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LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA REPORT ON GEOPHYSICAL SURVEY, JULY 2013

Neil Linford, Paul Linford, Andrew Payne and Ian Hardwick

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Research Report Series 56-2013

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REPORT ON GEOPHYSICAL SURVEYS, JULY 2013

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SUMMARY

Caesium magnetometer and Ground Penetrating Radar (GPR) surveys were conducted over an irregular curvilinear enclosure on the top of Kitridding Hill, Lupton, Cumbria, recorded through the initial aerial photographic phase of the National Archaeological Identification Surveys: Upland Pilot (RASMIS 6304). It was hoped that additional magnetic and GPR survey might enhance the archaeological record of the site, as the interior earthworks were in places indistinct and it is possible that the enclosure represents part of a wider complex of archaeological activity. A vehicle-towed, caesium magnetometer array was used to cover the earthworks (2.3ha) whilst the GPR was focused on a smaller area (1.0ha) of the interior to test the suitability of this technique at the site. The magnetic survey revealed a symmetric 'shield shaped' form to the enclosure and suggests further interior activity corroborated by the GPR results.

CONTRIBUTORS

The field work was conducted by Neil Linford, Paul Linford and Andy Payne from the English Heritage Geophysics Team. Ian Hardwick, a Heritage Environment Placement working within the above team, contributed to the interpretation of the geophysical data, figure preparation and the writing of this report.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to the land owner, Mr Jon Eskholme, for permission in granting access to his land to allow the survey to take place.

ARCHIVE LOCATION

Fort Cumberland.

DATE OF FIELDWORK AND REPORT

The fieldwork was conducted between 24th to 25th July 2013. The report was completed on 19th December 2013. The cover shows a view of the caesium magnetometer survey in progress.

CONTACT DETAILS

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CONTENTS

INTRODUCTION

Caesium magnetometer and Ground Penetrating Radar (GPR) surveys were conducted on the top of Kitridding Hill, Lupton, Cumbria, over a teardrop shaped enclosure recorded as an earthwork (NGR SD 583843, NRHE Monument HOB UID 43113, Figure 1) during the Upland pilot of the National Archaeological Identification Survey (NAIS) programme (NAIS Upland, Lakes and Dales; NHPP Project Number 3A4.312, RaSMIS 6304). The NAIS Upland pilot project covers the Arnside & Silverdale AONB together with parts of the proposed extensions to the Yorkshire Dales and Lake District National Parks, and aims to improve both the understanding of known sites and also include areas where the current archaeological record is sparse (Oakey 2013). The results of the project will directly feed into the management of these protected landscapes.

Geophysical survey was included in the project to complement the initial aerial investigation on selected sites in the Lune Valley, where ground-based methods could potentially enhance the assessment of the archaeological evidence (Linford *et al* 2013a, 2013b, 2013c). The site on the eastern side of Kitridding Hill was one of the main earthwork features identified from the aerial photography, appearing as a curvilinear defended enclosure of probable prehistoric origin defined by a ditch with both inner and outer banks for much of its perimeter, which form a 'teardrop' shape in plan. Several internal earthwork scoops or platforms were identified as potential hut sites or sub-enclosures, while external linear banks extending from the south-east appear less well defined than at the similar site at Castle Hill (NRHE Monument HOB UID 43942), perhaps due to a greater degree of land improvement at Kitridding. The aim of the geophysical survey was to elucidate any further evidence of internal, defensive and external activity to enhance the existing data and strengthen the case for designation.

The main enclosure earthworks are situated on a low saddle on the eastern side of Kitridding Hill, to the west of the Lune valley commanding views to the edge of the Pennines to the east, and down tributary valleys of the Lune and a routeway to the south-east. This, no doubt, partly explains the location of the enclosure, although a higher summit to the north-west overlooks it, possibly suggesting it was not predominantly defensive in function. The site is situated on Silurian Kirkby Moor Formation siltstone solid geology overlain by slowly permeable, seasonally waterlogged, fine silty and clayey soils of the 713d Cegin association (Soil Survey of England and Wales 1983; British Geological Survey (NERC) 2013). No superficial geology is mapped in the area, although local soil variation is possible due to topography and several small southward-flowing streams that pass through the enclosure promoting growth of some marginal vegetation. At the time of the survey the site was down to grass and weather conditions during the field work were warm, dry and sunny throughout.

Figure 1. The Kitridding curvilinear enclosure, defined as an earthwork composed of ditch and banks in the centre of the aerial photograph, situated on an east-facing spur of Kitridding Hill. North is to the bottom right of the image (28366/17 11-DEC-2012 © English Heritage).

METHOD

Magnetic survey

The magnetometer data was collected along the instrument swaths shown on Figure 2 using an array of six high sensitivity Geometrics G862 caesium vapour magnetometer sensors mounted on a non-magnetic sledge. This sledge was towed behind a low impact, all-terrain vehicle (ATV) which also provided the power supply and housed the data logging electronics. Five of the sensors were mounted in a linear array transverse to the direction of travel 0.5m apart and, vertically, ~0.2m above the ground surface. The sixth was fixed 1.0m directly above the central magnetometer in the array to act as a gradient sensor. The sensors were set to sample at a rate of 16Hz based on the typical average travel speed of the ATV (3.2m/s) giving a sampling density of ~0.2m by 0.5m along successive swaths. Each swath was separated from the last by approximately 2.5m, navigation and positional control being achieved using a Trimble 4700 series GPS receiver mounted on the sensor platform 1.75m in front of the central sensor. Sensor output and survey location was monitored during acquisition to ensure data quality and minimise the risk of gaps in the coverage due to the use of a grid-less system.

After data collection the corresponding readings from the gradient sensor were subtracted from the measurements made by the other five magnetometers to remove any transient magnetic field effects caused by the towing ATV. The median value of each instrument traverse was then adjusted to zero by subtracting a running median value calculated over a 60m 1D window. This operation corrects for slight biases added to the measurements owing to the diurnal variation of the Earth's magnetic field and any slight directional sensitivity of the sensors. A linear greyscale image of the combined magnetic data is shown superimposed over the base Ordnance Survey (OS) mapping on Figure 3 and minimally processed versions of the range truncated data (±50nT) are shown as a traceplot and linear greyscale image in Figures 5 and 6 respectively.

Ground Penetrating Radar survey

The Ground Penetrating Radar (GPR) data was collected along the instrument swaths shown on Figure 2 using Sensors and Software Pulse Ekko PE1000 console with a 450MHz centre frequency ground coupled antenna, to record reflections through a 50ns window. The antenna was mounted in small sledge towed behind an ATV together with a Trimble 4700 series GPS receiver to provide positional data. Individual GPR traces were collected at 0.05m intervals along profiles separated by approximately 0.5m, although the cross-line spacing was varied due to the topography and vegetation cover at the site.

Post acquisition processing involved the adjustment of time-zero to coincide with the true ground surface, background and noise removal, and the application of a suitable gain function to enhance late arrivals. Representative profiles from the GPR survey are shown on Figures 7, 8 and 9. An average sub-surface velocity of 0.0626m/ns was assumed following constant velocity tests on the data, and was used for the migration velocity field, the time to estimated depth conversion and the static topographic correction applied to the profiles on Figures 7, 8 and 9. In addition, owing to antenna coupling between the GPR transmitter and the ground to an approximate depth of $^{\lambda}/_{2}$, very near-surface reflection events should only be detectable below a depth of 0.07m if a centre frequency of 450MHz and a velocity of 0.0626m/ns are assumed. However, the broad bandwidth of an impulse GPR signal results in a range of frequencies to either side of the centre frequency which, in practice, will record significant near-surface reflections closer to the ground surface. Such reflections are often emphasised by presenting the data as amplitude time slices. In this case, the time slices were created from the entire data set, after applying a 2D-migration algorithm, by averaging data within successive 2ns (two-way travel time) windows (Linford 2004). Each resulting time slice, illustrated as a greyscale image in Figure 10 represents the variation of reflection strength through successive 0.06m intervals from the ground surface. A single time slice from between 6 and 8ns (0.18 to 0.24m) is shown superimposed over the base OS mapping on Figure 4.

