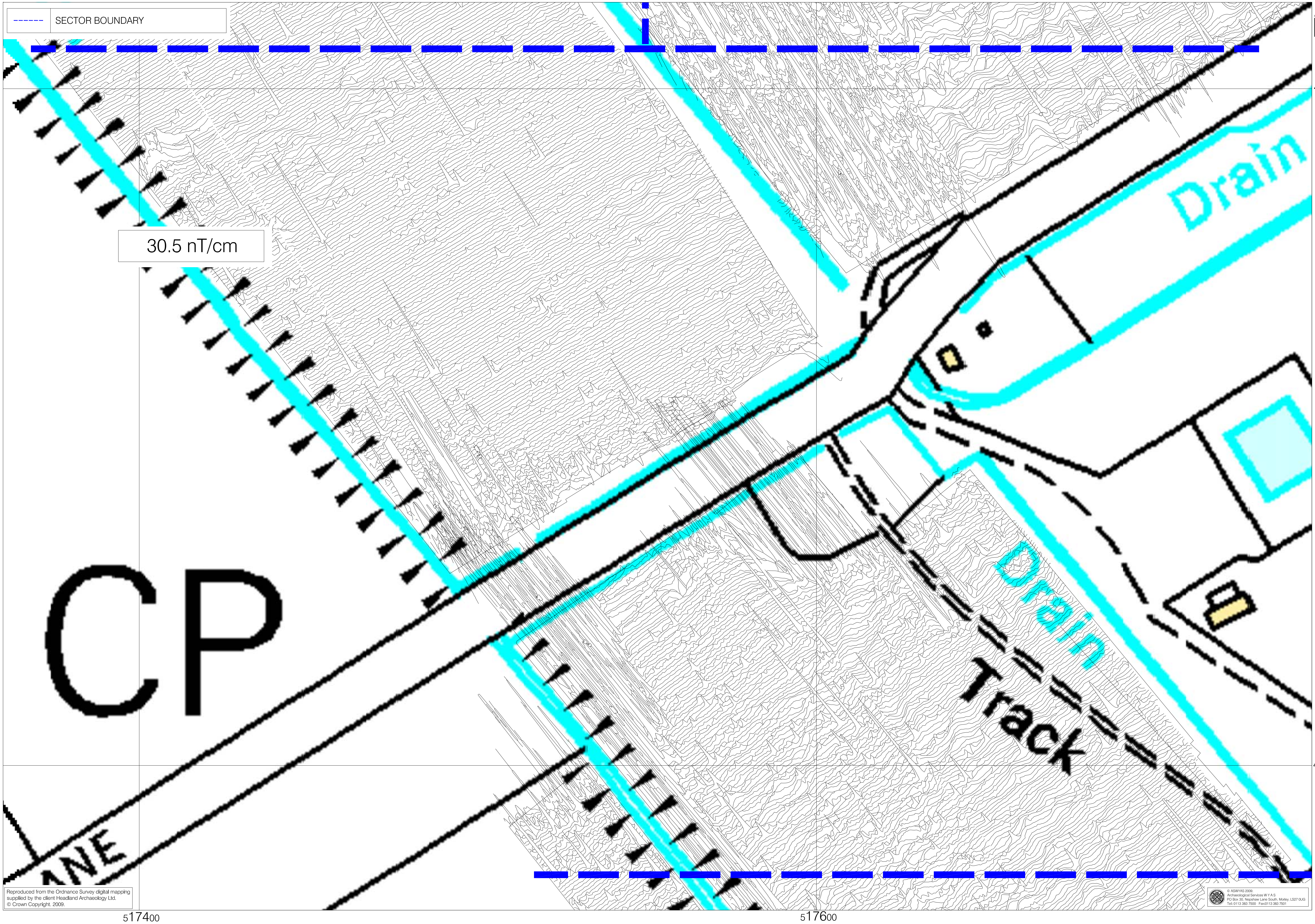

Fig. 11. XY trace plot of unprocessed magnetometer data; Field C, south and Field D, north (1:1000 @ A3)

