YG-DCO-036-5.3.7D

Yorkshire Green Energy Enablement (GREEN) Project

Volume 5

Document 5.3.7D ES Chapter 7 Appendix 7D - Tadcaster Geophysical Survey (Report)

Final Issue A

November 2022

Planning Inspectorate Reference: EN020024

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 Regulation 5(2)(a)

nationalgrid

Land east of Leeds Road, Tadcaster
Selby, North Yorkshire

Archaeological geophysical survey

Project No. ARC/3377/1279

October 2022

Table of Contents

1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at land east of Leeds Road, Tadcaster, Selby, North Yorkshire. The aim of the survey was to help establish the presence / absence, extent, character, relationships and date (as far as circumstances and the inherent limitations of the technique permits) of archaeological features within the survey area.

The survey was undertaken using a Phase Site Investigations Ltd multi-sensor array cart system (MACS). The MACS comprised 8 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger. The MACS data was collected on profiles spaced 0.5 m apart with readings taken at between 0.1 and 0.15 m intervals.

The survey has provided evidence for archaeological activity, in the form of archaeological enclosures / boundary ditches, ditches related to a Roman Road and adjacent roadside quarries associated with the Roman Road.

The magnetic data in the northern field has a generally disturbed / variable magnetic background that is due to the presence of magnetic material in the topsoil or sub-surface. This could be related to 'green waste', which is added to manure but which contains significant amounts of ferrous material, or it could be from a spread of rubble or other modern debris. It should be noted that this general disturbed magnetic background could potentially mask responses from some types of sub-surface features, particularly discrete features.

The survey has also identified anomalies that relate to modern material / objects (including possible and probable metal pipes), agricultural activity and numerous responses indicative of natural features / variations. There are a number of anomalies of uncertain origin and it is possible that some of these could be associated with archaeological features, although many of them are probably caused by agricultural activity or natural features / variations.

There are several areas where very strong responses or magnetic disturbance from modern features / material dominate the surrounding data. It should be recognised that the strength of the strong responses could mask anomalies from other sub-surface features in the area.

2. INTRODUCTION

2.1 Overview

Phase Site Investigations Ltd was commissioned by Cotswold Archaeology Ltd to carry out an archaeological geophysical survey at land east of Leeds Road, Tadcaster, Selby, North Yorkshire utilising magnetic gradiometers.

The aim of the survey was to help establish the presence / absence, extent, character, relationships and date (as far as circumstances and the inherent limitations of the technique permits) of archaeological features within the survey area.

The location of the site is shown in drawing ARC_3377_1279_01.

2.2 Site description

The site is situated approximately 2.75 km to the south-west of Tadcatser, North Yorkshire (approximate centre at NGR SE 460 417), and covered an area of approximately 14.8 ha.

The site encompassed one arable field, in the north of the site, and part of a second arable field in the south. A section of the northern field was under a mustard crop, at the time of the survey. The remaining parts of the site were under stubble. A manure heap was present in the corner of the northern field. Two electricity pylons were present in the site and three overhead cable poles were also present. The fields were bounded by hedgerows.

The western part of the site was relatively level and there was a slight downwards slope from north-west to south-east in the east of the site

The geology across the majority of the site consists of dolomitic limestone of the Brotherton Formation, with a band of calcareous mudstone of the Edlington Formation in the south of the site. There are no recorded superficial deposits (British Geological Survey, 2022).

2.3 Archaeological background

A geophysical survey and subsequent watching brief (Archaeological Services WYAS 2014) has previously been undertaken across part of the site as part of a project to install overhead electricity cables (including the installation of the pylons currently present in the site). This confirmed the presence of Late Iron Age / Romano-British enclosure / boundary ditches, which had previously been identified as cropmarks from aerial photographs. A Roman Road was also identified, which cuts across the current site on a broadly north to south alignment.

The Roman Road, and several other Roman Roads, have also been investigated by a geophysical survey, of a field immediately to the west of the current site and areas to the north of the current site. A draft report of this geophysical survey (Roman Roads Research Association, 2020), has kindly been provided courtesy of John Firth and Mike Haken. This confirms the routes of several roads by identifying the ditches either side of the roads, as well as indicating the presence of small-scale quarries either side of parts of the roads that are probably related to the roads' construction. A number of other archaeological features, predominantly enclosure / boundary ditches of probable Late Iron Age / Romano-British date, have also been identified by the geophysical survey.

Background information in the Roman Roads Research Association report indicates that the route of the Roman Road that cuts across the current site is visible on Environment Agency lidar data.

Historic maps (maps.nls.uk, 2022) show the line of Roman Ridge Roman Road, which is predominantly under the current A64 adjacent to the southern edge of the survey area. They also show that the Roman Road that cuts through the survey area from north to south was visible as an earthwork in maps from the 1800s.

2.4 Scope of work

The survey area was specified by the client.

The area containing a mustard crop was not accessible for survey. The presence of a manure heap, dense vegetation adjacent to field boundaries and electricity pylons further reduced coverage. The area accessible / suitable for survey was approximately 12.9 ha, the extents of which are shown in drawing ARC_3377_1279_02. For the purposes of this survey each area that could be surveyed has been given a number, as shown in drawing ARC_3377_1279_02.

No problems were encountered during the survey which was carried out between 26 September and 29 September 2022.

3. SURVEY METHODOLOGY

3.1 Magnetic survey

The survey was undertaken using a Phase Site Investigations Ltd multi-sensor array cart system (MACS).

The MACS comprised 8 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger. The Foerster gradiometers do not require balancing as each sensor is automatically 'zeroed' using the control unit software.

The MACS utilises an RTK GNSS system which means that survey grids do not have to be established. Instead an area is surveyed over a series of continuous profiles and the position of each data point is recorded using an RTK GNSS system. The sensors have a separation of 0.5 m which means that data was collected on profiles spaced at 0.5 m apart. Readings were taken at between 0.1 m and 0.15 m intervals.

Data is collected on zig-zag profiles along the full length or width of a field, although fields can be sub-divided if they are particularly large. Marker canes are set-out along field boundaries at set intervals and these are used to align the profiles. The survey profiles are usually offset from field boundaries, buildings and other metallic features by several metres to reduce the detrimental effect that these surface magnetic features have on the data. The location of the MACS data is converted direct to Ordnance Survey co-ordinates using the UK OSTN 15 projection. As the survey is referenced direct to Ordnance Survey National Grid co-ordinates temporary survey stations are not established.

3.2 Data processing and presentation

The MACS data was stored direct to a laptop using in-house software which automatically corrects for instrument drift and calculates a mean value for each profile. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. The data is gridded using in-house software and parameters are set based on the sensor spacing and mean values. No additional processing is required. The gridded data is then displayed in Surfer 9 (Golden Software) and image files of the data are created.

The data was exported as greyscale raster images (PNG files). Data for the entire site is presented at a scale of 1:2000 and plots for individual fields / areas (or parts of fields / areas) with accompanying interpretations are shown at a scale of 1:1500. All greyscale plots were clipped at -2 nT to 3 nT. Greyscale plots have been 'smoothed' using a visual interpolation but the data itself has not been interpolated.

The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *'220906_GeophysCAD.dwg'*. The base plan was in the Ordnance Survey National Grid co-ordinate system and as the survey grids / data were referenced directly to National Grid co-ordinates the data could be simply superimposed onto the base plan in the correct position.

X-Y trace plots were examined for all of the data and overlain onto the greyscale plot to assist in the interpretation, primarily to help identify dipolar and bipolar responses that will probably be associated with surface / near-surface iron objects. However, X-Y trace plots have not been presented here as they do not show any additional anomalies that are not visible in the greyscale data. A digital drawing showing the X-Y trace plot overlain on the greyscale plot is provided in the digital archive.

All isolated responses have been assessed using a combination of greyscale and X-Y trace plots. There are a large number of 'iron spike', isolated dipolar anomalies present in the data. There is little evidence to suggest that they are associated with archaeological features and so the majority of these have not been shown in the interpretation. Selected isolated dipolar / bipolar responses have been shown in proximity to some anomalies that are suggestive of archaeological features and some responses of uncertain origin. These responses are highly likely to be caused by modern material but the potential for these to be associated with archaeological features is increased slightly by their proximity to other anomalies / features.

