Middleham Castle
County Durham

Archaeological geophysical survey

Project No. ARC/2561/986

July 2019

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Date	23/07/19	Date	24/07/19

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1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at Middleham Castle, County Durham. 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

There are numerous relatively strong positive responses and a variable magnetic background across the north of the site. On most sites many of the types of responses that are present would usually be caused by relatively modern material. However, as the remains of Middleham Castle are known to be located within this area, it is possible that many of the responses could be related to material / features associated with the former castle but equally many of them could be caused by modern activity / material.

There are some clearly defined linear / curvi-linear anomalies and some weaker trends, that are suggestive of, or may relate, to sub-surface linear / curvi-linear features but there are also a large number of isolated positive responses and it is not certain if many of these are caused by the fragmented remains of linear / curvi-linear features, by discrete features or by other material.

A number of anomalies correspond with earthworks and will probably be associated with the remains of Middleham Castle. Anomalies indicative of infilled features related to enclosures / sub-enclosures are present in the north-west of the area. These do not appear to relate to earthworks and may pre-date Middleham Castle.

A number of trends are present in the south of the area but it is not certain if these are related to anthropogenic features / activity (of unknown date or function) or natural features / variations. A large number of other weak trends and positive responses are also present. Some of these could be related to archaeological features / activity (either associated with the remnants of Middleham Castle or features that may pre-date it) but in the majority of instances it is not possible to reliably determine their cause. Many of the responses could be caused by relatively modern material / activity or natural features / variations.

In summary, a number of anomalies relating to archaeological features / activity have been identified but there are numerous responses of uncertain origin. The large number of isolated responses (which could be caused by relatively modern material / activity but could also be caused by material associated with Middleham Castle) has made it difficult to reliably interpret many of the anomalies.

It should be recognised that a magnetic survey can identify infilled features, areas of burning and industrial activity and some types of structural features (depending on the material they are made of) but some types of structural remains may not produce a magnetic response. An earth resistance survey and / or a ground penetrating radar (GPR) could potentially better identify structural remains but it should also be recognised that the ground conditions are not ideal for either of these techniques and so coverage, and potentially the effectiveness of these techniques may be limited.

2. INTRODUCTION

2.1 Overview

Phase Site Investigations Ltd was commissioned by DigVentures, on behalf of Bright Water Landscape Partnership, to carry out an archaeological geophysical survey at Middleham Castle, County Durham 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_2561_986_01.

2.2 Site description

The site is situated at the southern edge of Bishop Middleham, County Durham (centred at NGR NZ 327 310) approximately 13 km to the south-east of Durham and covered an area of approximately 3 ha.

The site encompassed part of a rough pasture field with some extant stone walls related to the remains of Middleham Castle.

The northern part of the site was an area of higher ground sloping steeply downwards to the east, south and south-east. The southern part of the site was relatively level.

The ground was generally firm underfoot but was uneven in some areas in the east of the site. There were areas of dense vegetation and a gravel track ran through part of the site.

The topography of the site meant that the survey was split into two areas, as shown in the accompanying drawings.

The site was not defined by a physical boundary.

The geology of the site consists of dolostone of the Ford Formation. There are no recorded superficial deposits across the majority of the site but sand and gravel glaciofluvial deposits are present in the south of the site (British Geological Survey, 2019). The soils of the site are described as freely draining lime-rich loamy soils in the north and freely draining slightly acid loamy soils in the south (Soilscapes, 2019).

2.3 Archaeological background

The archaeological background of the site is summarised in a letter written by Dr David Mason of Durham County Council (2019) and a written scheme of investigation for geophysical survey prepared by DigVentures (2019). These highlight that that the site is located at Middleham Castle, a former manor-house of the Bishops of Durham between the 12th and 14th centuries. Middleham Castle is a Scheduled Monument (NHLE 1002330). A magnetic survey and an earthwork survey were undertaken at the site in the 1990s. The letter (Mason, 2019) indicates that,

'The remains of the castle/manor consists as a series of earthworks and the occasional fragment of masonry protruding through the turf. The higher quality examples of the latter are presumed to indicate the position of the principal building – the hall. Fishponds can be traced on the lower ground to the south and west.

