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# White Hill, Brandon, Suffolk

## Report on Geophysical Surveys, May 2024

Megan Clements, Neil Linford, Paul Linford, Andrew Payne and Nathalie Barrett

Geophysics

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# Summary

An earth resistance (0.54ha) survey, four Ground Penetrating Radar (GPR) and three Electrical Resistance Tomography (ERT) profiles were conducted over the monument known as White Hill in the Thetford Forest, Brandon, Suffolk, following a request from the Historic England East of England Regional Team. The surveys aimed to enhance the understanding of the monument, enabling it to be better placed in its historical landscape context and to contribute to the development of management solutions for its preservation. The geophysical results suggest the underlying monument at White Hill has a more diamond-like form, and a clear distinction between the mound, berm and the surrounding ditch can be seen on the north-eastern side of the monument. Other anomalies of possible archaeological or natural origin have also been identified.

## Contributors

The geophysical fieldwork was conducted by Megan Clements, Neil Linford, Paul Linford, Andrew Payne and Nathalie Barrett.

## Acknowledgements

The authors are grateful for the help of the Forestry Commission for their permission and assistance in arranging access for the survey to take place. The cover image shows the view towards White Hill with the photo taken from the southern end of the ride through the Hill (photograph taken by Andrew Payne).

## Archive location

Historic England, Fort Cumberland, Fort Cumberland Road, Portsmouth, PO4 9LD.

## Date of survey/research/investigation

The surveys were conducted between the 15th and 17th May 2024. The report was completed on 5th July 2024.

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# Contents

# Introduction

Ground Penetrating Radar (GPR), earth resistance and Electrical Resistance Tomography (ERT) surveys were conducted at the site of a presumed barrow of exceptional size at White Hill, Thetford Forest, Brandon, Suffolk. Whilst the form of White Hill shares all the characteristics of other known bell barrows, its extraordinary size and location within the Brandon Park Estate has led to suggestions that it may have been enhanced as a prospect mound in the 19th century. A Forestry Commission ride was driven through the centre of the mound as Thetford Forest was developed and, given the sandy Breckland geology, the exposed edges of the ride have become significantly eroded exposing the upper part of the internal mound structure. The geophysical surveys of the barrow aimed to improve understanding of the monument, its place in the wider historic landscape and contribute to the development of management solutions for supporting the preservation of the monument.

The monument (NHLE:1017787) includes the bell barrow known as White Hill, which is situated in the north-west corner of Brandon Park. The barrow is visible as a large oval earthen mound, which stands to a height of ~3m. It measures ~75m by 57m, and is surrounded by a berm up to ~22m wide and a ditch. The ditch has become partly infilled but is marked by a hollow up to ~22m wide and ~1m deep. A forest ride crosses the barrow in a north-west to south-east direction and has cut into the mound to a depth of ~2m (Historic England 1998).

The underlying bedrock geology at the site consists of Holywell Nodular Chalk with superficial deposits of cover sand surrounding the barrow and to the north, with peat to the south (Geological Survey of Great Britain 2010; British Geological Survey 2024). Freely draining, slightly acidic and sandy soils of the Newport 4 association (551g) have developed over the site (Soil Survey of England and Wales 1983; Soilscapes 2024).

The edges of the barrow on either side of the Forestry Commission ride were significantly eroded to sand. The rest of the barrow and the surrounding survey area was covered by young trees, brambles, heather and long grass interrupting continuous coverage in parts of the earth resistance survey. The weather on the first two days of the survey began with light rain and became increasingly hot with clear skies, followed by rain throughout the last day of the survey.

# Method

## Ground Penetrating Radar

A 3d-Radar (Kontur) MkIV GeoScope Continuous Wave Step Frequency (CWSF) Ground Penetrating Radar (GPR) system was used to conduct the survey collecting data with a multi-element DXG1820 vehicle towed, ground coupled antenna array (Linford *et al.* 2010; Eide *et al.* 2018). A roving Trimble R8s Global Navigation Satellite System (GNSS) receiver was mounted on the GPR antenna array, that together with a second R8s base station was used to provide continuous positional control for the survey collected along the instrument swaths shown on Figure 1. The GNSS base station receiver was adjusted to the National Grid Transformation OSTN15 using the Trimble VRS Now Network RTK delivery service. This uses the Ordnance Survey's GNSS correction network (OSNet) and gives a stated accuracy of 0.01-0.015m per point with vertical accuracy being half as precise. Ordnance Datum Newlyn (ODN) was used for elevation data.

Data were acquired at a 0.075m x 0.075m sample interval across a continuous wave step frequency range from 40MHz to 2.99GHz in 2MHz increments using a dwell time of 2ms. A single antenna element was monitored continuously to ensure data quality during acquisition together with automated processing software to produce real time amplitude time slice representations of the data as each successive instrument swath was recorded in the field (Linford 2013).

Post-acquisition processing involved conversion of the raw data to time-domain profiles (through a time window of 0 to 75ns), 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 full GPR survey data set are shown on Figure 4. An average sub-surface velocity of 0.0786m/ns was assumed following constant velocity tests on the data and was used for the time to estimated depth conversion, including appropriate topographic and tilt angle corrections to account for topographic variation (Goodman *et al.* 2006). Further details of both the frequency and time domain algorithms developed for processing this data can be found in Sala and Linford (2012).

Due to the overgrown vegetation across the site it was only possible to collect GPR data along the ride passing through the centre of the barrow.