RESULTS

Magnetic survey

A graphical summary of the significant magnetic anomalies, [m1-25], discussed in the following text, superimposed on the base OS map data, is provided in Figure 11.

General response

The magnitude of response at the site is relatively weak and shows some amorphous areas of disturbance [m1], perhaps due to outcrops or glacially transported deposits of more magnetic igneous or metamorphic rock. Three linear anomalies [m2-4], found in a slight valley on the hill slope, may also reflect geological or geomorphological processes, although a more significant relationship to the enclosure can not be entirely dismissed. Despite the influence of the background geology significant archaeological anomalies are discernible within the data.

The curvilinear enclosure and associated activity

The enclosure earthworks, initially identified from aerial photography appear as concentric, near symmetrical curvilinear negative [m5], and positive magnetic anomalies [m6-9], forming the overall shape of a 'shield'. Whilst the magnetic anomalies [m5-9] reflect the earthwork evidence (Figures 1 and 13(A)) of a perimeter ditch with external and internal banks, the geophysical response suggests a more regular and symmetrical form with the ditch having a sharply angled corner at the north-west as well as at the north-east. The interior bank is apparent only on the south-eastern edge [m7].

Within the enclosure linear anomalies [m10-12] respect the shape of the outer ditches and may represent further internal sub-division. The negative anomaly at [m13] appears to run between [m7] and [m10], but it is a much weaker response so its interpretation is less clear. Two almost circular negative anomalies [m14] and [m15] are likely to be internal enclosures, possibly for stock management. Smaller curvilinear anomalies [m16-19] and a slightly weaker response at [m20] are, perhaps, more likely to represent hut circles or smaller internal enclosures.

A small, rectilinear, positive response [m21] may also be suggestive of a similar settlement function to [m16-20] that appear, at least in part, to respect visible earthwork platforms. However, some of the larger magnetic anomalies, such as [m12], and the potential hut circles [m16-20], do not correlate completely with the aerial photography (*cf* Figure 13(A)).

Beyond the main earthworks [m22] and [m23] possibly represent additional enclosures, although this interpretation is more tentative due to the lower magnitude of response exhibited by these anomalies. Further, weak linear anomalies [m24] and [m25], could be indicative of former land divisions or be associated with either [m23] or the extant ridge and furrow identified from the aerial photography (Figure 13).

Ground Penetrating Radar (GPR) survey

A graphical summary of the significant GPR anomalies, [gpr1-16], discussed in the following text, superimposed on the base OS map data, is provided in Figure 12.

Uneven topography together with a variable density of vegetation over the site has led to some problems maintaining ground coupling with the antenna, but this does not appear to have unduly influenced the integrity of the results and signal penetration extends through a two-way travel time window of at least 40ns.

The response to the main enclosure earthworks is replicated in the GPR data as a series of high amplitude reflections [gpr1-7] from between 4 and 42ns (0.12 to 1.26m). These anomalies are, in part, more complex than the corresponding magnetic data [m6–11] showing a double response to the north [gpr1-4] with an apparent entrance gap at [gpr8], resolving to a single curvilinear reflection [gpr3 and 7] from 14ns (0.42m) onwards. Comparison between the extant earthworks and the GPR profiles suggests the topography has produced high amplitude anomalies over the double banks to the N and that the deeper response [gpr3 and 7] corresponds more directly to the lower lying ditch (*cf* Figures 7 and 13). The course of the ditch does not appear to be entirely represented by surface topographic expression, perhaps explaining the slight variation in the shape of the enclosure between the geophysical results and the aerial photography (eg [gpr5] on Figure 8).

The near-surface data reveals some apparent internal detail, also partially resolved by the magnetic survey, including a pattern of cellular internal divisions [gpr9] and series of more complex, discrete anomalies [gpr10-13] that correspond with extant platforms and depressions. Interpretation of the discrete anomalies is complicated, although some settlement function, such as hut circles or small stock enclosures seems possible. One of the anomalies [gpr13] is clearly defined as a low amplitude, rectilinear response 9m x 9m between 4 and 10ns (0.12 to 0.3m), although a more recent origin perhaps a lined pond to water stock should also be considered. Deeper lying reflectors [gpr14-16] from 24ns (0.72m) onwards are more diffuse and do not, necessarily correlate with the expression of the earthworks. One of these [gpr15] does follow an arc that respects the northern boundary of the enclosure, although it is difficult to ascertain whether this represents an earlier phase of the monument or an underlying geological structure.

CONCLUSION

Despite challenging surface conditions and relatively weak magnetic response geophysical survey has successfully provided useful results to elucidate the aerial mapping. In particular, the course of the enclosure ditch and bank, although less complete in the geophysical coverage, confirms an apparently more geometrical 'shield' shaped form, only partly described by the earthworks. A possible interruption in the north-west corner of the enclosure is suggested by the earthworks, although the bank and ditch are poorly preserved at this point, and appears as a more continuous ditch-type magnetic anomaly, forming a sharp angle on the north-west corner, so a deliberate entrance here seems unlikely; whether there was an entrance gap on the west side is, however, less clear. Both the magnetic survey and the more limited GPR results provide additional evidence for internal sub-division and possible occupation activity within the enclosure. Whilst some of this activity is associated with visible platforms or other topographic variation, many significant geophysical anomalies have no apparent surface expression. Wider survey of the area immediately surrounding the enclosure was limited due to the severe topography of the hilltop location although some additional, perhaps geological, anomalies were recorded.

