Historic England

Remote Sensing

Marble Hill Park, Twickenham, London Report on Geophysical Surveys, December 2015 and February 2016

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Discovery, Innovation and Science in the Historic Environment

Research Report Series no. 19-2016

MARBLE HILL PARK, TWICKENHAM, LONDON

REPORT ON GEOPHYSICAL SURVEYS, DECEMBER 2015 AND FEBRUARY 2016

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NGR: TQ 173 736

ISSN 2059-4453 (Online)

SUMMARY

Caesium magnetometer, earth resistance and Ground Penetrating Radar (GPR) surveys were conducted at Marble Hill Park, Twickenham, London, as part of a Shared Services Agreement project initiated by the English Heritage Trust to improve understanding of its landscape history in support of a Heritage Lottery Fund bid to develop facilities at the site. The surveys covered all accessible parts of the ~27 hectare site with GPR concentrated on the open areas and earth resistance survey focusing on areas planted with trees around the perimeter. Evidence for past use of the landscape has been detected ranging from relics of the eighteenth century designed landscape through to 20th century development of the site. The geophysical evidence appears to correlate with evidence from other forms of landscape investigation but additional work will be required to determine the nature of many of the anomalies detected.

CONTRIBUTORS
The geophysical fieldwork was conducted by Neil Linford, Paul Linford, Andrew Payne and Cara Pearce.

ACKNOWLEDGEMENTS
The authors are grateful to all the English Heritage Trust staff at Marble Hill House who made us welcome during our visits and assisted with queries and logistical arrangements, in particular Jennifer Rimmer, Andrea Arthan, Brian Clark and Gary Kielty. We are also grateful to Dave Moss the head gardener for sharing his extensive knowledge of the site which helped target areas for survey and the Coach House Café for excellent on-site sustenance during the winter weather.

ARCHIVE LOCATION
Fort Cumberland, Portsmouth.

DATE OF SURVEY
The fieldwork was conducted between 7th to 11th December 2015 and 1st to 5th February 2016 and the report completed on 21st April 2016. The cover image shows GPR survey in progress over the north lawn looking south towards Marble Hill House in the background.

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CONTENTS

INTRODUCTION

Geophysical surveys were carried out in the parkland surrounding Marble Hill House (NGR TQ 17300 73626; Richmond Road, Twickenham, London, TW1 2NL) as part of a project initiated by the English Heritage Trust (EHT) under its Shared Services Agreement with Historic England (RASMIS project number 7382, Twickenham Museum 2001; Linford and Payne 2011; Alexander 2015). The landscape park (AMIE Monument HOB UID 1142371/NRHE Number TQ 17 SE89) formed the pleasure grounds and gardens to the house built for Henrietta Howard, covering an area of almost 27 hectares. Landscaping appears to have begun in 1724 at the same time as house construction and was initially led by Charles Bridgeman. Alexander Pope produced a planting scheme, although it is not clear how much of this was implemented. The grounds were later altered in 1786 for the Earl of Buckinghamshire and in 1850 by Jonathan Peel. They have been open to the public since 1903 after being brought into public ownership the previous year and both house and grounds passed into the care of English Heritage in 1986 (information from AMIE).

The site sits on London Clay, a Palaeogene Period sedimentary clay and silt formation. This is overlain by superficial deposits of Langley Silt (formerly Brickearth) over the northern parts of the park and to the south, where the grounds approach the bank of the Thames, by alluvium (Geological Survey of England and Wales 1972, 2016). Soils appear to vary with the superficial geology being well drained coarse loamy and some sandy soils of the Hucklesbrook association (571w) to the north and stoneless mainly calcareous clayey soils affected by groundwater of the Thames association (814a) to the south between the house and river (Soil Survey of England and Wales 1983). This combination of solid and superficial geologies would be expected to produce relatively weak magnetic contrasts but, depending on season and drainage, prospects for contrasts in earth resistance are better. In the past London Clay soils, particularly at wet times of year, have been found to rapidly attenuate GPR signal.

The only previous geophysical survey recorded in the park was by Northamptonshire Archaeology who surveyed two 30m square grids over the South Lawn using a fluxgate magnetometer as part of an investigation into the garden remains commissioned by English Heritage (Northamptonshire Archaeology 2004). Results were inconclusive lending weight to the inference that magnetometry may not be the best technique given the site geology.

The park is currently kept as short-mown grass used for sports pitches with trees planted around the perimeter screening it from neighbouring roads and properties. A Ground Penetrating Radar (GPR) survey of ~16.5 ha was carried out over all open areas and earth resistance survey (3.0 ha) was used over the terraced area immediately S of the house and to extend coverage into tree covered areas inaccessible to the GPR system. During the initial visit a caesium magnetometer survey of 3.5 ha was also carried out over the north lawn to test magnetic response at the site but it was concluded that GPR was providing greater resolution, despite waterlogged site conditions, so resource was concentrated on extending coverage with the latter technique. During both survey visits the weather was generally mild but overcast with some showers and occasional sunny intervals.

METHOD

Magnetometer survey

Magnetometer data was collected along the instrument swaths shown on Figure 2 using an array of six Geometrics G862 caesium vapour sensors mounted on a non-magnetic sledge (Linford *et al.* 2015). The sledge was towed behind a low-impact All-Terrain Vehicle (ATV) which housed the power supply and data logging electronics. Five sensors were mounted 0.5m apart in a linear array transverse to the direction of travel and, vertically, ~0.25m above the ground surface. The sixth was fixed 1.0m directly above the centre of this array to act as a gradient sensor. The sensors sampled at a rate of 25Hz resulting in an along-line sample density of ~0.15m given typical ATV travel speeds of 3.5-4.0m/s. As the five non-gradient sensors were 0.5m apart, successive survey swaths were separated by approximately 2.5m to maintain a consistent traverse separation of 0.5m. Navigation and positional control were achieved using a Trimble R8 Global Navigation Satellite System (GNSS) receiver mounted on the sensor platform 1.75m in front of the central sensor and a second R8 base station receiver established using the Ordnance Survey VRS Now correction service. Sensor output and survey location were continuously monitored during acquisition to ensure data quality and minimise the risk of gaps in the coverage.

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 or other nearby vehicles. The median value of each instrument traverse was then adjusted to zero by subtracting a running median value calculated over a 50m 1D window (see for instance Mauring *et al.* 2002). This operation corrects for 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 in Figure 3 and minimally processed versions of the range truncated data (± 100nT/m) are shown as a trace plot and a histogram equalised greyscale image in Figure 6.

Earth resistance survey

Three separate areas totalling ~3 ha were laid out for earth resistance survey using the Trimble R8 GNSS system previously described, two in parts of the site planted with trees and a third over the area immediately south of Marble Hill House (Areas 1-3 respectively in Figure 1). Measurements were recorded over a series of 30m grids using a Geoscan RM15 resistance meter; a PA5 electrode frame in the twin-electrode configuration; and an MPX15 multiplexer to allow two separate datasets, with electrode separations of 0.5m and 1.0m, to be collected simultaneously. The 0.5m electrode separation coverage was designed to detect near-surface anomalies in the upper 0.6m of the subsurface whilst the 1.0m separation survey allowed anomalies to a depth of about 1.0-1.5m to be detected. For the 0.5m electrode separation survey readings were taken at a density of 0.5m by 1.0m while for the 1.0m separation survey the density was 1.0m by 1.0m. The results of the 0.5m electrode separation surveys after processing are shown in Figure 4.

Extreme values caused by high contact resistance were removed from all datasets using an adaptive thresholding median filter (Scollar *et al.* 1990) with radius 1m. However, in area 3 telluric currents caused by a nearby electrical system seemed to have affected the 1m measurements so a second filter with a fixed threshold of 1 ohm and a filter radius of 2m was also used to remove negative spikes only. Where there was an overnight, or longer, gap between surveying adjacent grids, slight differences in mean background levels were observed caused by changes in soil moisture conditions. The base levels of affected grids were therefore adjusted using an automated method similar to that of Haigh (1991).

Trace plots of both the 0.5m and 1m separation surveys of Areas 1-3 before any processing are shown in Figure 7. Greyscale plots of the processed datasets from Area 1 are shown in Figure 8 while the equivalent plots for Areas 2 and 3 are depicted in Figure 9. In Figures 8 and 9 an additional plot for each area is shown where the 0.5m and 1.0m separation datasets have been combined by a process of local subtraction. In this process a local linear least mean squares fit is calculated at each point by comparing 0.5m and corresponding 1.0m separation measurements in a 5m radius window. The calculated equation of best fit is used to estimate from the 1m separation measurement what the 0.5m measurement should have been and this is subtracted from the actual 0.5m measurement to produce a high-pass filtered dataset emphasising near-surface anomalies.

Ground Penetrating Radar survey

A 3d-Radar MkIV GeoScope Continuous Wave Stepped-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). A roving Trimble R8 Global Navigation Satellite System (GNSS) receiver, together with a second R8 base station receiver established using the Ordnance Survey VRS Now correction service, was mounted on the GPR antenna array to provide continuous positional control for the survey collected along the instrument swaths shown on Figure 3. Data were acquired at a 0.075m x 0.075m sample interval across a continuous wave stepped frequency range from 60MHz to 2.99GHz in 6MHz increments using a dwell time of 3ms. 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 50ns), 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 Figure 10. To aid visualisation amplitude time slices were created from the entire data set by averaging data within successive 3.2ns (two-way travel time) windows (e.g. Linford 2004). An average sub-surface velocity of 0.0923m/ns was assumed following constant velocity tests on the data, and was used as the velocity field for the time to estimated depth conversion. Each of the resulting time slices, shown as individual greyscale images, therefore represents the variation of reflection strength through successive ~0.16m intervals from the ground surface in Figures 11 and 12. 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 size of the resultant data set a semi-automated algorithm has been employed to extract the vector outline of significant anomalies shown on Figure 14. The algorithm uses edge detection to identify bound regions followed by a morphological classification based on the size and shape of the extracted anomalies. For example, the location of possible pits is made by selecting small, sub circular anomalies from the data set.