Anomalies associated with agricultural regimes are present in the data but each individual anomaly has not been shown on the interpretation. Instead, the general orientation of the regime is indicated.

The data was examined over several different ranges during the interpretation to ensure that the maximum information possible was obtained from the data.

The anomalies have been categorised based on the type of response that they exhibit and an interpretation as to the cause(s) or possible cause(s) of each anomaly type is also provided.

A general discussion of the anomalies is provided for the entire site and then the results are discussed on an area by area basis. A discussion of the general categories of anomaly which have been identified by the survey is provided in Appendix 1.5.

The geophysical interpretation drawing must be used in conjunction with the relevant results section and appendices of this report.

4. RESULTS

4.1 General

The data quality across the majority of the survey area is very good allowing the data to be viewed at a narrow range of readings to better identify weak anomalies. The data in parts of the site have a generally disturbed / variable magnetic background but this is due to the presence of magnetic material in the topsoil or sub-surface, rather than low data quality.

There are anomalies indicative of archaeological features present in parts of the site. Some of these anomalies are fragmented or discontinuous. It is possible that some of the sub-surface features associated with these responses were originally fragmented but it is considered more likely that many of the features have been differentially truncated by agricultural activity. It is also probable that some anomalies may become weaker in places because the magnetic susceptibility of the soils infilling them has decreased or there may be an increase in soil cover. Where the responses become weaker or more diffuse they are often shown as trends as it is not certain if a significant sub-surface feature is still present in that area, or if the magnetic responses is from the vestigial remains of a feature. Stronger responses, which may indicate where more extensive remains are present, have been shown as positive linear / curvi-linear responses.

The majority of Area 1 has a very large number of isolated responses, which produce a variable / ‘disturbed’ magnetic background. These are indicative of a spread of modern material. These could be related to ‘green waste’, which is added to manure but which contains significant amounts of ferrous material, or it could be from a spread of rubble or other modern debris. The number of isolated responses means that it is not possible to differentiate between the responses associated with modern material or any isolated responses that could have potential to be related to archaeological features / activity.

4.2 Area 1

Basic topography: The western part of the field was relatively level and there was a slight downwards slope from north-west to south-east in the east of the site

Field / Area description: Arable field. The majority was under stubble from a cereal crop but a section in the north contained a mustard crop, which could not be surveyed. Relatively firm underfoot. Bounded by hedges. A manure heap was present in the western corner of the field. Two electricity pylons were present, one on the southern boundary and one in the east of the field the site and three overhead cable poles were also present.

Summary of anomalies: Numerous isolated dipolar and small bipolar and isolated positive responses are present, a large majority, if not all, of which will be associated with relatively modern material. Selected responses have been shown on the interpretation where they are located in proximity to possible archaeological features / activity. Several larger isolated dipolar and bipolar responses have been shown. These are related to concentrations of, or larger objects or features, of relatively modern ferrous or fired material. They are not thought to be archaeological significant but have been shown to highlight areas where there may be significant relatively modern material / objects.

A possible linear bipolar anomaly that may be associated with sub-surface utility apparatus, such as a metal pipe. It is not certain if these responses relate to a feature(s) within or adjacent to the survey area.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area. It is not certain if the strong responses in the south of the area are related to a metal pipe that is located beyond the edge of the survey area or within it, or if there is more than one pipe present.

There are several strong linear responses that are artificial data products. These may be related to a sensor movement or jolt caused by rough / uneven ground or are a product of the very strong responses associated with adjacent structures. These responses are not related to a sub-surface feature and their presence has not affected the reliability of the survey or interpretation.

Two series of broadly parallel, positive linear responses are present that are associated with the modern ploughing regime(s).

There are a number of broadly parallel linear / curvi-linear responses, the majority of which will be related to natural features / variations, although some responses could be a product of agricultural activity.

Trends and positive linear / curvi-linear responses of uncertain origin. Some responses may be related to agricultural or drainage activity / features but others may be caused by archaeological features.

Positive linear / curvi-linear responses and trends associated with parts of archaeological enclosures / boundary ditches.

Further discussion / additional information:

As discussed above the majority of this area has a strongly variable / disturbed magnetic background, caused by a spread of a large amount of modern material. This could be related to green waste. It should be noted that this could mask responses from isolated features, should any such features be present.

Several larger / stronger isolated dipolar / bipolar anomalies have been shown. These are probably related to larger, or more magnetic, modern material but there is a slight chance that responses located overlaying, or in close proximity to, archaeological features could have an archaeological origin. Three of these responses (**Anomalies A**) will be related to overhead cable posts.

There are linear anomalies (**Anomalies B**) related to archaeological enclosures / boundary ditches. Some of the responses are fragmented or become very weak (shown as trends). This could indicate where the underlying features have been truncated to a greater extent or it could reflect changes in the magnetic properties of the fill material. There are several weak and / or short trends and positive linear responses (**Anomalies C**) that could be related to additional archaeological features but it is also possible that some, or all of these are caused by agricultural activity or natural features / variations.

4.3 Area 2

Basic topography: The western part of the field was relatively level and there was a slight downwards slope from north-west to south-east in the east of the site

Field / Area description: Part of an arable field that was under stubble from a cereal crop. Relatively firm underfoot. Bounded by hedges.

Summary of anomalies: Numerous isolated dipolar and small bipolar and isolated positive responses are present, a large majority, if not all, of which will be associated with relatively modern material. Selected responses have been shown on the interpretation where they are located in proximity to possible archaeological features / activity. Several larger isolated dipolar and bipolar responses have been shown.

A linear bipolar anomaly associated with sub-surface utility apparatus (probable metal pipe) and a possible linear bipolar anomaly that may be associated with additional utility apparatus / pipe(s).

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

There are several strong linear responses that are artificial data products. These may be related to a sensor movement or jolt caused by rough / uneven ground or are a product of the very strong responses associated with adjacent structures. These responses are not related to a sub-surface feature and their presence has not affected the reliability of the survey or interpretation.

Two series of broadly parallel, positive linear responses are present that are associated with the modern ploughing regime(s).

There are a number of broadly parallel linear / curvi-linear responses, the majority of which will be related to natural features / variations, although some responses could be a product of agricultural activity.

Trends and positive linear / curvi-linear responses of uncertain origin. Some responses may be related to agricultural or drainage activity / features but others may be caused by archaeological features.

Two broadly parallel alignments of trends are probably associated with the ditches either side of a Roman Road. Adjacent broad, diffuse areas of positive or negative responses are probably related to infilled quarries associated with the Roman Road.

Positive linear / curvi-linear responses and trends associated with parts of probable and possible archaeological ditches.

Further discussion / additional information:

Anomalies D are probably related to ditches either side of a Roman Road and the adjacent broad, diffuse areas of positive or negative responses are probably associated with infilled quarries associated with the Roman Road. It is possible that some trends could be associated with the edges of quarries, rather than infilled ditches.

Anomaly E is an alignment of responses related to an infilled archaeological ditch. This anomaly is weaker than the archaeological responses to the east, which could indicate that Anomaly E is related to a feature that differs from those causing Anomalies B, either from a different phase of activity or having a different function. Although it is also possible that the change in responses could simply reflect a change in the soil conditions across the site.

Anomaly F appears to also be related to an archaeological ditch but the anomaly becomes weaker at both ends so the full extent of this feature, its possible relationships to other features and potentially whether it has been cut through by the Roman Road is not clear.

There are a number of other weak and / or short trends and positive linear responses (**Anomalies C**) that could be related to additional archaeological features but it is also possible that some, or all of these are caused by agricultural activity or natural features / variations. It is likely that the Anomalies C responses in the east of the area are related to natural features / variations but given their proximity to other archaeological features an archaeological origin cannot be completely ruled out.

