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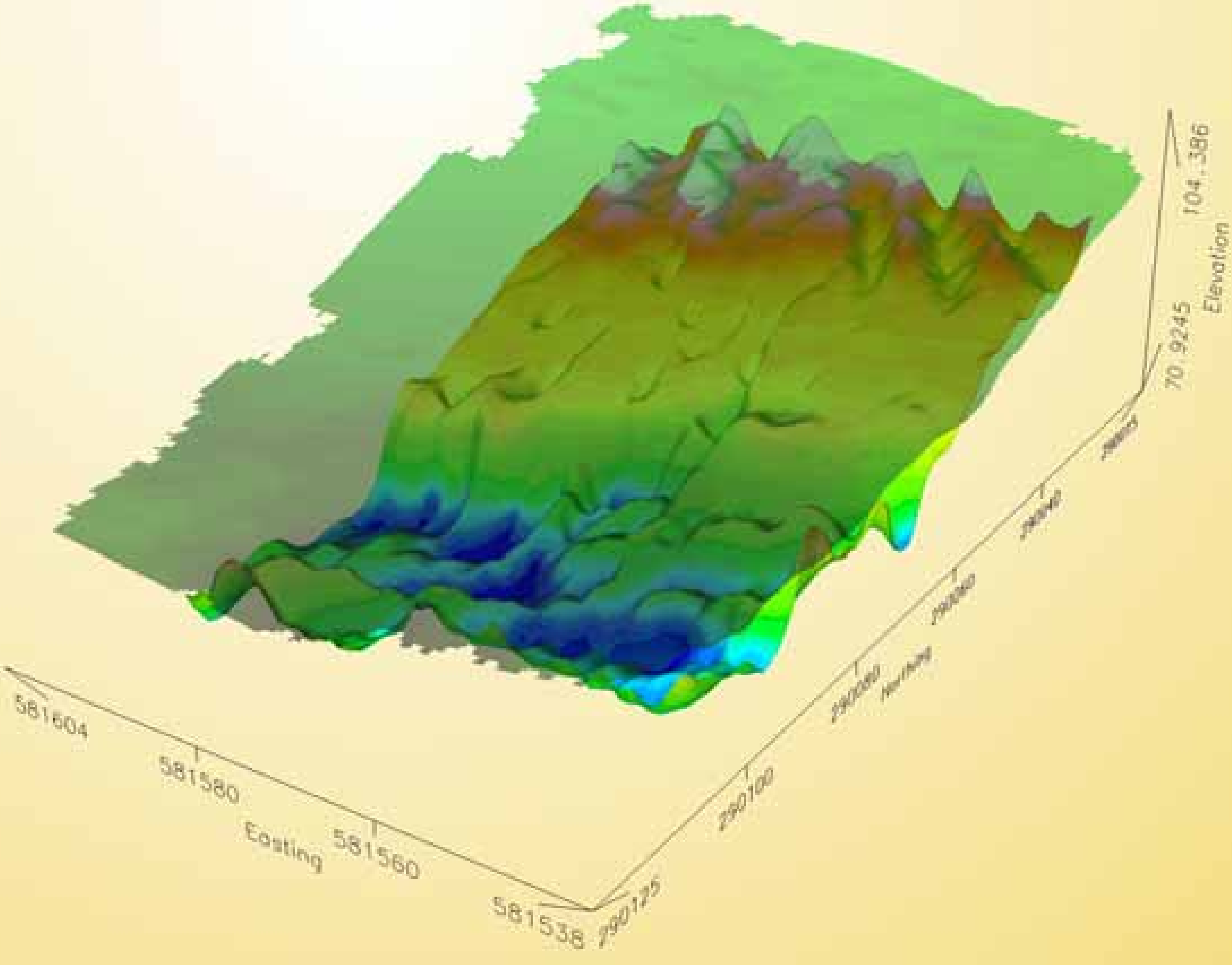
GRIMES GRAVES, NORFOLK
REPORT ON GEOPHYSICAL SURVEY, OCTOBER 2007

Neil Linford, Louise Martin and Jessica Holmes



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GRIME'S GRAVES, NORFOLK

REPORT ON GEOPHYSICAL SURVEY, NOVEMBER 2007

Neil Linford, Louise Martin and Jessica Holmes

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SUMMARY

A ground penetrating radar (GPR) survey was conducted over two trial areas at Grime's Graves, Norfolk, to identify suitable targets for investigation and sampling by a powered soil auger. The aim of the GPR survey was to provide more detailed information, including an estimation of depth, for a series of archaeological and geomorphological anomalies recognised through previous topographic, magnetic and earth resistance surveys. The GPR data were interpreted in the field to allow the auger survey to be conducted in conjunction with the geophysical survey and a number of suitable targets, including periglacial sand-filled stripes and possible further flint mining activity, were successfully identified. Conditions at the site proved to be particularly suitable for the GPR with good signal penetration to a depth of approximately 5m and allowed a detailed model of the buried palaeo-surface to be derived from the data set.

CONTRIBUTORS

The field work was conducted by Neil Linford and Louise Martin with the assistance of Jessica Holmes (University of Sheffield), Jennifer Heathcote (EH Regional Scientific Advisor, East of England) and Mathew Canti (EH Geoscientist).

ACKNOWLEDGEMENTS

This field work owes much to the useful discussions and enthusiasm for the site shared by Dave Field, Jim Leary and Pete Topping. We are grateful also to the site custodian for facilitating access and the services of the "flying flock" for grazing the vegetation to a manageable level. The cover shows an image of the sub-surface terrain model calculated from the GPR data overlain by a semi-transparent layer indicating the current site topography.

ARCHIVE LOCATION

Fort Cumberland.

DATE OF FIELDWORK AND REPORT

The fieldwork was conducted on the 19th and 23rd of November 2007 and the report was completed on 17th June 2009.

CONTACT DETAILS

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CONTENTS

INTRODUCTION

Grime's Graves is the only Neolithic flint mine open to visitors in Britain and contains over 400 shafts, pits, quarries and spoil heaps visible as distinct topographic anomalies covering a slightly raised area of approximately 6.5ha. Beyond this main area of visible remains, wind blown sand deposits have accumulated over the landscape and have obscured the identification of further prehistoric mining activity. The depth of these deposits is, perhaps, greatest in the bottom of a dry valley to the N of the site where the sand has in-filled a number of periglacial stripe features, well recognised as a type site in the literature (e.g. Ballantyne and Harris 1994, p96). Both the periglacial stripes and possible additional mine workings have been identified by previous aerial photographic and geophysical surveys (Sieveking *et al.* 1973; Payne 1993; Bartlett 2006); particularly an extensive earth resistance survey that indicated the potential depth extent of the geomorphological features (Favard and Dabas 2007).

The aim of the current ground penetrating radar (GPR) survey was to test the suitability of the site for this technique and, if successful, to identify and provide further detail of anomalies suitable for further investigation and sampling with a powered soil auger. This element of the work was conducted in conjunction with the GPR survey as part of an EH sponsored CASE PhD studentship, hosted by the University of Sheffield. Initial processing and interpretation of the GPR data was conducted in the field to assist with the accurate location of the auger samples.

Two areas were chosen to conduct the trial GPR survey, Area A located across the dry valley in the vicinity of the current access route to the site and Area B immediately N of the visible mine workings. The site itself is centred on an area of regularly grazed breckland (TL 815 900) surrounded by commercial forestry plantations. Soils of the Methwold and Worlington associations have developed over glaciofluvial drift and chalky till interspersed with underlying cretaceous chalk.

Weather conditions were generally dry and sunny throughout the survey.

METHOD

A survey grid was first established over the site using a Trimble kinematic differential global positioning system (GPS).

Ground Penetrating Radar survey

The Ground Penetrating Radar survey was conducted with a Sensors and Software Pulse Ekko PE1000 console and a 225MHz centre-frequency antenna. A subsurface velocity of ~0.1m/ns, determined from analysis of a common mid-point (CMP), was adopted as a reasonable average value for processing the data from the site and for the estimation of depth to reflection events in the recorded profiles.

Data was collected along parallel NS traverses separated by 1.0m for the survey over the dry valley and along an EW orientation at the same separation over the area containing the suspected shafts (Figure 1). Individual traces along each profile were separated by 0.05m and recorded the amplitude of reflections through a 60ns time-window in Area A, increased to 80ns in Area B given the depth of penetration achieved at this site (e.g. Figures 4 and 7). 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.

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 0.2m if a centre frequency of 225MHz and a velocity of 0.1m/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). Each resulting time slice, illustrated as a greyscale image in Figures 5 and 8 represents the variation of reflection strength through successive ~0.2m intervals from the ground surface. Figures 2 and 3 show a representative amplitude time slice, superimposed over the base OS mapping together with the location of the auger cores (Appendix 1).

Topographic survey

Variation of the local topography over the two survey areas was collected with a Trimble differential kinematic GPS over an irregular grid with a sampling interval of approximately 2m. The resulting digital terrain model (DTM) was then interpolated onto a regular grid to allow the topographic variation along each recorded instrument traverse to be extracted and an appropriate static shift applied to each GPR profile, expressed in relation to the absolute elevation of site (e.g. Figures 4, 7 and 11).

RESULTS

Graphical summaries of the anomalies discussed in the following text, superimposed on the base Ordnance Survey map data, are provided in Figure 6 for Area A and Figure 9 for Area B.