RESULTS

Magnetometer survey

A graphical summary of significant magnetic anomalies [**m1-6**] discussed in the following text superimposed on base OS map data is provided in Figure 13.

The W half of the north lawn is crossed by several service pipes or cables [**m1a-d**] likely to date from the recent past. [1b and 1d] exhibit high magnitude ferrous anomalies while [1c] may be of ceramic construction and [1a] has a much lower magnitude anomaly suggesting modern materials. It is interesting that 1b and 1c appear to converge in the centre of the lawn as there is nothing on the surface to suggest what they might have originally supplied.

The largest anomaly [**m2**] runs approximately NW-SE from Richmond Road directly towards Marble Hill House and appears to represent a metalled road or drive. At its southernmost end it possibly widens and terminates in a circular area although proximity to the edge of the survey makes this interpretation uncertain. The alternation between high magnitude positive and negative polarities suggests a construction material with a thermoremanent magnetisation such as ceramic or asphalt. This is believed to be a driveway installed by the Cunard family around 1900 during their thwarted attempt to develop the park for private housing (Brian Clark *pers. comm.*).

As this drive approaches the house, a large ferrous anomaly with a peak gradient greater than 3,000nT/m can be discerned [**m3**] positioned adjacent on its E side. This corresponds with a complex of anomalies detected in the GPR survey and is likely to represent a structure or installation either contemporary with the drive or be associated with later C20th use of site. To the E is a rectangular configuration of four discrete ferrous anomalies [**m4**]**,** and other similar anomalies have been indicated across the survey area. The magnitude and symmetric form of the anomalies suggests they are caused by vertically oriented ferrous rods and they are probably associated with the modern use of this area for sports pitches.

Weak (~1-2 nT/m) narrow ditch anomalies have been detected at [**m5a-b**] but their cause is unclear and they may date from any period from the prehistoric to modern. In the SW of the survey area a collection of broad weak anomalies [**m6**] are likely to be caused by subsurface variations in the superficial geology. It is possible that topographic variation here was more pronounced prior to the C18th landscaping.

Distributed across the survey area a series of weak, parallel, linear ditch anomalies have been indicated running on a ~SW-NE alignment and spaced ~3-

3.5m apart. It is likely that these are drainage ditches possibly established at the time the area was landscaped.

Earth resistance survey

A graphical summary of significant earth resistance anomalies [**r1-17**] discussed in the following text superimposed on base OS map data is provided in Figure 13.

Area 1

In the northern corner, a rectilinear arrangement of high resistance linear anomalies has been detected [**r1**] which exhibit strong contrasts in both the shallow 0.5m and deeper 1m separation datasets suggesting potentially substantial wall footings. Remains of a brick wall were discovered just to the N of the survey area during preparation work for a community-run model market garden in the vicinity of the former kitchen garden situated here (King 2016, *pers. comm.*). These anomalies may well be related, possibly representing a layout of rectangular walled gardens as suggested by a survey of the estate depicted in the Richmond and Twickenham Times (1898). A possible alternative explanation is that there was a building at this location.

Running S from this area is a low resistance ditch anomaly [**r2**] which appears to have one or more discrete, square pit anomalies set into its edges. Near [r1] it turns through a right angle to run ~15m W. It forms a link between the kitchen garden area and the landscape garden anomalies [r4] further S and may be associated with either kitchen garden activity or formal planting relating to the designed landscape.

At [**r3**] a combination of discrete low and high resistance anomalies appears to form a rectilinear arrangement on a broadly N-S axis. Immediately W the survey has responded strongly to the repeated lime wash re-marking of a football pitch on a very similar N-S alignment (cf Gaffney and Gater 2003,; Figures 42, 43 and 67) and it may therefore represent remains a temporary stand erected for a sporting event. However, it might also mark the site of a structure associated with the earlier formal garden or, as it is still in close proximity, an arrangement of planting beds associated with the kitchen gardens.

S of [r2-3] at [**r4**] an arrangement of high resistance anomalies suggests the former presence of a series of metalled paths or walkways. Given their intersecting layout these seem likely to have been associated with the C18th designed landscape and a very similar arrangement of paths is depicted in the first edition 6 inch to the mile Ordnance Survey map (Ordnance Survey 1871).

Progressing S to the middle of the survey area [**r5**] one of these path anomalies can be traced running S past a line of discrete low resistance anomalies. It is possible these represent tree planting pits perhaps screening the view E from the house. One is particularly strong and exhibits an inverted response with a high resistance centre surrounded by a circular low resistance area ~8m in diameter. This might represent remains of a statue base or similar monument intended as an eye-catcher glimpsed between the tree settings.

The abovementioned path continues S through an amorphous area of high resistance measurements [**r6**] which, given its highly localised nature, suggests a spread of rubble rather than variation in underlying geology. If so, it may represent demolition rubble from Little Marble Hill which the 1867 Surrey VI Ordnance Survey map shows stood slightly to the S of this location along with a summer house. At the SE corner of the survey area this path turns through a right angle [**r7**] to run SW eventually joining the track detected by the GPR survey (see below) running SE across the football pitch field. An offset curving projection and a triangular spur suggest possible areas of hardstanding in front of buildings, the S end of Little Marble Hill would have been in close proximity to the former.

At [**r8**] fragmentary evidence has been detected for rectilinear wall footings on an alignment parallel to the adjacent bank of the Thames which may indicate that other structures once stood in this vicinity. A map of 1711 by amateur architect John Erskine, the 11th Earl of Mar, entitled "Scatch of the Grounds at Twittinhame…" shows three buildings in this location enigmatically labelled "the hatters" while the 1741-5 map by John Rocque shows four structures collectively labelled "The Glass House" (Twickenham Museum 2001) which suggests an association with the glass making industry. The absence of any clearly detected ground plans may indicate later remodelling of the area involving removal of the structures, possibly at the time Little Marble Hill was constructed. Several linear low resistance anomalies on different alignments, some still expressed in surface topography, also appear to run through this area. The strongest of these appear to correspond with a body of water marked at this location in the second edition 6 inch to the mile Ordnance Survey map (Ordnance Survey 1898).

As in Area 3, there is a sharp boundary separating a region of higher background resistivity to the N from a region of very low earth resistance approaching the Thames to the S. This may indicate the transition of the superficial geology from Langley Silt to alluvium.

Area 2

Given time constraints, only a small area of tree planting immediately S of the tennis courts was surveyed using earth resistance making it difficult to fully interpret the pattern of anomalies detected. At [**r9**] three parallel linear low resistance, possible ditch anomalies run out of the survey area on an NW-SE axis possibly associated with either previous landscaping or sports pitches. To the S linear high resistance anomalies [**r10**] suggest this area might once have been landscaped to form earthen banks screening the edge of the property similar to those still extant running parallel to Richmond road to the N. It is also possible that the stronger linear anomalies in this vicinity reflect remains of the “Sweet Walk” recorded as having been in this vicinity.

Area 3

The narrow high resistance linear anomaly [**r11**] running SSE through the survey area from Marble Hill House towards the Thames corresponds to the line of a known modern service (see discussion of [gpr8] below). Parallel to this the survey has detected a brick culvert known to run from the E wing of the house towards the Thames as a high resistance linear anomaly [**r12**]. Both 0.5m and 1m electrode separation surveys show this as a strong anomaly suggesting that it extends to some depth (~2m) beneath the surface. [r12] has a break in it ~25m S of the house adjacent to an area of high resistance which may suggest some disruption or damage or that it is crossed by another linear anomaly running E-W. The 1750 plan (MC 184/10/1 M12, Norfolk records Office) shows the area of tree planting to the immediate E with a broad E-W walk running into it which may support the latter conjecture.

At [**r13**] the near surface results suggest a possible rectilinear feature measuring ~10m E-W by 7.5m N-S. This inference must be considered highly conjectural as it is only visible in the combined 0.5m and 1m separation results after subtraction and occurs in an area where the latter were affected by electrical noise. Nevertheless, this symmetrically central position relative to the S aspect of the house and the two areas of tree planting to the E and W would be an attractive place to site a garden feature.

At [**r14**] a complex of high resistance linear anomalies appears to form a line of, possibly, three square panels of a formal garden design. Each panel is ~5m across and the complete arrangement would close the gap between the two stands of trees that bracket the S aspect of house. The anomaly of the easternmost panel is disrupted by the culvert anomaly [r12] although it is not clear whether this is simply the superposition of anomalies or whether it represents actual intercutting. The other two panels both show evidence for a circular central feature ~2m in diameter. While the plan revealed by earth resistance measurement is rather fragmentary, some of the anomalies are of high magnitude suggesting substantial construction. Indeed, at the position labelled [**r14**], where the culvert anomaly intercuts, the deeper 1m separation results suggest the possibility of substantial buried remains – a possible site of the second grotto?

A high resistance linear bank [**r15**] divides ground exhibiting higher background resistivity to the N from the noticeably lower background resistivity of the lawn running S towards the Thames. This may denote the line of change in superficial geology (as suggested at [r8] above) as the strength of anomalies forming [r14] changes markedly as they cross its line which is suggestive of change in subsurface conditions. [**r15**] may indicate the strike of the original slope of the land in this area, C18th landscaping having since altered it to be parallel to the S face of the house. However, the 1750 plan shows a layout of paths running through a possible Elysian garden layout around the grotto in this area and [r15] also correlates with the southernmost of these.

