ARCHAEOLOGICAL SERVICES WYAS

Yorkshire and Humber Carbon Capture Scheme (CCS)
Cross Country Pipeline
Camblesforth to Tollingham
North Yorkshire

Geophysical Survey

Report no. 2600

March 2014

Client: AECOM

REGISTERED · IfA · ORGANISATION

Yorkshire and Humber Carbon Capture Scheme (CCS) Cross Country Pipeline

Camblesforth to Tollingham

(North Yorkshire Section)

Geophysical Survey

Summary

A geophysical (magnetometer) survey, covering approximately 76.5 hectares, was carried out along the preferred route of the Camblesforth to Tollingham (North Yorkshire) section of the Yorkshire and Humber Carbon Capture Scheme (CCS) Cross Country Pipeline. The proposed locations of a Compressor Station and Pipeline Inspection Gauges were also surveyed. Anomalies caused by recent and historic agricultural practice, geological variation and modern activity have been located throughout the corridor. Two areas of possible archaeological interest have been identified – probable former field boundaries which pre-date the first edition Ordnance Survey map (1853) and possible ploughed-out medieval fish ponds. Therefore, on the basis of the geophysical survey, the archaeological potential is assessed as being low throughout the corridor.

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Report Information

Client:	AECOM
Address:	5th Floor, 2 City Walk, Leeds, LS11 9AR
Report Type:	Geophysical Survey
Location:	Camblesforth to Tollingham
County:	North Yorkshire
Grid Reference:	SE 6690 2530 and SE 6680 2820 to SE 6915 2700
Period(s) of activity:	Medieval?/post-medieval?
Report Number:	2600
Project Number:	3992
Site Code:	DVC12
OASIS ID	archaeol11-177729
Planning Application No.:	
Date of fieldwork:	November 2012 – December 2013
Date of report:	March 2014
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Authorisation for distribution: ---

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1 Introduction

Archaeological Services WYAS (ASWYAS) were commissioned by AECOM, on behalf of their client, National Grid, to undertake a programme of geophysical (magnetometer) survey along the proposed route of the Yorkshire and Humber Carbon Capture Scheme (CCS) Cross Country Pipeline and its associated infrastructure. The proposed route runs from Drax Power Station, in North Yorkshire, to the east coast near Barmston, in East Yorkshire (see Fig. 1), a distance of 74 kilometres. The route is divided into four sections – Camblesforth to Tollingham, Tollingham to Dalton, Dalton to Skerne and Skerne to Barmston. The Camblesforth to Tollingham section crosses the county boundary between North and East Yorkshire and therefore, to allow for ease of reporting and administration purposes, this section is further subdivided into North Yorkshire and East Yorkshire sections.

This report relates to the Camblesforth to Tollingham (North Yorkshire) section, which runs from Drax Power Station to the River Ouse. It includes the proposed site of a Compressor Station to the south of Drax, the proposed site of Pipeline Inspection Gauges to the north of the Power Station and two proposed set-down areas to the south-east of Drax village (see Fig. 2). During the course of the survey the route of the pipeline corridor and location and extent of infrastructure was revised. Waterlogging and access issues also restricted access in certain areas. The scheme boundary shown on all figures represents the current proposals; previous boundaries are not displayed. Any apparent 'gaps' in the survey or areas surveyed 'outside' the displayed corridor are due to the reasons outlined above. The scheme of work was undertaken in accordance with guidance contained with the National Planning Policy Framework (2012) and to a Written Scheme of Investigation (WSI), produced by AECOM and approved by North Yorkshire County Council and Humber Archaeology Partnership. The geophysical survey was carried out between November 27th 2012 and December 3rd 2013.

Site location, land-use and topography

The Camblesforth to Tollingham (North Yorkshire) section starts from a proposed Compressor Station, SE 6690 2530, to the south of Drax Power Station running in a north-easterly direction. To the south-east of Drax, the route divides and an arm runs to the north of the power station to the site of proposed Pipeline Inspection Gauges, SE 6680 2820. The route ends at the River Ouse, SE 6915 2700, also the county boundary (see Fig. 2). This section of the route crosses predominantly arable farmland with occasional pasture fields. The section is notably flat with the topography varying little between 3m above Ordnance Datum (aOD) and 5m aOD.

Geology and soils

The underlying bedrock comprises sandstone of the Sherwood Sandstone Group which are overlain by a mixture of alluvium and glaciolacustrine deposits including sands, gravels, clays and silts (British Geological Survey 2013). The soils along this section comprise a mixture of fine and coarse silts - marine alluvium of the Blacktoft soil association and deep, well-drained coarse loams and sands – glaciofluvial drift of the Wick 1 soil association (Soil Survey of England and Wales, 1983).

2 Archaeological Background

The following archaeological background is summarised from draft baseline information provided by the client. A more detailed and comprehensive assessment of the archaeological background will be contained within the Environmental Impact Assessment (EIA), currently in preparation. Preliminary data from the EIA does, however, indicate more than 257 archaeological records within the Camblesforth to Tollingham search area (as entered on the North Yorkshire Historic Environment Record, Humber Archaeological Partnership Sites and Monuments Record, and the National Monuments Record). An additional six assets were identified during a review of aerial photographs, while thirty sites or find spots were recorded during an archaeological walkover survey undertaken by the client. More than half of the records relate to post-medieval activity but with a significant number (45) relating to prehistoric activity. The wider former floodplain environment across which the route traverses is thought to be rich in prehistoric archaeology, although assets from this period are limited within the immediate environs of the proposed pipeline, possibly due to the post-medieval practice of warping. This practice improved the fertility of the land by allowing river water to flood onto agricultural land, depositing layers of alluvial silts (warp) and sediments, before allowing the water to drain away. Warping is known to have been applied on the Humberhead levels where the high tide of the River Ouse and River Derwent made the practicalities of the process relatively simple.

Evidence for Roman activity within the environs of the scheme is known from at least 60 heritage assests including settlement sites, field systems and the remains of industrial processes. A Romano-British settlement and villa site is recorded 500m to the east of the route, south-east of Scurff Hall (see Figs 6, 7 and 8). Early medieval heritage assets are relatively limited, although the site of St. Wilfreds Chapel has been identified through post holes identified during excavations close to the Roman villa site. Medieval assets are more visible within the landscape with a total of 41 assets recorded. Three moated sites within the immediate environs of the proposed route are recorded as scheduled monuments, at Castle Hill (CT21 – see Figs 3, 4 and 5), to the south of Drax, Scruff Hall (CT3 – see Figs 6, 7 and 8) to the east, and the Augustinian Priory (CT22 – see Figs 6, 7 and 8) to the north of Drax Power Station. In-filled fish ponds associated with the Augustinian Priory have been recorded to the south of the site (CT25 and CT26 – see Figs 10, 11 and 12).

Therefore, on the current evidence base, the application area is considered to have a moderate archaeological potential.

3 Aims, Methodology and Presentation

The main aim of the geophysical survey was to provide sufficient information to enable an assessment to be made of the impact of the proposed development on any potential archaeological remains and for mitigation proposals, if appropriate, to be recommended. To achieve this aim a magnetometer survey covering the whole of the pipeline corridor was carried out, a total of 76.5 hectares.

The general objectives of the geophysical survey were:

- to provide information about the nature and possible interpretation of any magnetic anomalies identified;
- to therefore determine the presence/absence and extent of any buried archaeological features; and
- to prepare a report summarising the results of the survey.

Magnetometer survey

The site grid was laid out using a Trimble VRS differential Global Positioning System (Trimble 5800 model). Bartington Grad601 magnetic gradiometers were used during the survey taking readings at 0.25m intervals on zig-zag traverses 1m apart within 30m by 30m grids so that 3600 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.

Reporting

A general site location plan, incorporating the Ordnance Survey map and showing the four overall sections, is shown in Figure 1 at a scale of 1:250000. Figure 2 is a large scale (1:50000) overview of the Camblesforth to Tollingham section showing the extent of the pipeline corridor and its associated infrastructure. At this scale the corridor has been divided into three blocks. Figures 3 to 11 inclusive show the processed greyscale magnetometer data, the first edition Ordnance Survey mapping and the overview interpretation of the data along the route at a scale of 1:5000. Detailed data plots ('raw' and processed) and full interpretative figures are presented at a scale of 1:2000 in Figures 12 to 44 inclusive with the route split into nine sectors. The survey area numbers which are depicted on Figures 3 to 44 inclusive were assigned prior to the fieldwork to aid communications with the client. Archaeological identifier numbers, depicted on the same figures correspond to those in the draft baseline information provided by the client.

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.

Archaeological Services WYAS is registered with the Online Access to the Index of archaeological investigations project (OASIS). The OASIS ID for this project is archaeol11-177729 .

The geophysical survey methodology, report and any recommendations comply with guidelines outlined by English Heritage (David *et al.* 2008) and by the Institute for Archaeologists (IfA 2013). All figures reproduced from Ordnance Survey mapping are with the permission of the controller of Her Majesty's Stationery Office (© Crown copyright).

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 and Discussion (see Figs 3 to 44 inclusive)

Magnetometer Survey

The anomalies identified by the survey fall into a number of different types and categories according to their origin and these are discussed below and cross-referenced to specific examples and locations along the proposed pipeline route.

Ferrous and Modern Anomalies

Ferrous responses, either as individual 'spike' anomalies or more extensive areas of magnetic disturbance, are typically caused by modern ferrous (magnetic) debris, either on the ground surface or in the plough-soil, or are due to the proximity of magnetic material in field boundaries, buildings or other above ground features. Little importance is normally given to such anomalies, unless there is any supporting evidence for an archaeological interpretation. Ferrous debris or material is common on rural sites, often being present as a consequence of manuring or tipping/infilling. Throughout the route iron 'spike' anomalies are common and there is no obvious pattern or clustering to their distribution to suggest anything other than a random background scatter of ferrous debris in the plough-soil.

Clusters of ferrous anomalies coalescing into larger areas of magnetic disturbance have been identified at a number of locations, predominantly adjacent to roads, tracks, pylons, boundaries or drains. Examples include the area adjacent to Hales Lane in Area 988 (see Figs 18, 19 and 20) or adjacent to the disused railway in Area 991 (see Figs 30, 31 and 32). These clusters are not considered to be of archaeological significance. High-magnitude dipolar linear anomalies have been identified traversing Area 239 (see Figs 30, 31 and 32) and the eastern part of Area 999 (see Figs 36, 37 and 38). These anomalies delineate the route of service pipes. An isolated, amorphous area of magnetic disturbance, **A**, has been identified within Area 243 (see Figs 36, 37 and 38). This area is located a short distance to the north of AECOM archaeological identifier CT25 which is recorded as a ploughed out fish pond. It is possible that the magnetic disturbance relates to magnetically enhanced material backfilled into the former pond although a modern cause is also plausible.

Agricultural Anomalies

Parallel linear trend anomalies have been identified in most sections of the survey corridor. The most numerous trend anomalies are caused by ploughing. The close spacing between these anomalies are typical of modern ploughing. More widely spaced linear trend anomalies can be seen within Area 240 (see Figs 31 to 36 inclusive). These anomalies are more likely to locate field drains.

Over the last 150 years the size of the fields has been increased by the removal of many of the boundaries shown on the first edition Ordnance Survey map; these boundaries are indicated on the 1:5000 overview figures (see Figs 4, 7 and 10). Some of these former boundaries have been identified in the geophysical survey as linear and curvilinear anomalies, such as the east/west aligned anomaly which traverses Areas 247 and Area 989 (see Figs 21, 22 and 23) and the curvilinear anomaly, **B**, which has been identified traversing Area 244, south of the Augustinian Priory (see Figs 36, 37 and 38). This anomaly marks a clear geological boundary, bounding an area of probable alluvium deposits to the north. The alignment of the anomaly, running towards the site of a fish pond (CT124), may suggest a function associated with the pond.

It is noticeable that some of the former boundaries identified only manifest as very weak magnetic anomalies, while others are not visible at all. This suggests there exists a low magnetic contrast between cut features, such as the soil-filled former boundary ditches, and the surrounding soils and alluvium deposits. Low magnitude, discrete archaeological anomalies, therefore, may remain undetected.

Geological Anomalies

A relatively uniform magnetic background has been identified across the Camblesforth to Tollingham (North Yorkshire) section, and therefore few anomalies have been ascribed a geological origin. Those that have, manifest as clear, broad anomalies in the data. One such area has been identified within the south of Area 233 as two roughly concentric sub-circular anomalies, **C**, measuring approximately 80m in diameter (see Figs 13, 14 and 15). Whilst the circular nature of this anomaly is interesting, the anomaly is very low in magnitude and the absence of more discrete anomalies in the vicinity tends to preclude against an archaeological interpretation. Furthermore, two linear trend anomalies, indicative of field drains, have been identified traversing this part of the field only. This would suggest that the anomaly lies in an area of poorer drainage, perhaps indicating a former pond or an area of seasonal waterlogging.

A series of parallel curvilinear trends have been identified within Area 216 (see Figs 25, 26 and 27) and Area 253 (see Figs 39, 40 and 41). The trends differ in magnitude and are thought to indicate a series of silting episodes deposited by River Ouse at varying stages of flood. Further south-west of this area, within Area 218, a curvilinear anomaly, **D**, interpreted as being geological, is likely to relate to a former silted up rivulet or watercourse. Further anomalies resulting from water actions and episodes of silting are visible within Area 994 (see Figs 34, 35 and 36) and Area 244 (see Figs 37, 38 and 39). Elsewhere, occasional discrete anomalies of varying magnitude have been identified which have been assigned a geological interpretation. These are thought to be due to natural variations in the composition and depth of soil deposits, perhaps reflecting the fact that, prior to extensive drainage from the medieval period onwards, the land was largely flood plain.

Possible Archaeological Anomalies

No anomalies of obvious archaeological potential have been identified within the Camblesforth to Tollingham (North Yorkshire) section. As discussed above, an area of magnetic disturbance, **A**, within Area 243 may relate to material associated with a ploughed-out fish pond. To the south of Drax village, linear anomalies, **E** and **F**, locating soil-filled ditches, have been identified within Area 236, and have been ascribed an archaeological interpretation as they do not correspond to any features depicted on earlier Ordnance Survey mapping (see Figs 15, 16 and 17). However, the anomalies are orientated parallel and perpendicular to known field boundaries and roads and it likely, therefore, that these anomalies relate to former field boundaries pre-dating the publication of the first edition Ordnance Survey map in 1853.

5 Conclusions

As well as the ubiquitous anomalies caused by ploughing trends, drains and ferrous scatters, the geophysical survey has identified two areas containing anomalies which have tentatively been ascribed a potential archaeological interpretation. Linear anomalies, **E** and **F**, within Area 236 are thought to indicate former field boundaries pre-dating the first edition Ordnance Survey map, whilst an amorphous area of magnetic disturbance, **A**, within Area 243 may relate to ploughed-out material associated with an in-filled medieval fish pond.

The survey has not identified any anomalies of definite archaeological potential within the Camblesforth to Tollingham (North Yorkshire) section, and very few of any potential at all. Those that have been ascribed some potential are likely to have a medieval or post-medieval origin. It is not clear whether the apparent absence of archaeological anomalies is an accurate reflection of the absence of archaeological activity in the pipeline corridor. As noted earlier, the low-lying floodplain environment through which the route passes is thought to be rich in prehistoric archaeology, with Roman and early medieval sites also known within close proximity of the pipeline corridor. Several former field boundaries have not been detected by the survey, suggesting a low magnetic contrast between cut features and the surrounding soils and alluvium deposits. It is also worth noting that geophysical (magnetometer) survey is perhaps most successful in identifying areas of enclosed settlement and less so at locating activity associated with a more transient or seasonal utilisation of land, as is often the case with prehistoric archaeology. Couple this with the possible masking effects of post-medieval warping processes and it is thought possible that low magnitude anomalies of archaeological potential may remain beyond the detection of the magnetometer. Nevertheless, on the basis of the geophysical survey, the archaeological potential within the Camblesforth to Tollingham (North Yorkshire) section is assessed as being low.

Disclaimer

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

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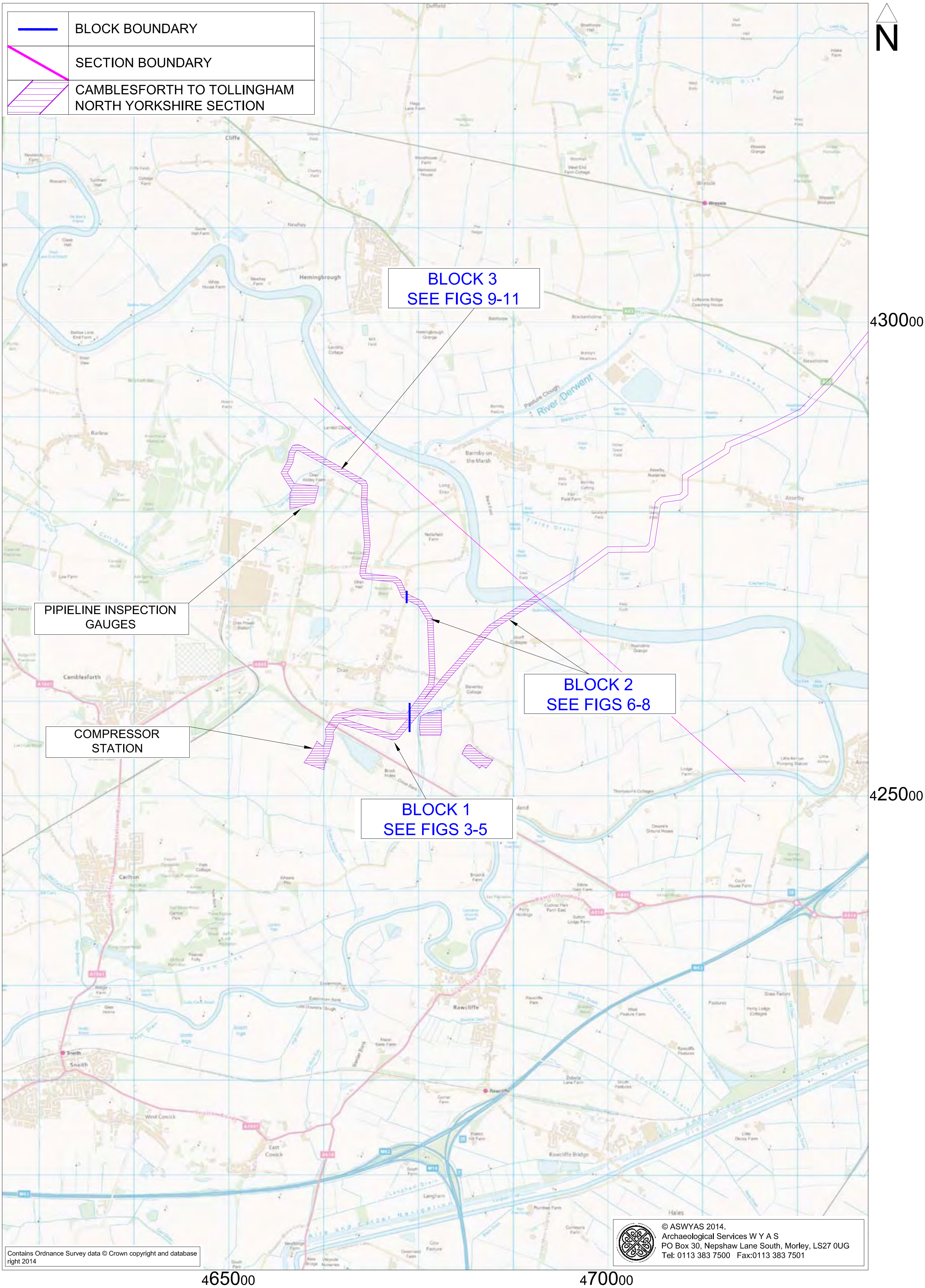

Fig. 2. Overview of section showing block areas (1:50000 @ A4)

0 500m

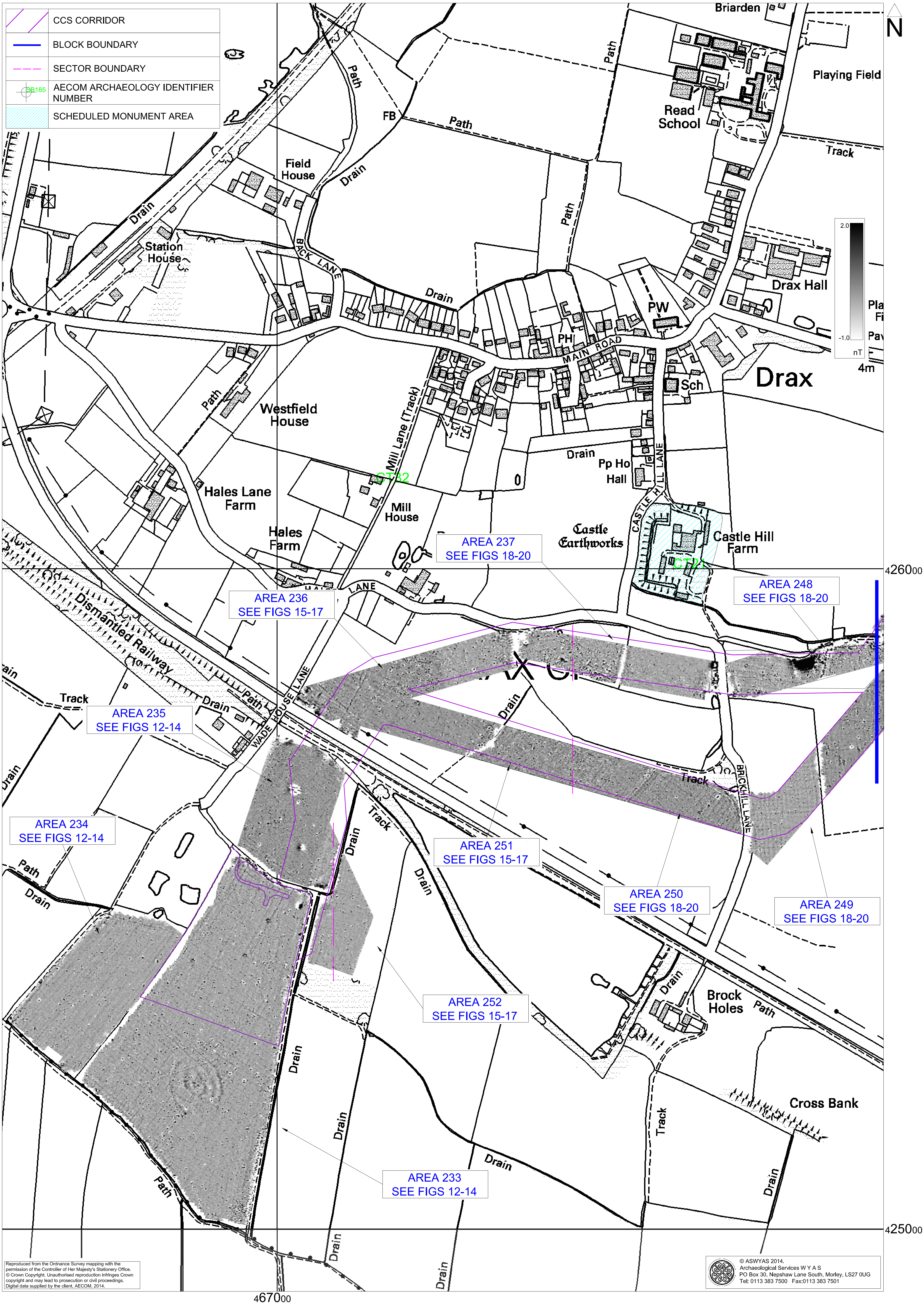

Fig. 3. Processed greyscale magnetometer data; Block 1 (1:5000 @ A3)