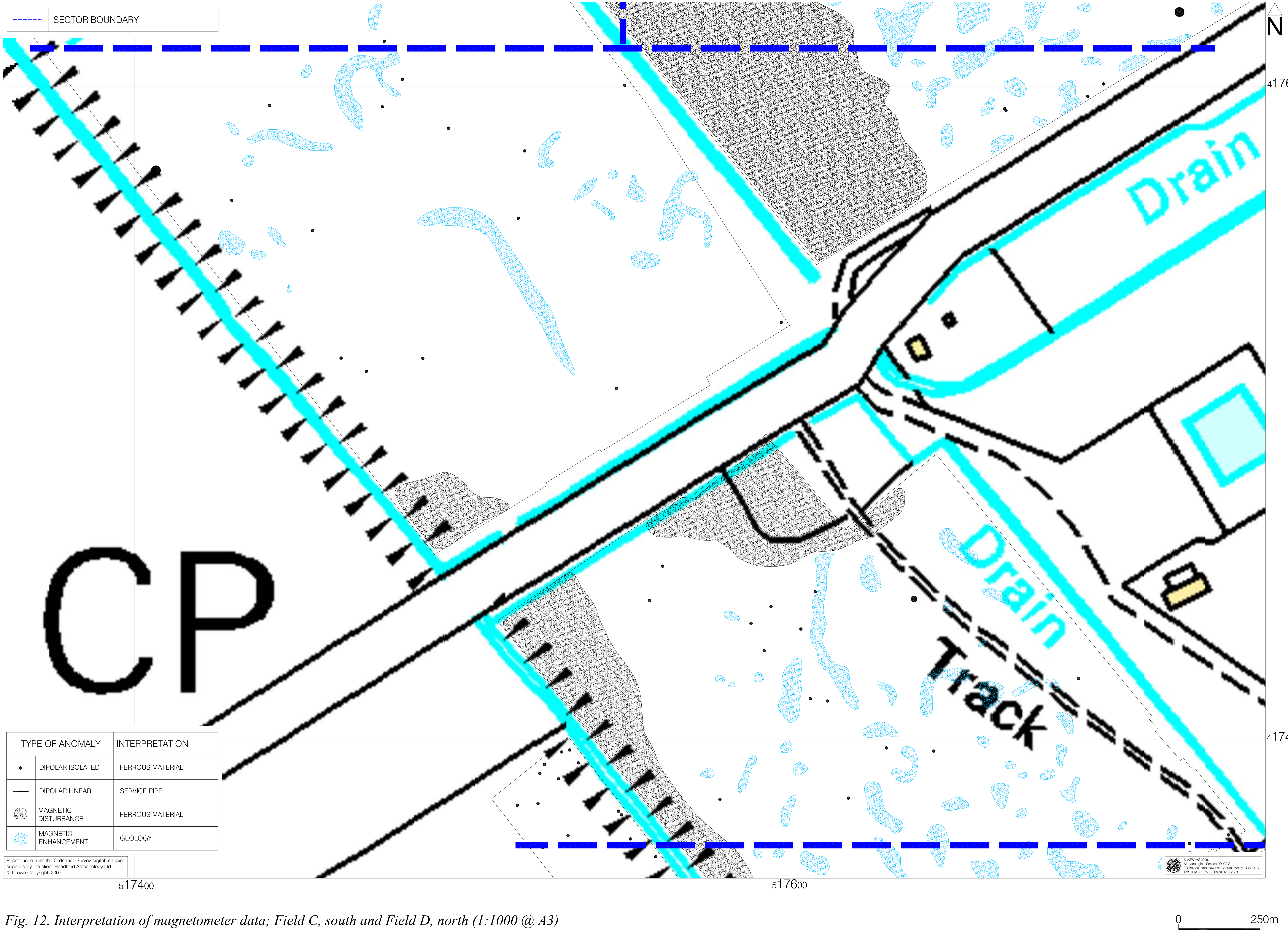

Fig. 12. Interpretation of magnetometer data; Field C, south and Field D, north (1:1000 @ A3)

