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Land east of Shipton by Beningbrough
North Yorkshire

Archaeological geophysical survey

Project No. ARC/3261/1277

October 2022

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Date	12/10/22	Date	12/10/22

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1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at land adjacent to the A19 near Shipton by Beningbrough, 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.

A significant part of the site could not be surveyed because of ground conditions at the time of the survey.

The survey has provided evidence for archaeological activity, in the form of part of an enclosure with adjoining annexes or sub-enclosures. There are anomalies suggestive of one or two hut circles, as well as other probable / possible archaeological features, some of which could suggest multi-phase activity, within and adjacent to the enclosure.

The magnetic data 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.

There are cropmarked features within the site but it is worth noting that the majority of these features, as well as the current ploughing regime and several former field boundaries do not produce clear, well-defined responses. This suggests that the soils could have a relatively weak magnetic susceptibility that may not be sufficiently high enough to produce measurable magnetic responses for some types of feature. This could mean that some features may only produce weak or intermittent responses or may not produce measurable magnetic responses. It is probable that there are archaeological features present within the site that have not been identified by the survey.

Many of the anomalies associated with archaeological features 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 and it is also probable that some anomalies may become weaker in places because the magnetic susceptibility of the soils infilling them has decreased.

There are anomalies associated with agricultural activity and a large number of anomalies of uncertain origin, the majority of which are weak, diffuse or fragmented. Some responses could be related to sub-surface features but the type of feature is not certain. Many will be caused by drainage, agricultural or natural features but the possibility that some could be associated with parts of archaeological features cannot be discounted.

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 Shipton by Beningbrough, 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_3261_1277_01.

2.2 Site description

The site is situated at land adjacent to the A19 near Shipton by Beningbrough, North Yorkshire (approximate centre at NGR SE 561 580). The site was approximately 7.5 km to the north-west of York and covered an area of approximately 23.9 ha.

The site encompassed parts of two arable fields. One of the fields had recently been ploughed / harrowed and was very uneven underfoot. The majority of the other field was under stubble, from a cereal crop, at the time of survey, although the south-west of this field contained a sunflower crop and there was dense vegetation along the western boundary of the field. The ground in this field was relatively level and firm underfoot. The two fields were separated by a drainage ditch (Moor Gutter) and were bounded by hedgerows. Some edges of the survey area were not fixed on the ground by physical boundaries.

The geology of the site consists of sandstone of the Sherwood Sandstone Group which is, in most parts, overlain by clay of the Alne Glaciolacustrine Formation with pockets of sands of the Sutton Sand Formation along the north-western and north-eastern boundaries (British Geological Survey, 2022).

2.3 Archaeological background

An archaeological / heritage desk-based assessment was not available at the time of writing this report.

It is understood that there is a cropmarked enclosure in the north of the site, which was excavated in the later 1960s (*pers. comm.,* Daniele Pirisino, Cotswold Archaeology, 2022). An excerpt from an archaeological investigations report (West Yorkshire Archaeology Service, 1993) shows interpreted cropmarks in the north and north-west of the site and a conjected line of a Roman Road is also shown to pass through the site, along the line of the current drainage ditch separating the two fields. The archaeological investigations report shows that a limited geophysical survey was undertaken within the current site, targeted across some of the cropmarks. A basic interpretation, identifying potential features, is shown but the reproduction of the geophysical data plot is of insufficient quality to assess the reliability of this interpretation or compare it to the current survey. Several historic field boundaries are shown, within the site, on the mapping in the excerpt from the archaeological investigations report, that are no longer present.

2.4 Scope of work

The survey area was specified by the client.

The ploughed / harrowed field was not suitable for survey as the uneven ground condition meant it could not be traversed safely without there being an undue risk of tripping. The area containing the sunflower crop and areas of dense vegetation could also not be surveyed. This resulted in the area accessible / suitable for survey being reduced to approximately 14.9 ha, the extents of which are shown in drawing ARC_3261_1277 _02.