Area A - the dry valley

The near-surface amplitude time slices between 0 and 16ns (0 to 0.8m) shown on Figure 5 demonstrate a largely uniform response, due in part to the uneven nature of the breckland terrain, interrupted by the course of the access track **[gpr1]** that appears initially as a linear anomaly to approximately 20ns (1m). The influence of the track appears to extend as an area of low amplitude response visible from 44ns (2.2m) onwards, but it is possible that this is due to signal attenuation in the near-surface layers rather than the physical extent of the feature itself.

A much greater distinction between the low amplitude response over the raised chalk ridge to the S and the much stronger reflections from the wind blown sand deposits in the lower lying dry valley is visible from 20ns (1.0m) onwards (cf Bristow and Jol 2003).

The response to the sand filled, periglacial stripes also becomes readily apparent as a series of high amplitude, linear anomalies **[gpr2]** to the S of the survey area and, in part, these are also evident in the near-surface data. When viewed in profile the periglacial stripes appear as a more complex group of individual reflectors continuing without any distinct facies (e.g. Figure 4, Line 10), possibly due to the occasional flint pebbles noted in the subsequent auger logs (Appendix 1).

A similar response, composed of discrete individual reflectors, is also found down into the dry valley to the N and probably accounts for the high amplitude values in this area recorded in the time slices. Further examination of the profiles through the dry valley shows a series of more continuous reflectors, perhaps describing the interface between the wind blown sand and the channel bottom. Some evidence for additional 'V' shaped structures within the channel is suggested by the profiles and this is, in part, replicated in the time slices by two parallel low amplitude linear anomalies **[gpr3]** and a larger, discrete response **[gpr4]**.

Area B – mine workings

The signal to noise ratio in Area B appears similar to the near-surface response recorded over the dry valley and no significant anomalies are visible in the time slice data earlier than 20ns (1.0m). From this depth onwards a series of discrete, pit-type responses **[gpr5 - 15]** are evident to the S of the survey area in close proximity to the extant mine workings (Figures 3, 8 and 9). The anomalies vary between approximately 4 and 6m in diameter and demonstrate a size and morphology not too dissimilar to the extant shafts to suggest these represent a continuation of the mine working activity. The maximum depth extent is difficult to fully assess from the GPR data, due to more severe signal attenuation in the later time slices. However, the majority of the pit-type anomalies extend to 60ns (3.0m) and there is some evidence to suggest that **[gpr7]** continues to 80ns (4.0m). The significance of the low amplitude response surrounding each of the pit-type anomalies is uncertain, although this may represent spoil from the mine shafts. A tentative, high-amplitude anomaly **[gpr16]** also appears to enclose **[gpr9]** and may represent a more pronounced bank of spoil or, perhaps, a larger mine working.

The pit-type anomalies appear to be better defined in the profile data where they can be seen in the near-surface (between 0 to 20ns) as a sloping linear response descending into a more complex pattern of high-amplitude reflectors (e.g. Figure 7). The GPR profiles confirm the depth extent of mine workings, to at least 3m from the ground surface, and suggest the presence of other, more subtle buried depressions that are not represented in the amplitude time slices (e.g. **[gpr17 - 19]** on Figure 7). There is also evidence for an undulating linear horizon at a depth of approximately 50ns (2.25m) from the surface punctuated by a number of discrete, high-amplitude reflections (dashed red line on Figure 7). This would appear to coincide with the depth to the unweathered chalk bedrock or a seam of flint targeted by the mine shafts.

Comparison with the coring survey

A full description of all the cores sampled during the GPR survey is provided in Appendix 1 and the location of each core is shown on Figures 2 and 3. Three of the cores, GGS 2, GGP 3 and GGH 2, were located to investigate specific anomalies identified by the geophysical survey and these are shown graphically superimposed over the relevant GPR profiles, together with an abbreviated interpretation of the results on Figures 4 and 7. Core GGS 2, taken through the location of a periglacial stripe, suggests a more considerable depth to these features with the sand deposits encountered here extending to beyond 5m. It is unclear whether this represents the depth of the soil stripe or, perhaps, some more extensive feature such as an ice wedge or fissure (e.g. Ballantyne and Harris 1994, Figure 4.11). The GPR survey has not, apparently, identified the stratigraphy revealed by the core beyond a horizontal reflector that may correlate with the soliflucted clay deposit between 1.61 and 1.7m and a general, complex response of individual point reflectors associated with the sand deposits. This differs from the GPR response to the colluviated sand found in the dry valley, sampled in core GGP 3, which contains few, if any discrete reflectors. However, the interface between the sand and the underlying deposits of alluvium and chalk forming the bottom of the original channel is evident on the GPR profile, recorded here at a depth of approximately 2m from the current ground surface.

A single core, GGH 2, was successfully recovered from Area B on the edge of one of the large pit-type GPR anomalies. The GPR response appears to correlate well with the initial deposits of blown sand, until a band of chalk and sand rubble is encountered between 1.2 and 2.5m where the signal appears to attenuate more rapidly. The interface with the underlying chalk bedrock at 2.5m has been detected by the GPR survey as an intermittent horizontal reflector.

Mapping the sub-surface terrain

Analysis of the GPR profiles has already indicated a distinct contrast in the amplitude of reflections at the apparent interface between the coversand deposits and the underlying, bedrock chalk (Figures 4 and 7). This interface is even more distinct following the application of 2D Stolt migration and extracting the amplitude envelope of the resulting topographically corrected data traces (e.g. Figure 10). Given that the coversand deposits have obscured much of the topography associated with the original ground surface, such as the profile of the channel in the dry valley, and also appear to have in-filled buried mine working shafts and glacial stripes, this interface layer may be of great interest for palaeo-landscape reconstruction.

An initial attempt to visualise this interface by selecting an appropriate iso-surface to cut-away high amplitude reflectors from a raster cube of the entire data set proved unsuccessful, due to the relatively high degree of noise present and variation in the magnitude of response between transects across the site (*cf* Fig23, Linford 2006). Attempts to reduce the influence of noise within the data cube, for example through the application of a low-pass filtering algorithm, removed too much detail from the resulting image of the chalk interface layer to be of use.

This prompted the development of an algorithm to automatically pick the deepest lying amplitude interface from a moving average window centred on each trace in turn across the individual data transects. Figure 10 shows two representative profiles with the calculated vector chalk interface layer superimposed over the raster image of the enveloped GPR data. The algorithm copes well with the inherently noisy nature of the data set, although the necessary averaging may underestimate the depth to the interface where this is overlain by a less distinct layer of weathered chalk.

The resulting vector data set represents a sub-surface terrain model where the depth to the interface layer is mapped across the area covered by the GPR survey in a manner akin to recording the surface topography of the site. This data may be readily visualised as a false perspective pseudo 3D model of the buried land surface either with, or without, the inclusion of a semi-transparent layer representing the overlying modern topography. In Area A the morphology of the periglacial stripes is clearly shown gouged into the underlying chalk ridge to the S (Figure11(A)). The profile of the dry valley is also well represented, despite the considerable quantity of wind blown sand that has obscured the expression of the original land surface in the current topography of the site.

Over Area B the sub-surface terrain model slopes downwards to the N from the extant mine workings and this trend is accurately reflected by the surface DTM. However, the sub-surface terrain model suggests a degree of undulation that is not expressed on the surface, including a number of additional mine-working shafts bordering the extant earthworks to the S of the survey area. These shafts appear to be represented by a raised annular bank surrounding a central depression extending to depths of at least 2m. The banks of neighbouring shafts appear to be conjoined in similar manner to the extant earthworks, suggesting waste from each new excavation was partially emptied into finished workings. The density of the mine workings revealed by the sub-surface terrain model is also seen to rapidly diminish to the N where the identification of individual shafts is less distinct. This may, in part, be due to increased overburden obscuring the identification of shafts as the original land surfaces falls away to the N (Figure 11), although the maximum depth extent would appear to be well within the range of the radar at this site. The remains of two outlying mine workings are extant just beyond Area B on a ridge of higher ground immediately above the dry valley, perhaps suggesting the density of the main workings diminishes to the N where only more isolated groups of pits are found.

CONCLUSION

Trial GPR survey at Grimes Graves has proved successful and revealed that conditions at the site are very well suited to the use of this technique. The high resistance, aeolian sands that cover much of the site appear to be readily transparent to the GPR signal and have allowed for the identification of significant reflectors to depths in excess of 3m from the current ground surface using a 225MHz centre frequency antenna. Some difficulty was encountered maintaining coupling of the antenna to the ground surface due to the uneven nature of the Breckland terrain. However, this did not prevent the identification of significant anomalies associated with both geomorphological features, such as the periglacial striping widely reported within this area, and the location of previously unrecognised flint mining shafts that are not expressed in the surface topography of the site.

Visualising such a complex 3-dimensional data set in terms of the original buried land surface provided a particular challenge, met through the development of an algorithm to automatically detect the change in signal envelope amplitude associated with the interface between wind blown sand and the underlying chalk. This approach allowed detailed models of the sub-surface terrain to be recovered accounting for the variable surface topography and provided a unique visualisation of significant features, enhancing the interpretation of the GPR data compared with scrutiny of individual profiles or through horizontal (constant depth) amplitude time slices. A series of core samples recovered during the survey, targeted from the field interpretation of the GPR data, confirmed the approximate depth estimates and likely nature of the physical interfaces represented by the geophysical anomalies.

LIST OF ENCLOSED FIGURES

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APPENDIX 1

Coring at Grime's Graves, East Anglia.

21-23 November 2007.