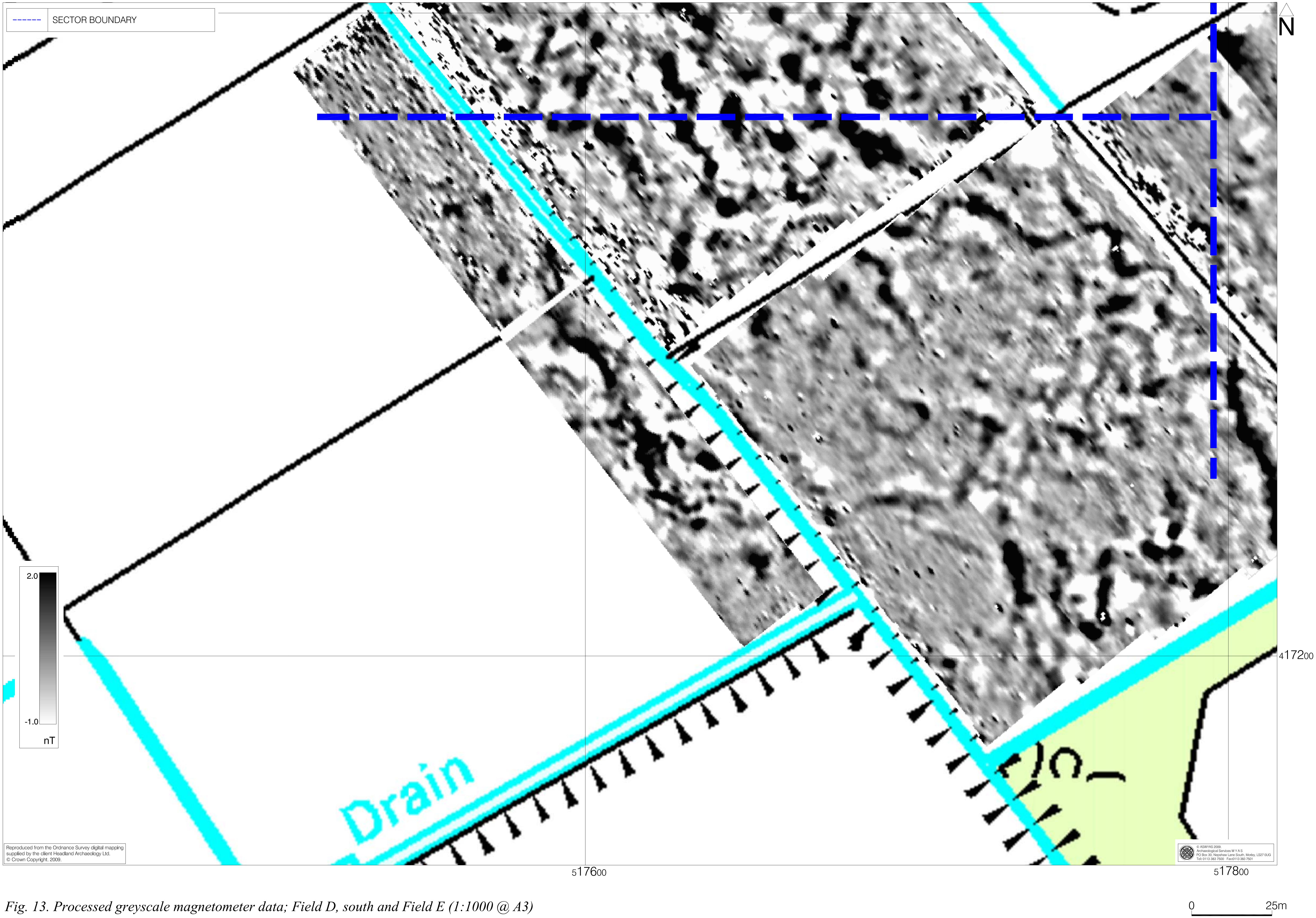

Fig. 13. Processed greyscale magnetometer data; Field D, south and Field E (1:1000 @ A3)