The layout of the buildings is poorly understood. Similarly, the degree of survival/extent of stone-robbing and damage through other causes is unknown. Also, a number of Roman *objects have been recovered from Bishop Middleham and its immediate vicinity perhaps suggesting much earlier settlement in the area.*'

2.4 Scope of work

The survey area was specified by the client and it was requested that a magnetic survey should be undertaken in the first instance.

Due to the presence of dense vegetation and steep slopes the area accessible / suitable for survey was reduced to approximately 1.6 ha, the extents of which are shown in drawings ARC_2561_986_02 and ARC_2561_986_03.

No other problems were encountered during the survey which was carried out on 11th July 2019.

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 02 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) and are shown with an accompanying interpretation at a scale of 1:1000. Greyscale plots have been clipped at -2 nT to 3 nT and -5 to 5 nT. The 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 *'Middleham-Castle.dxg'*. 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. 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. Responses of this type are usually caused by modern material but can, in some instance be related to archaeological objects / material. The majority of these responses will probably be related to modern material and so have not been shown on the interpretation. Selected stronger isolated dipolar responses have been shown in proximity to some anomalies that are suggestive of archaeological features and some responses of uncertain origin. These responses are probably also 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.

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. There are areas that have a variable magnetic background but this is due to the presence of magnetic material in the topsoil or sub-surface, rather than low data quality.

The data has been displayed at two ranges in the report; a 'standard' range of -2 to 3 nT and a wider range of -5 nT to 5 nT. The latter allows the stronger responses to be better visualised through the variable background but some weaker responses, notably in the south of the site, are not visible at the wider range.

The categories of anomaly, and their possible causes, which have been identified by the survey are discussed in detail below.

4.2 Area 1

Basic topography: Generally level but with some very uneven areas.

Summary of anomalies: Numerous isolated dipolar and bipolar responses, the majority of which are probably modern in origin. Selected responses have been shown on the interpretation. The majority, if not all of these are also probably modern in origin but it is possible that some responses could be associated with archaeological features or material.

A larger isolated bipolar response has been shown. This is probably related to a concentration of, or larger object or feature, of relatively modern ferrous or fired material

Areas of magnetic disturbance associated with surface / near surface ferrous or fired material. Responses of this type are usually caused by modern material but it is possible that some of these anomalies could be related to archaeological material.

Very strong responses associated with strongly magnetic modern features / material. The feature / material causing the response may be located beyond the survey area.

A relatively strong, positive curvi-linear trend corresponds with the position of a gravel track and will be related to this feature.

Trends of uncertain origin. Some trends may be related to archaeological features or remnants of features.

Numerous isolated positive responses. They could be related to deeper buried ferrous / fired material or infilled isolated features but could also be the geological / pedological in origin.

Positive linear / curvi-linear responses of uncertain origin. Some responses may be caused by infilled linear / curvi-linear features but others could relate to other sub-surface features of uncertain date and function.

Positive linear / curvi-linear responses probably associated with the remnants of archaeological features.

Further discussion / additional information:

There are numerous relatively strong positive responses and a variable magnetic background across this area. On most sites many of the types of responses that are present would usually be caused by relatively modern material. However, as the remains of Middleham Castle are known to be located within this area, it is possible that many of the responses could be related to material / features associated with the former castle but equally many of them could be caused by modern activity / material.

There are some clearly defined linear / curvi-linear anomalies and some weaker trends, that are suggestive of, or may relate, to linear / curvi-linear features but there are also a large number of isolated positive responses and it is not certain if many of these are caused by the fragmented remains of linear / curvi-linear features, by discrete features or by other material.

