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Geophysics

Kirby Hall, Gretton, North Northamptonshire Report on Geophysical Survey, July 2021

Neil Linford

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KIRBY HALL, GRETTON, NORTH NORTHAMPTONSHIRE REPORT ON GEOPHYSICAL SURVEY, JULY 2021

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SUMMARY

A Ground Penetrating Radar (GPR) survey was conducted at Kirby Hall, Gretton, North Northamptonshire, to investigate the immediate vicinity of a collapsed flagstone in a small storeroom adjacent to the Great Hall. The collapse occurred following substantial waterlogging of the ground floor of the building over the previous winter and the survey was extended to cover the whole flagstone floor of the Great Hall. Additional GPR coverage was conducted over the South Lawn beyond the building to determine the location and condition of drainage conduits serving the building known from a previous earth resistance survey. The GPR survey was conducted in response to a request from the English Heritage Trust in advance of works to address the flagstone collapse. A combined area of 0.4ha was surveyed with the data from within the storeroom suggesting the voiding in the immediate area of the flagstone collapse is relatively localised. Areas of high amplitude response within the Great Hall may require further invasive investigation to determine whether this remains structurally sound. Results from the South Lawn corroborate the previous earth resistance survey and suggested some additional detail associated with possible structural remains.

CONTRIBUTORS
The geophysical fieldwork was conducted by Neil Linford and Andrew Payne.

ACKNOWLEDGEMENTS
The author is grateful to colleagues from EHT at Kirby Hall who arranged access to the site to allow the survey to take place.

ARCHIVE LOCATION
Fort Cumberland, Portsmouth.

DATE OF SURVEY
The fieldwork was conducted on 26-30th July 2021 and the report was completed on 7th March 2022. The cover image shows the survey of the storeroom adjacent to the Great Hall in progress with the collapse flagstone visible in the foreground (photograph taken by A Payne).

CONTACT DETAILS
Dr Neil Linford, Geophysics Team, Historic England, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD.
Tel: 02392 856761. Email: neil.linford@historicengland.org.uk

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INTRODUCTION

A Ground Penetrating Radar (GPR) survey was conducted at Kirby Hall, Gretton, North Northamptonshire, (Listed building entry 1374889, Scheduled Ancient Monument List entry 1014421) to investigate the immediate vicinity of a collapsed flagstone in a small storeroom adjacent to the Great Hall. The GPR survey was conducted in response to a request from the English Heritage Trust following a particularly wet winter that led to the flooding of both the Great Hall and a small adjacent storeroom. The floors in both rooms are constructed from suspended flagstones and an isolated area of collapse appeared following the flooding event in the storeroom. It was hoped that GPR survey within the storeroom may help to identify the size and nature of underlying void in advance of works to address the flagstone collapse. The survey was extended to include the Great Hall within the main building to determine the location of any further possible voiding, and also over the south lawn to investigate the complex pattern of drainage known to exist here. The work has been agreed under the Shared Services Agreement and addresses Historic England corporate plan tier three objective “S4A.2 Support the English Heritage Trust in creating new knowledge”.

Construction of Kirby Hall, began in 1570 and survives today as both roofed and ruined standing buildings, together with associated service buildings, the earthwork and buried remains of C17th formal gardens. The small medieval settlement remains of the village of Kirby, abandoned by the early C17th, are found to the south and north of Gretton Brook, including the church and a possible early manor house. Previous magnetic and earth resistance surveys at the site revealed numerous anomalies associated with both the formal gardens and complex drainage system between the building and Gretton Brook to the south (Dix 1991; Linford 1992).

Calcareous soils of the Evesham 1 Association have developed over Middle Jurassic Lower Lincolnshire limestone (Soil Survey of England and Wales 1983; Geological Survey of Great Britain (England and Wales) 2002). Survey within the interior of the building was conducted directly over the flagstone floor surface and the south lawn down to mown grass interrupted by some tree planting. Weather conditions were generally dry and overcast, with some light rain at times.

METHOD

A 3d-Radar MkIV GeoScope Continuous Wave Step Frequency (CWSF) Ground Penetrating Radar (GPR) system was used to conduct the survey collecting data with a hand operated multi-element DXG0908 ground coupled antenna array inside the building and a vehicle towed DXG1820 (Linford *et al.* 2010; Eide *et al.* 2018). A Trimble S5 tracking total station and active reflector prism mounted on the GPR array was used to provide continuous positional control for the survey collected along the instrument swaths shown on Figure 1. Control points for the total station were established using a Trimble R8s Global Navigation Satellite System (GNSS) receiver adjusted to the National Grid Transformation OSTN15 using the Trimble VRS Now Network RTK delivery service. This uses the Ordnance Survey's GNSS correction network (OSNet) and gives a stated accuracy of 0.01-0.015m per point with vertical accuracy being half as precise.

Data were acquired at a 0.075m by 0.075m sample interval across a continuous wave stepped frequency range from 40MHz to 2.99GHz in 2MHz increments using a dwell time of 5ms. A single antenna element was monitored continuously to ensure data quality during acquisition together with automated processing software to produce real time amplitude time slice representations of the data as each successive instrument swath was recorded in the field (Linford 2013).