LIST OF ENCLOSED FIGURES

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Figure 2

LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA

Location of geophysical surveys, July 2013

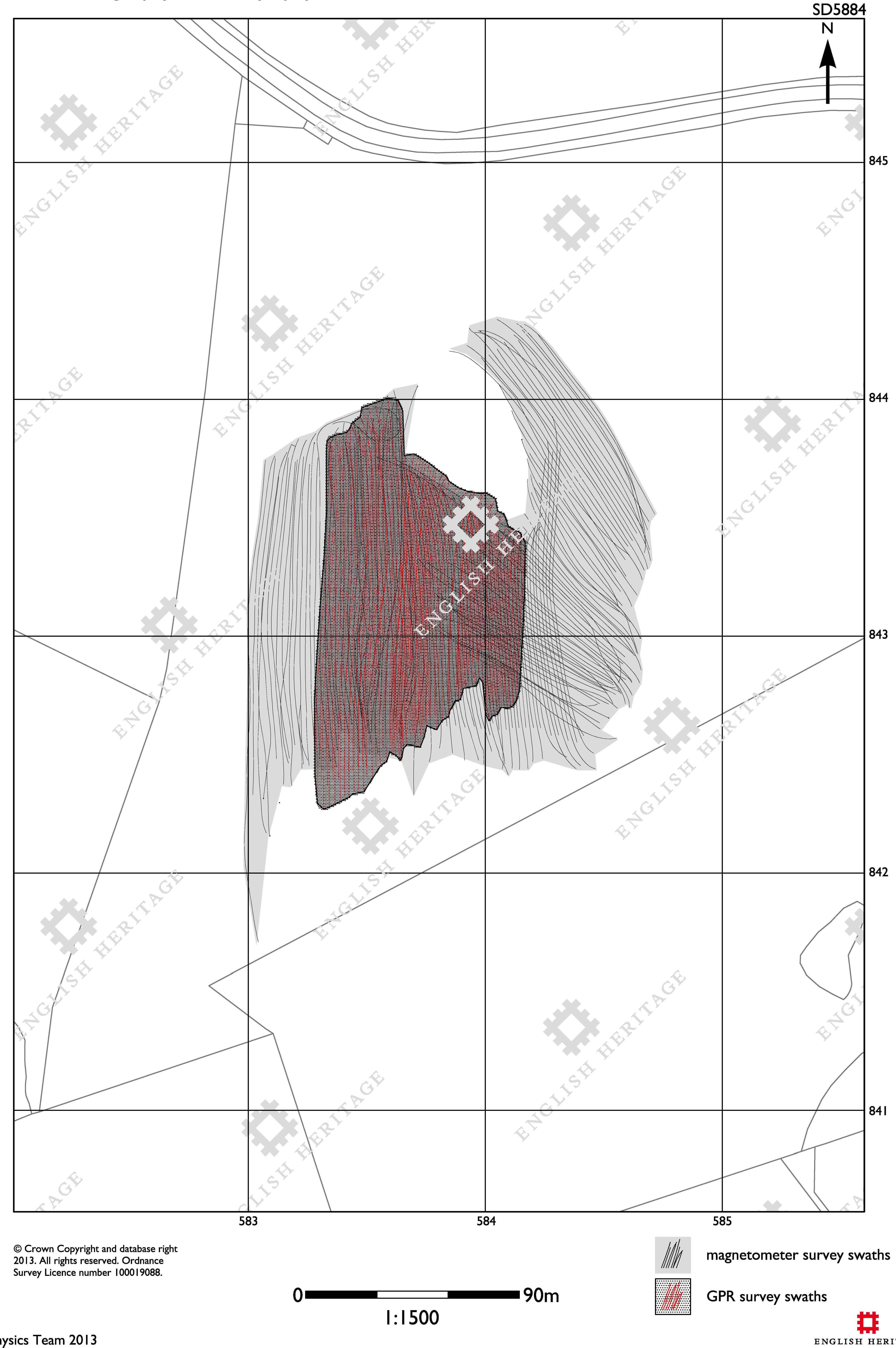

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Figure 3

LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA

Location of caesium magnetometer survey, July 2013

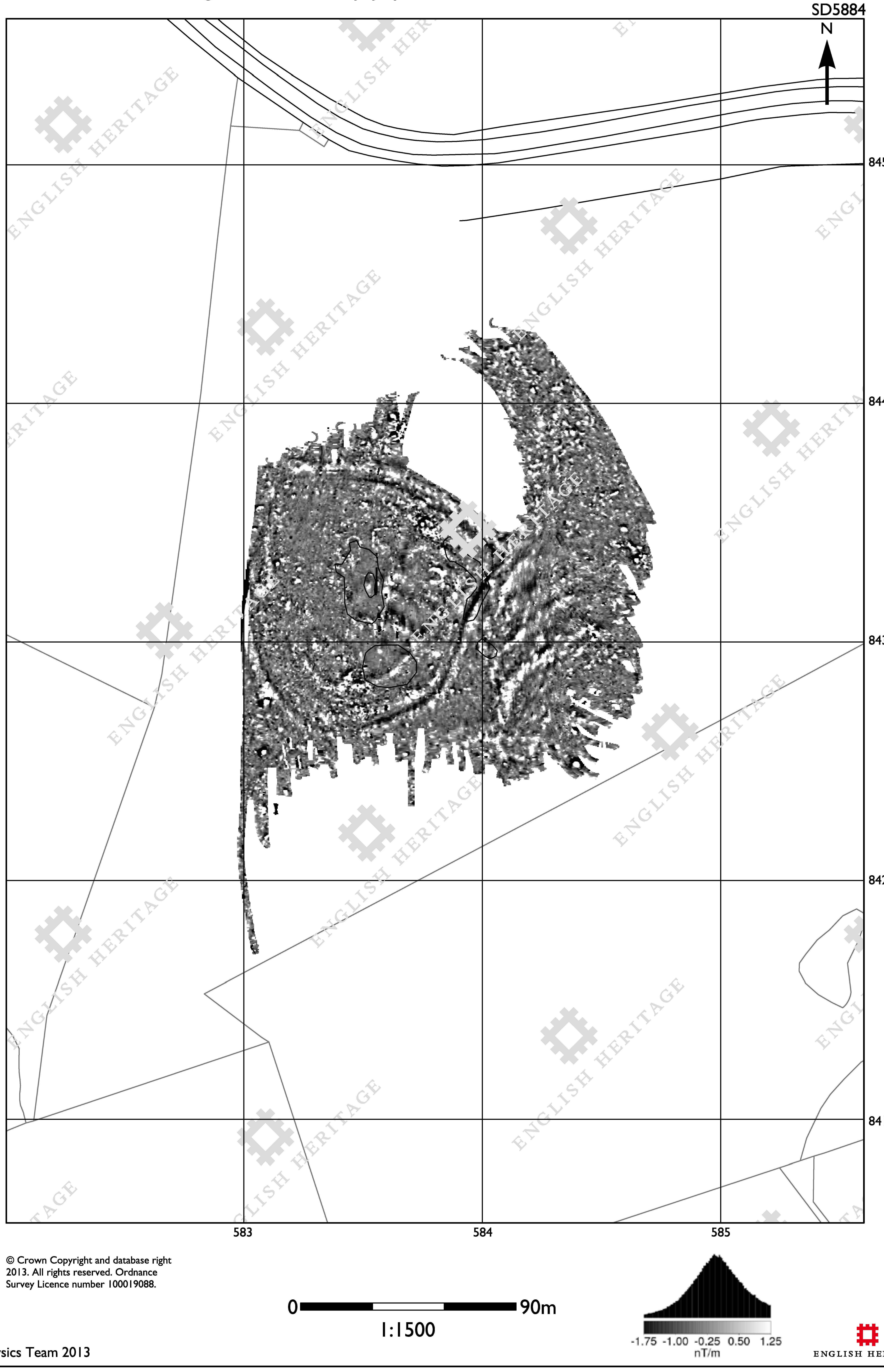

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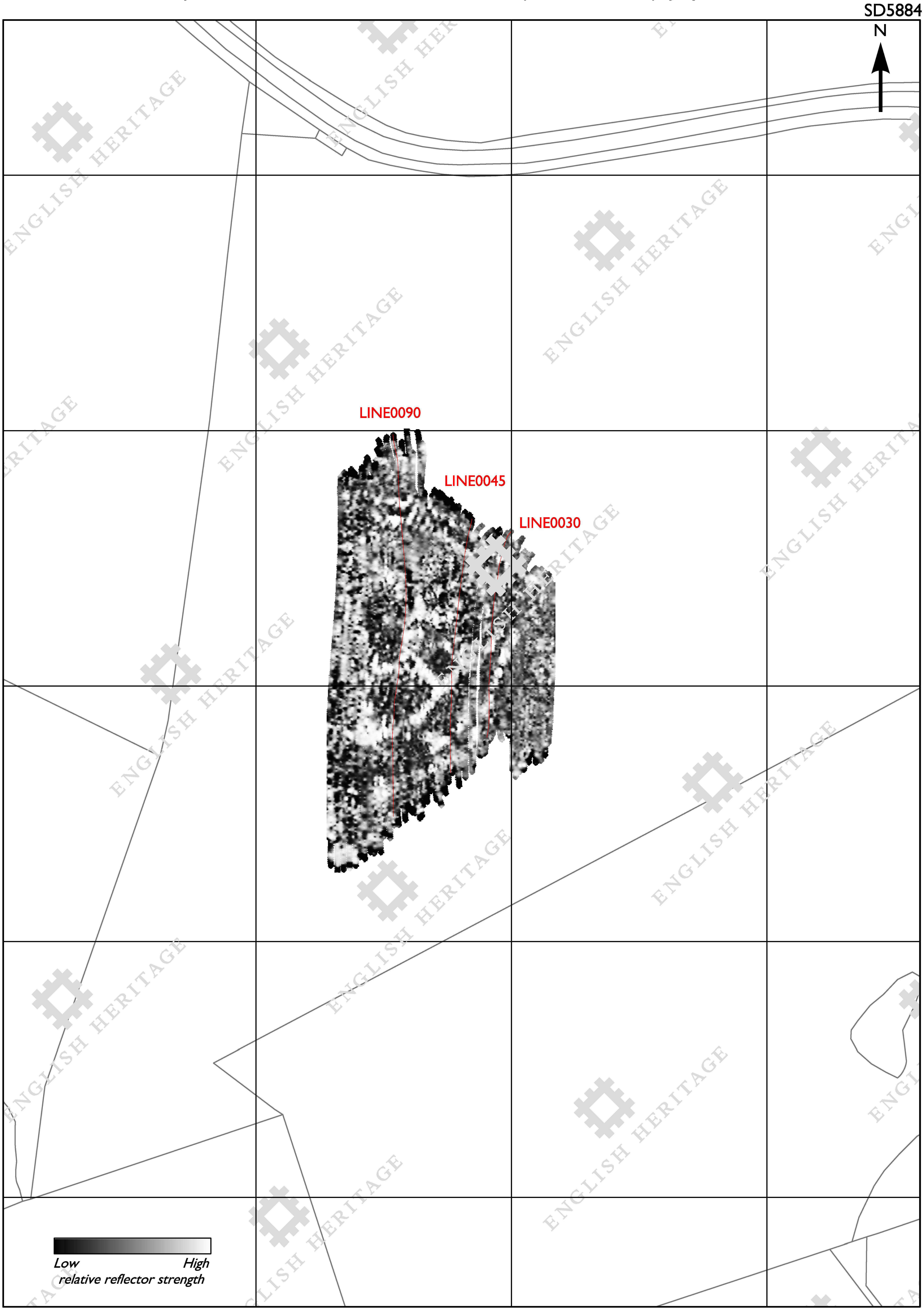
Figure 4

LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA

Location of GPR amplitude time slice between 6 and 8ns (0.18 to 0.24m), July 2013



0 90m

1:1500

location of GPR profile shown on Figures 7, 8 and 9

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Figure 5

LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA
Caesium magnetometer survey, July 2013

Traceplot of minimally processed data

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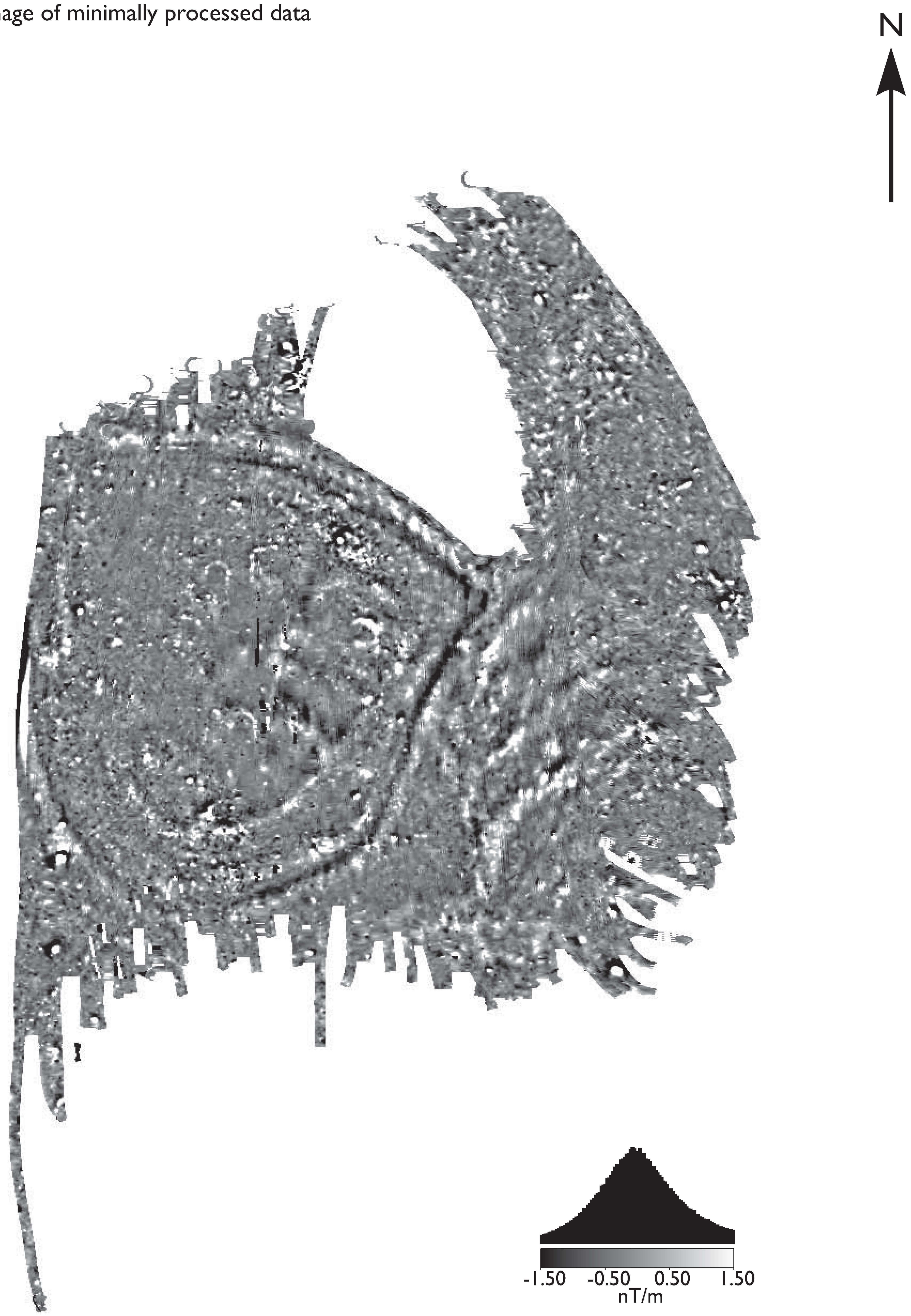
Figure 6

LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA
Caesium magnetometer survey, July 2013

