Land to the South of Scroggs Wood
Kendal, Cumbria

Archaeological geophysical survey

Project No. ARC/1518/555

June 2015

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Project No. ARC/1518/555

Report prepared by		**Report checked by**	
Name	Mark Whittingham BA MSc MCIfA	Name	Nicola Fairs BSc MSc DIC CGeol FGS
Signature		Signature	
Date	04/06/15	Date	05/06/15

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DIGITAL COPY OF REPORT CAN BE FOUND ON CD ATTACHED TO BACK COVER

1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at a site to the south of Scroggs Wood in Kendal. 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 the Phase Site Investigations Ltd multi-sensor array cart system (MACS). The MACS comprises 6 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger. The MACS data was collected on profiles spaced 1 m apart with readings taken at between 0.1 and 0.15 m intervals.

The majority of the anomalies identified by this survey are thought to relate to agricultural practice, modern material / objects or geological / pedological variations but there are a number of anomalies of uncertain or unknown origin.

There is a linear / curvi-linear anomaly in the west of the site that is suggestive of an infilled ditch but there is insufficient evidence to definitely confirm if this is archaeological in origin.

The survey has identified a complex of broad / diffuse positive linear / curvi-linear anomalies that are thought to be caused by natural infilled fissures in the bedrock. However, the responses do vary and there are a number of anomalies of less certain origin. Whilst the origin of the latter is less clear there is no evidence in the magnetic data to indicate that the majority of them are anthropogenic in origin. A known Roman kiln is present adjacent to the north-east of the site and potentially some responses of uncertain origin in this part of the site could be caused by related features but there is no definitive evidence in the data to confirm this.

INTRODUCTION

1.1 Overview

Phase Site Investigations Ltd was commissioned by Greenlane Archaeology Ltd to carry out an archaeological geophysical survey at a site adjacent to Scroggs Lane, Kendal 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_1518_555_01.

1.2 Site description

The site is situated south of Scroggs Wood, Kendal in Cumbria (centred at NGR SD 509 904).

The site covered an area of approximately 18.3 ha and encompassed two fields; one arable and one pasture. Each field has been given a number as shown in drawing ARC_1518_555_02. The fields had a general slope downwards to the east and had significant slopes and undulations within them. They were bounded by hedges and metallic fencing.

The geology of the site consists of Great Scar Limestone, the majority of the site has no superficial deposits except in the north-east where there is glacial till (British Geological Survey, 2015).

1.3 Archaeological background

An archaeological desk-based assessment has been undertaken by Greenlane Archaeology Ltd (2014). This highlighted that the site is located in an area where activity from the Roman and medieval periods are known and a number of finds from these periods had been identified within the site.

The Roman fort at Watercrook (a scheduled monument) lies to the north-east of the site, across a watercourse and a Roman kiln is present immediately to the north-east of the site.

1.4 Scope of work

The survey area was specified by the client based on a proposed development boundary.

Vegetation cover restricted coverage slightly around the edges of the fields and a small part of Field 2 could not be surveyed as the slope was too steep to safely survey. Pig sties were present in Field 2 and small areas around these could not be surveyed. An area of approximately 16.8 ha was covered by the magnetic survey, the location of which is shown in drawing ARC_1518_555_02.

No other problems were encountered during the survey which was carried out between 12 May and 15 May 2015.

2. SURVEY METHODOLOGY

2.1 Magnetic survey

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

The MACS comprised 4 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 1 m apart. Readings were taken at between 0.1 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.

The location of the survey grids was recorded directly to Ordnance Survey National Grid co-ordinates using the UKO OSTN2 projection to an accuracy better than 0.03 m. As the survey was related direct to Ordnance Survey National Grid co-ordinates temporary survey stations were not established.

2.2 Data processing and presentation

The MACS data was stored direct to a laptop using in-house software which automatically corrects for instrument drift. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. No additional data processing is required and the data is gridded in Surfer 9 (Golden Software) using the Kriging option.

The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *57232027_os-detail-12-month-licence.dxf'*. The base plan was in the 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.

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 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. Only the stronger responses, or those that could have archaeological potential, have been shown on the interpretation.

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

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

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

A general discussion of the anomalies is provided for the entire site and then the results are discussed on an field by field 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.

3. RESULTS

3.1 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 a number of broad, diffuse linear / curvi-linear anomalies and trends present in the data. Although these are relatively regular in shape they do not form a pattern that would suggests that they are archaeological in origin and their diffuse nature would tend to indicate that they are caused by natural features.

Broadly parallel positive linear anomalies are present in most of the data, associated with modern ploughing activity. The presence of these responses and the anomalies caused by the probable natural features indicate that the soil has a magnetic susceptibility that is sufficiently high to produce measureable magnetic responses when enhanced and suggests that if significant infilled archaeological features are present that they would also produce measureable magnetic responses.

3.2 Field 1

Basic topography: Undulating

Field description: Arable with semi-mature crop. Firm underfoot. Bounded by fencing, hedges and dense vegetation.

Summary of anomalies: Numerous isolated responses, the majority of which are probably geological or modern in origin.

A linear dipolar anomalies associated with modern sub-surface utility apparatus (pipe or cable).

Very strong responses associated with strongly magnetic modern features / material.

Weak positive linear responses associated with modern ploughing regime(s).

Broad, diffuse linear / curvi-linear anomalies and trends. Some of these may be associated with infilled features but the majority are thought to be natural in origin.

Trends of uncertain origin.

A positive curvi-linear anomaly indicative of an infilled feature The response is suggestive of an anthropogenic feature and could be archaeological in origin.

Further discussion / additional information:

The broad diffuse responses and trends could be caused by infilled features or a spread of magnetic material but while individual or adjoining groups of responses are relatively regular in shape the pattern of responses, and diffuse nature of the anomalies are strongly suggestive of natural features. There is no obvious regularity or cohesion to the overall complex of anomalies that would indicate that they are caused by archaeological features. The underlying limestone geology is prone to fissures, which would become infilled with soil over time, and whilst the pattern of responses is not typical of such features it is considered more likely that natural features and variations are the cause of the anomalies, rather than anthropogenic features.

A well-defined positive curvi-linear anomaly is present in the west of the field that is suggestive of an anthropogenic feature (**Anomaly A**). The anomaly could be caused by an infilled archaeological ditch but it becomes less coherent and the responses terminate in the north and in the field to the south and so a more definitive interpretation is not possible. Weaker trends may indicate continuations of the feature.