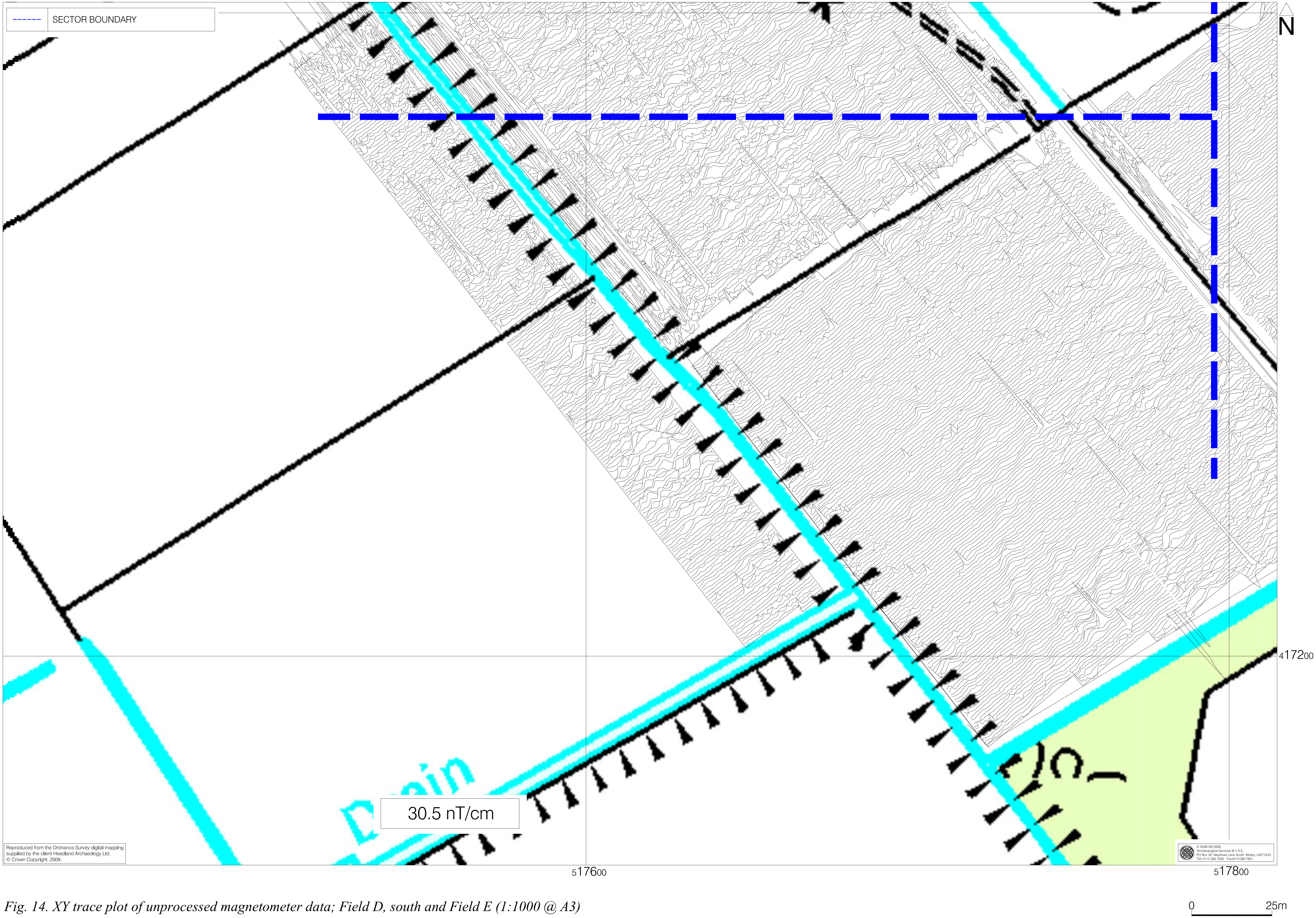

Fig. 14. XY trace plot of unprocessed magnetometer data; Field D, south and Field E (1:1000 @ A3)