Jessica Holmes (author),
Matthew Canti, Jen Heathcote, Neil Linford and Louise Martin.

Introduction

Coring was carried out in order to assess the following aims:

1. To describe/ determine the sedimentary profile, depth and age (using OSL dating) of a now extinct palaeo-channel on the site.
2. To describe/ determine the sedimentary profile, depth and age of a series of thermokarstic periglacial stripe features located on the slope of the hill.
3. To determine whether any new flint mining shafts could be located within an area close to the main mining site that had had no previous geophysical survey work done.

Nine holes in total were drilled however, as some of these were replicate holes (used solely to obtain sand samples for OSL dating), it was only necessary to describe the sediment profiles from five of the holes. The core descriptions and interpretations derived from them are presented below.

GGP 1. NGR: 581590 290089 (23m along GPR transect 49 from N).

Drilled to obtain OSL sand sample from deepest point of channel, but core failed below 0.29 m.

Depth (m)	Stratigraphic description
0 – 0.04:	Very dark grey (10YR 3/1) medium silty sand. Frequent fine roots. Stone-free. Loose compaction.
0.04 - 0.29:	Dark yellowish brown (10YR 4/4) medium silty sand. Occasional rootlets. Occasional flint pebbles <0.05 m. Large flint ~0.10 m at base of deposit. Moderate compaction.
0.29 – 1.40:	Discarded material (would not remain within the drill head, so became mixed).
2.66 onwards	Chalk bedrock

Depth (m)	Initial interpretation:
0 – 0.04	Humic topsoil

0.04 – 0.29	Ploughsoil
0.29- onwards	Mixed material fallen from drill head.

GGP 2. NGR: 581590 290086 (30m along GPR transect 49 from N).

This core was drilled in attempt to obtain OSL sand samples from within the channel.

Depth (m)	Stratigraphic description
0 - 0.04:	Very dark grey (10YR 3/1) medium silty sand. Frequent fine roots. Stone-free. Loose compaction.
0.04 – 0.32:	Dark yellowish brown (10YR 4/4) medium silty sand. Occasional rootlets. Occasional flint pebbles <0.05 m. Moderate compaction.
0.32 – 0.51:	Strong brown (7.5YR 5/8) medium sand. Occasional flint pebbles. Moderate compaction.
0.51 – 0.61:	Yellowish brown (10YR 5/8) medium sand. Stone-free. Loose compaction.
0.61 – 1.21:	Yellowish brown (10YR 5/6) medium sand. Occasional flint pebbles. Moderate compaction.
1.21 – 1.52:	Yellow (10YR 7/6) medium sand. Stone-free. Loose compaction.

Depth (m)	Initial interpretation:
0 – 0.04	Humic topsoil
0.04 – 0.32	Ploughsoil
0.32 – 0.51	Colluviated sand with some podsolic development.
0.51 – 0.61	Blown sand
0.61 – 1.21	Colluviated sand
1.21 – 1.52	Blown sand

GGP 3. NGR: 581589 290082 (26m along GPR transect 49 from N).

This core was drilled to assess the double reflectors within the GPR data.

Depth (m)	Stratigraphic description
0 - 0.04:	Very dark grey (10YR 3/1) medium silty sand. Frequent fine roots. Stone-free. Loose compaction.
0.04 – 0.30:	Dark yellowish brown (10YR 4/4) medium silty sand. Occasional rootlets. Occasional flint pebbles <0.05 m. Moderate compaction.
0.30 – 1.84:	Colluvium (various layers). Sands containing flint grit, pebbles and cobbles.
1.84 - 1.86:	Chalk band.
1.86 – 2.25:	Yellowish brown (10YR 5/8) coarse sand. Occasional flint pebbles. Moderate compaction.
2.25 onwards	Chalk bedrock.

Depth (m)	Initial interpretation:
0 – 0.04	Humic topsoil
0.04 – 0.30	Ploughsoil
0.30 – 1.84	Colluviated sand.
1.84 – 1.86	Weathered chalk detritus
1.86 – 2.25	Alluvium or coversand

GGP 4 NGR: 581590 290088

This core was manually augered in order to retrieve ploughsoil sediments for OSL dating at 0.30 m. Therefore, the sediments within it were not described.

GGP 5 NGR: 581590 290087

This core was manually augered in order to retrieve subsoil (Bh) sediments for OSL dating at 0.45 m. Therefore, the sediments within it were not described.

GGS 2. NGR: 581551 290033 (10 x 10 m NE from SW corner of GPR grid).

This core was drilled in order to record the stratigraphic profile within a periglacial stripe which could then be used to inform the sampling strategy for collecting sand samples for OSL dating.

Depth (m)	Stratigraphic description
0 – 0.25:	Very dark grey (10YR 3/2) medium silty sand. Moderate compaction.
0.25 – 0.49:	Dark yellowish brown (10YR 4/4) medium silty sand. Occasional flint grit. Strong compaction.
0.49 – 0.60:	Yellowish brown (10YR 5/6) medium sand. Occasional flint pebbles. Loose compaction.
0.60 – 0.76:	Yellowish brown (10YR 5/8) medium sand. Stone-free. Loose compaction.
0.76 – 1.18:	Brownish yellow (10YR 6/6) coarse sand. Occasional flint grit. Loose compaction.
1.18 – 1.48:	Brownish yellow (10YR 6/6) mixed sand. Frequent chalk mottles. Occasional flint pebbles. Strongly compacted.
1.48 – 1.61:	Yellowish brown (10YR 5/6) medium sand. Occasional chalk mottles. Occasional grit and pebbles. Loose compaction.
1.61 – 1.70:	Yellow (10YR 7/6) clay. Moderate grit and pebbles. Strong compaction.
1.70 – 1.79:	Brownish yellow (10YR 6/6) medium sand. Occasional grit. Stone-free. Loose compaction.
1.79 – 2.00:	Brownish yellow (10YR 6/6) silty clay. Stone-free. Strong

	compaction.
2.00 – 2.59:	Light yellowish brown (2.5Y 6/4) clay. Frequent grit. Occasional flint pebbles. Strong compaction.
2.59 – 2.65:	Yellow (2.5Y 7/6) silty clay lens. Frequent grit. Strong compaction.
2.65 – 3.05:	Light yellowish brown (2.5Y 6/4) clay. Frequent grit. Occasional flint pebbles. Strong compaction.
3.05 – 3.13:	Olive yellow (2.5Y 6/8) silty clay lens. Occasional grit and pebbles. Strong compaction.
3.13 – 3.35:	Yellow (2.5Y 7/6) silty clay. Moderate sand lenses within deposit (0.05 m deep). Stone-free. Strong compaction.
3.35 – 3.48:	Olive yellow (2.5Y 6/6) clay. Ironstone(?) inclusion or iron pan? Occasional degraded chalk nodules. Strong compaction.
3.48 – 3.80:	Finely laminated strong brown (7.5Y 5/8) silts and yellow (10YR 7/6) clay. Stone-free. Moderate compaction.
3.80 – 3.88:	Laminated yellow (10YR 7/8) and strong brown (7.5Y 5/8) coarse sands. Stone-free. Loose compaction.
3.88 – 4.48:	Mixed sand. Mostly brownish yellow (10YR 6/8) with some yellow (10YR 7/8). Occasional chalk mottles. Stone-free. Loose compaction.
4.48 – 4.69:	Yellow (10YR 7/6) coarse sand. Frequent degraded chalk. Loose compaction.
4.69 – 4.91:	Yellow (10YR 7/8) medium sand. Stone-free. Moderate compaction.
4.91 – 5.00:	Brownish yellow (10YR 6/8) sandy silt. Occasional grit. Strong compaction.
5.00 onwards	Core not bottomed.

Depth (m)	Initial interpretation:
0 – 0.25	Ploughsoil
0.25 – 0.49	Colluviated sand with some soil development
0.49 – 0.60	Colluviated sand.
0.60 – 0.76	Blown sand
0.76 – 1.48	Colluviated sand
1.48 – 1.61	Blown sand
1.61 – 1.70	Soliflucted clay deposit
1.70 – 1.79	Colluviated sand
1.79 – 3.48	Till or soliflucted clay deposit
3.48 – 3.80	Ripple marks from alternating seasonal deposition
3.80 – 5.00	Coversand

<u>GGS 3.</u> <u>NGR: 581551 290033</u>

(10 x 10 m NE from SW corner of GPR grid).

This core was drilled in order to obtain sand samples for OSL dating from within a periglacial stripe. The sediments were not recorded.

GGH 2. NGR: 581755 289993
(20m N and 53m E from SW corner of 2nd GPR grid)

Depth (m) Stratigraphic description

0 – 0.30: Dark brown (10YR 3/3) silty sand. Moderate compaction.
0.30 – 0.50: Yellowish brown (10YR 5/4) and very dark greyish brown (10YR 3/2) mixed sand. Moderate flint pebbles. Loose compaction.
0.50 – 0.73: Brownish yellow (10YR 6/6) medium sand. Stone-free. Loose compaction.
0.73 – 0.78: Strong brown (7.5YR 5/8) medium sand. Occasional grit. Stone-free. Loose compaction. Iron-pan at base.
0.78 - 1.20: Brecciated chalk.
1.20 – 2.50: Yellow (10YR 7/6) mixed sand and chalk.
2.50 onwards Soft, weathered, non-brecciated chalk bedrock.