To the W of the survey area two approximately rectilinear low resistance anomalies ~2-4m across can be discerned [**r16**] surrounded by areas of higher resistance. These may represent former planting pits with the linear low resistance anomaly passing between them being a former path. On the other side of the survey area [**r17**], further linear high resistance anomalies running around the grotto appear to correlate with paths depicted in the conjectural Elysian garden layout suggested by the 1750 estate plan.

Ground Penetrating Radar survey

A graphical summary of the significant GPR anomalies, [**gpr1-46**] discussed in the following text, superimposed on the base OS map data, is provided in Figure 14.

Significant reflections have been recorded throughout the 50ns two-way travel time window, although later reflections beyond ~40ns become more highly attenuated particularly in the low lying, waterlogged area to the S of the site adjacent to the river. The very near surface data between 0 and 3.2ns (0.0 - 0.16m) has responded to the immediate surface conditions with the areas of un-mown grass, [**gpr1**], well-worn pathways [**gpr2**] and the Astroturf cricket pitch [**gpr3**] being particularly evident. From approximately 3.2ns (0.16m) onwards low amplitude anomalies corresponding to the line marking paint of both the past and present location of the sports pitches are evident [**gpr4**], and clearly has a long term impact on the local conductivity of the soil (cf Gaffney and Gater 2003,; Figures 42, 43 and 67).

The roots of mature trees [**gpr5**] have also been imaged within the near-surface data together with a series of pipes [**gpr6**] and trenches [**gpr7**] detected across the site but mainly running to serve the house, including [**gpr8**] a recent electricity supply installed on the South Lawn to facilitate the staging of events (Brian Clark *pers. comm.*). Other near-surface anomalies [**gpr9-12**] to the N of the house seem most likely to represent former playing surfaces or facilities such as cricket nets [**gpr9**] and practice pitches [**gpr12**] perhaps. Planar areas of high amplitude response [**gpr13**] evident from between 3.2 and 41.6ns (0.16 to 2.06m) are most likely to represent gravel deposits and are overlain to the N of the house by a series of broad, parallel anomalies [**gpr14**], possibly indicative of ridge and furrow or other agricultural activity at the site.

The driveway heading N from the house detected by the magnetic survey [**m2**] has been replicated in the GPR data [**gpr15**] together with a similar, 'T' shaped response [**gpr16**] to the E, beyond the magnetometer coverage. Anomaly [**gpr15**] is, perhaps, quite wide (12m) for road although the presence of linear services including some discrete reflectors persistent throughout the data set suggests this may have been designed as a more general conduit for infrastructure to support the proposed housing development. A complex group of anomalies [**gpr17**] may possibly be associated with [**gpr15**], and consists of a rectilinear building type structure, approximately 6m x 3m, adjacent to a 4m square reflector surrounded by an amorphous area of high amplitude response. The presence of a possible service [**gpr6**] running from the house to [**gpr17**] may suggest an alternative interpretation, perhaps a second world war searchlight or other civil defence installation. Closer to the house [**gpr15**] passes through what appears to be an original arc [**gpr18**] of the carriage turning circle.

A linear distribution of low [**gpr19**] and more scattered high amplitude pit-type anomalies [**gpr20**] may well be indicative of a former garden design, with [**gpr19**] sharing an orientation with the layout of the main house. The anomalies at [**gpr21**] close to the stable block are more difficult to interpret but may well be related to structural remains.

To the S of the house the terraced South Lawn drops down to the Thames where the known brick culvert has been identified [**gpr22**] between 6.4 and 32ns (0.32 to 1.58m), with a fall towards the river and the recent electricity cable [**gpr8**] running parallel immediately to the W. Despite the presence of the services the radar data has revealed what appears to be an Italianate style formal garden layout [**gpr23**], in an area shown as a panel of trees on the historic mapping (OS Historic County Mapping Series: Middlesex 1843 - 1893 Epoch 1). The design consists of three semi-circular parterres with a diameter segment of 8m set in a rectangular layout of paths, but it would appear that any traces of, presumably symmetrical anomalies, have not survived to the W. The anomalies related to the garden layout [**gpr23**] are evident in the data from between 3.2 and 35.2ns (0.16 to 1.74m), suggesting they are either quite substantial causative features or formed from material that has encouraged the signal to reverberate through the time window. The response is most persistent to the E of [**gpr23**] where the reflections apparently continue to 50ns and this could, potentially, a deeper lying target such as the putative second grotto. However, a second high amplitude anomaly [**gpr24**] to the W mirrors the location of the extant grotto and is evident within the data between 3.2 and 41.6ns (0.16 to 2.06m), possibly suggesting and alternative location, although [**gpr24**] together with [**gpr25**] and [**gpr26**] may also be related to the nine pin alley shown on *c*1750 estate plan (Norfolk Records Office 1750).

The South Lawn contains additional anomalies apparently related to either the terracing [**gpr27**], possible elements of former planting or garden designs [**gpr28**], and others that are difficult to fully interpret [**gpr29**] and are possibly due to the underlying geology. A linear EW high amplitude wall, track way or boundary [**gpr30**] is found to the S and extends beyond the South Lawn across the site both to the W and E, where it appears as a low amplitude, ditch type response. There is a marked change in response to the S of [**gpr30**] as the lower lying, alluvial soils close to the river attenuate the incident signal and it is possible that [**gpr30**] represents a limit to flooding from the Thames.

To the W [**gpr30**] passes through the lower lying, waterlogged, West Meadow set out for two rugby pitches with the line markings for the half-way, twenty-two, goal and dead ball lines visible as low amplitude anomalies. Toward the centre of this area a low amplitude anomaly [**gpr31**] corresponds with an octagonal garden feature shown on the 1751 survey plan surviving as mature trees recorded by the historic mapping until, presumably, clearance for the sports pitches and allotments during the war. Where the ground rises to the N a modern service is seen to pass through a small, rectilinear reflector [**gpr32**] and is, perhaps related to an inspection chamber or silt trap. A more intriguing, high amplitude anomaly is partially described at [**gpr33**] between 9.6 and 35.2ns (0.47 to 1.74m) and lies approximately 25m SW of the known Ice House and could, potentially represent a similar subterranean structure and, perhaps, offers another possible location for a second grotto.

Following [**gpr30**] E it passes through the series extant earthworks, immediately N of the Black Walnut, that have largely been replicated in the GPR data with some suggestion of structural remains at [**gpr34**]. No evidence for the small building at the location shown on the historic mapping (OS Historic County Mapping Series: London 1891 - 1921 Epoch 2) have been found, but complete survey coverage in this area has been partially interrupted by the presence of mature trees. Heading further E [**gpr30**] appears to follow the course of two parallel low amplitude responses leading towards the former site of Little Marble Hill House, where a complex response within the trees [**gpr35**] is found at the southern extent of the driveway [**gpr36**]. A straight section of [**gpr36**] heads NW, apparently heading towards the White Lodge Gate where it crosses the North Lawn as an interrupted low amplitude response, and curved portion [**gpr37**] follows a course towards the modern car park and East Gate. The branch of [**gpr37**] to the E, shown on the first Epoch of historic mapping (OS Historic County Mapping Series: Middlesex 1843 - 1893 Epoch 2), is also evident [**gpr38**].

It is of interest to note that subsequent historic mapping shows the establishment of two Ordnance Survey trigonometry points one approximately half way along [**gpr38**], although by this time the track way was no longer recorded by the OS, and the other to the S beyond the limits of the survey on towpath (OS Historic County Mapping Series: London 1891 - 1921 Epoch 2). The original OS baseline, established by General William Roy in 1784, lies close to the site between Hounslow Heath and Hampton, but it seems more likely that these points were established by General Jonathan Peel, who owned Marble Hill House between 1825 until his death in 1879, and served his elder brother the Prime Minister Sir Robert Peel as Surveyor General of the Ordnance. No convincing geophysical anomaly relating to the northern point is immediately obvious, but these may well have been rather ephemeral monuments such as the buried cartwheels used to originally mark Roy's baseline.

A high amplitude, wall-type response [**gpr39**], appears later than [**gpr37**] but is itself cut by the presumably more recent service [**gpr6**]. Other similar wall-type anomalies are found in this area [**gpr40**] and perhaps relate to either the previous land division in the park or elements of the pleasure gardens. Some more curious, circular anomalies [**gpr41-46**] of differing diameter also appear throughout this area and do not, immediately, suggest a direct association with recent sports activity or former pitches. It is certainly possible that [**gpr41-46**] represents elements of the wider pleasure gardens and, perhaps, the largest of these [**gpr41**] could even represent the location of the short lived "The Priory of St. Hubert" folly constructed around 1757 and removed after Henrietta Howard's death a decade later.

CONCLUSIONS

Three geophysical techniques were tested at Marble Hill Park and, while the coverage with each varied, between them an area of ~20 ha representing all accessible parts of the park was surveyed. Magnetometer survey performed as anticipated given the geology and site type, detecting relatively few in-filled ditch anomalies and responding mainly to ferrous and thermoremanent materials deriving from structures likely to have been constructed in the last two centuries. For this reason, magnetometer survey was abandoned after surveying the North Lawn in favour of the other techniques.

By contrast GPR performed better than anticipated over a wet London Clay geology detecting a wealth of superimposed anomalies reflecting the changing land use of the park through time. Earth resistance survey also performed well and over Area 3 a strong correlation with the GPR results was observed giving confidence that, as at other designed landscapes where the two have been compared, both will reveal the primary subsurface remains likely to be present (see for instance Linford and Payne 2011). As the towed GPR array provided the higher level of detail, it proved the most rapid and effective method for surveying the remaining open areas of the site. However, while slower, earth resistance survey provided the only means of surveying between closely spaced trees and bushes and was therefore used to extend the survey area to the edges of the park in Areas 1 and 2.