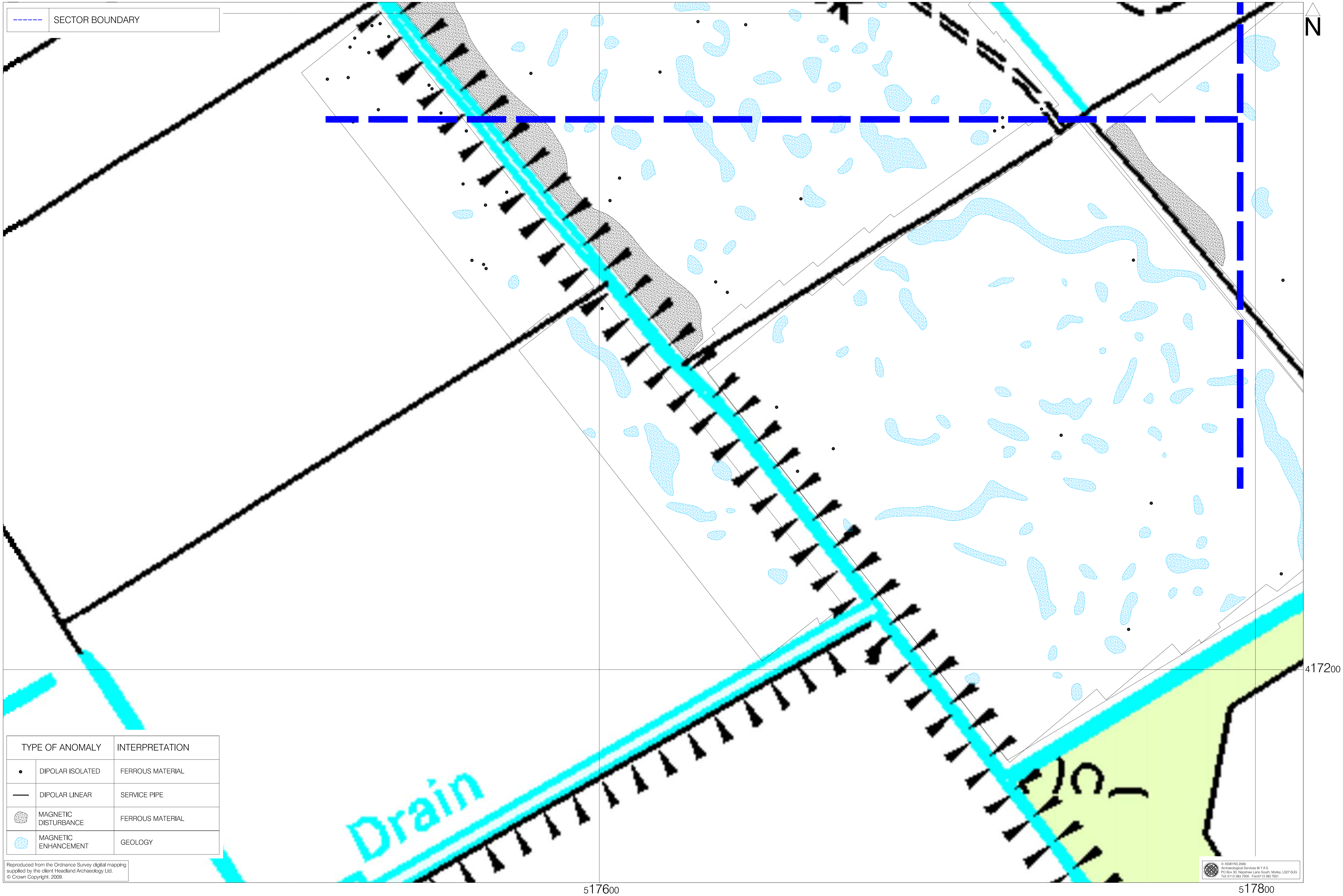

Fig. 15. Interpretation of magnetometer data; Field D, south and Field E (1:1000 @ A3)