Anomalies A are a group of relatively strong positive linear / curvi-linear anomalies suggestive of infilled features. They are probably related to one or more enclosures or sub-enclosures. They do not appear to correspond with visible earthworks and could pre-date Middleham Castle. Within part of Anomaly A there are a number of isolated positive and dipolar responses (**Anomalies B**). It is not certain if these are related to Anomalies A, if they are they could indicate the presence of discrete features or areas of burning or other industrial activity. However, it is possible that they are caused by modern material or by material related to Middleham Castle.

Anomalies C are relatively strong positive linear anomalies. They are suggestive of infilled features but it is not certain if these may relate to the remains of Middleham Castle, Anomalies A, or other features.

There are a number of anomalies (**Anomalies D**) which correspond, broadly correspond or are aligned with earthworks and are probably related to the remains of Middleham Castle, although in many cases the exact type of feature that has caused the response is not certain.

Anomaly E is a strong isolated bipolar response. Typically these types of responses are indicative of relatively modern ferrous or fired material. However, it is possible that the response could be caused by material or a feature related Middleham Castle.

There are a number of weak trends in the east of the area. The exact cause of these is not certain. These may be caused by features related Middleham Castle, the archaeological features identified as Anomalies A or may be related to other features / activity.

4.3 Area 2

Basic topography: Relatively level.

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation for this areas as there is no evidence to suggest they may be related to archaeological features / activity.

Areas of magnetic disturbance associated with relatively modern features / material.

A very strong response associated with strongly magnetic, usually above ground, modern feature / material. The feature causing the response may be / are located beyond the survey area.

A diffuse curvi-linear anomaly corresponds with the position of a former field boundary and will be related to this feature.

A diffuse recti-linear anomaly corresponds with the position of a track and will be related to this feature.

A negative linear anomaly probably associated with an agricultural feature, non-magnetic pipe or trench.

Broad, diffuse areas of positive and / or negative responses indicative of natural features variations.

Several trends of uncertain origin. Some trends may be related to archaeological features or remnants of features.

Numerous isolated positive responses. The majority of these are probably geological / pedological in origin or related to relatively modern deeper buried ferrous / fired material but some could be caused by archaeological features / activity.

Further discussion / additional information:

The background magnetic data is much more uniform in this area. There are some broad responses in the north of the area that could be caused by natural features / variations. Several trends (**Anomalies F**) in this part of the area may be related to natural features / variations but it is possible that some of them could be caused by the remnants of sub-surface features.

Anomaly G is an area of magnetic disturbance and linear trend that broadly aligns with a track shown on historic maps and an area of raised ground visible on-site. The responses will be caused by this feature. A response corresponding with a former field boundary is also present in this area

There is an area of variable responses in the south of the area that is probably related to natural variations (possibly associated with sand and gravel glaciofluvial deposits). There are numerous trends in this area and it is likely that the majority of them are also caused by natural features / variations but it is possible that some of them could be related to infilled features. The remaining trends are all too weak and short to reliably interpret. Generally the trends do not form any obvious patterns or relationships that would indicate that they may be associated with sub-surface features and it is likely that they are simply a product of the agricultural or other relatively modern activity or natural variations. However, due to their proximity to known archaeological activity an archaeological origin for the trends cannot be discounted.

5. DISCUSSION AND CONCLUSIONS

There are numerous relatively strong positive responses and a variable magnetic background across the north of the site. On most sites many of the types of responses that are present would usually be caused by relatively modern material. However, as the remains of Middleham Castle are known to be located within this area, it is possible that many of the responses could be related to material / features associated with the former castle but equally many of them could be caused by modern activity / material.