No other problems were encountered during the survey which was carried out between 12th September and 16th 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 OSTN15 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). The data is relatively 'noisy' with a variable magnetic background and general magnetic disturbance caused by a significant spread of modern material across the site. The data have therefore been shown at two ranges; a range of -2 nT to 3 nT, which is 'standard' for archaeological surveys, and a relatively wide (for archaeological surveys) range of -5 to 5 nT. The latter smooths out the data and can make it easier to identify some anomalies but very weak responses may not be visible in the wider range. The 'standard' plot is presented, showing the site boundary, in drawing ARC_3261_1277_02 (scale 1:3000) and a greyscale plot with an accompanying interpretation, at a wider range, are shown in drawings ARC_3261_1277_03 and ARC_3261_1277_04 respectively (scale 1:2000). The two different ranges that the data has been displayed at show that the 'noise' / general magnetic disturbance, although present across the majority if the site, is less noticeable in the wider range (-5 nT to 5 nT). This indicates that much of the magnetic disturbance is probably caused by relatively small surface / near surface material.

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 very large number of 'iron spike', isolated dipolar anomalies present in the data. There is no evidence to suggest that they are associated with archaeological features and so these have not been shown in the interpretation. The very large number of isolated responses, related to modern material, would effectively mask any responses associated with small discrete features, should any such features be present and it has not been possible to identify any isolated responses that could have potential to be related to archaeological features / activity.

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. 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 has 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.

It is worth noting that the current ploughing regime, several former field boundaries and some cropmarked features do not produce clear, well-defined responses. This suggests that the soils could have a relatively weak magnetic susceptibility that may not be sufficiently high enough to produce measureable magnetic responses for some types of feature. This could mean that some features may only produce weak or intermittent responses or may not produce measureable magnetic responses.

There are anomalies indicative of archaeological features present in part of the site. Many 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.

4.2 Anomaly types and further discussion

4.2.1 Isolated responses – probable modern features / activity / material

There are a very large number of **isolated dipolar** responses (iron spikes) across the survey area. These contain a strong positive and negative component and are indicative of ferrous or fired material on or near to the surface. Numerous **isolated bipolar** responses are also present. These have strong positive and negative components but are not technically magnetic dipoles. They tend to be caused by ferrous or fired material on or near to the surface and are usually produced from larger, or more strongly magnetic, objects (compared to dipolar anomalies) or a concentration of strongly magnetic smaller objects. In the large majority of cases these two types of isolated responses will be caused by modern material. However, the potential for some of these to be associated with archaeological features / material may be increased slightly by their proximity to other anomalies / features.

There are also numerous **isolated positive responses** across the survey area. This type of response can be caused by discrete infilled features (both anthropogenic and natural), areas of burning / industrial activity or deeper buried, relatively modern, ferrous or fired material.

4.2.2 Linear / curvi-linear anomalies and trends – agricultural features / activity

There is a series of **weak, broadly parallel positive linear anomalies** that are associated with recent agricultural ploughing regimes.

A weak, diffuse trend (**Anomaly A**) is present which broadly corresponds with the location of a former field boundary. It is possible that Anomaly A is related to this former feature, although it could also be caused by agricultural activity or a natural variation.

4.2.3 Linear / curvi-linear positive anomalies and trends – archaeological features and uncertain cause

Anomalies are present in the north of the field that are associated with part of an archaeological enclosure and other possible / probable archaeological features. These anomalies are generally weak, diffuse and / or fragmented. It is possible that this is because they have been severely truncated by later agricultural activity but it is also possible that the soils infilling the features have a relatively low magnetic susceptibility and so the anomalies produced are relatively weak. This would explain why some cropmarked features that are shown in other parts of the site have not produced clear anomalies. The responses in the north could be stronger because this could be an area of settlement, and settlement activity (predominantly fires) tends to enhance the magnetic susceptibility of the soils to a greater extent than areas away from a settlement.

The anomalies appear to form part of an enclosure (**Anomalies B**), with a possible annexe or adjoining sub-enclosures (**Anomalies C**). There is one circular anomaly (**Anomaly D**) and possibly a second, although the latter (**Anomaly E**) is more irregular in shape, which could be related to hut circles. A linear response appears to cut through Anomaly D and if this is also caused by an archaeological feature then it indicates at least two phases of archaeological activity. There are numerous other linear / curvi-linear responses in this area, within and adjacent to the enclosure, and some of these could be related to additional archaeological features but they are generally too weak to reliably interpret and some could be a product of agricultural activity or natural variations.

