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AUDLEY END HOUSE AND PARK, SAFFRON WALDEN, ESSEX
REPORT ON GEOPHYSICAL SURVEYS, 2009-2010

Neil Linford and Andrew Payne

ARCHAEOLOGICAL SCIENCE

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SUMMARY

Earth resistance and ground penetrating radar (GPR) surveys were undertaken to support a programme of investigative research into the historic development of the designed landscape at Audley End Park with the aim of providing improved interpretation facilities at the property. The survey covered the lawn areas to the west and north-west of Audley End House to investigate the enlarged Jacobean palatial buildings and the environs of Place Pond to the north-east, where historic mapping suggested remains of earlier monastic buildings associated with the abbey of Walden might survive. A plethora of resistance and GPR anomalies indicate the presence of substantial buried structures under the lawn directly west of the current house, likely to represent surviving remains of the Outer Court, as well as elements of the Tudor period landscape immediately pre-dating the transition from the monastic to country house phase of the site.

CONTRIBUTORS

The field work was conducted by Neil Linford, Paul Linford, Louise Martin and Andrew Payne with assistance in October 2009 from Sam Cheyney (Leicester University) and Jacopo Sala (3d-Radar), Andrew David and Simon Thurley in May 2010.

ACKNOWLEDGEMENTS

The authors wish to thank Neil Cole, Rebecca Lee and Linda Dyer (Visitor Operations East Territory) for facilitating access to conduct the survey and Research Department colleagues including Magnus Alexander, Wayne Cocroft, Andrew Lowerre and Brian Kerr for advice on potential target areas for geophysical survey (based on historic mapping evidence) and the subsequent interpretation of the results. Dr Andrew Hann (Senior Properties Historian, Properties Research) provided similar helpful discussion. The grounds maintenance staff at Audley End generously made site facilities for overnight equipment storage available to the Geophysics Team during the survey. The cover photograph shows the Ground Penetrating Radar survey conducted in May 2010 in progress on the west lawn area adjacent to Audley End House.

ARCHIVE LOCATION

Fort Cumberland.

DATE OF FIELDWORK AND REPORT

The fieldwork was conducted over a period of two weeks during the 19-23rd October 2009 and 24-28th May 2010. The report was completed on 24th January 2011.

CONTACT DETAILS

Andrew Payne, Geophysics Team, English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD.
Tel: 023 9285 6750. Email: andy.payne@english-heritage.org.uk

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INTRODUCTION

Geophysical surveys were carried out in October 2009 and May 2010 at Audley End House (NGR TL 5246 3184; Scheduled Monument Ex 84) and its associated designed landscape (Registered Garden 1254) to further inform the interpretation and presentation of the site through a multidisciplinary research project (Cocroft 2010). The aim of the project is to recover evidence of former phases of landscape and building design, partially indicated by historic mapping as the house evolved from its earlier medieval monastic form through the Tudor period onwards.

The present 17th century house sits within a re-created mid-19th century parterre garden, with pleasure grounds by Richard Woods, surrounded by an 18th century park conceived and partly laid out by Lancelot 'Capability' Brown between 1762 and 1767. The purpose of the geophysical surveys was to recover evidence of earlier garden layouts as well as land-use and settlement prior to the development of the designed landscape of the 1760s, which survives largely intact. In addition, it was hoped that remnants of the original palatial buildings (known as the Outer Court) dating from the 17th century and demolished in the 18th century, might be recovered from the lawn area immediately west of the current house (Area 1).

This report also incorporates the results from an earlier earth resistance survey of the Elysian Garden to the north west of the site (Area 2) conducted during July 1994 in advance of a proposed garden restoration scheme. Coverage with this technique has been extended to include an area of possible Tudor buildings depicted on historical mapping around Place Pond (Area 3), and further complemented through the use of Ground Penetrating Radar (GPR) over a complex of remains indicated by the initial earth resistance survey in Area 1.

The site lies on river terrace deposits at the foot of the western slopes of the chalkland valley of the River Cam. The solid geology consists of Cretaceous Lower Chalk and chalky drift over which well drained calcareous coarse and fine loamy soils of the Swaffham Prior Association have developed (Geological Survey of Great Britain (England and Wales) 1952; Soil Survey of England and Wales 1983). Striped and polygonal soil patterns are known to occur locally in these geological conditions. Alluvial deposits are present along the margins of the rivers and streams, but these only cover a minor part of the total area surveyed towards the eastern and northern limits. The outlying elements of the designed landscape are found on higher ground formed over deposits of Upper Chalk capped by chalky boulder clay. All the surveys were undertaken over grass lawn areas during periods of settled dry weather, except for one period of heavy rain towards the end of the October 2009 survey that abruptly decreased the background resistance.

METHOD

i) Earth Resistance survey

Earth resistance measurements were collected on a 30m grid (Figure 1) established with a Trimble 4800 series differential Global Positioning System (GPS). Over the majority of the survey area (Figure 1, Areas 1 and 2) a Geoscan RM15 resistance meter was employed in the twin electrode configuration using an MPX15 multiplexer and an adjustable PA20 electrode frame, to allow readings to be collected simultaneously at both a standard 0.5m and a more deeply penetrating 1.0m mobile electrode spacing. Sample intervals of 0.5m x 1.0m or 1.0m x 1.0m were used for the 0.5m and 1.0m mobile electrode separations respectively. In the separate area surveyed around Place Pond in May 2010 (Figure 1, Area 3) only a single 0.5m mobile electrode separation was employed due to high surface contact resistance. The same single electrode spacing survey methodology was employed for the earlier survey of the Elysian Garden area in July 1994.

Post-acquisition processing of the twin electrode data included the application of a 2m by 2m thresholding median filter to remove isolated high readings caused by poor electrode contact with the soil (Scollar *et al.* 1990, 492). Discontinuities between grid edges were reduced by modifying the statistical distribution of adjacent data sets or applying an edge matching process using a linearly weighted combination of the original values and a 1D high-pass median filter of window width 10m applied to columns of data parallel to the mismatched grid edge. Traceplots and greyscale images of the resulting data are shown in Figures 3, 4, 8(A) and 8(B) for the 0.5m mobile electrode spacing readings and Figures 5 and 6 for the more limited coverage with the 1.0m mobile electrode spacing survey. A Wallis contrast enhancement algorithm with a radius of 5m (Scollar *et al.* 1990, 506-12) was also applied to enhance significant anomalies within areas of reduced background variation found over poorly drained soils close to the River Cam (Figures 2, 7 and 8(C)).

In addition, near-surface anomalies the multiplexed earth resistance measurements were enhanced by subtracting the deeper penetrating 1.0m mobile electrode spacing readings from the 0.5m data, following an appropriate correction for the geometry of the electrode array (Figure 7(A)). Deeper lying anomalies were accentuated by obtaining the second principal component from the correlation of the two data sets to isolate image features prevalent in the 1.0m mobile electrode spacing measurements (Gonzalez and Wintz 1987; Linford 2003, Figures 7(B) and 7(C)).

ii) Ground Penetrating Radar (GPR)

A 3d-Radar GeoScope Continuous Wave Stepped-Frequency (CWSF) radar system was used to conduct the survey collecting data with a multi-element V1821 vehicle towed, air launched antenna array (Linford *et al.* 2010). Data were acquired at a 0.075m x 0.075m sample interval across a continuous wave stepped frequency range from 50 to 1250MHz 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 in-field amplitude time slice representations of the entire data set in real time as each successive instrument swath was recorded. The location of the GPR survey area is shown on Figures 1 and 9.

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, after applying a 2D-migration algorithm, by averaging data within successive 1.2ns (two-way travel time) windows (e.g. Linford 2004). An average sub-surface velocity of 0.117m/ns was assumed following constant velocity tests on the data, and was used for both migration velocity field and the time to estimated depth conversion. Each of the resulting time slices, shown as individual greyscale images in Figures 11 and 12, therefore represents the variation of reflection strength through successive ~0.06m intervals from the ground surface. Further details of both the frequency and time domain algorithms developed for processing this data, including the variable hyberbola velocity model used for the migration can be found in Sala and Linford (2010).

RESULTS

Area 1 – The West Lawn

i) Background

Historical mapping and contemporary engravings indicate the presence of the Outer Court of the Jacobean House in this area (Drury 2010), prior to its demolition when the house was reduced in size by Sir John Vanburgh in 1721. The house was connected to the London Road by a tree-lined approach from a bridge across the Cam, which may also survive in this area. A carriage turning circle was also added directly in front of the house from c1725, over part of the area previously occupied by the Outer Court (Drury 2010, 39). In addition, the earliest surviving Tudor maps (Drury 2010, 38) show a north-south road crossing the west lawn with an adjacent village settlement, removed during the subsequent development of the house.

ii) Earth resistance data

A graphical summary of the anomalies discussed in the following text, superimposed over the base OS map data, is provided in Figure 13.

A broad east-west aligned high resistance anomaly [r1] runs from the river Cam towards the entrance of the former Outer Court and suggests a substantial approach feature. To the west [r1] appears to terminate at a series of high resistance anomalies [r2], that may indicate a former bridge abutment to carry the approach road over the former artificially straightened course of the river. Variation in the magnitude of response along the course of [r1] suggests only the partial survival of the original metalled surface, although [r1] appears to connect with parallel north-south aligned linear high resistance anomalies at [r3], likely to represent the western boundary of the former Outer Court.

A plethora of high resistance anomalies to the east of [r1/r3] suggest the presence of building remains related to the 17th century house. The precise definition of individual wall alignments, building ranges and room partitions is difficult to fully discern from the earth resistance data, possibly due to extensive overlying deposits of rubble and demolition material. However, the general extent of the building remains and some internal detail is evident including the position of the central gatehouse at [r4] (aligned with [r1]), indications of possible wings or building ranges projecting west from the current house at [r5] and [r6], and a central series of rectangular structures at [r7].

In general, the building remains in this area respect the orientation of the surviving house, although the likely presence of earlier monastic structures is a distinct possibility that could potentially result in a complex and confusing pattern of anomalies. Further processing of the earth resistance data, to enhance deeper responses from near surface anomalies has revealed a rectangular range of buildings at [r8] (Figure 7(B) and (C)). The structures at [r8] are likely to be either a deeply buried, possibly earlier building phase or represent the survival of more substantial wall footings. Within the near surface data an arrangement of concentric circular high resistance anomalies [r9] is interpreted as the traces of a former carriage turning circle, dating from the 18th century Capability Brown designed phase of the grounds after the Outer Court had been removed.

Elements of the Tudor landscape immediately post-dating the monastic phase of Audley End have also been revealed, such as the group of high resistance anomalies [r10-12] that may well represent an earlier SSW-NNE aligned roadway and adjacent buildings depicted on the Tudor mapping (Drury 2010, 38). The Tudor road [r10] is most clearly resolved in the south, where it is not obscured by later activity as it is to the north, and appears better defined in the 1.0m electrode separation data as might be expected from an earlier, more deeply buried causative feature.

The original course of the river Cam in the Tudor period may, possibly, be indicated by a change in background resistance values at [r13], together with perhaps later attempts at canalisation indicated by [r14-16]. The high resistance response at [r16] is particularly suggestive of the deliberate infilling of a former channel with coarse-grained material, such as rubble or sand and gravel.

A number of localised high resistance anomalies [r17-18] may represent former garden features or, perhaps, activity associated with the Special Operations Executive stationed at Audley End during the Second World War (Drury 2010). The circular low resistance anomaly with adjoining linear high resistance responses at [r19] may also represent a previous ornamental garden feature or, possibly, a structure to regulate access from the Cambridge gate.

To the west and northern extremities of the west lawn two narrow linear high resistance anomalies represent either drains or service conduits: [r20] follows a north-south alignment and eventually connects with a more extensive pattern of drainage features [r35] mapped in Area 2, and [r21] runs along side the access road from the house possibly draining into the river Cam. A linear low resistance anomaly [r22] in the same area as [r20] is likely to represent a former drainage ditch or an in-filled trench containing buried services such as a cable or pipe.

iii) GPR survey

The general response of the site to the GPR in this area is most favourable, despite the potential presence of alluvial deposits from the river Cam to the west and the extensive redevelopment of the buildings and gardens. Significant reflections have been recorded through a time window of at least 36ns (approximately 1.8m) and this allows the response from a wide range of buried remains to be discerned. The relative depth information provided by the GPR data set may separate successive building phases over the site, although care should be taken where later, more substantial remains extend to a greater depth cutting through earlier periods of construction.

A graphical summary of significant anomalies identified by the GPR survey is provided in Figure 14.

As would be expected, the very early reflections between 0.0 and 2.4ns (0.0 to 0.12m) are dominated by the response from visible surface features, such as the kerbs of the current access road [gpr1] from the Lion gate and the course of a utility trench [gpr2] clearly distinguishable during the field work as a parch mark around the northern perimeter of the GPR survey area. However, a series of more significant anomalies are also visible in the near-surface data, suggesting a relatively shallow depth of soil above the top of the surviving remains.