Depth (m)	Initial interpretation:
0 – 0.30	Ploughsoil
0.30 – 0.50	Colluviated sand
0.50 – 0.73	Blown sand
0.73 – 0.78	Blown sand
0.78 – 1.20	Brecciated (weathered) chalk
1.20 – 2.50	Chalk and sand rubble

GGH 3 NGR: 581760 28992

This core was drilled where the GPR survey had suggested the deepest point of a shaft might be. However, brecciated chalk bedrock was reached at 0.68 m and so the hole was abandoned.

Figure 1

GRIME'S GRAVES, NORFOLK

Location of geophysical survey, November 2007.

TL 8190

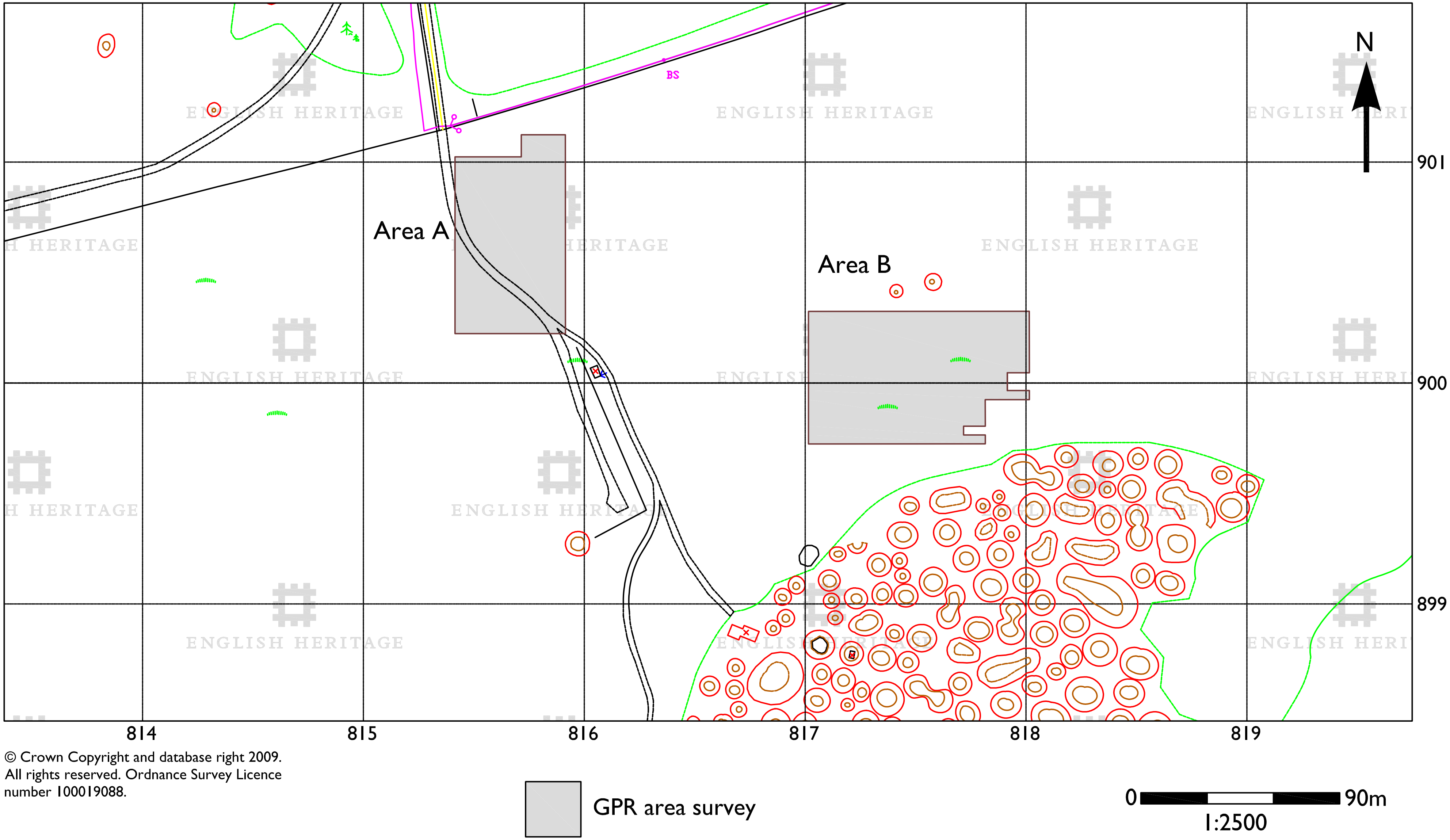

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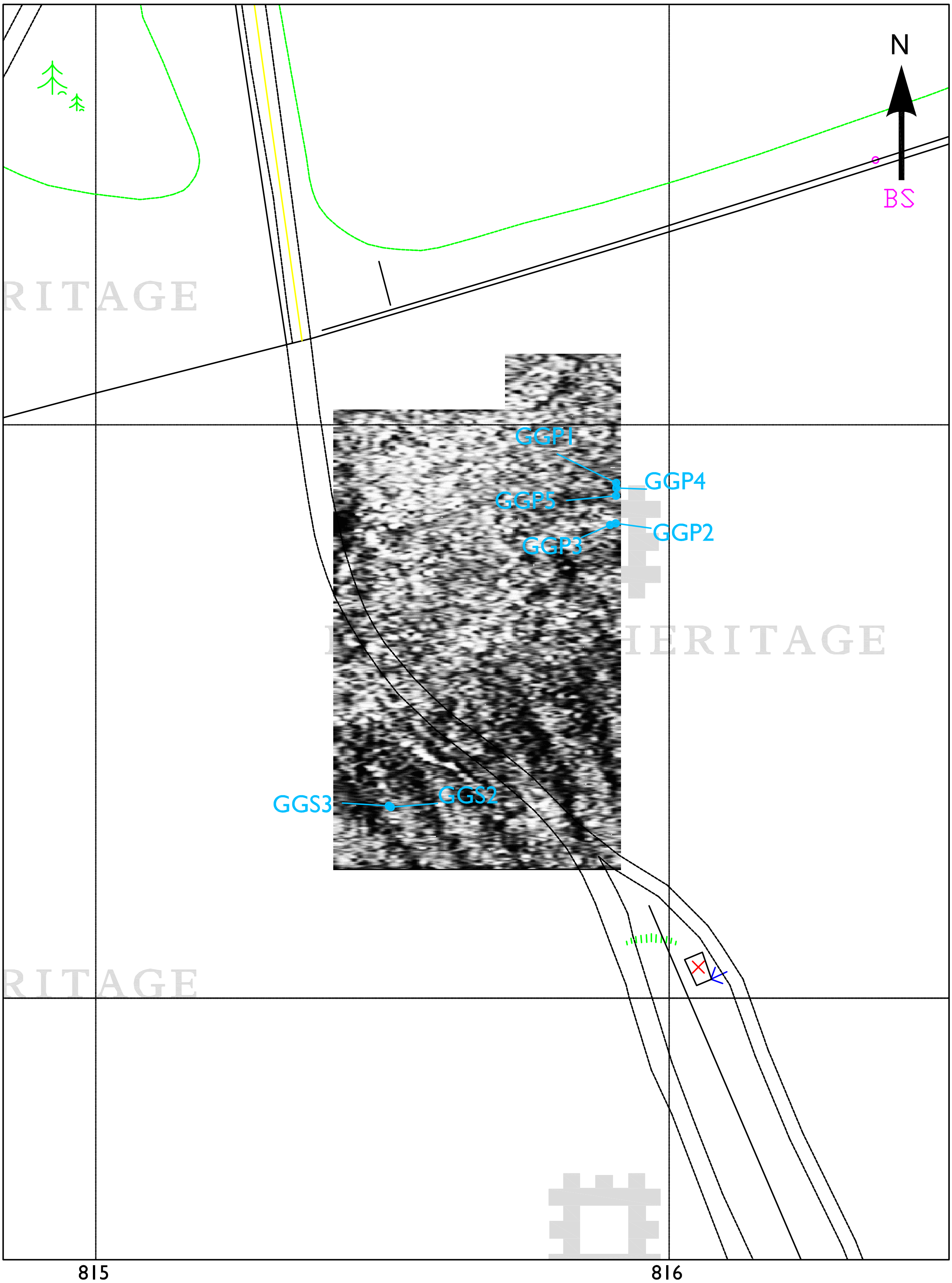
Figure 2