0 25m

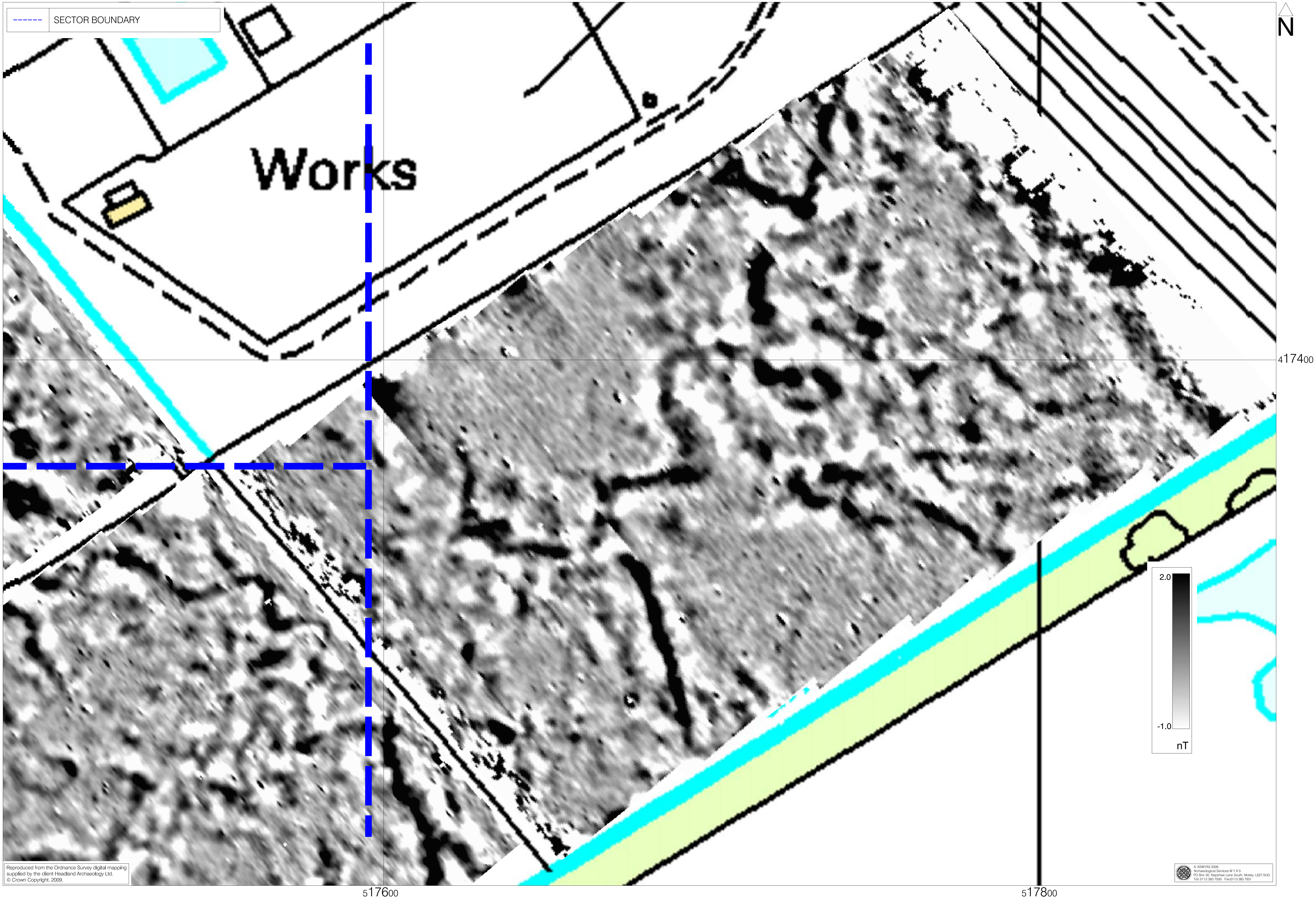

Fig. 16. Processed greyscale magnetometer data; Field F (1:1000 @ A3)