There are numerous other trends and weak positive linear anomalies across the area, most of which are too weak and / or fragmented / diffuse to reliably interpret. Some are relatively straight and slightly stronger / more coherent and could have potential to be related to parts of sub-surface features but they do not form any obvious patterns or relationships that would help interpret their cause. **Anomalies F** are relatively strong and straight and these are in proximity to a former field boundary. The responses are suggestive of modern features, such as field drains, but it is possible that they have a different cause. **Anomalies G** are on the same alignment as agricultural activity but are slightly stronger than the adjacent agricultural responses. Their cause is not certain but they are more suggestive of modern activity, such as drainage or agricultural features, than archaeological. **Anomaly H** stands out as it is slightly stronger than the adjacent anomalies but the anomaly is too short to reliably interpret. There is a slight suggestion for an alignment of trends to the west / north-west and if these are related to a continuation of a feature then Anomaly H could possibly be caused by part of an archaeological feature. There are other trends that stand out slightly and may form patterns or relationships (**Anomalies I**). It is possible that some of these could be related to parts of archaeological features but again they are too weak to reliably interpret and they could be caused by agricultural activity or natural variations. The same is true for the other trends across the site. **Anomalies J** are weak and do not really stand out but they are in proximity to a cropmarked feature (a possible enclosure) and there is a slight possibility that they could be related to this feature.

5. DISCUSSION AND CONCLUSIONS

A significant part of the site could not be surveyed because of ground conditions at the time of the survey.

The survey has provided evidence for archaeological activity, in the form of part of an enclosure with adjoining annexes or sub-enclosures. There are anomalies suggestive of one or two hut circles, as well as other probable / possible archaeological features, some of which could suggest multi-phase activity, within and adjacent to the enclosure.

The magnetic data 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.

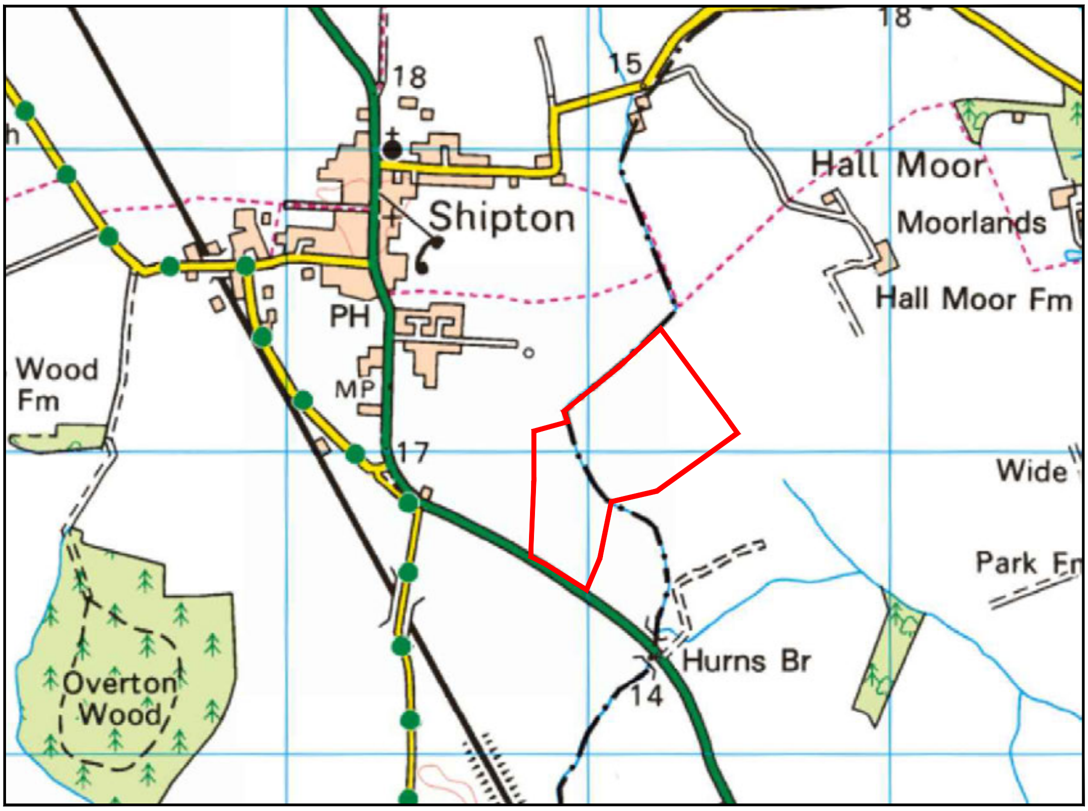
There are cropmarked features within the site but it is worth noting that the majority of these features, as well as the current ploughing regime and several former field boundaries do not produce clear, well-defined responses. This suggests that the soils could have a relatively weak magnetic susceptibility that may not be sufficiently high enough to produce measurable magnetic responses for some types of feature. This could mean that some features may only produce weak or intermittent responses or may not produce measurable magnetic responses. It is probable that there are archaeological features present within the site that have not been identified by the survey.