Post-acquisition processing involved conversion of the raw data to time-domain profiles (through a time window of 0 to 75ns), adjustment of time-zero to coincide with the true ground surface, background and noise removal, and the application of a suitable gain function to enhance late arrivals. Representative profiles from the GPR survey are shown on Figure 4. To aid visualisation amplitude time slices were created from the entire data set by averaging data within successive 2.5ns (two-way travel time) windows (e.g. Linford 2004). An average sub-surface velocity of 0.142m/ns was assumed for the Great Hall, and 0.132m/ns for the South Lawn, 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 therefore represents the variation of reflection strength through successive ~0.18m intervals from the ground surface in the Great Hall and 0.17m intervals over the South Lawn, shown as individual greyscale images on Figures 2, 3 and 5-8. 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 Figures 9 and 10. The algorithm uses edge detection to identify bounded 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 (Linford and Linford 2017).

RESULTS

A graphical summary of the significant GPR anomalies, [gpr1-34] discussed in the following text, superimposed on the base OS map data is provided in Figures 9 and 10.

Great Hall (Figure 9)

Reflections have been recorded throughout the 75ns two-way travel time window, although there are few significant later responses beyond ~45ns (3.2m), although some of the later anomalies may be due to near-surface multiples. The location of the visible collapse in the storeroom (room 0023) appears in the very near-surface data at [gpr1] and expands into a larger anomaly [gpr2] extending across the width of the room from between 7.5 and 30.0ns (0.55 to 2.13m). The response to [gpr2] is complex and, due to the air-filled nature of the void space, contains some contribution from air-wave reflections. A similar high-amplitude anomaly [gpr3] is found to the south between 10.0 and 27.5ns (0.71 to 1.95m), but appears to be more discrete in areal extent. As [gpr3] appears more clearly defined in the near-surface it may, potentially, suggest an area of delamination beneath the flagstones rather than air-filled voiding.

A series of high amplitude anomalies are found across the Great Hall (room 0022) visible from approximately 7.5ns (0.53m). Many of these anomalies, for example [gpr4-8], are relatively shallow, perhaps associated with localised delamination or settling immediately beneath the flagstones, that appears to form a dipping layer into the centre of the hall (Figure 4). A highly tentative linear trend [gpr9] is apparent between 15.0 and 27.5ns (1.07 to 1.95m) orientated approximately between the internal door from room 0024 to the entrance from the South Lawn. Anomalies [gpr10-13] within the Great Hall appear to be more substantial and may, potentially, represent localised areas of more significant structural voiding or damage. The concentration of anomalies [gpr11] and [gpr12] to the north of the Great Hall may, perhaps be associated with structural elements of the wall between the entrance from the courtyard and external door allowing access to the South Lawn.

South Lawn (Figure 10)

The near-surface data between 0.0 and 5.0ns (0 to 0.33m) contains a series of anomalies [gpr14] that are most likely associated with mole runs across the lawn. From approximately 2.5ns (0.17m) onwards a series of linear anomalies corroborate the results of the previous earth resistance survey over the South Lawn that revealed a complex network of drainage and other services, including an electricity supply cable [gpr15], a guttering outfall from the bay windows of the hall [gpr16], and parallel responses to a collecting drain [gpr17] and possible retaining wall or path [gpr18] (Linford 1992, Plan C, anomalies (24), (13), (18) and (19) respectively). The GPR data has also clarified the response of several anomalies that could not be fully interpreted in the earth resistance data with [gpr19] appearing to represent a near-surface paths, visible between 5.0 and 10.0ns (0.33 to 0.66m), and [gpr20] further drainage falling away from the house (Linford 1992, Plan C, anomalies (10) and (14)). Two more subtle drain-type responses [gpr21] and [gpr22] exit from at the same point from the house, with a possible spur [gpr23] between [gpr21] and [gpr20], although the relationship between these two anomalies is more complicated as they fall towards Gretton Brook suggesting, perhaps, that [gpr21] may be a more recent service at slightly more shallow depth. Anomaly [gpr22] continues around the south face of the building, apparently deviating around mature planting that again may possibly suggest a more recently routed service.

Rectilinear anomalies [gpr25] and [gpr26] are found on the same alignment as the main hall between 2.5 and 40.0ns (0.17 to 2.64m) and are suggestive of structural remains, perhaps either an extended building range or possible garden features. This corroborates the interpretation of similar anomalies found in the earth resistance data, with the GPR response confirming deeper lying wall footings perhaps further supporting the original suggestion of a walled garden or water feature (Linford 1992, Plan C, anomaly (11)). A spur [gpr27] to the drain [gpr20] cuts through the structural remains at [gpr26] and whilst it is difficult to suggest a more precise association between these anomalies they do appear to share a common orientation with the main house.

Two discrete high amplitude anomalies are found at [gpr28] and [gpr29] and may, perhaps, represent small garden features such as statue bases. There is also a more complex groups of anomalies [gpr30] to the south of the survey area, possibly a large pit, rubble spread or other evidence of former landscaping, perhaps also associated with a dipping reflector [gpr31] found immediately to the east. A similar group of amorphous high amplitude anomalies is found north towards the house at [gpr32] that correlates with an area of previously recorded poorly define magnetic response (Linford 1992, Plan C, anomaly (30)). There are also two low amplitude linear anomalies, [gpr33] and [gpr34] between 22.5 and 35.0ns (1.49 to 2.31m), that perhaps suggest further land drainage features.

CONCLUSIONS

The GPR survey has identified two areas of high amplitude response, most likely associated with subsurface voids, in the area immediately adjacent to the visible collapse of the flagstone floor in the storeroom. Both anomalies appear to be relatively discrete and, in the case of collapsed flagstone, the extent of the voiding correlates with the limited observation possible from the surface (Figure

11). It is difficult to suggest the cause of the collapse from the geophysical data although it seems likely that the recent flooding events have weakened the grouting between the flagstones allowing them to collapse into the underlying voids. Results from the Great Hall suggest a number of areas of similar high amplitude response that may either be associated with subsurface voiding or settling where further invasive investigation and monitoring would be advisable.

