APETHORPE HALL, Northamptonshire.

Report on geophysical surveys, September 2005.

Summary

A geophysical survey was conducted over the East Courtyard and selected areas within the fabric of Apethorpe Hall, Apethorpe, Northamptonshire. Earth resistance survey was successfully conducted over the open areas of lawn within the East Courtyard and this was complemented by a Ground Penetrating Radar (GPR survey). Both techniques revealed anomalies associated with the former structure of the Hall, including the putative remains of the original East Range. GPR survey of selected areas within the standing building proved less successful, although a possible continuation of an original wall footing was revealed in the cellar beneath the North Range.

APETHORPE HALL, Northamptonshire.

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Introduction

Geophysical surveys over an area of approximately 0.1 ha were conducted in the East Courtyard and part of the interior of Apethorpe Hall in Northamptonshire. The Grade 1 listed Hall was originally built in the late 15th century, but has undergone numerous extensions and modifications between then and the mid 20th century when the building and grounds were used as a community school (Cattell 2005, 2). The building has been unoccupied since 1983 and has suffered a chequered recent history of neglect, that has led to its description as “the most important country house at risk in the country”. A Compulsory Purchase Order was approved in 2003 (Cattell 2005, 2) and vital repairs are now being conducted by English Heritage who hope to secure the future of the Hall.

Previous geophysical work at this site consists of magnetic surveys conducted by Engineering Archaeological Services (EAS) over various open areas of the estate, including the East Courtyard where a single modern service and other areas of magnetic disturbance were revealed (Brooks and Laws 2002). In addition, an earth resistance survey was also commissioned from Northamptonshire Archaeology over the North Lawn in advance of tree planting (Butler 2005).

The aim of the current geophysical survey was to further investigate the archaeological response in the East Courtyard using techniques more suited to locating building remains and also to attempt to reveal any previous foundations in four key areas within the hall, namely: the South Range where it has been speculated the site of a chapel and the White Hall might be found; in two previously open courtyard areas (Rooms e and f following the nomenclature of Heward and Taylor 1996, fig. 70), now enclosed inside the main building where original walls were thought to extend; and finally in a cellar beneath the North Range where it was thought an original wall had been truncated.

The site (centred on TL023954) lies on slowly permeable calcareous clayey soils of the Evesham 1 association (Soil Survey of England and Wales 1983) developed over Lower Lincolnshire Limestone (British Geological Survey 1976). At the time of the survey the courtyard was lined on two sides by a double set of scaffolding erected to provide cover for the roof. The remaining area was laid to grass with a border along the N edge, bisected by two hard-standing paths. Inside the building the rooms were predominantly empty though metal panel radiators, reinforced concrete and in the cellar the main electrical distribution boards for the building provided possible sources of interference.

Method

Earth resistance survey

Measurements were collected with a Geoscan RM15 resistance meter and a PA5 electrode frame in the Twin-Electrode configuration in the available area within the courtyard (see Figure 1). Readings were collected using the standard method outlined in note 1 of Annex 1, with readings taken at 0.5m along traverses separated by 0.5m. The data-set was additionally processed with a high-pass filter and presented as a linear greyscale superimposed over the metric survey plan of the plan (at a scale of 1:500) in Figure 2. Figure 3 shows plots of the minimally processed raw data, presented as both an X-Y traceplot and an equal area greyscale, together with greyscale representations of the data following the application of a Gaussian high-pass (radius 3m) and contrast enhancing Wallis filters (radius 5m), at a scale of 1:300. A graphical summary of significant earth resistance anomalies from the East Courtyard is provided in Figure 4.

Ground Penetrating Radar (GPR)

GPR survey was conducted in the East Courtyard and over four areas within the building: the South Range (Chapel and White Hall); the cellar beneath the North Range; and the former courtyards e and f in the West Range (Figure 1). A Sensors and Software Pulse Ekko PE1000 console was used with a variety of sample intervals and antennas detailed in Table 1.

Table1: Details of GPR sampling strategy.

Area of site	***Survey type***	***Sample interval***		***Antenna centre frequency***	***Time window***
		Line	***Trace***	***(average velocity)***	
East Courtyard	Area	0.5m	0.05m	450MHz (0.075m/ns)	60ns
South Range	Transects (3)	n/a	0.05m	900/450/225MHz (0.073m/ns)	80ns
Courtyard e	Transects (11)	0.5m	0.05m	900/450/225MHz (0.075m/ns)	50ns
Courtyard f	Transects (10)	0.3m	0.05m	900/450/225MHz (0.075m/ns)	50ns
Cellar	Transects (8)	0.6m	0.05m	450MHz (0.075m/ns)	50ns

The average subsurface velocity was estimated from both field CMP data and the analysis of diffraction tails of hyperbolic responses identified in the profiles. Table 1 shows the velocity adopted for each area of the site that was subsequently used for processing the data and estimating the depth to reflection events in the recorded profiles. Post acquisition processing involved the adjustment of time-zero to coincide with the true ground surface, removal of any low frequency transient response (dewow), noise removal and the application of a suitable gain function to enhance late arrivals.

Where appropriate, spurious above ground reflections, for example from the scaffold supporting the South and East Ranges of the east courtyard and the interior walls of the building, were suppressed by the application of a linear Radon (τ-p) transform (e.g. Durrani and Bisset 1984). These spurious responses are distinguished by their high velocity (~0.3m/ns) and appear as distinctive sloping linear anomalies within the majority of recorded profiles (e.g. S_1-S_1' and S_2-S_2' on Figure 5(A)). The linear Radon transform integrates energy from the *x-t* domain along a straight line path with an intercept τ and slope (or "slowness") *p*. Linear responses therefore map to narrow zones within the τ-p domain and may be separated by both angle of dip (slope) and intercept times. Figure 5(B) demonstrates how horizontal responses (e.g. L_1-L_1' and L_2-L_2') are clearly distinguished from the energy associated with the spurious above ground reflections (e.g. S_1-S_1' and S_2-S_2') that may then be muted in the τ-p domain. Application of an inverse Radon transform restores the muted transform to the *x-t* domain removing the spurious above ground reflections at the expense of some low-pass filtering of the data (Figure 5(C)).

In addition, owing to antenna coupling between the GPR transmitter and the ground to an approximate depth of $^{\lambda}/_{2}$, very near surface reflection events should only be detectable below a depth of 0.083m if a centre frequency of 450MHz and a velocity of 0.075m/ns are assumed. However, the broad bandwidth of an impulse GPR signal results in a range of frequencies to either side of the centre frequency which, in practice, will record significant near-surface reflections closer to the ground surface. Such reflections are often emphasised by presenting the data as amplitude time slices. In this case, the time-slices were created from the entire data set, after applying a 2D-migration algorithm, by averaging data within successive 2ns (two-way travel time) windows (e.g. Linford 2004). For the East Courtyard each resulting time slice, illustrated as a greyscale image in Figure 6 and 7 represents the variation of reflection strength through successive ~0.075m intervals from the ground surface.

Results

Graphical summaries of significant anomalies are provided on Figure 4 for the earth resistance and Figures 8, 9 and 12 for the GPR data. Numbers in [ ] refer to specific anomalies discussed below.

East Courtyard

Earth resistance

The area available for survey was severely limited by buildings, scaffolding and two hard standing paths laid to concrete paving slabs. This restricted area did not allow the wider background response of the site to be fully considered and may, as a consequence, draw undue attention to minor anomalies of uncertain significance.

Two low resistance linear anomalies [R1-2] cross the survey area in an approximately NW-SE direction. There is a correlation between [R1] and the ferrous anomaly 'O' in the magnetometer survey conducted by EAS (Brooks and Laws 2002, Figure 13) that suggests the presence of a modern service. Anomaly [R2] does not appear to have a magnetic signature; however, the low resistance response probably indicates a service trench containing a non-magnetic, plastic, pipe.