## Earth Resistance

Measurements were recorded over a series of 30m grids established with a Trimble R8s GNSS, Figure 1, using a Geoscan RM85 earth resistance meter, internal multiplexer, and a PA5 electrode frame in the Twin-Electrode configuration, to allow two separate surveys, with mobile electrode separations of 0.5m and 1.0m, to be collected simultaneously. The 0.5m mobile electrode separation coverage was designed to detect near-surface anomalies in the upper 0.5m of the subsurface whilst the 1.0m separation survey allowed anomalies to a depth of about 1-1.25m to be detected. For the 0.5m mobile electrode separation survey readings were taken at a density of 0.5m x 1.0m whilst for the 1.0m separation survey they were taken at a density of 1.0m x 1.0m.

It proved difficult to collect readings over the areas of extreme erosion on either side of the current footpath due to the high contact resistance of the eroded sandy soil. There were also multiple instances across the site where readings could not be taken due to the dense vegetation.

Extreme values caused by high contact resistance were suppressed using an adaptive thresholding median filter with radius 1m (Scollar *et al.* 1990). The results for the near-surface 0.5m mobile electrode separation survey are depicted as a linear greyscale image in Figure 2 superimposed on the base OS mapping data. Figure 5 shows the minimally processed data from both the 0.5m and 1.0m mobile electrode separation data, presented as trace plots, linear and histogram equalised greyscale images of the processed datasets following the application of extreme value noise reduction. The application of a Wallis contrast-enhancing filter has also been applied to both the 0.5m and 1.0m data sets with a radius of 3m and edge to background ratio of 0.5.

## Earth Resistance Tomography

Three ERT profiles were laid across the monument: WH01 and WH02, which measured 94m long and consisted of a line of 95 electrodes, and WH03, which measured 63m long and consisted of 64 electrodes. Each of the electrodes were spaced 1m apart. The profiles were located using a Trimble R8s Global Navigation Satellite System (GNSS) receiver adjusted to the National Grid Transformation OSTN15 using the Trimble VRS Now Network RTK delivery system. This uses the Ordnance Survey's GNSS correction network (OSNet) and gives a stated accuracy of 0.01-0.015m per point with vertical accuracy being half as precise. Ordnance Datum Newlyn (ODN) was used for elevation data. The profiles were located based on ground observations and to take cross-sectional profiles of the hill. Once each profile was established, the individual electrode positions and heights were recorded using the GNSS system. The location of the profiles superimposed onto base Ordinance Survey (OS) mapping is depicted in Figure 1.

Earth resistance measurements were made with a Campus Tigre multiplexed earth resistance meter controlled by ImagerPro2006 software running on a field laptop computer. The expanding Wenner alpha electrode configuration was employed owing to its high signal to noise ratio. Despite best efforts to reseat and dampen the soil around electrodes it was not possible to reduce all electrode contact resistances below the recommended 1500 Ω threshold owing to the high sand content of the soil. This has limited the depth of current penetration and thus the maximum depth imaged by the electrical section. It has also affected data quality and, even at shallower depths where readings were generally possible, several stations had to be excluded from the inversion where it was not possible to measure a non-zero resistance.

Data from the profiles were inverted to infer subsurface resistivity models using Geotomo Software's Res2dinv software (version 3.56.39), with the measurements of the electrode positions incorporated to allow topographic correction. Error estimation during the inversion used the robust inversion method (absolute errors or the L1 norm) which is more tolerant of discontinuities between adjacent cells and thus tends to resolve boundaries between layers more sharply than the standard least mean squares inversion. Colour images of the resistivity output model profiles are shown in Figure 3.

# Results

## Ground Penetrating Radar

Significant GPR anomalies, [**gpr1-11**] discussed in the following text, are shown annotated on Figure 4.

Significant reflections have been recorded throughout the 75ns two-way travel time although radio-frequency burst noise becomes more apparent beyond approximately 45ns, possibly due to the proximity of the site to the Lakenheath airbase ~2.5km to the south-west of the site.

The access across the in-filled ditch to the ride from the south-east is dominated by a high-amplitude response [**gpr1**], possibly due to made-ground reducing wear along the path. Two gently dipping horizons are also visible and may related to a tip layer of the made-ground in the near-surface [**gpr2**] and a deeper geological interface [**gpr3**]. A low-amplitude ditch-type response [**gpr4**] appears at ~45m along the profile and seems to suggest a 'V'-shaped profile approximately 12m wide and 2m deep that may represent an earlier phase of construction.

Immediately beyond [**gpr4**], the topography begins to rise over the central mound of the barrow. There is limited evidence for any internal detail within the mound beyond possible animal burrows or pit-type anomalies at [**gpr5**] and [**gpr6**], together with a horizontal layer [**gpr7**] found at an elevation of approximately 9.3m. It is possible that [**gpr7**] represents an original ground surface covered over by material forming the barrow mound. A sharply dipping interface [**gpr8**] is found to the north of the barrow mound that potentially suggests the edge face of the encircling low-amplitude ditch [**gpr9**]. The ditch [**gpr9**] to the north of the barrow is less well defined and may have been obscured by wind-blown cover sand deposits with a possible gently dipping near-surface [**gpr10**] and deeper [**gpr11**] facies evident in the data here.

## Earth Resistance

A graphical summary of significant earth resistance anomalies [**r1**-**11**] discussed in the following text superimposed on the base OS mapping data is provided in Figure 6.