Immediately to the west of the current house a complex of building remains are found that clearly correlate with the historic mapping records, where the GPR data provides a considerable enhancement of detail to complement the previous earth resistance survey. The location of the Jacobean Outer Court may clearly be discerned as three conjoined ranges [gpr3-5] aligned with the current house, extending from between ~2.4 and 36ns (0.12 to 1.8m). A series of room divisions can also be traced with each individual range, even to the south where the GPR has imaged remains surviving from 12.0ns (~0.6m) onwards beneath the metalled surface of the modern access road. The South range [gpr5] in particular shows details of the bay window from the south-west corner tower and the wall of the cloister inside the wing of divided rooms.

The central gated entrance through the west range of the former Outer Court is evident as a pair of rectangular anomalies at [gpr6] that most likely represent the gate piers shown with similar dimensions on the engraving of *"A general ground plot"* produced by Winstanley (Drury 2010, 38). Two semi-circular anomalies [gpr7], visible from between

7.2 and 10.8ns (0.36 to 0.54m) may well relate to the northern pair of circular gate lodge towers shown on Winstanley's c1676 *"General Prospect of the Royal Palace of Auydlyene"* (Drury 2010, 38). Evidence for the matching southern pair is more difficult to discern, perhaps due to the apparently shallow depth of the wall foundations supporting the bayed frontage of these towers. Other internal details, such as the circular anomaly [gpr8] in the West range between the gate lodge and little hall, appear at a similar depth between 6.0 and 9.6ns (0.3 to 0.48m) but are difficult to reconcile with the architectural records and historic plans of the site.

A large rectangular anomaly [gpr9; corresponding with r1], with dimensions of 70m x 15m, is visible between 2.4 and 20.4ns (0.12 to 1.02m) and follows an alignment with the gate house that supports the suggestion of a metalled carriage drive leading to the Outer Court from a lost bridge over the Cam. Similar to the earth resistance data, the metalled surface represented by [gpr9] ends abruptly against a north-south orientated wall [gpr10] approximately 15m before the gate house entrance, although two more subtle linear anomalies [gpr11 and 12] appear to extend on to meet the Outer Court gate house. Other anomalies, such as the possible drain run [gpr13] also respect [gpr10], although the approximate fall over the length of [gpr13] appears to be 0.3m from the Cam towards the house, perhaps indicating a water supply conduit. This may, therefore, suggest a more complicated arrangement of drainage collects or water supply associated with the house. The western extent of [gpr13] also appears to respect another potential drain (see [gpr33] below) and falls short of the current course of the river.

Whilst some wall-type anomalies [gpr14] are found closer to the Cam, where [gpr9] would extend to meet the river, these are not complete enough to necessarily suggest the location of a bridge crossing. It is also unclear how [gpr15] relates to [gpr9]; the two anomalies certainly coincide, although on different orientations suggesting [gpr15] may represent the partial course of a road or pathway removed during the later landscaping of the site and construction of [gpr9]. To the east the alignment of [gpr9] would extend through the gate house piers at [gpr6] and meet the centre of the carriage turning circle identified in the earth resistance survey [r9]. This latter element, dating from the early 18th century following the removal of the North and South ranges of the Outer Court, is also replicated in the GPR data at [gpr16] and extends from between 1.2 and 10.8ns (0.06 and 0.54m). The very near surface data shows [gpr16] as a pair of concentric sub-circular bounding walls, with some evidence for a hard surface occurring from 4.8ns (0.24m onwards).

The interior of the Outer Court also contains evidence of extensive building remains apparently pre-dating the Jacobean phases of development recorded on the historic plans. These buildings are distinguished from the Outer Court by their location and alignment, rather than a significant difference in the burial depth or maximum extent of the associated anomalies in the radar data. This suggests the individual phases are heavily inter-cut with one another following the demolition and re-modelling of the previous buildings. A central range with interior subdivisions [gpr17] extends on an east-west alignment across the Outer Court and joins a more fragmented wing [gpr18] running north-south. Both [gpr17] and [gpr18] are visible, in part, through the full depth range of the data from between 1.2 and 36ns (0.06 to 1.8m) and evidence for a floor layer, or possible accumulation of collapsed rubble is found within an interior room at [gpr19] from 10.8ns (0.54m) onwards. Other, more fragmented linear anomalies [gpr20-23] may well be related to [gpr17] and [gpr18], although there is some suggestion that these potentially earlier phases may have been partially robbed out. For example, by 22.8ns (1.14m) [gpr20] extends to meet [gpr18] but appears to be truncated from the east in the overlying time slices. This suggests that [gpr20] either represents a sloping wall, falling by approximately 0.85m across its length of 25m, or as the subtle ditch-type negative anomaly at 12ns suggests, part of this wall was removed during the construction of the Outer Court.

Together with the corresponding anomalies from the earth resistance survey, [gpr17-23] appears to provide evidence for buildings related to either the Tudor House or, perhaps, the earlier remains of the monastic abbey. Distinguishing the different phases of building to the north in the vicinity of [gpr3] and beneath the metalled access route immediately in front of the standing building is more complicated, as the fragmented anomalies [gpr24 and 25] found in both areas are difficult to fully interpret. The group of wall-type responses found partially under the modern road at [gpr26] could also represent building remains, although their parallel alignment might also suggest a continuation of the road running in front of the Outer Court to the south.

A second group of parallel linear anomalies [gpr27] suggestive of a road route appears from 9.6ns (0.48m) underlying [gpr10] and heading south on a different alignment to the Outer Court. This anomaly largely replicates the course of [r10], interpreted as the Tudor road, with the wall-type responses [gpr28-31] possibly representing the partial remains of contemporary buildings from the earlier village along this route.

Further to the west of the GPR survey area an extensive network of linear drains are found extending across the lawn. The main drainage conduit [gpr32] (replicated as [r20] in the earth resistance results) is apparent from 9.6ns (0.48m) and falls approximately 0.2m from north to south, although some indication of the trench appears in the very near surface data, perhaps due to some subtle topographic expression. A number of linear anomalies [e.g. groups at gpr33 and 34] extend from [gpr32] to the west and, most likely, represent land drains feeding into the main conduit. The two main groups at [gpr33 and 34] extend approximately 30m west from [gpr32], but [gpr35] continues for quite a considerable distance cutting across the Tudor road suggesting differing phases of construction. An additional drain [gpr36] appears to run on a slightly different alignment at a greater depth with a fall from 0.6 to 0.9m from north to south. Both [gpr32] and [gpr36] converge with [gpr2] and [gpr13] in the north-west corner of the survey area where the linear anomalies appear to continue west towards the river and north across the road. An additional spur, heading west to the river, is found at [gpr37] and may well connect to both [gpr32] and [gpr36] at this point.

In the south-west corner of the survey area a small right angled anomaly [gpr38] converges with [gpr32] at the southern edge of the survey before turning abruptly west towards the river. Comparison with a plan of the known drainage conduits from the site (Field 1976) shows a drain following this course in this location. It also seems likely that the linear anomaly [gpr39] heading to the east might also represent a further drain from its apparent shared alignment with [gpr38]. Internal linear structures enclosed by [gpr38] may represent additional drains cut to empty into the river immediately to the west, suggesting this slightly lower lying area of the lawn required additional drainage measures.

The area of lawn adjacent to the river also contains a number of more amorphous anomalies suggestive of fluvial deposits, most likely related to either a previous course of the Cam or construction of deliberate ponds. For example, [gpr40] to the north-west partially describes a sub-rectangular anomaly that shelves inward from between 8.4 and 22.8ns (0.42 and 1.14m) and perhaps represents the lining of a former pond. Beyond a depth of 1.14m [gpr40] gives way to a more diffuse anomaly [gpr41] that possibly indicates the previous course of the river bank prior to canalisation. The location of the land drains at [gpr33] in the centre of [gpr40] most probably represents a deliberate attempt to control the soil moisture conditions in an area of former ponding that might be more liable to flooding.

Area 2 – North Lawn and Elysian Garden

i) Background

Historic mapping suggests the presence of water features, a variety of formal garden layouts and a few small isolated buildings in this area during the Tudor and Jacobean periods, including a structure described as the Keeper's Lodge (Drury 2010, 39). A chain of monastic fish-ponds depicted on the Tudor mapping survive in the north-east and provide a useful point of reference when combining the historic map regression with more recent survey data. This area also contains the Elysian Garden, covered by an earlier geophysical survey in 1994 in an attempt to trace the course of grassed-over paths to facilitate the accurate reinstatement of the former garden design.

ii) Earth resistance data

Some caution is required when interpreting the data from this area due to the presence of large trees which may have caused localised increases in resistance due to absorption of water into root systems or physical obstruction of electrode contact with the soil. Observations of the anomalies recorded during the dry conditions in May 2010 suggests some large specimen trees may have been deliberately planted over earlier structures in an attempt to partially disguise them.

A concentration of high resistance rectangular cells [r23] suggests a complex of buried building ranges and walled yards directly to the west of the Victorian service range of

Audley End House, perhaps the remains of the "Brewhouse Yard" shown on the 1688 Winstanley plan (Drury 2010, 38). To the west of [r23] a linear high resistance anomaly [r24] may represent a continuation of the earlier north-south Tudor road detected at [r10] in Area 1 and the less well defined responses [r25], extending west from [r24] towards Stable Bridge, may relate to either the former northern boundary of the outermost walled courtyard enclosure or, perhaps, a road to the river crossing (Warren 1753). Other anomalies at [r26 and r27] may indicate further buildings aligned along the western side of the Tudor road, but these responses may also be caused, in part, by the large mature trees present in this area.

A series of drainage conduits [r28] and service trenches [r29-r30], defined by linear high and low resistance anomalies respectively, pass from the Victorian service range towards the river. Preliminary results from a survey conducted with an electromagnetic soil conductivity meter suggest [r29-r30] are likely to represent modern services whilst [r28] may indicate a high resistance response from a stone-lined drainage or water supply conduit of earlier, possibly even monastic origin (C Leech pers. comm., Field 1976).

Low resistance anomalies at [r31] may indicate a series of ponds, perhaps related to one of the many phases of enclosed wilderness or grove type garden including water features suggested by the historic mapping in this area prior to the Capability Brown landscape (Warren 1753). However, the variable nature of the resistance response surrounding this area is difficult to fully interpret and may reflect the more general disturbance from former landscaping, planting and earlier water features.

A line of possible tree planting pits [r33] appears to bound [r31] to the south, together with a strongly resolved linear high resistance anomaly at [r34] that may represent a walled boundary to the north. The area covered by [r31] may be further enclosed to the east by the Tudor road [r32], although this is rather indistinct to the north, and to the west by a herringbone pattern of land drains [r35], connected to the wider drainage network [r20-22]. The drains were interpreted as medieval culverts by an earlier measured survey, but the geophysical survey has mapped this system more extensively than before (Field 1976), The location of a former large pond may be indicated by the low resistance anomaly at [r36] and it is possible that the high resistance responses at [r37] represent the remains of the monumental arch-way entrance to the Elysian Garden, known to have existed in this area (Sutherill M 1997). The chain of medieval fish-ponds surviving from the monastic period is also visible as a series of oblong areas of mixed response [r38-r40], suggestive of varying in-filling material, apparently linked by narrow interconnecting channels shown as linear low resistance

The response to former pathways in the Elysian Garden are probably indicated by a series of curvilinear anomalies [r41-44], some of which [r41] are still partially visible as a slight raised earthwork and grass-mark features and can be traced south for 100m where it runs along the boundary of a now vegetated area [r42]. A second possible meandering path has been detected at [r43] and appears to correspond with drawings of the original garden design (Sutherill M 1997). Further more intermittent anomalies at [r44] are also, tentatively, interpreted as former paths. A number probable drainage conduits running into the River Cam have also been detected at [r45] together with several low resistance linear responses [r46], likely to represent modern services. More generalised areas of high resistance at [r47-50] may relate to elements of the former garden, for example the location of the garden pavilion ("Turkish Tent") shown on contemporary paintings of the Elysian Garden possibly associated with the polygonal low resistance anomaly within an area of higher response found at [r47] (Sutherill M 1997; Drury 2010, 34 'The cascade in the Elysian Garden' by William Tomkins, c. 1788).

An area of mixed higher background response cut by numerous narrow linear low resistance anomalies is found at [r51-53], possibly representing either geological variation or a combination of drains and ditched enclosure boundaries perhaps cut through artificially made-up ground. However, the increased background resistance in this area does not suggest the presence of building remains. The pronounced curvilinear (semi-circular) high resistance anomaly at [r54] marks the boundary earthwork bank constructed around the modern visitor car-park.