Perpendicular to [R1], and bisecting it at the approximate centre of the courtyard is a high resistance discontinuous linear anomaly [R3]. This may represent a wall footing or perhaps just compacted ground from a former path.

In the SE corner of the survey area a very high resistance linear anomaly [R4] has been recorded, that appears to narrow slightly to the S after branching to the SE parallel to [R1]. Anomaly [R4] is likely to be a wall footing, but is not fully described in the survey due to the presence of the scaffolding supporting the South and East Ranges.

Various other high resistance anomalies have been recorded, mainly to the W of the NS path. The archaeological significance of many of these is unclear but the strongest anomalies [R5-9] possibly indicate more solid remains, although only [R8] and [R9] seem large enough to indicate potential buildings, perhaps in the form of rubble or a compacted floor.

Ground Penetrating Radar (GPR)

The GPR data from the East courtyard is presented as a series of amplitude time slices in Figure 7 with each successive time slice representing the magnitude of reflection strength in successive 0.075m layers from the ground surface. This is illustrated by the response to the paved walkways that appear from the first time slice (between 0 and 2ns) throughout the near surface data but begins to fade from 12ns (~0.5m) onwards allowing underlying targets to be imaged. A single time slice between 18 and 20ns is also shown superimposed over the metric plan of the building in Figure 6. As would be expected there is a good correlation between the earth resistance and GPR data sets with the latter providing a useful estimate to determine the depth of buried targets.

A number of linear anomalies [GPR1 on Figure 8] are found to the N and E of the oriel window suggesting some realignment and possible additional buildings (or garden/architectural features) in this area. The GPR anomalies do not correlate directly with the individual earth resistance responses (e.g. [R7] and [R8]), perhaps lending further support to the presence of building rubble or less well defined architectural fragments.

More significant wall-type anomalies [GPR2] are found in the SE of the survey area and corroborate [R4] in the resistance data. Due to the scaffolding these anomalies are not fully described to the S and E in the available survey area, but are suggestive of an earlier building range possibly extending to meet the North Range. Further possible building remains are found at [GPR3], but again this anomaly is not fully described in the survey area due to the scaffolding. The GPR data suggests a more rectilinear causative feature between 16 and 24ns (~0.6 to 0.9m) when compared to the corresponding, more diffuse, earth resistance anomaly [R9]. The latter may be indicative of a rubble layer overlying the wall-type responses evident in the GPR data.

A more tentative, circular anomaly [GPR4] is found slightly off-set from the geometric centre of the current courtyard. This anomaly is not replicated in the earth resistance survey and only occurs between 22 and 26ns (~0.825 to 0.925m), indicating a more ephemeral underlying structure. It is possible that [GPR4] represents an earlier garden feature within the courtyard, although the site was used as a film set in the 1980s that included the construction of a circular, mock fountain for the production of “Porterhouse Blue” (K. Morrison *pers. comm.*).

[GPR5] is almost certainly a service trench appearing as a ditch-type response in the earth resistance survey and a discrete high amplitude reflector in the GPR data between 10 and 14ns. This anomaly is not replicated in the magnetic data and could well represent a non-ferrous pipe or stone culvert collecting rain water from the down pipe visible at the oriel window where this anomaly originates.

A second possible service trench identified in both the earth resistance [R1] and GPR [GPR6] surveys is replicated in the magnetic data (Brooks and Laws 2002, Figure 13). This suggests the presence of a steel cable or pipe, possibly indicating an electrical supply across the courtyard from the main distribution panel found in the cellar beneath the North Range. Whilst [GPR6]/[R1] is almost certainly, in part, a modern service (electricity) both the earth resistance and GPR anomalies suggest a more significant causative feature. The resistance anomaly shows a low resistance ditch-type response (possibly the modern cable trench?) together with a high resistance linear anomaly immediately to the N. This leads to the centre of the current courtyard where a similar diagonal linear anomaly [R3] apparently extends from the centre to the NE corner of the courtyard. These anomalies are partially replicated by the GPR data together with two, less distinct, responses forming the "southern" diagonals identified as [?R3] and the continuation of [R1]. Is it possible that these anomalies represent a former garden layout in the courtyard, perhaps marked by stone kerbing, and have been partially reused to accommodate modern services? Due to the likely presence of live cabling appropriate care and attention should be exercised when examining these anomalies invasively.

South Range (Chapel and White Hall)

Only GPR measurements were possible within the fabric of the building itself and these were, in part, compromised by the presence of the standing structure and spurious above ground reflections. Three transects of data were collected (each repeated with 900, 450 and 225MHz centre frequency antennas) in the South Range over the flag stone corridor overlooking the East Courtyard (Figure 9). The individual GPR profiles are shown in Figure 10 with annotation to indicate significant anomalies discussed below. The location of selected anomalies are also shown superimposed over the metric plan of the South Range on Figure 9.

A number of near-surface point reflectors [GPR7-13] are evident within the data and possibly relate to either the course of internal services, such as hot water supply pipes for the central heating system installed in conduits immediately beneath the flag stone floor, or irregularities, possibly void spaces, in the flooring itself (e.g. the multiple reflections seen at the door kerb found at [GPR9]).

A discontinuous, horizontal reflector [GPR14], possibly a compacted layer beneath the surface flag stones, is found across all three profiles at 15ns (~0.6m) and rapid attenuation of the GPR signal occurs immediately below this. Despite this signal attenuation a second horizontal anomaly [GPR15] may be discerned as a later reflection at 30ns (~1.1m) in the low frequency data, together with a number of broad, hyperbolic responses [GPR16 - 20] at a similar depth. Whilst [GPR16 - 20] may be caused by off-line reflections from a surface feature, analysis of the hyperbola tails (*cf* Abbas *et al.* 2005) estimates a subsurface velocity of ~0.086m/ns, much lower than that expected from a spurious air-wave reflection (0.3m/ns). This suggests the anomalies are indeed produced by subsurface architectural features, possibly wall footings, associated with the lower compacted layer [GPR15].

Two anomalies of potential interest are found on Line 2 to the W of the former chapel, a complex wall type response [GPR21] and a low amplitude anomaly [GPR22]. Whilst both [GPR21] and [GPR22] are replicated in the 900, 450 and 225MHz data no parallel profiles were collected in this area, limiting the interpretation of these anomalies.

Former Courtyard (Room e)

Eleven parallel profiles separated by 0.5m were collected using 900, 450 and 225MHz antennas in this room that was enclosed from an original open courtyard. Data acquisition was hampered by the restricted dimensions and the presence of strong surface reflectors (e.g. modern panel radiators).

Only the higher centre frequency antennas (900 and 450MHz) produced useful results and selected minimally processed profiles are shown on Figure 11(A), together with a graphical summary of anomalies superimposed over a metric plan of the current building fabric (Figure 12). The prominent air-wave anomalies have not been removed from the selected profiles in Figure 11 (*cf* Figure 5).

Two horizontal reflectors [GPR23 and 24] appear across the majority of profiles collected in Room e at 20 and 40ns (~0.75m and 1.5m) respectively and may represent compacted layers beneath the modern concrete floor. A void space was noted within the concrete during the survey and it is possible that the series of anomalies appearing in the 450MHz data [GPR25], forming an approximately linear arrangement to the S of the surface area, are related to the partial failure of the modern flooring. A similar pattern of anomalies [GPR26] is found to the N, although these are only readily discernible in the shallower, 900MHz data. Both [GPR25] and [GPR26] appear within the very near surface data, between 0 and 10ns (0 to ~0.4m), suggesting they are reflections from either the concrete floor or a complex air-wave reflection within the room.

Former Courtyard (Room f)

Figures 11(B) and 12 also show the results from the 10 NS orientated traverses separated by 0.3m collected in Room f. Again, only the 450 and 900MHz centre frequency antennas have produced useful information and the absence of metal radiator panels has reduced, but not entirely eliminated, the incidence of energy associated with spurious air-wave reflections.