Linear greyscale image of minimally processed data



0 60m
1:1000

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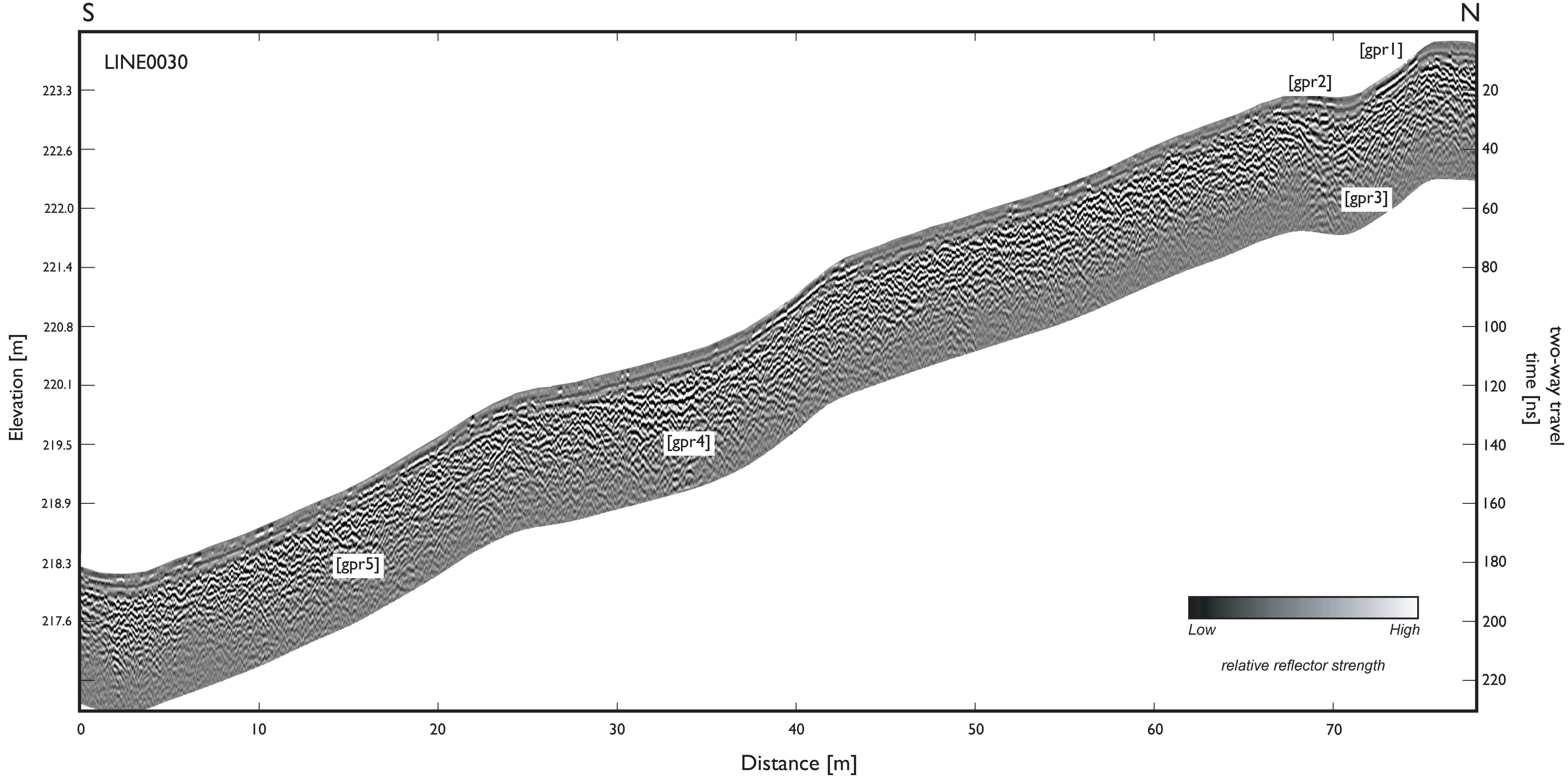
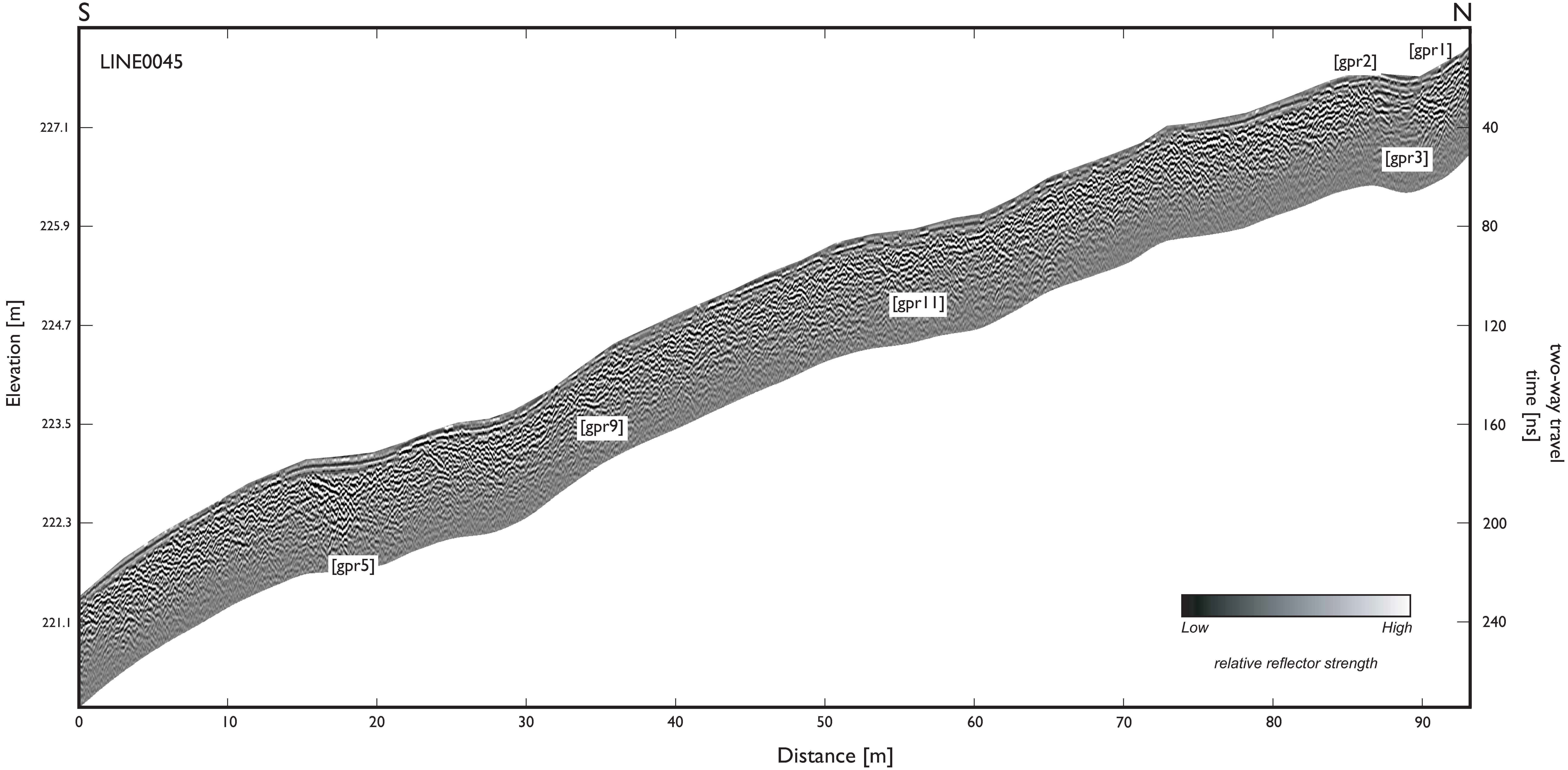
LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA
Selected GPR profile, July 2013

Figure 7



LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA
Selected GPR profile, July 2013