Many of the anomalies associated with archaeological features 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 and it is also probable that some anomalies may become weaker in places because the magnetic susceptibility of the soils infilling them has decreased.

There are anomalies associated with agricultural activity and a large number of anomalies of uncertain origin, the majority of which are weak, diffuse or fragmented. Some responses could be related to sub-surface features but the type of feature is not certain. Many will be caused by drainage, agricultural or natural features but the possibility that some could be associated with parts of archaeological features cannot be discounted.

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.

N



SITE LOCATION

SCALE

0m 500m 1000m

Scale [A4 Sheet] AS SHOWN	Drawing ARC_3261_1277_01	Status FINAL

Client: COTSWOLD ARCHAEOLOGY MILTON KEYNES

Site: LAND EAST OF SHIPTON BY BENINGBROUGH NORTH YORKSHIRE

Title: SITE LOCATION MAP

Job No: ARC_3261_1277

		Drawn	RS
Chk.	MW	Date	16/09/2022

NOTE

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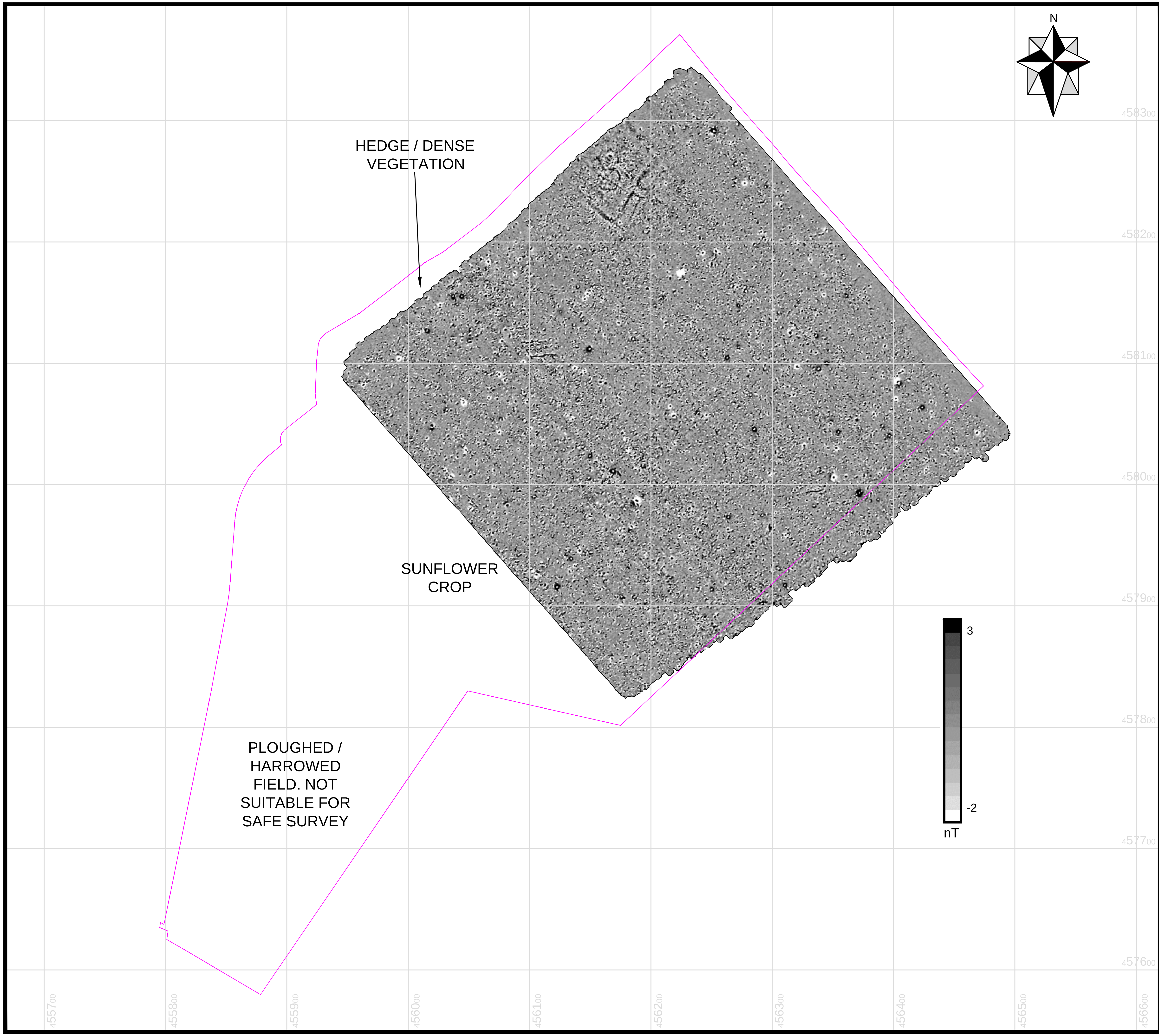