0 100m

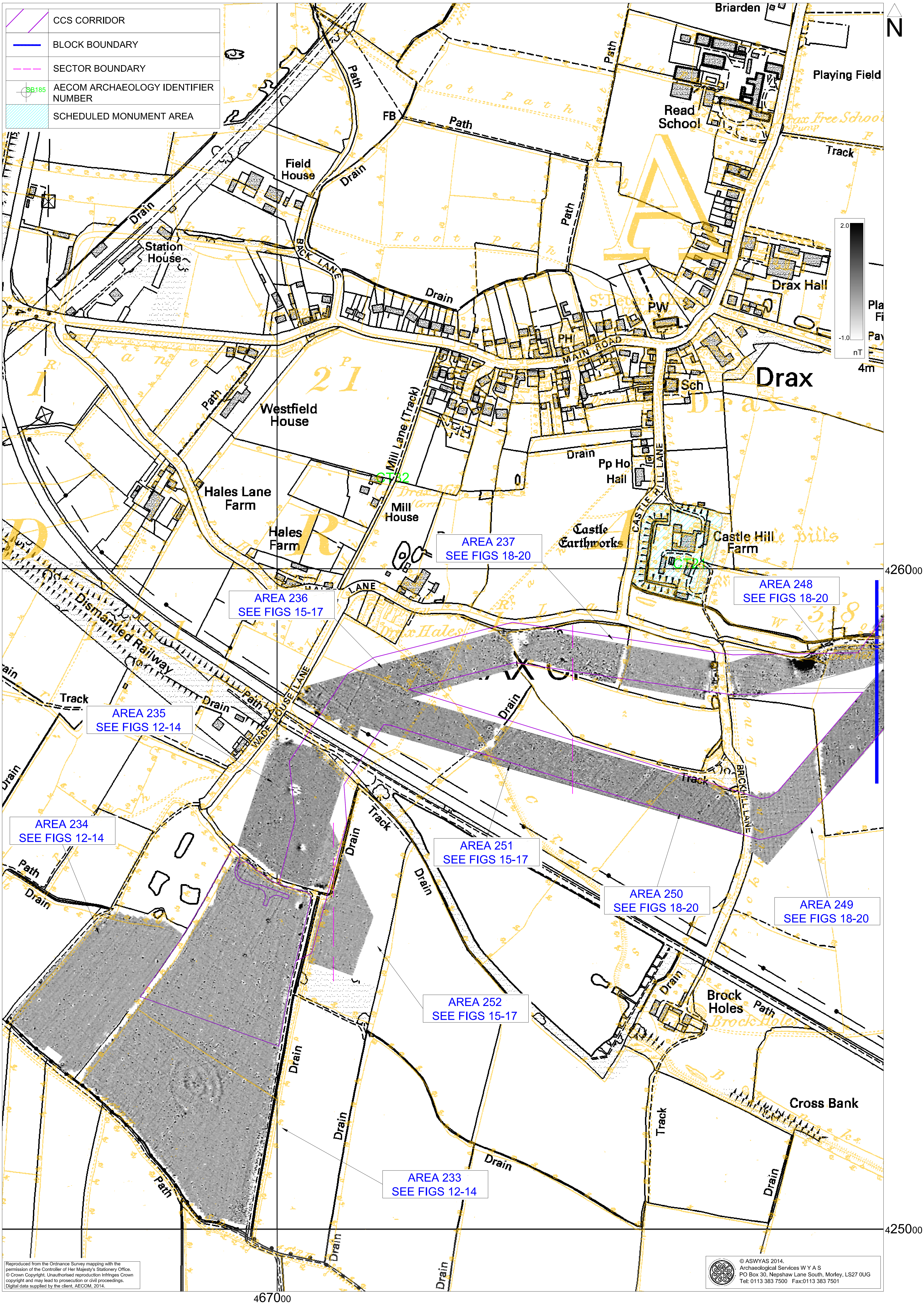

Fig. 4. Processed greyscale magnetometer data showing first edition Ordnance Survey mapping; Block 1 (1:5000 @ A3)

0 100m

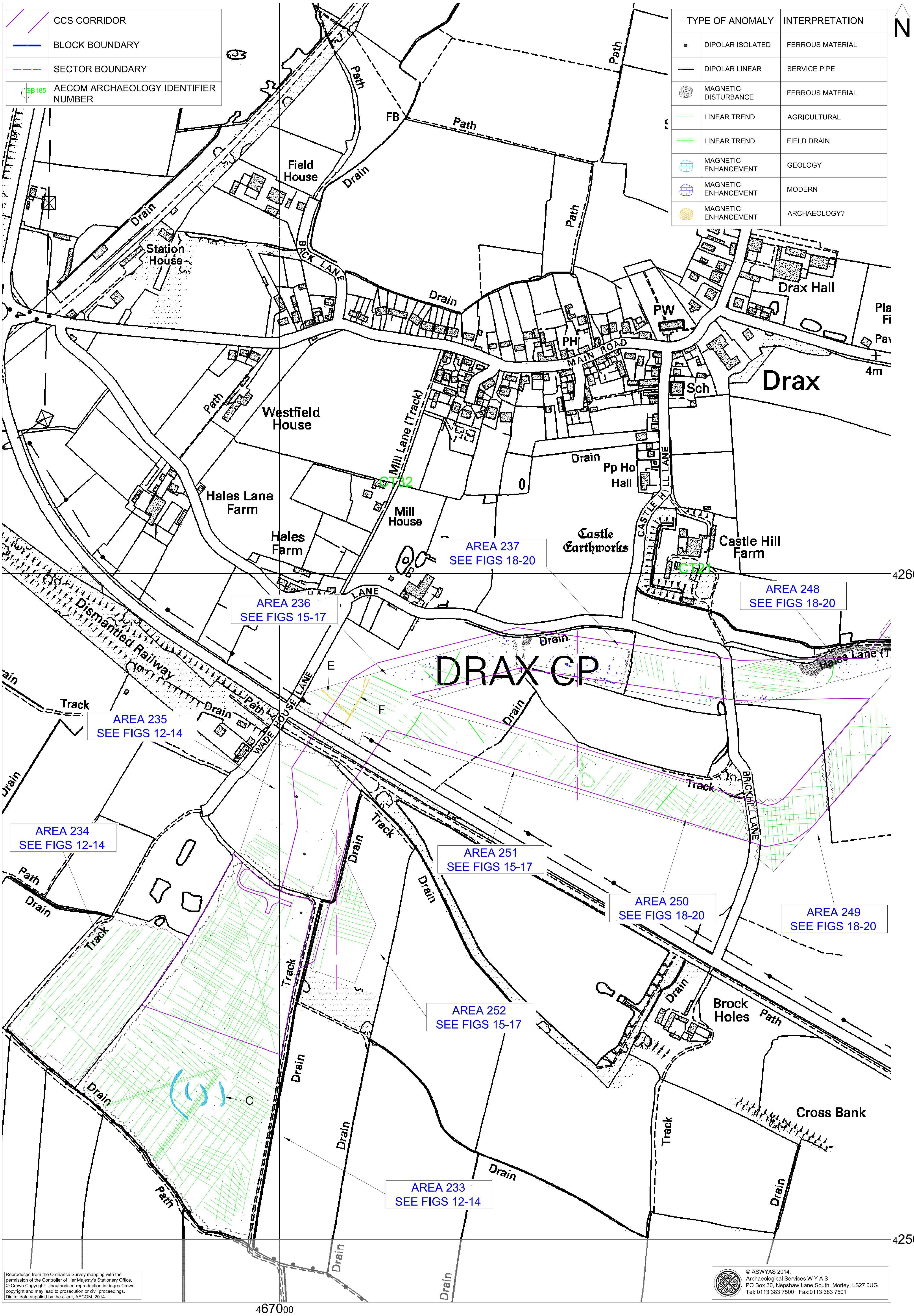

Fig. 5. Interpretation of magnetometer data; Block 1 (1:5000 @ A3)

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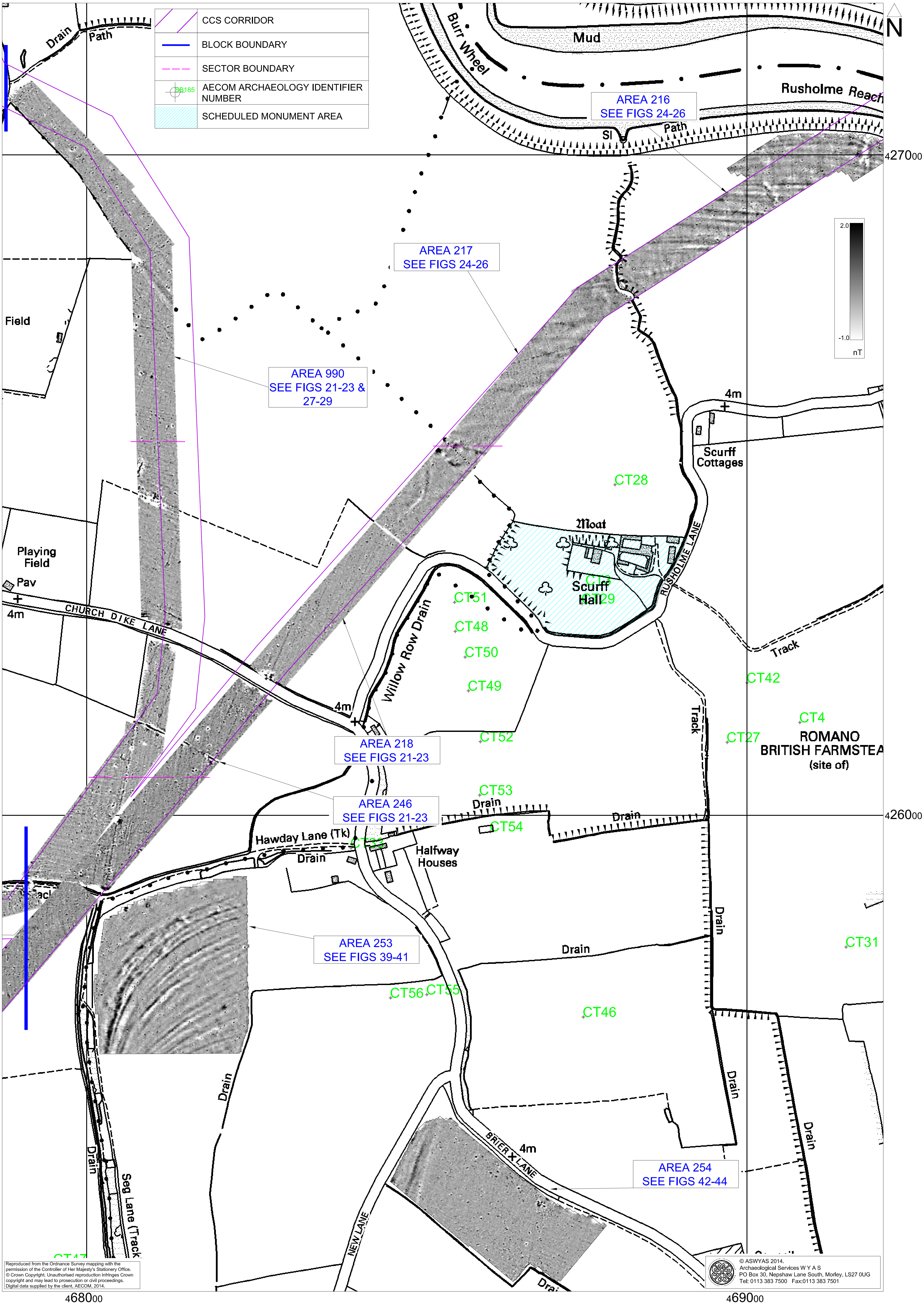

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Fig. 6. Processed greyscale magnetometer data; Block 2 (1:5000 @ A3)

0 100m

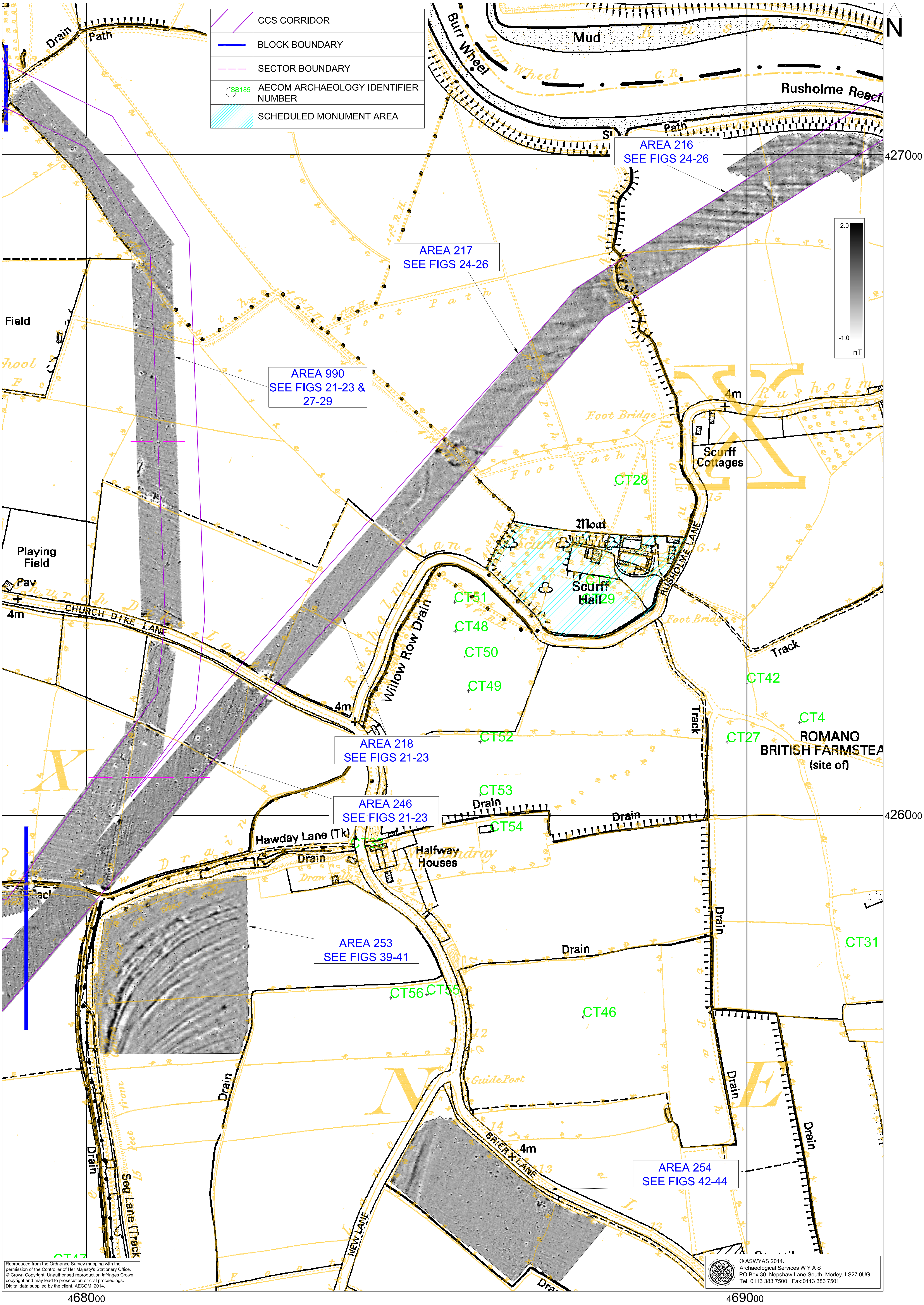

Fig. 7. Processed greyscale magnetometer data showing first edition Ordnance Survey mapping; Block 2 (1:5000 @ A3)

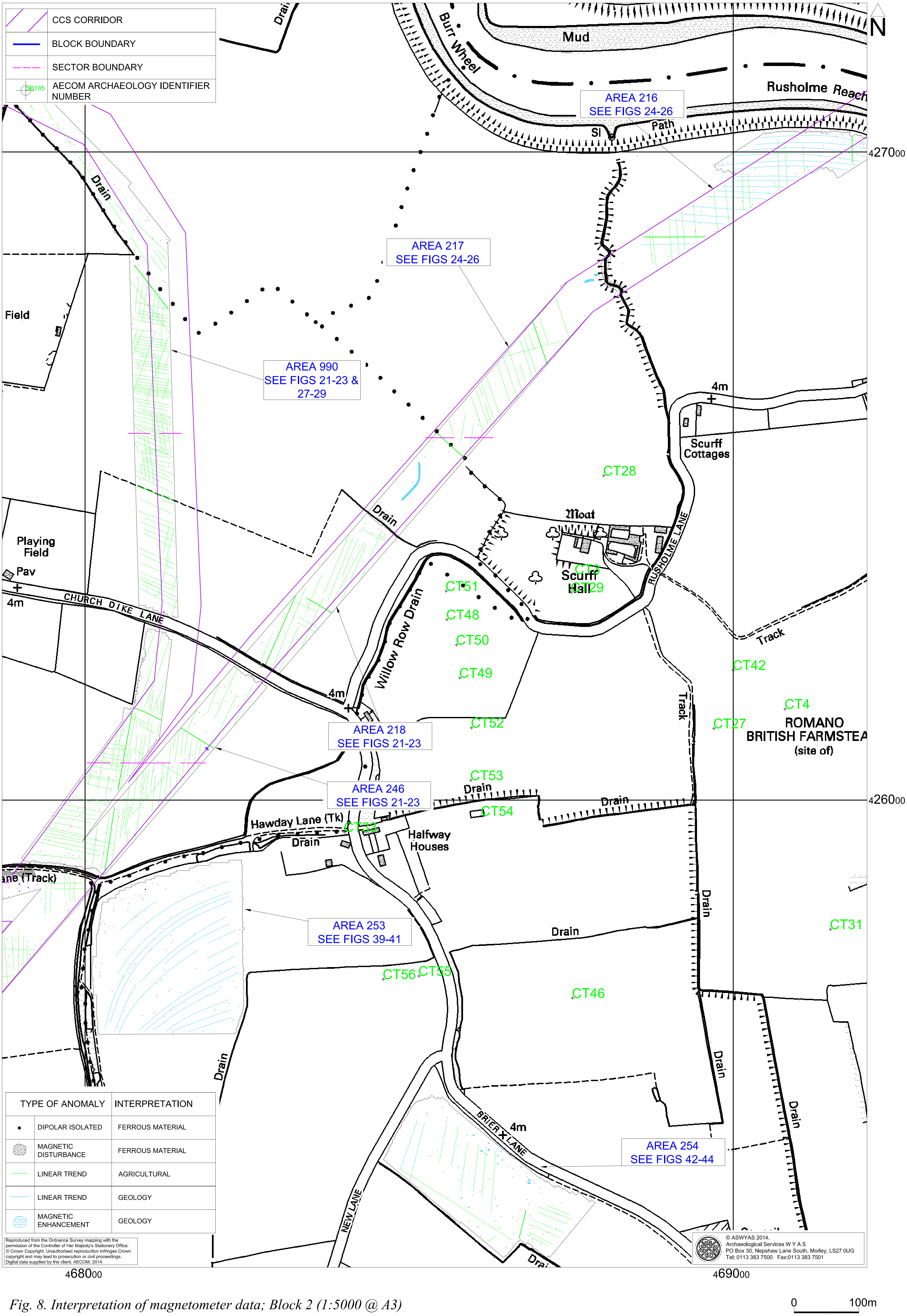

Fig. 8. Interpretation of magnetometer data; Block 2 (1:5000 @ A3)