Survey over the Great Lawn largely corroborates the results of the previous earth resistance survey over the same the area, confirming a complex drainage network serving the gardens and house. The GPR data does suggest some more evidence for more structural remains with deeper wall-footings, again enhancing the earth resistance survey.

Figure 11 Partially collapsed flagstone (left) in the storeroom together with a view of through the opening to reveal the underlying void space (right). It would appear that the flagstone floor is suspended between structural walls with no additional packing material to stabilise the void.

LIST OF ENCLOSED FIGURES

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KIRBY HALL, GRETTON, NORTH NORTHAMPTONSHIRE
Location of GPR instrument swaths, July 2021

Figure 1

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GPR amplitude time slice between 22.5 and 25.0ns (~1.13 - 1.25m),
South Lawn, July 2021

Figure 2

0 30m
1:500

2021-07-25-001 Location of selected GPR profiles shown on Figure 3

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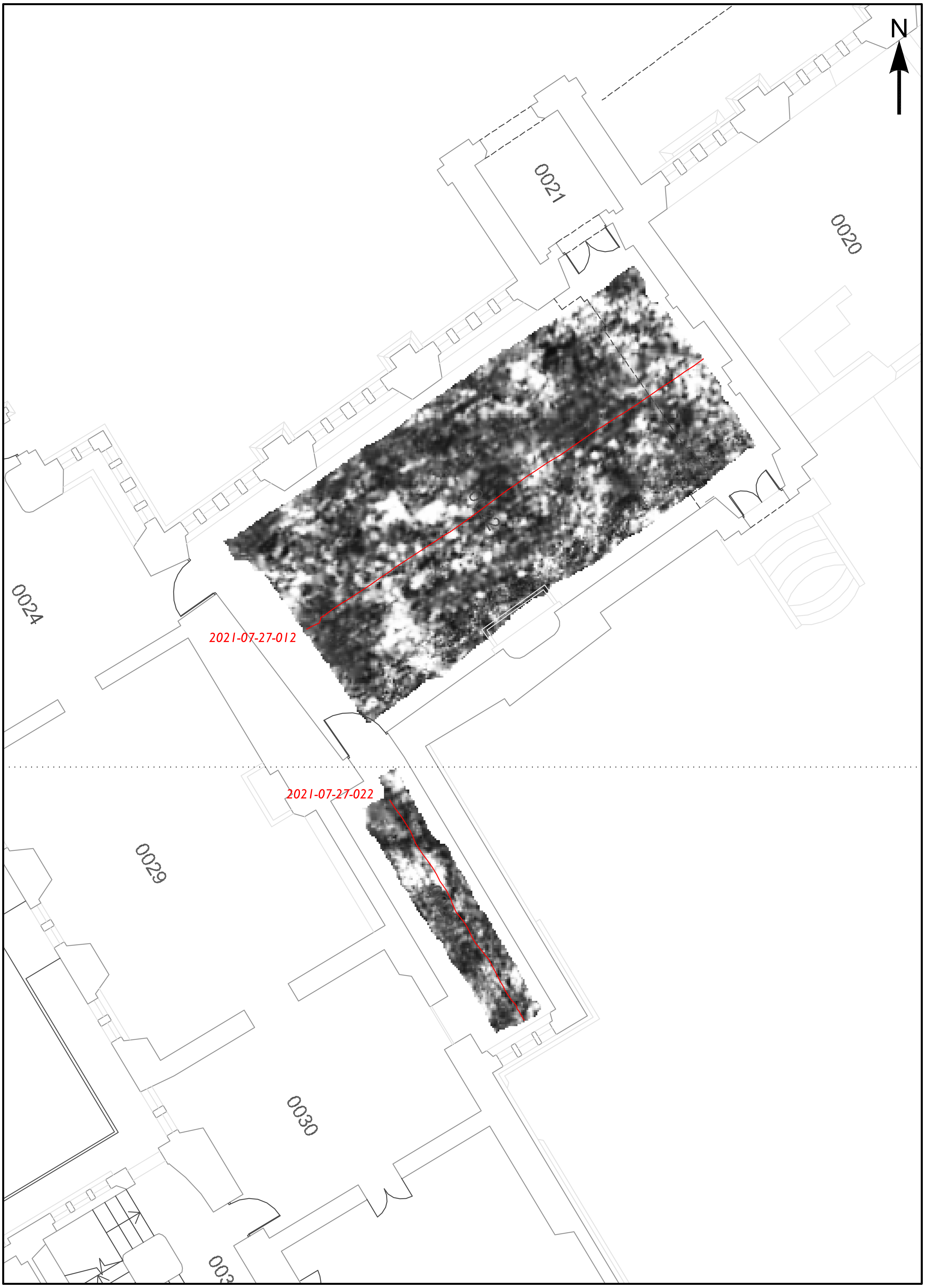
KIRBY HALL, GRETTON, NORTH NORTHAMPTONSHIRE
GPR amplitude time slice between 10.0 and 12.5ns (0.71 - 0.89m), Great Hall, July 2021