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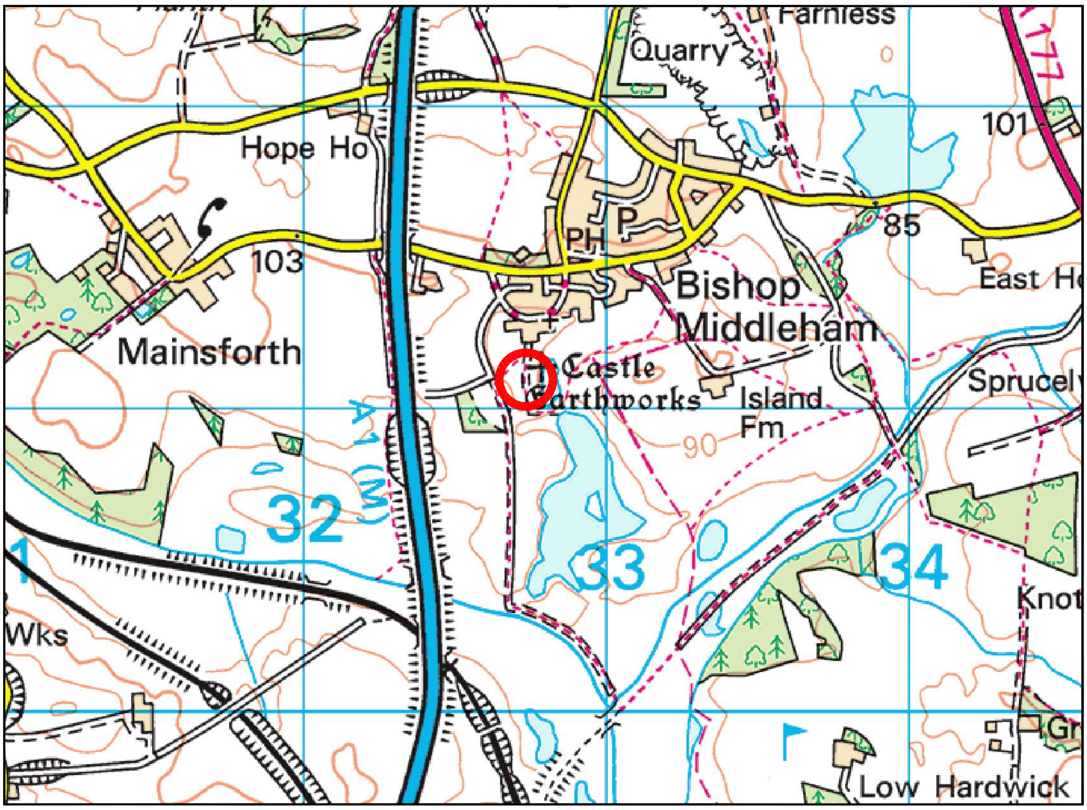
In summary, a number of anomalies relating to archaeological features / activity have been identified but there are numerous responses of uncertain origin. The large number of isolated responses (which could be caused by relatively modern material / activity but could also be caused by material associated with Middleham Castle) has made it difficult to reliably interpret many if the anomalies.

It should be recognised that a magnetic survey can identify infilled features, areas of burning and industrial activity and some types of structural features (depending on the material they are made of) but some types of structural remains may not produce a magnetic response. An earth resistance survey and / or a ground penetrating radar (GPR) could potentially better identify structural remains but it should also be recognised that the ground conditions are not ideal for either of these techniques and so coverage, and potentially the effectiveness of these techniques may be limited.

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



32
31
30

NZ 32 33 34

SITE LOCATION

SCALE

0m 500m 1000m

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Scale [A4 Sheet]	Drawing	Status
AS SHOWN	ARC_2561_986_01	FINAL