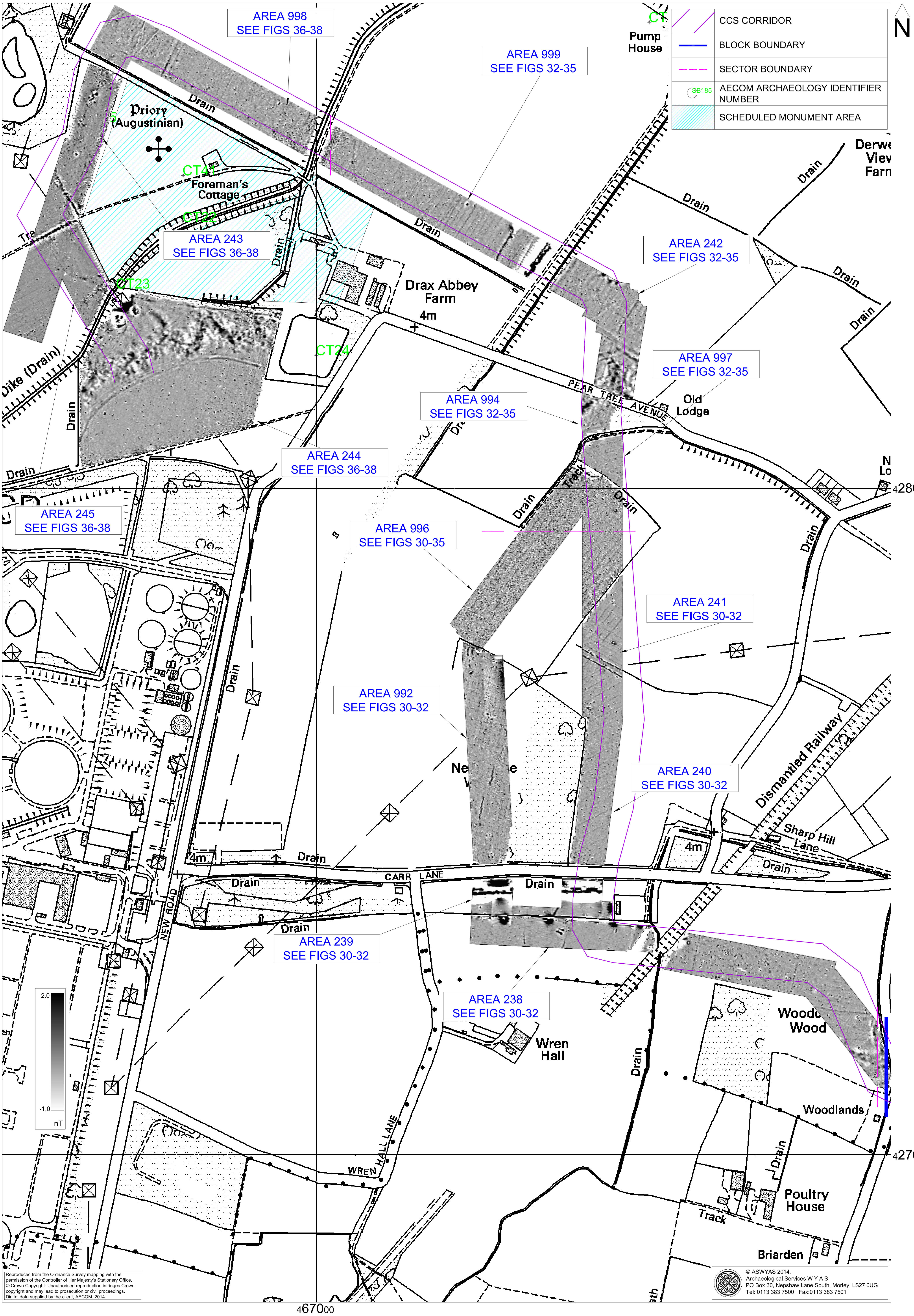

Fig. 9. Processed greyscale magnetometer data; Block 3 (1:5000 @ A3)

0 100m

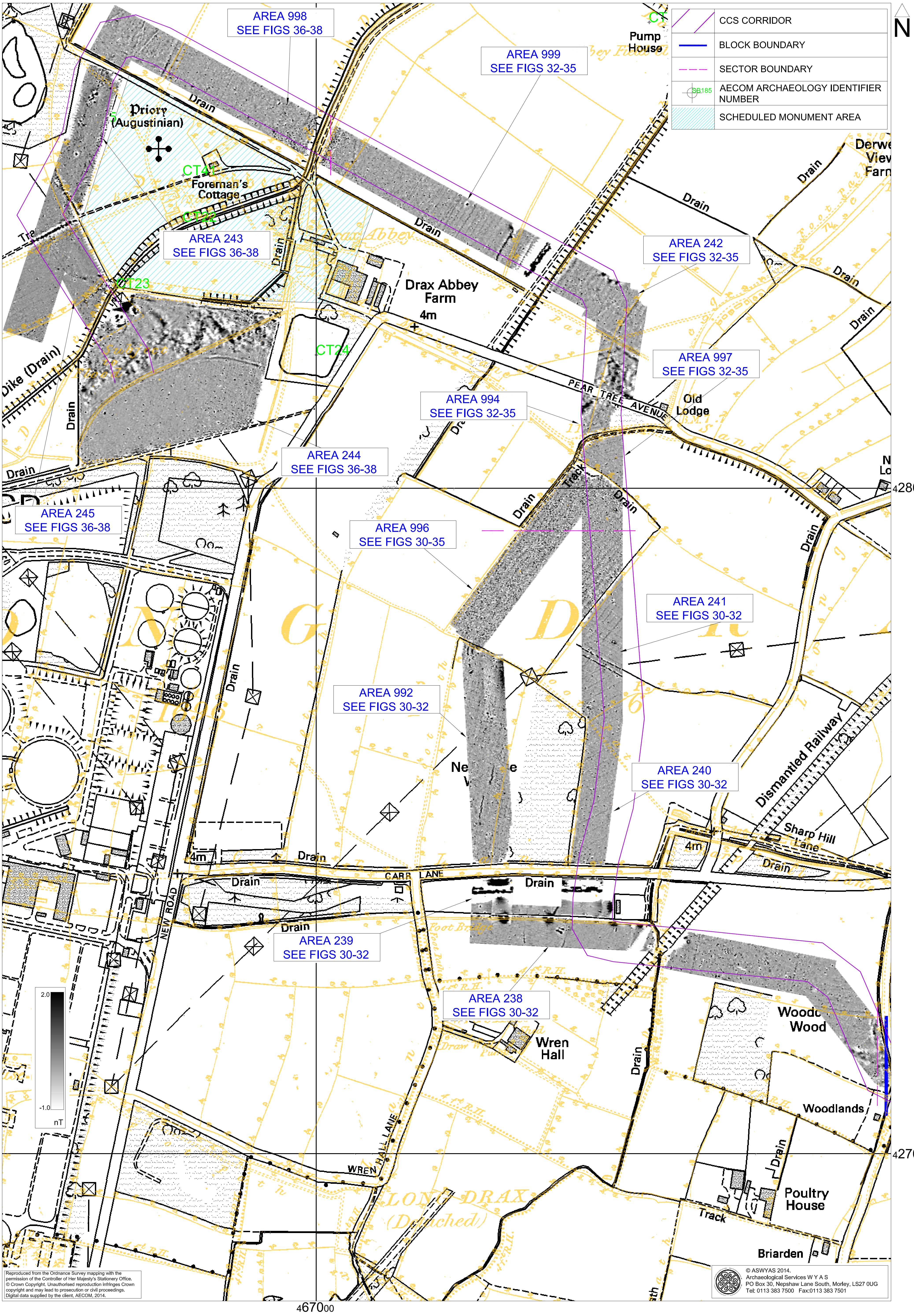

Fig. 10. Processed greyscale magnetometer data showing first edition Ordnance Survey mapping; Block 3 (1:5000 @ A3)

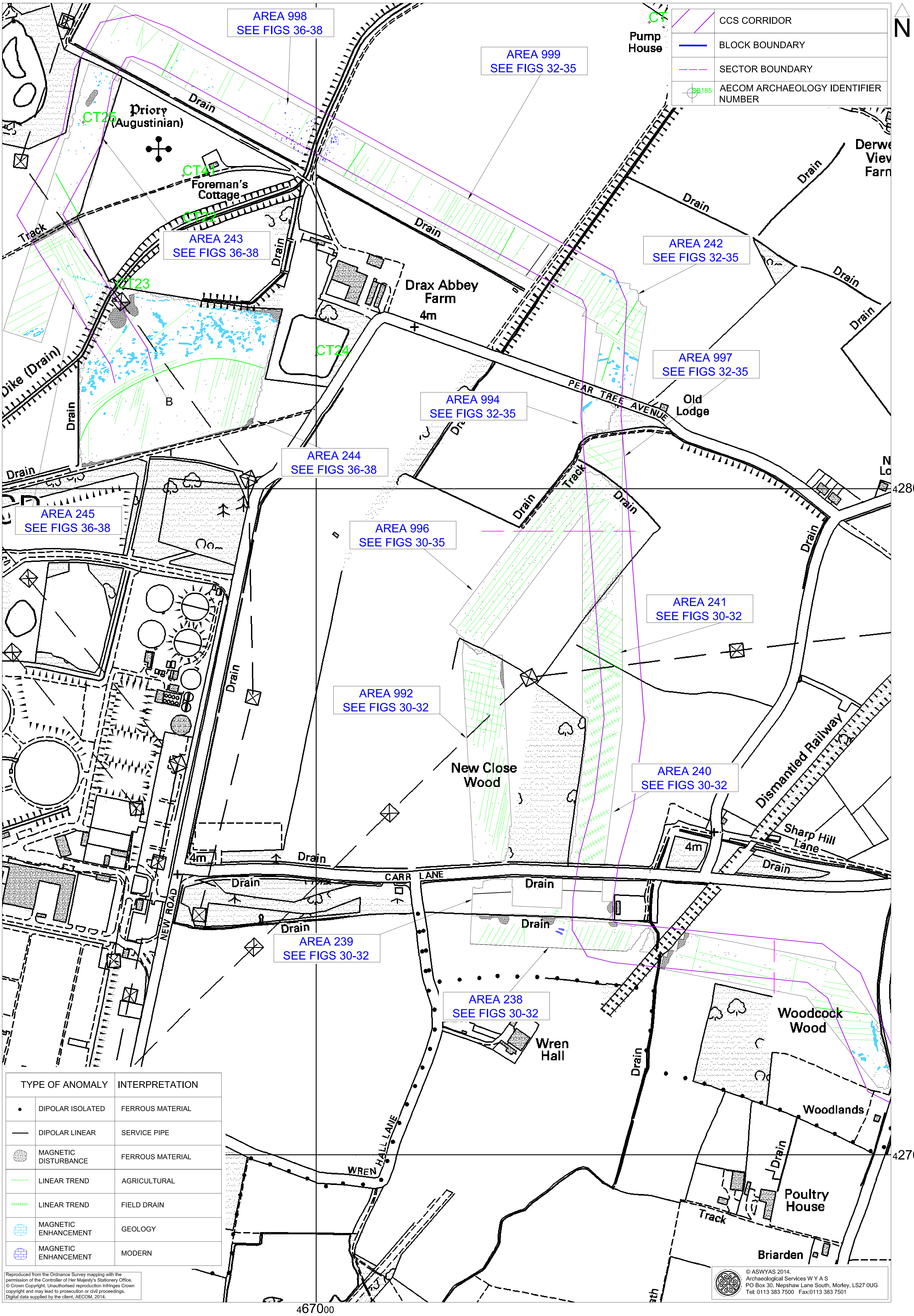

Fig. 11. Interpretation of magnetometer data; Block 3 (1:5000 @ A3)

0 100m

Fig. 12. Processed greyscale magnetometer data; Sector 1 (1:2000 @ A3)

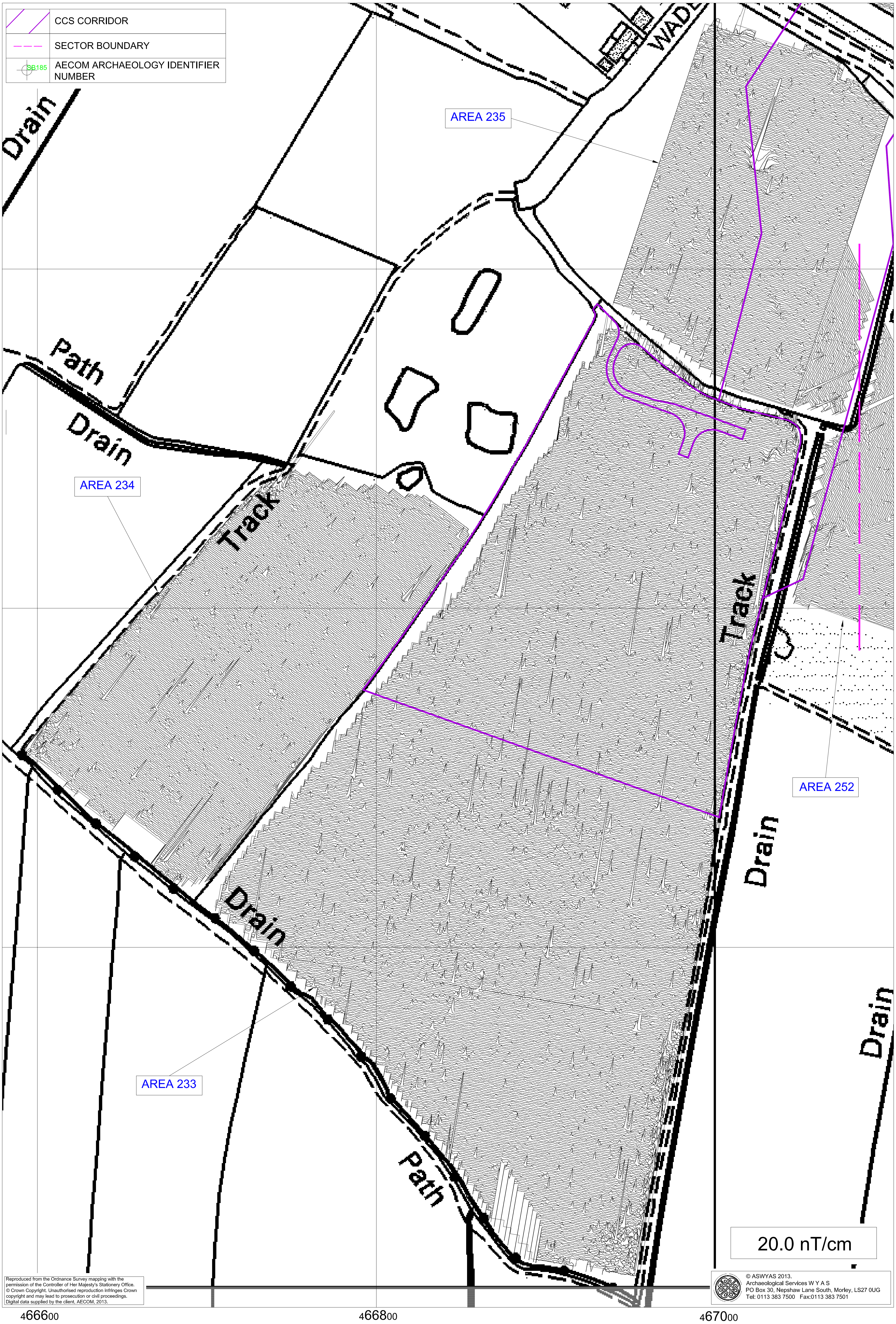

Fig. 13. XY trace plot of minimally processed magnetometer data; Sector 1 (1:2000 @ A3)

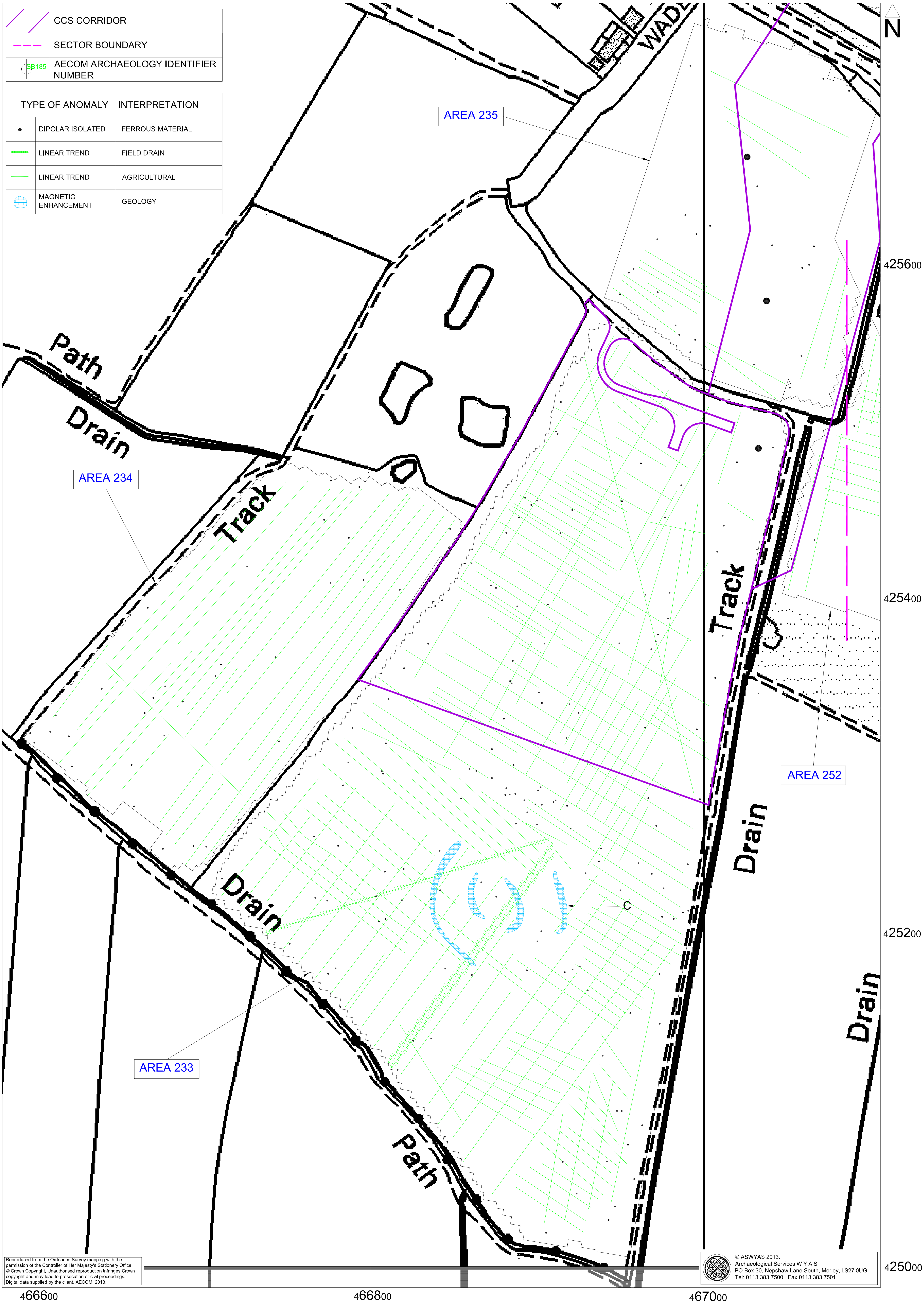

Fig. 14. Interpretation of magnetometer data; Sector 1 (1:2000 @ A3)

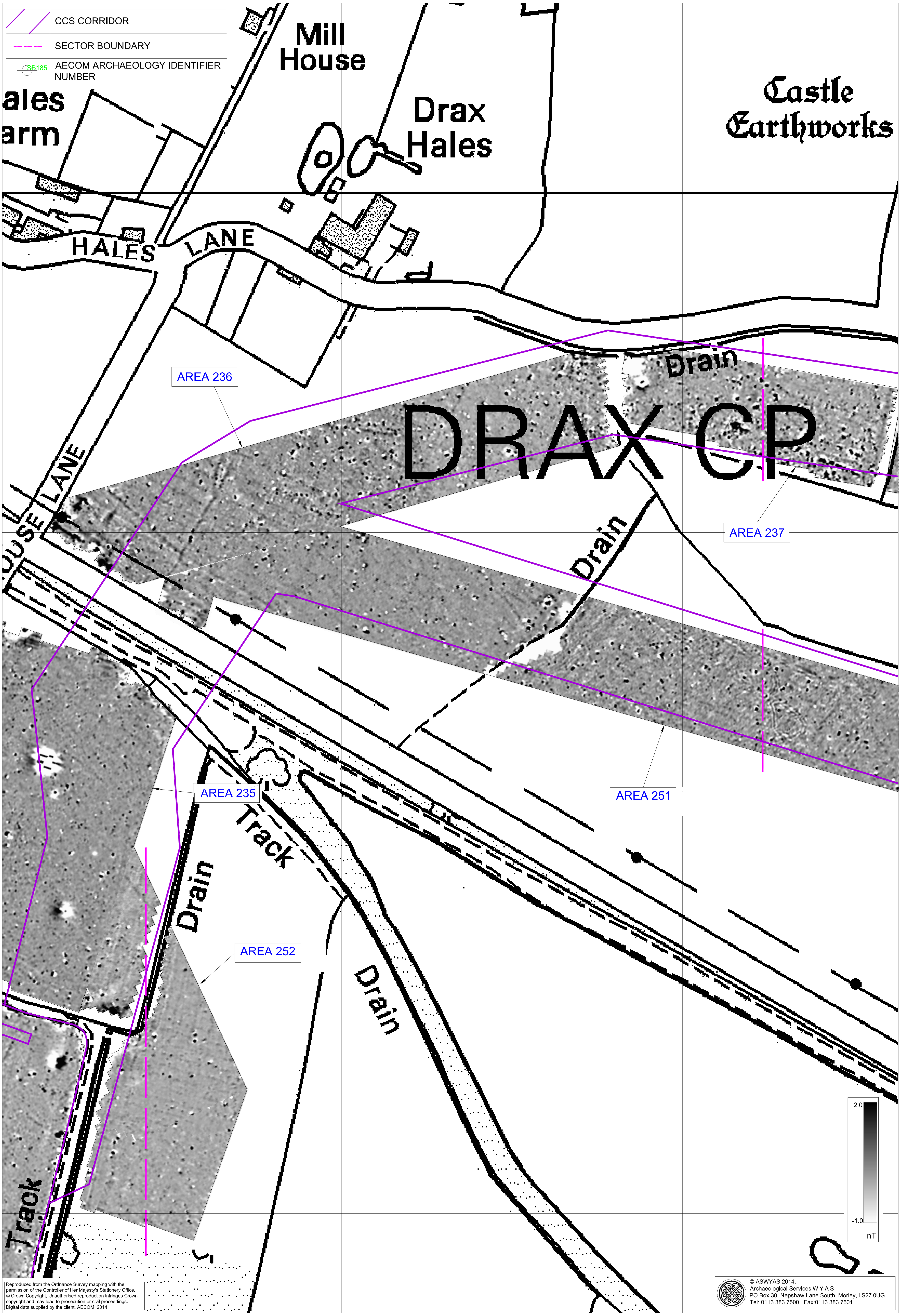

Fig. 15. Processed greyscale magnetometer data; Sector 2 (1:2000 @ A3)