GRIME'S GRAVES, NORFOLK

GPR amplitude time slice from Area A between 16 and 20ns

TL 8190



auger core

0 30m
1:1000

Low *High*
relative reflector strength

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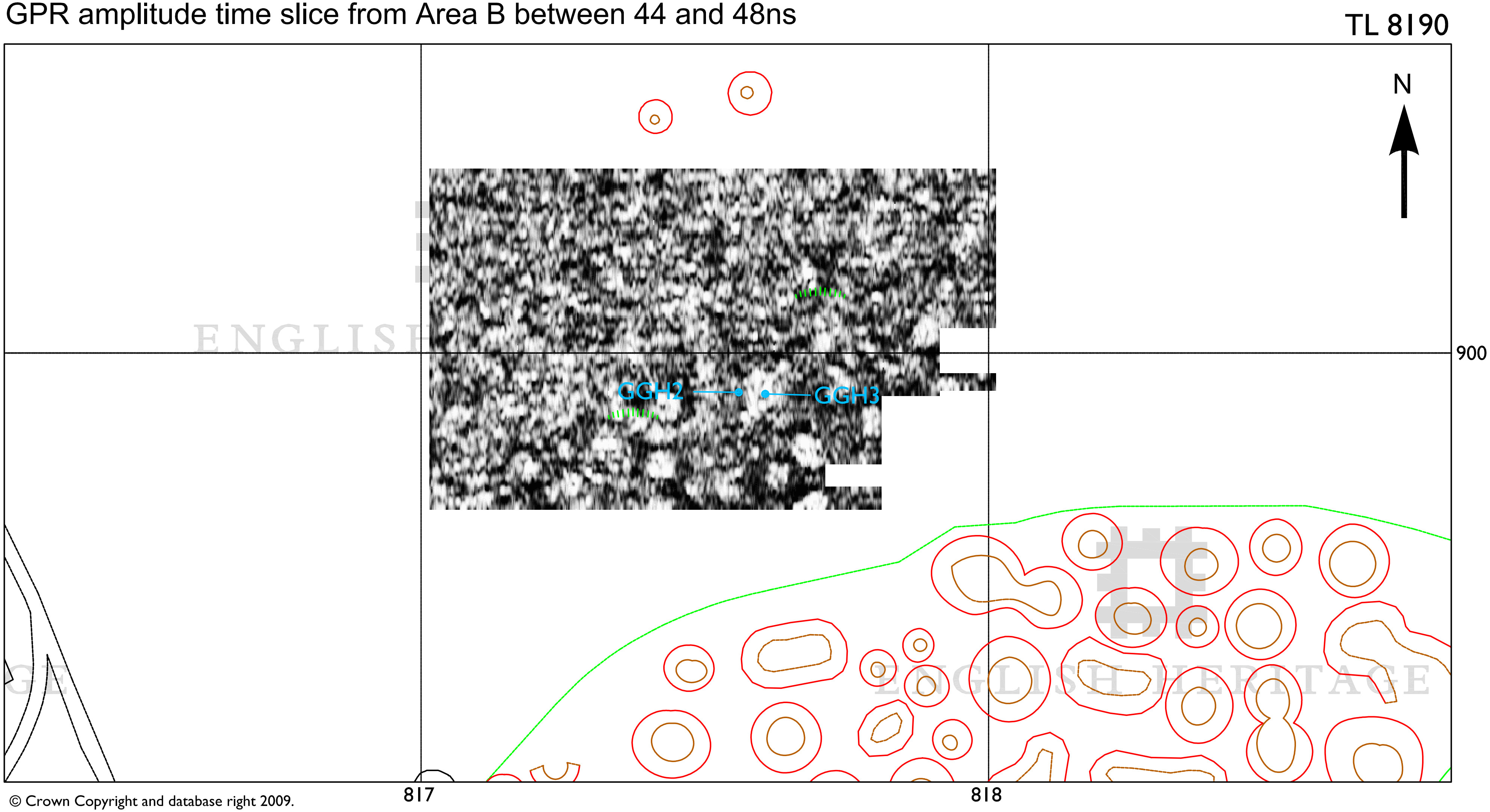
Figure 3

GRIME'S GRAVES, NORFOLK

GPR amplitude time slice from Area B between 44 and 48ns



auger core

Low *High*

relative reflector strength

0 60m

1:1000

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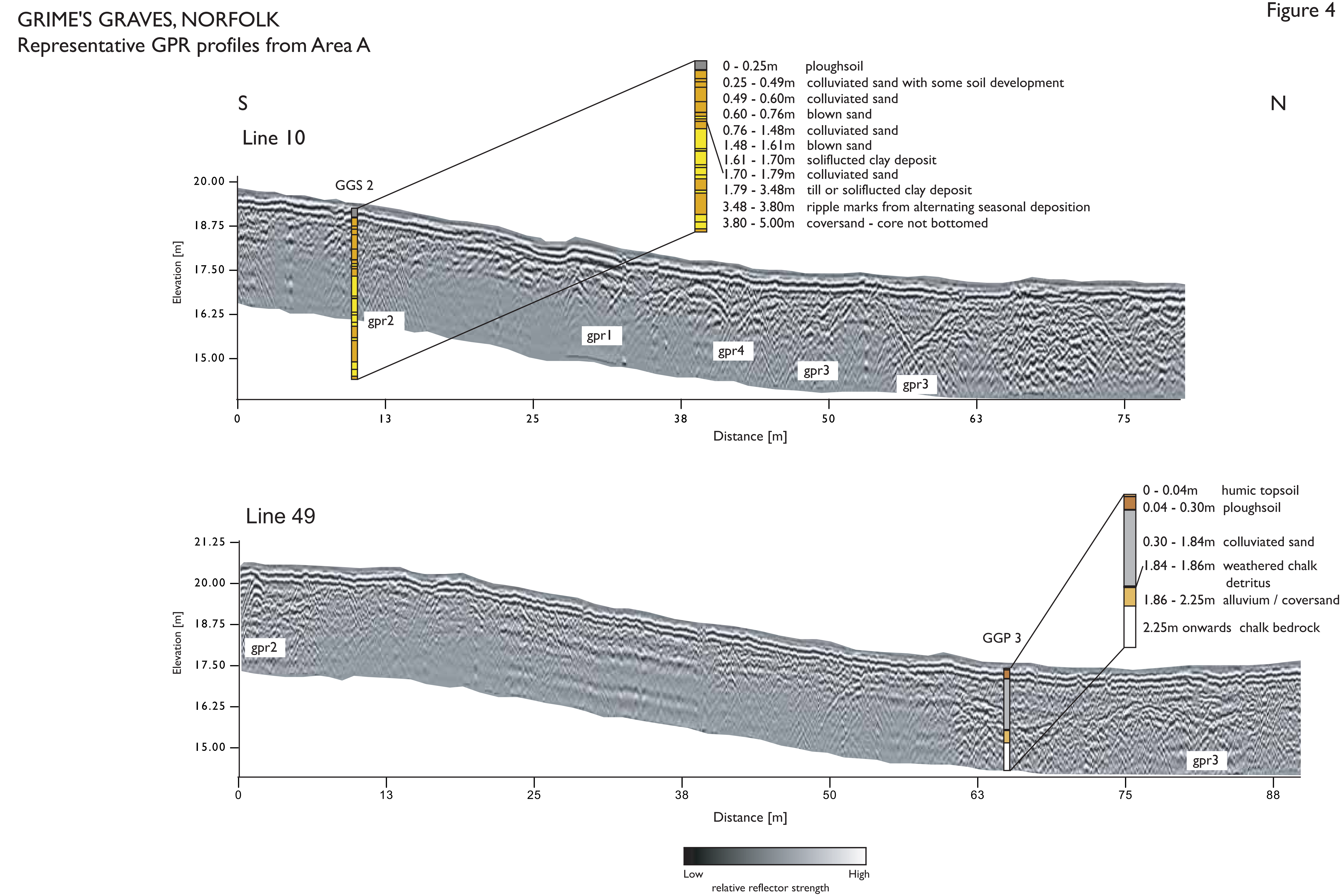
Figure 4



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GRIME'S GRAVES, NORFOLK
GPR Amplitude time slices from Area A, November 2007.