Area 3 – Environs of Place Pond

i) Background

Historic mapping evidence suggest the current water feature at Place Pond is the much reduced eastern end of a larger elongated pond, already established in the monastic period, which later served as a large ornamental lake. A courtyard complex of buildings is also depicted on the Tudor mapping to the south of the pond, immediately adjacent to boundary wall and close to the gateway from the park for the road to Saffron Walden. An additional north-south road is also shown following inside of the park boundary wall, although all of these features, apart from the remnants of the earlier pond, have been removed through subsequent remodelling.

ii) Earth resistance data

The linear low resistance anomalies [r55-56], and lines of unrecorded readings due to the compacted bare earth surfaces or metalled road surface, are due to modern vehicle tracks associated with the overspill car-parking and events access to the south of Place Pond. The modern track at [r55] appears to cut across and interrupt a rectilinear area of high resistance response [r57] within which a number of stronger linear high resistance anomalies are apparent, suggestive of possible building remains as shown by the Tudor period mapping. A longer and wider equally pronounced area of high resistance [r58] runs orthogonal to [r57] and again contains suggestions for localised concentrations of building rubble demolition material. However, these anomalies are not sufficiently well resolved or fully described within the extents of the survey to reveal more than an impression of the demolished building complex.

To the east a group of linear high resistance anomalies [r59] shares a similar alignment to [r58] and varies from a triple to a more intermittent double or single linear response as at heads north across the current survey coverage, possibly indicating the former boundary wall of the Tudor period park, before the later expansion of both the house and surrounding parkland. The variation in response along the course of [r59] may be due to the presence of the former road running around the boundary wall with a possible entrance gateway found, perhaps, at [r60] to accommodate the road to Saffron Walden.

A high resistance linear anomaly at [r61], running into the pond area from the tributary stream of the Cam to the north, probably represents a water supply conduit. A similar anomaly [r62] is present exiting the south side of the pond corresponding to a visible drain channelling water from Place Pond towards the "ha ha" ditch separating the formal garden to the east of Audley End House from the wider parkland. A narrow low resistance linear anomaly seen clearly cutting through higher resistance deposits at [r63] possibly represents a service trench of more recent origin.

No obvious evidence for the dovecote depicted on the Tudor mapping to the north of Place Pond was found, apart from a number of slight increases in resistance at [r64 and r65]. However, it is possible that such a structure may only have been added to the Tudor mapping for reasons of artistic invention, or may well have been too insubstantial to leave remains detectable by geophysical means.

CONCLUSION

The geophysical survey results have successfully revealed the location of substantial building remains under the west lawn, no doubt representing the former Outer Court of the Jacobean house at its grandest and most palatial extent before it was reduced in size to current proportions. These anomalies indicate the remains of the Outer Court buildings extended for a distance of some 90m from the current house and exhibit considerable complexity, suggesting a series of construction phases. A wide avenue approach has also been resolved leading from the Outer Court buildings to a former crossing point over the River Cam. The complexity of the building remains has been resolved by the differential response recorded by the near-surface and deeper penetrating earth resistance data sets further complemented by the subsequent GPR coverage, allowing more recent elements such as the carriage turning circle to be separated from more substantial earlier building remains.

The geophysical survey also serves to verify much of the historic mapping evidence. It confirms the survival and location of many structures in relation to modern mapping and argues against consideration of the contemporary records as only "design plans" for works in progress, thus allowing for a much enhanced understanding of the landscape history of Audley End. In this regard, the large scale GPR survey has been particularly valuable, providing highly detailed images of the surviving building remains to a depth of approximately 1.8m and confirming the presence of many architectural features evident from contemporary depictions of the site that could not be resolved through the earth resistance data alone.

Additional evidence has also been obtained for elements of the landscape design in the wider parkland around the house. Although it was by no means certain that original garden features would survive in a detectable form due to subsequent alteration of the design, the wider earth resistance survey has revealed a wealth of information that reflects the multi-phased development of the parkland. Despite the inherent complexity of these results, some particular phases of the gardens have been detected including ponds, pathways and built structures associated with the late 18th century Elysian Garden and possible indications of an earlier grove type layout of the Jacobean period further to the south. The geophysical survey has also revealed remains of the earlier history of Audley End in the immediate post-dissolution period, prior to the development of the later house and associated designed landscape. These include the possible former monastic home grange inherited from the earlier abbey situated in the environs of Place Pond, the original boundary of the park and the remains of a roadside settlement swept away by the subsequent expansion of Audley End in the early 17th century. Evidence for alteration of the Cam has also been revealed, including the possible course of the river during the medieval period and subsequent canalisation contemporary with the Jacobean Outer Court.

LIST OF ENCLOSED FIGURES

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

REFERENCES

Cocroft, W 2010 *'Audley End, Essex, Historic Landscape Investigation, Research Execution Stage 2 Project Design. A Project Design for the first stage of work in support of the interpretation and presentation of the historic designed landscape.'*. English Heritage, Conservation and Protection, Research Department unpublished project design.

Drury, P 2010 *Audley End*, London, English Heritage.

Field, B 1976 Audley End, survey of underground conduits, drawing No. AS3/8, Department of the Environment, Ancient Monuments Branch.

Geological Survey of Great Britain (England and Wales) 1952 Saffron Walden, England and Wales Sheet 205, Drift edition. One inch geology map series., Ordnance Survey, Chessington, Surrey.

Gonzalez, R C and Wintz, P 1987 *Digital Image Processing*, 2nd ed. edn. Reading, MA, Addison-Wesley.

Linford, N 2003 *'West Heslerton, North Yorkshire: Report on Geophysical Survey, September 2002'*. English Heritage Centre for Archaeology Report Series 67/2003.

Linford, N 2004 'From Hypocaust to Hyperbola: Ground Penetrating Radar surveys over mainly Roman remains in the U.K.'. *Archaeological Prospection*, 11 (4), 237-246.

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 *Processing stepped frequency continuous wave GPR systems to obtain maximum value from archaeological data sets*. In Crocco, L, Orlando, L, Persico, R and Pieraccini, M (Editors), Proceedings of the XIII International Conference on Ground Penetrating Radar Lecce (Italy), 21-25 June 2010 2010 (Lecce: IEEE).

Scollar, I, Tabbagh, A, Hesse, A and Herzog, I, Eds. 1990 *Archaeological Prospecting and Remote Sensing*. Cambridge.

Soil Survey of England and Wales 1983 Soils of England and Wales: Sheet 6 - South East England, 1:250,000 soil map. Harpenden, Lawes Agricultural Trust.

Sutherill M 1997 'The buildings of the Elysium Garden at Audley End'. *The Georgian Group Journal*, 7, 94-104.

Warren, F 1753 Survey of Audley End Park, unpublished historic map, (NMR negative number A(CN)9811/20).

ANNEX 1: NOTES ON STANDARD PROCEDURES

1) Earth Resistance Survey

Each 30 metre grid square is surveyed by making repeated parallel traverses across it, all aligned parallel to one pair of the grid square's edges, and each separated by a distance of 1 metre from the last; the first and last traverses being 0.5 metres from the nearest parallel grid square edge. Readings are taken along each traverse at 1 metre intervals, the first and last readings being 0.5 metres from the nearest grid square edge.
Unless otherwise stated the measurements are made with a Geoscan RM15 earth resistance meter incorporating a built-in data logger, using the twin electrode configuration with a 0.5 metre mobile electrode separation. As it is usually only relative changes in earth resistance that are of interest in archaeological prospecting, no attempt is made to correct these measurements for the geometry of the twin electrode array to produce an estimate of the true apparent resistivity. Thus, the readings presented in plots will be the actual values of earth resistance recorded by the meter, measured in Ohms (Ω). Where correction to apparent resistivity has been made, for comparison with other electrical prospecting techniques, the results are quoted in the units of apparent resistivity, Ohm-m (Ωm).

Measurements are recorded digitally by the RM15 meter and subsequently transferred to a portable laptop computer for permanent storage and preliminary processing. Additional processing is performed on return to Fort Cumberland using desktop workstations.

2) Magnetometer Survey

Each 30 metre grid square is surveyed by making repeated parallel traverses across it, all parallel to that pair of grid square edges most closely aligned with the direction of magnetic N. Each traverse is separated by a distance of 1 metre from the last; the first and last traverses being 0.5 metre from the nearest parallel grid square edge. Readings are taken along each traverse at 0.25 metre intervals, the first and last readings being 0.125 metre from the nearest grid square edge.

These traverses are walked in so called 'zig-zag' fashion, in which the direction of travel alternates between adjacent traverses to maximise survey speed. Where possible, the magnetometer is always kept facing in the same direction, regardless of the direction of travel, to minimise heading error. However, this may be dependent on the instrument design in use.

Unless otherwise stated the measurements are made with either a Bartington Grad601 or a Geoscan FM36 fluxgate gradiometer which incorporate two vertically aligned fluxgates, one situated either 1.0m or 0.5 metres above the other; the bottom fluxgate is carried at a height of approximately 0.2 metres above the ground surface. Both instruments incorporate a built-in data logger that records measurements digitally; these are subsequently transferred to a portable laptop computer for permanent storage and preliminary processing. Additional processing is performed on return to Fort Cumberland using desktop workstations.

It is the opinion of the manufacturer of the Geoscan instrument that two sensors placed 0.5 metres apart cannot produce a true estimate of vertical magnetic gradient unless the bottom sensor is far removed from the ground surface. Hence, when results are presented, the difference between the field intensity measured by the top and bottom sensors is quoted in units of nanotesla (nT) rather than in the units of magnetic gradient, nanotesla per metre (nT/m).

3) Resistivity Profiling

This technique measures the electrical resistivity of the subsurface in a similar manner to the standard resistivity mapping method outlined in note 1. However, instead of mapping changes in the near surface resistivity over an area, it produces a vertical section, illustrating how resistivity varies with increasing depth. This is possible because the resistivity meter becomes sensitive to more deeply buried anomalies as the separation between the measurement electrodes is increased. Hence, instead of using a single, fixed electrode separation as in resistivity mapping, readings are repeated over the same point with increasing separations to investigate the resistivity at greater depths. It should be noted that the relationship between electrode separation and depth sensitivity is complex so the vertical scale quoted for the section is only approximate. Furthermore, as depth of investigation increases the size of the smallest anomaly that can be resolved also increases.

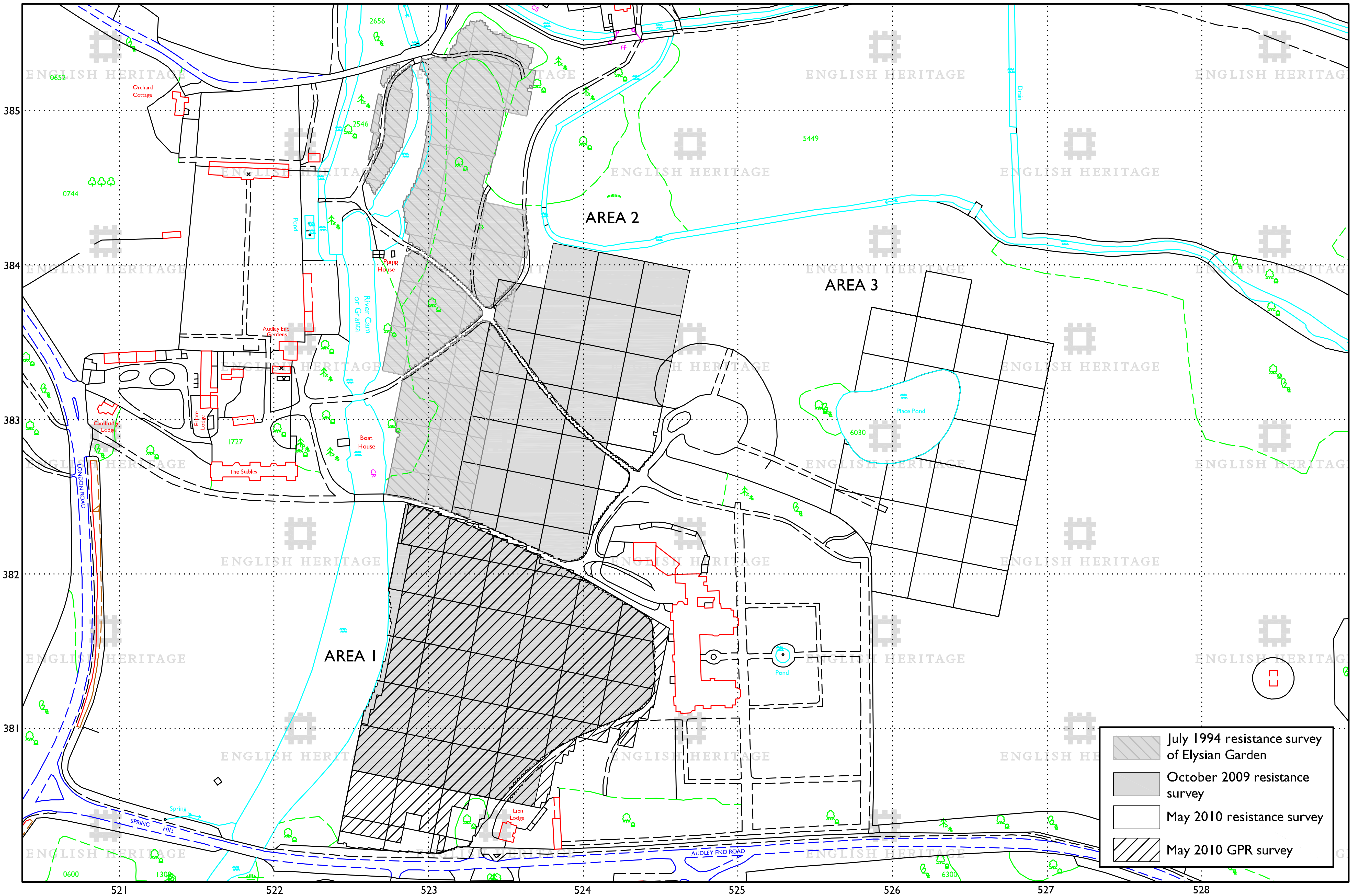
Typically a line of 25 electrodes is laid out separated by 1 or 0.5 metre intervals. The resistivity of a vertical section is measured by selecting successive four electrode subsets at increasing separations and making a resistivity measurement with each. Several different schemes may be employed to determine which electrode subsets to use, of which the Wenner and Dipole-Dipole are typical examples. A Campus Geopulse earth resistance meter, with built in multiplexer, is used to make the measurements and the Campus Imager software is used to automate reading collection and construct a resistivity section from the results.