The very near-surface data between 0 and 5ns (0 to ~0.2m) shows some slight undulation, perhaps due to irregularities beneath the modern ceramic tiled floor. In places, a number of anomalies [GPR27, 28 and 29] appear to originate from deeper targets extending from 5 to 15ns (~0.2 to 0.6m), although the significance of these responses and suggestion of linear grouping (e.g. [GPR29]) remains highly tentative.

North Range Cellar

Due to the restricted access and low lighting levels data in the cellar was only recorded with the 450MHz centre frequency antenna. A total of 8 NS orientated traverses separated by 0.3m were collected, arranged into two groups of 4 profiles either side of a central brick support pier (see photographs on Figure 13). Significant anomalies abstracted from the individual profiles are shown on Figure 12. However, as no metric plan of the cellar was available the GPR profiles are superimposed over the ground floor plan.

The main object of the survey in the cellar was to test for the presence of any footings associated with a truncated section of original walling entering the cellar to from the E. Profiles immediately adjacent to the truncated wall section (Lines c1 – 4) do not show any convincing evidence for wall footings beyond a comparatively broad area of shallow disturbance [GPR30] between 10 and 15ns (~0.4 to 0.6m). This latter anomaly could not be fully described due to the presence of the brick support piers but a more distinct, wall-type response [GPR31] does continue through the profiles recorded to the W. Anomaly [GPR31] appears to extend to 30ns (1.1m), deep enough to suggest a substantial wall footing. Due to the presence of the main electrical distribution boards for the house, care should be taken to establish that these anomalies are not due to modern live services prior to invasive investigation, although most of the visible cabling appears to run overhead across the ceiling of the cellar.

Conclusion

Geophysical survey over the open space within the East courtyard has revealed a number of significant anomalies, apparently related to the former structure of the hall before the later additions of the current South and East Ranges. The presence of modern paving and a substantial scaffold reduced the area available for the survey in the courtyard and created some spurious air-wave reflections in the GPR data. Some of the earth resistance and GPR anomalies identified by the survey probably also relate to modern services and more recent structures within the courtyard. GPR survey within selected areas of the standing building proved less successful, although a possible continuation of an original wall footing was revealed in the cellar beneath the North Range.

Surveyed by:	N Linford L Martin	Date of survey:	26-29/9/2005
Reported by:	N Linford L Martin	Date of report:	11/5/2006

Geophysics Team,
English Heritage.

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List of figures.

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 the Centre for Archaeology 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 North. 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 the Centre for Archaeology 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 nano-Tesla (nT) rather than in the units of magnetic gradient, nano-Tesla 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

APETHORPE HALL, Northamptonshire
Location of geophysical surveys, September 2005

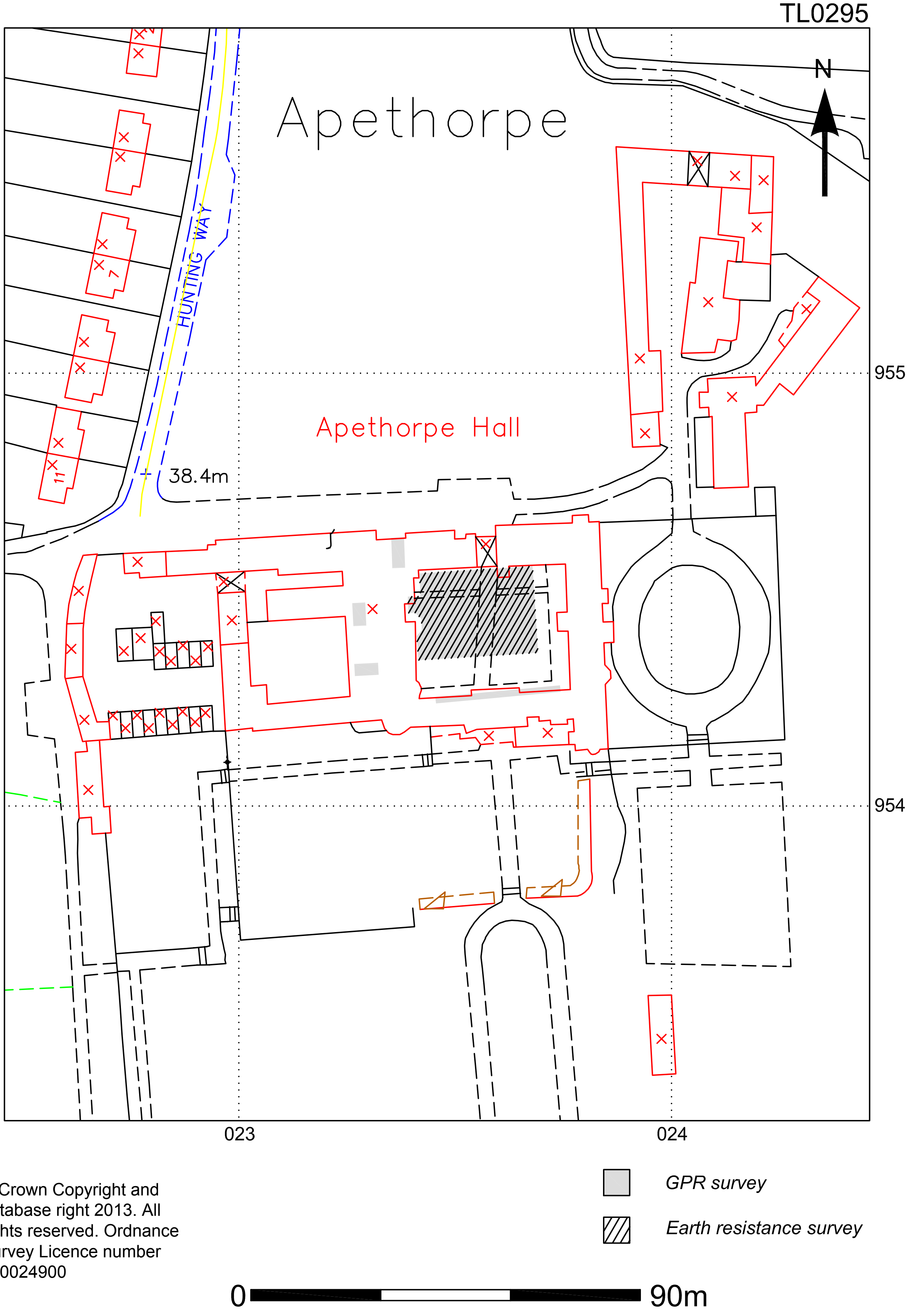

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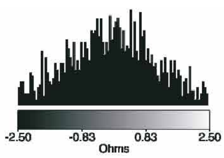
Figure 2

APETHORPE HALL, Northamptonshire
Location of earth resistance survey, September 2005



0 15m
1:500

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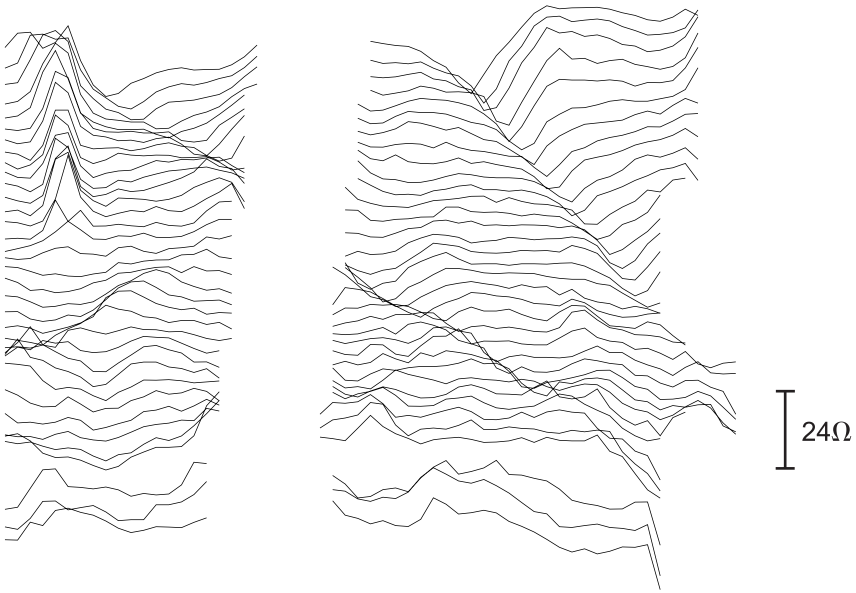
APETHORPE HALL, Northamptonshire