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Scale [A3 Sheet]	Drawing	Status
1:3000	ARC_3261_1277_02	FINAL

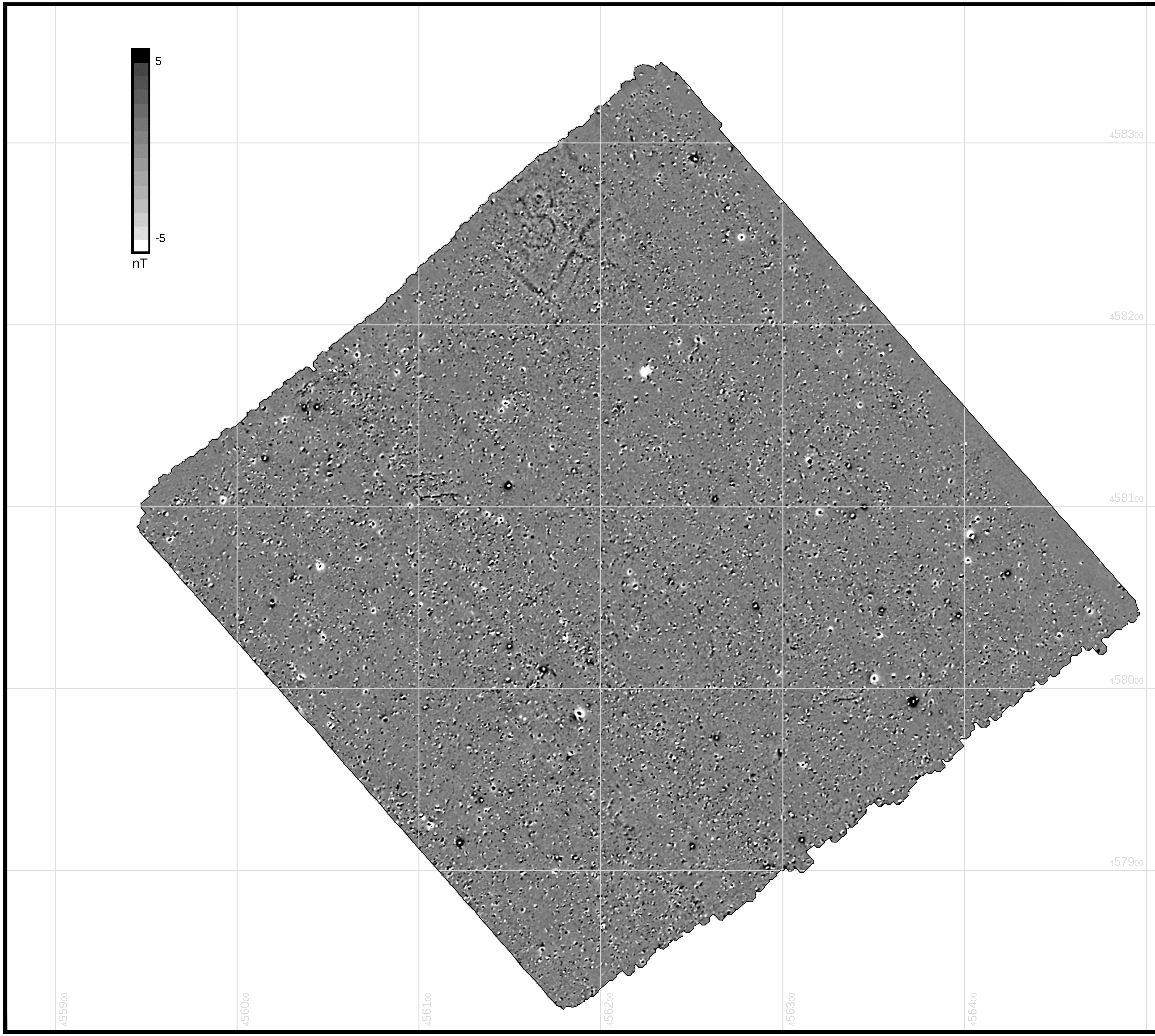
Client: COTSWOLD ARCHAEOLOGY LTD MILTON KEYNES