In the east of the field there are several areas where there are broad, strong positive responses, some of which form linear / curvi-linear patterns (**Anomalies B**). These response are generally stronger but less well-defined than the complex of possible natural features to the east. However, there is no pattern to their distribution that would suggest that they are archaeological in origin and it is possible that these are also caused by natural features / variations, which are either close to the surface or have more magnetic material within them.

In the north-east of the field there are a number of strong, discrete, positive responses (**Anomalies C**) that do not form the same regular patterns or trends as those to the south and south-west and there are several trends (**Anomalies D**) that have different alignments to the complex of possible natural responses. The lack of a clear pattern to the distribution of these anomalies, either natural or man-made, makes their interpretation difficult but the proximity of a known Roman kiln adjacent to this part of the field means that an archaeological origin for some of the responses should not be completely ruled out.

3.3 Field 2

Basic topography:	Undulating with some steep slopes
Field description:	Pasture. Firm underfoot. Bounded by fencing, hedges and dense vegetation.
Summary of anomalies:	Numerous isolated responses, the majority of which are probably geological or modern in origin.
	Very strong responses associated with strongly magnetic modern features / material.
	Negative linear anomalies probably associated with modern drainage features or possibly plastic pipes.
	Weak positive linear responses associated with modern ploughing regime(s).
	Broad, diffuse linear / curvi-linear anomalies and trends. Some of these may be associated with infilled features but the majority are thought to be natural in origin.
	Trends of uncertain origin.
	A fragmented positive curvi-linear anomaly indicative of an infilled feature The response is suggestive of an anthropogenic feature and could be archaeological in origin.

Further discussion / additional information:

Negative anomalies are present but on this geology they are not considered to have archaeological potential and their linearity suggests that they are caused by modern features, such as field drains or plastic water pipes.

A fragmented, positive, curvi-linear anomaly in the west indicates a continuation of a feature visible in Field 1 (**Anomaly A).** The anomaly becomes weaker and less coherent to the south and whilst it is suggestive of an anthropogenic feature and hence could be caused by an infilled archaeological ditch this cannot be determined with certainty. Weaker trends may indicate continuations of the feature.

As discussed for Field 1 there are a number of broad diffuse responses and trends that are suggestive of natural features and other trends and responses of less certain origin but which are not indicative of anthropogenic features (**Anomaly B**).

4. DISCUSSION AND CONCLUSIONS

The majority of the anomalies identified by this survey are thought to relate to agricultural practice, modern material / objects or geological / pedological variations but there are a number of anomalies of uncertain or unknown origin.

There is a linear / curvi-linear anomaly in the west of the site that is suggestive of an infilled ditch but there is insufficient evidence to definitely confirm if this is archaeological in origin.

The survey has identified a complex of broad / diffuse positive linear / curvi-linear anomalies that are thought to be caused by natural infilled fissures in the bedrock. However, the responses do vary and there are a number of anomalies of less certain origin. Whilst the origin of the latter is less clear there is no evidence in the magnetic data to indicate that the majority of them are anthropogenic in origin. A known Roman kiln is present adjacent to the north-east of the site and potentially some responses of uncertain origin in this part of the site could be caused by related features but there is no definitive evidence in the data to confirm this.

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

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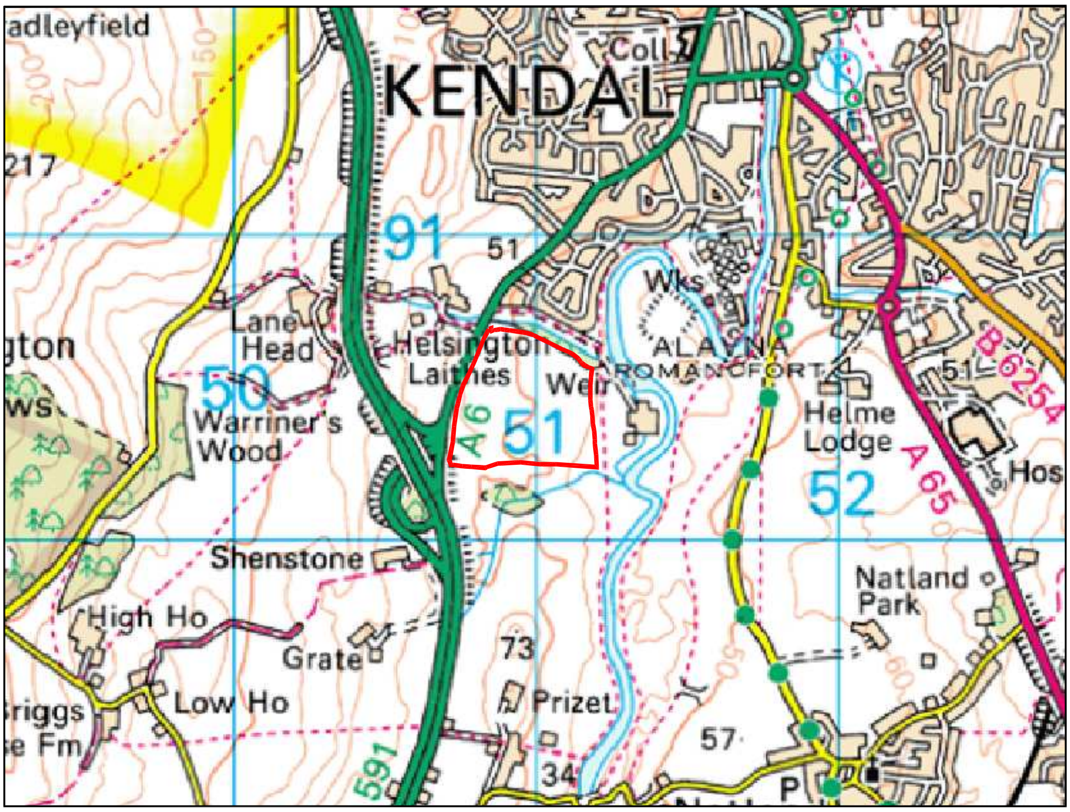