The areas of very high resistance [**r1**] primarily correspond with the extreme erosion of the mound, becoming almost bare sand, on either side of the ride, although the central ride itself appears as a low resistance anomaly [**r2**], likely a paradoxical response due to a very thin layer of topsoil along the ride (Scollar *et al.* 1990). The form of the mound [**r3**] appears to be more diamond-like in shape indicated by a higher resistance area with relatively well-defined edges. The mound seems to plateau in the north-east, forming the berm [**r4**] and with a clear distinction in resistance between the two, with subtle variations in the resistance response within the berm. The same distinction in resistance between the mound and berm cannot be seen in the south-west. Within [**r4**] are three pit-type anomalies [**r5**] most clearly visible in the Wallis-filtered data set (Figure 5(D)). The anomalies may be remnants of former tree-root disturbance or animal burrows, however an origin of archaeological significance cannot be discounted.

A curvilinear [**r6**] and sub-circular area [**r7**] of very high resistance are found in the east and south-west of the mound, both most likely the result of erosion, although it is possible the anomalies are of archaeological significance. The surrounding ditch has also been identified in the north of the survey area as a linear, low resistance anomaly [**r8**]. To the south of the survey area a discrete low resistance anomaly [**r9**], is most likely associated with a depression, such as a pit or old tree hole. Within the vicinity of [**r9**] is a linear low resistance anomaly [**r10**], which may represent a former cut-ditch, and a high resistance slightly curved response [**r11**] could be an area of geological variation. However, given the position of [**r10**] and [**r11**] towards the edge of the survey area, these interpretations are tentative.

## Earth Resistance Tomography

Significant ERT anomalies [**ert1**-**6**] discussed in the following text are shown annotated on Figure 3.

The sandy high resistance core of the barrow [**ert1**] has been detected as being just below the surface layer of the current ground level, with the material of the mound being ~2-3m thick and lying above the chalk bedrock [**ert2**]. The same material has been used to construct the berm [**ert3**], however it appears to be slightly less resistive than the central core mound. A possible rising outer-bank [**ert4**] has also been identified and has a similar magnitude of response to the mound and berm. The surrounding ditch [**ert5**] has also been identified and from the two profiles that cross the full width of the ditch, ERT_WH01 and ERT_WH03, the ditch appears to be ~5m in width.

From observing all three profiles, it appears the monument has an asymmetrical diamond form. The berm along ERT_WH01 and ERT_WH02 is smaller than the one identified along ERT_WH03 and the slope of the mound is much more pronounced along ERT_WH03. In addition, the slope is gentler, with the berm shorter in the south-west than the north-east in ERT_WH02. It is possible the monument may have undergone a process of re-shaping. This could have occurred through anthropogenic activities or natural erosion and re-deposition of wind-blown deposits.

Within ERT_WH02 is a well-defined, very high-resistance anomaly [**ert6**] that contrasts with the immediate surroundings within the slope of the mound. It is difficult to determine an exact origin for [**ert6**] but it is possible that it could be of either archaeological significance or represent a tree stump.

From observing the ERT results, it is estimated that 4m of the monument remains between the current surface and the natural bedrock.

# Conclusions

The geophysical surveys, particularly the earth resistance coverage, suggest that the form of White Hill is of an asymmetrical diamond shape that is partially obscured within the current topographic expression. While the monument as a whole appears to take on a diamond-like rather than rounded form, the north-eastern half seems to have more clearly defined edges, while the changes between the barrow features are less distinct in the south-west. It is not possible from the geophysical results to determine if these differences are associated with the original construction of the mound, later anthropogenic interference or natural landscape changes. The berm, surrounding ditch, and outer-bank have been identified, along with several anomalies of possible archaeological or natural origin.

# List of Enclosed Figures

# References


British Geological Survey 2024. "Brandon, West Suffolk, England." British Geology Viewer. Retrieved 27/02/2024, from https://geologyviewer.bgs.ac.uk/.

Eide, E, Linford, N, Persico, R and Sala, J 2018 'Advanced SFCW GPR systems' *in* Persico, R, Piro, S and Linford, N (eds), *Innovation in Near-Surface Geophysics Instrumentation, Application, and Data Processing Methods* Amsterdam: Elsevier, 253-285.

Geological Survey of Great Britain 2010 Thetford, Geological Survey of England and Wales, Sheet 174. Solid and Drift Edition Drift. Notthingham, The Director General of the Ordnance Survey.

Goodman, D, Nishimura, Y, Hongo, H and Higashi, N 2006 'Correcting for topography and the tilt of ground-penetrating radar antennae'. *Archaeological Prospection*, **13** (2), 157-161.

Historic England 1998. "Bell barrow known as White Hill." National Heritage List for England. Retrieved 27/02/2024, from https://historicengland.org.uk/listing/the-list/list-entry/1017787.

Linford, N 2013. *Rapid processing of GPR time slices for data visualisation during field acquisition*. In Neubauer, W, Trinks, I, Salisbury, R and Einwogerer, C (Editors), Archaeological Prospection, Proceedings of the 10th International Conference, May 29th - June 2nd 2013 2013 (Vienna: Austrian Academy of Sciences Press). 176-78.

Linford, N, Linford, P, Martin, L and Payne, A 2010 'Stepped-frequency GPR survey with a multi-element array antenna: Results from field application on archaeological sites'. *Archaeological Prospection*, **17** (3), 187-198.

Sala, J and Linford, N 2012 'Processing stepped frequency continuous wave GPR systems to obtain maximum value from archaeological data sets '. *Near Surface Geophysics*, **10** (1), 3-10.