Site: LAND EAST OF SHIPTON BY BENINGBROUGH NORTH YORKSHIRE

Title: LOCATION OF SITE SHOWING MAGNETIC GRADIENT DATA ('STANDARD' RANGE)

Job No: ARC_3261_1277

Surveyed	RS, MP	Drawn	RS
Chk.	MW	Date	15/09/2022



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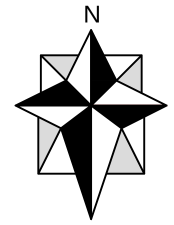

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Scale [A3 Sheet]	Drawing	Status
1:2000	ARC_3261_1277_03	FINAL

Client: COTSWOLD ARCHAEOLOGY LTD MILTON KEYNES

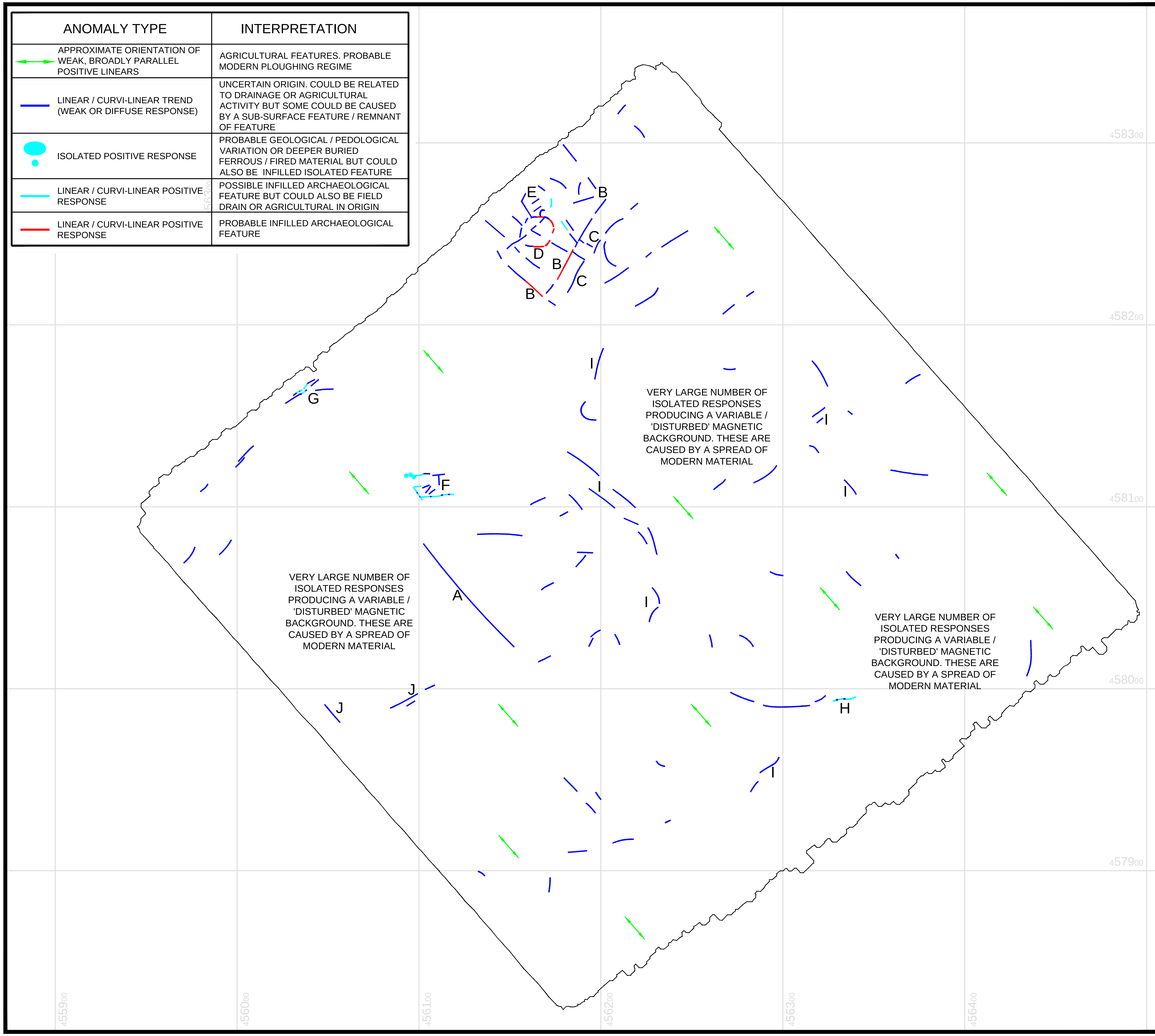
Site: LAND EAST OF SHIPTON BY BENINGBROUGH NORTH YORKSHIRE