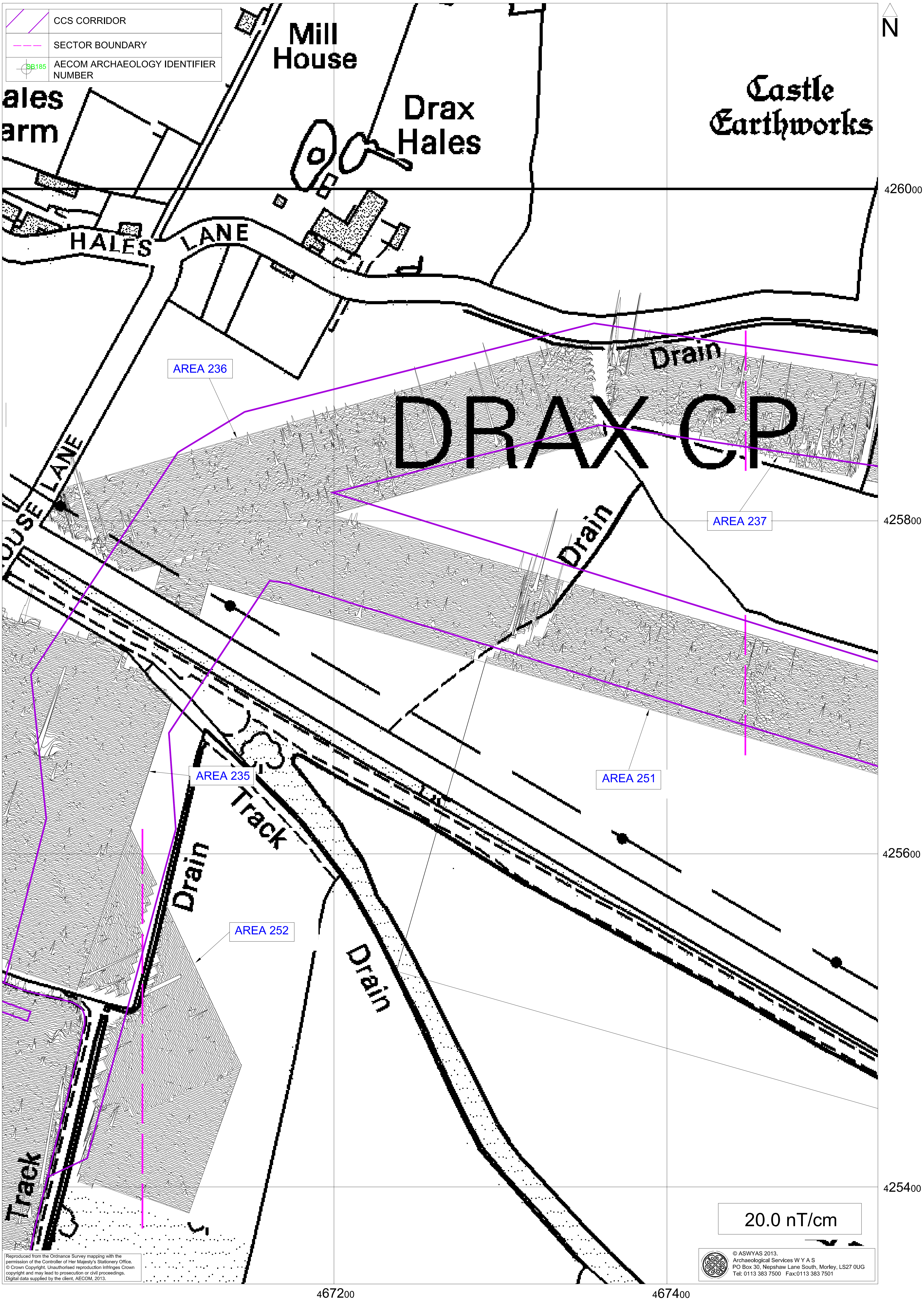

Fig. 16. XY trace plot of minimally processed magnetometer data; Sector 2 (1:2000 @ A3)

0 40m

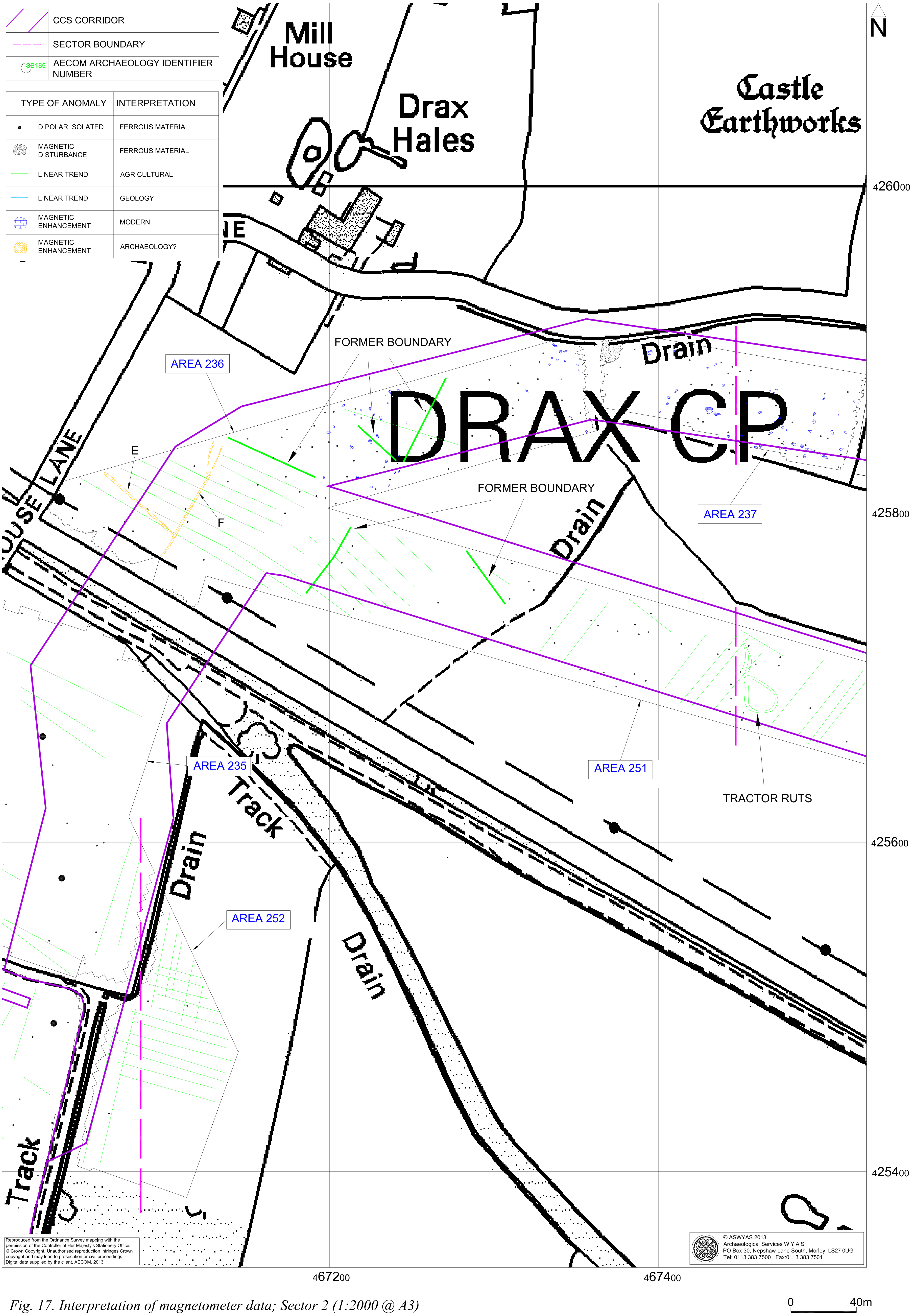

Fig. 17. Interpretation of magnetometer data; Sector 2 (1:2000 @ A3)

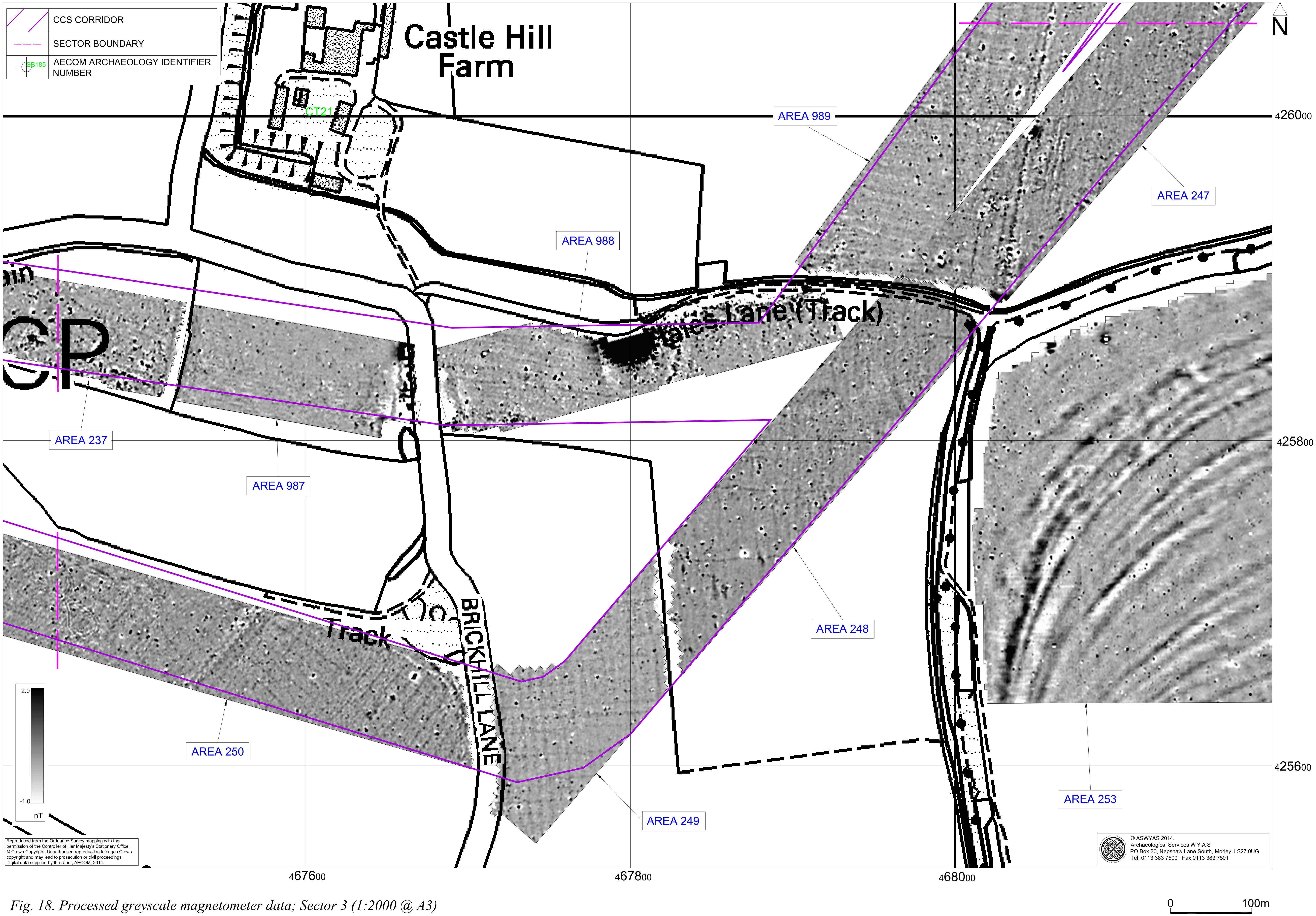

Fig. 18. Processed greyscale magnetometer data; Sector 3 (1:2000 @ A3)

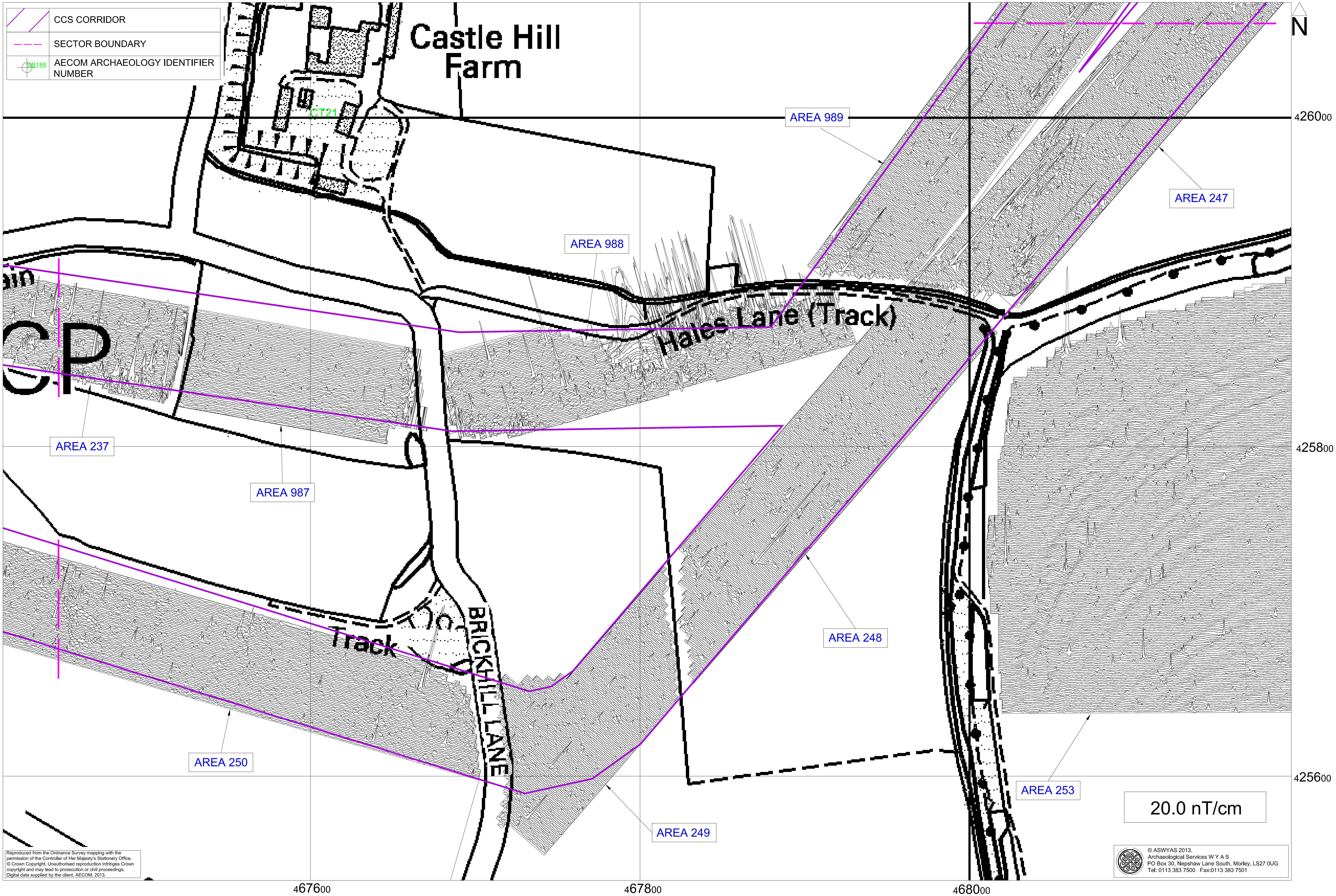

Fig. 19. XY trace plot of minimally processed magnetometer data; Sector 3 (1:2000 @ A3)

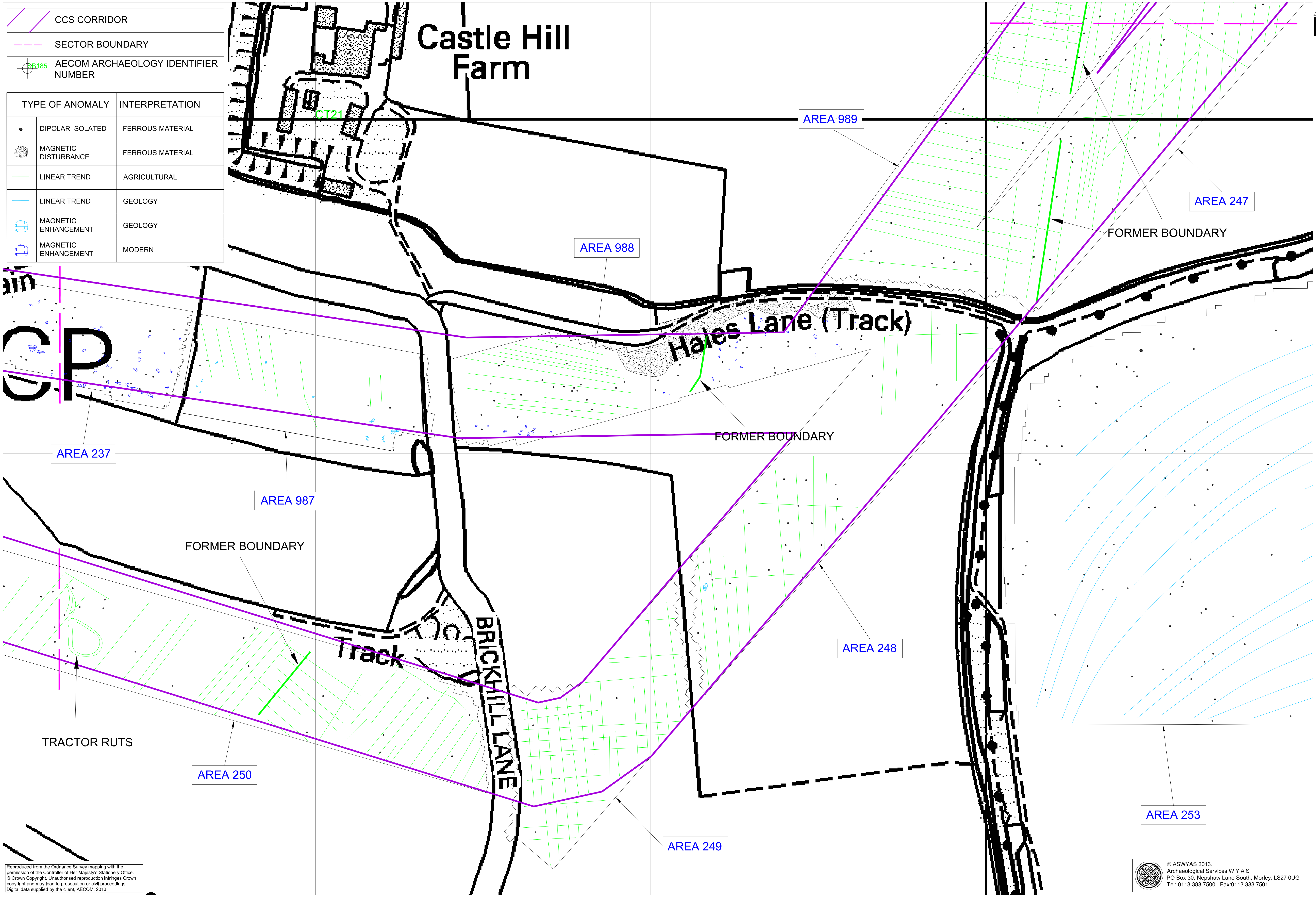

Fig. 20. Interpretation of magnetometer data; Sector 3 (1:2000 @ A3)

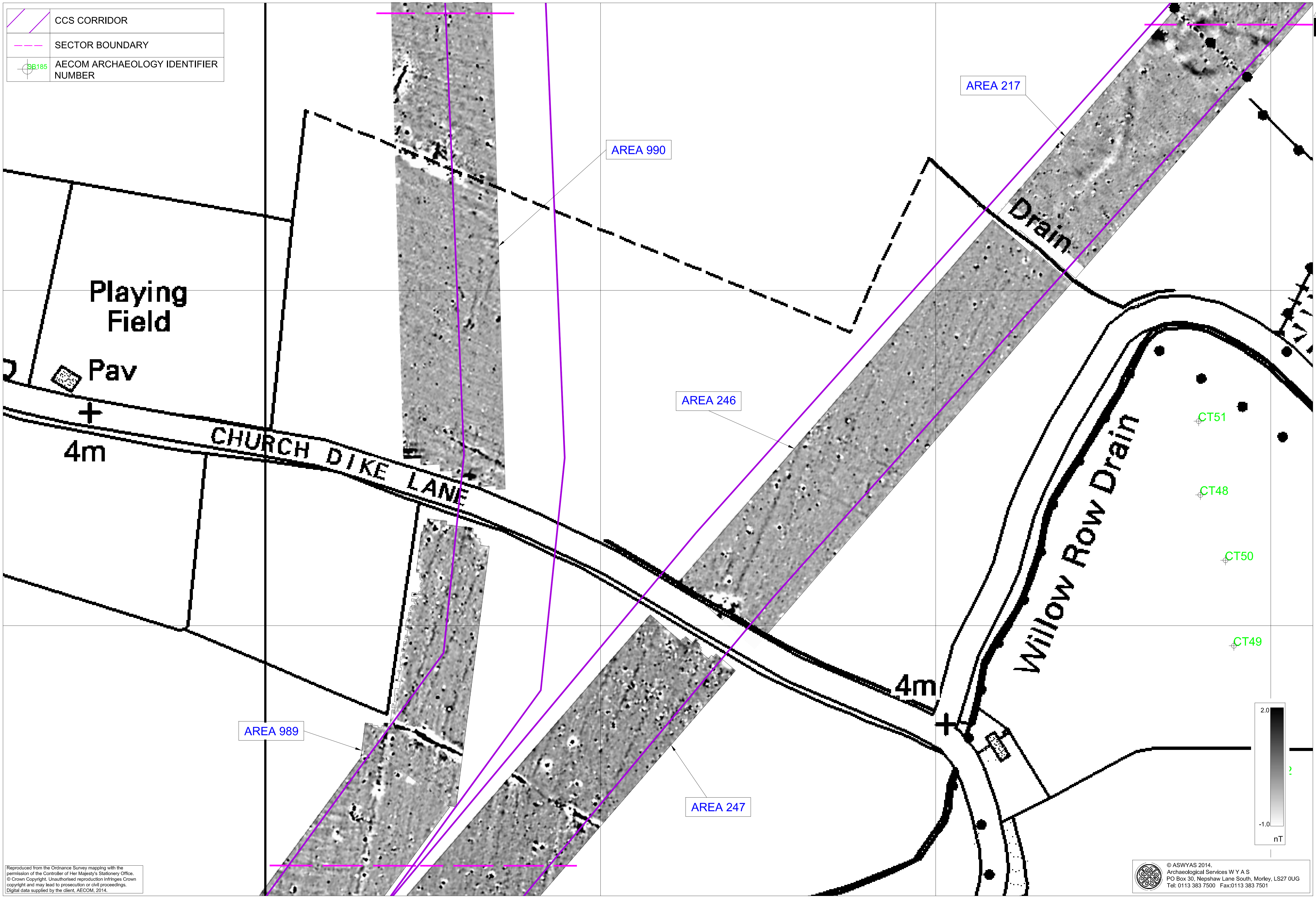

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Fig. 21. Processed greyscale magnetometer data; Sector 4 (1:2000 @ A3)