5. DISCUSSION AND CONCLUSIONS

The survey has provided evidence for archaeological activity, in the form of archaeological enclosures / boundary ditches, ditches related to a Roman Road and adjacent roadside quarries associated with the Roman Road.

The magnetic data in the northern field has a generally disturbed / variable magnetic background that is due to the presence of magnetic material in the topsoil or sub-surface. This could be related to 'green waste', which is added to manure but which contains significant amounts of ferrous material, or it could be from a spread of rubble or other modern debris. It should be noted that this general disturbed magnetic background could potentially mask responses from some types of sub-surface features, particularly discrete features.

The survey has also identified anomalies that relate to modern material / objects (including possible and probable metal pipes), agricultural activity and numerous responses indicative of natural features / variations. There are a number of anomalies of uncertain origin and it is possible that some of these could be associated with archaeological features, although many of them are probably caused by agricultural activity or natural features / variations.

There are several areas where very strong responses or magnetic disturbance from modern features / material dominate the surrounding data. It should be recognised that the strength of the strong responses could mask anomalies from other sub-surface features in the area.

It should be noted that a geophysical survey does not directly locate sub-surface features - it identifies variations or anomalies in the background response caused by features. The interpretation of geophysical anomalies is often subjective and it is rarely possible to identify the cause of all such anomalies. Not all features will produce a measurable anomaly and the effectiveness of a geophysical survey is also dependant on the site-specific conditions. The main factors that may limit whether a feature can be detected are the composition of a feature, its depth and size and the surrounding material. It is not possible to guarantee that a geophysical survey will identify all sub-surface features. Confirmation on the identification of anomalies and the presence or absence of sub-surface features can only be achieved by intrusive investigation.

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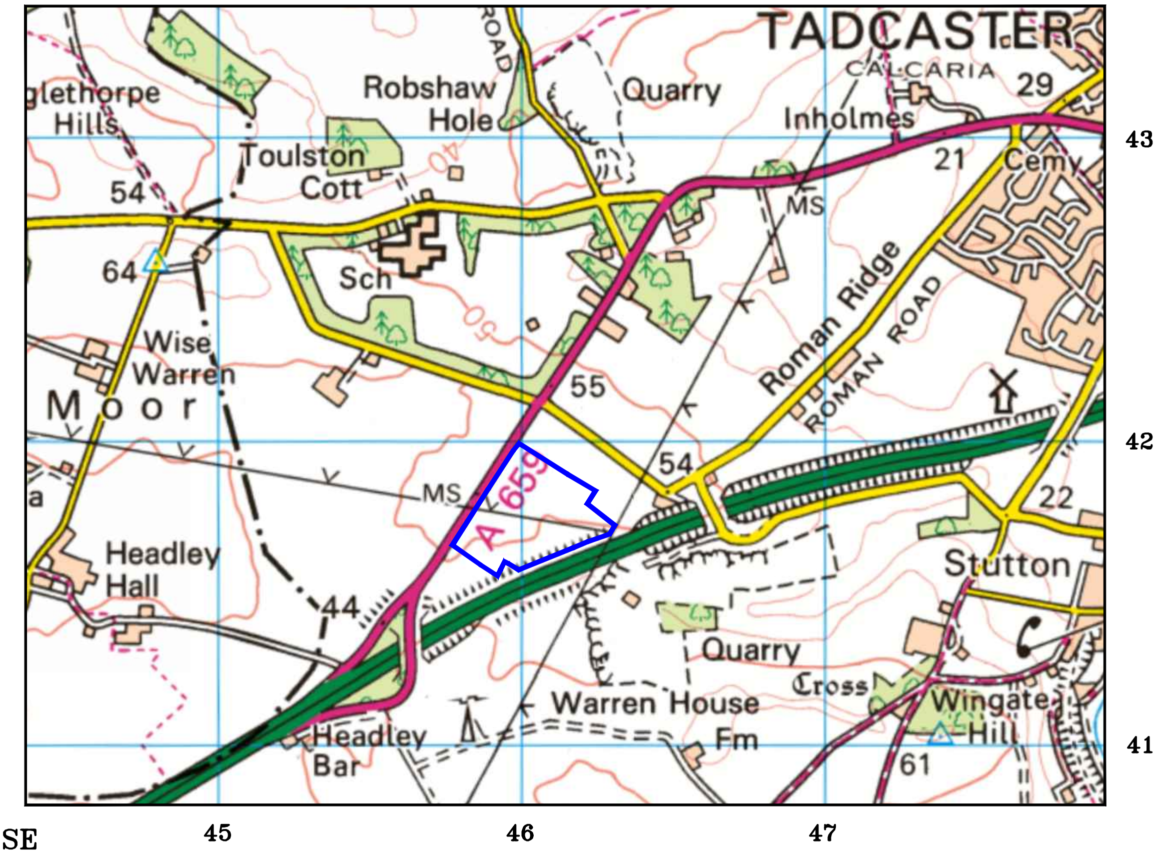

SITE LOCATION

SCALE

0m 500m 1000m

NOTE

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Scale [A4 Sheet]: AS SHOWN	Drawing: ARC_3377_1279_01	Status: FINAL

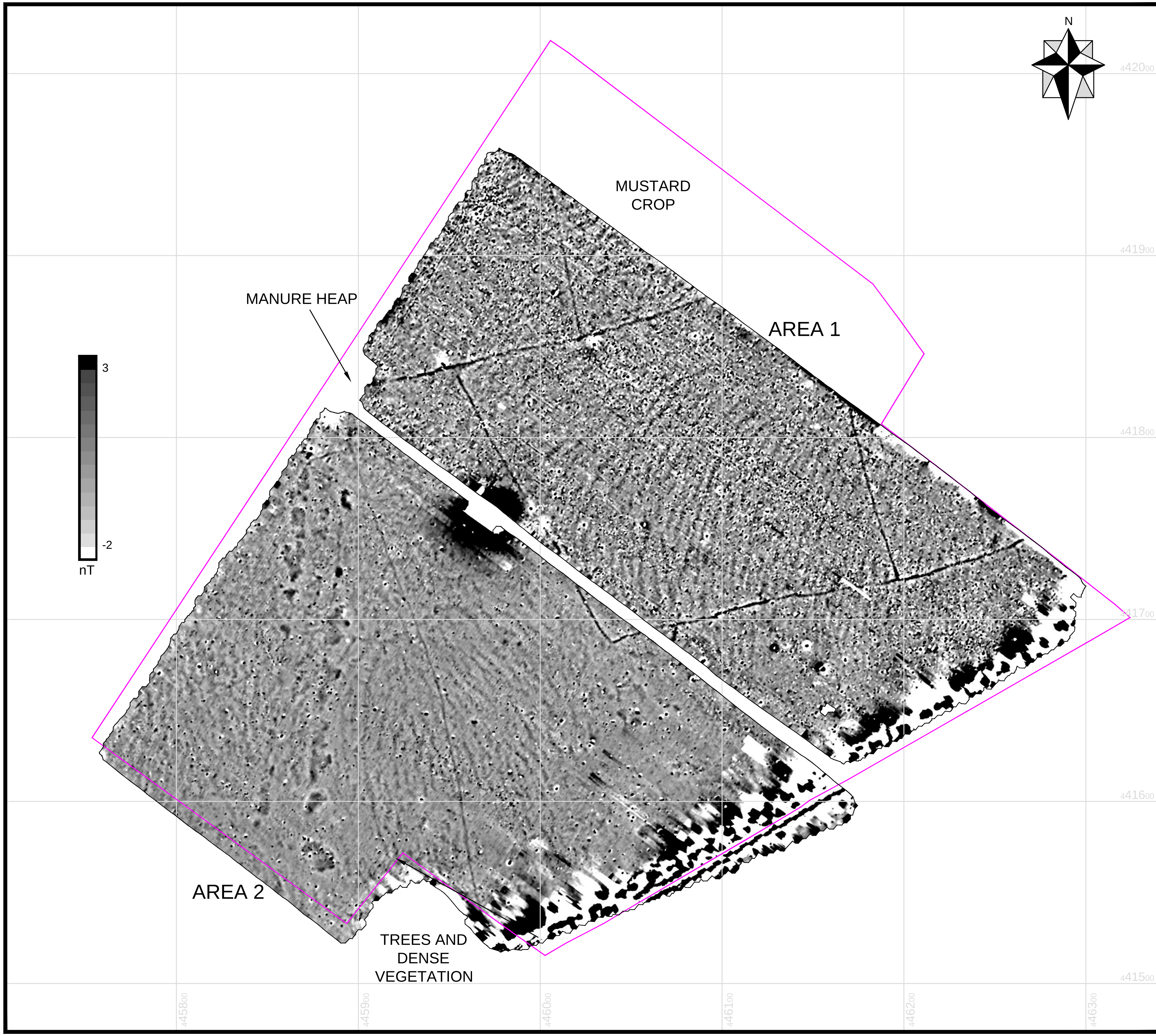
Client: COTSWOLD ARCHAEOLOGY MILTON KEYNES