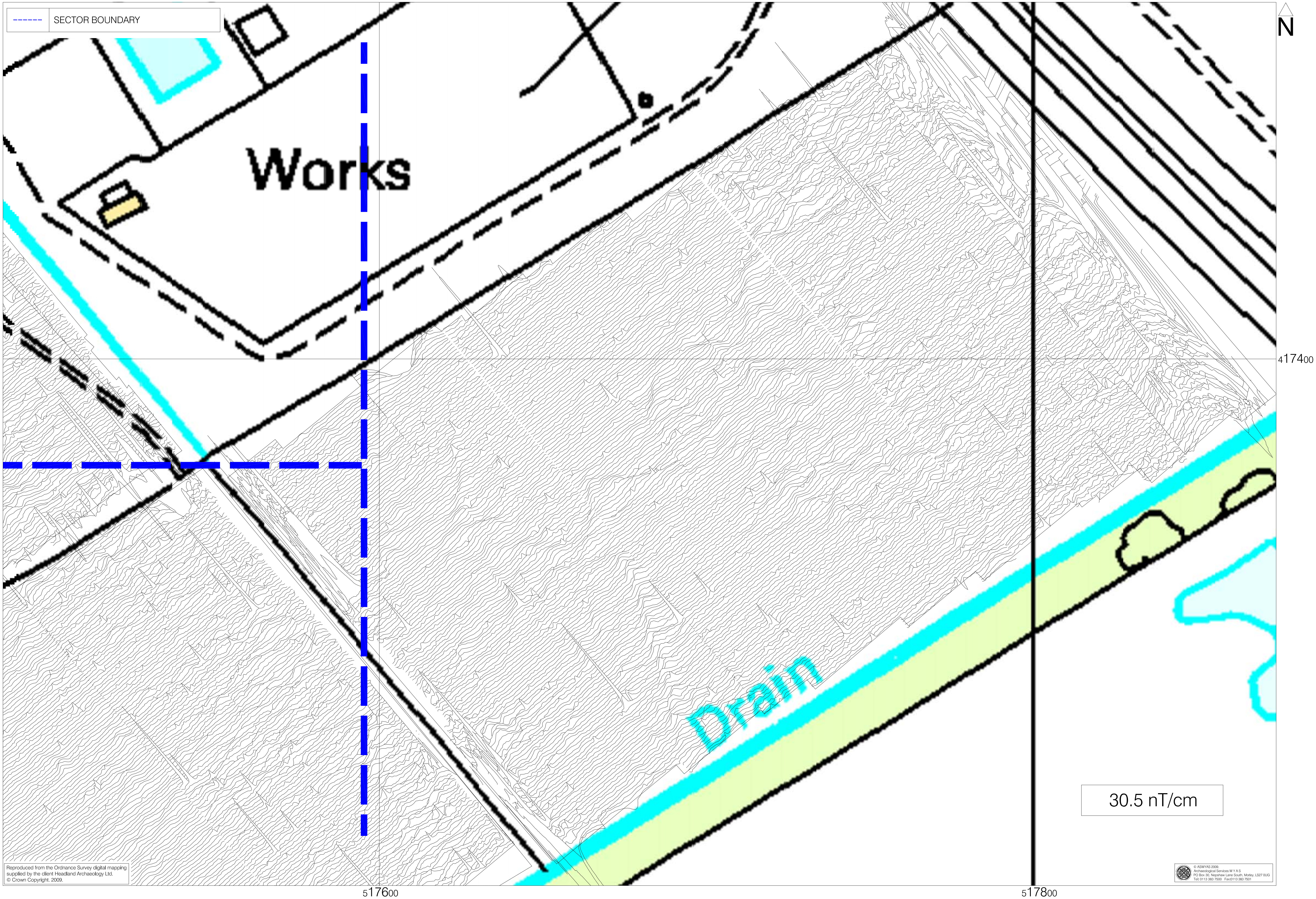

Fig. 17. XY trace plot of unprocessed magnetometer data; Field F (1:1000 @ A3)