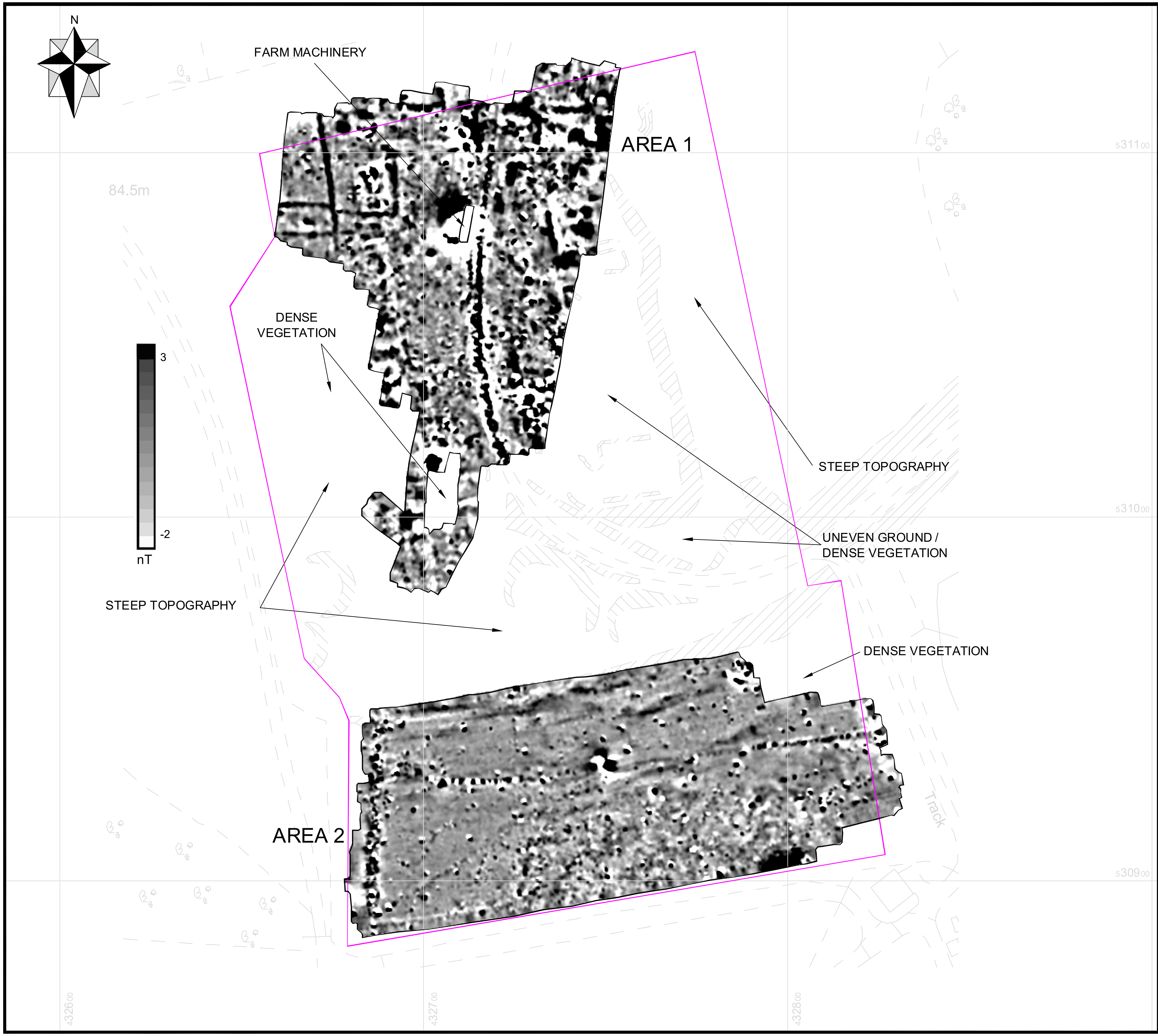
Client: DIGVENTRURES BARNARD CASTLE

Site: MIDDLEHAM CASTLE COUNTY DURHAM

Title: SITE LOCATION MAP

Job No: ARC_2561_986

		Drawn	CA
Chk.	MW	Date	12/07/2019



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Scale [A3 Sheet]	Drawing	Status
1:1000	ARC_2561_986_02	FINAL