91

90

SD 50 51 52

SITE LOCATION

SCALE

0m 500m 1000m

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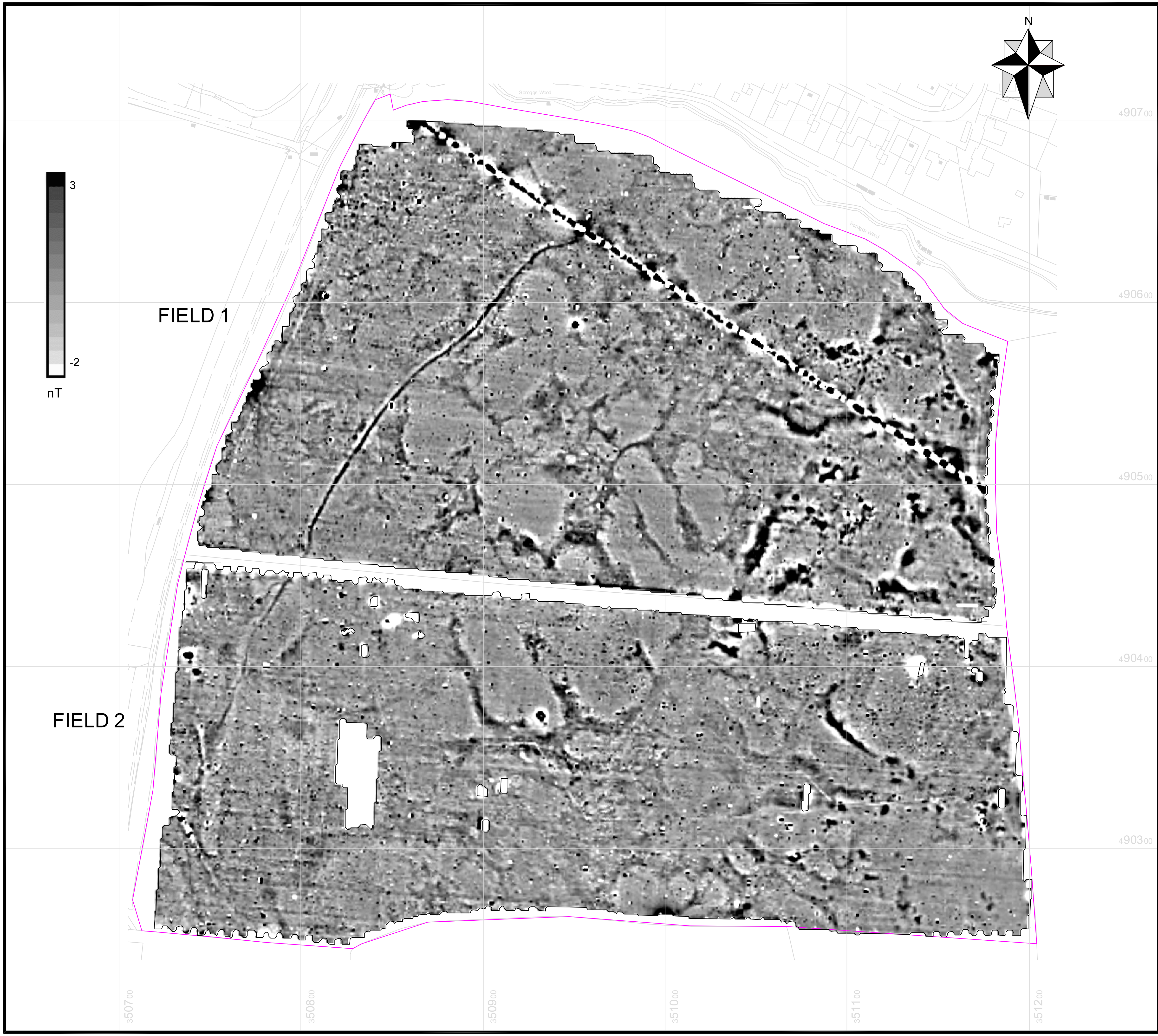
	Client GREENLANE ARCHAEOLOGY LTD ULVERSTON, CUMBRIA		
PHASE SITE INVESTIGATIONS	Site LAND TO THE SOUTH OF SCROGGS WOOD, KENDAL		
	Title SITE LOCATION MAP		
	Job No ARC_1518_555		
		Drawn	NF
	Chk. MW	Date	27/05/2015

Phase Site Investigations Ltd, 703A Whinfield Drive, Aycliffe Business Park, Newton Aycliffe, County Durham, DL5 6AU

T: +44 [0] 01325 311 751
F: +44 [0] 01325 310 819
E: enquiries@PhaseSI.com
W: www.PhaseSI.com



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PHASE SITE INVESTIGATIONS

Phase Site Investigations Ltd, 703A Whinfield Drive, Aycliffe Business Park, Newton Aycliffe, County Durham, DL5 6AU

T: +44 [0] 01325 311 751
F: +44 [0] 01325 310 819
E: enquiries@PhaseSI.com
W: www.PhaseSI.com

Scale [A3 Sheet]	Drawing	Status
1:2000	ARC_1518_555_02	FINAL

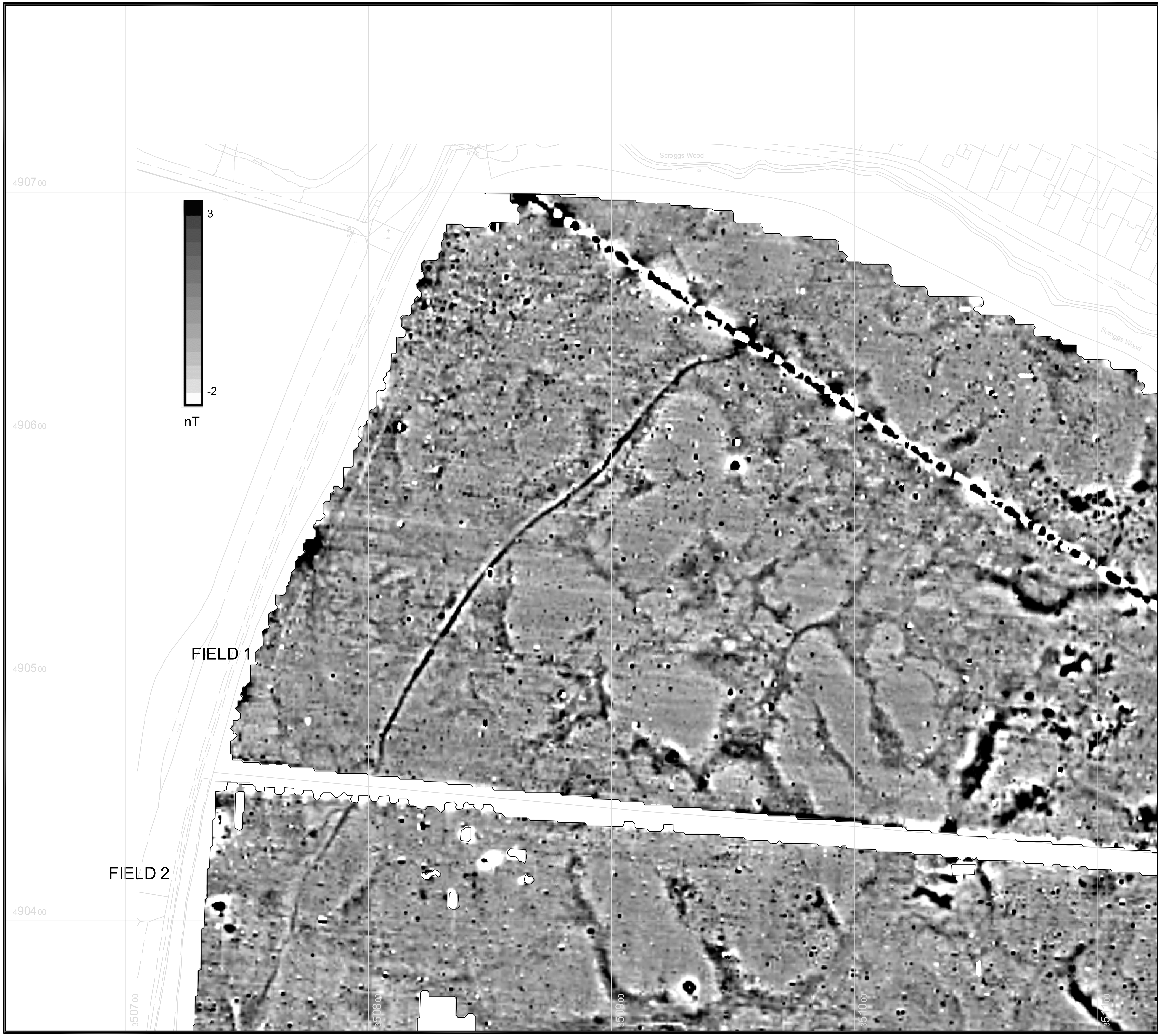
Client: GREENLANE ARCHAEOLOGY LTD
ULVERSTON, CUMBRIA