The survey results have revealed a palimpsest of anomalies distributed across Marble Hill Park (see Figure 15) and many of these can be correlated with features visible on historic maps reflecting the changing use of the landscape over time. There are, however, also anomalies suggesting additional features not recorded by the mapping and these will need to be verified by comparison with other forms of research.

LIST OF ENCLOSED FIGURES

Figure 8 Linear greyscale plots of processed earth resistance data from Area 1: (A) 0.5m electrode separation dataset; (B) 1.0m electrode separation dataset; (C) local subtraction of (B) from (A) to enhance near-surface features (1:1250).

Figure 9 Linear greyscale plots of processed earth resistance data from Areas 2 and 3: (A) 0.5m electrode separation dataset from Area 2; (B) 1.0m electrode separation dataset from Area 2; (C) local subtraction of (B) from (A) to enhance near-surface features; (D) to (F) show the corresponding plots for Area 3 (1:1000).

Figure 10 Representative topographically corrected profiles from the GPR survey shown as greyscale images with annotation denoting significant anomalies. The location of the selected profiles can be found on Figure 5.

Figure 11 GPR amplitude time slices between 0.0 and 25.6ns (0.0 – 1.26m), (1:6000).

Figure 12 GPR amplitude time slices between 25.6 and 49.0ns (1.26 – 2.37m) (1:6000).

Figure 13 Graphical summary of significant magnetic and earth resistance anomalies superimposed over the base OS mapping (1:2500).

Figure 14 Graphical summary of significant GPR anomalies superimposed over the base OS mapping (1:2500).

Figure 15 Graphical summary of most significant anomalies from all surveys superimposed over the base OS mapping (1:2500).

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King, G 2016 Gillian King of the Greater London Archaeology Advisory Service visited Marble Hill park on 27/11/2013 to record a wall footing discovered by the HLF funded Jam Yesterday Jam Tomorrow Project while preparing the ground for a model market garden in the vicinity of the original kitchen garden. A brick footing four courses (~40-45cm) wide was uncovered running WSW to ENE about 7-10m N of the N edge of earth resistance survey Area 1. Gillian has an archive of photographs, notes and a sample brick at GLAAS. (reported to P Linford on 28/04/2016.)

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Figure 1

MARBLE HILL PARK, TWICKENHAM, LONDON

Location of caesium magnetometer and earth resistance surveys, December 2015 and February 2016

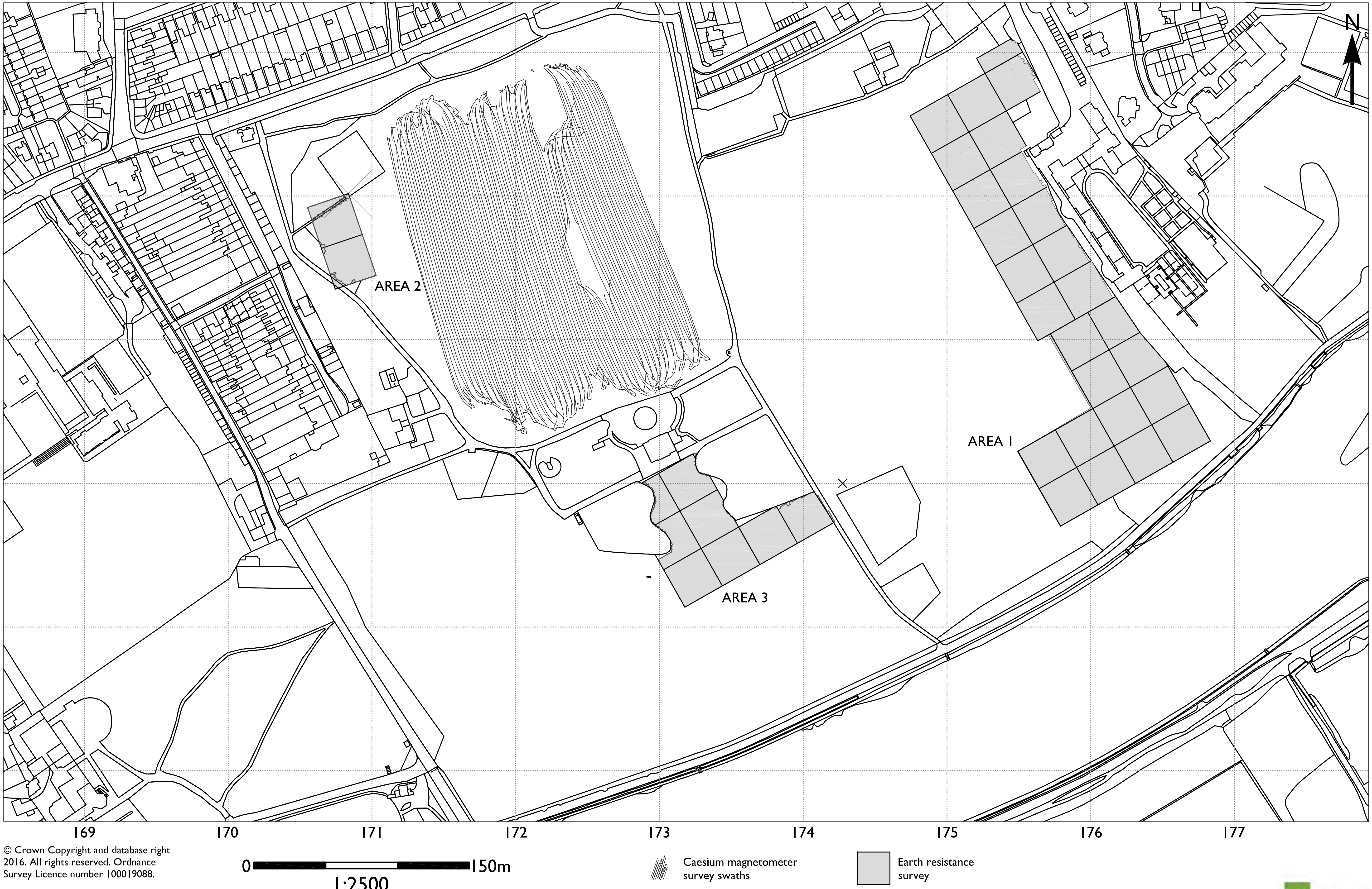

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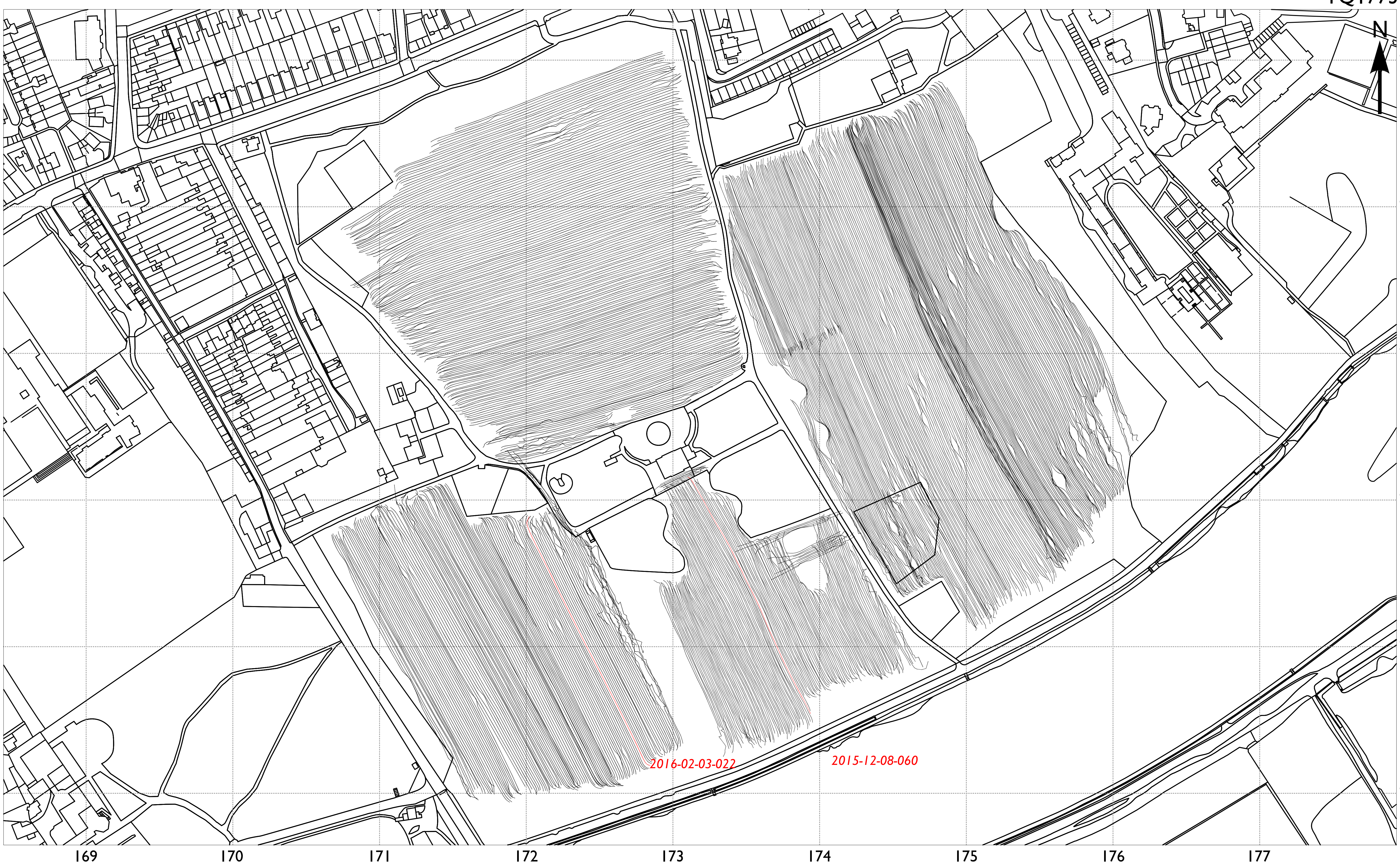
Figure 2