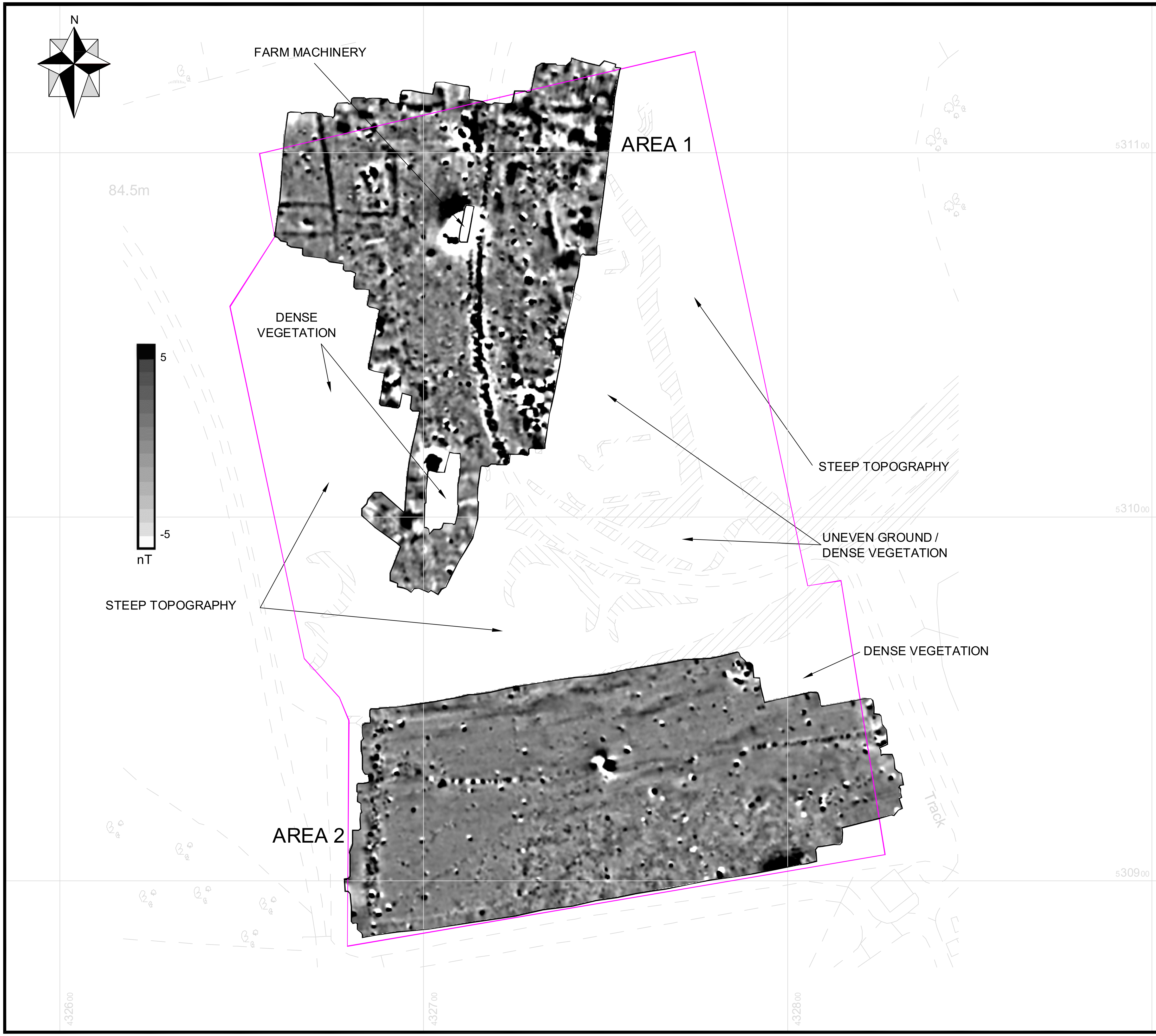
Client: DIGVENTURES LTD BARNARD CASTLE

Site: MIDDLEHAM CASTLE COUNTY DURHAM

Title: LOCATION OF SITE SHOWING MAGNETIC GRADIENT DATA AT A 'STANDARD' RANGE (-2 TO 3 nT)