Site: LAND TO THE SOUTH OF
SCROGGS WOOD, KENDAL

Title: LOCATION OF SITE SHOWING
MAGNETIC GRADIENT DATA

Job No: ARC_1518_555

Surveyed	SP, JG	Drawn	MW
Chk.	NF	Date	15/05/2015



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PHASE SITE INVESTIGATIONS

Phase Site Investigations Ltd, 703A Whinfield Drive, Aycliffe Business Park, Newton Aycliffe, County Durham, DL5 6AU

T: +44 [0] 01325 311 751
F: +44 [0] 01325 310 819
E: enquiries@PhaseSI.com
W: www.PhaseSI.com

Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_1518_555_03	FINAL

Client: GREENLANE ARCHAEOLOGY LTD
ULVERSTON, CUMBRIA

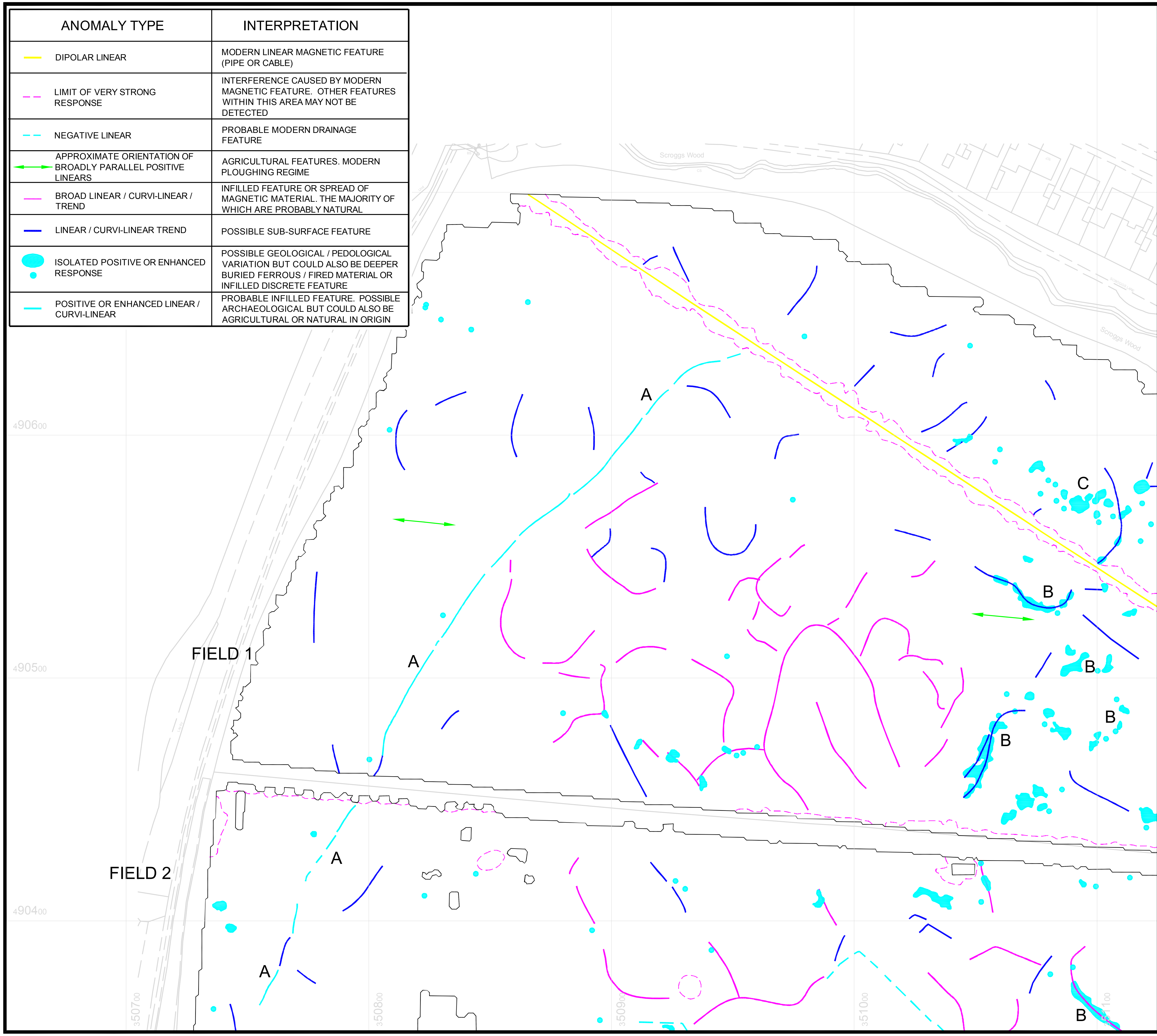
Site: LAND TO THE SOUTH OF
SCROGGS WOOD, KENDAL