Figure 3



0 3m
1:100

Low High
relative reflector strength

2021-07-25-001 Location of selected GPR profiles shown on Figure 3

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Figure 4

Selected GPR profiles, July 2021

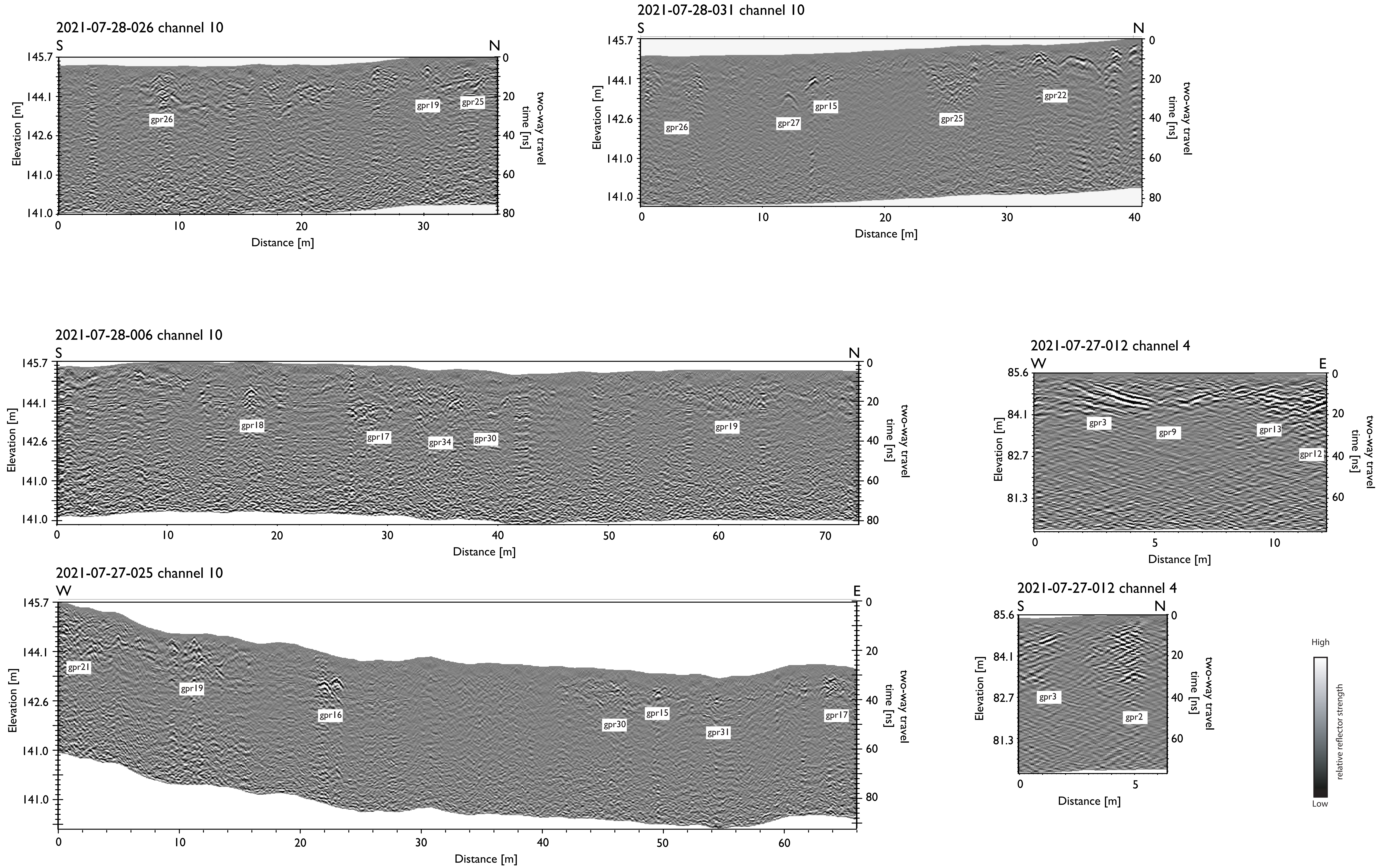

Figure 5

KIRBY HALL, GRETTON, NORTH NORTHAMPTONSHIRE
GPR amplitude time slices between 0.0 and 40.0ns (0.0 to 2.64m), South Lawn, July 2021