Figure 5

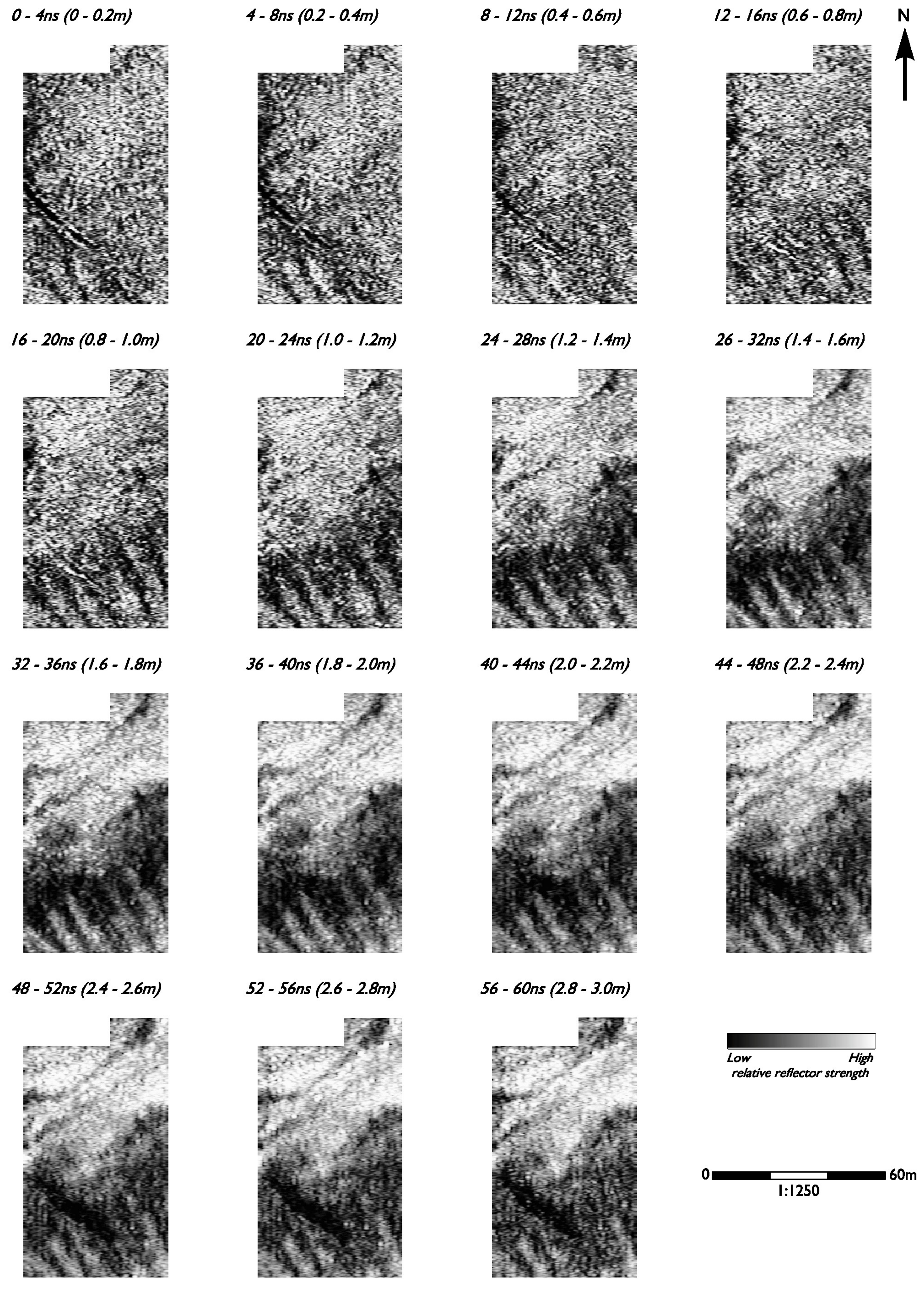

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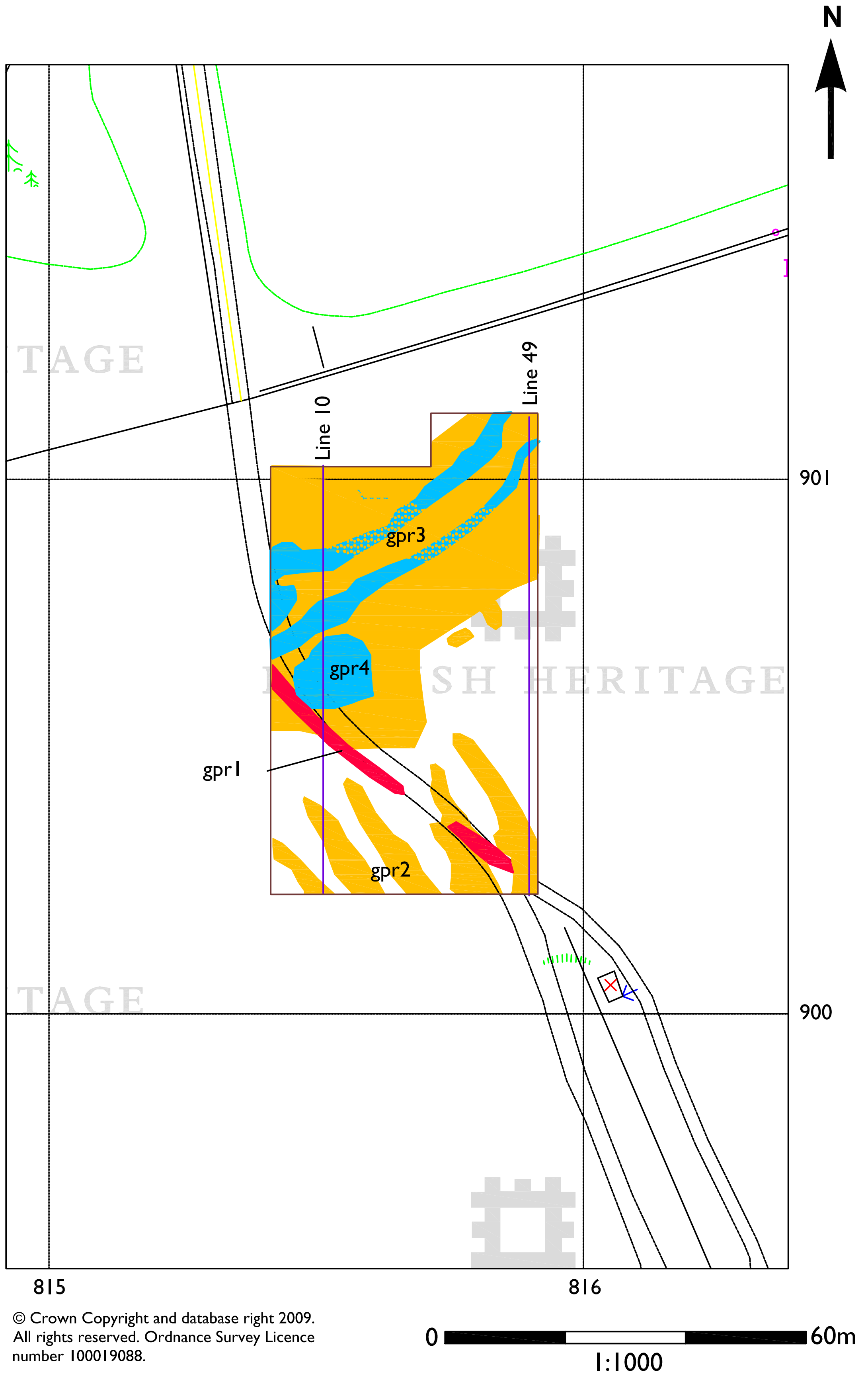
Figure 6

GRIME'S GRAVES, NORFOLK
Graphical summary of significant GPR anomalies
Area A, November 2007

TL 8190



GPR profile shown on Figure4

High amplitude reflector

Low amplitude reflector

Modern feature (road)

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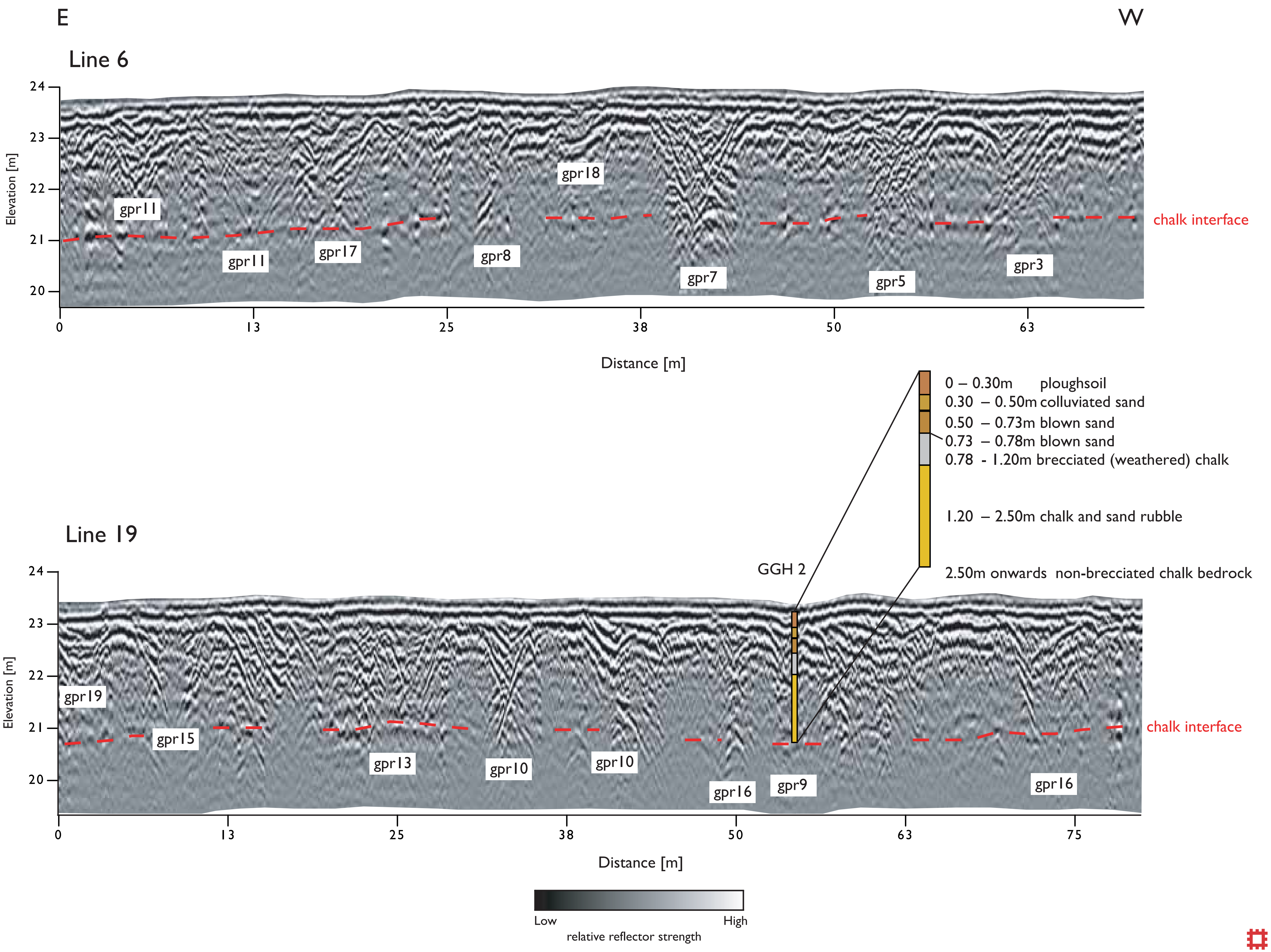
GRIME'S GRAVES, NORFOLK

Representative GPR profiles from Area B

Figure 7



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GRIME'S GRAVES, NORFOLK
GPR Amplitude time slices from Area B, November 2007.