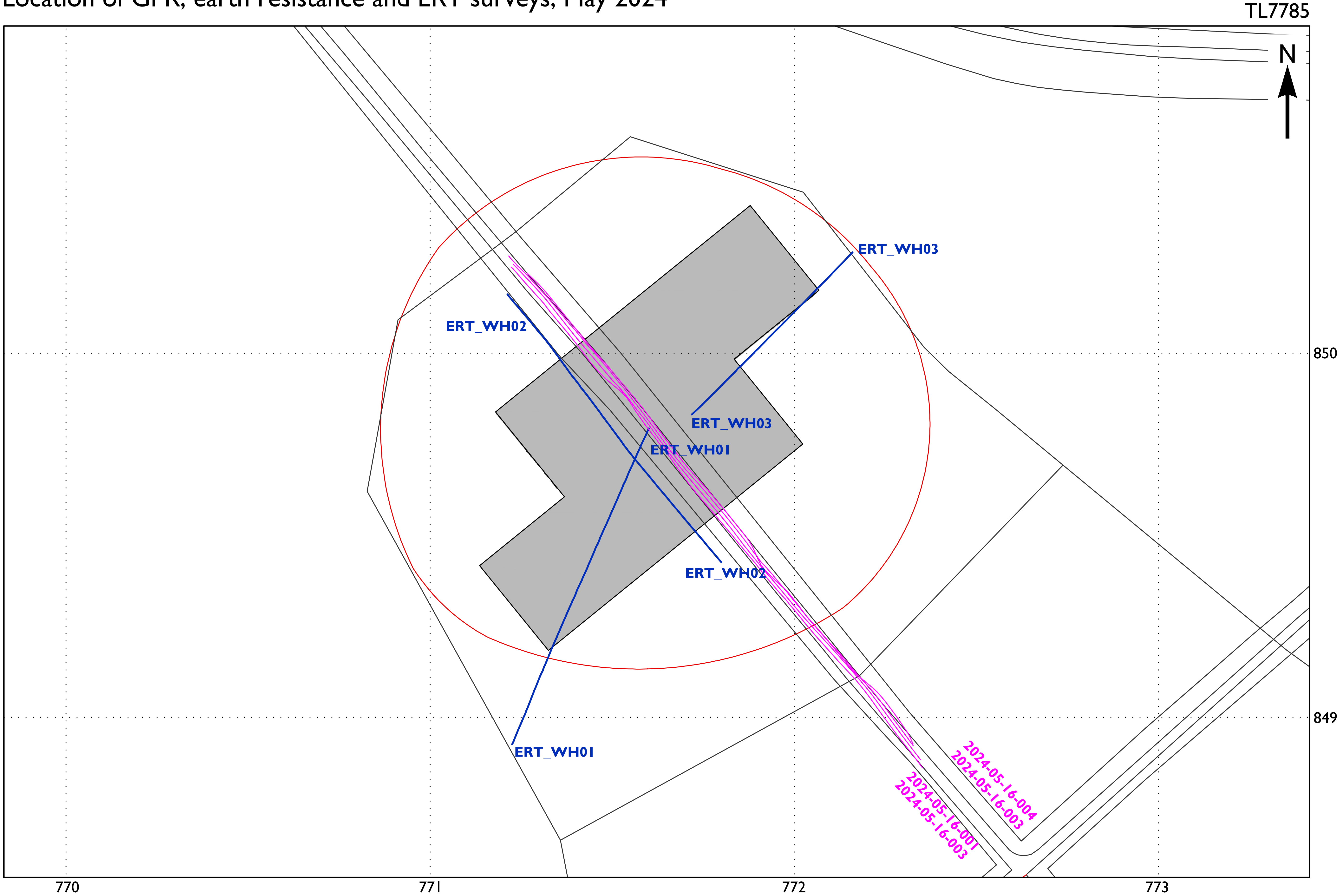
Scollar, I, Tabbagh, A, Hesse, A and Herzog, I 1990 *Archaeological Prospecting and Remote Sensing*. Topics in Remote Sensing. Cambridge, Cambridge University Press.

Soil Survey of England and Wales 1983 Soils of England and Wales, Sheet 4 - Eastern England, 1:250,000 scale soil map, Lawes Agricultural Trust, Harpenden.

Soilscapes 2024. "Brandon, IP27, Suffolk, Eastern England." Retrieved 27/02/2024, from https://www.landis.org.uk/soilscapes/.

Figure 1

# WHITE HILL, BRANDON, SUFFOLK
## Location of GPR, earth resistance and ERT surveys, May 2024






0 90m
1:1000

extent of scheduled monument
extent of earth resistance survey
location of GPR profiles shown on Figure 4
line of ERT traverses