Site: LAND EAST OF LEEDS ROAD, TADCASTER SELBY, NORTH YORKSHIRE

Title: SITE LOCATION MAP

Job No: ARC_3377_1279

		Drawn	RS
Chk.	MW	Date	30/09/2022



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SITE BOUNDARY

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Scale [A3 Sheet]	Drawing	Status
1:2000	ARC_3377_1279_02	FINAL

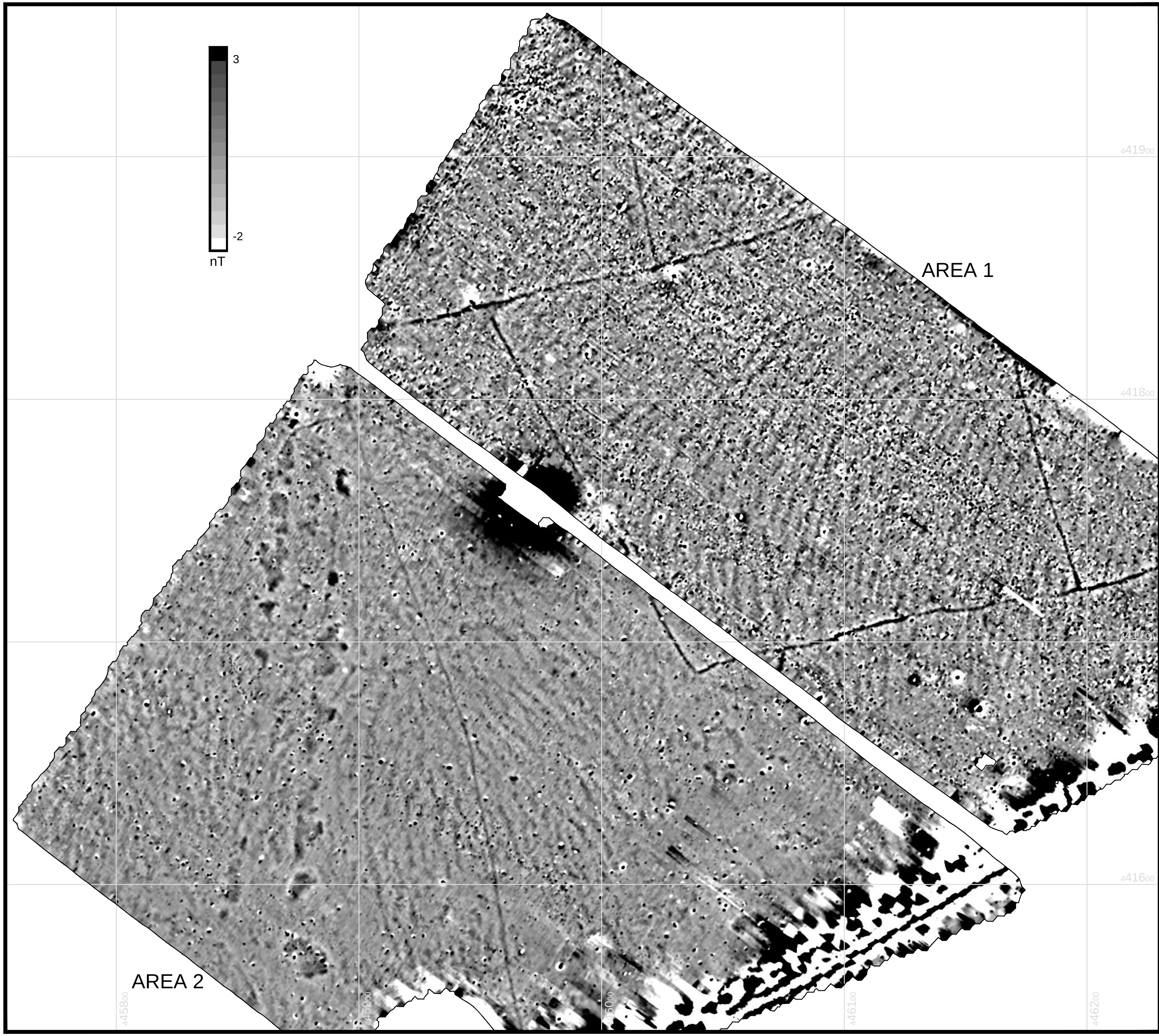
Client
COTSWOLD ARCHAEOLOGY
MILTON KEYNES

Site
LAND EAST OF LEEDS ROAD, TADCASTER
SELBY, NORTH YORKSHIRE

Title
LOCATION OF SITE SHOWING
MAGNETIC GRADIENT DATA

Job No
ARC_3377_1279

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	29/09/2022



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Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_3377_1279_03	FINAL

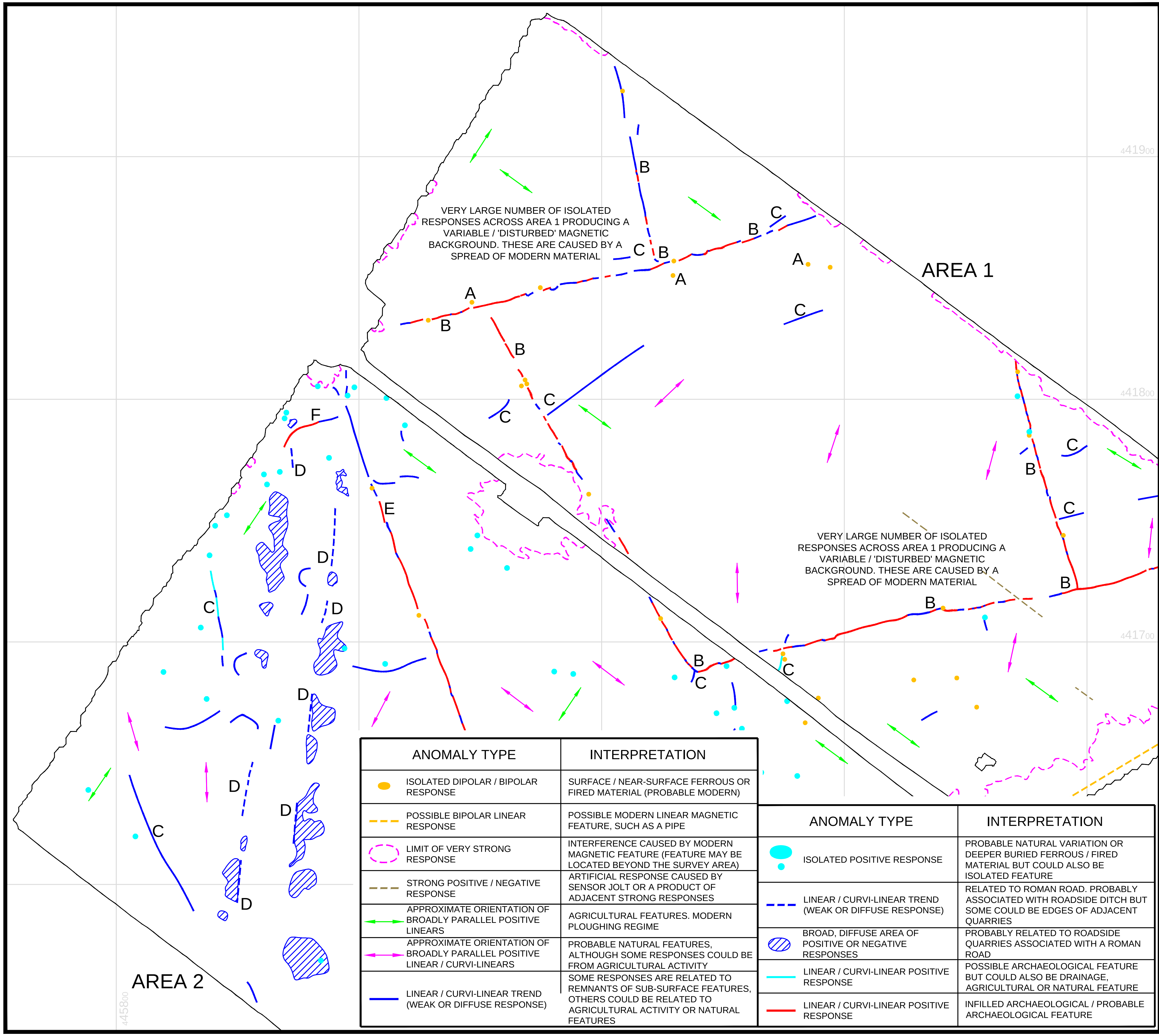
Client
COTSWOLD ARCHAEOLOGY
MILTON KEYNES