Figure 8



LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA

Selected GPR profile, July 2013

Figure 9

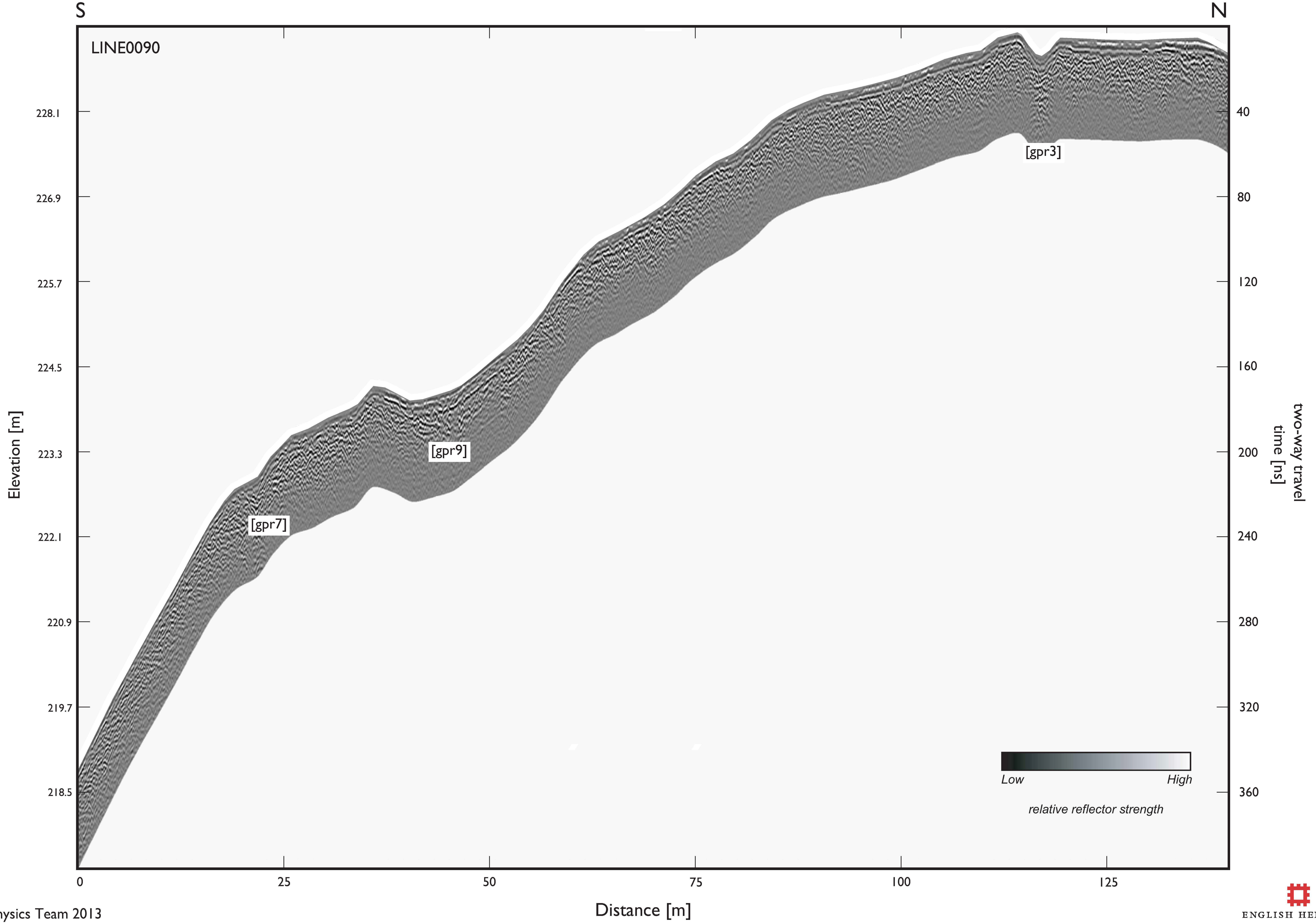


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Figure 10

LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA
GPR amplitude time slices from between 0.0 and 42ns (0 - 1.26m), July 2013

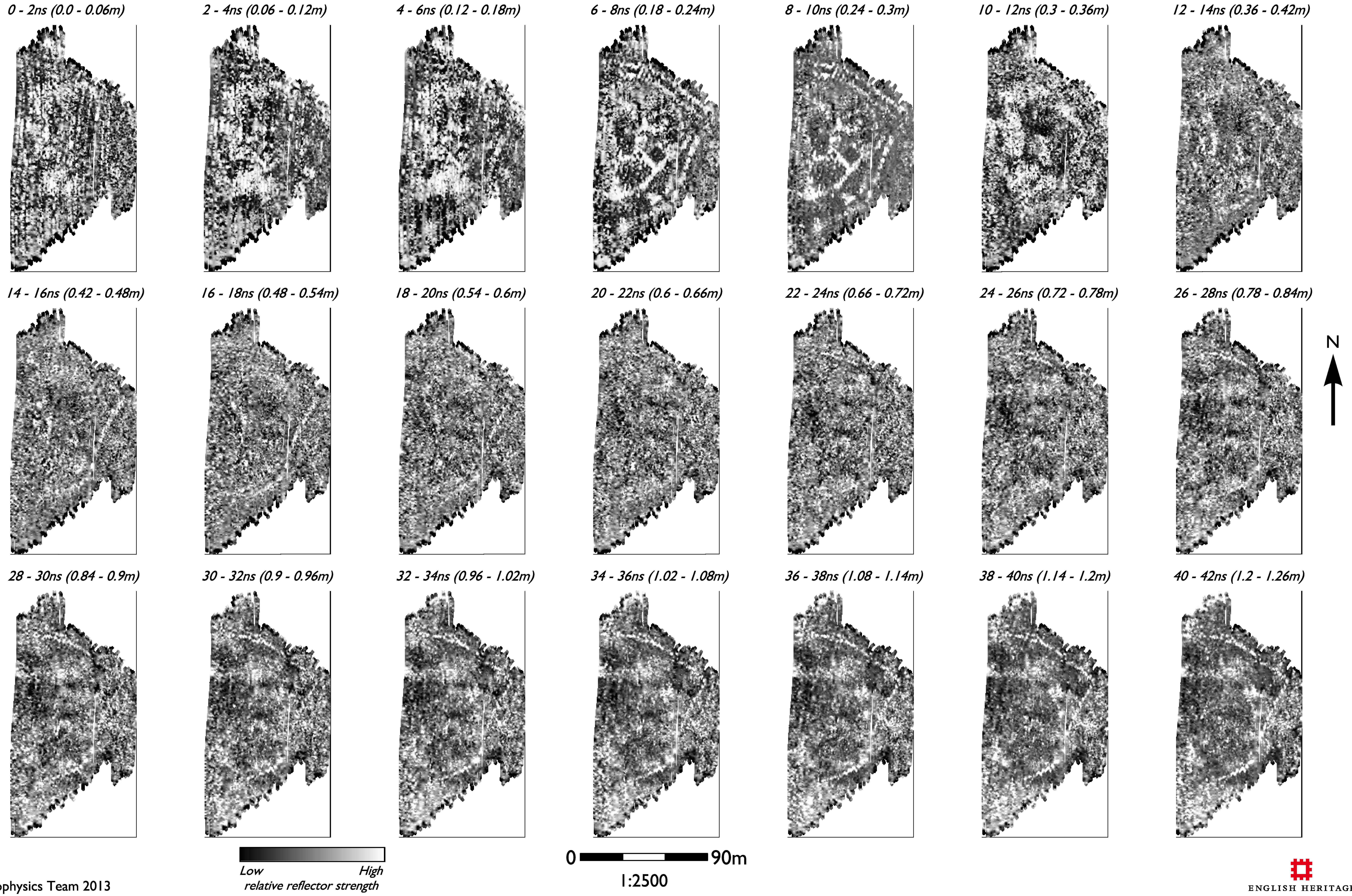
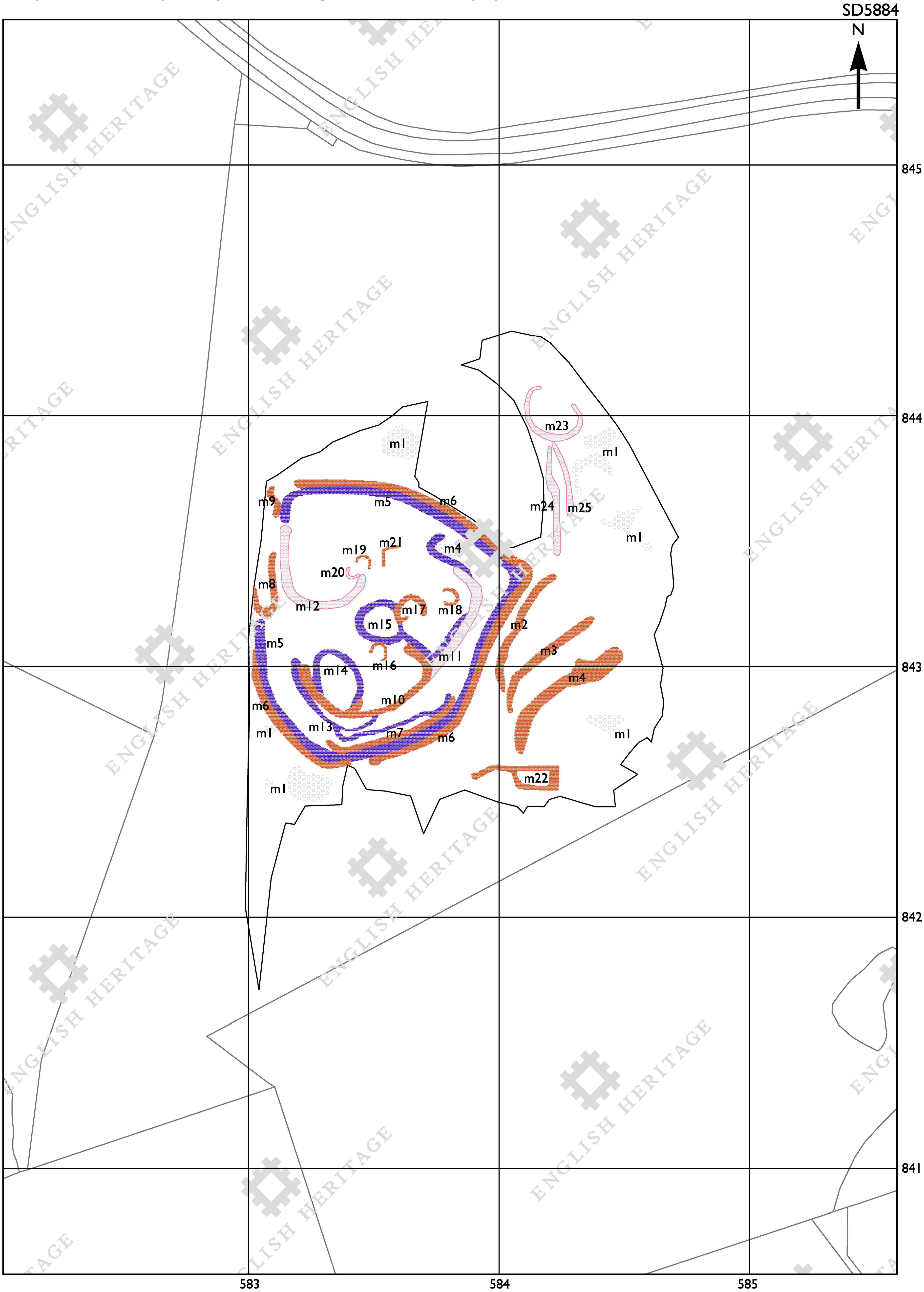