Title: GREYSCALE PLOT OF MAGNETIC GRADIENT DATA: WESTERN PART OF FIELD 1 AND NORTH-WESTERN PART OF FIELD 2

Job No: ARC_1518_555

Surveyed	SP, JG	Drawn	MW
Chk.	NF	Date	15/05/2015

ANOMALY TYPE	INTERPRETATION
DIPOLAR LINEAR	MODERN LINEAR MAGNETIC FEATURE (PIPE OR CABLE)
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE. OTHER FEATURES WITHIN THIS AREA MAY NOT BE DETECTED
NEGATIVE LINEAR	PROBABLE MODERN DRAINAGE FEATURE
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL FEATURES. MODERN PLOUGHING REGIME
BROAD LINEAR / CURVI-LINEAR / TREND	INFILLED FEATURE OR SPREAD OF MAGNETIC MATERIAL. THE MAJORITY OF WHICH ARE PROBABLY NATURAL
LINEAR / CURVI-LINEAR TREND	POSSIBLE SUB-SURFACE FEATURE
ISOLATED POSITIVE OR ENHANCED RESPONSE	POSSIBLE GEOLOGICAL / PEDOLOGICAL VARIATION BUT COULD ALSO BE DEEPER BURIED FERROUS / FIRED MATERIAL OR INFILLED DISCRETE FEATURE
POSITIVE OR ENHANCED LINEAR / CURVI-LINEAR	PROBABLE INFILLED FEATURE. POSSIBLE ARCHAEOLOGICAL BUT COULD ALSO BE AGRICULTURAL OR NATURAL IN ORIGIN



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Phase Site Investigations Ltd, 703A Whinfield Drive, Aycliffe Business Park, Newton Aycliffe, County Durham, DL5 6AU

T: +44 [0] 01325 311 751
F: +44 [0] 01325 310 819
E: enquiries@PhaseSI.com
W: www.PhaseSI.com

Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_1518_555_04	FINAL

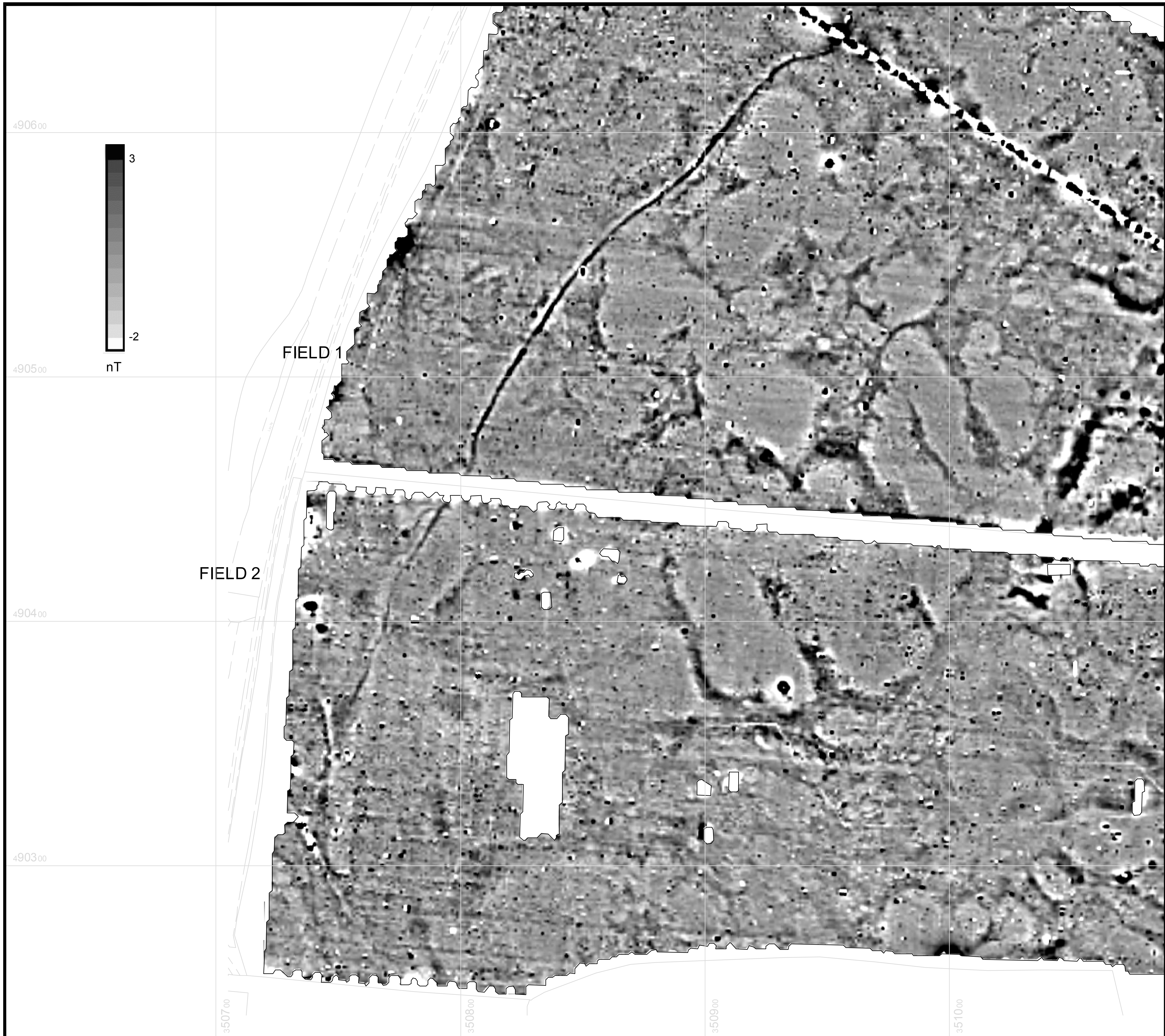
Client: GREENLANE ARCHAEOLOGY LTD
ULVERSTON, CUMBRIA

Site: LAND TO THE SOUTH OF SCROGGS WOOD, KENDAL

Title: INTERPRETATION OF MAGNETIC GRADIENT DATA: WESTERN PART OF FIELD 1 AND NORTH-WESTERN PART OF FIELD 2

Job No: ARC_1518_555

Surveyed	SP, JG	Drawn	MW
Chk.	NF	Date	15/05/2015



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Phase Site Investigations Ltd, 703A Whinfield Drive, Aycliffe Business Park, Newton Aycliffe, County Durham, DL5 6AU