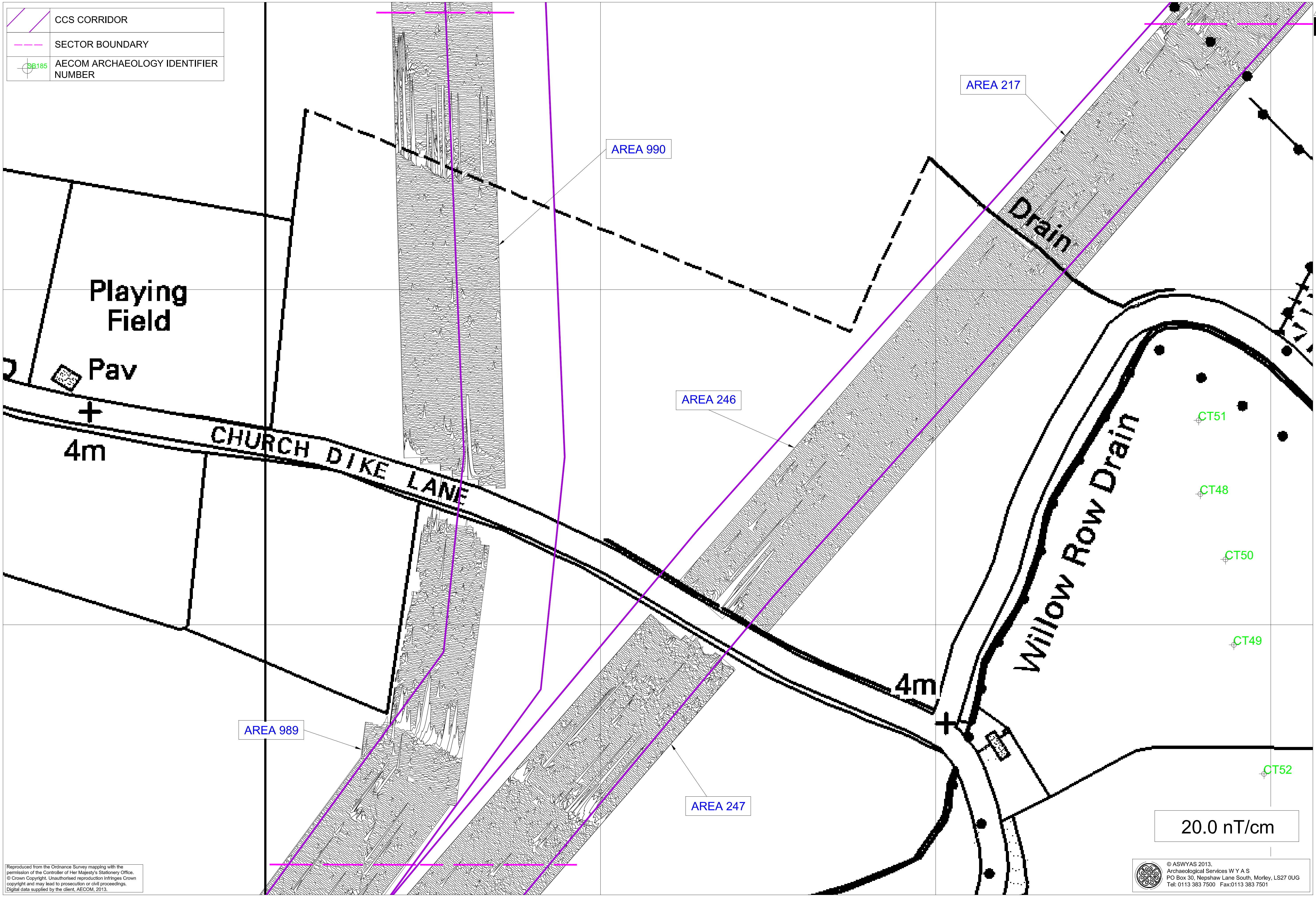

Fig. 22. XY trace plot of minimally processed magnetometer data; Sector 4 (1:2000 @ A3)

0 40m

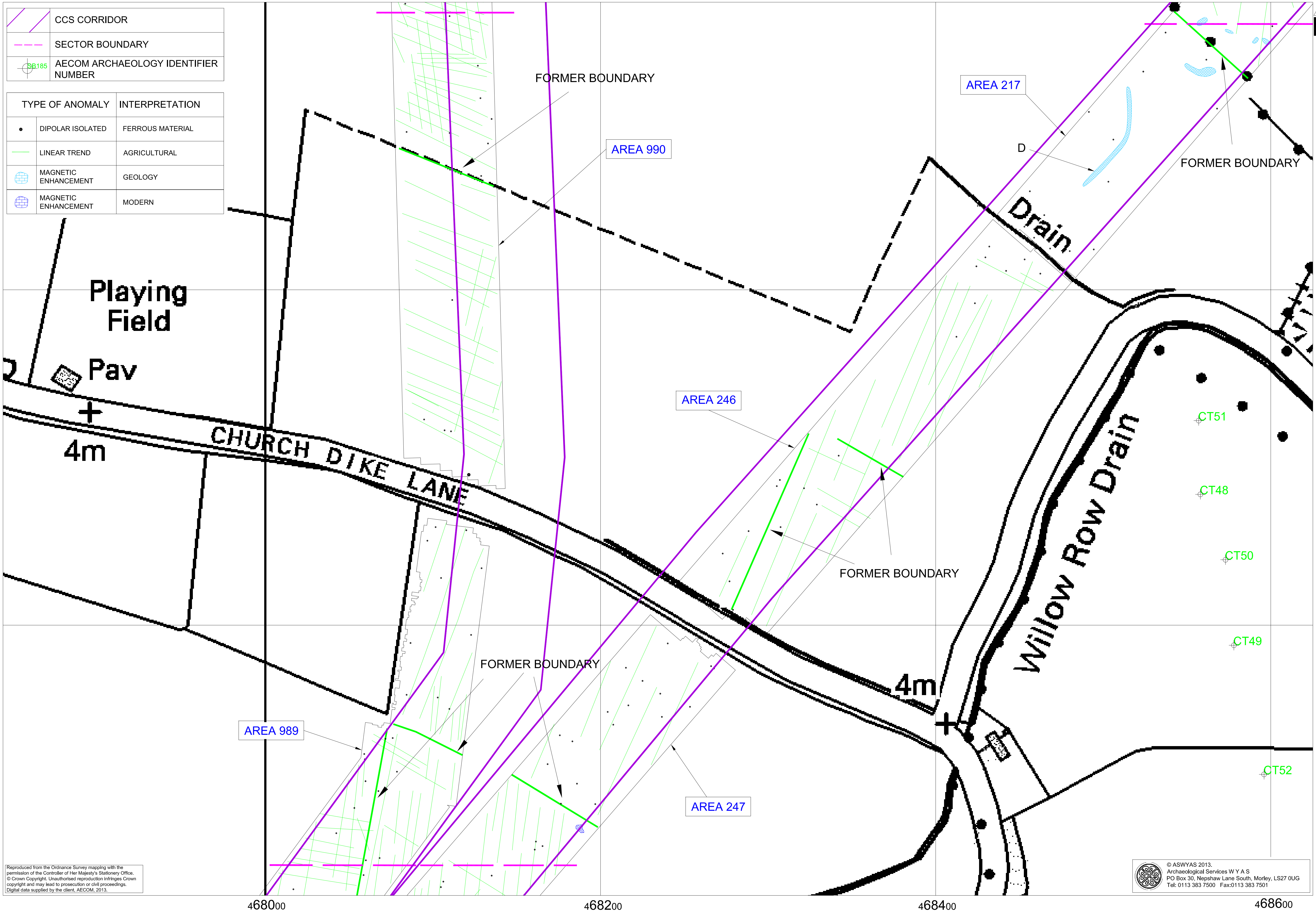

Fig. 23. Interpretation of magnetometer data; Sector 4 (1:2000 @ A3)

0 100m

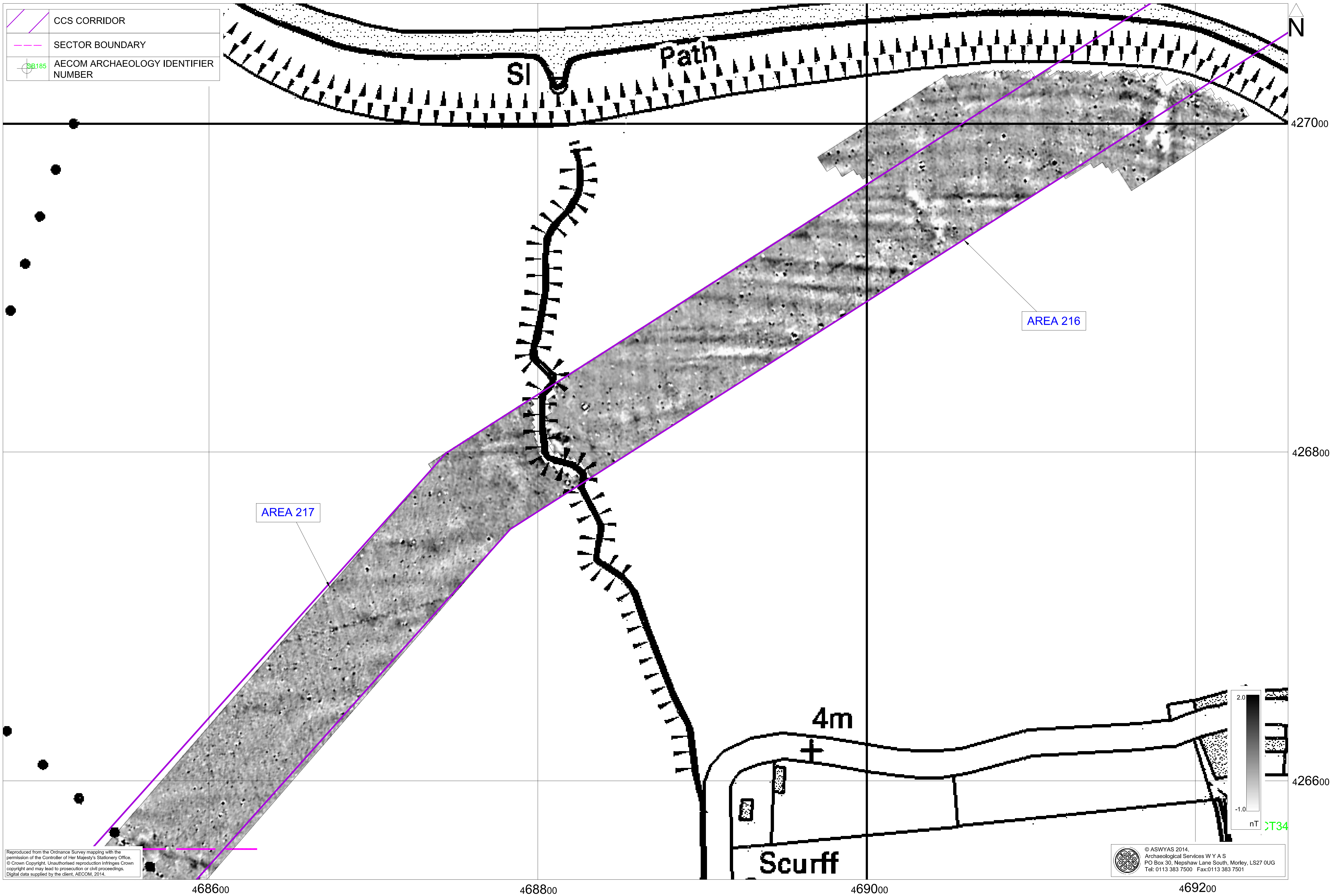

Fig. 24. Processed greyscale magnetometer data; Sector 5 (1:2000 @ A3)

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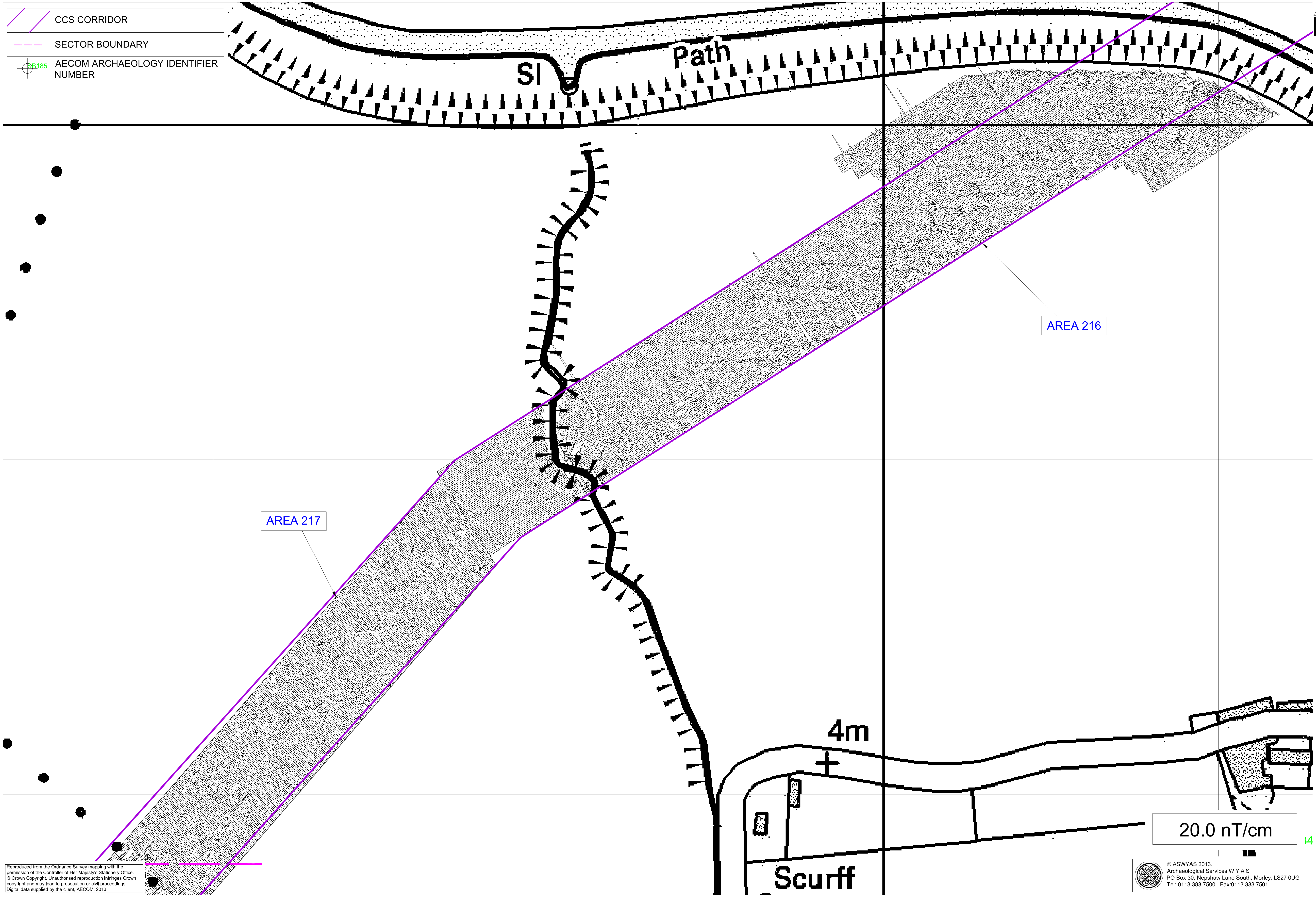

Fig. 25. XY trace plot of minimally processed magnetometer data; Sector 5 (1:2000 @ A3)

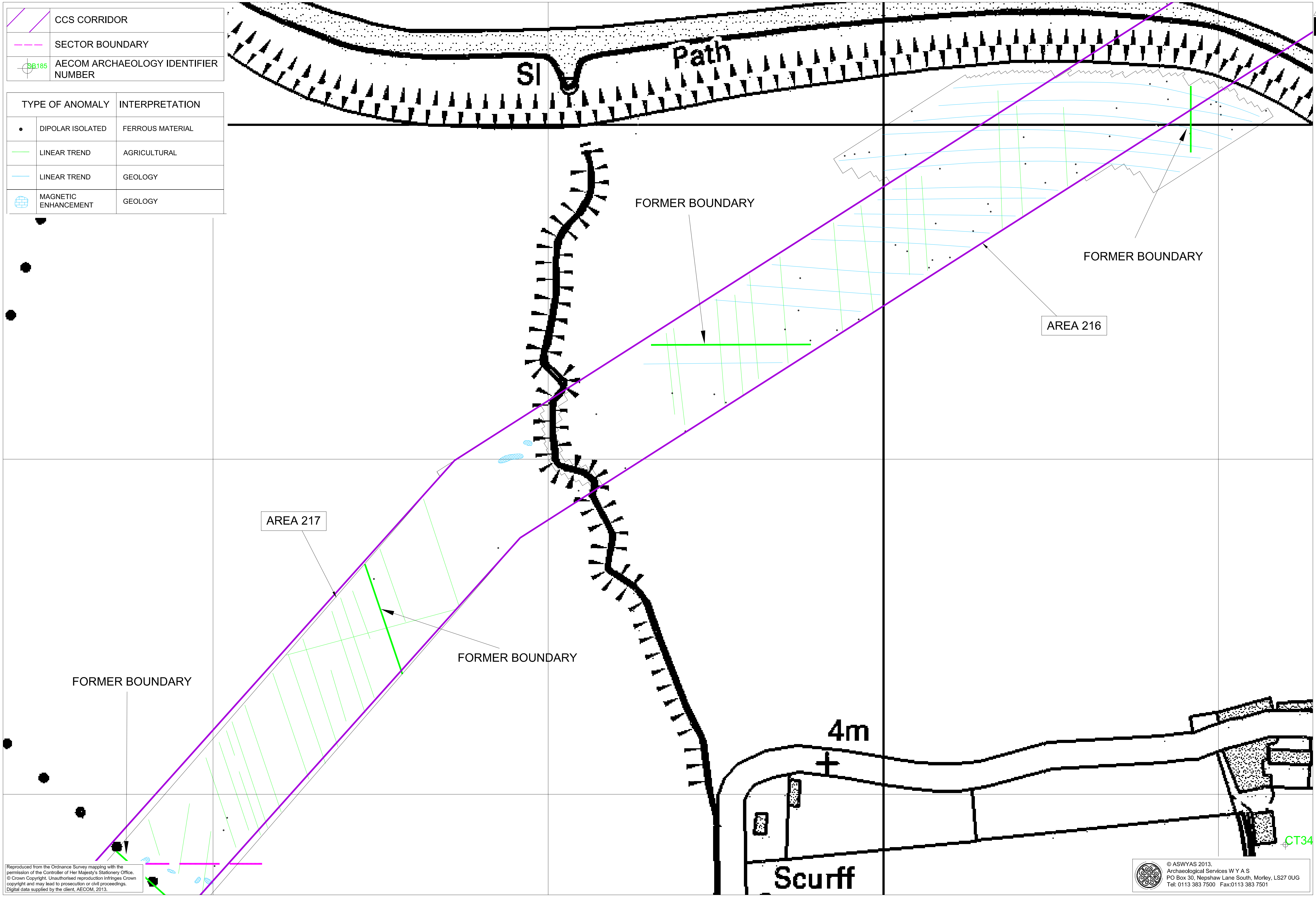

Fig. 26. Interpretation of magnetometer data; Sector 5 (1:2000 @ A3)

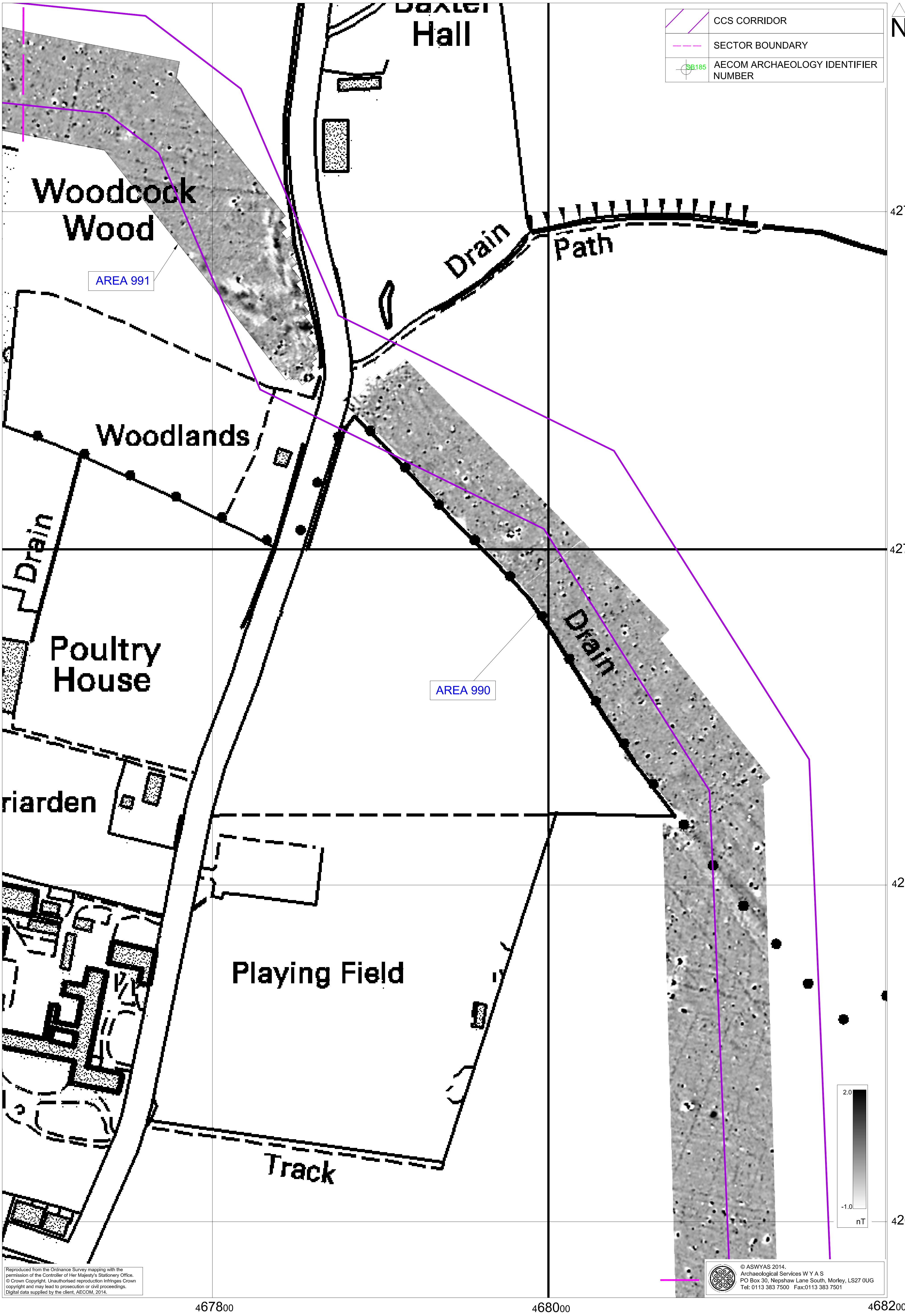

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Fig. 27. Processed greyscale magnetometer data; Sector 6 (1:2000 @ A3)