Figure 11

LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA

Graphical summary of significant magnetic anomalies, July 2013



positive magnetic | negative magnetic
weakly magnetic | magnetic noise

0 — 90m

1:1500

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Figure 12

LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA

Graphical summary of significant GPR anomalies

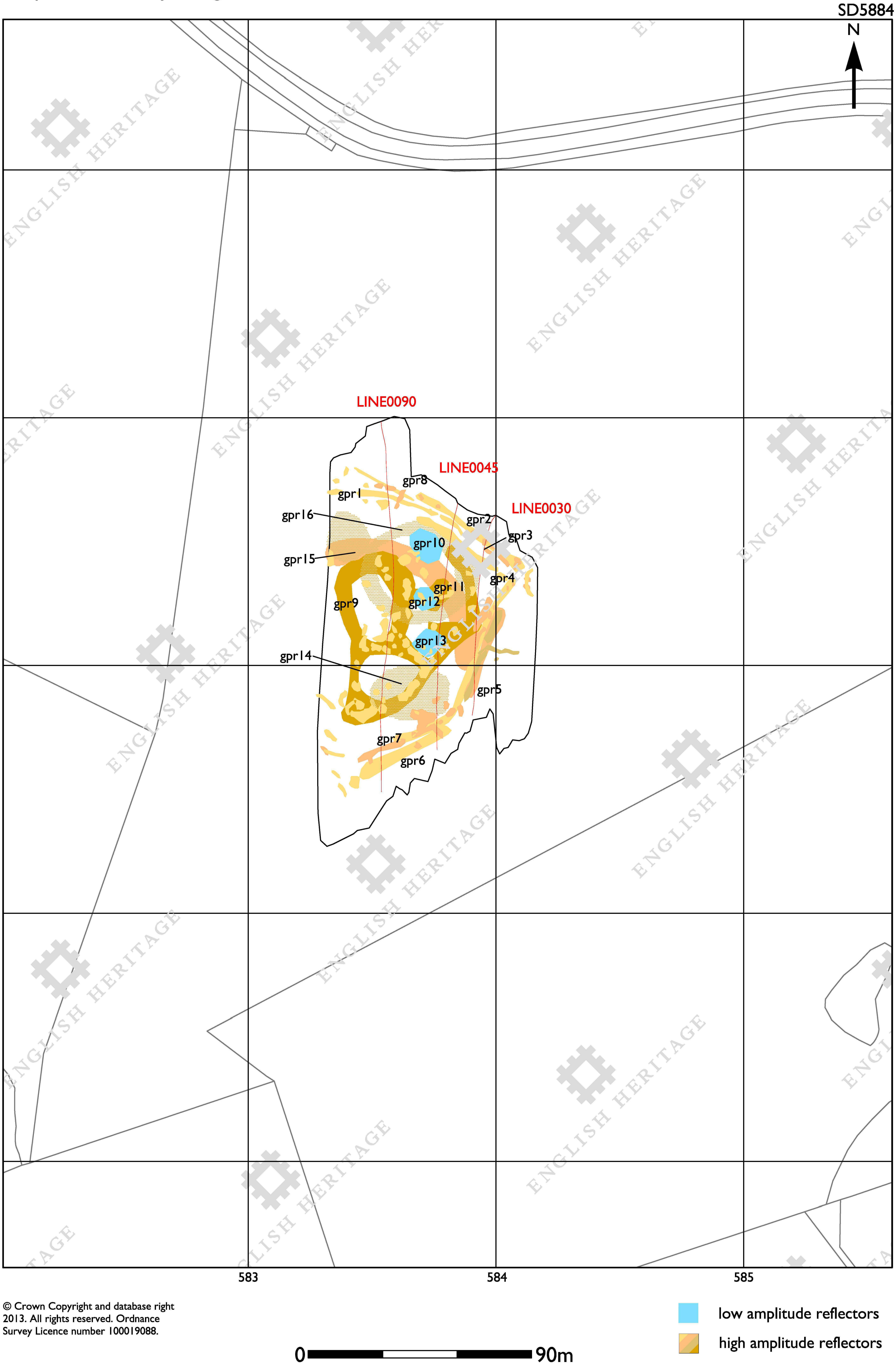

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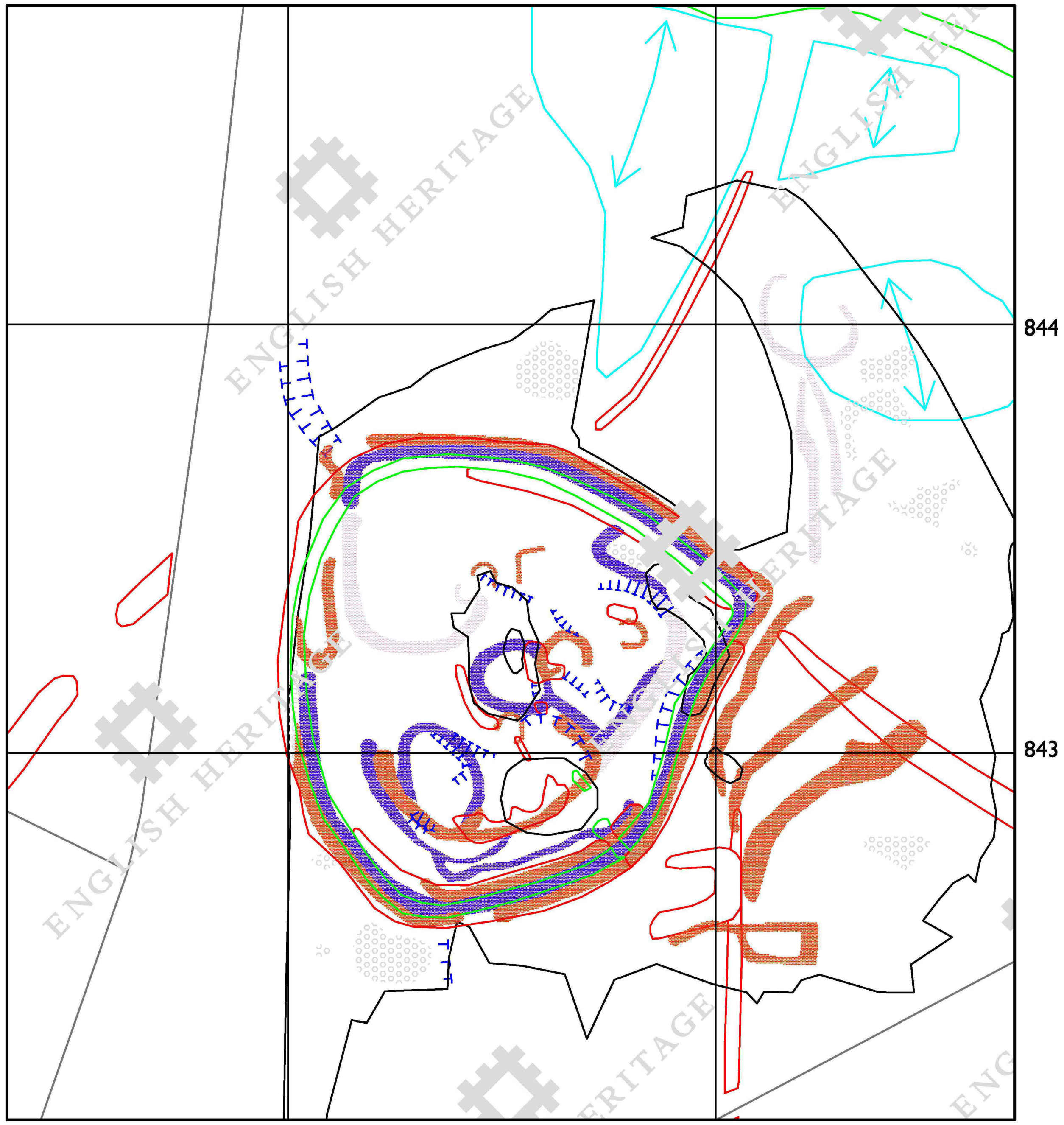
Figure 13

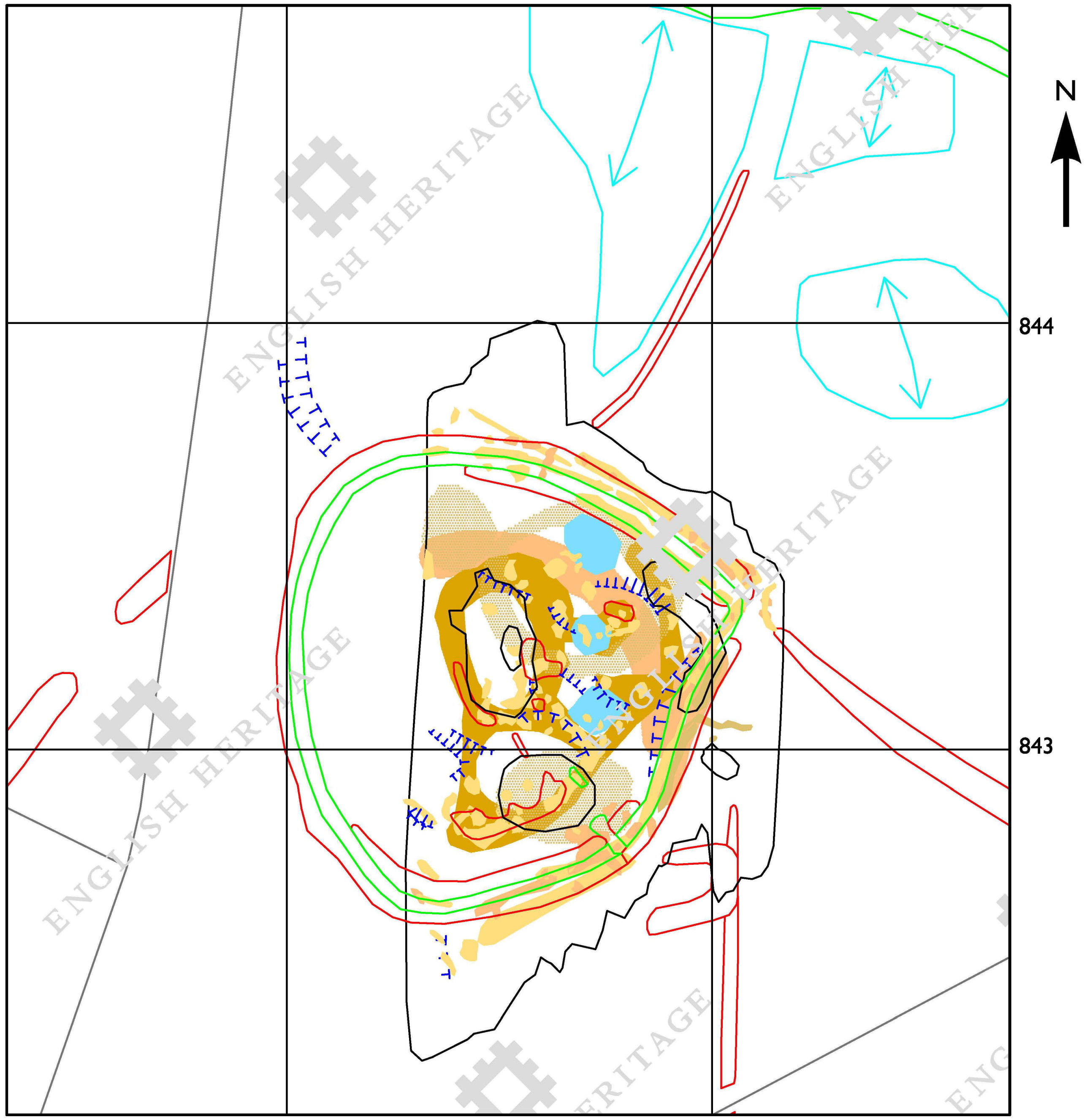