Site
LAND EAST OF LEEDS ROAD, TADCASTER
SELBY, NORTH YORKSHIRE

Title
GREYSCALE PLOTS OF MAGNETIC GRADIENT DATA: MAJORITY OF AREAS 1 AND 2

Job No
ARC_3377_1279

Surveyed	JW, RS	Drawn	MW
Chk.	NF	Date	29/09/2022



ANOMALY TYPE	INTERPRETATION
ISOLATED DIPOLAR / BIPOLAR RESPONSE	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
POSSIBLE BIPOLAR LINEAR RESPONSE	POSSIBLE MODERN LINEAR MAGNETIC FEATURE, SUCH AS A PIPE
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
STRONG POSITIVE / NEGATIVE RESPONSE	ARTIFICIAL RESPONSE CAUSED BY SENSOR JOLT OR A PRODUCT OF ADJACENT STRONG RESPONSES
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL FEATURES. MODERN PLOUGHING REGIME
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEAR / CURVI-LINEARS	PROBABLE NATURAL FEATURES, ALTHOUGH SOME RESPONSES COULD BE FROM AGRICULTURAL ACTIVITY
LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	SOME RESPONSES ARE RELATED TO REMNANTS OF SUB-SURFACE FEATURES, OTHERS COULD BE RELATED TO AGRICULTURAL ACTIVITY OR NATURAL FEATURES

ANOMALY TYPE	INTERPRETATION
ISOLATED POSITIVE RESPONSE	PROBABLE NATURAL VARIATION OR DEEPER BURIED FERROUS / FIRED MATERIAL BUT COULD ALSO BE ISOLATED FEATURE
LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	RELATED TO ROMAN ROAD. PROBABLY ASSOCIATED WITH ROADSIDE DITCH BUT SOME COULD BE EDGES OF ADJACENT QUARRIES
BROAD, DIFFUSE AREA OF POSITIVE OR NEGATIVE RESPONSES	PROBABLY RELATED TO ROADSIDE QUARRIES ASSOCIATED WITH A ROMAN ROAD
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE ARCHAEOLOGICAL FEATURE BUT COULD ALSO BE DRAINAGE, AGRICULTURAL OR NATURAL FEATURE
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	INFILLED ARCHAEOLOGICAL / PROBABLE ARCHAEOLOGICAL FEATURE

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Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_3377_1279_04	FINAL

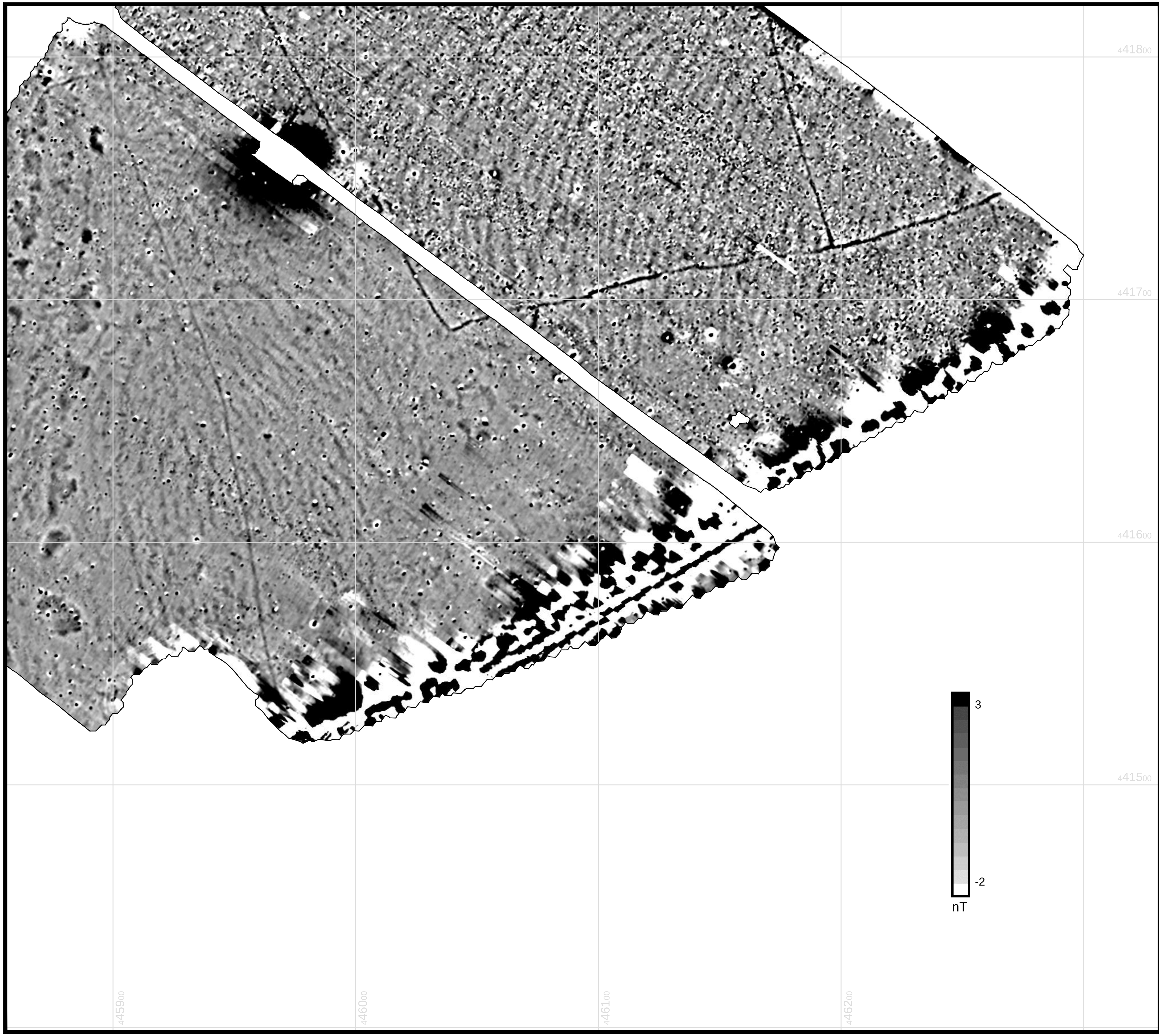
Client: COTSWOLD ARCHAEOLOGY MILTON KEYNES