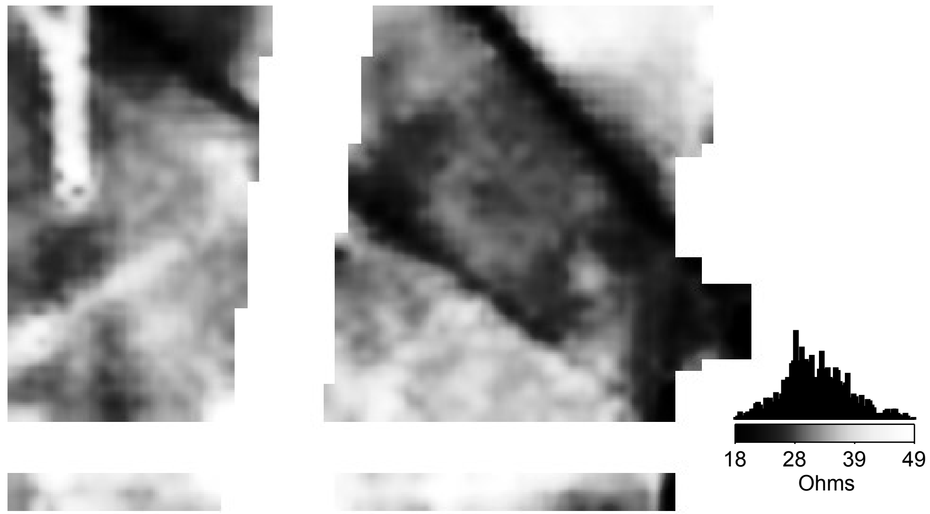
Eastern Courtyard Earth resistance survey, September 2005.

Figure 3

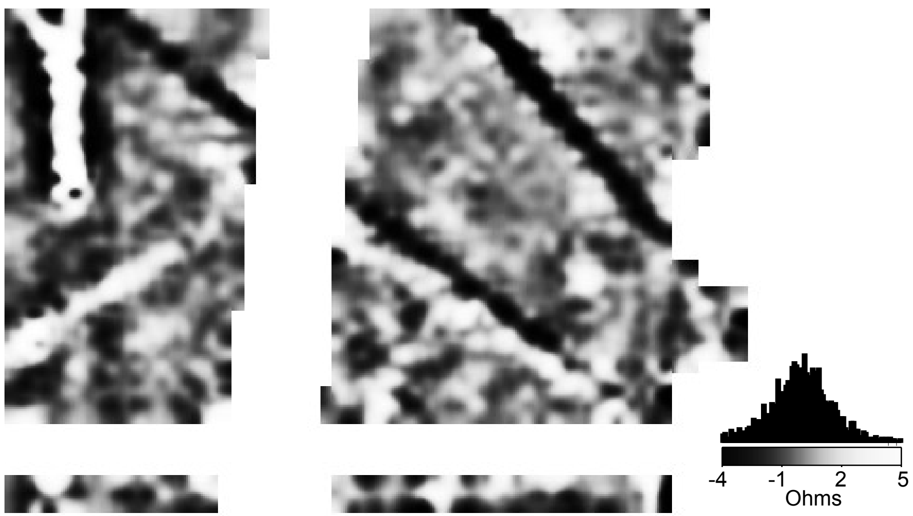
(A) Traceplot of earth resistance data.



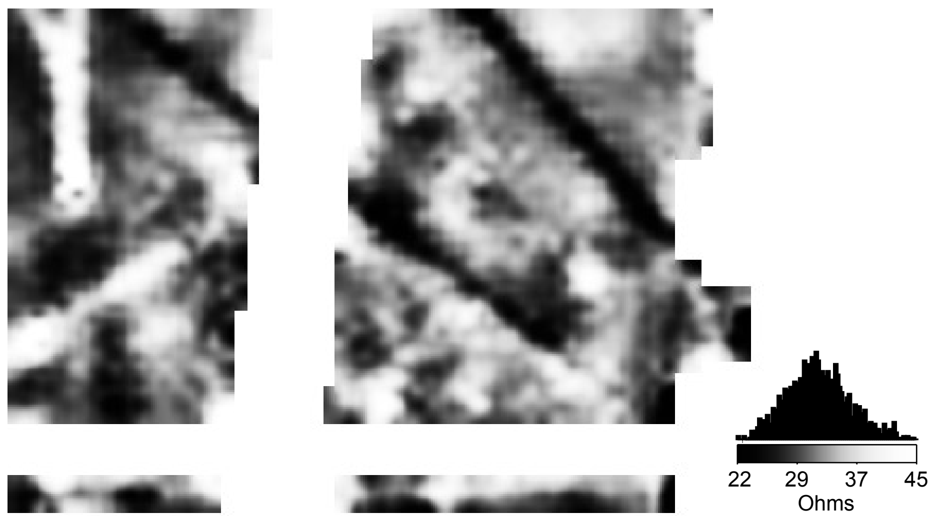
(B) Greyscale of earth resistance data.



(C) Greyscale of high pass filtered earth resistance data.



(D) Greyscale of Wallis filtered earth resistance data.



0 15m

1:300

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Figure 4

APETHORPE HALL, Northamptonshire
Summary of significant earth resistance anomalies, East Courtyard

TL0295

0 30m
1:500

High resistance anomaly

Low resistance anomaly

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APETHORPE HALL, Northamptonshire
Suppression of spurious surface GPR reflections