Figure 1

AUDLEY END HOUSE AND PARK, ESSEX

Location of geophysical surveys July 1994, October 2009, May 2010

TL 5238



0 150m
1:2500

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Figure 2

AUDLEY END HOUSE AND PARK, ESSEX

Location of earth resistance surveys July 1994, October 2009, May 2010

TL 5238

0 150m
1:2500

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Figure 3

Twin electrode earth resistance survey combined results from Areas 1 and 2, July 1994, October 2009 and May 2010

Traceplot of despiked and edgematched 0.5m mobile electrode separation data

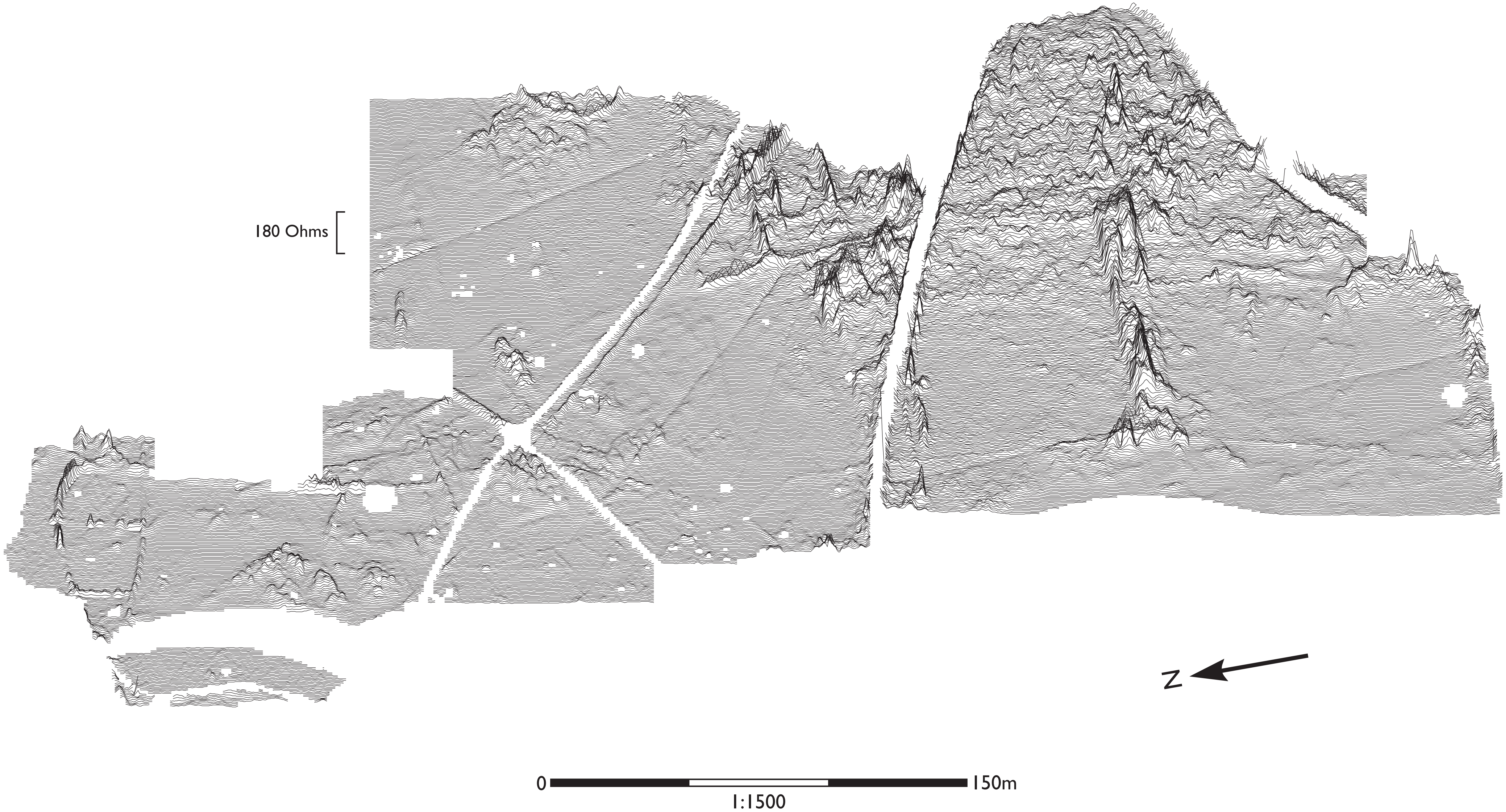

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Figure 4

Twin electrode earth resistance survey combined results from Areas1 and 2 , July 1994, October 2009 and May 2010

Equal area greyscale plot of despiked and edgematched 0.5m mobile electrode separation data

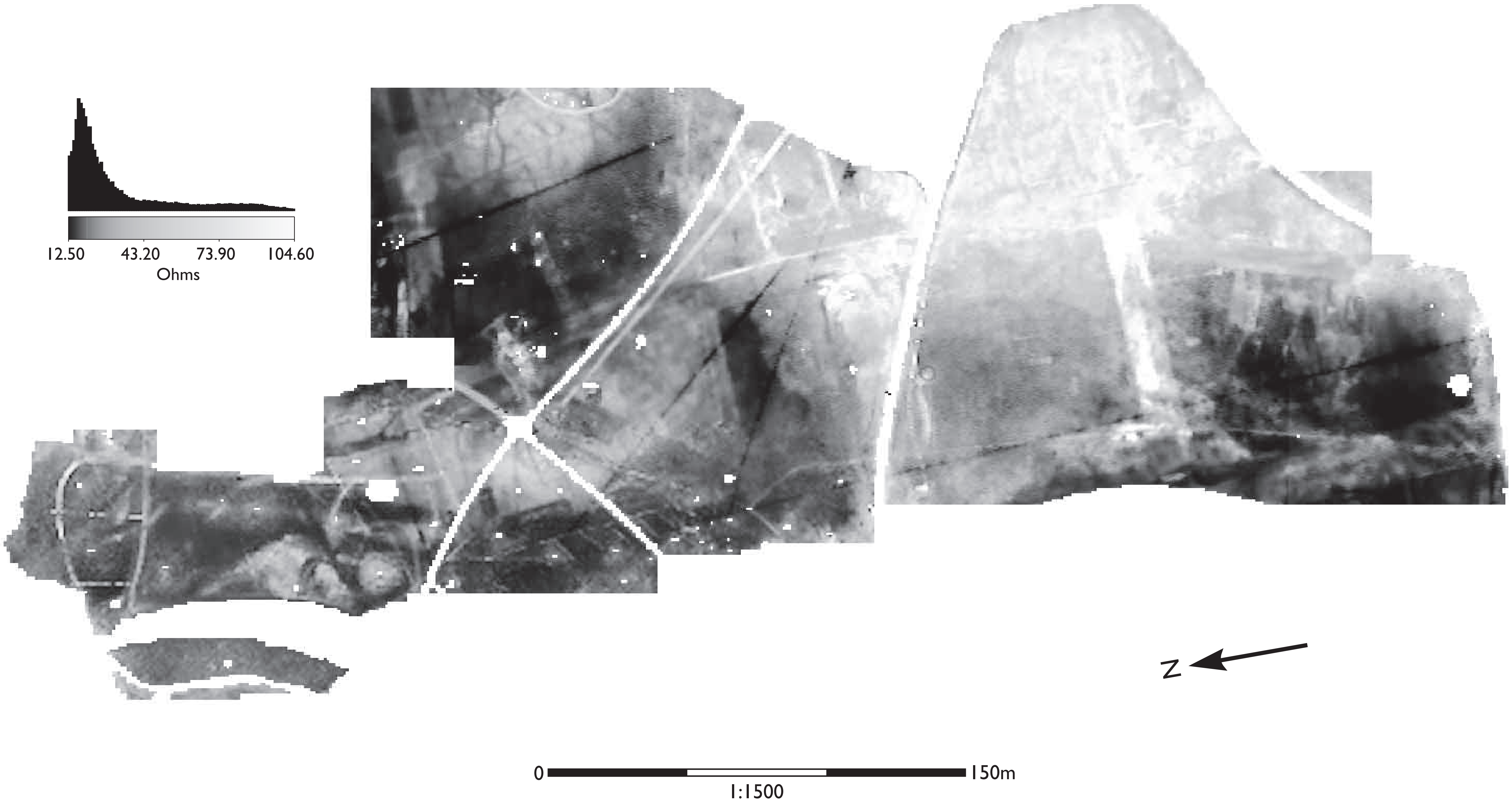

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Figure 5

Twin electrode earth resistance survey combined results from Areas 1 and 2, October 2009 and May 2010