Site: LAND EAST OF LEEDS ROAD, TADCASTER SELBY, NORTH YORKSHIRE

Title: INTERPRETATION OF MAGNETIC GRADIENT DATA: MAJORITY OF AREAS 1 AND 2

Job No: ARC_3377_1279

Surveyed	JW, RS	Drawn	MW
Chk.	NF	Date	29/09/2022



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Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_3377_1279_05	FINAL

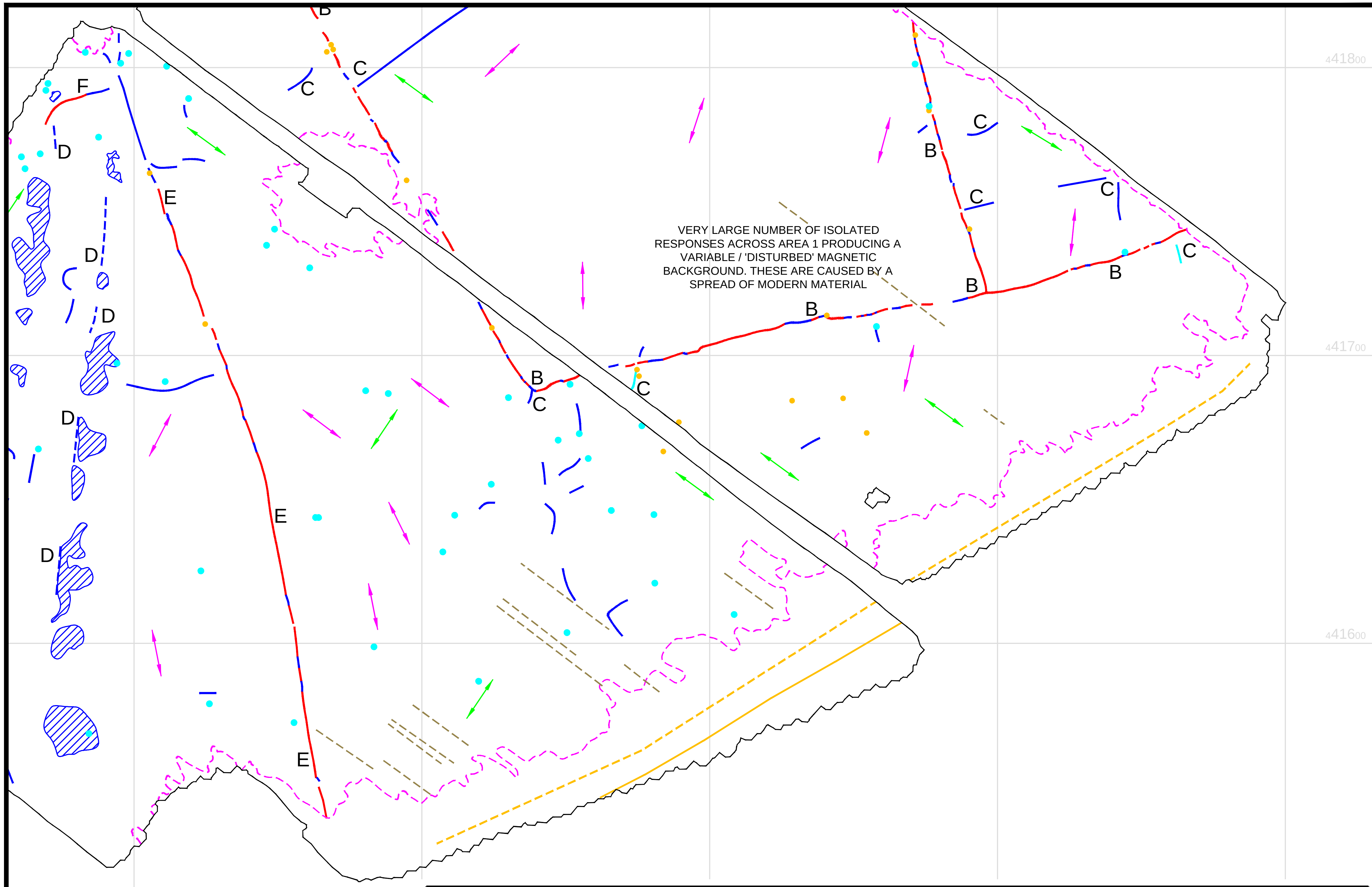
Client
COTSWOLD ARCHAEOLOGY
MILTON KEYNES

Site
LAND EAST OF LEEDS ROAD, TADCASTER
SELBY, NORTH YORKSHIRE

Title
GREYSCALE PLOTS OF MAGNETIC GRADIENT DATA: MAJORITY OF AREAS 1 AND 2

Job No
ARC_3377_1279

Surveyed	JW, RS	Drawn	MW
Chk.	NF	Date	29/09/2022



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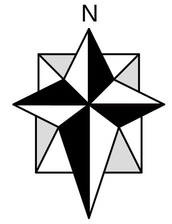

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ANOMALY TYPE	INTERPRETATION
ISOLATED DIPOLAR / BIPOLAR RESPONSE	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
BIPOLAR LINEAR RESPONSE	MODERN LINEAR MAGNETIC FEATURE. PROBABLE METAL PIPE
POSSIBLE BIPOLAR LINEAR RESPONSE	POSSIBLE MODERN LINEAR MAGNETIC FEATURE, SUCH AS A PIPE
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
STRONG POSITIVE / NEGATIVE RESPONSE	ARTIFICIAL RESPONSE CAUSED BY SENSOR JOLT OR A PRODUCT OF ADJACENT STRONG RESPONSES
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL FEATURES. MODERN PLOUGHING REGIME
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEAR / CURVI-LINEARS	PROBABLE NATURAL FEATURES, ALTHOUGH SOME RESPONSES COULD BE FROM AGRICULTURAL ACTIVITY

ANOMALY TYPE	INTERPRETATION
LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	SOME RESPONSES ARE RELATED TO REMNANTS OF SUB-SURFACE FEATURES, OTHERS COULD BE RELATED TO AGRICULTURAL ACTIVITY OR NATURAL FEATURES
ISOLATED POSITIVE RESPONSE	PROBABLE NATURAL VARIATION OR DEEPER BURIED FERROUS / FIRED MATERIAL BUT COULD ALSO BE ISOLATED FEATURE
LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	RELATED TO ROMAN ROAD. PROBABLY ASSOCIATED WITH ROADSIDE DITCH BUT SOME COULD BE EDGES OF ADJACENT QUARRIES
BROAD, DIFFUSE AREA OF POSITIVE OR NEGATIVE RESPONSES	PROBABLY RELATED TO ROADSIDE QUARRIES ASSOCIATED WITH A ROMAN ROAD
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE ARCHAEOLOGICAL FEATURE BUT COULD ALSO BE DRAINAGE, AGRICULTURAL OR NATURAL FEATURE
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	INFILLED ARCHAEOLOGICAL / PROBABLE ARCHAEOLOGICAL FEATURE

Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_3377_1279_06	FINAL

Client
COTSWOLD ARCHAEOLOGY
MILTON KEYNES

Site
LAND EAST OF LEEDS ROAD, TADCASTER
SELBY, NORTH YORKSHIRE

Title
INTERPRETATION OF MAGNETIC GRADIENT DATA: MAJORITY OF AREAS 1 AND 2

Job No
ARC_3377_1279

Surveyed	JW, RS	Drawn	MW
Chk.	NF	Date	29/09/2022

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APPENDIX 1

Magnetic survey: technical information

1.1 Theoretical background

1.1.1 Magnetic instruments measure the value of the Earth's magnetic field; the units of which are nanoTeslas (nT). The presence of surface and sub-surface features can cause variations or anomalies in this magnetic field. The strength of the anomaly is dependent on the magnetic properties of a feature and the material that surrounds it. The two magnetic properties that are of most interest are magnetic susceptibility and thermoremnant magnetism.

1.1.2 Magnetic susceptibility indicates the amount of ferrous (iron) minerals that are present. These can be redistributed or changed (enhanced) by human activity. If enhanced material subsequently fills in features such as pits or ditches then these can produce localised increases in magnetic responses (anomalies) which can be detected by a magnetic gradiometer even when the features are buried under additional soil cover.