0 25m

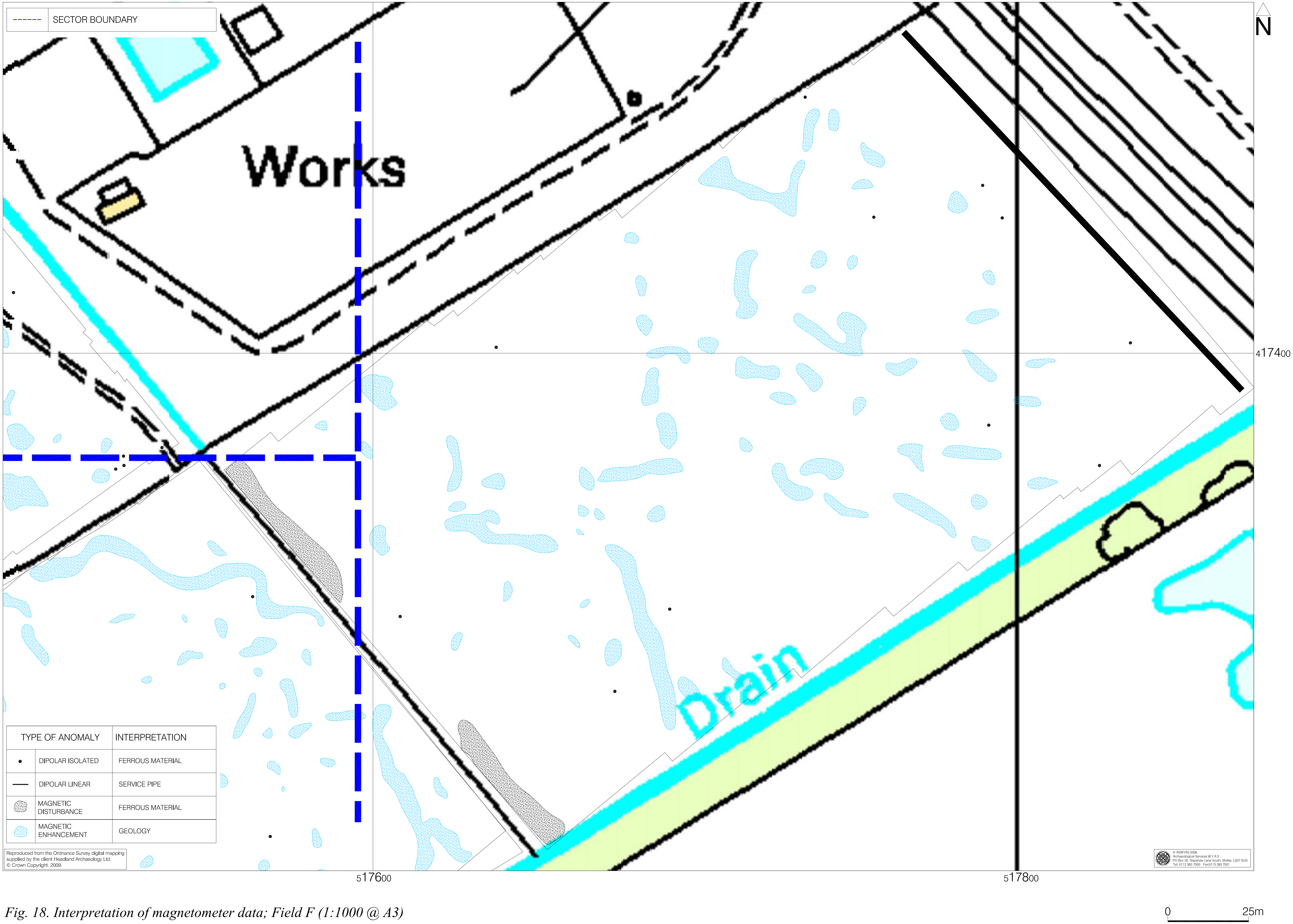

Fig. 18. Interpretation of magnetometer data; Field F (1:1000 @ A3)

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. The magnetic susceptibility of a soil can also be enhanced by the application of heat and the fermentation and bacterial effects associated with rubbish decomposition. The area of enhancement is usually quite large, mainly due to the tendency of discard areas to extend beyond the limit of the occupation site itself, and spreading by the plough. An advantage of magnetic susceptibility over magnetometry is that a certain amount of occupational activity will cause the same proportional change in susceptibility, however weakly magnetic is the soil, and so does not depend on the magnetic contrast between the topsoil and deeper layers. Susceptibility survey is therefore able to detect areas of occupation even in the absence of cut features. On the other hand susceptibility survey is more vulnerable to the masking effects of layers of colluvium and alluvium as the technique, using the Bartington system, can generally only measure variation in the first 0.15m of ploughsoil.

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.

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. These anomalies are often caused by agricultural activity, either ploughing or land drains being 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. For field surveys a Bartington MS2 meter with MS2D field loop is used due to its speed and simplicity. 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 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 a 'negative' scanning result should be validated by 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 0.25m 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 3600 readings were obtained for each 30m by 30m 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 into local boundaries and other permanent landscape features and to temporary reference points (survey marker stakes) that were established and left in place at the completion of the fieldwork for accurate geo-referencing. The locations of the temporary reference points are shown on Figure 3 and the Ordnance Survey grid co-ordinates tabulated below. The internal accuracy of these markers is better than 0.05m. The survey grids were then super-imposed onto a base map provided by the client as a 'best fit' to produce the displayed block locations. It is estimated that the average 'best fit' error is better than +/- 1.5m. However, it should be noted that Ordnance Survey positional accuracy for digital map data has an error of 0.5m for urban and floodplain areas, 1.0m for rural areas and 2.5m for mountain and moorland areas. This potential error must be considered if co-ordinates are measured off for relocation purposes.

Station	Easting	Northing
A	517759.8299	417746.3148
B	517645.6365	417898.2624
C	517527.7175	417643.9087
D	517737.4209	417379.1804
E	517756.7308	417355.9108

Archaeological Services WYAS cannot accept responsibility for errors of fact or opinion resulting from data supplied by a third party.

Appendix 3: Geophysical archive

The geophysical archive comprises:-

- an archive disk containing compressed (WinZip 8) files of the raw data, report text (Microsoft Word 2000), and graphics files (Adobe Illustrator CS2 and AutoCAD 2008) 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 may 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).

Bibliography

David, A., N. Linford, P. Linford and L. Martin, 2008. *Geophysical Survey in Archaeological Field Evaluation: Research and Professional Services Guidelines (2nd edition)* English Heritage

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