Figure 5

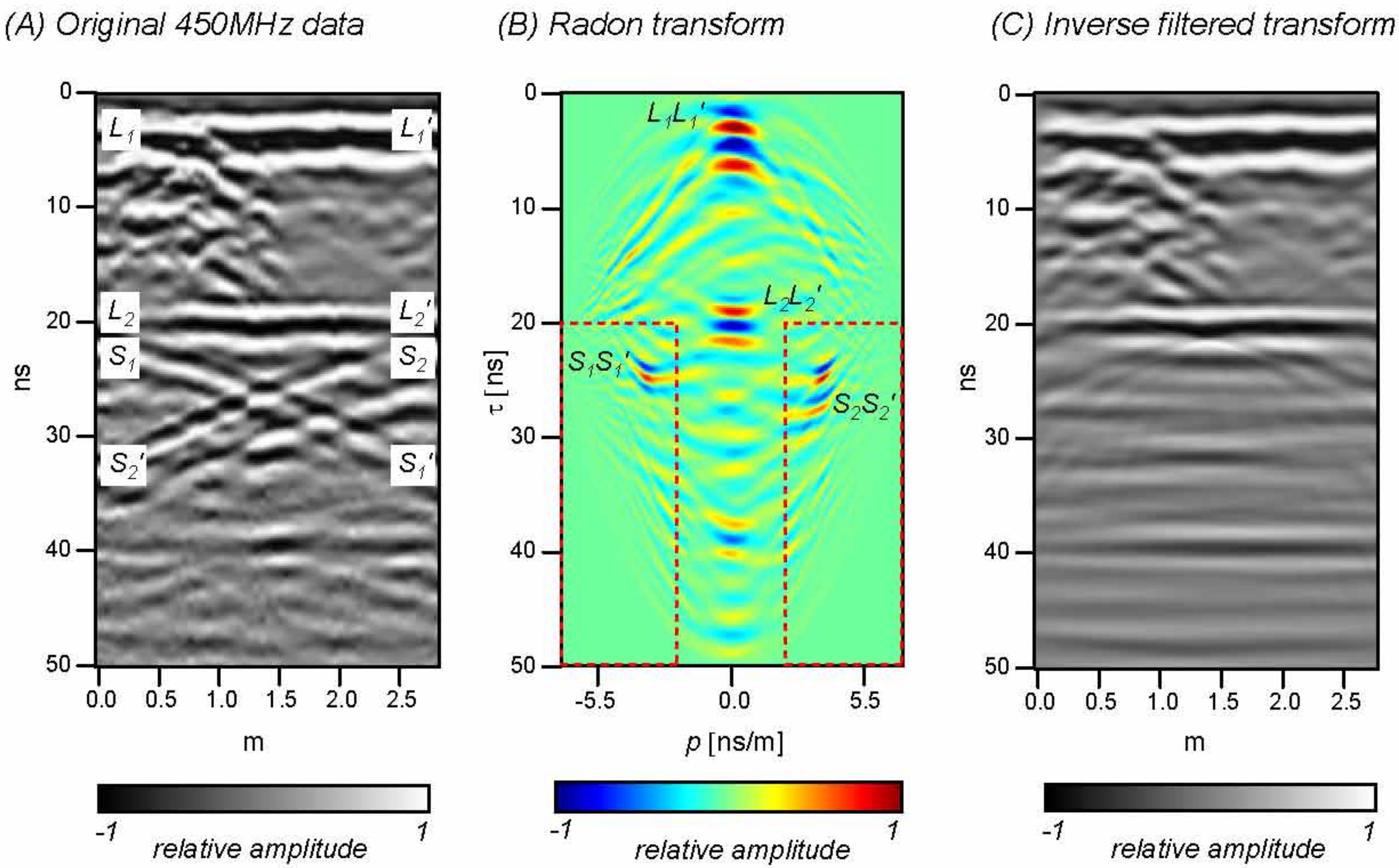

Figure 6

APETHORPE HALL, Northamptonshire
18-20ns GPR amplitude time slice, East Courtyard

N

0 30m
1:500

Low *High*
relative reflector strength

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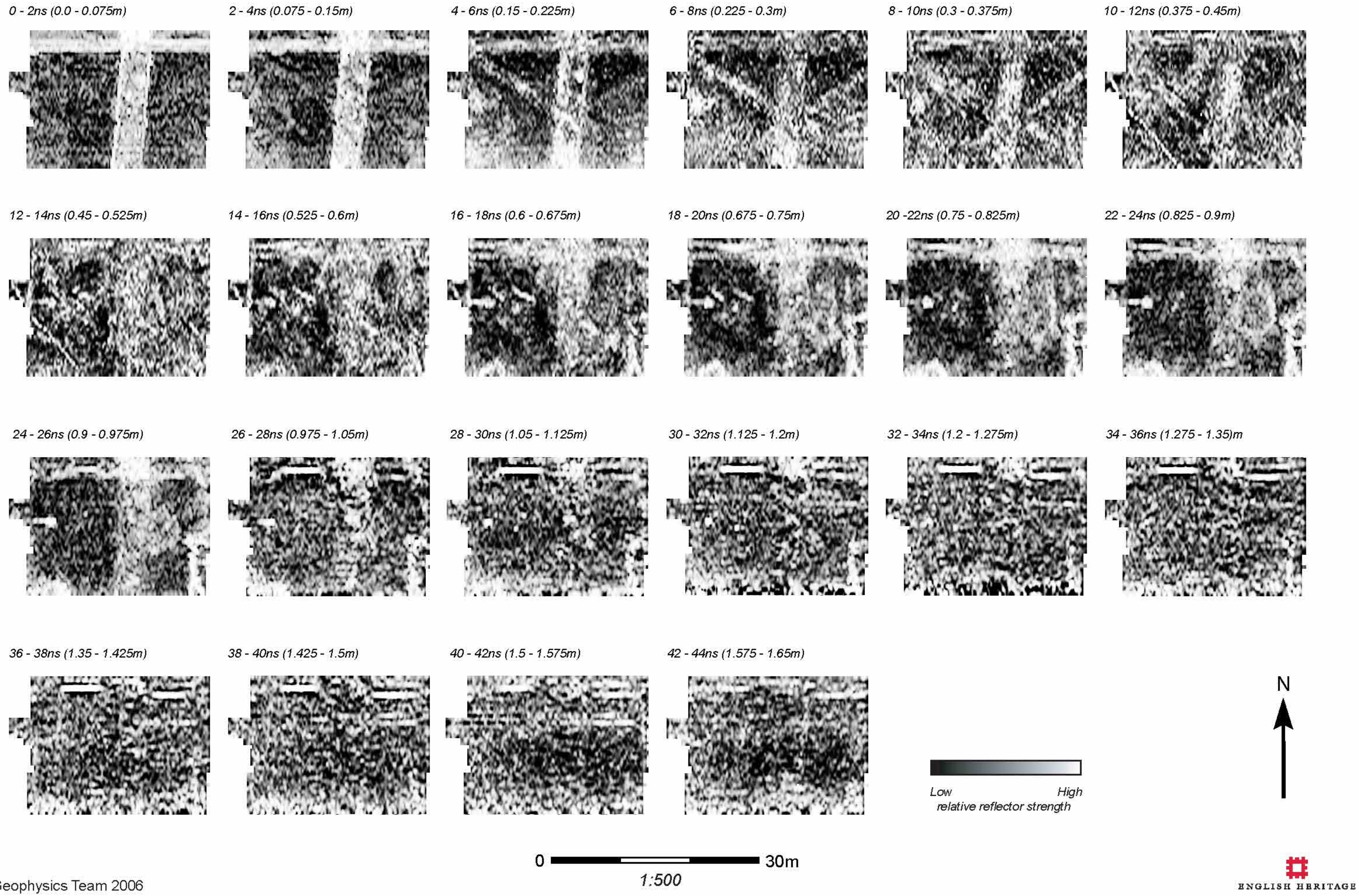
Figure 7

APETHORPE HALL, Northamptonshire
East Courtyard 450MHz GPR amplitude time slices 450MHz, September 2005