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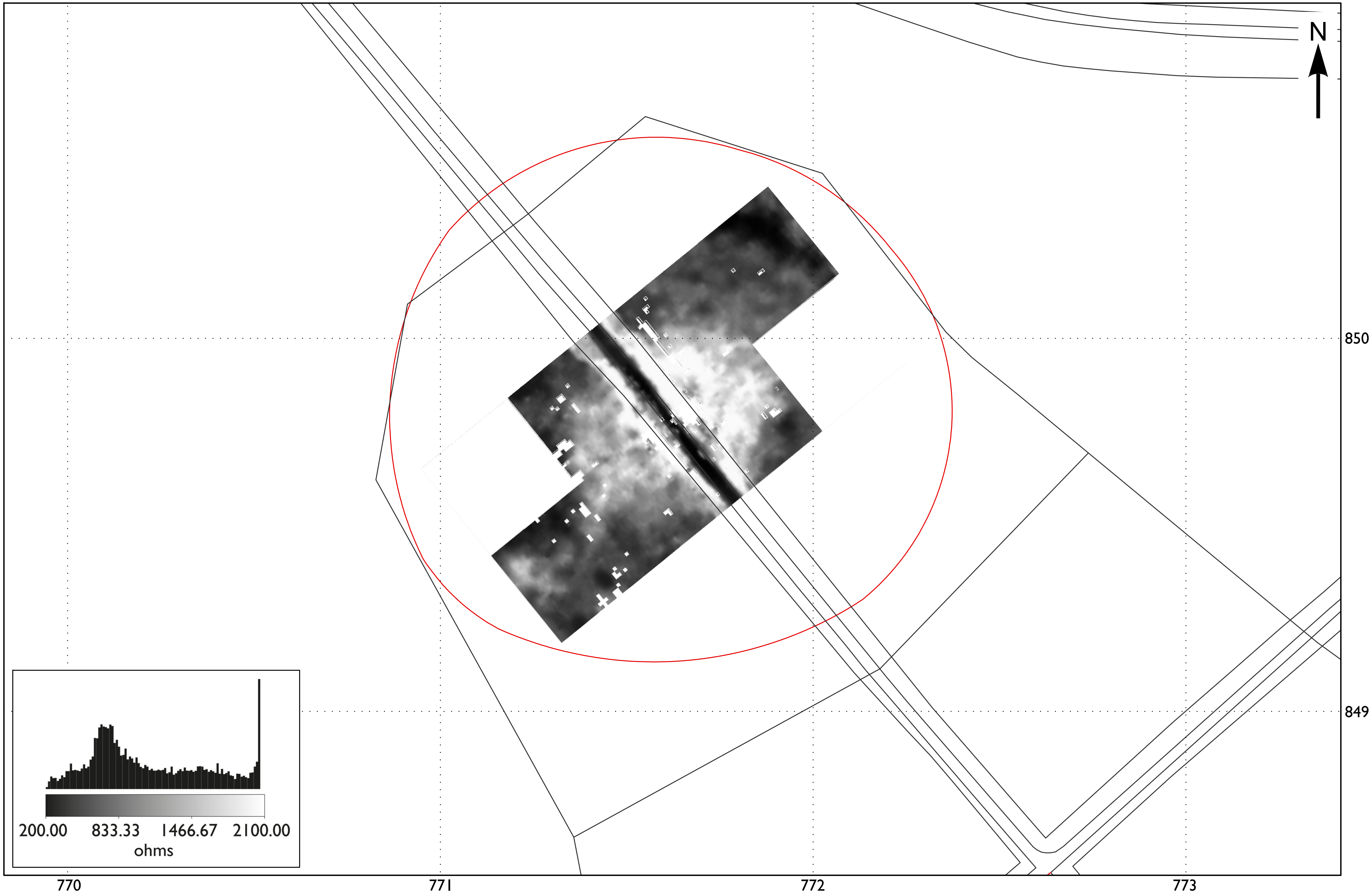
Figure 2

# WHITE HILL, BRANDON, SUFFOLK

Linear greyscale image of 0.5m mobile electrode separation earth resistance survey, May 2024






0 90m

1:1000

extent of scheduled monument

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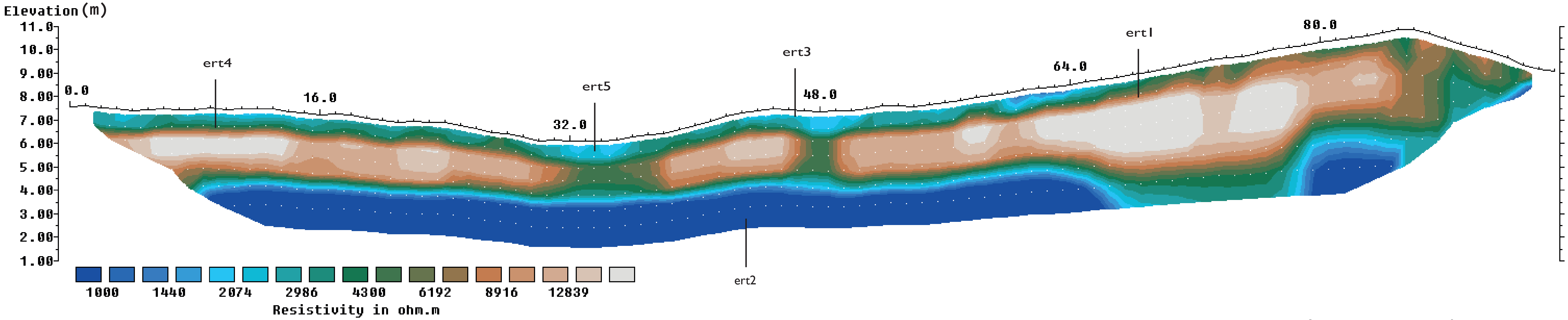
# WHITE HILL, BRANDON, SUFFOLK