Traceplot of despiked and edgematched 1.0m mobile electrode separation data

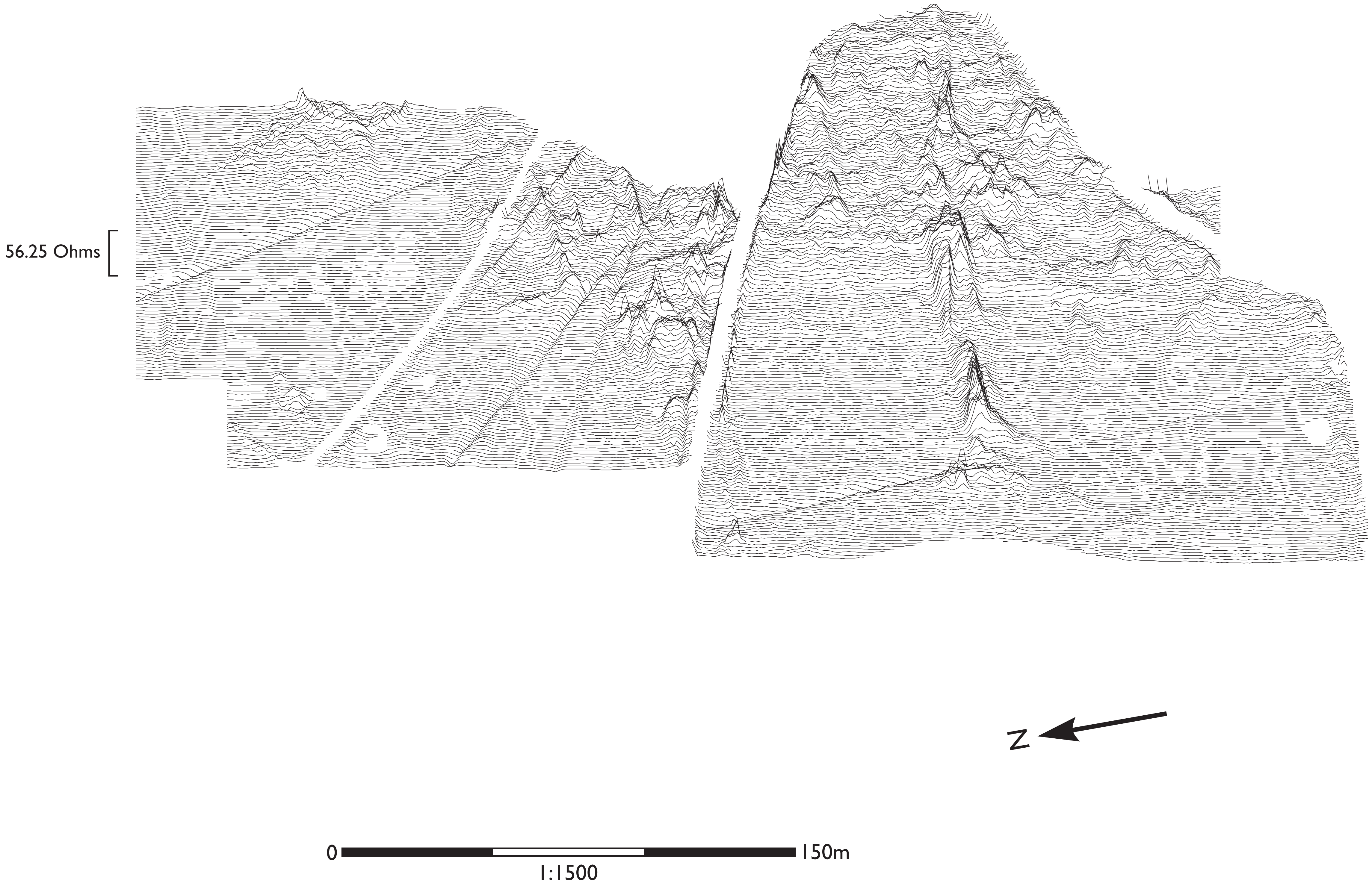

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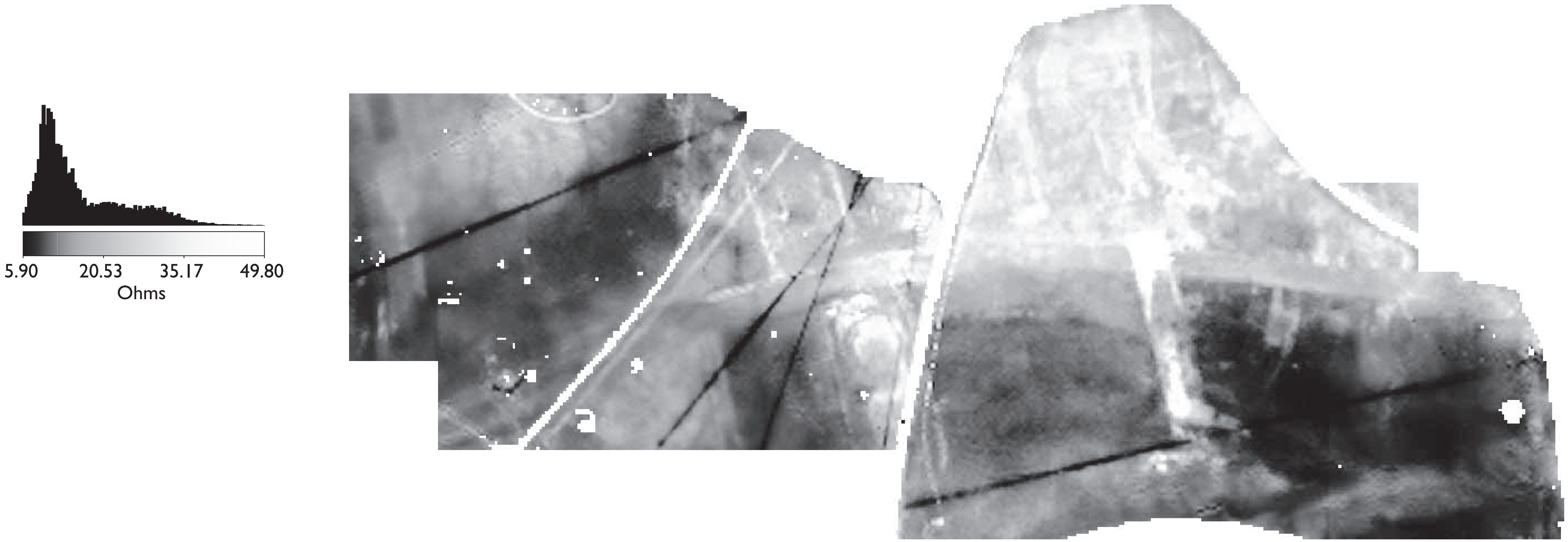
Figure 6

AUDLEY END HOUSE AND PARK, ESSEX

Twin electrode earth resistance survey combined results from Areas1 and 2, October 2009 and May 2010

Equal area greyscale plot of despiked and edgematched 1.0m mobile electrode separation data



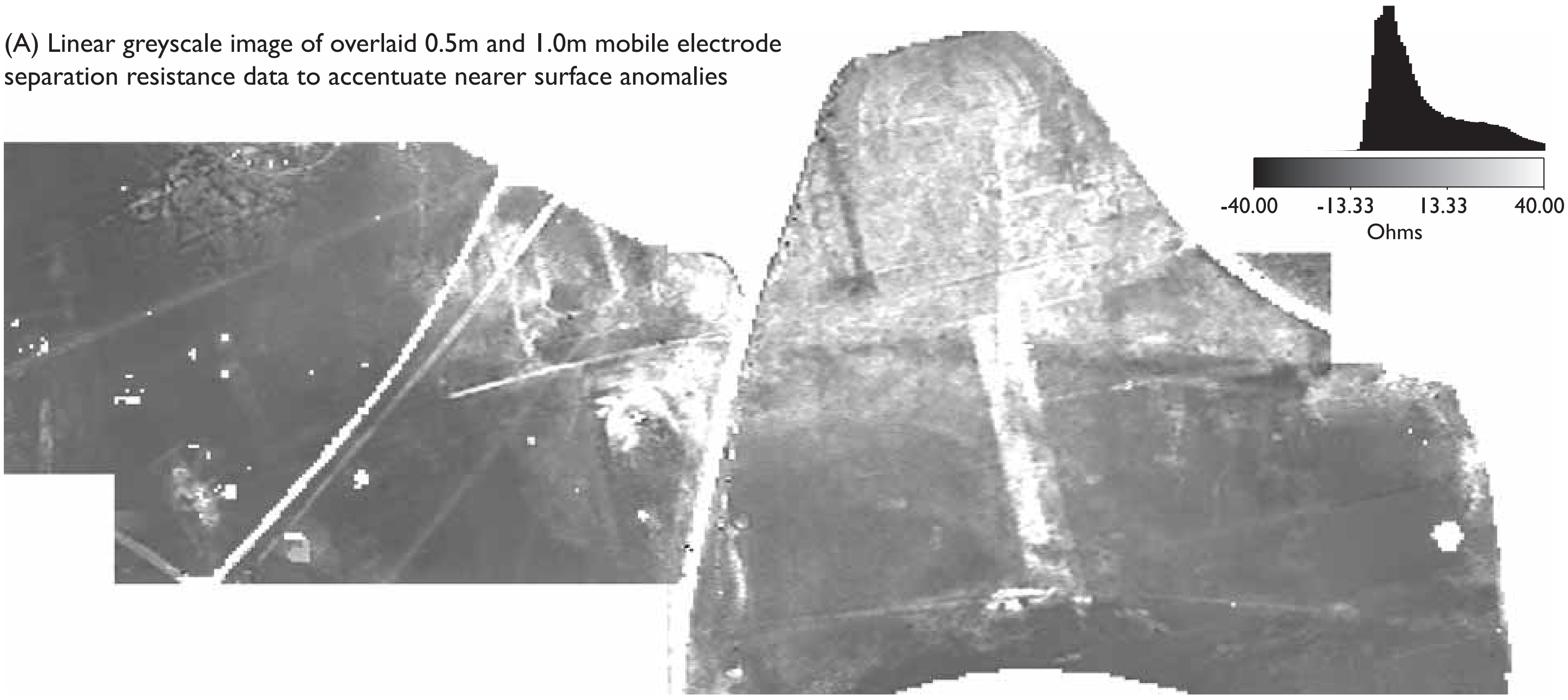
N

0 150m
1:1500

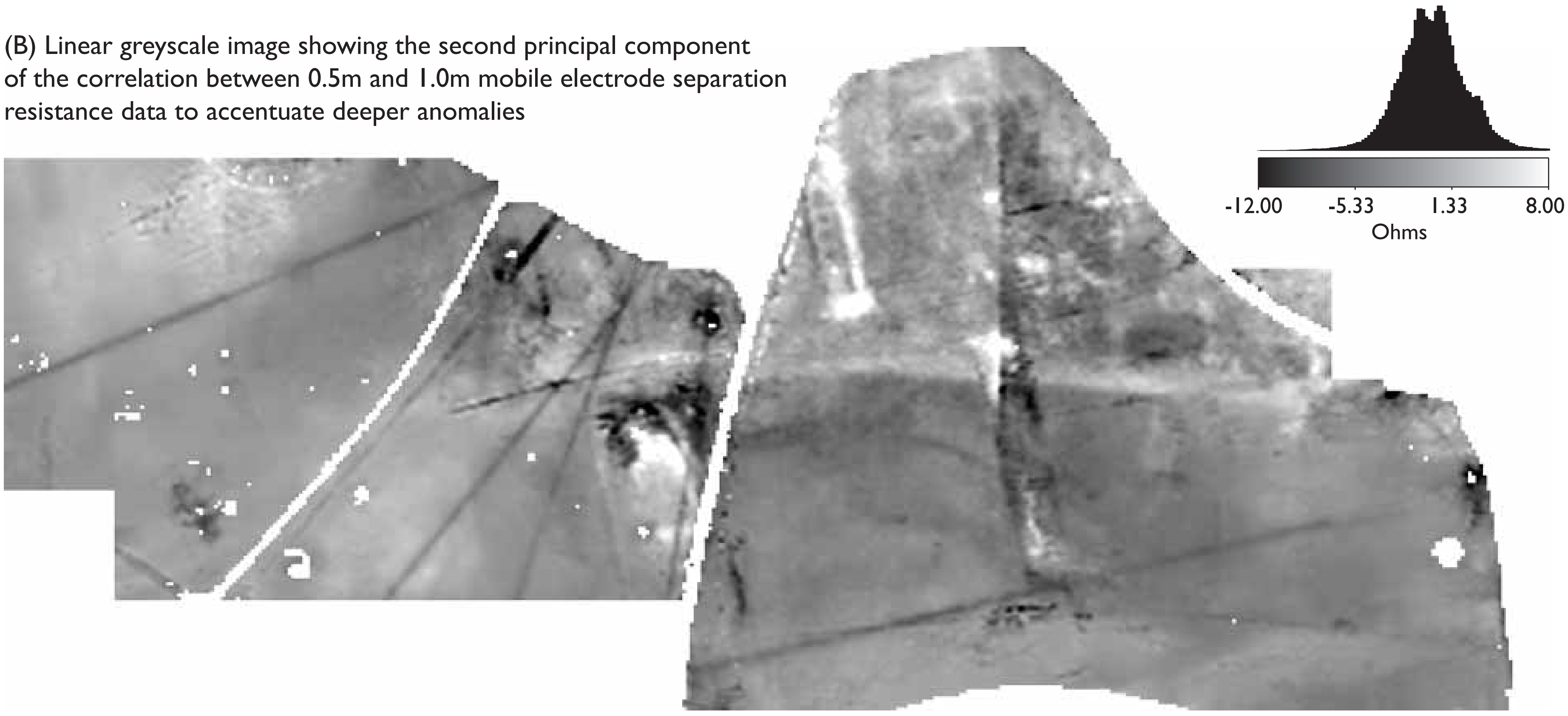
AUDLEY END HOUSE AND PARK, ESSEX

Processed multiplexed earth resistance data Areas 1 and 2

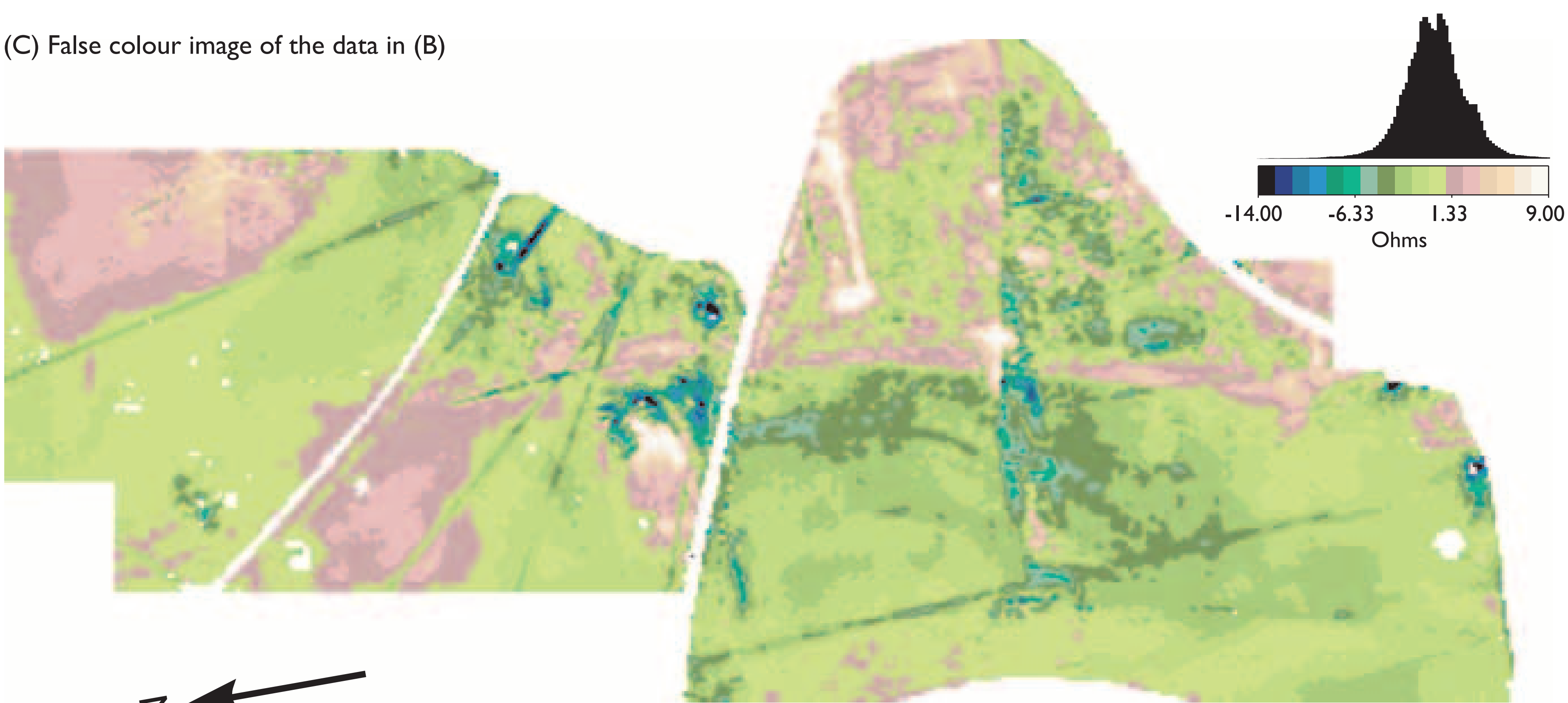
(A) Linear greyscale image of overlaid 0.5m and 1.0m mobile electrode separation resistance data to accentuate nearer surface anomalies