MARBLE HILL PARK, TWICKENHAM, LONDON
Location of GPR survey swaths, December 2015 and February 2016



Geophysics Team 2016

Historic England

Figure 3

MARBLE HILL PARK, TWICKENHAM, LONDON
Location of caesium magnetometer survey, December 2015

Geophysics Team 2016

Historic England

Figure 4

MARBLE HILL PARK, TWICKENHAM, LONDON

Location of earth resistance surveys, December 2015 and February 2016

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Figure 5

MARBLE HILL PARK, TWICKENHAM, LONDON

GPR amplitude time slice between 9.6 - 12.8ns (0.47 - 0.62m), December 2015 and February 2016

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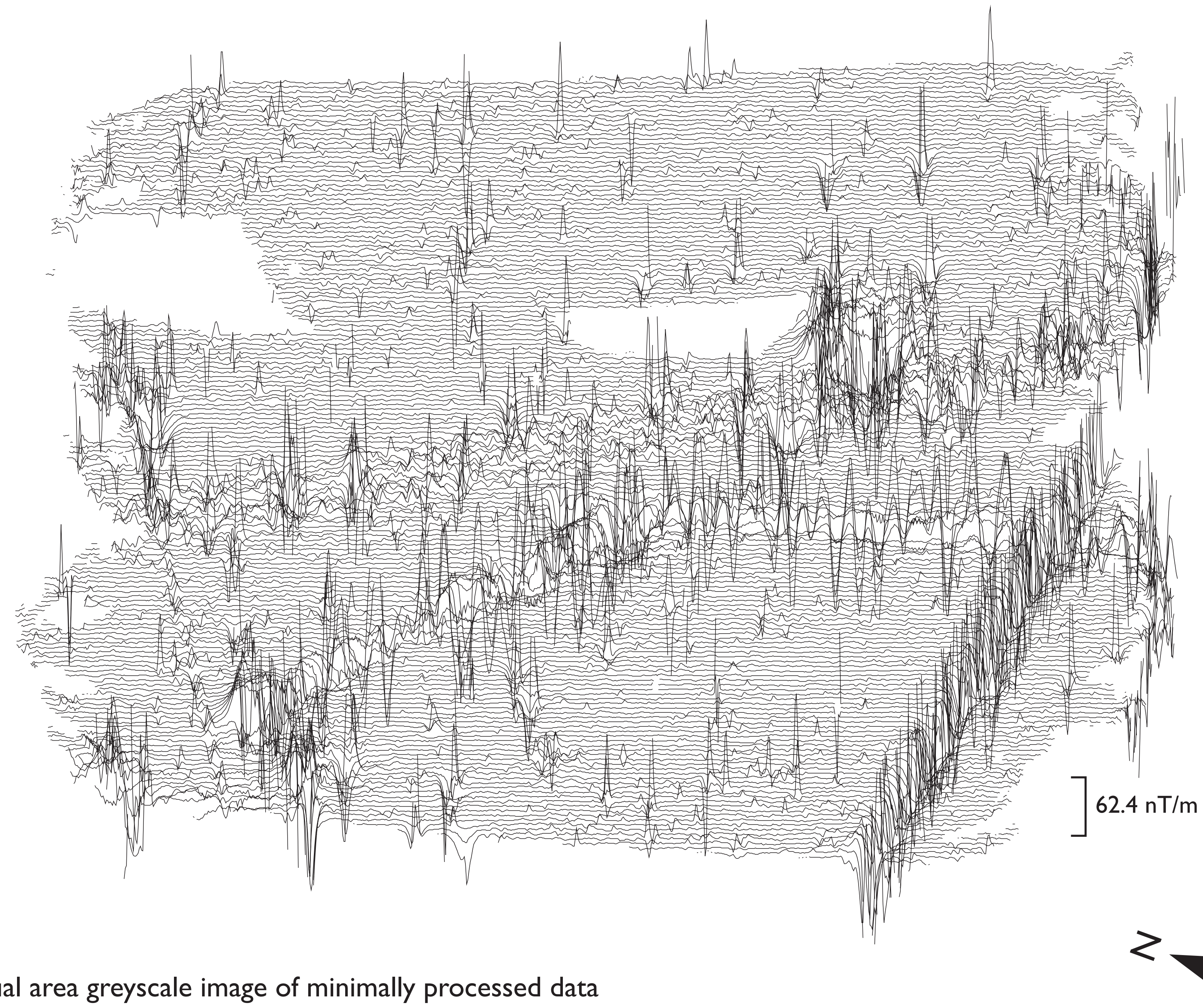
Figure 6