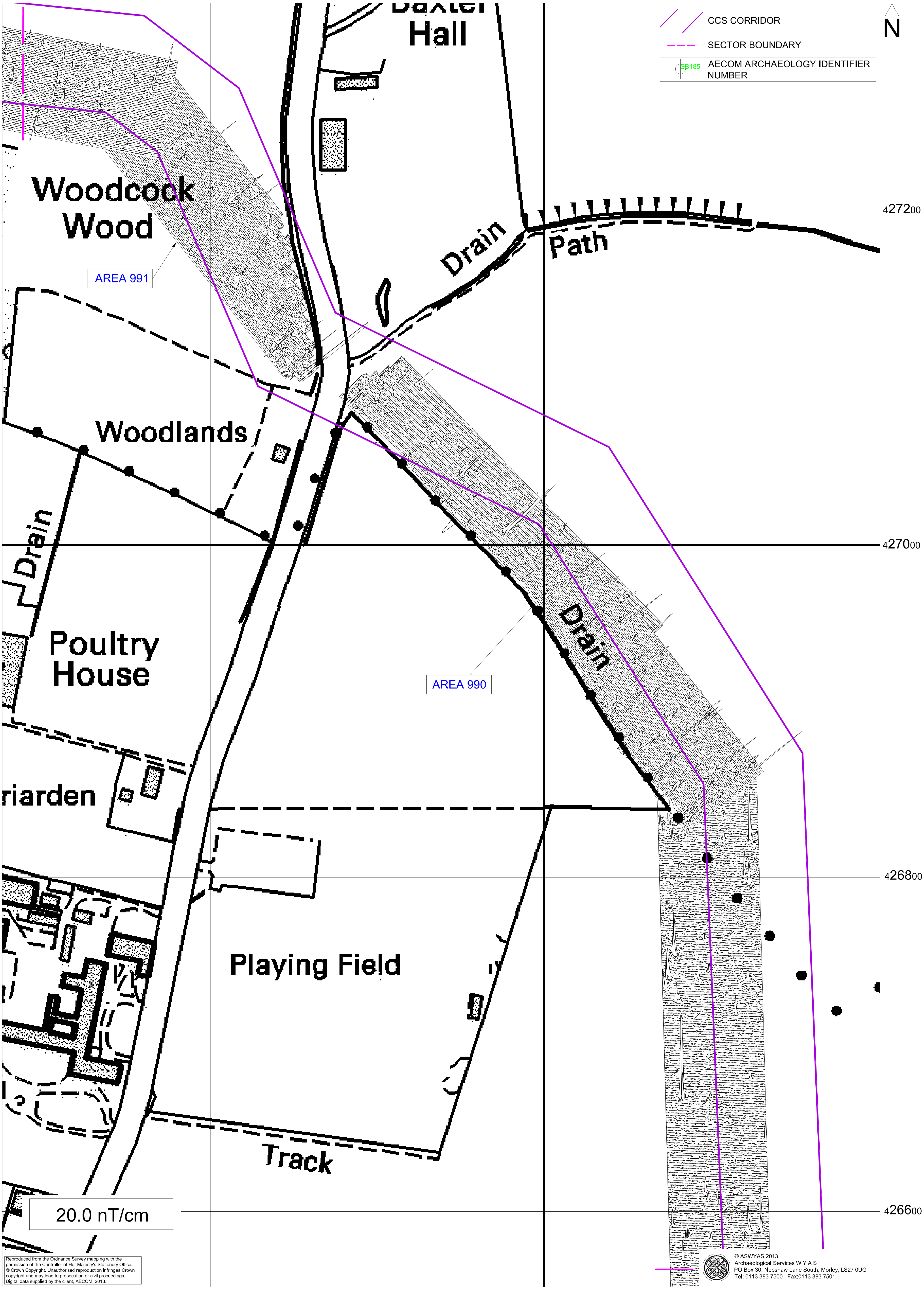

Fig. 28. XY trace plot of minimally processed magnetometer data; Sector 6 (1:2000 @ A3)

0 40m

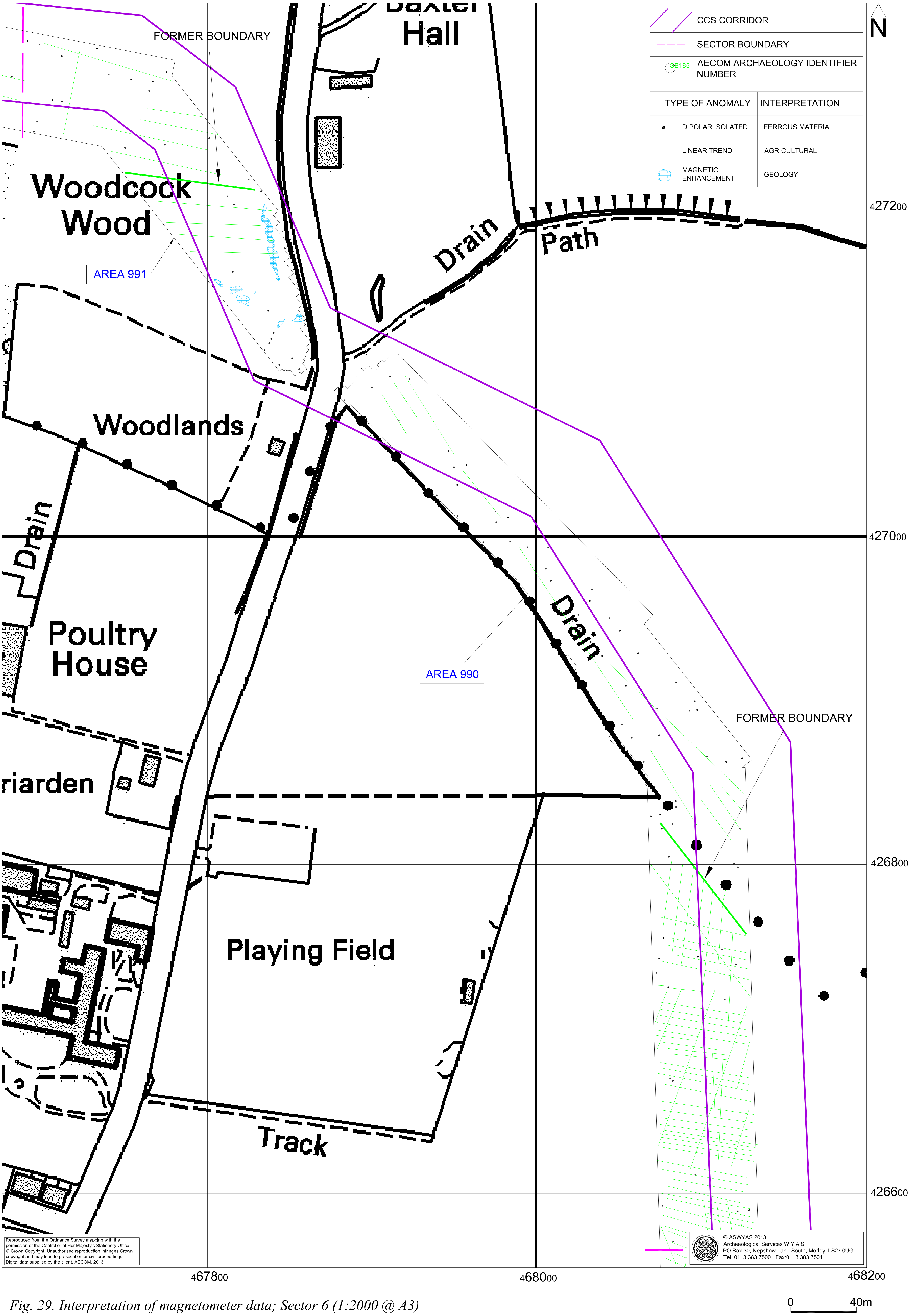

Fig. 29. Interpretation of magnetometer data; Sector 6 (1:2000 @ A3)

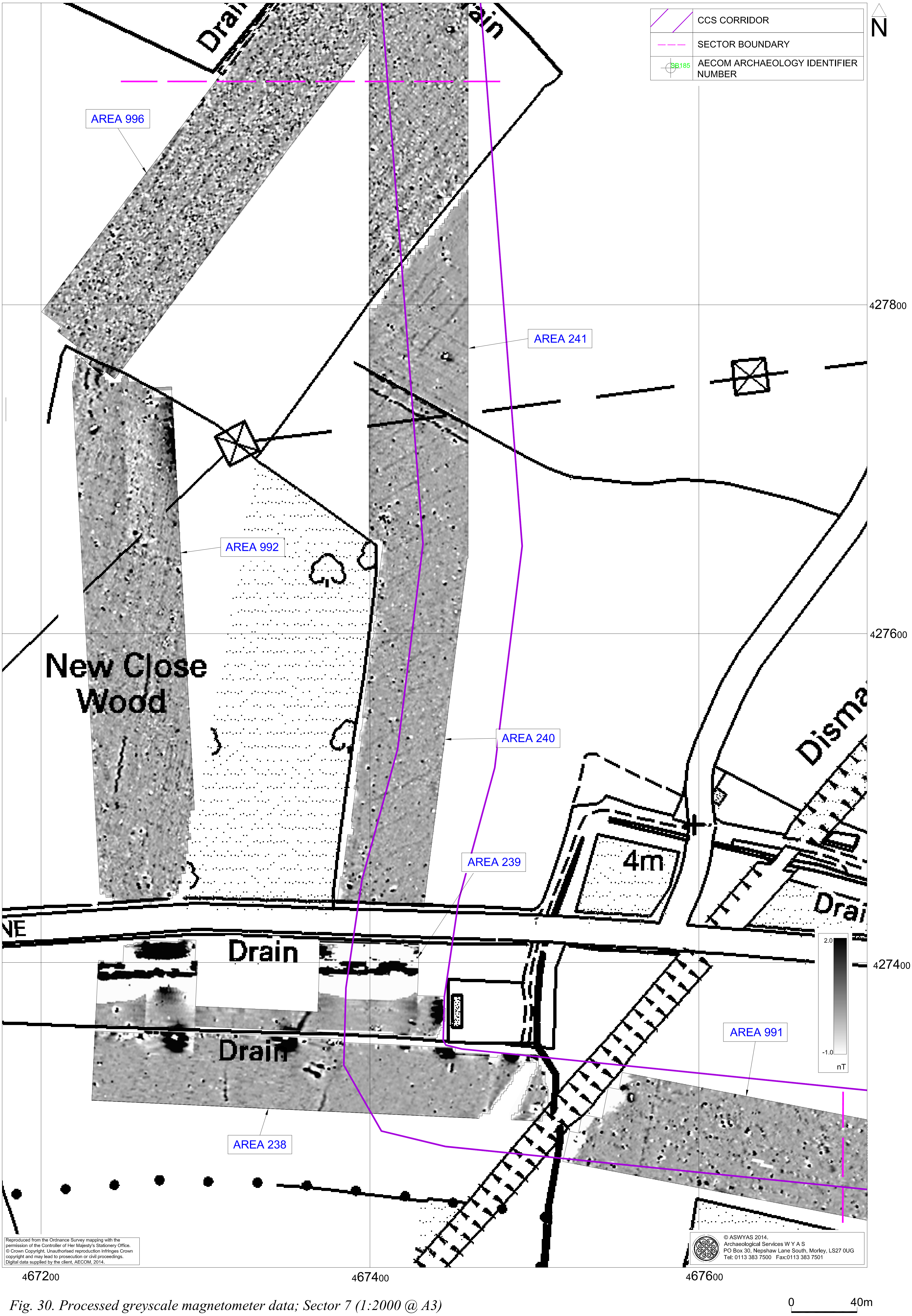

Fig. 30. Processed greyscale magnetometer data; Sector 7 (1:2000 @ A3)

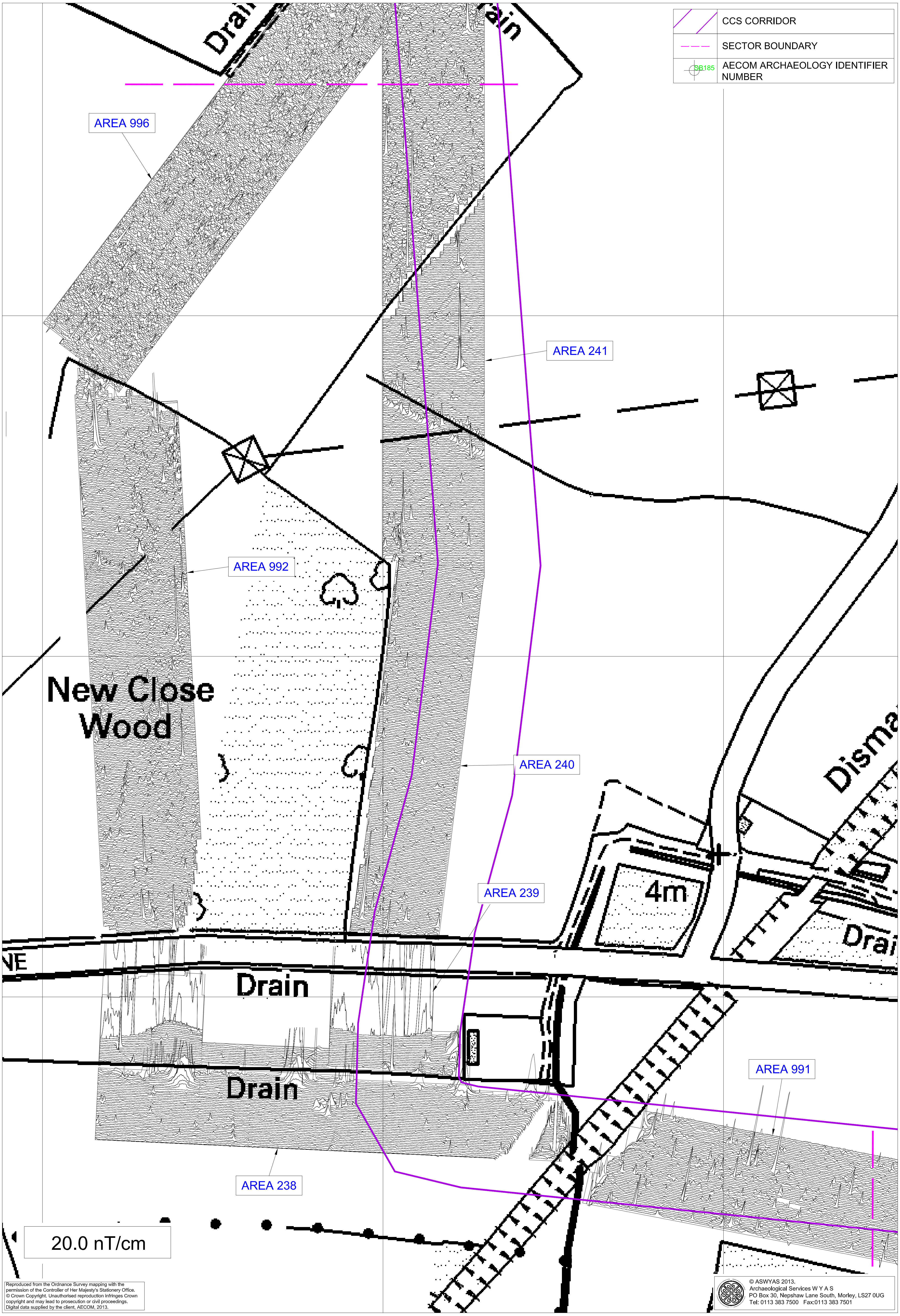

Fig. 31. XY trace plot of minimally processed magnetometer data; Sector 7 (1:2000 @ A3)

0 40m

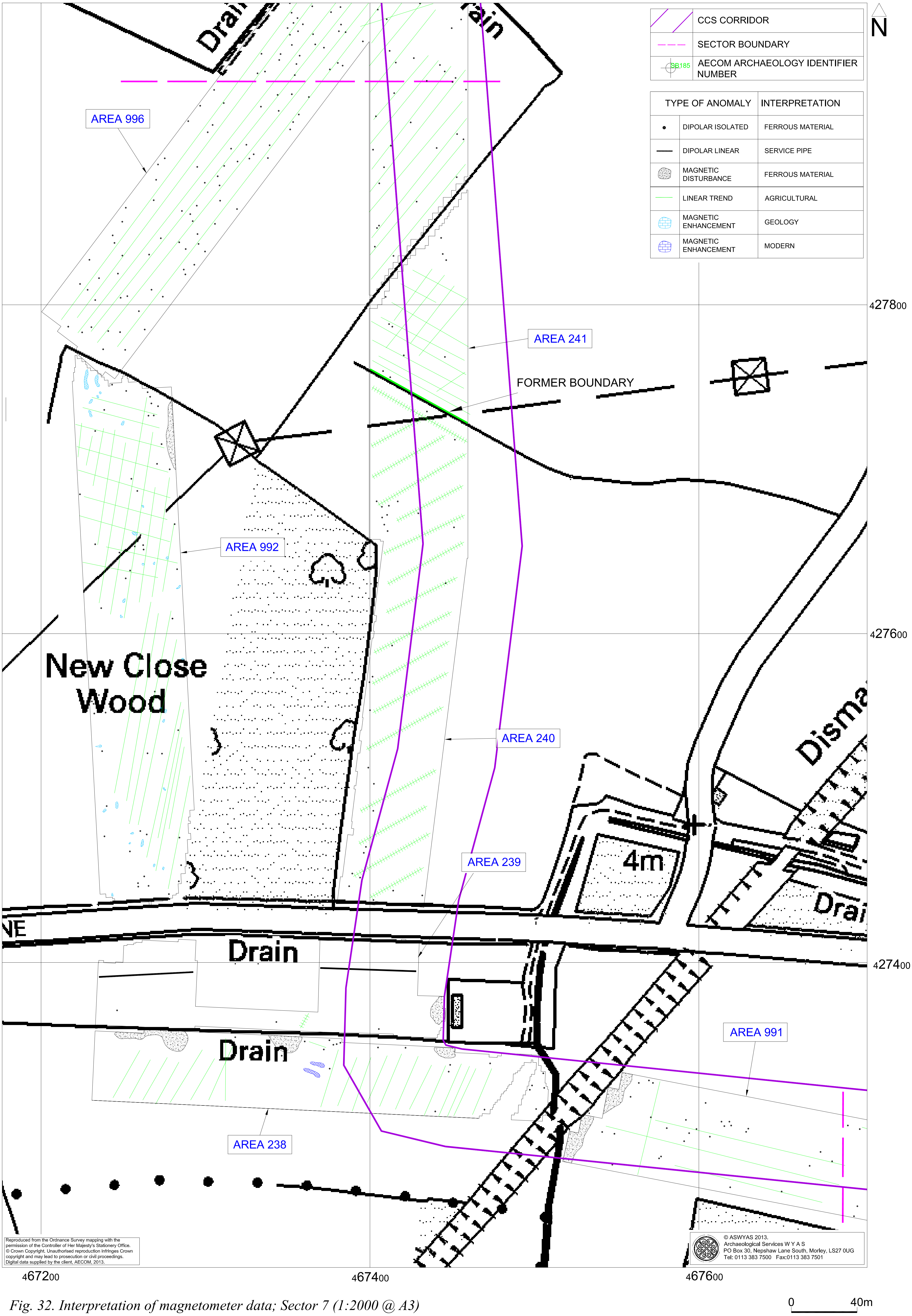

Fig. 32. Interpretation of magnetometer data; Sector 7 (1:2000 @ A3)

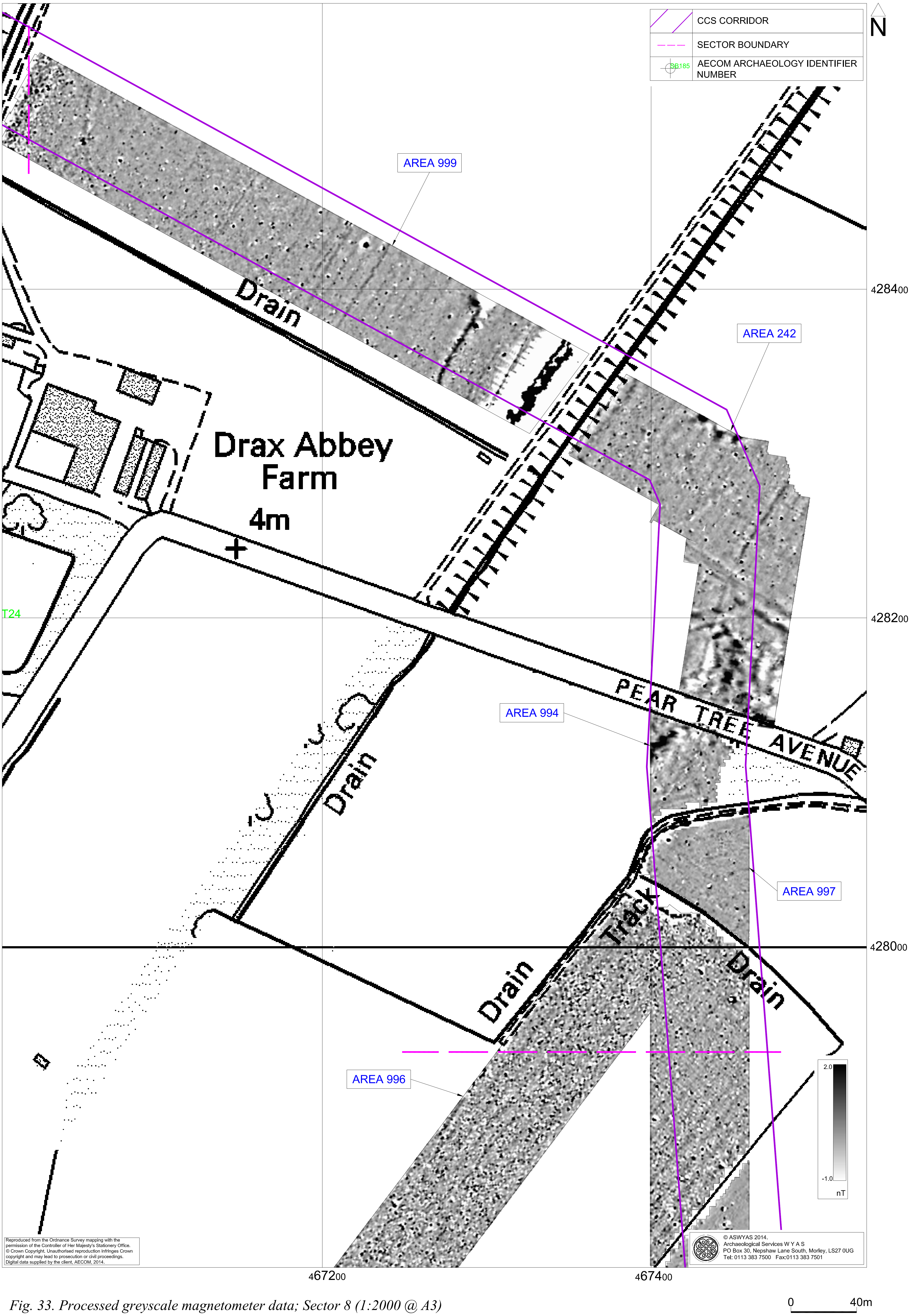

Fig. 33. Processed greyscale magnetometer data; Sector 8 (1:2000 @ A3)