(B) Linear greyscale image showing the second principal component of the correlation between 0.5m and 1.0m mobile electrode separation resistance data to accentuate deeper anomalies



(C) False colour image of the data in (B)



N

0 150m

1:1750

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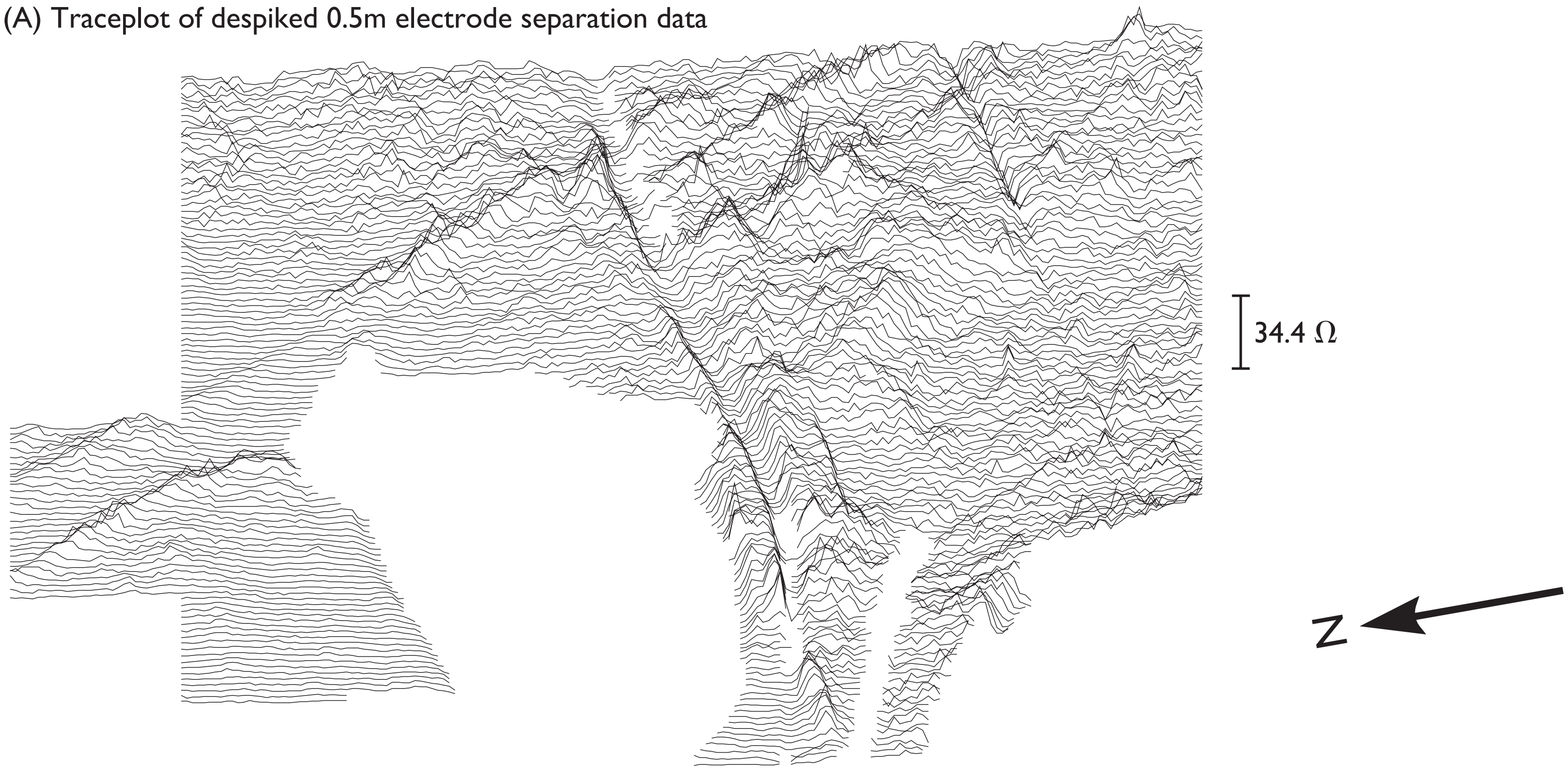
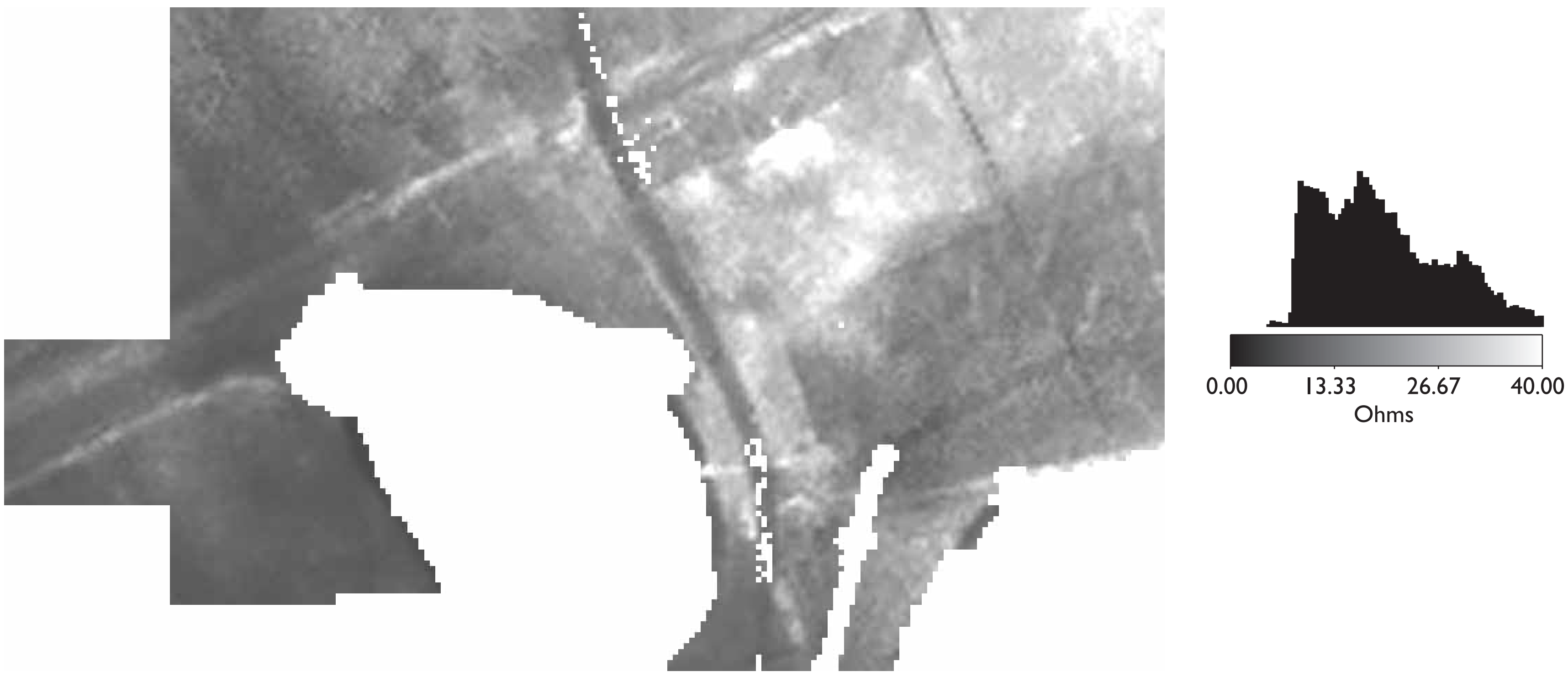
Earth resistance survey of Area 3, Place Pond, May 2010

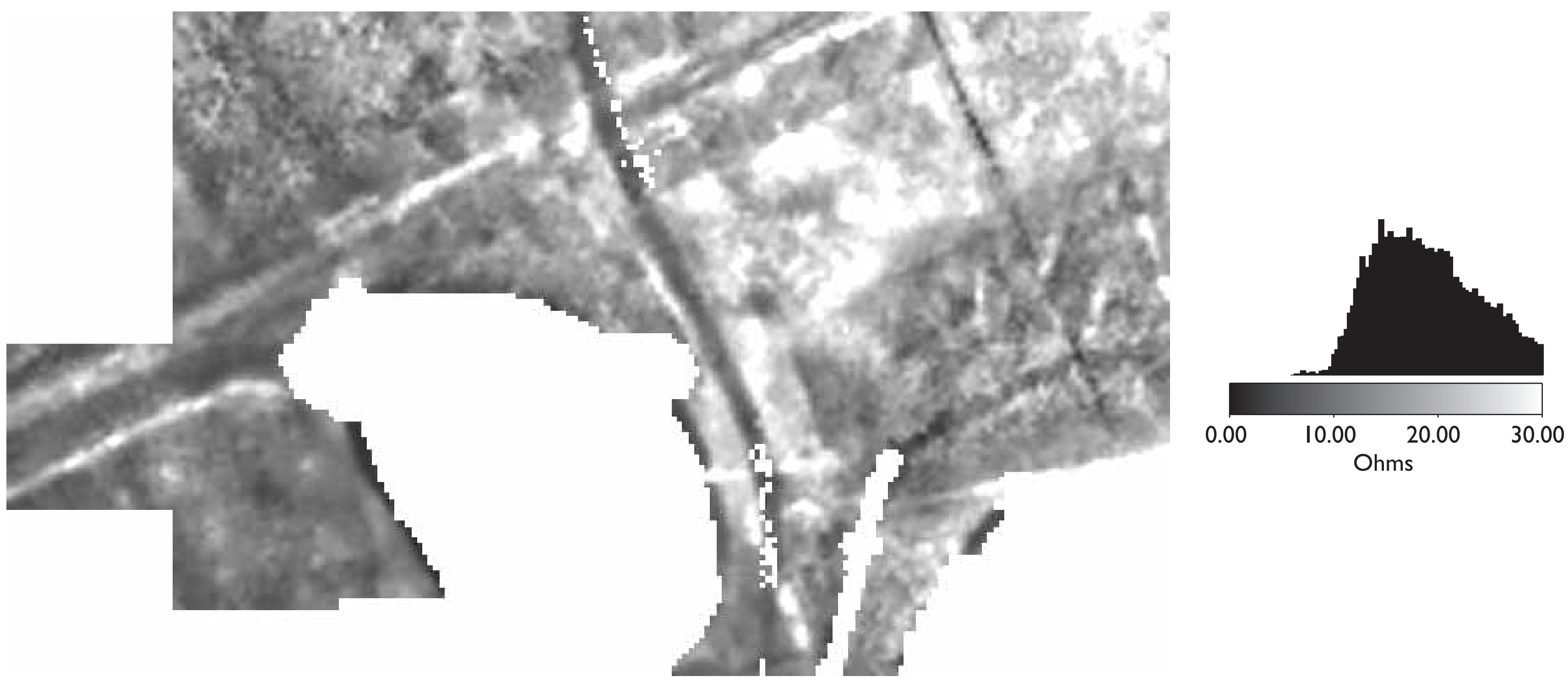
(A) Traceplot of despiked 0.5m electrode separation data