MARBLE HILL PARK, TWICKENHAM, LONDON
Caesium magnetometer survey, December 2015

(A) Trace plot of minimally processed data



(B) Equal area greyscale image of minimally processed data

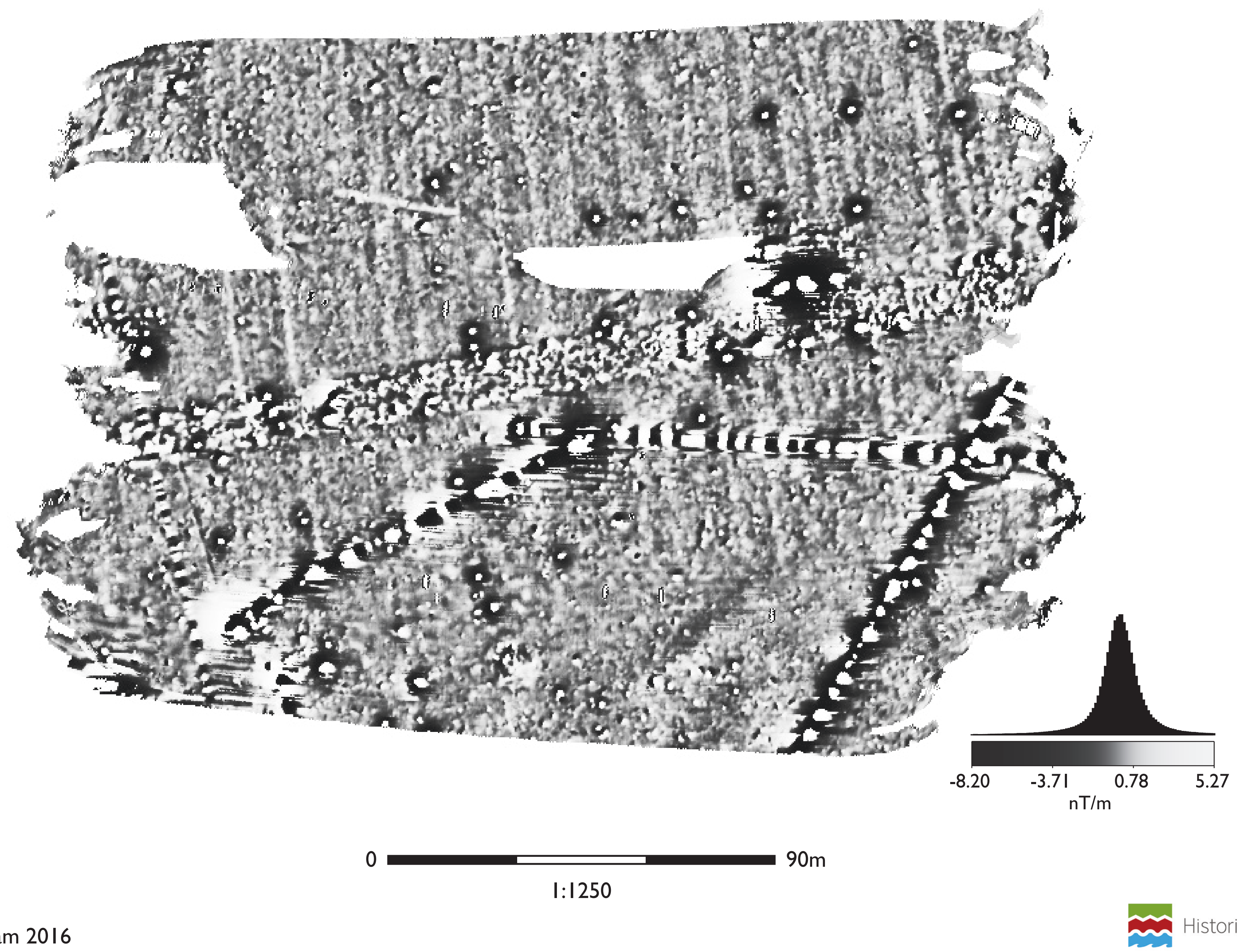


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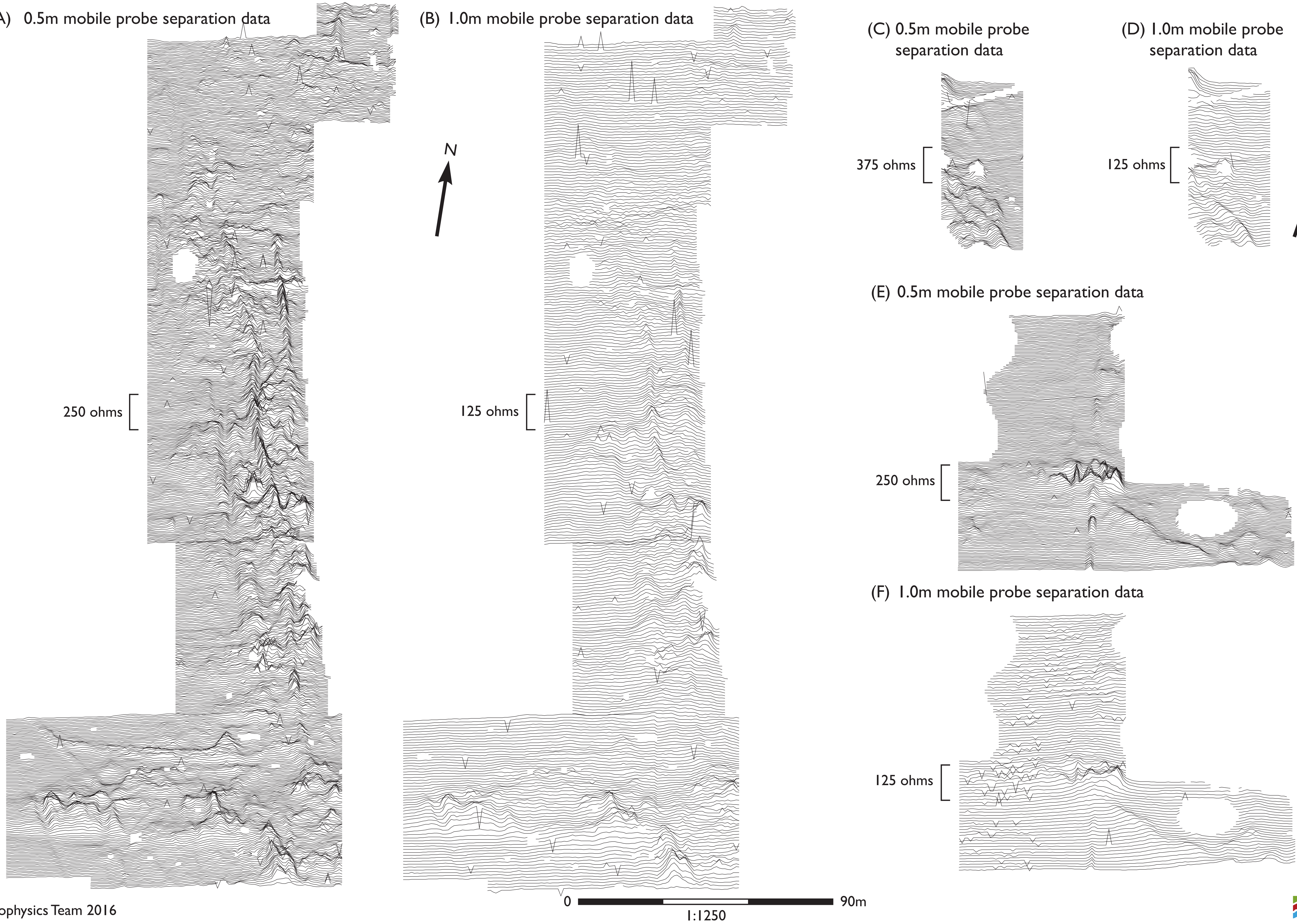
Figure 7

MARBLE HILL PARK, TWICKENHAM, LONDON

Trace plots of unprocessed earth resistance surveys, Areas 1, 2 and 3. December 2015 and February 2016



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Earth resistance greyscale plots, Area 1, December 2015 and February 2016

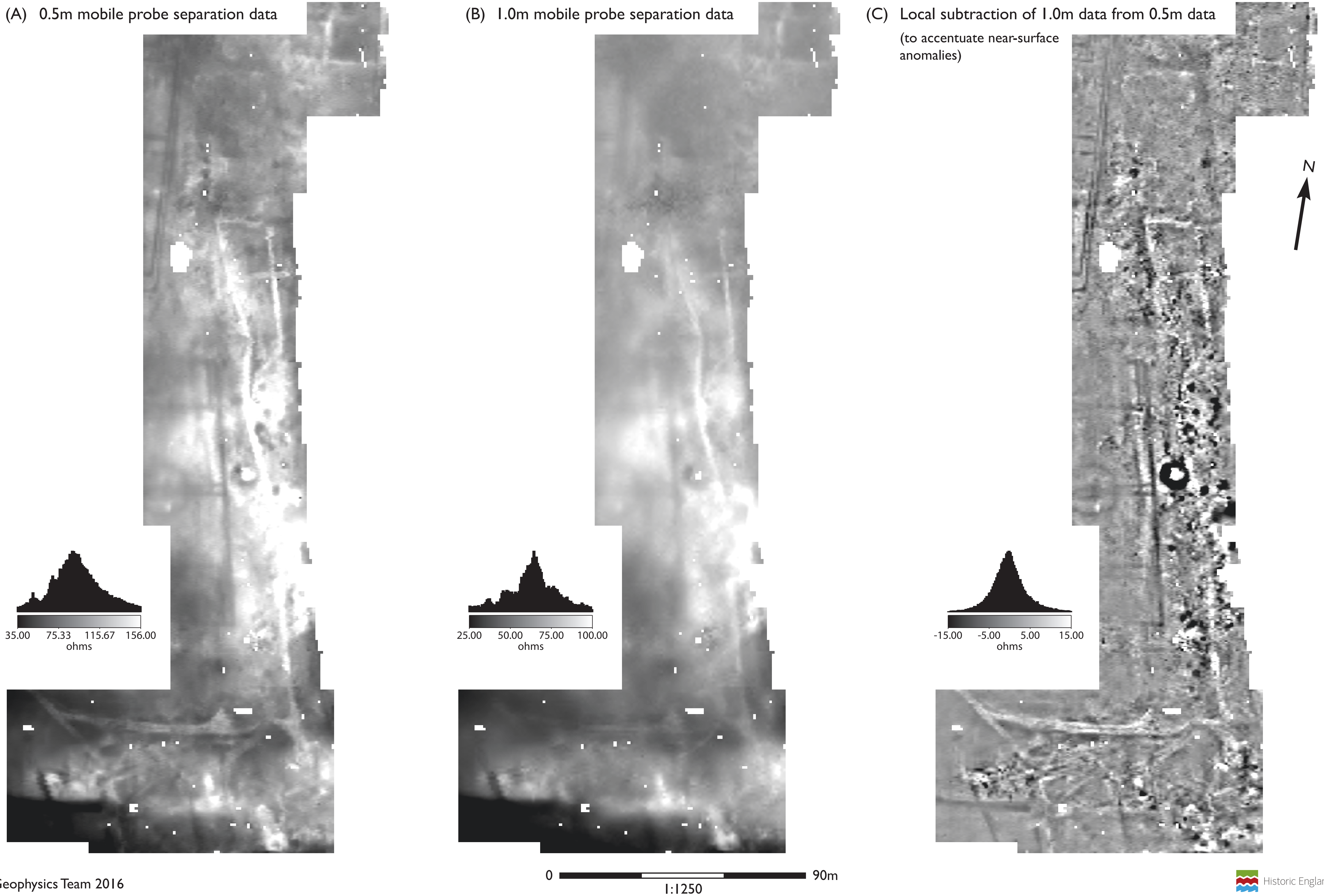
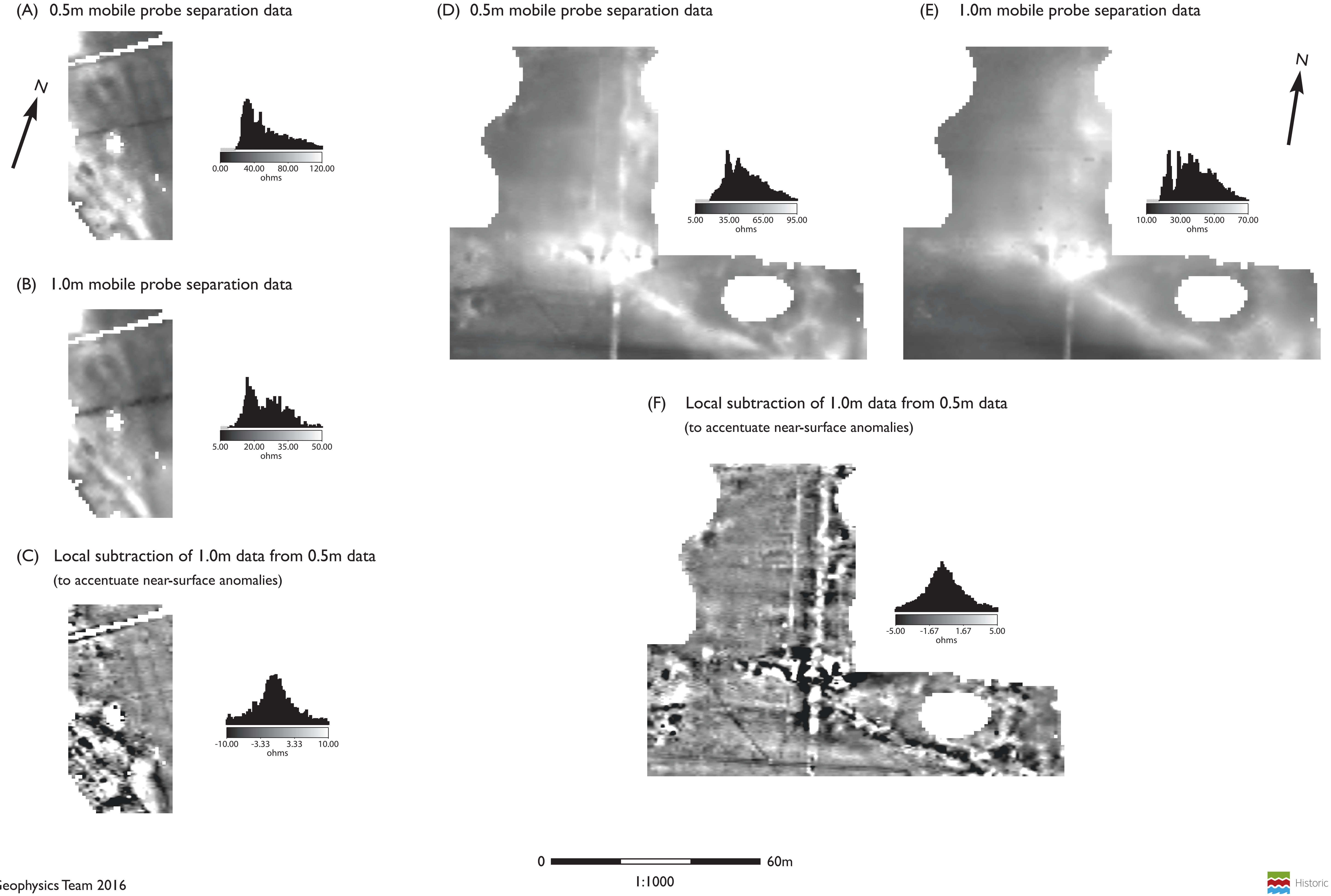