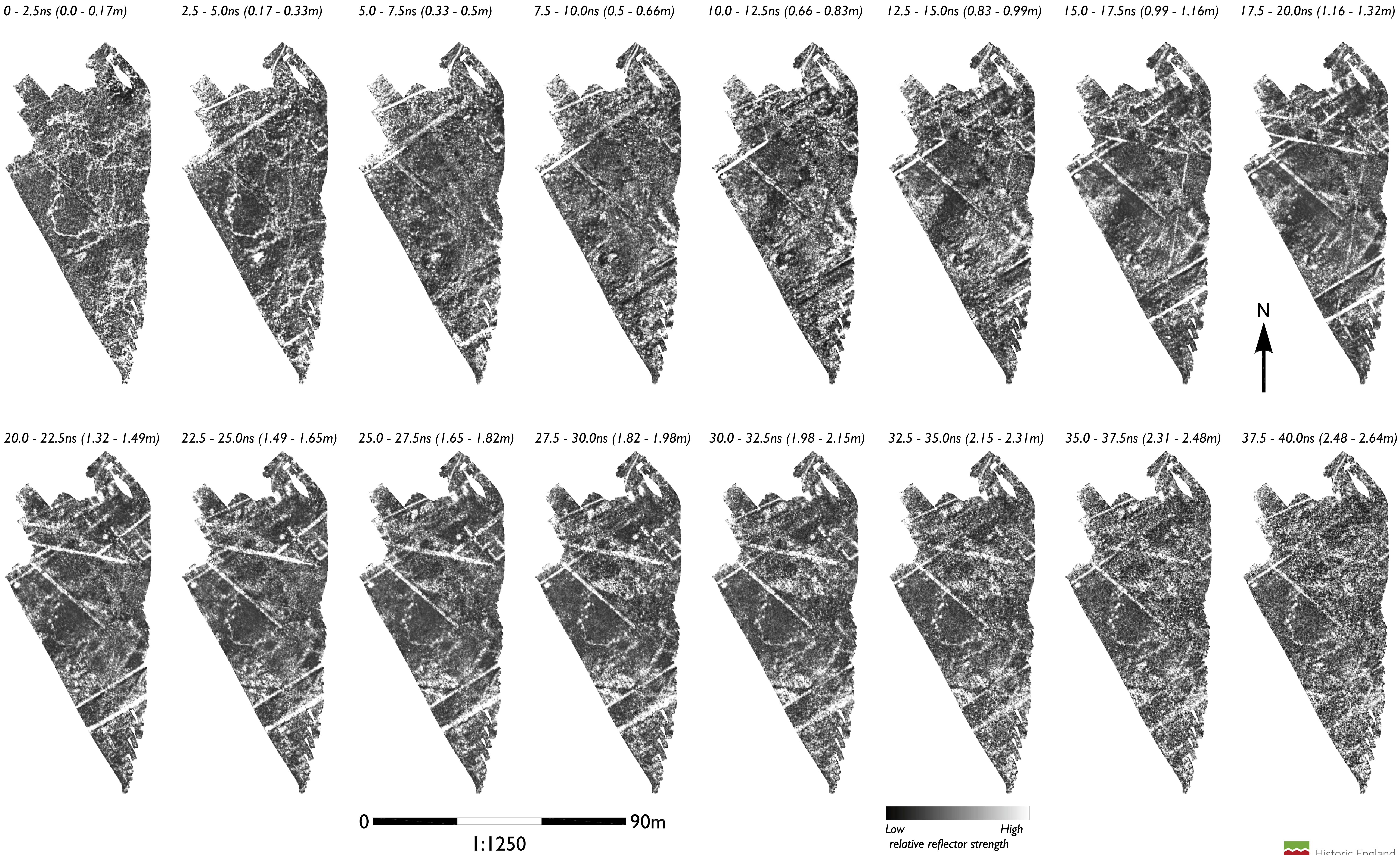

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Figure 6

KIRBY HALL, GRETTON, NORTH NORTHAMPTONSHIRE
GPR amplitude time slices between 40.0 and 75.0ns (2.64 to 4.95m), South Lawn, July 2021

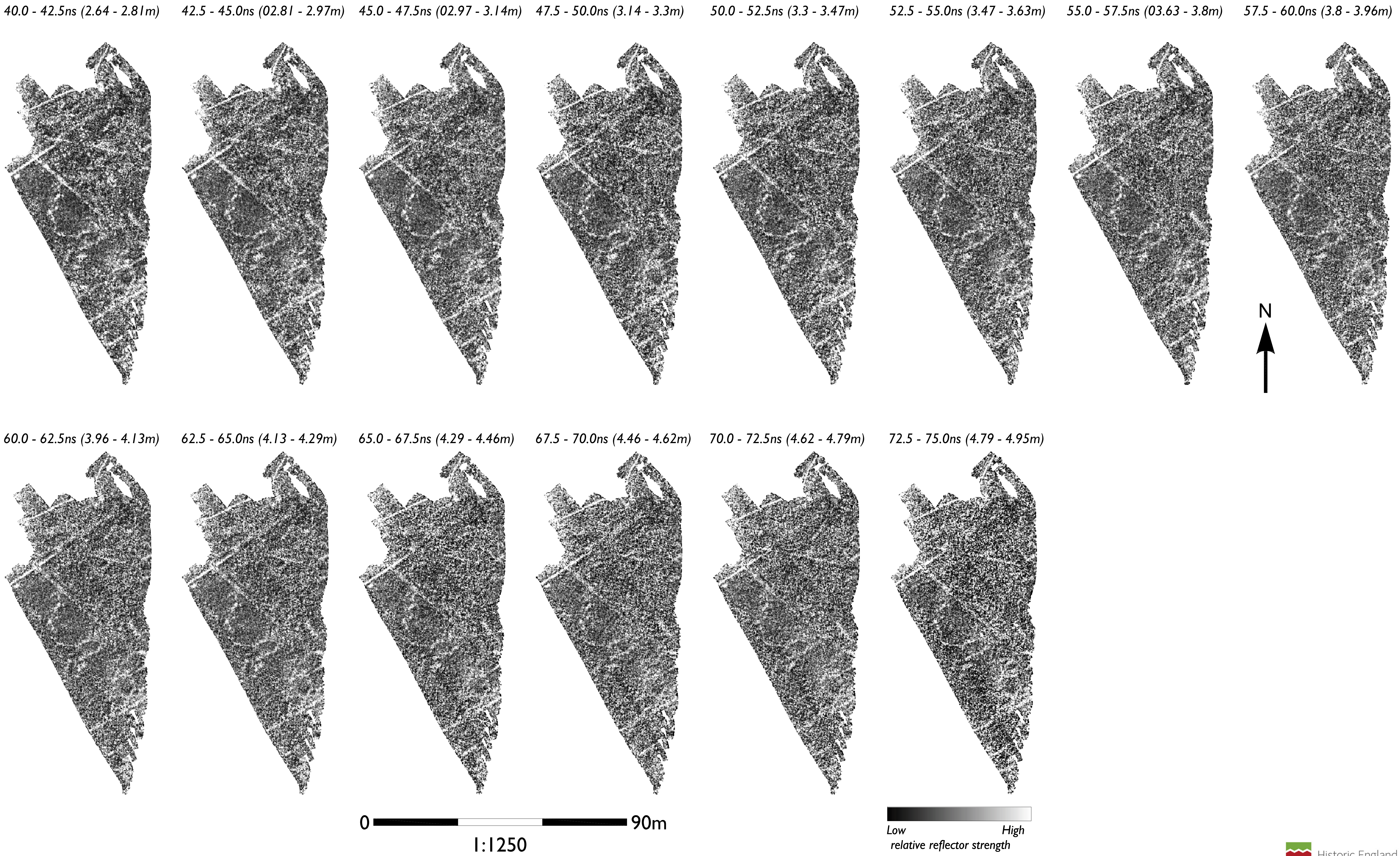

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Figure 7

KIRBY HALL, GRETTON, NORTH NORTHAMPTONSHIRE
GPR amplitude time slices between 0.0 and 30.0ns (0.0 to 2.13m), Great Hall, July 2021