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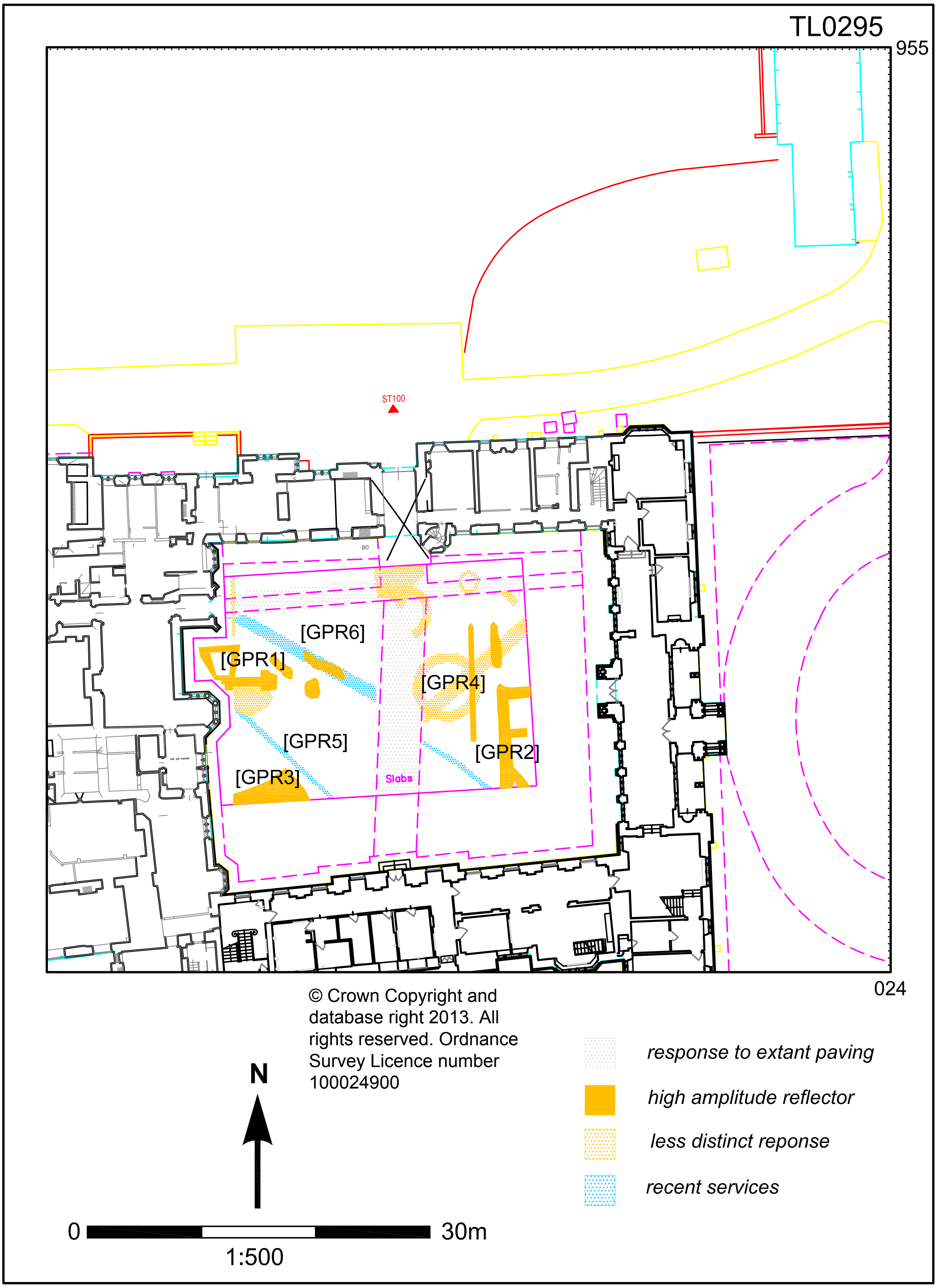
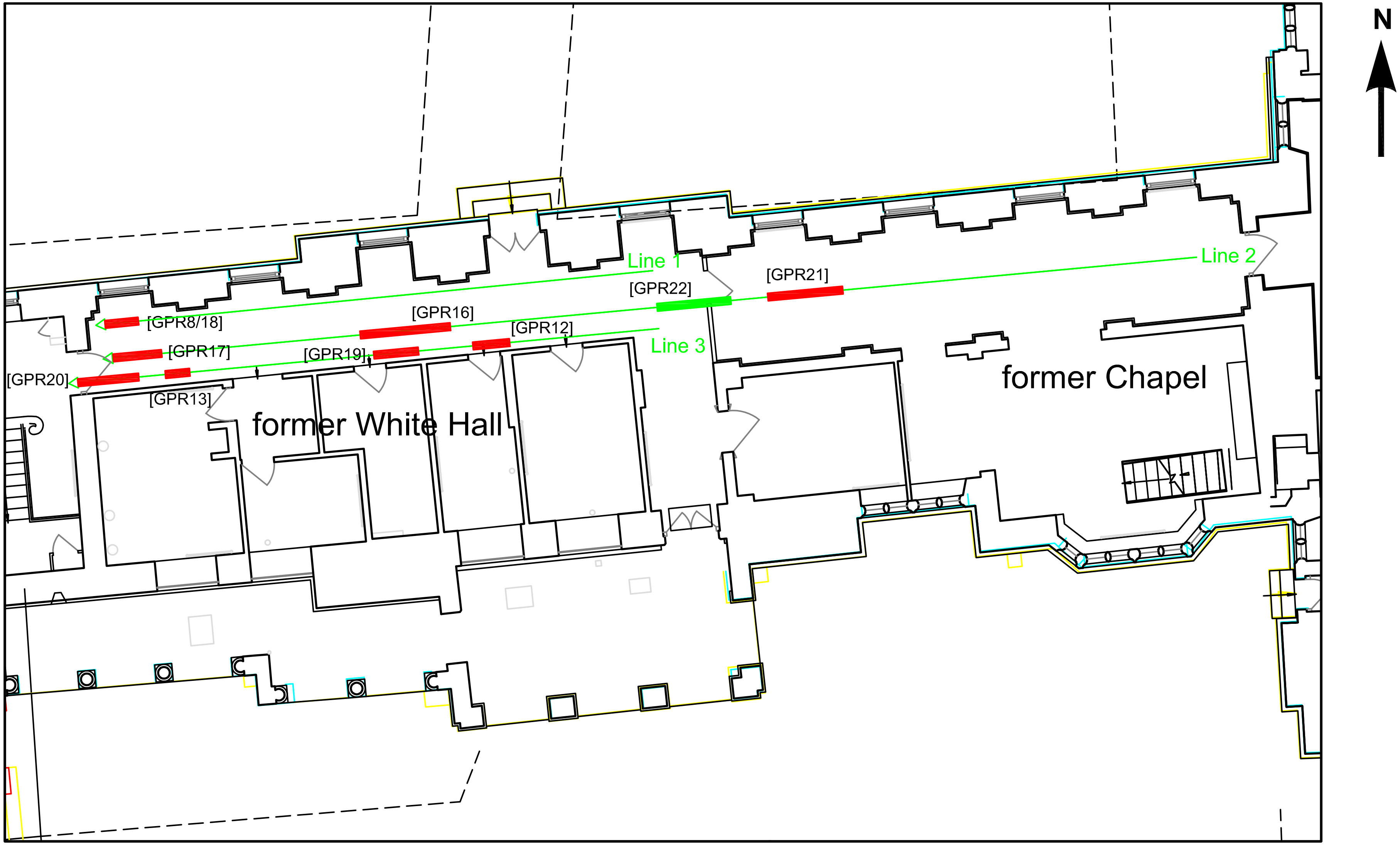
APETHORPE HALL, Northamptonshire
Summary of significant GPR anomalies, East Courtyard



APETHORPE HALL, Northamptonshire
Summary of significant GPR anomalies, South Range