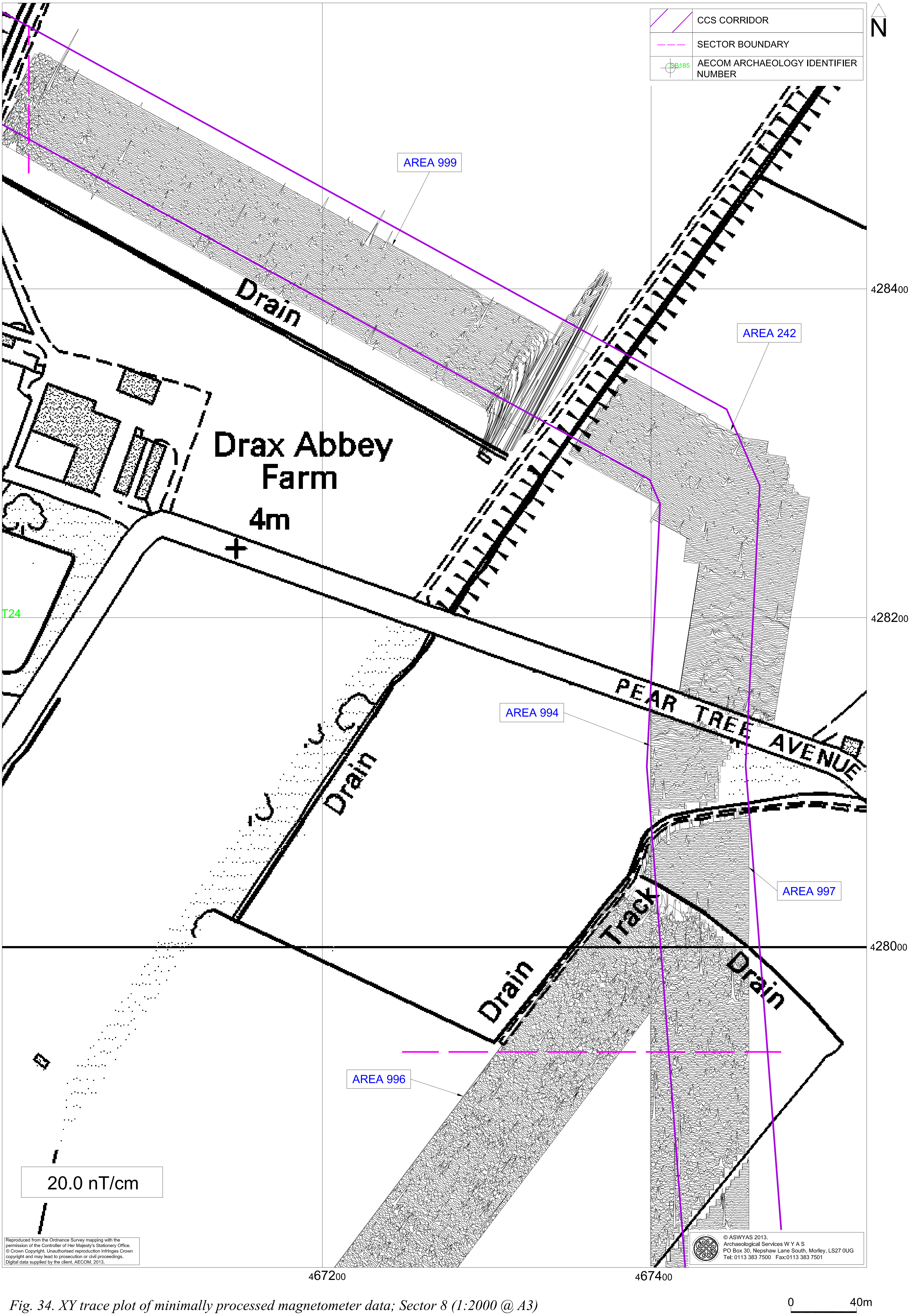

Fig. 34. XY trace plot of minimally processed magnetometer data; Sector 8 (1:2000 @ A3)

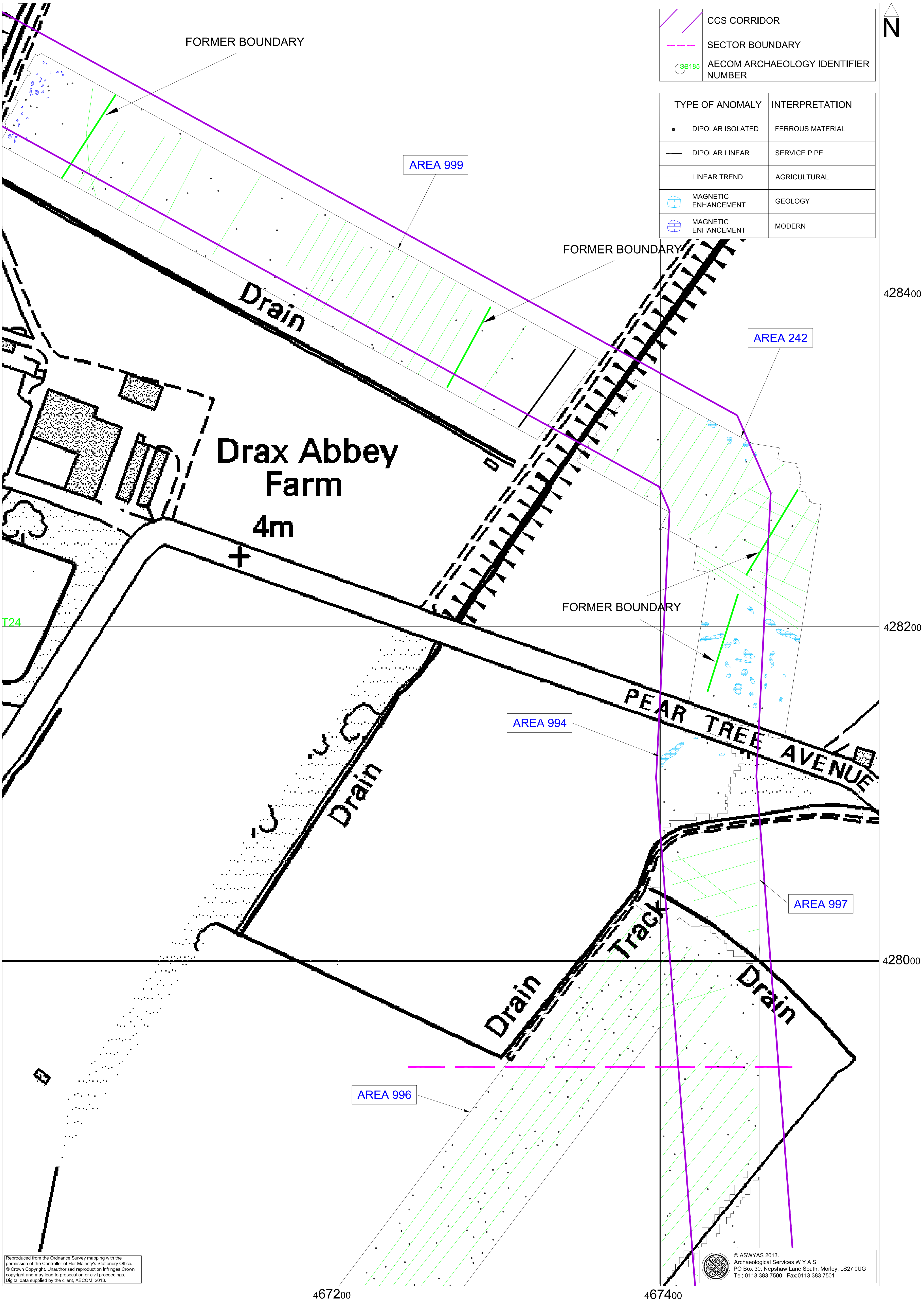

Fig. 35. Interpretation of magnetometer data; Sector 8 (1:2000 @ A3)

0 40m

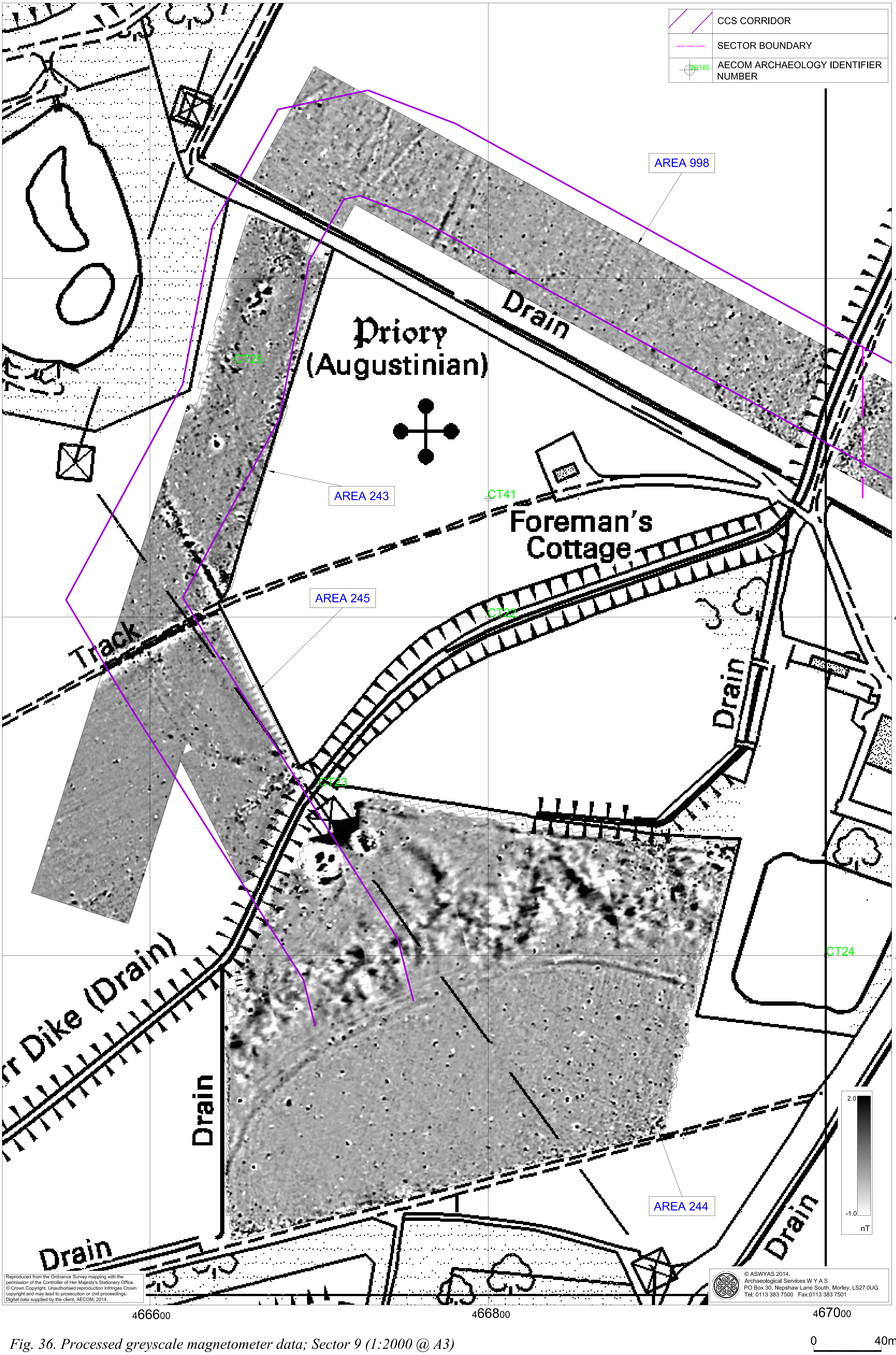

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Fig. 36. Processed greyscale magnetometer data; Sector 9 (1:2000 @ A3)

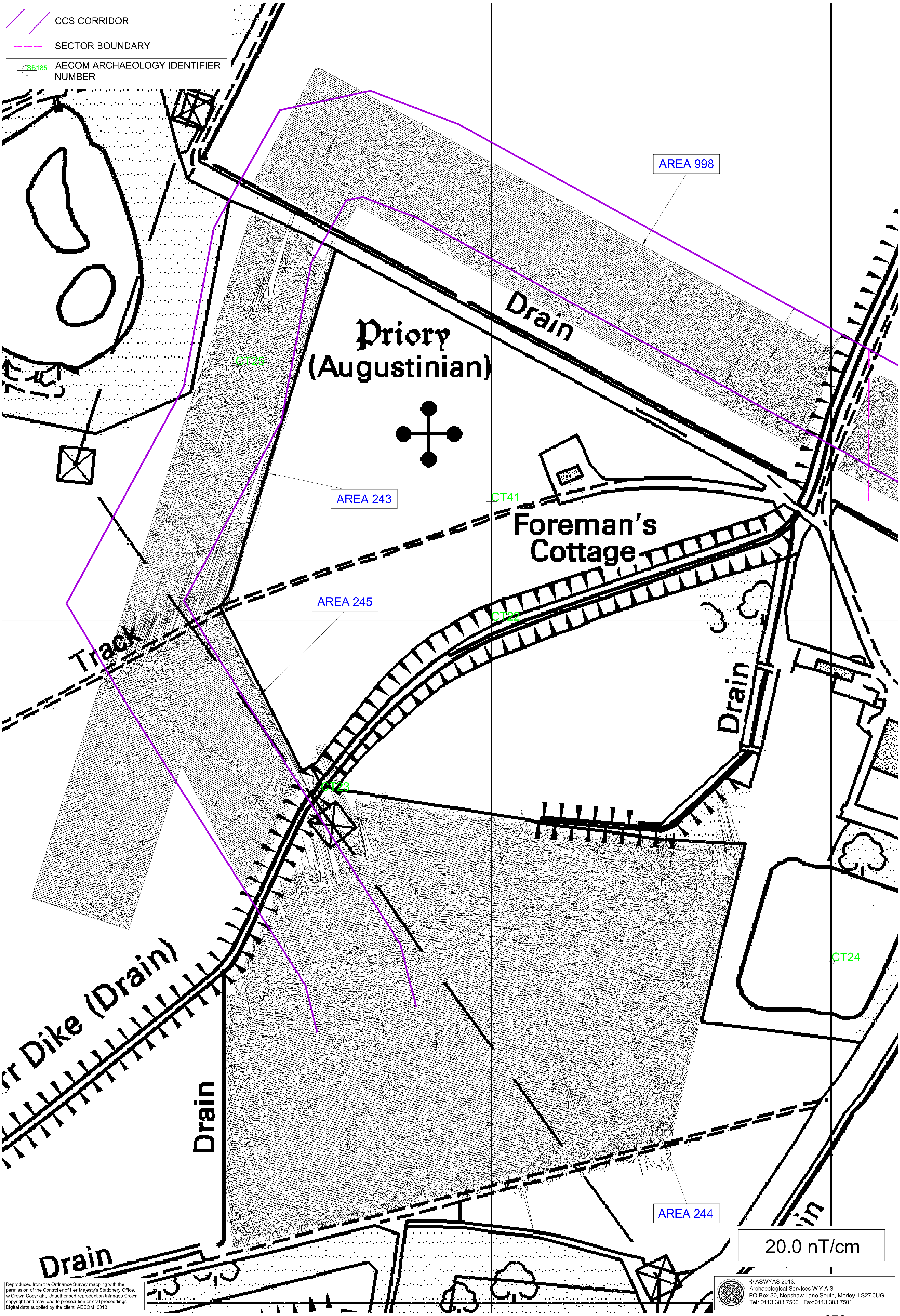

Fig. 37. XY trace plot of minimally processed magnetometer data; Sector 9 (1:2000 @ A3)

0 40m

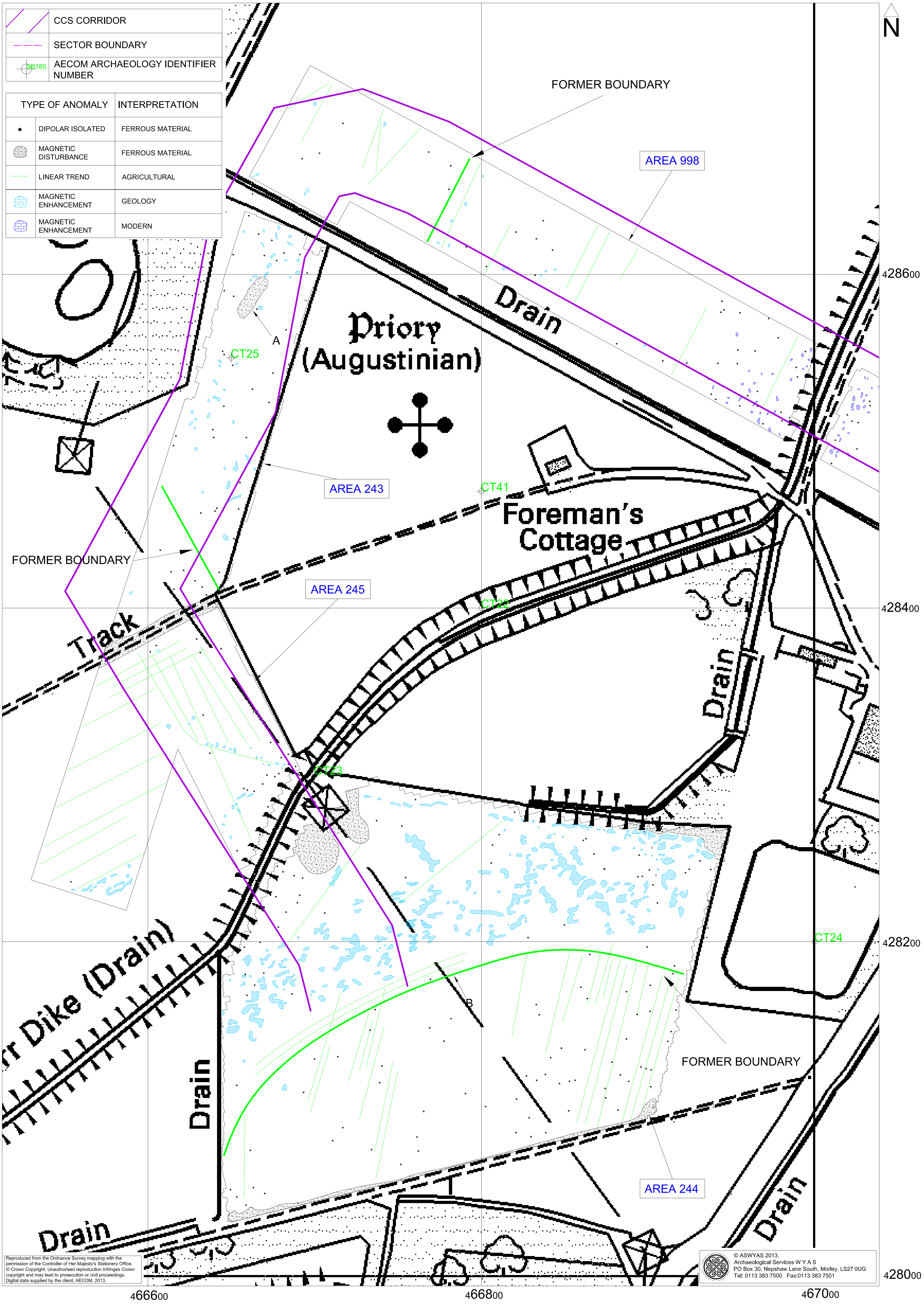

Fig. 38. Interpretation of magnetometer data; Sector 9 (1:2000 @ A3)