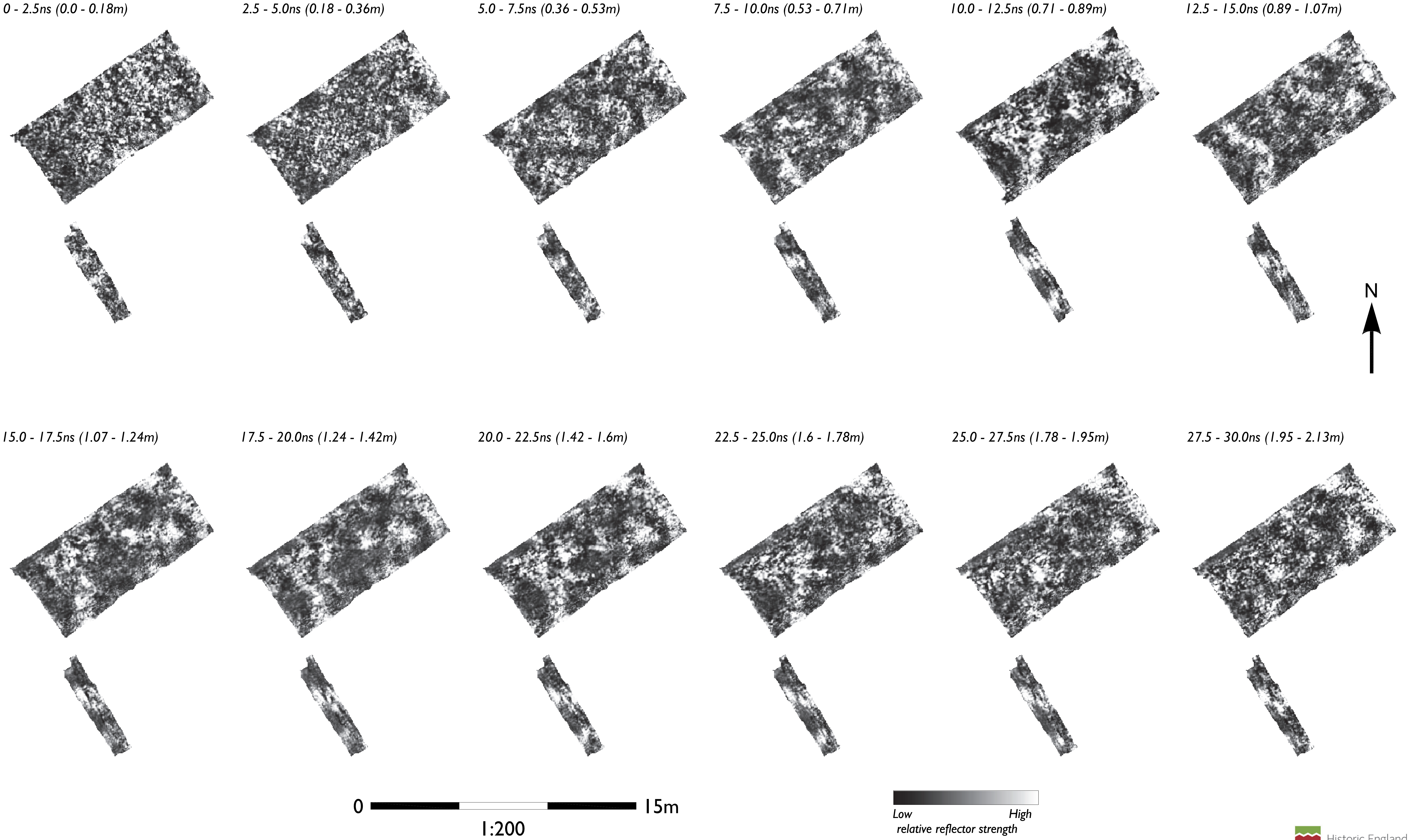

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Figure 8

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GPR amplitude time slices between 30.0 and 60.0ns (2.13 to 4.26m), Great Hall, July 2021