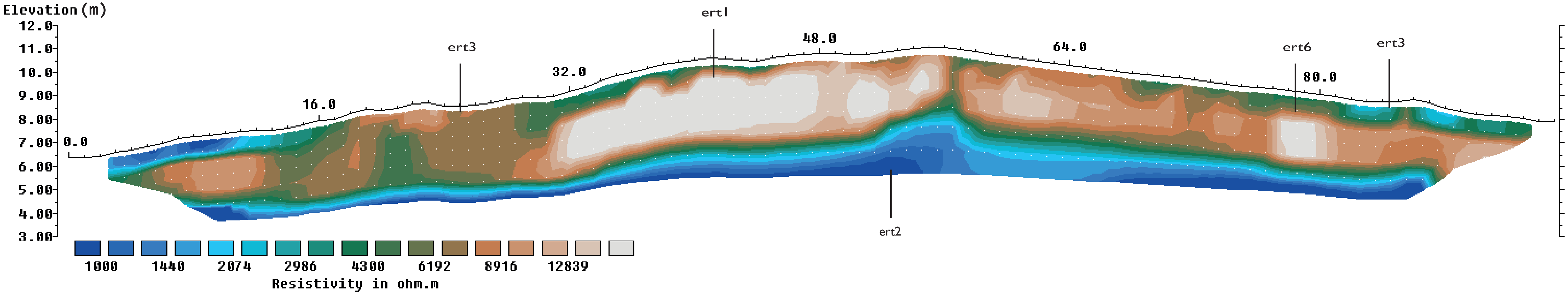
Figure 3

## Colour-scale images of ERT output resistivity model profiles, May 2024 (vertical exaggeration x1.5)

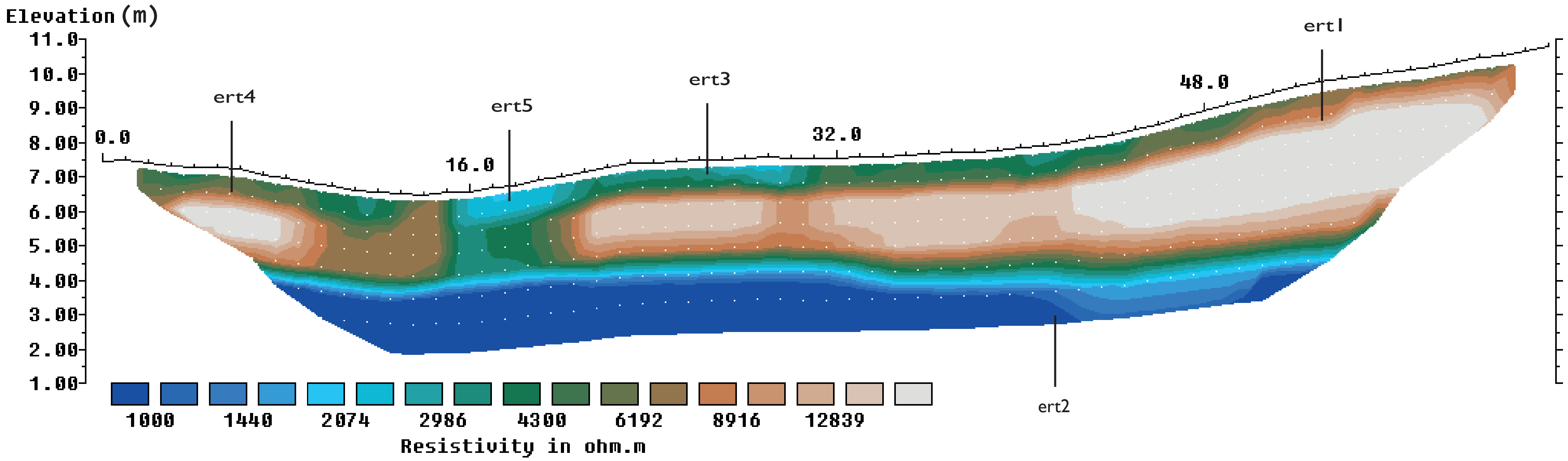
(A) ERT_WH01: 96m long SW to NE section annotated with significant anomalies ert1-5 (absolute error between model and field measurements = 1.6%)

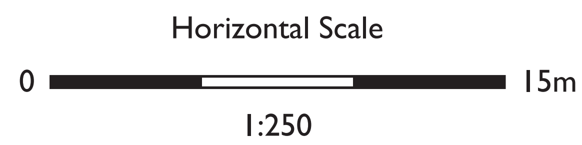



(B) ERT_WH02: 96m long N to S section annotated with significant anomalies ert1-6 (absolute error between model and field measurements = 1.5%)




(C) ERT_WH03: 64m long E to W section annotated with significant anomalies ert1-5 (absolute error between model and field measurements = 1.8%)