Title: GREYSCALE PLOT OF MAGNETIC GRADIENT DATA (RELATIVELY WIDE RANGE)

Job No: ARC_3261_1277

Surveyed	RS, MP	Drawn	JW
Chk.	MW	Date	15/09/2022

ANOMALY TYPE	INTERPRETATION
APPROXIMATE ORIENTATION OF WEAK, BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL FEATURES. PROBABLE MODERN PLOUGHING REGIME
LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	UNCERTAIN ORIGIN. COULD BE RELATED TO DRAINAGE OR AGRICULTURAL ACTIVITY BUT SOME COULD BE CAUSED BY A SUB-SURFACE FEATURE / REMNANT OF FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE GEOLOGICAL / PEDOLOGICAL VARIATION OR DEEPER BURIED FERROUS / FIRED MATERIAL BUT COULD ALSO BE INFILLED ISOLATED FEATURE
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE INFILLED ARCHAEOLOGICAL FEATURE BUT COULD ALSO BE FIELD DRAIN OR AGRICULTURAL IN ORIGIN
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	PROBABLE INFILLED ARCHAEOLOGICAL FEATURE



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Scale [A3 Sheet]	Drawing	Status
1:2000	ARC_3261_1277_04	FINAL

Client
COTSWOLD ARCHAEOLOGY LTD
MILTON KEYNES

Site
LAND EAST OF SHIPTON
BY BENINGBROUGH
NORTH YORKSHIRE

Title
INTERPRETATION OF MAGNETIC
GRADIENT DATA

Job No
ARC_3261_1277

Surveyed	RS, MP	Drawn	JW, MW
Chk.	NF	Date	15/09/2022

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West Yorkshire Archaeology Service, 1993, Shipton by Beningbrough Bypass, Archaeological Investigations, Volume 2

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 **OSTN15** 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). The data is relatively 'noisy' with a variable magnetic background and general magnetic disturbance caused by a significant spread of modern material across the site. The data have therefore been shown at two ranges; a range of -2 nT to 3 nT, which is 'standard' for archaeological surveys, and a relatively wide (for archaeological surveys) range of -5 to 5 nT. The latter smooths out the data and can make it easier to identify some anomalies but very weak responses may not be visible in the wider range. The 'standard' plot is presented, showing the site boundary, in drawing ARC_3261_1277_02 (scale 1:3000) and a greyscale plot with an accompanying interpretation, at a wider range, are shown in drawings ARC_3261_1277_03 and ARC_3261_1277_04 respectively (scale 1:2000). The two different ranges that the data has been displayed at show that the 'noise' / general magnetic disturbance, although present across the majority if the site, is less noticeable in the wider range (-5 nT to 5 nT). This indicates that much of the magnetic disturbance is probably caused by relatively small surface / near surface material.

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.

At this site the very large number of responses 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.

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.

There are no bipolar linear anomalies in this data set.

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.

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.

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.

There are no anomalies of this type in this data set.

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 very large number of isolated responses and lack of an obvious pattern to their distribution suggests that these anomalies are probably associated with ferrous or fired material.

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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