LAKES AND DALES NAIS, KITRIDDING HILL, LUPTON, CUMBRIA

Comparison between the geophysical anomalies and aerial mapping evidence

(A) Significant magnetic anomalies



(B) Significant GPR anomalies



aerial mapping evidence

- rig and furrow area / alignment
- bank
- scarp
- ditch

0 90m

1:1500

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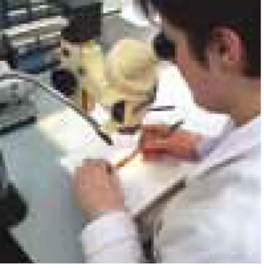
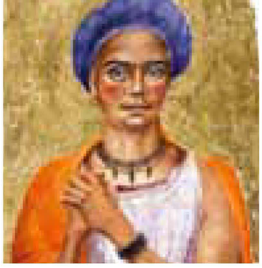

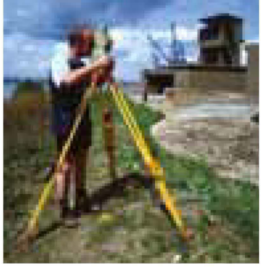
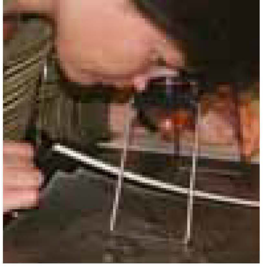


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