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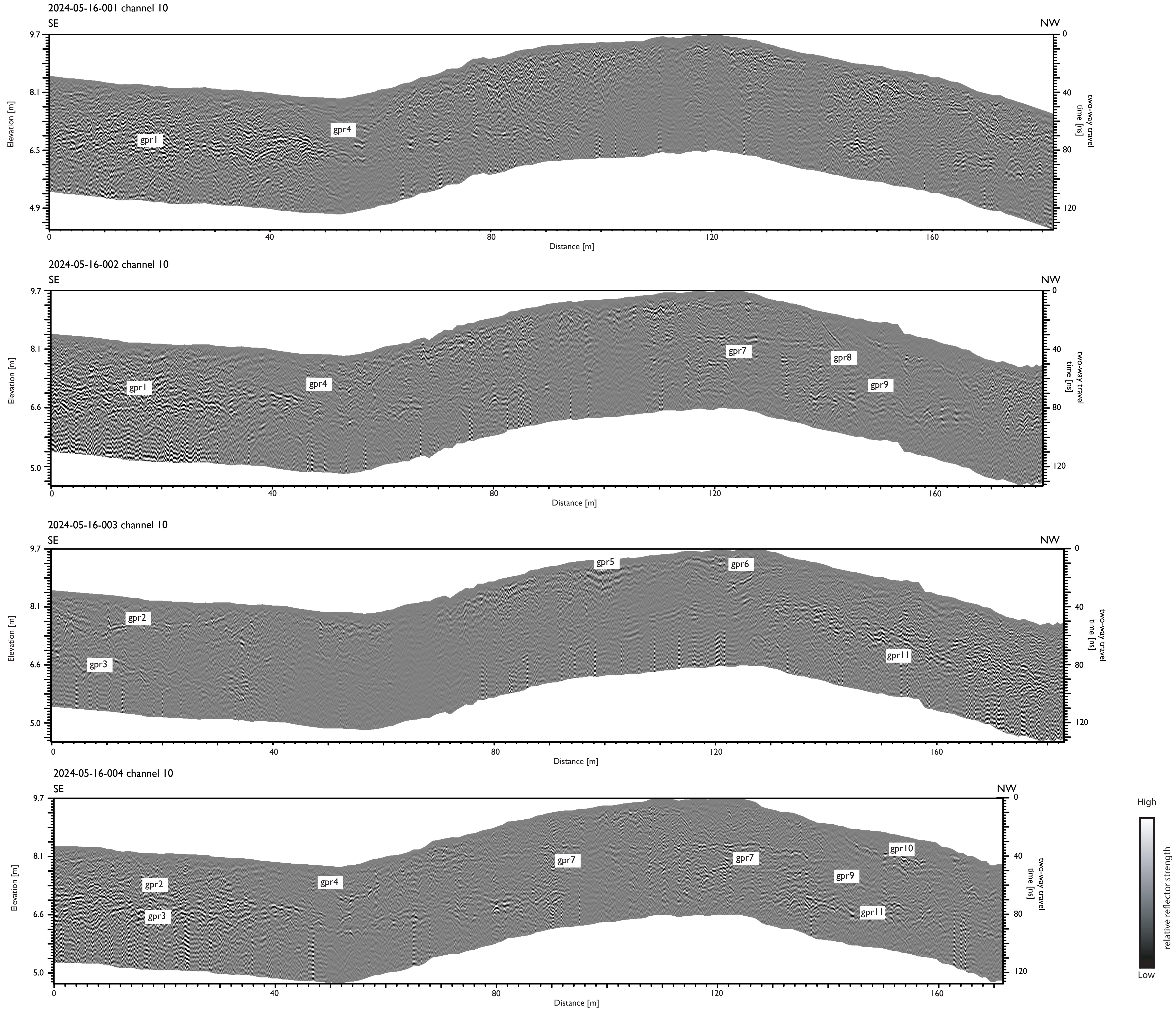
WHITE HILL, BRANDON, SUFFOLK

Representative topographically corrected GPR profiles, May 2024

Figure 4

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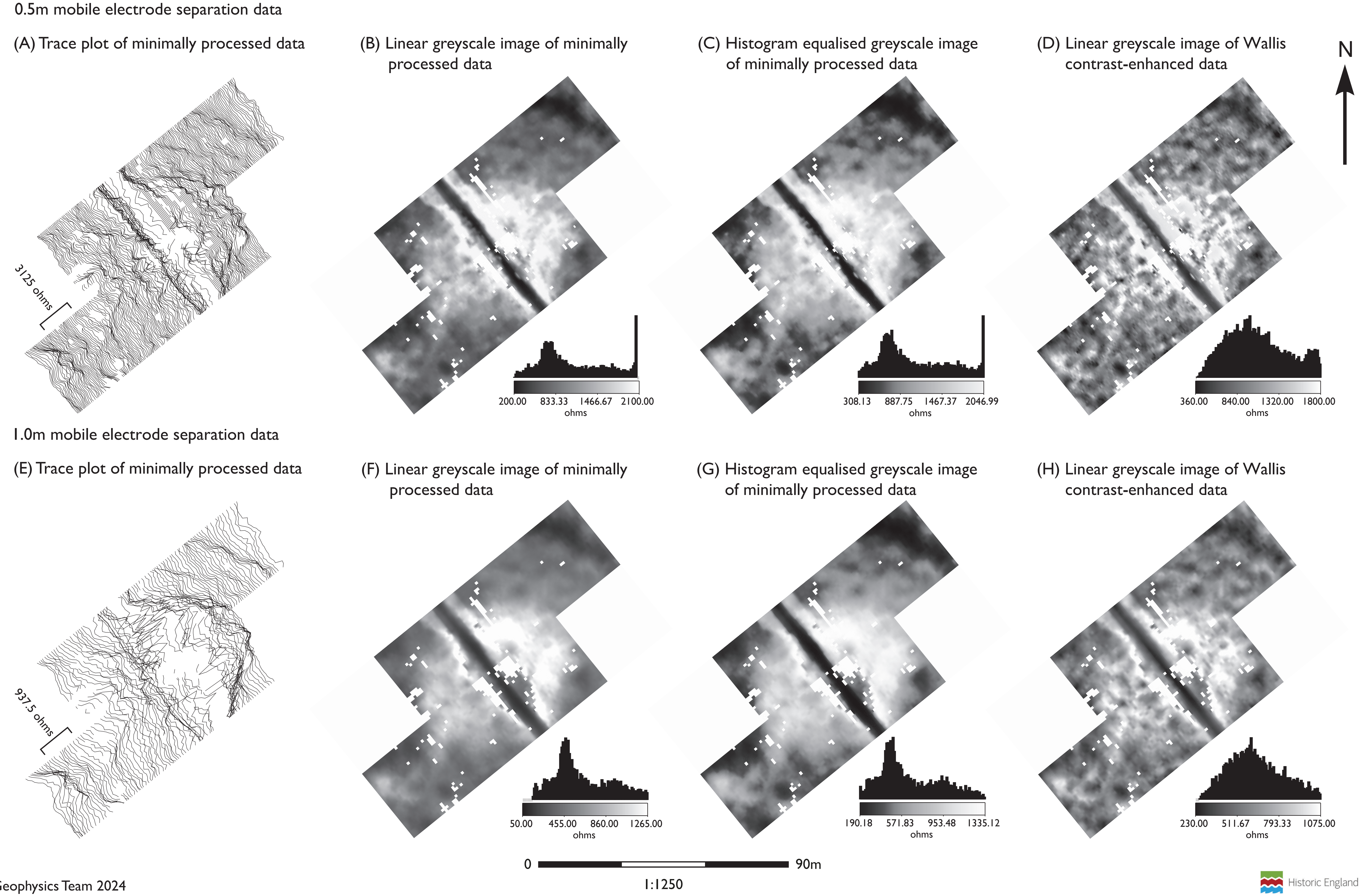
# WHITE HILL, BRANDON, SUFFOLK
## Earth resistance survey, May 2024