Figure 9



Low amplitude anomaly

possible structure or ground disturbance

0 15m
1:150

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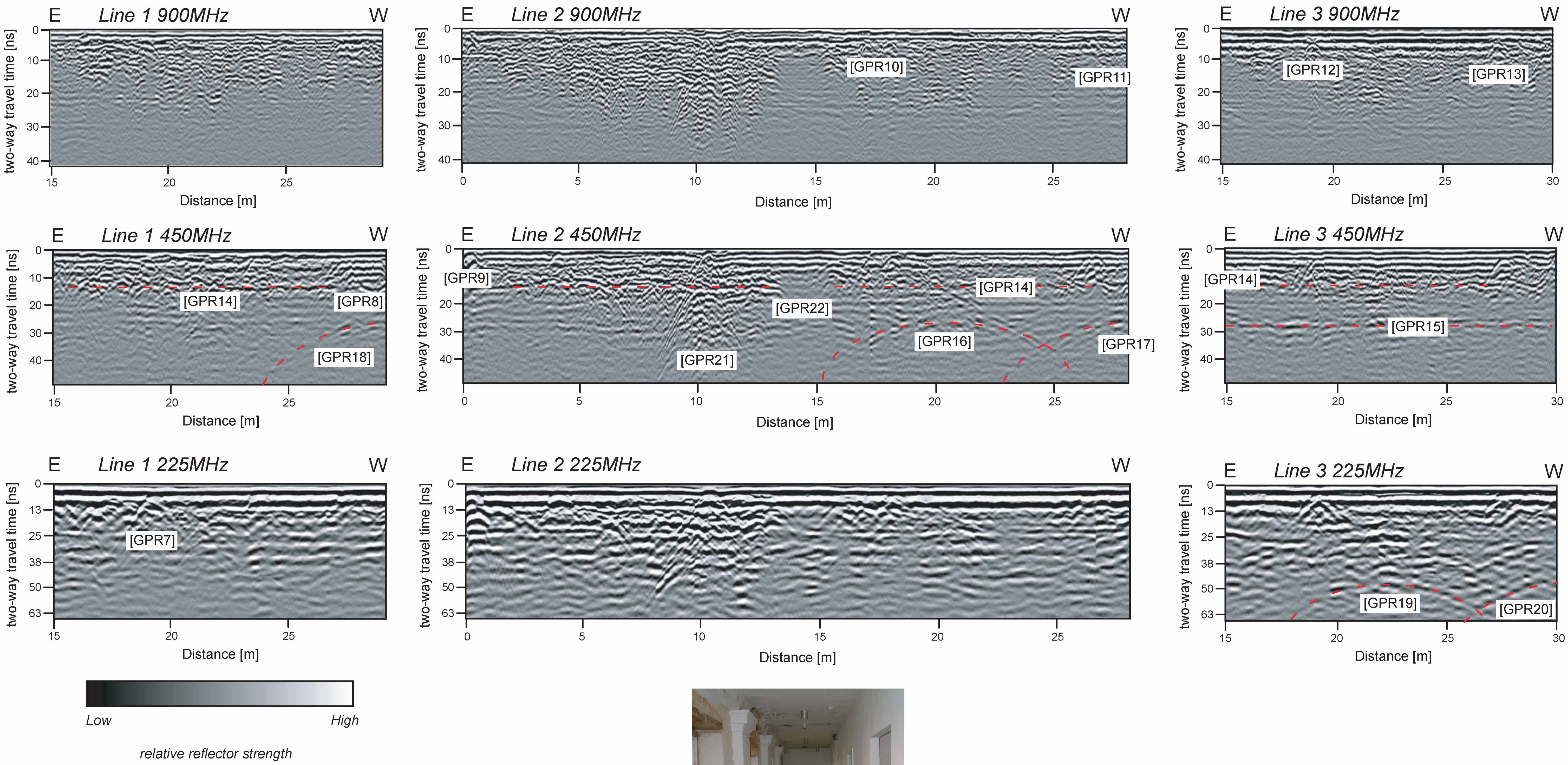
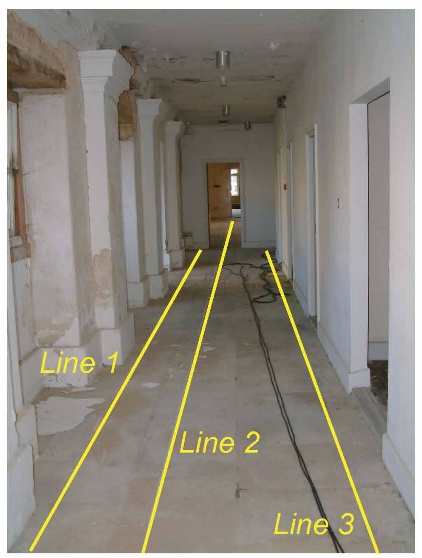
APETHORPE HALL, Northamptonshire
GPR survey, Chapel and White Hall, September 2005.

Figure 10





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APETHORPE HALL, Northamptonshire
GPR survey, Rooms e and f, September 2005.