(B) Linear greyscale image of despiked 0.5m electrode separation data



(C) Linear greyscale image of Wallis enhanced 0.5m electrode separation data



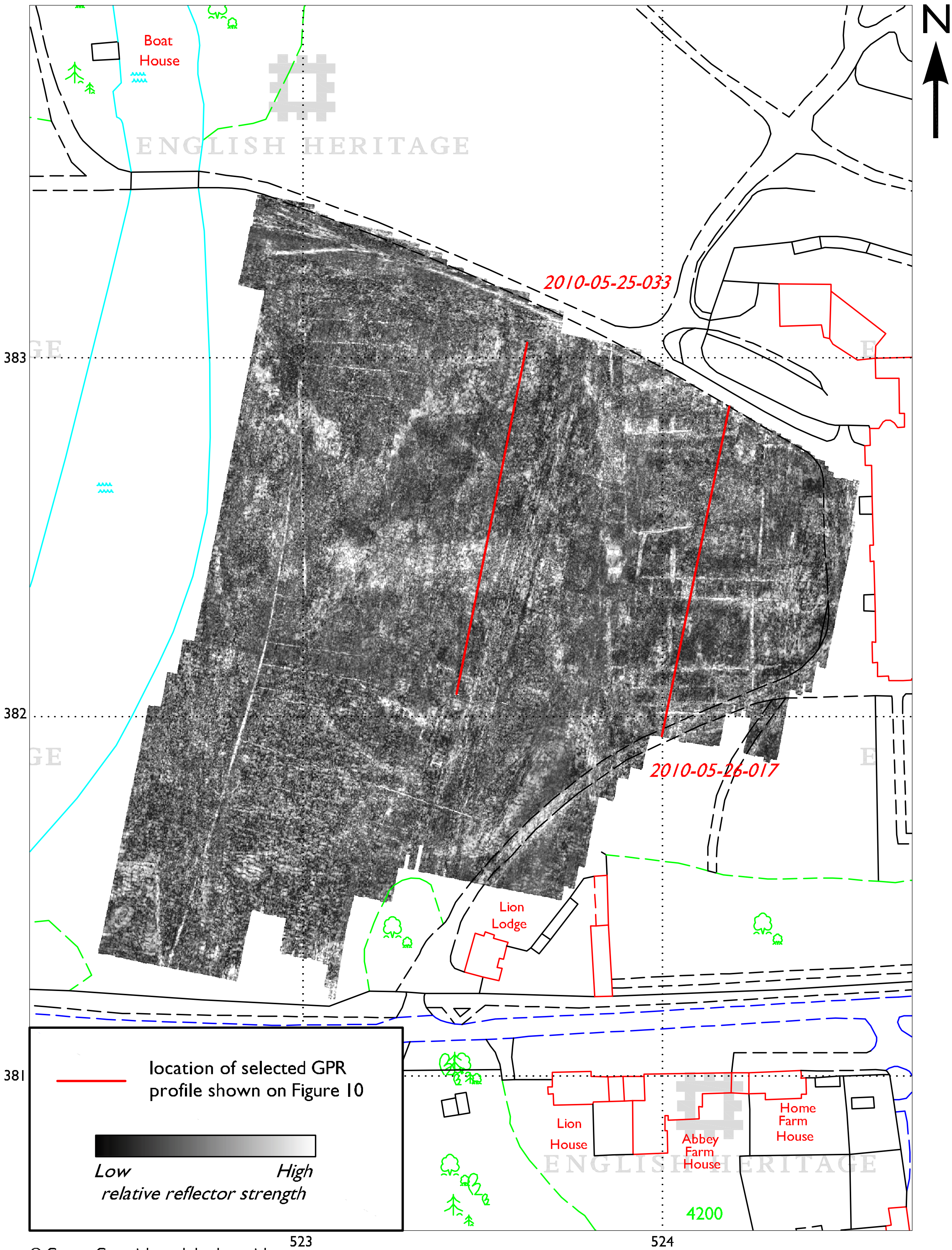
0 90m

1:1250

Figure 9

AUDLEY END HOUSE AND PARK, ESSEX
GPR Amplitude time slice between 12.0 to 13.2ns (0.6 to 0.66m), Area 1, May 2010

TL 5238



0 60m

1:1250

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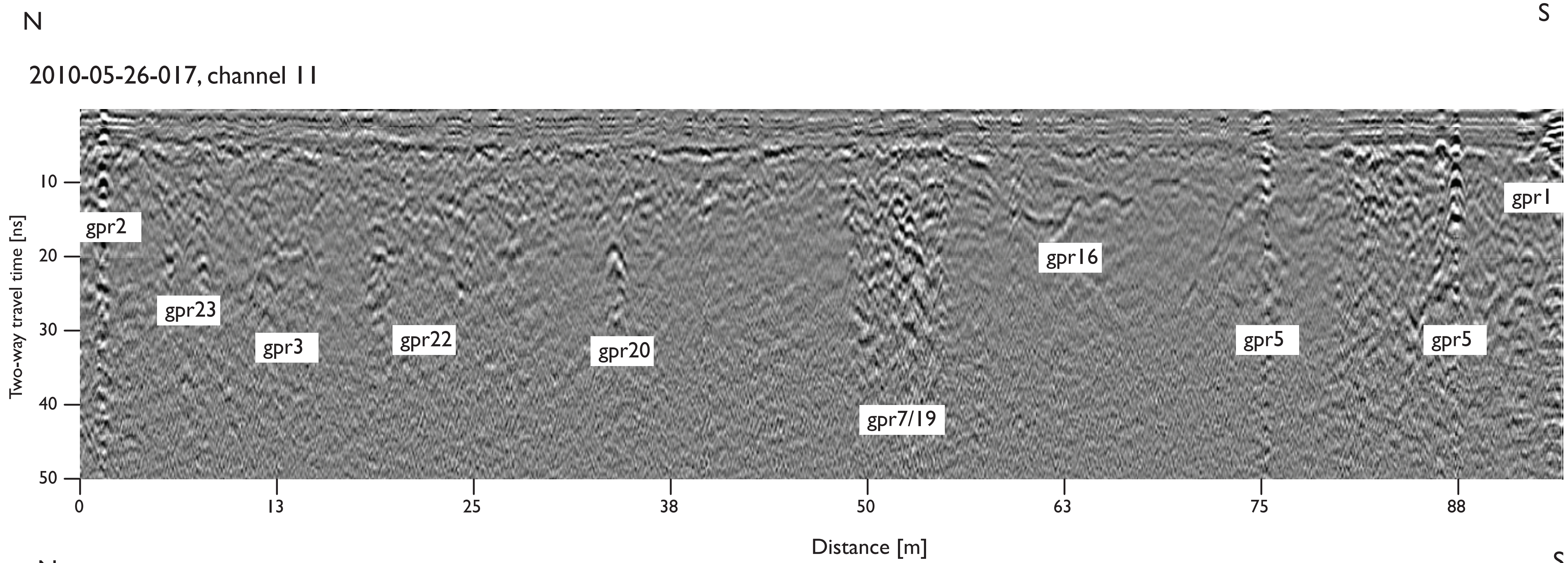
Figure 10

AUDLEY END HOUSE AND PARK, ESSEX
Selected GPR profiles from Area 1, May 2010



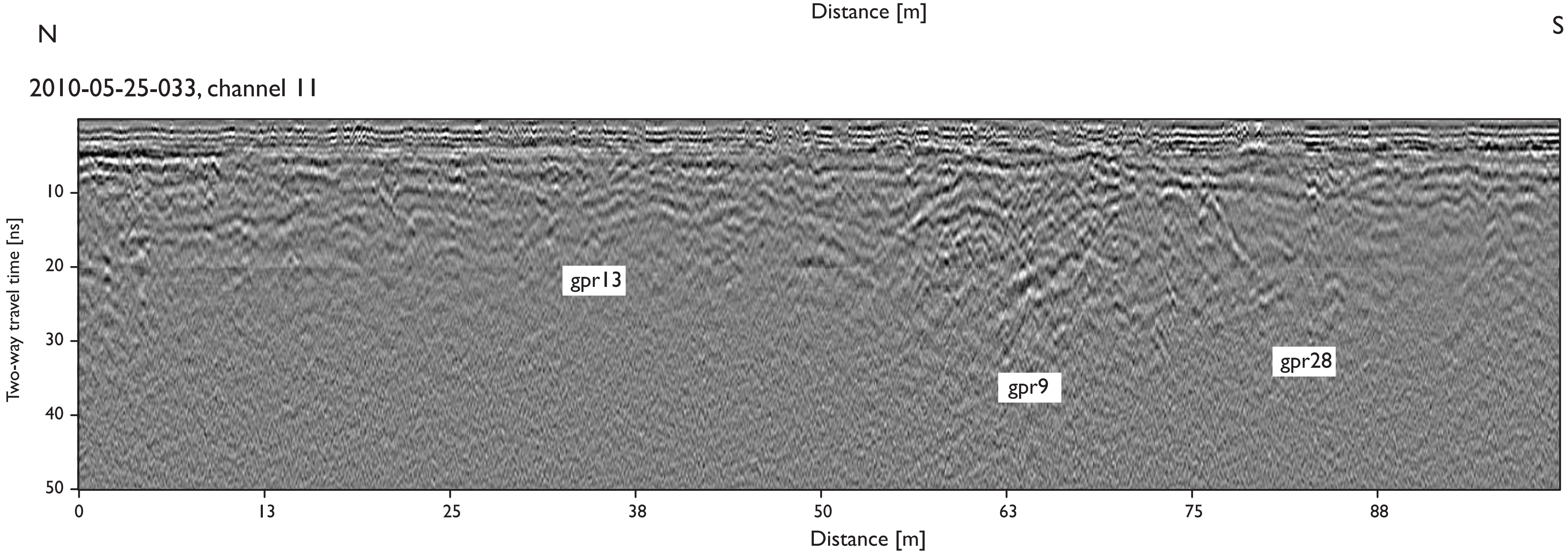
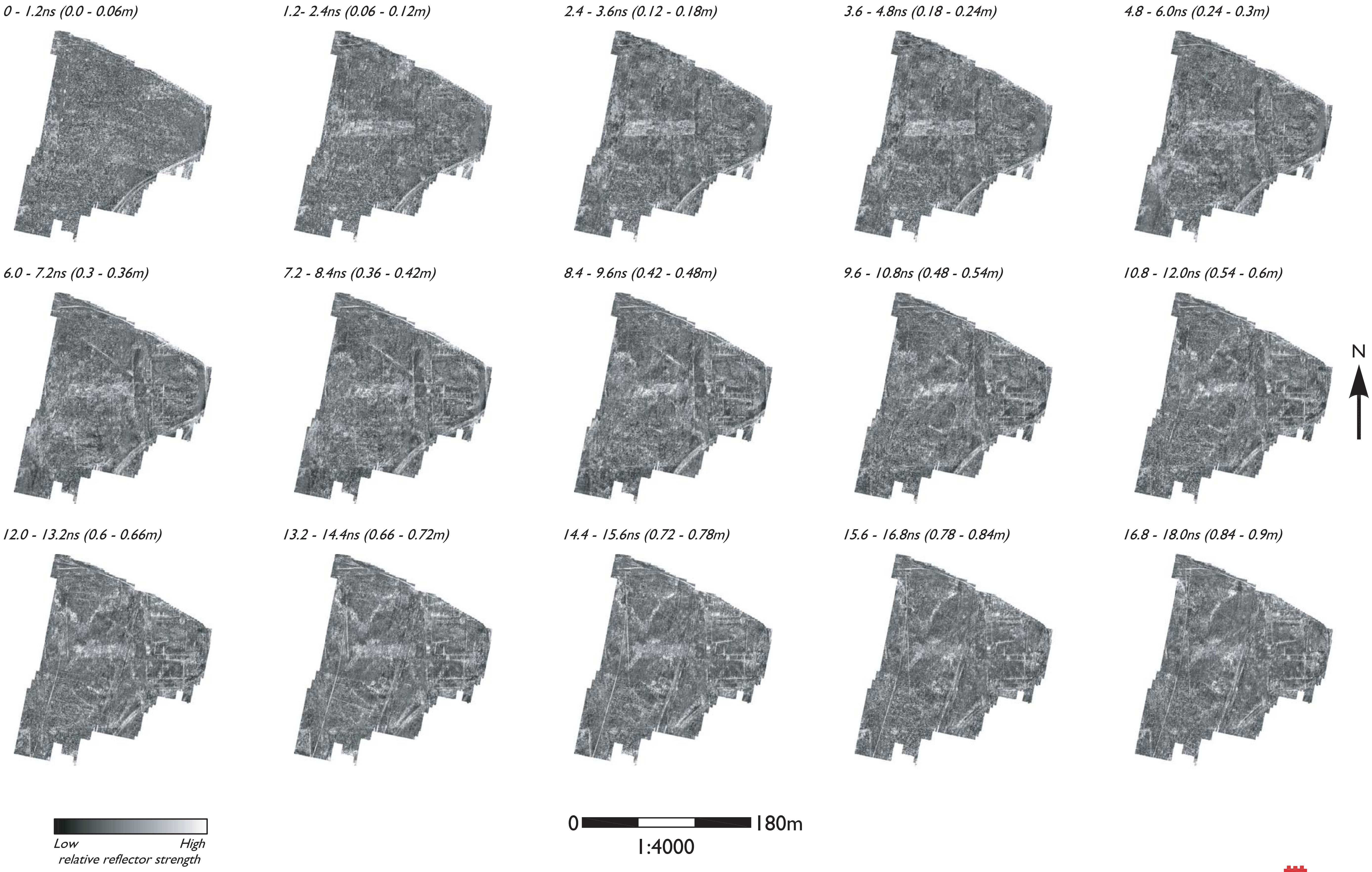


Figure 11

AUDLEY END HOUSE AND PARK, ESSEX
GPR amplitude time slices from 0.0 to 18.0ns, May 2010.