T: +44 [0] 01325 311 751
F: +44 [0] 01325 310 819
E: enquiries@PhaseSI.com
W: www.PhaseSI.com

Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_1518_555_05	FINAL

Client: GREENLANE ARCHAEOLOGY LTD
ULVERSTON, CUMBRIA

Site: LAND TO THE SOUTH OF
SCROGGS WOOD, KENDAL

Title: GREYSCALE PLOT OF MAGNETIC GRADIENT DATA: WESTERN PART OF FIELD 1 AND SOUTH-WESTERN PART OF FIELD 2

Job No: ARC_1518_555

Surveyed	SP, JG	Drawn	MW
Chk.	NF	Date	15/05/2015

ANOMALY TYPE	INTERPRETATION
DIPOLAR LINEAR	MODERN LINEAR MAGNETIC FEATURE (PIPE OR CABLE)
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE. OTHER FEATURES WITHIN THIS AREA MAY NOT BE DETECTED
NEGATIVE LINEAR	PROBABLE MODERN DRAINAGE FEATURE
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL FEATURES. MODERN PLOUGHING REGIME
BROAD LINEAR / CURVI-LINEAR / TREND	INFILLED FEATURE OR SPREAD OF MAGNETIC MATERIAL. THE MAJORITY OF WHICH ARE PROBABLY NATURAL
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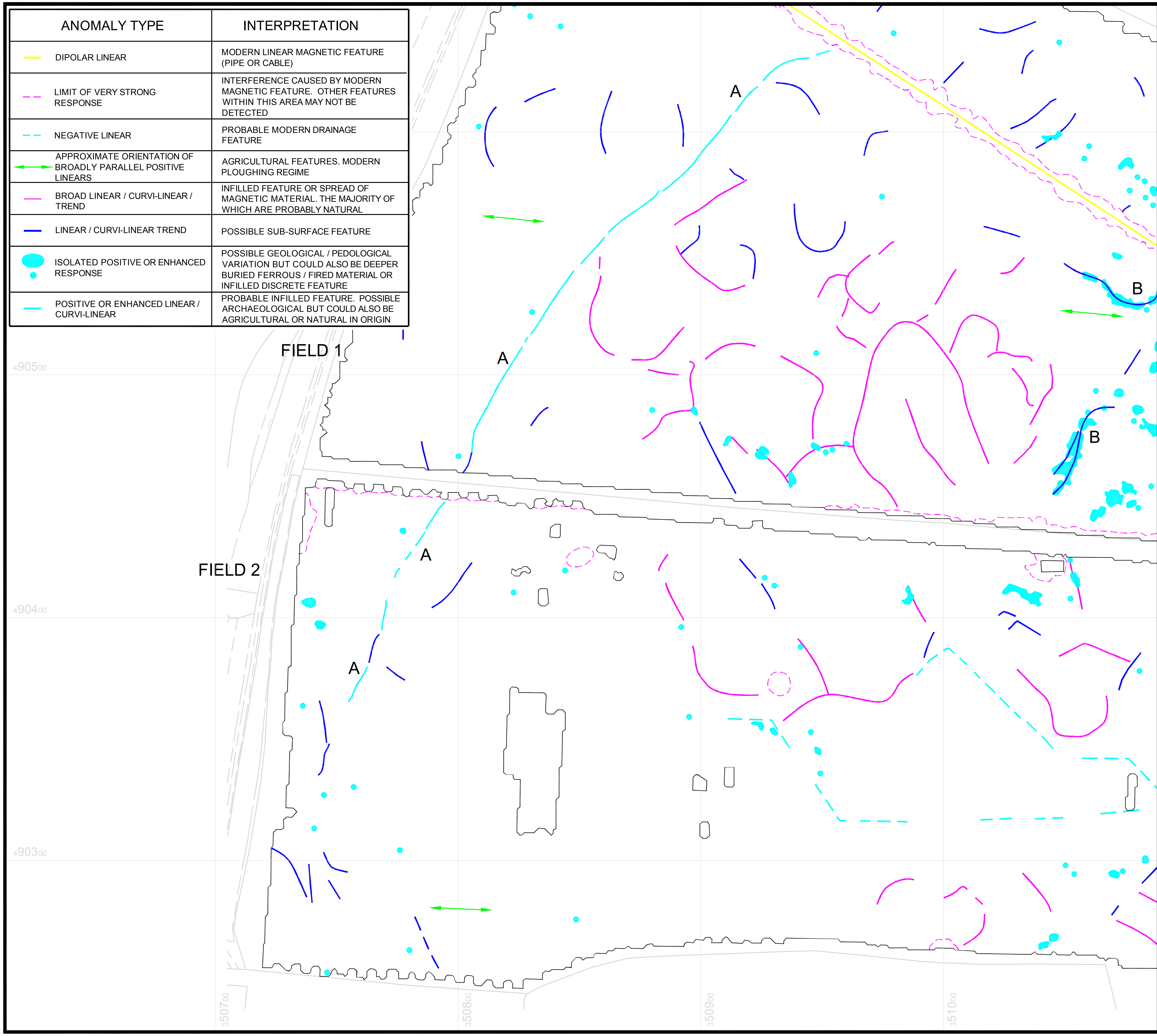
ISOLATED POSITIVE OR ENHANCED RESPONSE	POSSIBLE GEOLOGICAL / PEDOLOGICAL VARIATION BUT COULD ALSO BE DEEPER BURIED FERROUS / FIRED MATERIAL OR INFILLED DISCRETE FEATURE
POSITIVE OR ENHANCED LINEAR / CURVI-LINEAR	PROBABLE INFILLED FEATURE. POSSIBLE ARCHAEOLOGICAL BUT COULD ALSO BE AGRICULTURAL OR NATURAL IN ORIGIN



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Phase Site Investigations Ltd, 703A Whinfield Drive, Aycliffe Business Park, Newton Aycliffe, County Durham, DL5 6AU

T: +44 [0] 01325 311 751
F: +44 [0] 01325 310 819
E: enquiries@PhaseSI.com
W: www.PhaseSI.com

Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_1518_555_06	FINAL

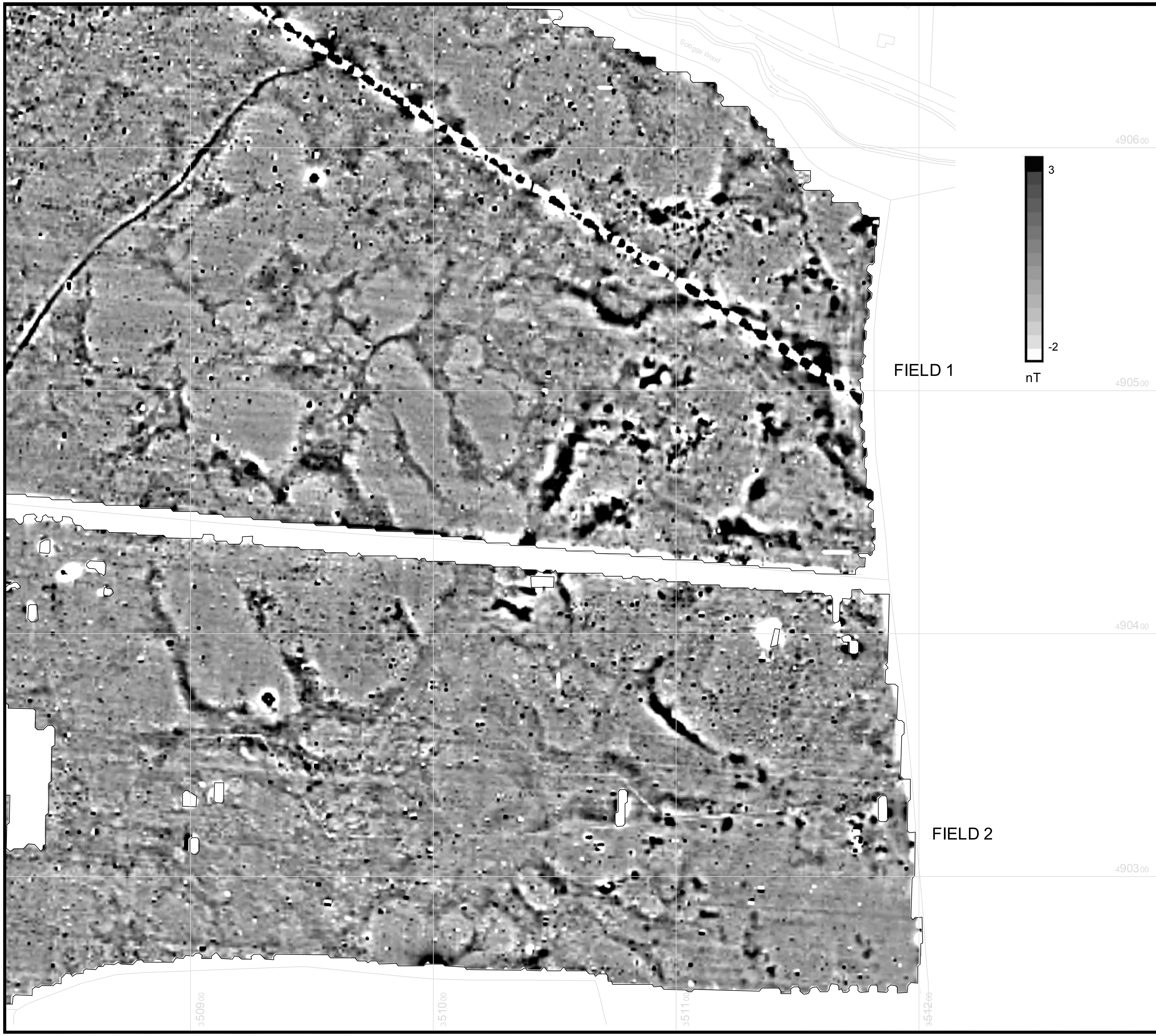
Client: GREENLANE ARCHAEOLOGY LTD ULVERSTON, CUMBRIA

Site: LAND TO THE SOUTH OF SCROGGS WOOD, KENDAL

Title: INTERPRETATION OF MAGNETIC GRADIENT DATA: WESTERN PART OF FIELD 1 AND SOUTH-WESTERN PART OF FIELD 2

Job No: ARC_1518_555

Surveyed	SP, JG	Drawn	MW
Chk.	NF	Date	15/05/2015



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E: enquiries@PhaseSI.com
W: www.PhaseSI.com

Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_1518_555_07	FINAL

Client: GREENLANE ARCHAEOLOGY LTD
ULVERSTON, CUMBRIA

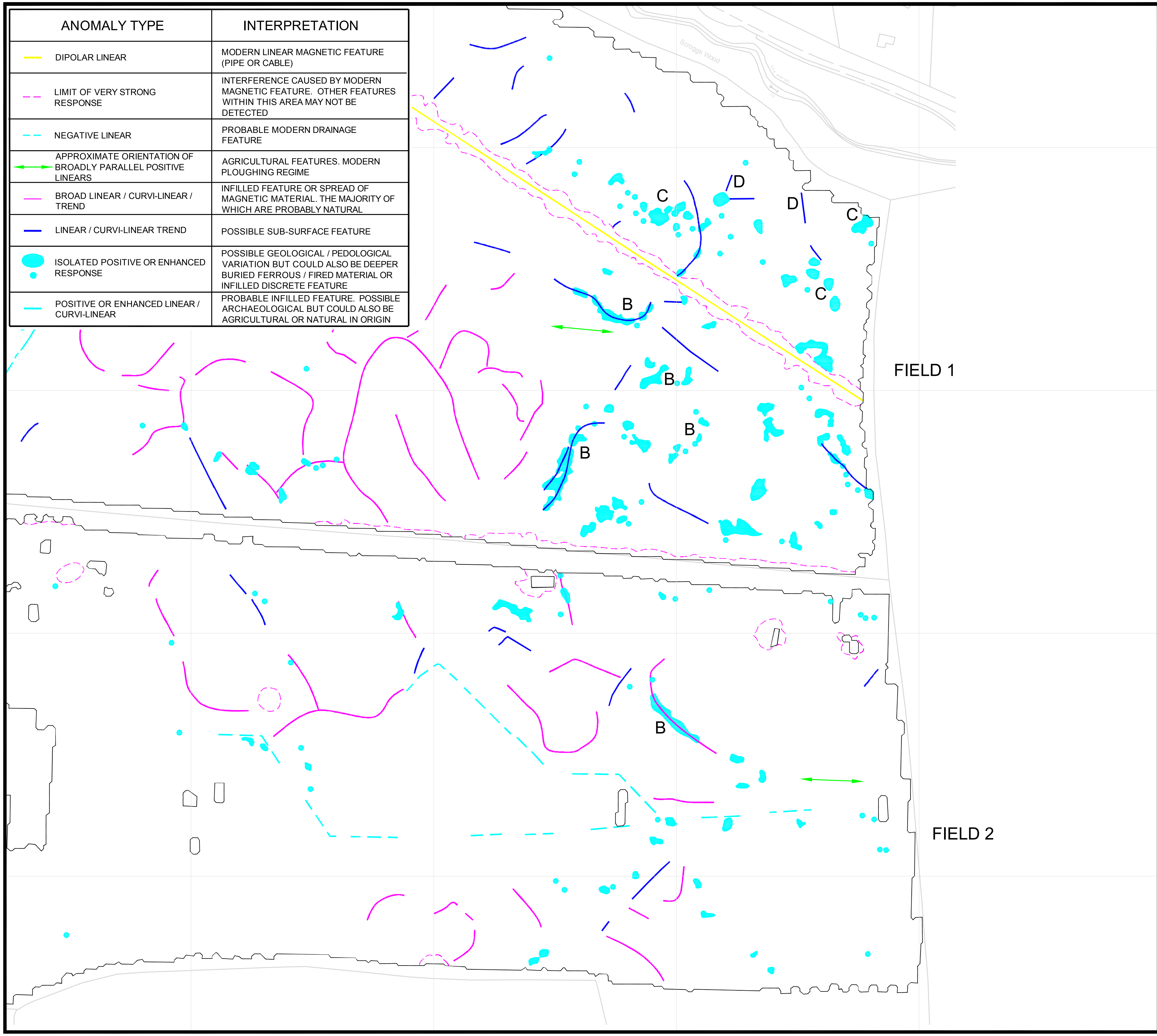
Site: LAND TO THE SOUTH OF
SCROGGS WOOD, KENDAL