1.1.3 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 which intrude into the topsoil may give a negative magnetic response relative to the background level. The strength of magnetic responses that a feature will produce will depend on the background magnetic susceptibility, how rapidly the feature has been infilled, the level and type of human activity in the area and the size and depth of a feature. Not all infilled features can be detected and natural variations can also produce localised positive and negative anomalies.

1.1.4 Thermoremnant magnetism indicates the amount of magnetism inherent in an object as a result of heating. Material that has been heated to a high temperature (fired), such as brick, can acquire strong magnetic properties and so although they may not appear to have a high iron content they can produce strong magnetic anomalies

1.1.5 The magnetic survey method is highly sensitive to interference from surface and near-surface magnetic 'contaminants'. Surface features such as metallic fencing, reinforced concrete, buildings or walls all have very strong magnetic signatures that can dominate readings collected adjacent to them. Identification of anomalies caused by sub-surface features is therefore more difficult, or even impossible, in the vicinity of surface magnetic features. The presence of made ground also has a detrimental effect on the magnetic data quality as this usually contains magnetic material in the form of metallic scrap and brick. Identification of features beneath made ground is still possible if the target feature is reasonably large and has a strong magnetic response but smaller features or magnetically weak features are unlikely to be identified.

1.1.6 The interpretation of magnetic anomalies is often subjective and it is rarely possible to identify the cause of all magnetic anomalies. Not all features will produce a measurable magnetic response and the effectiveness of a magnetic survey is also dependant on the site-specific conditions. The main factors that may limit whether a feature can be detected are the composition of a feature, its depth and size and the surrounding material. It is not possible to guarantee that a magnetic survey will identify all sub-surface features.

1.1.7 Most high resolution, near surface magnetic surveys utilise a magnetic gradiometer. A gradiometer is a hand-held instrument that consists of two magnetic sensors, one positioned directly above the other, which allows measurement of the magnetic gradient component of the magnetic field. A gradiometer configuration eliminates the need for applying corrections due to natural variations in the overall field strength that occur during the course of a day but it only measures relative variations in the local magnetic field and so comparison of absolute values between sites is not possible.

1.1.8 Features that are commonly located using magnetic surveys include archaeological ditches and pits, buried structures or foundations, mineshafts, unexploded ordnance, metallic pipes and cables, buried piles and pile caps. The technique can also be used for geological mapping; particularly the location of igneous intrusions.

1.2 Instrumentation

1.2.1 A multi-sensor array cart system (MACS) utilising 8 Foerster 4.032 Ferex CON 650 gradiometers, spaced at 0.5 m intervals, with a control unit and data logger was used for the magnetic survey.

1.3 Survey methodology

1.3.1 The MACS utilises an RTK GNSS system which means that survey grids do not have to be established. Instead an area is surveyed over a series of continuous profiles and the position of each data point is recorded using an RTK GNSS system. The sensors have a separation of 0.5 m which means that data was collected on profiles spaced at 0.5 m apart. Readings were taken at between 0.1 m and 0.15 m intervals.

1.3.2 Data is collected on zig-zag profiles along the full length or width of a field, although fields can be sub-divided if they are particularly large. Marker canes are set-out along field boundaries at set intervals and these are used to align the profiles. The survey profiles are usually offset from field boundaries, buildings and other metallic features by several metres to reduce the detrimental effect that these surface magnetic features have on the data. The location of the MACS data is converted direct to Ordnance Survey co-ordinates using the UK OSTN 15 projection. As the data is related direct to Ordnance Survey National Grid co-ordinates temporary survey stations are not established.

1.3.3 The Foerster gradiometers have a resolution of 0.2 nT but the stability of the cart system significantly reduces noise caused by instrument tilt and movement when compared with a traditional hand-held gradiometer system and the increased data intervals provide a higher resolution data set. The sensors have a range of ± 10,000nT and readings are taken at 0.1 nT resolution.

1.4 Data processing and presentation

1.4.1 The MACS data is stored direct to a laptop using in-house software which automatically corrects for instrument drift and calculates a mean value for each profile. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. The data is gridded using in-house software and parameters are set based on the sensor spacing and mean values. No additional processing is required. The gridded data is then displayed in Surfer 9 (Golden Software) and image files of the data are created.

1.4.2 The data was exported as greyscale raster images (PNG files). Data for the entire site is presented at a scale of 1:2000 and plots for individual fields / areas (or parts of fields / areas) with accompanying interpretations are shown at a scale of 1:1500. All greyscale plots were clipped at -2 nT to 3 nT. Greyscale plots have been 'smoothed' using a visual interpolation but the data itself has not been interpolated.

1.4.3 The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *'220906_GeophysCAD.dwg'*. The base plan was in the Ordnance Survey National Grid co-ordinate system and as the survey grids / data were referenced directly to National Grid co-ordinates the data could be simply superimposed onto the base plan in the correct position.

1.5 Interpretation

1.5.1 The anomalies have been categorised based on the type of response that they have and an interpretation as to the cause(s) or possible cause(s) of each anomaly type is also provided. The following anomaly types may be present within the data:

Dipolar, bipolar and strong responses

Dipolar and bipolar responses are those that have a sharp variation between strongly positive and negative components.

In the majority of cases these responses are usually caused by modern ferrous features / objects, although fired material (such as brick), some ferrous or industrial archaeological features and strongly magnetic gravel could also produce dipolar and bipolar responses.

Isolated dipolar responses are those that have a single positive and negative element. They are usually caused by isolated, ferrous or fired material on or near to the surface. The objects that cause dipolar responses are usually relatively small, such as spent shotgun cartridges, iron nails and horseshoes (hence they are often referred to as 'iron spikes') or pieces of modern brick or pot. Some types of archaeological artefacts can also produce this type of response but unless there is strong supporting evidence to the contrary they are assumed not to be of archaeological significance.

Bipolar anomalies have strong positive and negative components but are not technically magnetic dipoles. The majority of **isolated bipolar responses** are caused by ferrous or fired material on or near to the surface. These responses tend to be produced from larger objects, compared to dipolar anomalies, or a concentration of smaller objects. Some archaeological features/ activity, including areas of burning or industrial activity can also produce this type of response but unless there is strong supporting evidence to the contrary they are assumed not to be of archaeological significance.

Isolated dipolar and bipolar responses have not been shown on the interpretation as there is no evidence to suggest that they may be archaeological in origin. A large majority, if not all, of the dipolar and bipolar responses at this site will be non-archaeological in origin but there may be greater potential for them to be related to archaeological features / activity where they are located in proximity to probable or possible archaeological features. Selected isolated responses have therefore been shown on the interpretation. Several larger isolated bipolar responses have been shown as these could be associated with more significant sub-surface features or material (although in this instance they are not thought to be of archaeological interest).

Bipolar linear anomalies are usually produced by metallic buried pipes / cables, although some ceramic pipes or features containing fired material, such as brick structures or foundations, can also produce bipolar anomalies. In some instances the anomaly can extend for a significant distance beyond the feature that produces the anomaly. Bipolar anomalies are often very strong and can potentially mask responses from other sub-surface features in the vicinity of the underlying feature.

Areas containing numerous **strong dipolar / bipolar responses** (**magnetic disturbance)** are usually caused by greater concentrations of ferrous or fired material and are often found adjacent to field boundaries where such material tends to accumulate. Above ground metallic or strongly magnetic features, such as fences, gates, pylons and buildings can also produce very strong bipolar responses. If an area of magnetic disturbance is located away from existing field boundaries then it could indicate a former field boundary, several large isolated objects in close proximity, an area where modern material has been tipped or an infilled cut feature, such as a quarry pit. Areas of dipolar / bipolar response can occasionally be caused by features / material associated with archaeological industrial activity or natural deposits that have varying magnetic properties but they are usually caused by modern activity. Responses in areas of magnetic disturbance can sometimes be so strong that archaeological features located beneath them may not be detected.

There are no significant areas of magnetic disturbance in this data set.