Figure 9

MARBLE HILL PARK, TWICKENHAM, LONDON

Earth resistance greyscale, Area 2 and 3, December 2015 and February 2016



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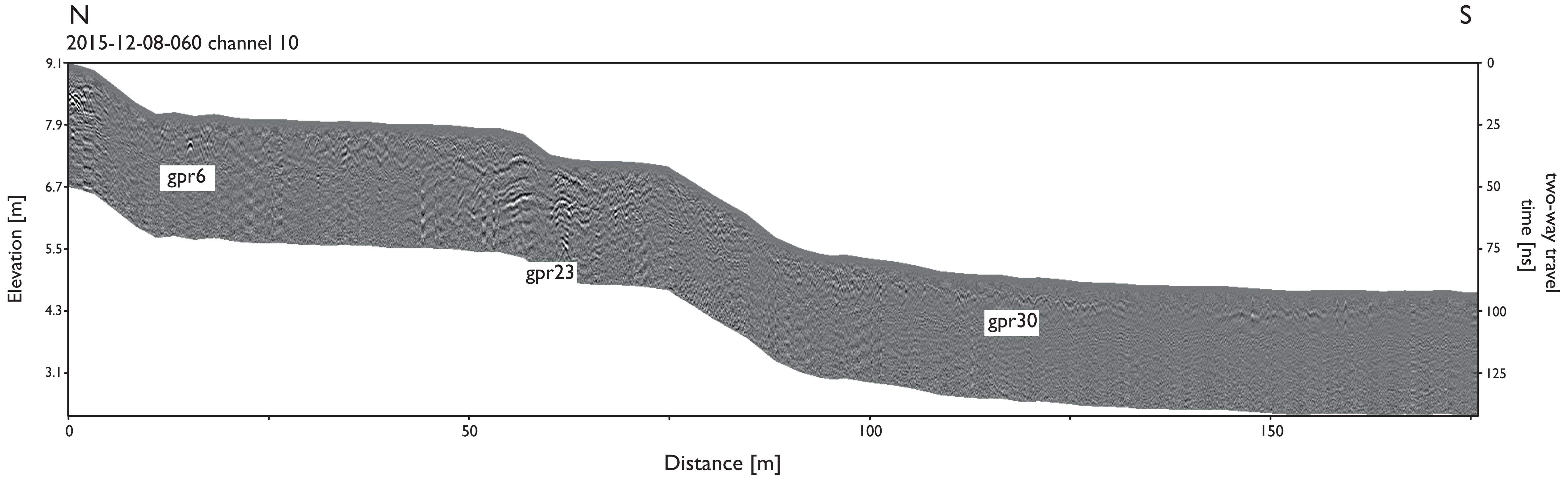
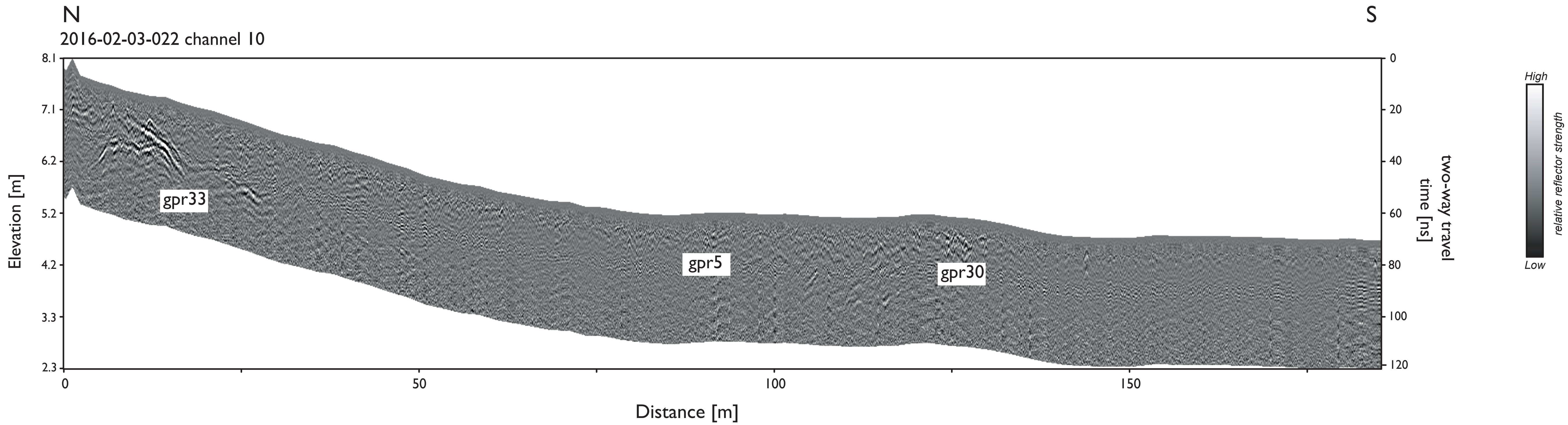
Topographically corrected GPR profiles, December 2015 and February 2016

Figure 10





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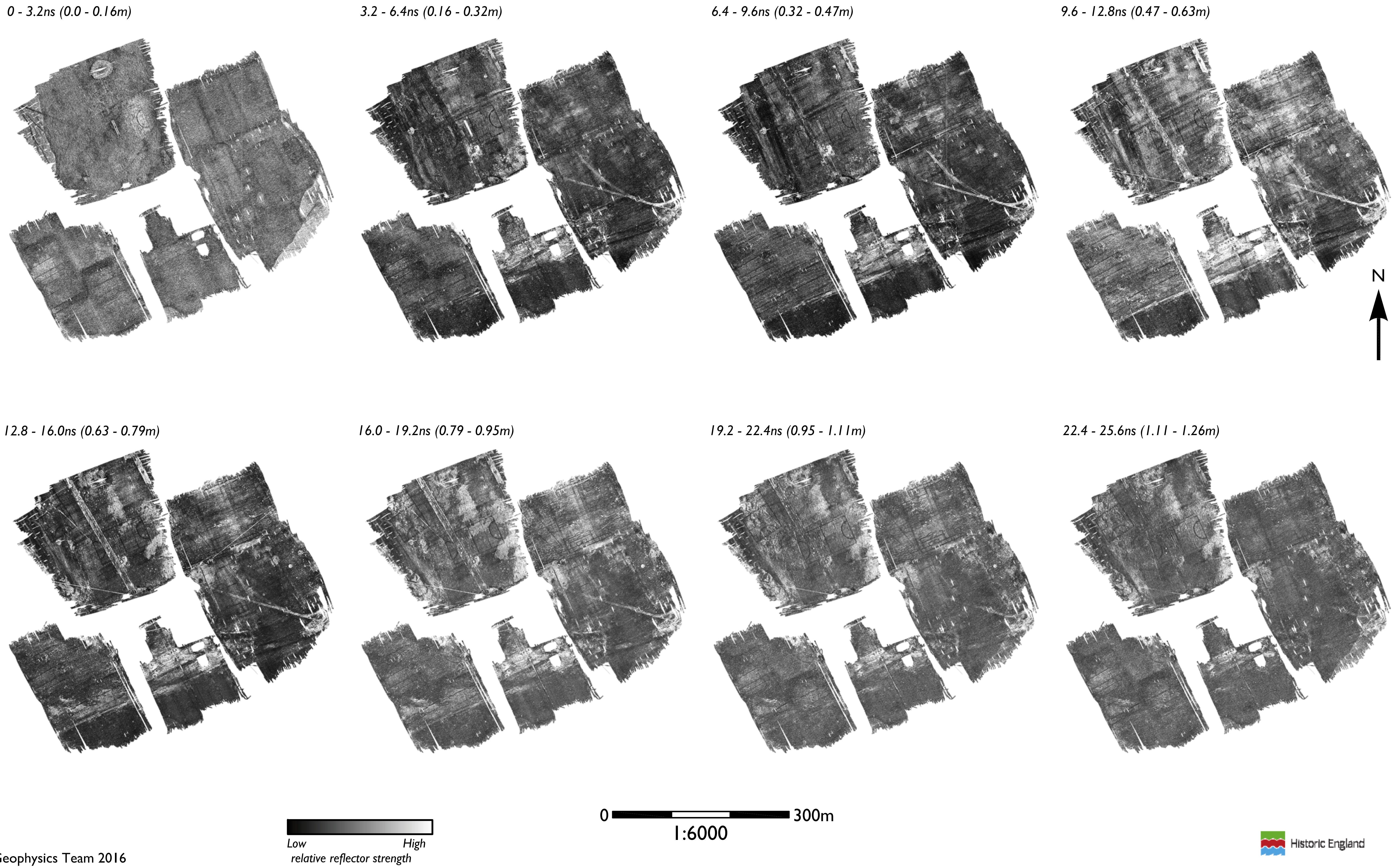
GPR amplitude time slices between 0.0 - 25.6ns (0.0 to 1.26m), December 2015 and February 2016