Figure 8

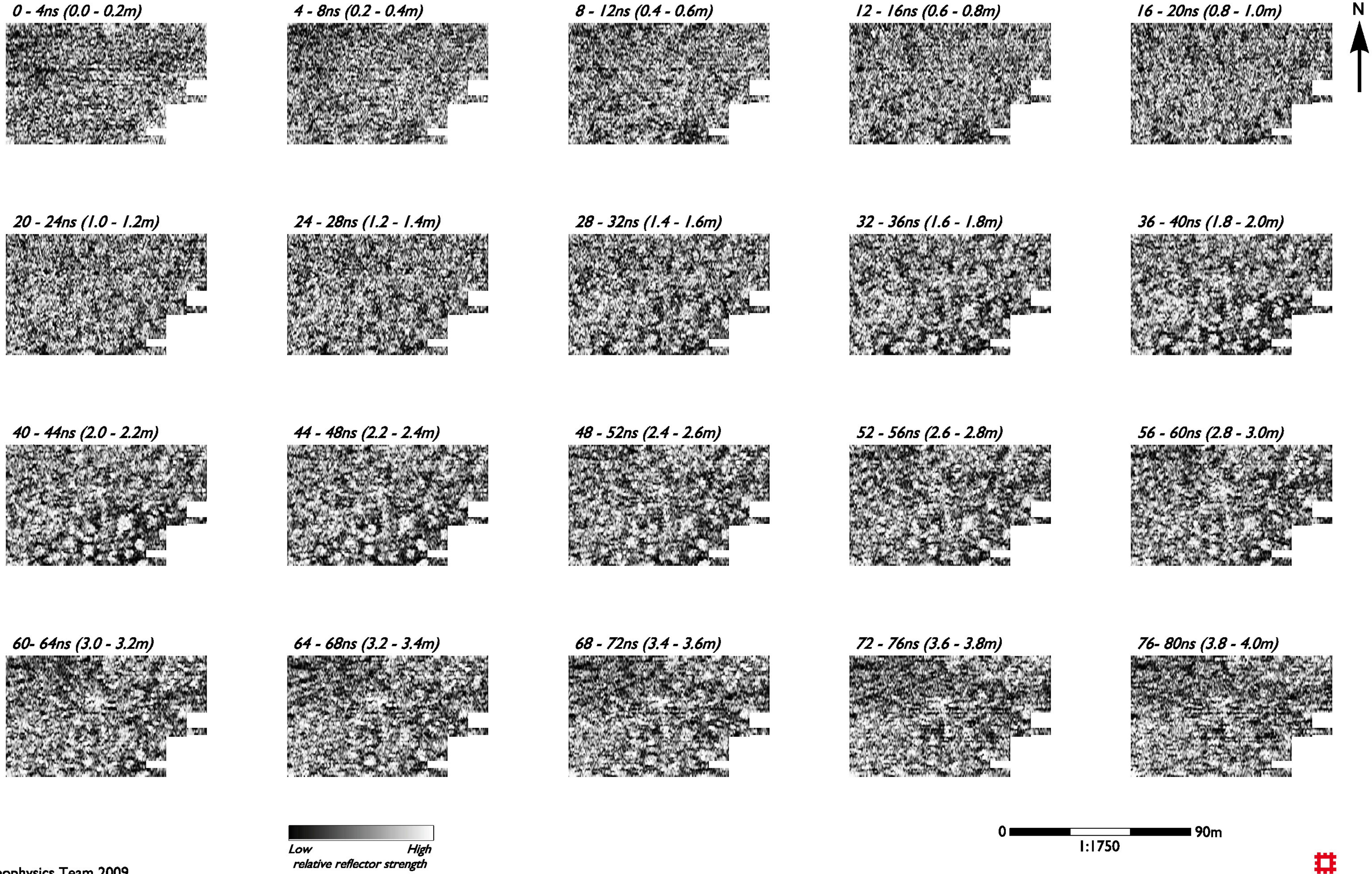

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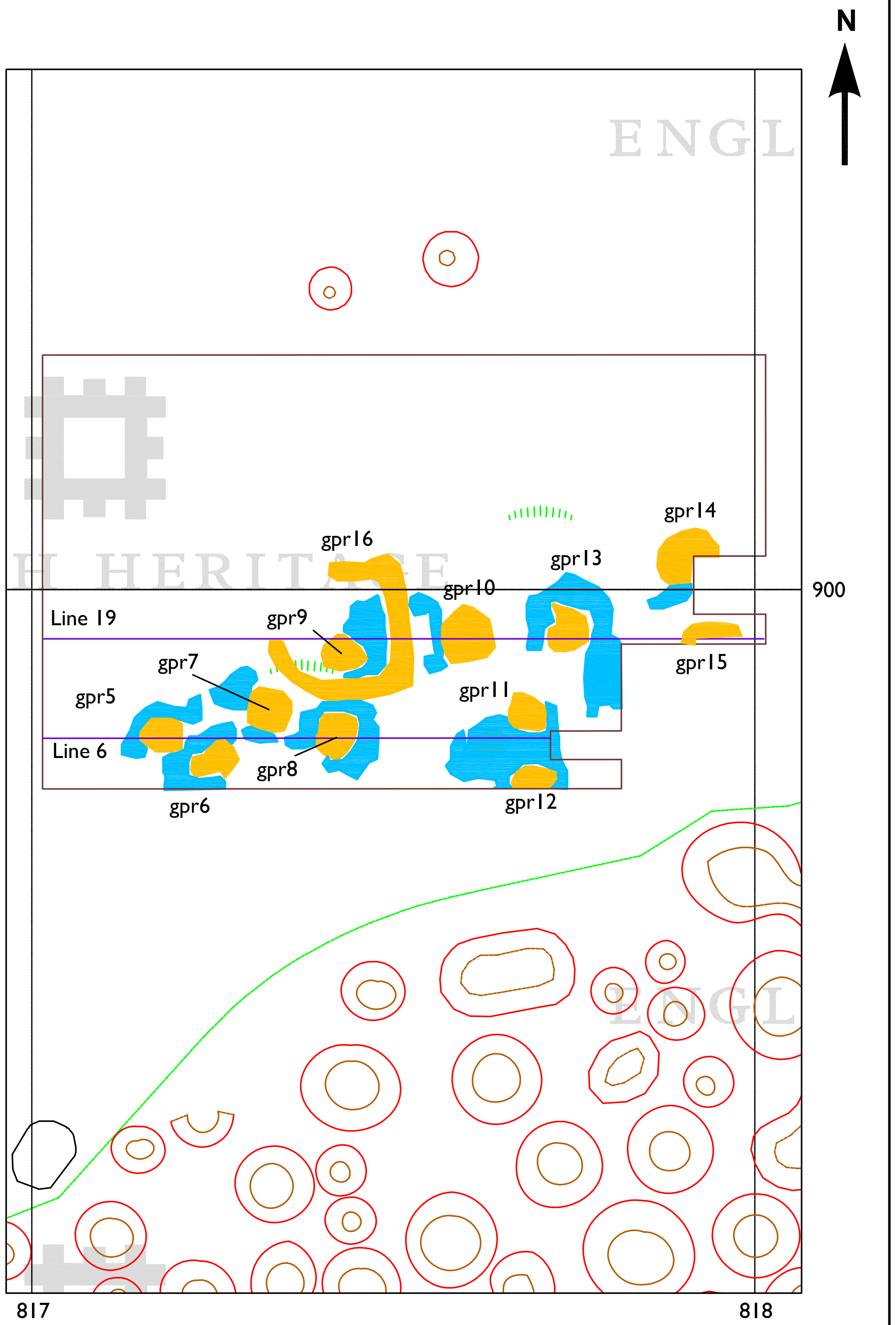
Figure 9

GRIME'S GRAVES, NORFOLK
Graphical summary of significant GPR anomalies
Area B, November 2007