Very strong responses, notably bipolar anomalies, from modern features can dominate the data for a significant distance beyond the feature. The extent of these areas is usually shown either as part of the bipolar anomaly or as a **limit of very strong response.** It should be noted that this effect extends beyond the feature and so the limit of the response does not correspond to the actual size or location of the feature within it. In many cases where these strong responses are present at the edge of survey area the feature causing the anomaly be actually be located beyond the survey area. It should be recognised that other sub-surface features located within these areas may not be detected.

There are several **strong linear responses** that are artificial data products. These are either related to a sensor movement or jolt caused by rough ground or are a product of very strong responses caused by material adjacent to the survey area. These responses are not related to a sub-surface feature and their presence has not affected the reliability of the survey or interpretation.

Negative linear / curvi-linear anomalies

Negative linear / curvi-linear anomalies occur when a feature has lower magnetic readings than the surrounding material and can often be associated with ploughing regimes or plastic / concrete pipes or natural features.

They can also indicate the presence of a feature that cuts into magnetic soils or bedrock and which is infilled with less magnetic material and in certain geologies can be associated with archaeological features.

There are no significant negative linear anomalies in this data set.

Linear / curvi-linear anomalies (probable agricultural)

In many geological / pedological conditions agricultural features / regimes can produce magnetic anomalies due to the accumulation / alignment of magnetic topsoil. In most cases these are exhibited as a series of **broadly parallel positive linear** anomalies. The majority of these responses are associated with modern ploughing regimes but in some instances, where the responses are broader and more widely spaced, they can indicate the presence of the remnants of ridge and furrow.

Field drain systems can also produce linear anomalies, usually where the drains are made from fired ceramic or infilled with magnetic gravels.

Where a series of parallel anomalies are present then the approximate orientation of the anomalies are shown on the interpretation drawing to indicate the direction of the agricultural regime but for the sake of clarity individual anomalies have not been shown.

Individual anomalies may be shown if the response is not part of a regime.

Broad area of positive / negative responses

Broad areas of positive / negative responses can have a variety of causes. If the areas are generally quite large and irregular in shape then they are usually suggestive of natural features, such as lenses of sand and gravel deposits, palaeochannels or other natural features / variations where the natural material differs from the surrounding sub-surface. In some instances anomalies of this type can be associated with anthropogenic (usually modern) activity.

Linear / curvi-linear trends

An anomaly is categorised as a **trend** if it is not certain that the response is associated with an extant sub-surface feature. Trends are usually weak, irregular, diffuse or discontinuous and it is usually not certain what their cause is, if they represent significant sub-surface features or even if they are associated with definite features.

It is possible that some of the trends are associated with geological / pedological variations. Others may be produced by artificial constructs within the data, either caused by processing or in some instances by intersecting anomalies (usually different agricultural regimes) that give the appearance of curving or regular shapes. Many trends are a product of weak, naturally occurring responses that happen to form a regular pattern but which are not associated with a sub-surface feature.

In some instances former features that have been severely truncated can still produce broad, diffuse or weak responses even if the underlying feature has been removed. This is due to the presence of magnetic soils associated with the former feature still being present along its route. In other instances the magnetic properties of the soils filling a feature may vary and so the magnetic signature of the feature can change, even if the sub-surface feature itself remains uniform. If a response from a feature becomes significantly weak or diffuse then part of the anomaly may be shown as a trend as it is uncertain if the feature is still present or has been severely truncated or removed.

Isolated positive responses

Isolated positive responses can occur if the magnetism of a feature, area or material has been enhanced or if a feature is naturally more magnetic than the surrounding material. It is often difficult to determine which of these factors causes any given responses and so the origin of this type of anomaly can be difficult to determine. They can have a variety of causes including geological variations, infilled archaeological features, areas of burning (including hearths), industrial archaeological features, such as kilns, or deeper buried ferrous material and modern fired material.

The large number of isolated responses and lack of an obvious pattern to their distribution suggests that the majority of these anomalies are probably associated with geological /

pedological variations or deeper buried ferrous or fired material. Only the larger or stronger areas of positive response have been shown on the interpretation. The majority, if not all of these responses, will be related to natural variations or relatively modern material but have been shown as their exact cause cannot be determined with certainty.

Positive linear / curvi-linear anomalies

Positive magnetic anomalies indicate an increase in magnetism and if the resulting anomaly is linear or curvi-linear then this can indicate the presence of a man-made feature. **Positive or enhanced linear / curvi-linear** anomalies can be associated with agricultural activity, drainage features but they can also be caused by ditches that are infilled with magnetically enhanced material and as such can indicate the presence of archaeological features. Some natural infilled features can also produce positive anomalies.

1.5.2 Several different ranges of data were used in the interpretation to ensure that the maximum information possible is obtained from the data.

1.5.3 X-Y trace plots were examined for all of the data and overlain onto the greyscale plot to assist in the interpretation, primarily to help identify dipolar / bipolar responses that will probably be associated with surface / near-surface iron objects. X-Y trace plots have not been used in the report as they do not show any additional anomalies that are not visible in the greyscale data. A digital drawing showing the X-Y trace plot overlain on the greyscale plot has been provided in the digital archive.

1.5.4 All isolated responses have been assessed using a combination of greyscale and X-Y trace plots.

1.5.5 Anomalies associated with agricultural regimes are present in the data. The general orientation of these regimes has been shown on the interpretation but, for the sake of clarity, each individual anomaly has not been shown.

1.5.6 The greyscale plots and the accompanying interpretations of the anomalies identified in the magnetic data are presented as 2D AutoCAD drawings. The interpretation is made based on the type, size, strength and morphology of the anomalies, coupled with the available information on the site conditions. Each type of anomaly is displayed in separate, easily identifiable layers annotated as appropriate.

1.6 Limitations of magnetic surveys

1.6.1 The magnetic survey method requires the operator to walk over the site at a constant walking pace whilst holding the instrument. The presence of an uneven ground surface, dense, high or mature vegetation or surface obstructions may mean that some areas cannot be surveyed.

1.6.2 The depth at which features can be detected will vary depending on their composition, size, the surrounding material and the type of magnetometer used for the survey. In good conditions large, magnetic targets, such as buried drums or tanks can be located at depths of more than 4 m. Smaller targets, such as buried foundations or archaeological features can be located at depths of between 1 m and 2 m.

1.6.3 A magnetic survey is highly sensitive to interference from surface and near-surface magnetic ‘contaminants’. Surface features such as metallic fencing, reinforced concrete, buildings or walls all have very strong magnetic signatures that can dominate readings collected adjacent to them. Identification of anomalies caused by sub-surface features is therefore more difficult or even not possible in the vicinity of surface and near-surface magnetic features.

1.6.4 The presence of made ground also has a detrimental effect on the magnetic data quality as this usually contains magnetic material in the form of metallic scrap and brick. Identification of features beneath made ground is still possible if the target feature is reasonably large and has a strong magnetic response but smaller features or magnetically weak features are unlikely to be identified.

1.6.5 It should be noted that anomalies that are interpreted as modern in origin may 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.

1.6.6 A magnetic survey does not directly locate sub-surface features - it identifies variations or anomalies in the local magnetic field caused by features. It can be possible to interpret the cause of anomalies based on the size, shape and strength of response but it should be recognised that a magnetic survey produces a plan of magnetic variations and not a plan of all sub-surface features. Interpretation of the anomalies is often subjective and it is rarely possible to identify the cause of all magnetic anomalies. Geological or pedological (soil) variations or features can produce responses similar to those caused by man-made (anthropogenic) features.

1.6.7 Anomalies identified by a magnetic survey are located in plan. It is not usually possible to obtain reliable depth information on the features that cause the anomalies.

1.6.8 Not all features will produce a measurable magnetic response and the effectiveness of a magnetic survey is also dependant on the site-specific conditions. It is not possible to guarantee that a magnetic survey will identify all sub-surface features. A magnetic survey is often most-effective at identifying sub-surface features when used in conjunction with other complementary geophysical techniques.

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