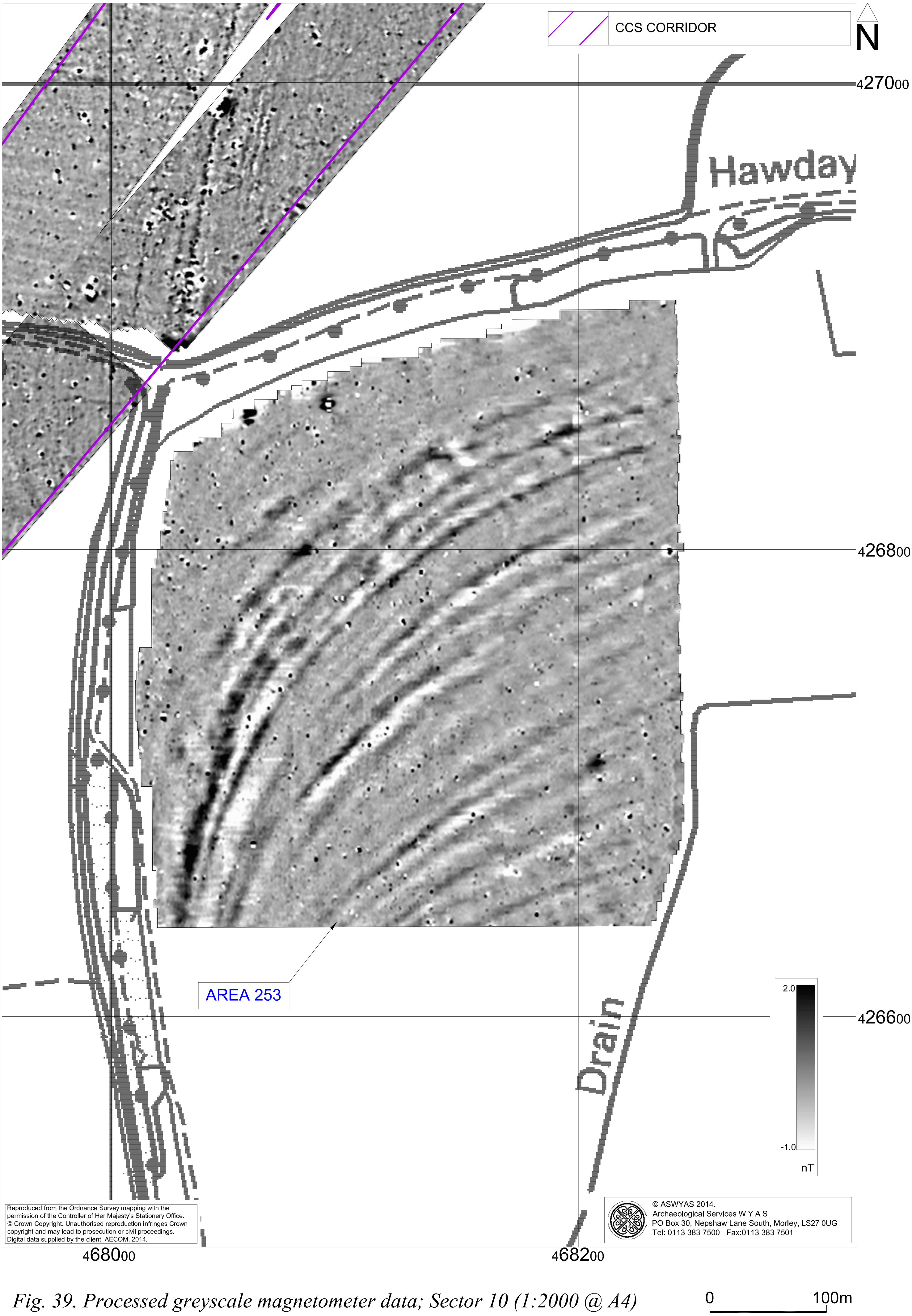

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Fig. 39. Processed greyscale magnetometer data; Sector 10 (1:2000 @ A4)

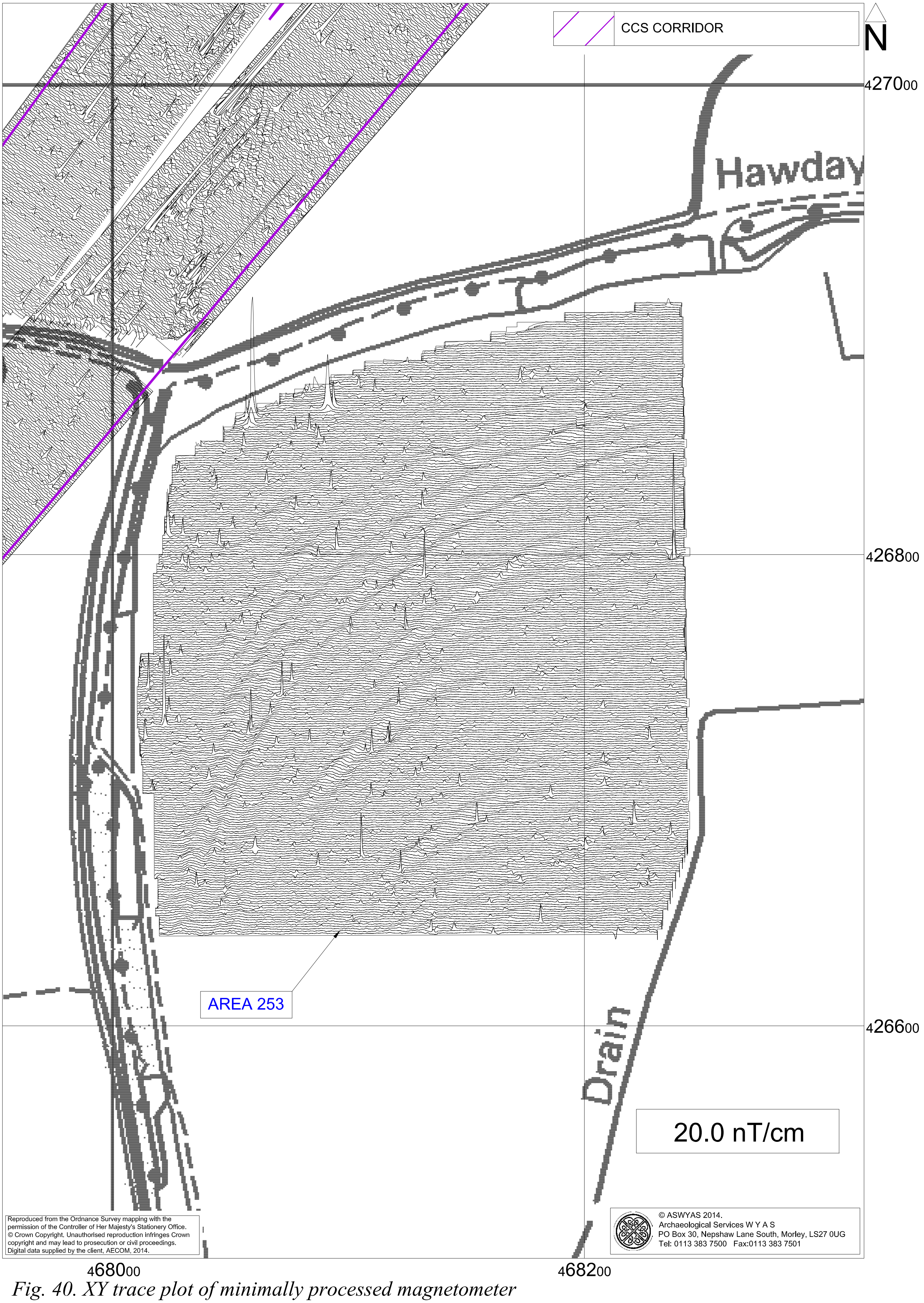

Fig. 40. XY trace plot of minimally processed magnetometer data; Sector 10 (1:2000 @ A4)

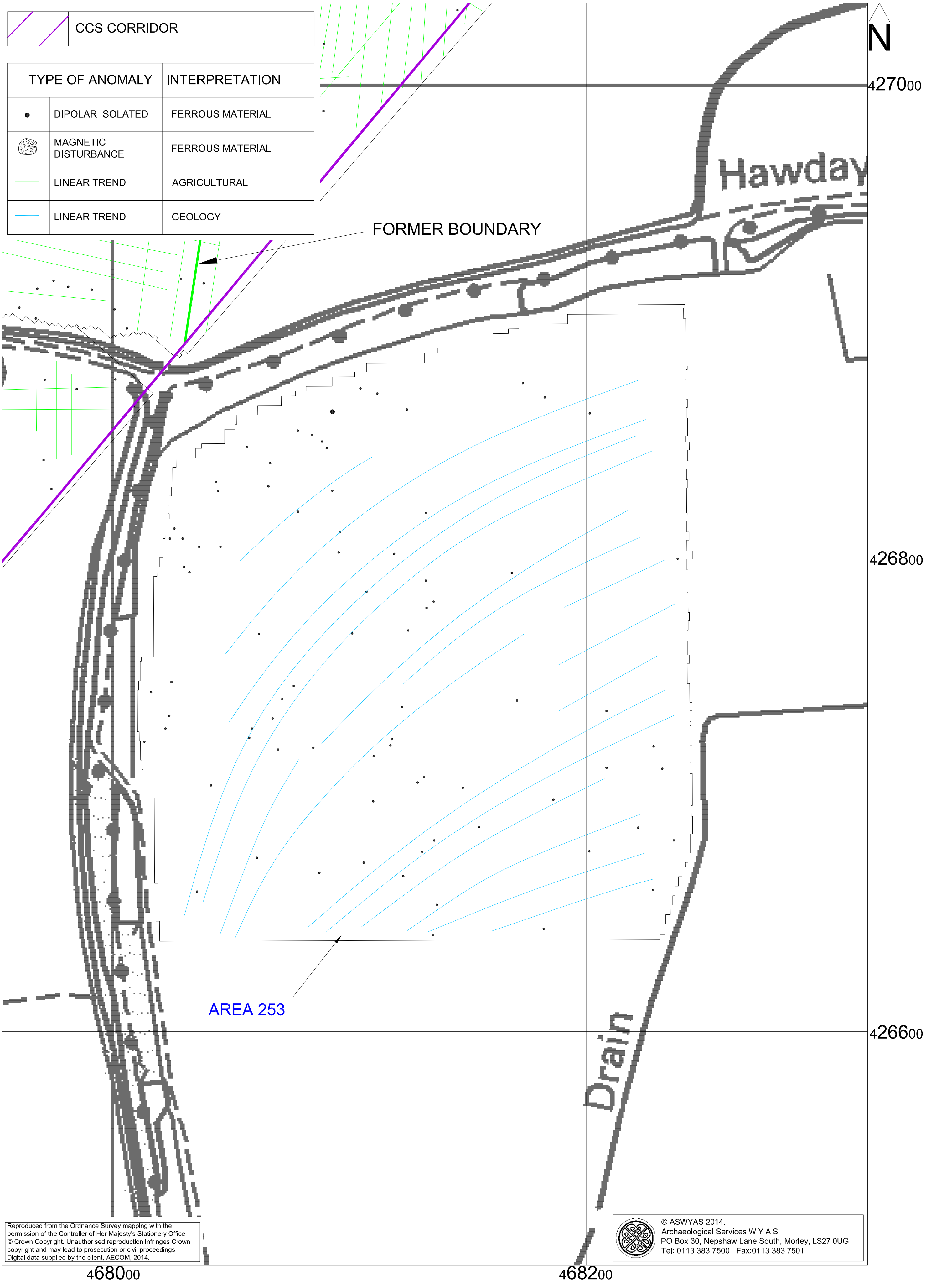

Fig. 41. Interpretation of magnetometer data; Sector 10 (1:2000 @ A4)

0 100m

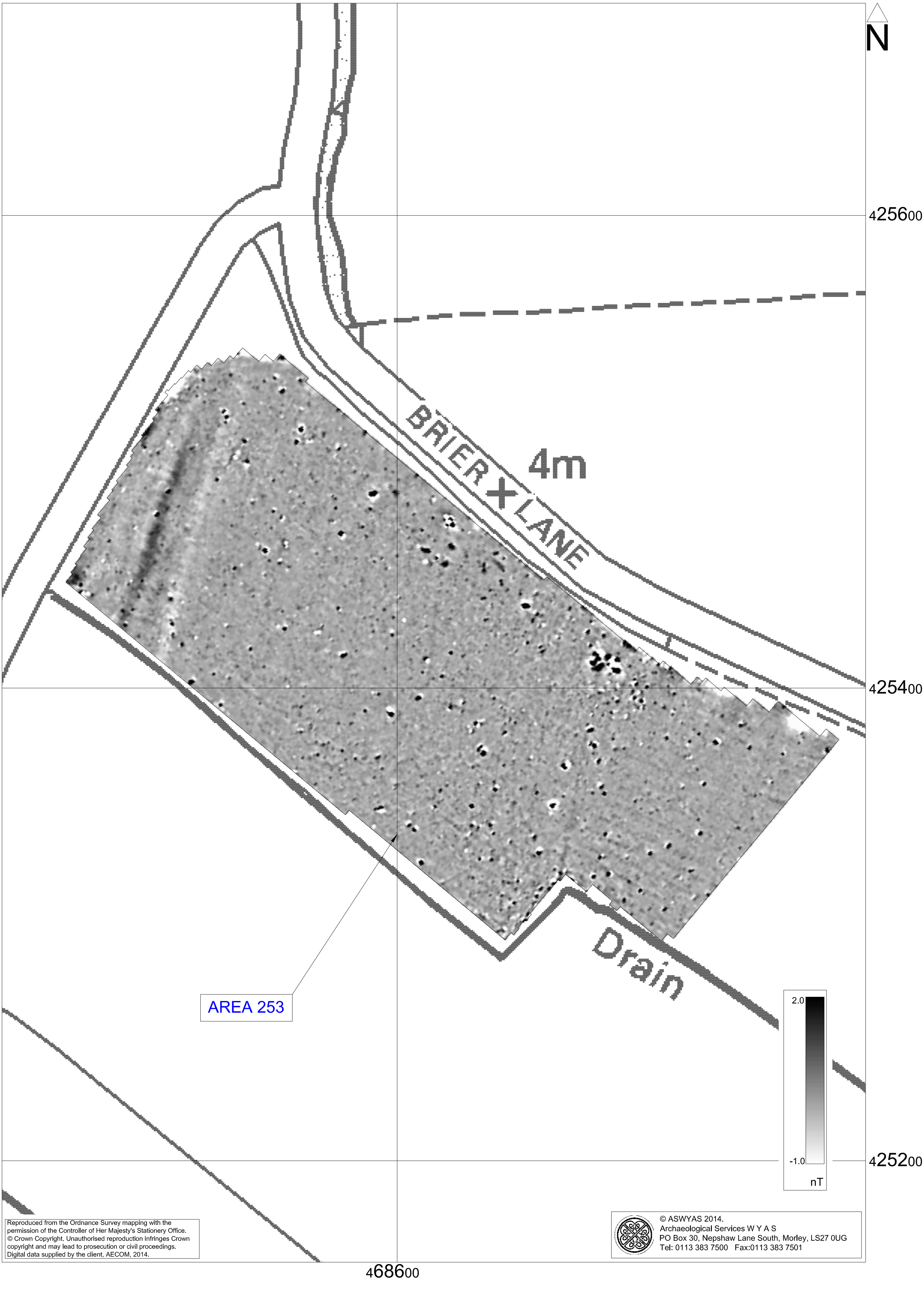

Fig. 42. Processed greyscale magnetometer data; Sector 11 (1:2000 @ A4)

0 100m

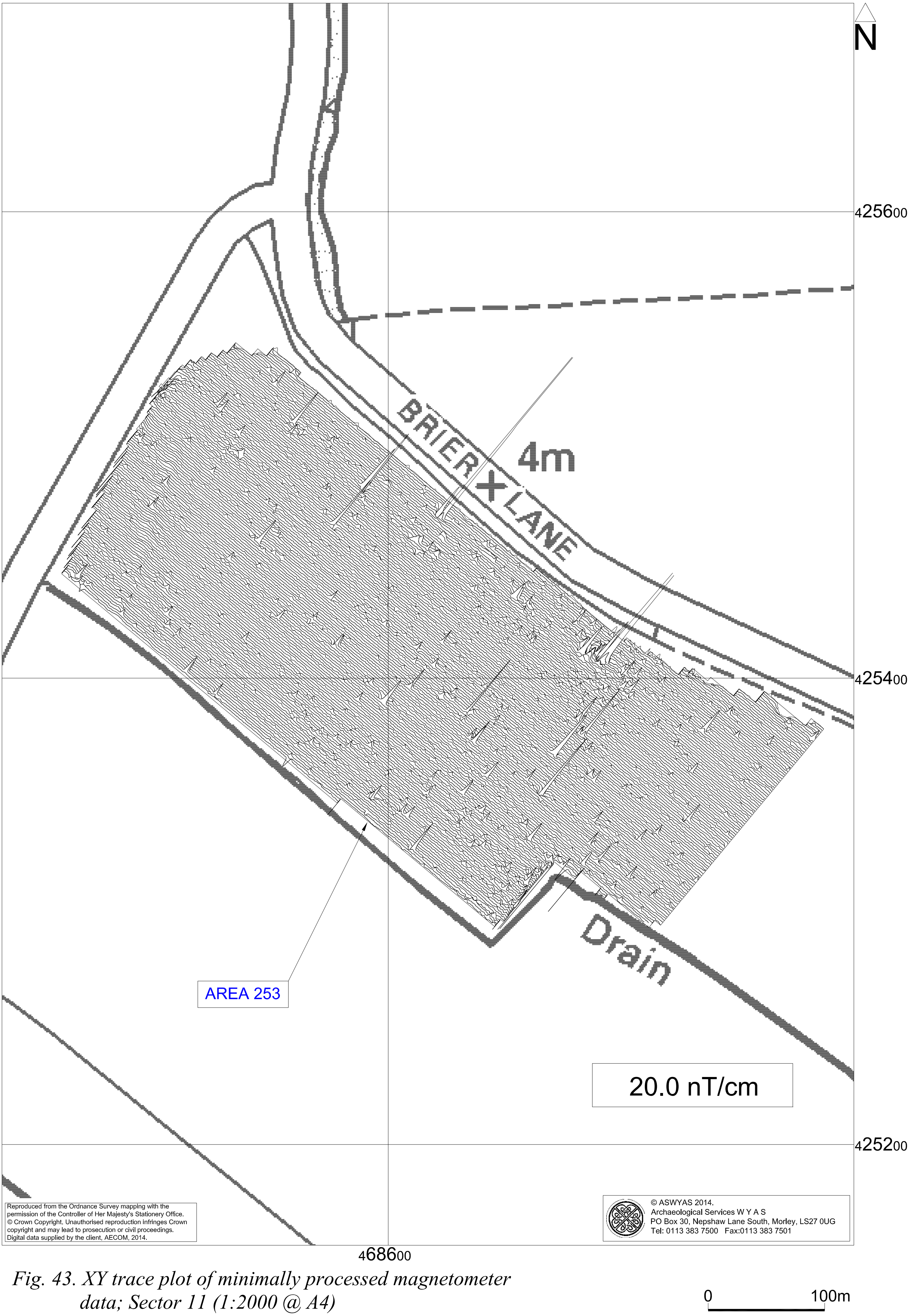

Fig. 43. XY trace plot of minimally processed magnetometer data; Sector 11 (1:2000 @ A4)

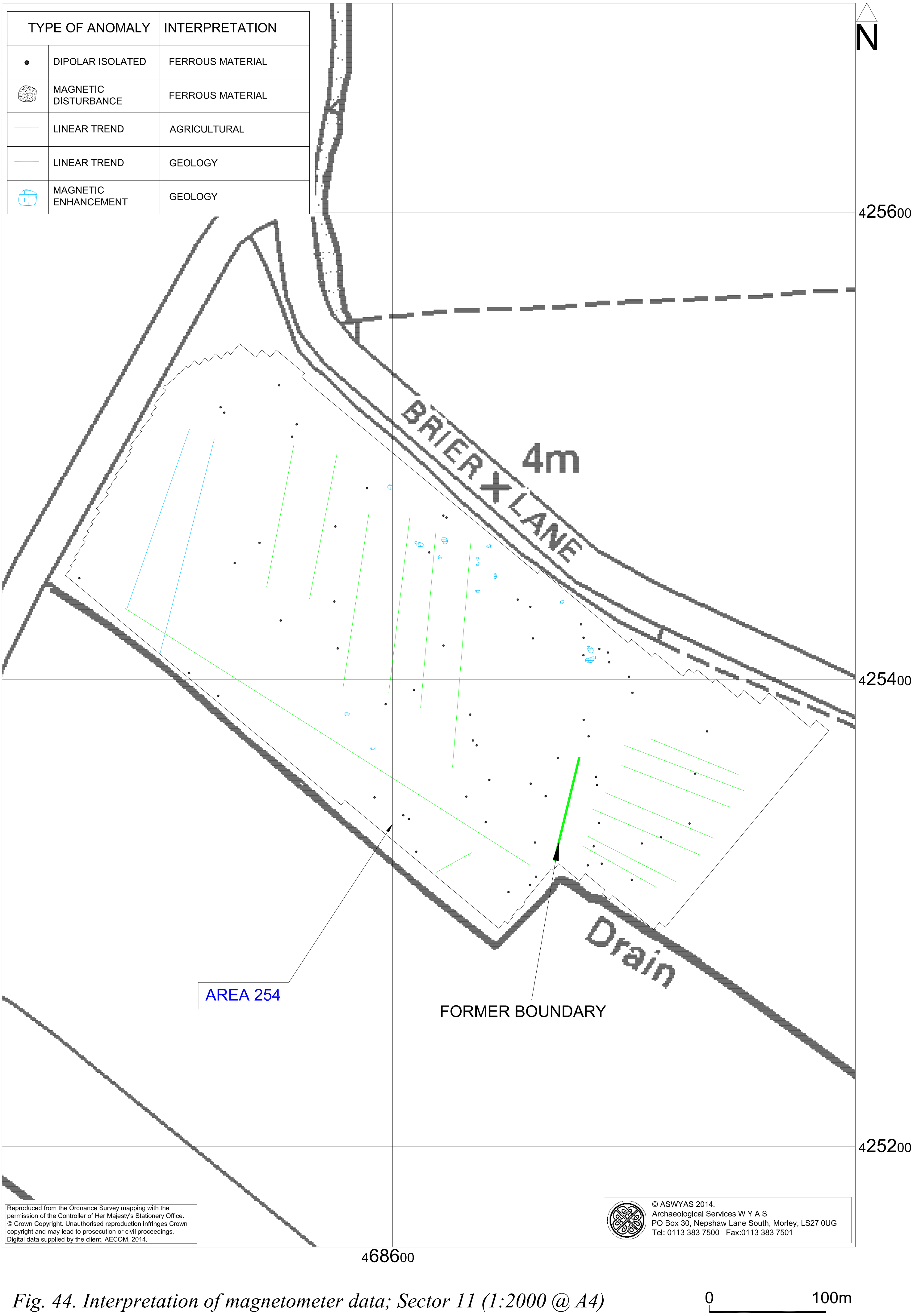

Fig. 44. Interpretation of magnetometer data; Sector 11 (1:2000 @ A4)

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.

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 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 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 30m by 30m 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 Trimble VRS differential Global Positioning System (Trimble 5800 model). The accuracy of this equipment is better then 0.01m. The survey grids were then super-imposed onto a base map provided by the client to produce the displayed block locations. 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 hard copies of the mapping rather than using the digital co-ordinates.

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; and
- 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 North Yorkshire Historic Environment Record).

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