Figure 11



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GPR amplitude time slices between 25.6 - 49.0ns (1.26 to 2.37m), December 2015 and February 2016

Figure 12

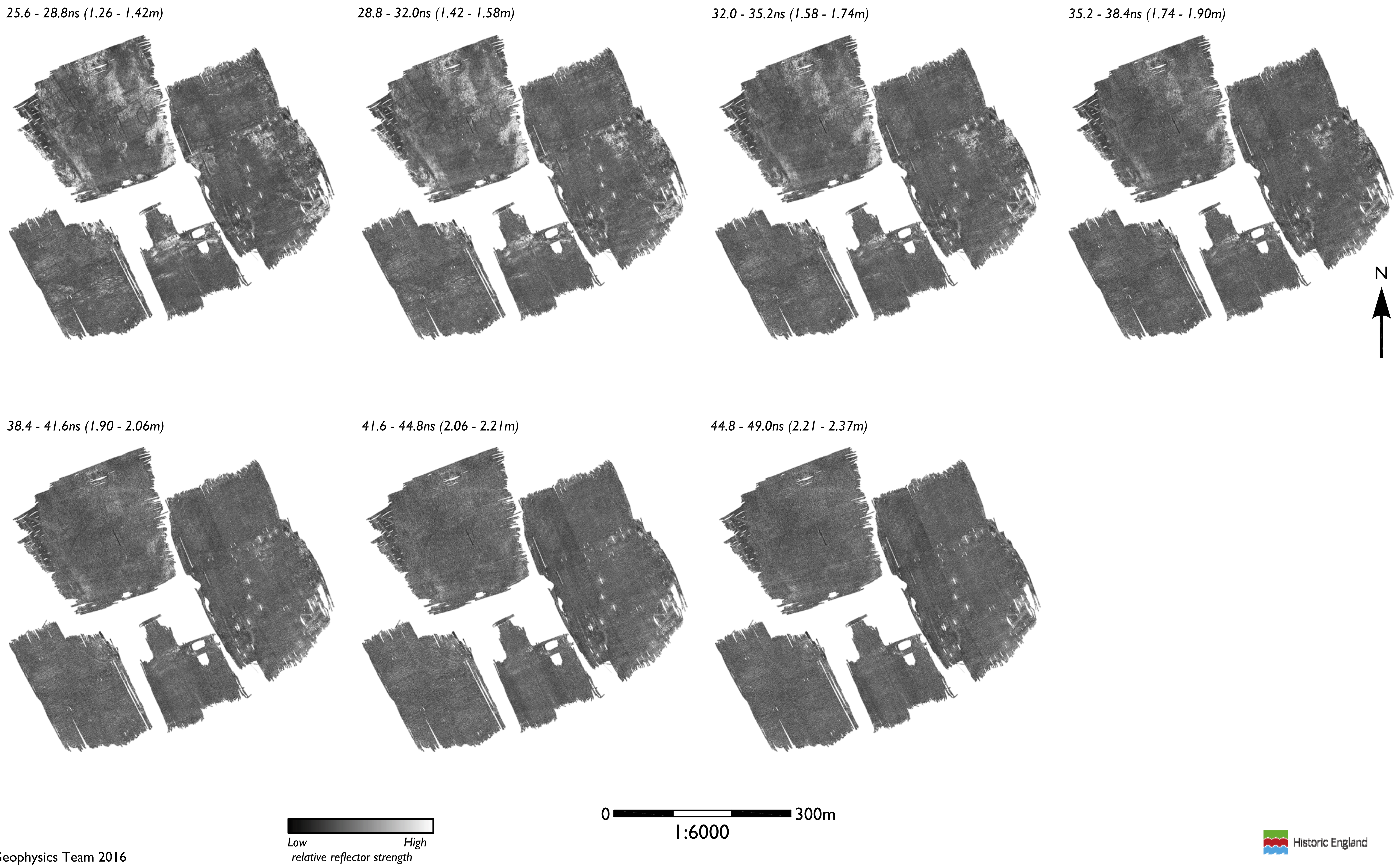

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Figure 13

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Graphical summary of significant magnetometer and earth resistance anomalies, December 2015 and February 2016

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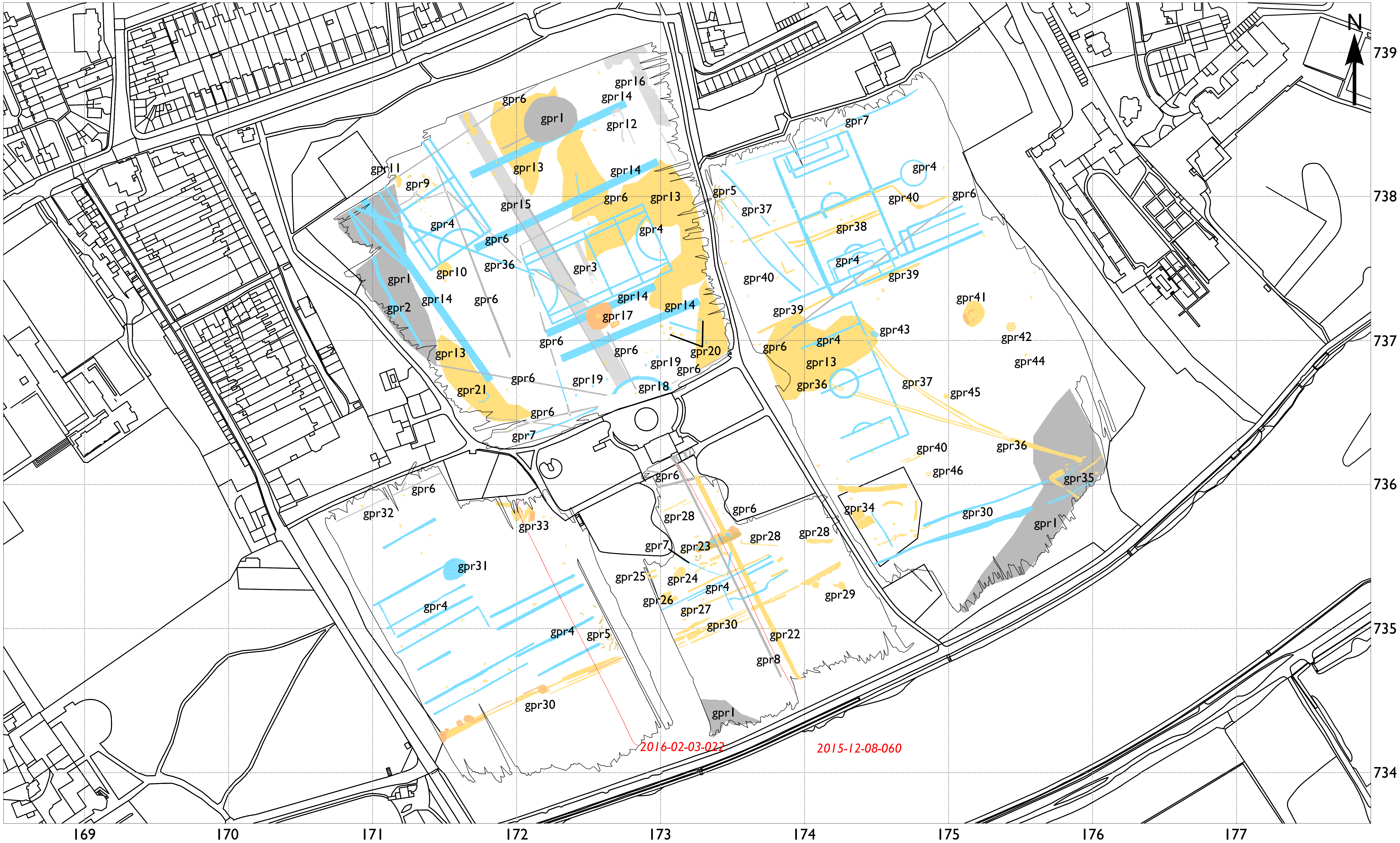
Figure 14

MARBLE HILL PARK, TWICKENHAM, LONDON

Graphical summary of significant GPR anomalies, December 2015 and February 2016

TQ1773



0 150m

1:2500

low amplitude reflectors

high amplitude reflectors

anomalies of known or recent origin

2015-12-08-060 Location of selected GPR profiles shown on Figure 10

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Graphical summary of most significant anomalies from all surveys, December 2015 and February 2016

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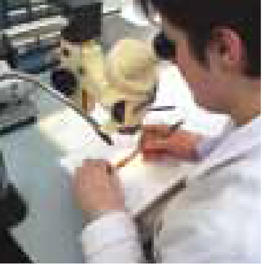
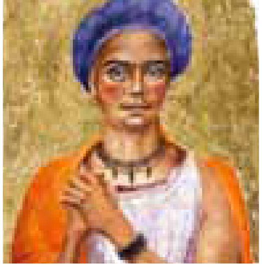


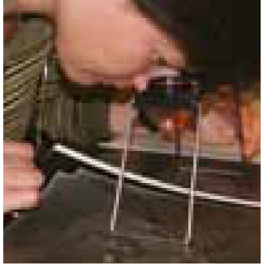


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