TL 8190



0 60m
1:1000

GPR profile shown on Figure 7

Low amplitude reflector

High amplitude reflector

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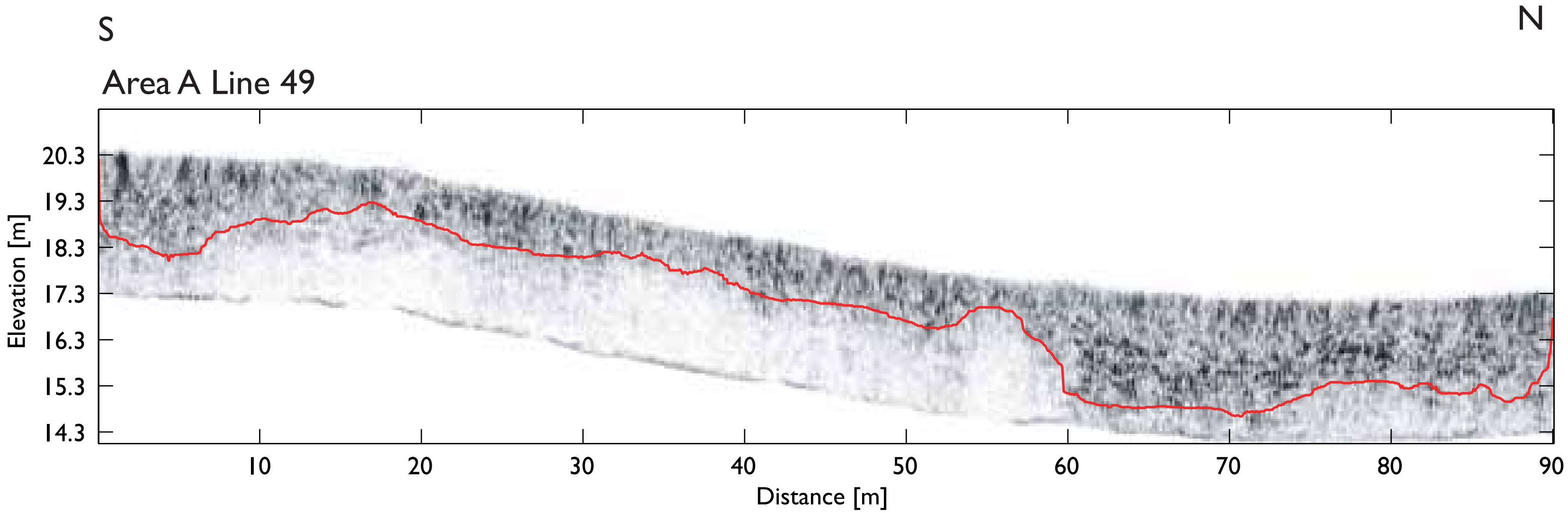
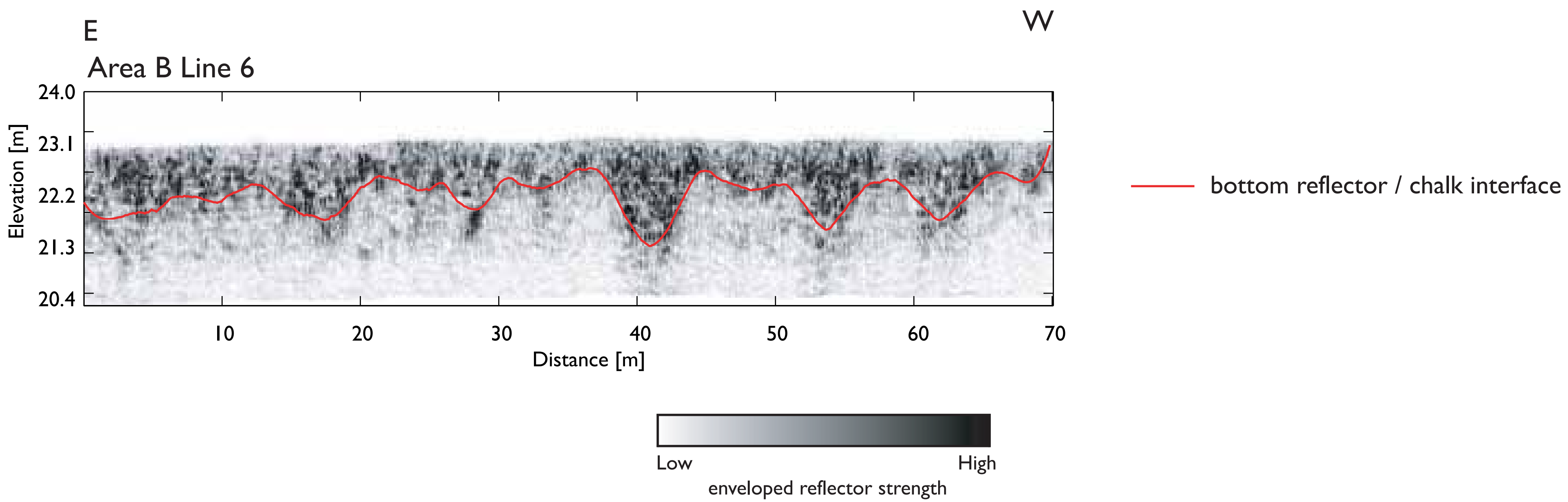
GRIME'S GRAVES, NORFOLK

Representative GPR profiles showing approximate depth to bottom reflector

Figure 10





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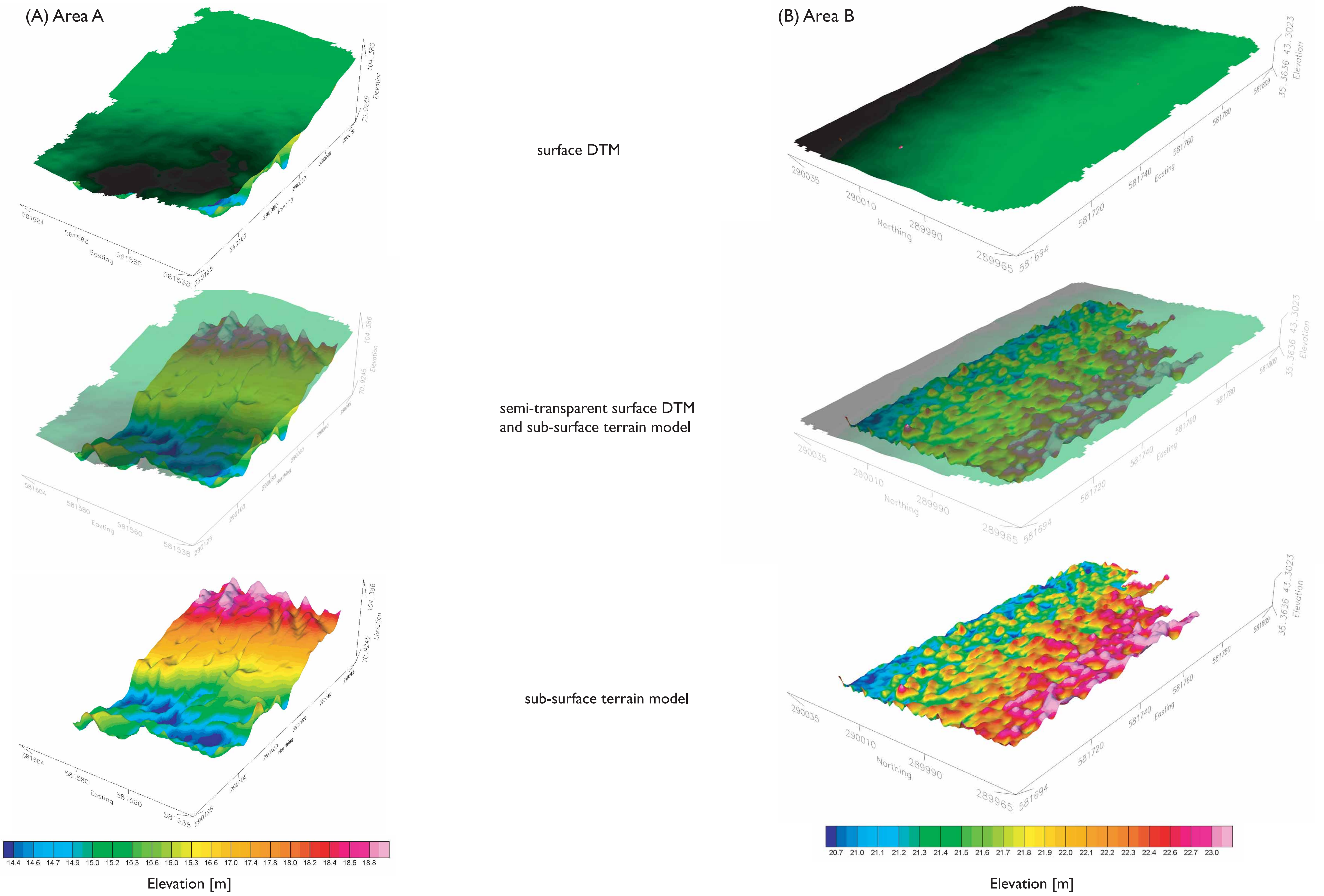
GRIME'S GRAVES, NORFOLK

False perspective views of the site topography and underlying sub-surface terrain model

Figure 11



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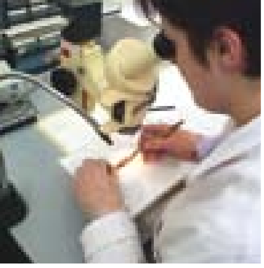
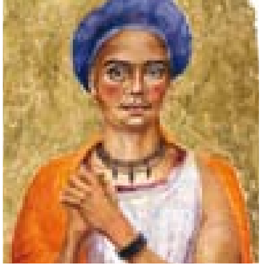



ENGLISH HERITAGE RESEARCH DEPARTMENT

English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for sustainable management, and to promote the widest access, appreciation and enjoyment of our heritage.

The Research Department provides English Heritage with this capacity in the fields of buildings history, archaeology, and landscape history. It brings together seven teams with complementary investigative and analytical skills to provide integrated research expertise across the range of the historic environment. These are:

* *Aerial Survey and Investigation*
* *Archaeological Projects (excavation)*
* *Archaeological Science*
* *Archaeological Survey and Investigation (landscape analysis)*
* *Architectural Investigation*
* *Imaging, Graphics and Survey (including measured and metric survey, and photography)*
* *Survey of London*

The Research Department undertakes a wide range of investigative and analytical projects, and provides quality assurance and management support for externally-commissioned research. We aim for innovative work of the highest quality which will set agendas and standards for the historic environment sector. In support of this, and to build capacity and promote best practice in the sector, we also publish guidance and provide advice and training. We support outreach and education activities and build these in to our projects and programmes wherever possible.

We make the results of our work available through the Research Department Report Series, and through journal publications and monographs. Our publication Research News, which appears three times a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities. A full list of Research Department Reports, with abstracts and information on how to obtain copies, may be found on www.english-heritage.org.uk/researchreports

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