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AUDLEY END HOUSE AND PARK, ESSEX
GPR amplitude time slices from 18.0 to 36.0ns, May 2010.

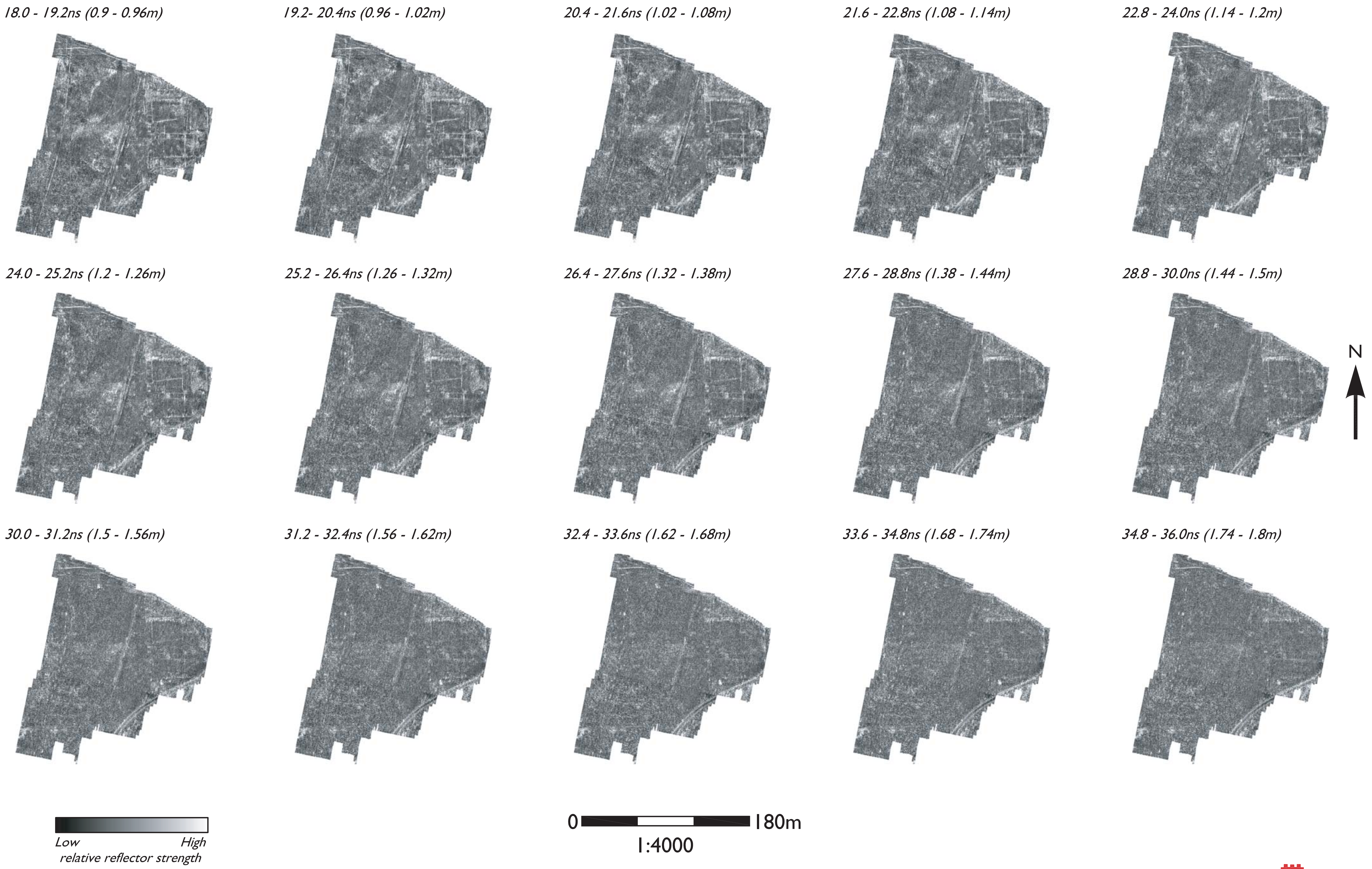

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Figure 13

Graphical summary of significant earth resistance anomalies July 1994, October 2009, May 2010

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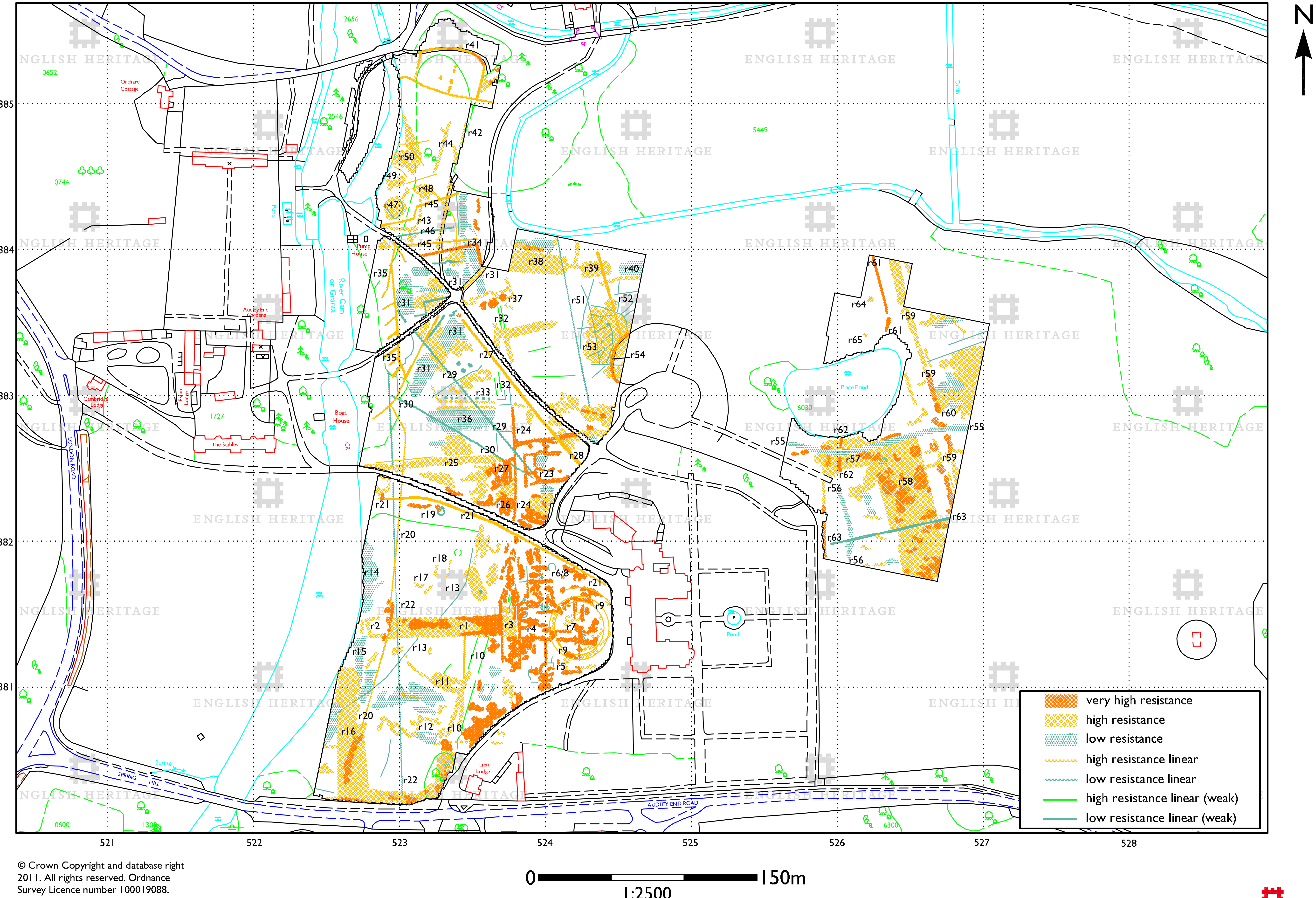

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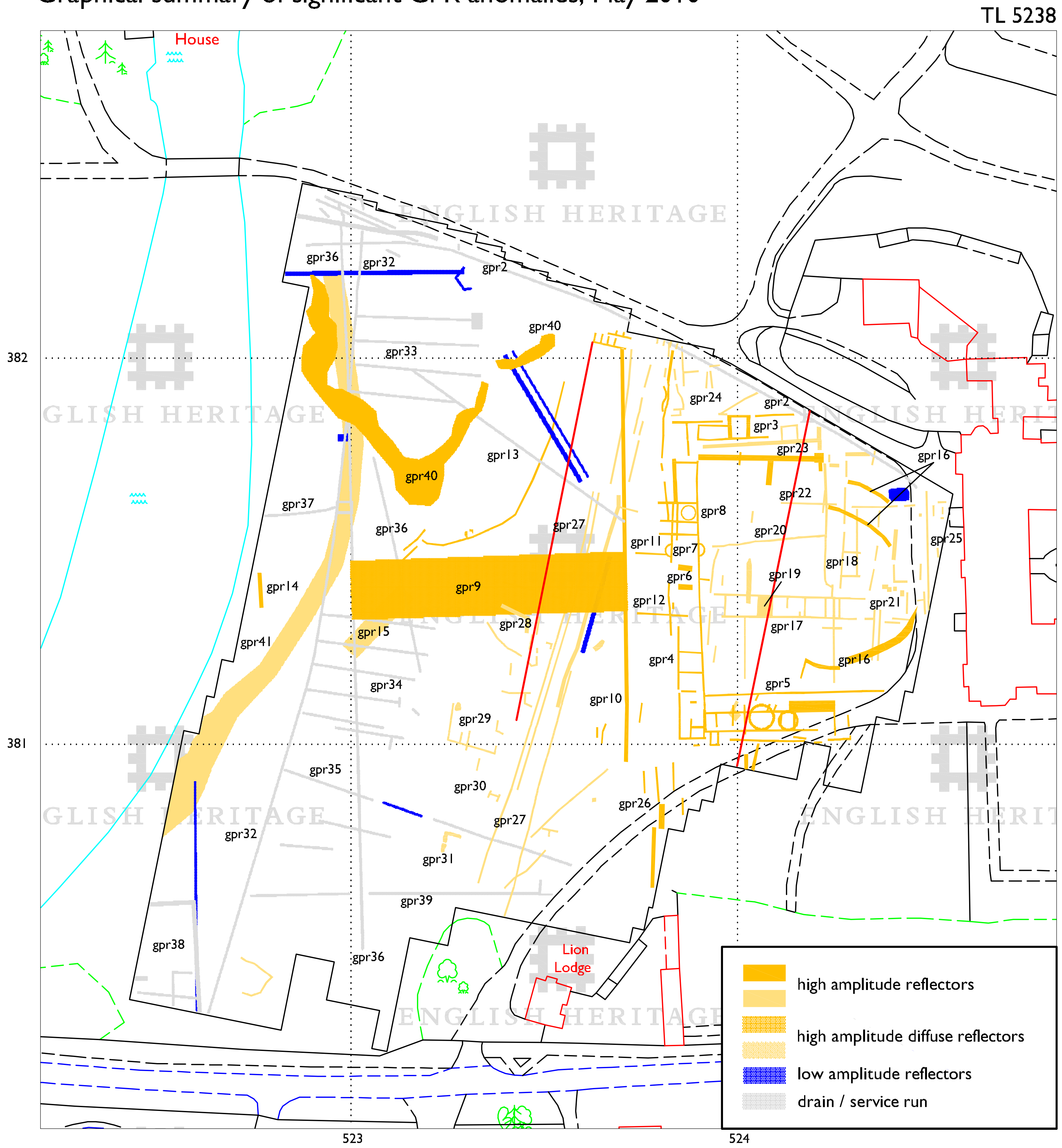
Figure 14

AUDLEY END HOUSE AND PARK, ESSEX
Graphical summary of significant GPR anomalies, May 2010



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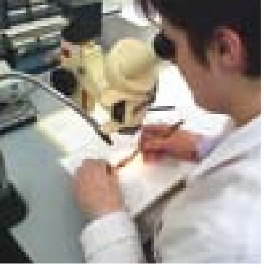
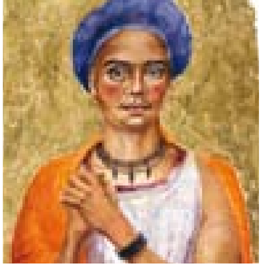



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* *Archaeological Projects (excavation)*
* *Archaeological Science*
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* *Architectural Investigation*
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