Job No: ARC_2561_986

Surveyed	JW, AB, CA	Drawn	JW, CA
Chk.	NF, MW	Date	11/07/2019



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Scale [A3 Sheet]	Drawing	Status
1:1000	ARC_2561_986_03	FINAL

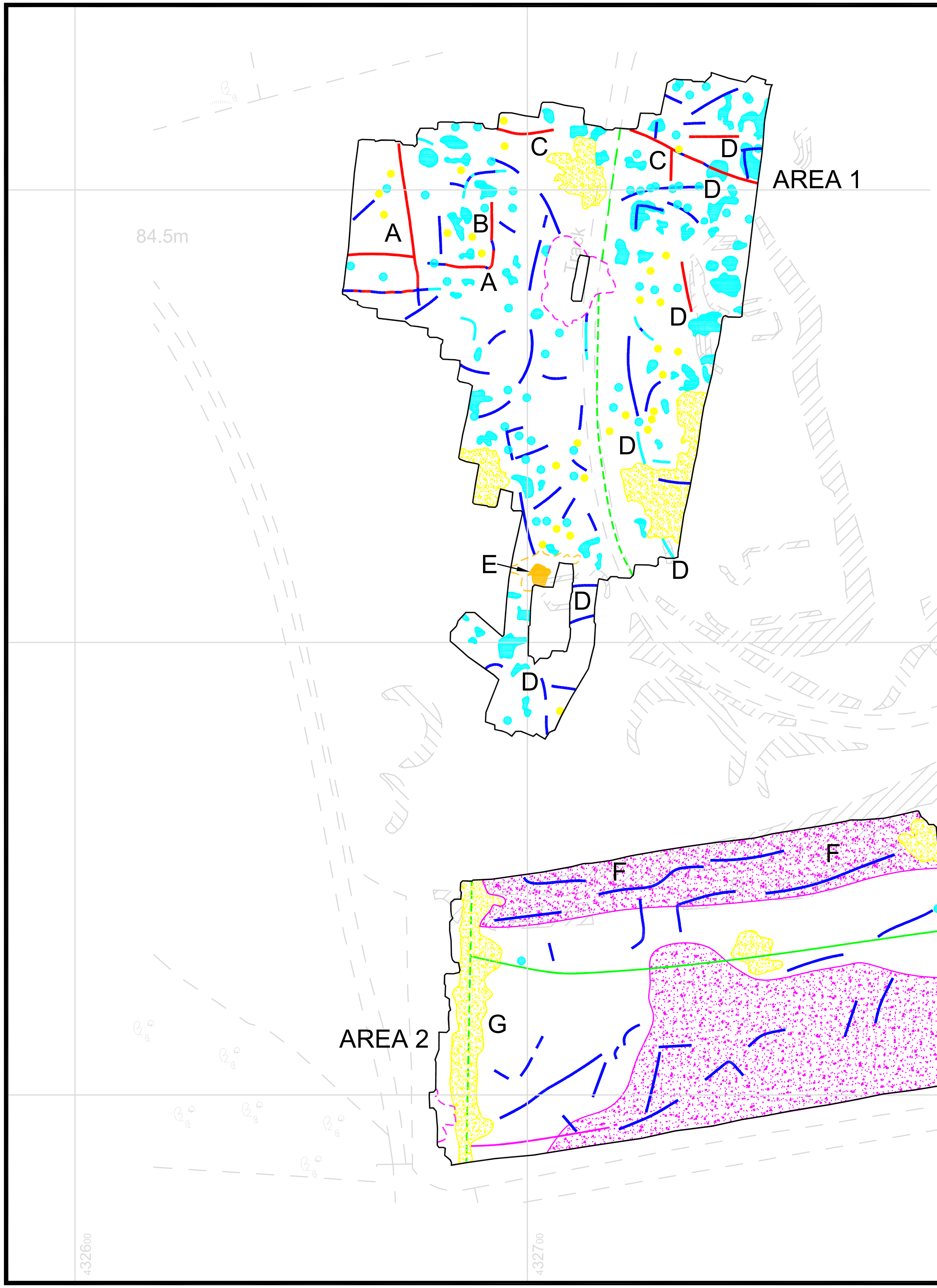
Client: DIGVENTURES LTD BARNARD CASTLE

Site: MIDDLEHAM CASTLE COUNTY DURHAM

Title: LOCATION OF SITE SHOWING MAGNETIC GRADIENT DATA AT A WIDER RANGE (-5 TO 5 nT)