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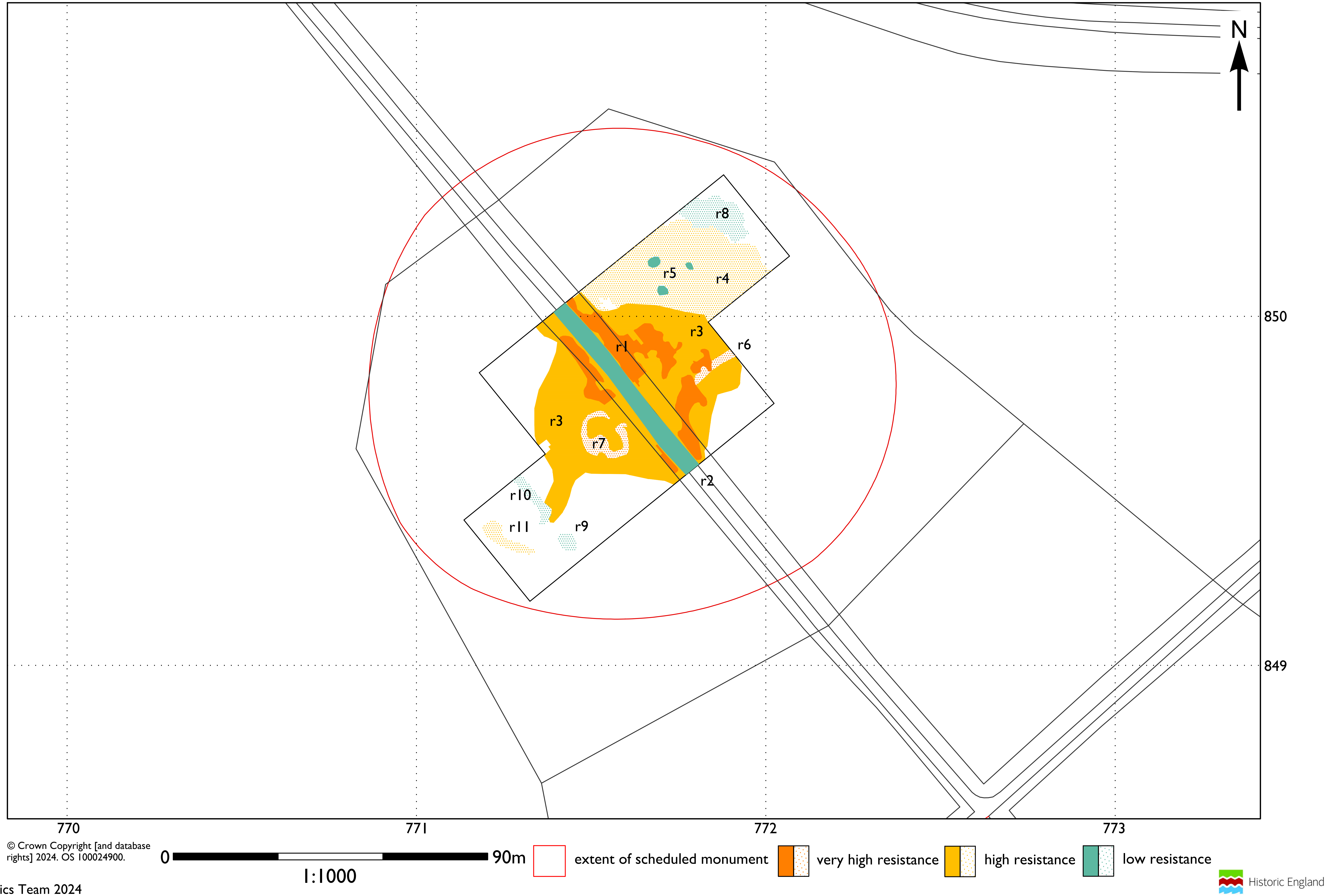
# WHITE HILL, BRANDON, SUFFOLK

## Graphical summary of significant earth resistance anomalies, May 2024



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