Title: GREYSCALE PLOT OF MAGNETIC GRADIENT DATA: EASTERN PARTS OF FIELD 1 AND 2

Job No: ARC_1518_555

Surveyed	SP, JG	Drawn	MW
Chk.	NF	Date	15/05/2015

ANOMALY TYPE	INTERPRETATION
DIPOLAR LINEAR	MODERN LINEAR MAGNETIC FEATURE (PIPE OR CABLE)
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE. OTHER FEATURES WITHIN THIS AREA MAY NOT BE DETECTED
NEGATIVE LINEAR	PROBABLE MODERN DRAINAGE FEATURE
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL FEATURES. MODERN PLOUGHING REGIME
BROAD LINEAR / CURVI-LINEAR / TREND	INFILLED FEATURE OR SPREAD OF MAGNETIC MATERIAL. THE MAJORITY OF WHICH ARE PROBABLY NATURAL
LINEAR / CURVI-LINEAR TREND	POSSIBLE SUB-SURFACE FEATURE
ISOLATED POSITIVE OR ENHANCED RESPONSE	POSSIBLE GEOLOGICAL / PEDOLOGICAL VARIATION BUT COULD ALSO BE DEEPER BURIED FERROUS / FIRED MATERIAL OR INFILLED DISCRETE FEATURE
POSITIVE OR ENHANCED LINEAR / CURVI-LINEAR	PROBABLE INFILLED FEATURE. POSSIBLE ARCHAEOLOGICAL BUT COULD ALSO BE AGRICULTURAL OR NATURAL IN ORIGIN



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E: enquiries@PhaseSI.com
W: www.PhaseSI.com

Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_1518_555_08	FINAL

Client: GREENLANE ARCHAEOLOGY LTD, ULVERSTON, CUMBRIA

Site: LAND TO THE SOUTH OF SCROGGS WOOD, KENDAL

Title: INTERPRETATION OF MAGNETIC GRADIENT DATA: EASTERN PARTS OF FIELD 1 AND 2

Job No: ARC_1518_555

Surveyed	SP, JG	Drawn	MW
Chk.	NF	Date	15/05/2015

BIBLIOGRAPHY AND REFERENCES

Greenlane Archaeology Ltd, 2014, Land to the south of Scroggs Wood, Kendal, Cumbria, Archaeological desk-based assessment

British Geological Survey, 2015, online resource - www.bgs.ac.uk

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 4 Foerster 4.032 Ferex CON 650 gradiometers, spaced at 1.0 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 1.0 m which means that data was collected on profiles spaced at 1.0 m apart. Readings were taken at between 0.1 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.

1.3.3 The location of the survey grids was recorded directly to Ordnance Survey National Grid co-ordinates using the UKO OSTN2 projection to an accuracy better than 0.03 m. As the survey was related direct to Ordnance Survey National Grid co-ordinates temporary survey stations were not established.

1.3.4 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 was stored automatically to a laptop using in-house software which automatically corrects for instrument drift. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. No additional data processing is required and the data is gridded in Surfer 9 (Golden Software) using the Kriging option.

1.4.2 The data was exported as raster images (PNG files), and are presented in greyscale format at 1:1500.

1.4.3 The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *57232027_os-detail-12-month-licence.dxf'*. The base plan was in the 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 responses

Dipolar responses are those that have a sharp variation between strongly positive and negative components. In the majority of cases dipolar 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 responses.

There are numerous **isolated dipolar responses** (iron spikes) across the survey area that are indicative of ferrous or fired material on or near to the surface. The isolated responses are often caused by small objects, such as spent shotgun cartridges, iron nails and horseshoes or pieces of modern brick or pot. 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. This type of anomaly have not been shown on the interpretation as there is no evidence to suggest that they may be archaeological in origin.

Areas containing strong or numerous dipolar responses (**magnetic disturbance)** are usually caused by 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 dipolar 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 response can occasionally be caused by features / material associated with archaeological industrial activity but they are usually caused by modern activity. Responses in areas of magnetic disturbance can sometimes be so strong that archaeological features located beneath them may not be detected. There are no significant areas of magnetic disturbance in this data set.

Linear anomalies that contain dipolar responses (categorised as **dipolar linear**) are usually caused by modern pipes or cables.

Very strong responses from modern features can dominate the data for a significant distance beyond the feature. The extent of these areas is usually shown 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. 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. It can often be associated with ploughing regimes or plastic / concrete pipes.

They can 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 responses relate to drainage features or a service trench.

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.

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 or enhanced responses

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

The large number of isolated responses and lack of an obvious pattern to their distribution suggests that these the majority anomalies are probably associated with geological / pedological variations. Only the larger or stronger areas of positive response have been shown on the interpretation.

Positive or enhanced 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 or sometimes infilled natural 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.

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 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 anomies 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 modern ploughing are present in the data. The general orientation of these has been shown on the interpretation but 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.