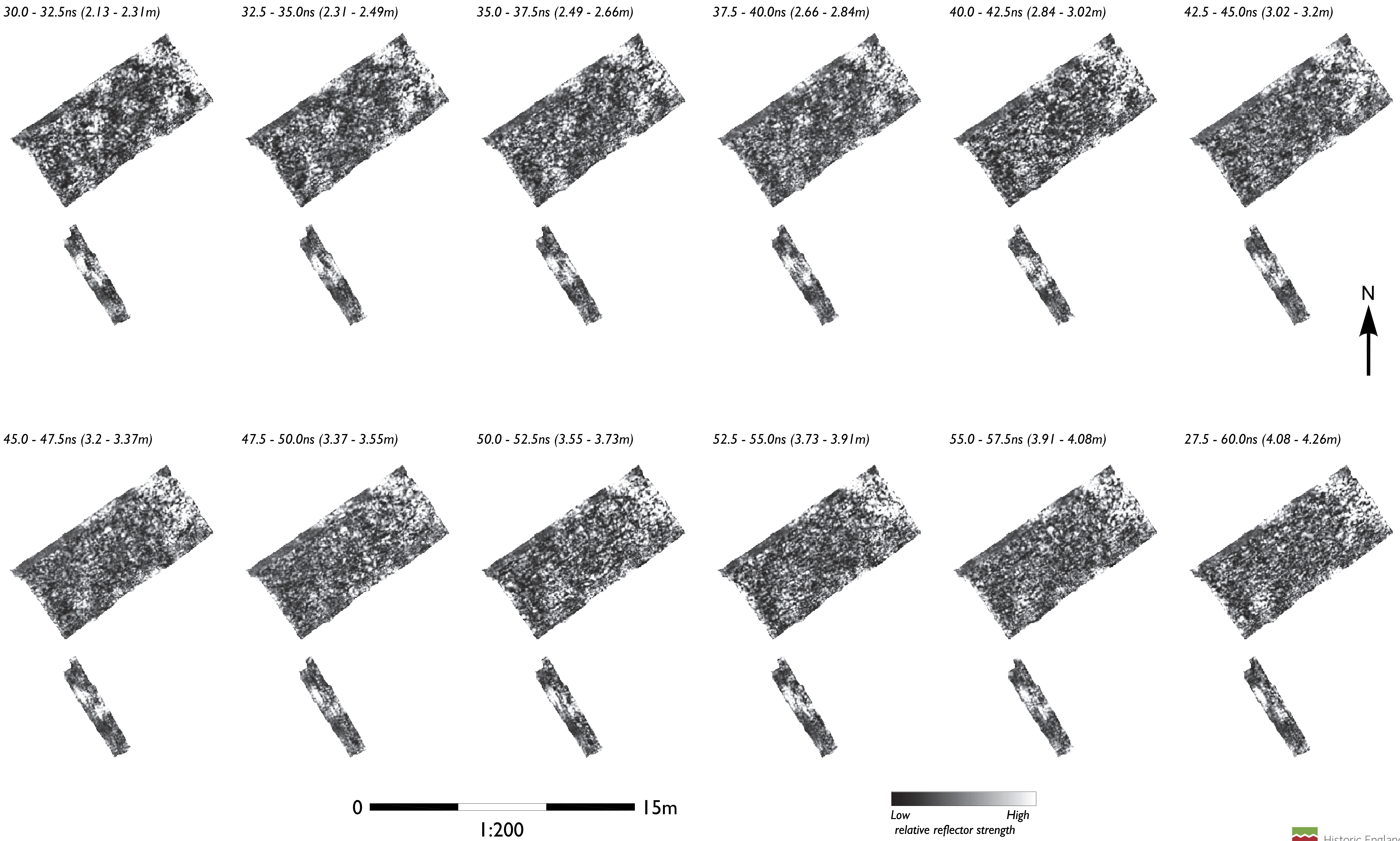

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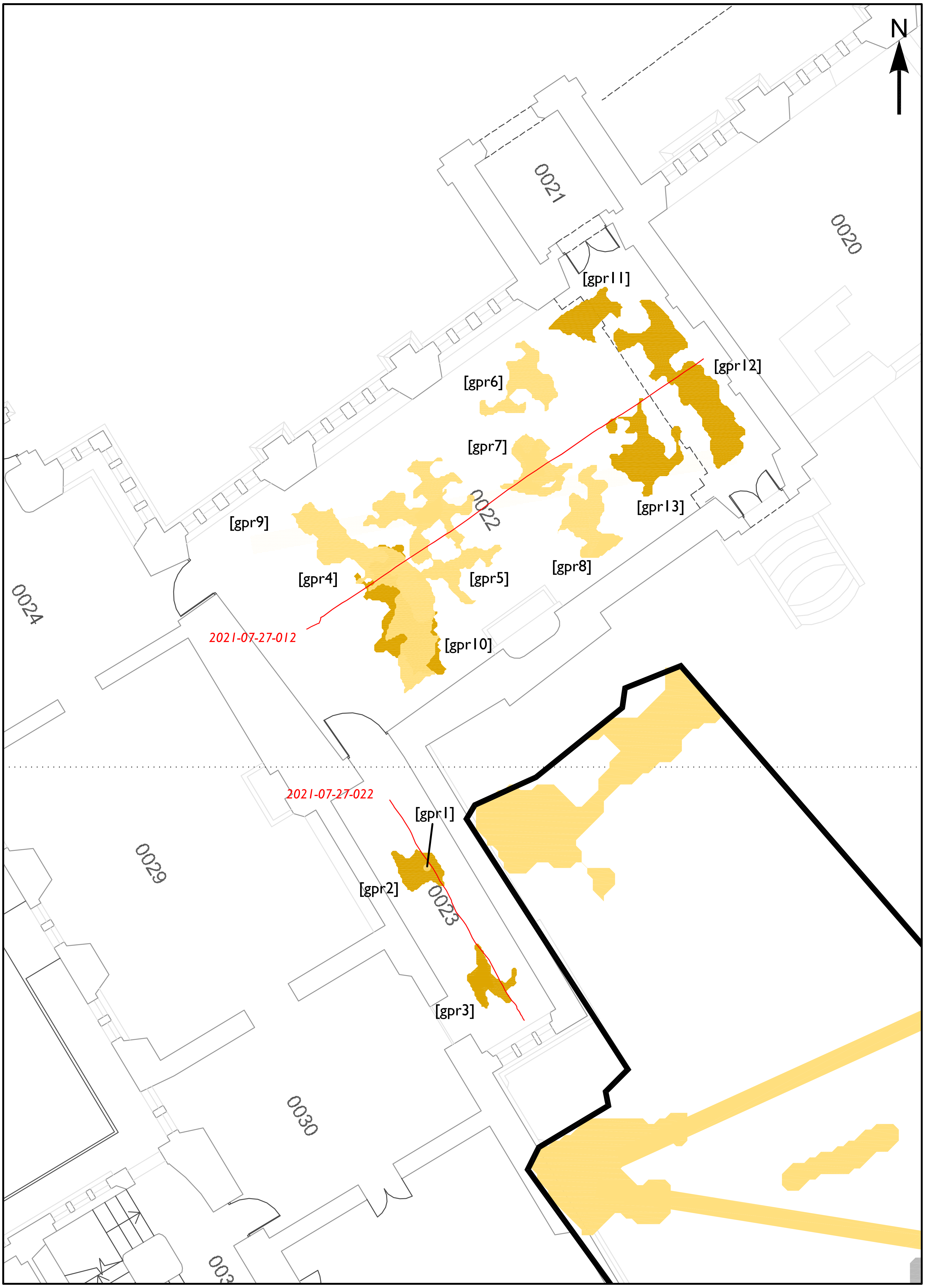
Figure 9