Job No: ARC_2561_986

Surveyed	JW, AB, CA	Drawn	JW, CA
Chk.	NF, MW	Date	11/07/2019



ANOMALY TYPE	INTERPRETATION
ISOLATED DIPOLAR RESPONSE (IRON SPIKE)	ISOLATED SURFACE / NEAR-SURFACE FERROUS MATERIAL / OBJECT
ISOLATED BIPOLAR RESPONSE (SHOWING POSITIVE COMPONENT AND EXTENT OF ANOMALY)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
AREA OF STRONG DIPOLAR / BIPOLAR RESPONSES (MAGNETIC DISTURBANCE)	SURFACE / NEAR SURFACE FERROUS OR FIRED MATERIAL. PROBABLE MODERN BUT SOME RESPONSES COULD BE RELATED TO ARCHAEOLOGICAL MATERIAL
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
LINEAR TREND	BROADLY CORRESPONDS WITH FORMER FIELD BOUNDARY. RESPONSES WILL BE RELATED TO THIS FEATURE
LINEAR TREND	BROADLY CORRESPONDS WITH A TRACKWAY. RESPONSES WILL BE RELATED TO THIS FEATURE
NEGATIVE LINEAR	POSSIBLE AGRICULTURAL FEATURE, NON-MAGNETIC PIPE OR TRENCH
BROAD AREA OF POSITIVE AND NEGATIVE RESPONSES	PROBABLE NATURAL FEATURE / VARIATIONS
LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	UNCERTAIN ORIGIN. POSSIBLE SUB-SURFACE FEATURE / REMNANT OF FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE DEEPER BURIED FERROUS / FIRED MATERIAL OR INFILLED ISOLATED FEATURE BUT COULD ALSO BE GEOLOGICAL / PEDOLOGICAL VARIATION
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE INFILLED ARCHAEOLOGICAL FEATURE BUT COULD ALSO BE AGRICULTURAL IN ORIGIN
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	INFILLED ARCHAEOLOGICAL FEATURE

NOTES

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Scale [A3 Sheet]	Drawing	Status
1:1000	ARC_2561_986_04	FINAL

Client: DIGVENTURES LTD BARNARD CASTLE

Site: MIDDLEHAM CASTLE COUNTY DURHAM

Title: INTERPRETATION OF MAGNETIC GRADIENT DATA

Job No: ARC_2561_986

Surveyed	JW, AB, CA	Drawn	JW, CA
Chk.	NF, MW	Date	11/07/2019

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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 02 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 raster images (PNG files), and are presented in greyscale format at 1:1000.

1.4.3 The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *'Middleham-Castle.dxf'*. The base plan was in the Ordnance Survey National Grid co-ordinate system and as the survey grids were set-out 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.

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.

Bipolar linear anomalies are usually produced by buried pipes / cables that are usually metallic, although in some instances ceramic pipes can also produce popular anomalies. In some instances the anomaly can extend for a sigfncaint 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 pipe or cable.

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 anomalies

Negative 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.

On this site it is believed that the negative linear anomaly is caused by agricultural activity or a drainage feature.

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.

There are no anomalies indicative of agricultural features in this data set.

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.

Larger or stronger areas of positive response have been shown on the interpretation as have those isolated responses located in close proximity to possible or probable archaeological features. These anomalies could also be associated with geological / pedological variations or be related to relatively modern material / activity but their size or proximity to other anomalies increases their archaeological potential.

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 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.