Figure 11

(A) Selected GPR Profiles Room e

(B) Selected GPR Profiles Room f

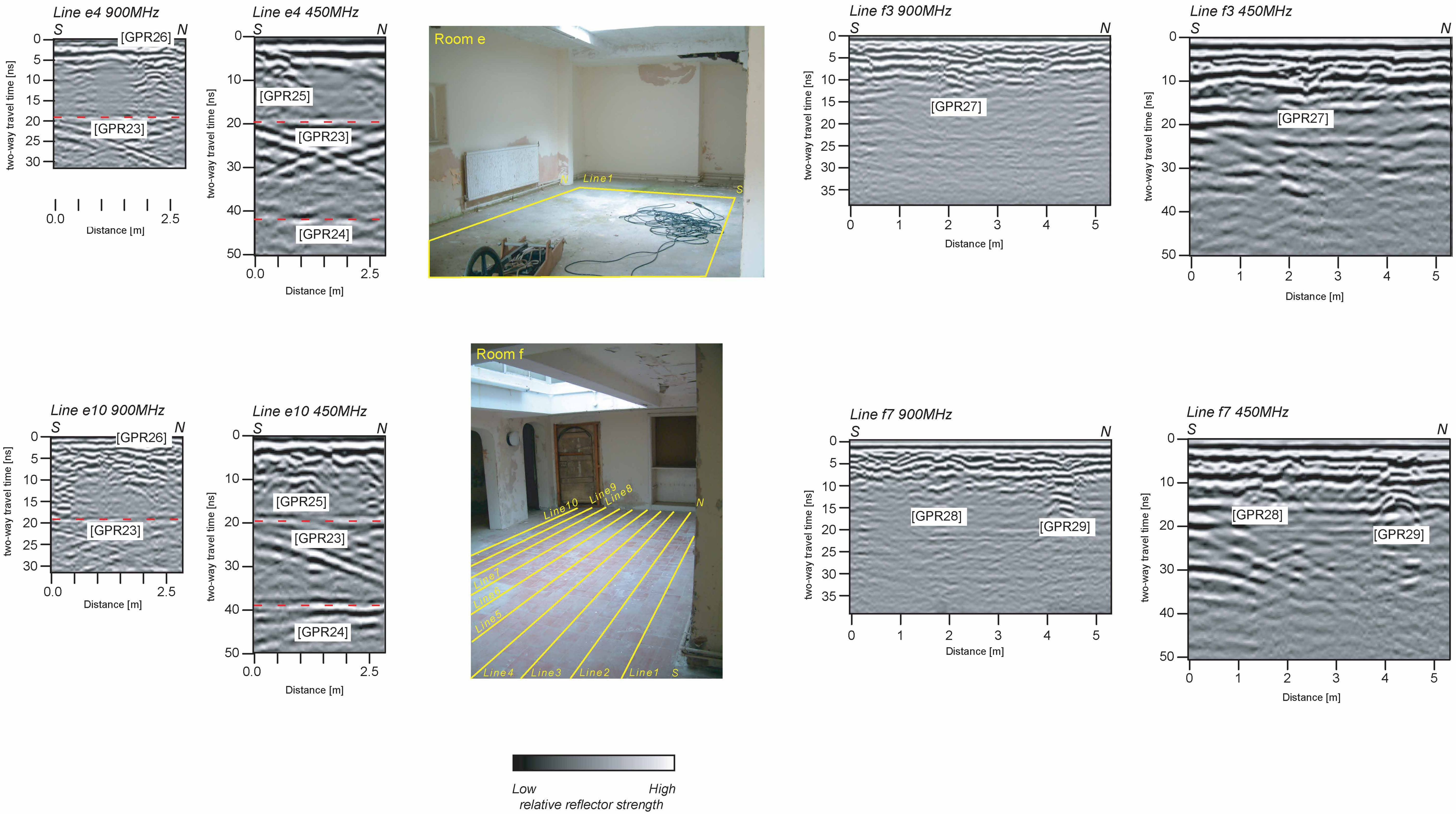

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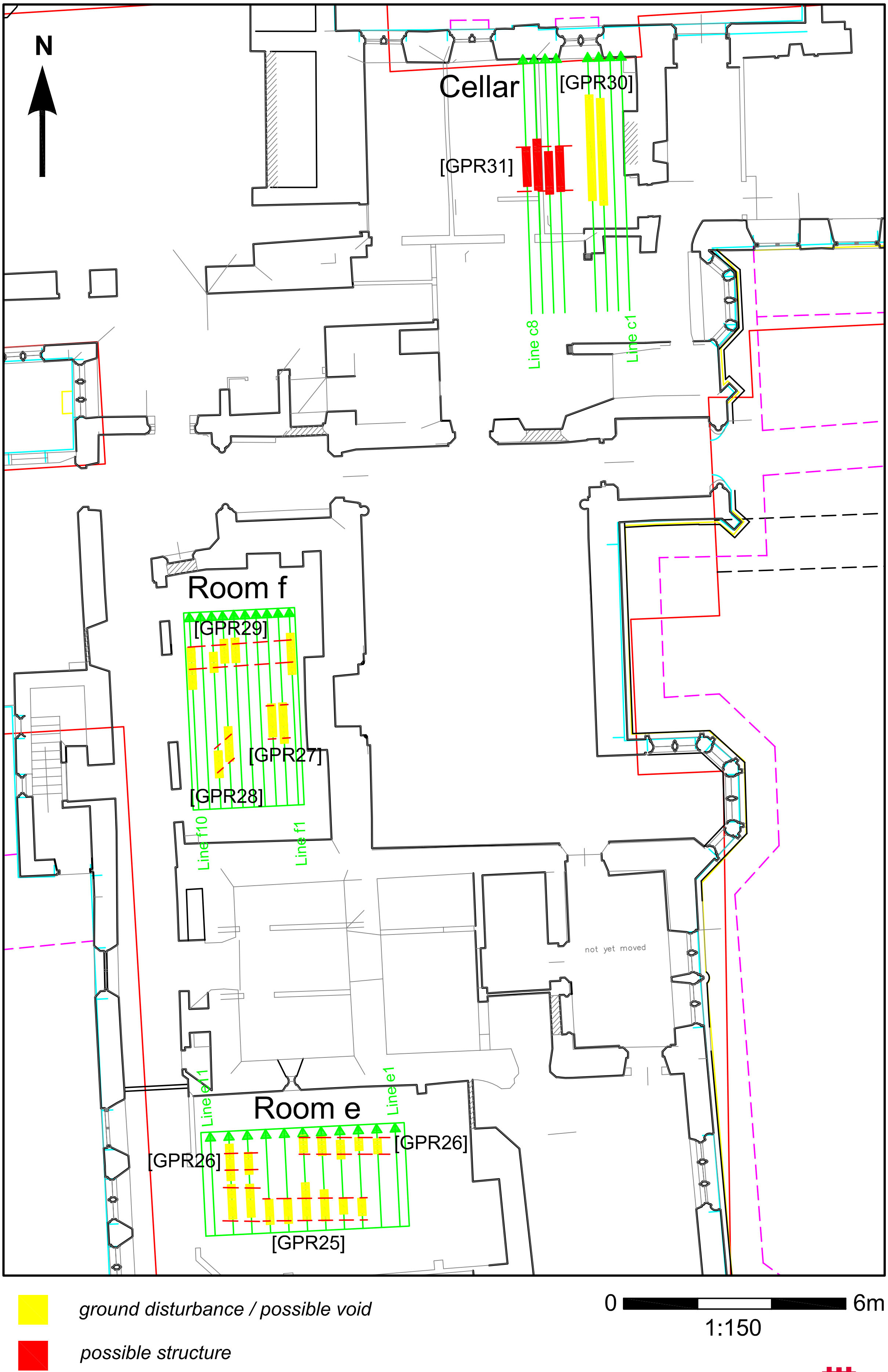
Figure 12

APETHORPE HALL, Northamptonshire
Summary of significant GPR anomalies, Rooms e, f and Cellar



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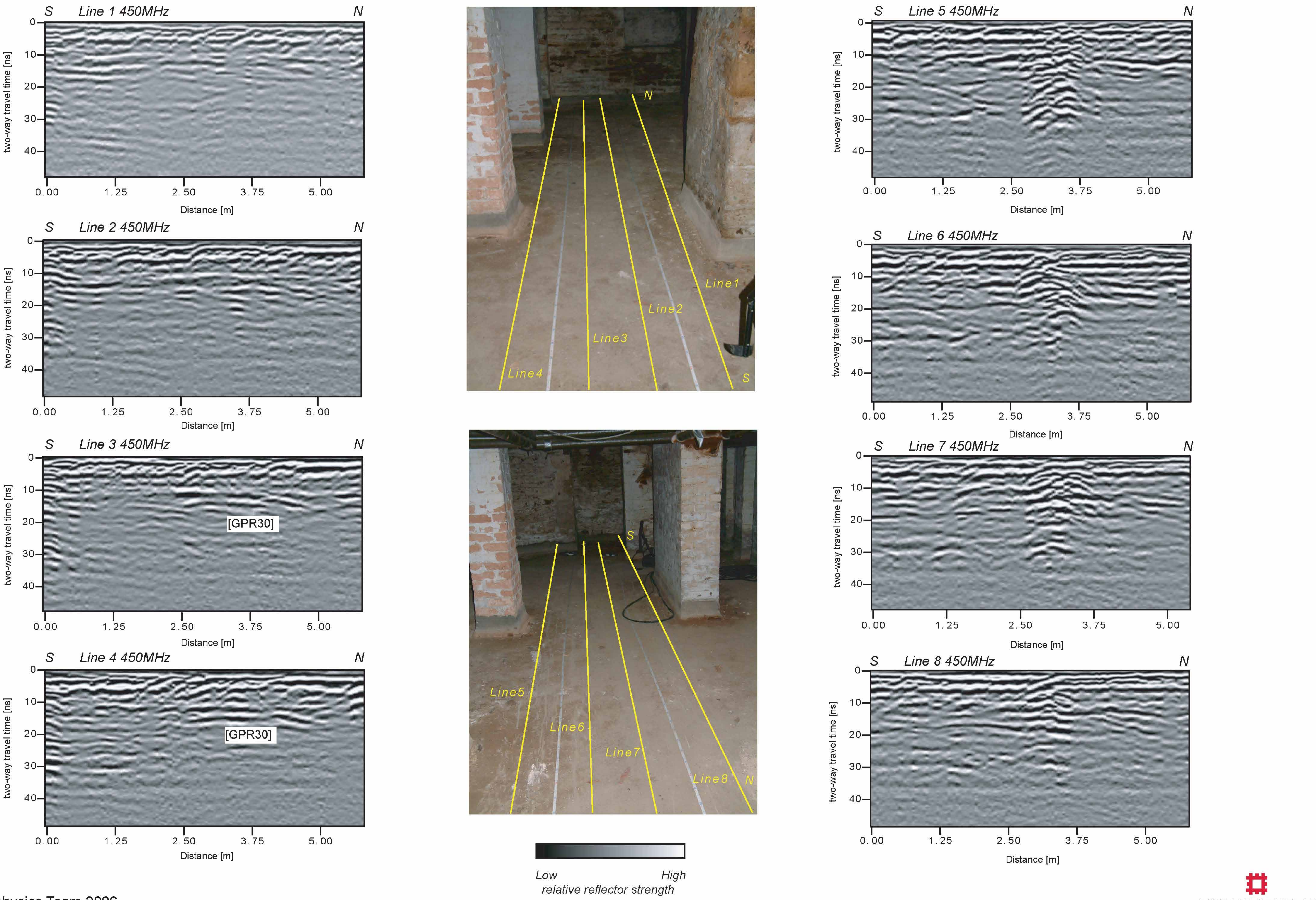
APETHORPE HALL, Northamptonshire
Ground Penetrating Radar survey, Cellar, September 2005.

Figure 13



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