Graphical summary of significant GPR anomalies, Great Hall, July 2021



0 3m
1:100

low amplitude reflectors
high amplitude reflectors
2021-07-25-001 Location of selected GPR profiles shown on Figure 3
anomalies of known or recent origin

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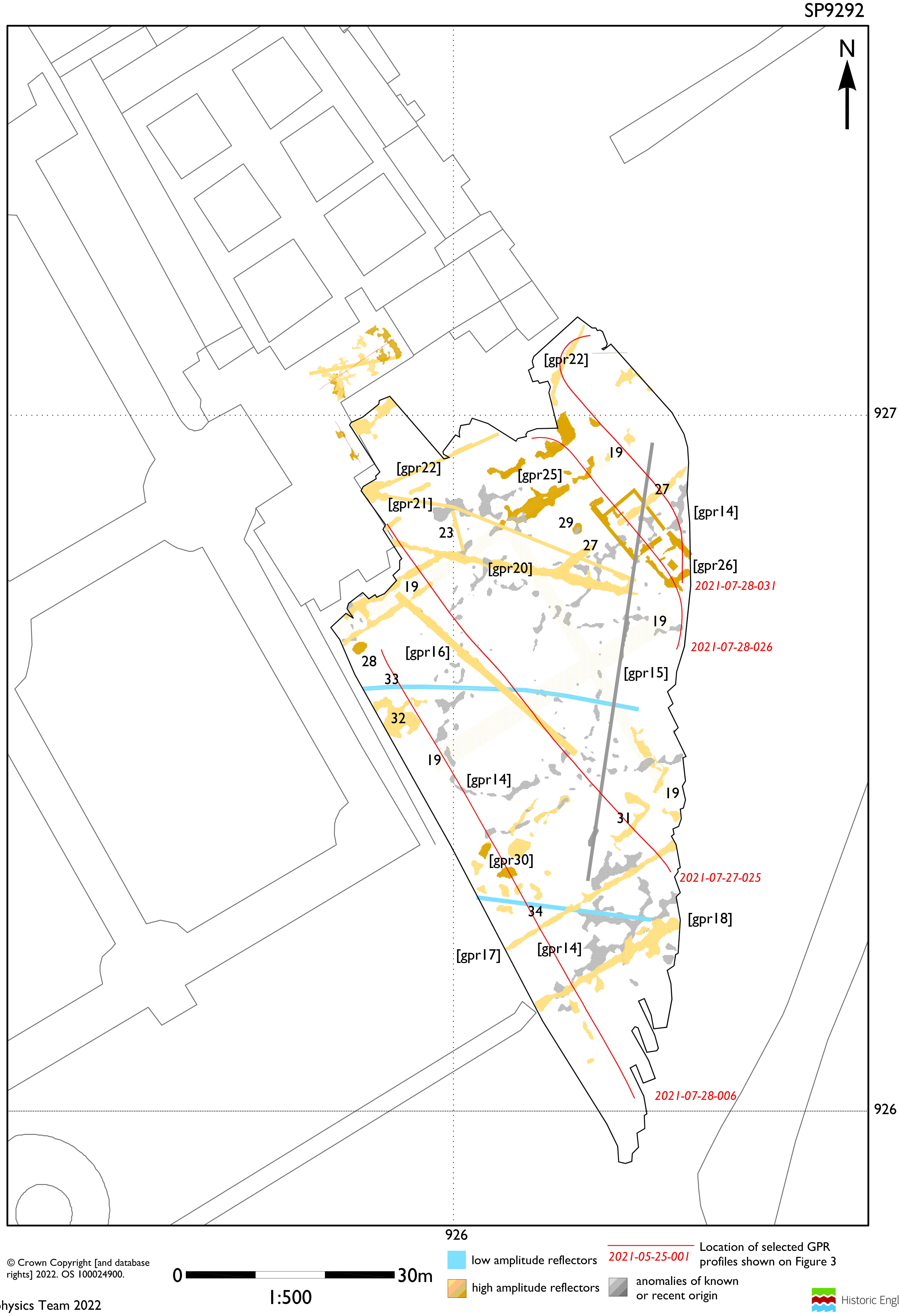
Figure 10

Graphical summary of significant GPR anomalies, South Lawn, July 2021



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