WEST HESLERTON, North Yorkshire.

Report on geophysical survey, September 2002.

Summary

Earth resistance and ground penetrating radar (GPR) surveys were conducted over two areas at West Heslerton, North Yorkshire, believed to contain Roman building remains. Ambiguous results within the first area, where no previous geophysical survey had been conducted, led to investigation in the vicinity of a second, previously excavated Roman shrine to determine the geophysical response of such a known structure. Whilst a subtle GPR response was associated with an area adjacent to the location of the excavated structure, no further evidence for similar building remains was revealed in either the earth resistance or GPR the surveys.

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Introduction

A Ground Penetrating Radar (GPR) survey was requested to investigate an apparent building platform (~50m $\times$ 50m) found at the top of a dry valley on the lower escarpment of the Wolds above the village of West Heslerton, North Yorkshire (Field 1). From comparison with other sites in the area the presence of a Roman building seemed likely due to the well protected, elevated position afforded by the apparent platform (D. Powesland *pers. comm.*). In addition, extensive magnetic survey and excavation has revealed a wealth of archaeological activity in Field 2 immediately N of the suspected building platform, including the remains of a Roman shrine constructed from compacted chalk. These excavations also revealed the presence of substantial colluvial overburden deposited within the bottom of the dry valleys running down from the Wolds, necessitating the use of geophysical survey techniques with an enhanced depth penetration.

The site (SE 917 756) lies on well drained calcareous silty soils of the Upton 1 association (Soil Survey of England and Wales, 1983) developed over Upper Cretaceous chalk (British Geological survey, 1950). As noted above, deeper, fine silty calcareous soils may develop locally in coombes and dry valleys. At the time of the survey the field containing the possible building platform (Field 1) was down to permanent pasture and the area investigated in the field to the N (Field 2) lay fallow following the recent harvest of a cereal crop. Weather conditions at the time of the survey were dry and bright with no significant rainfall.

Method

The Ground Penetrating Radar (GPR) survey was conducted with a Pulse Ekko PE1000 console and a 225MHz centre frequency antenna. The 225MHz antenna was selected as the most suitable centre frequency for obtaining the optimum depth of penetration and lateral resolution required to image the expected archaeological targets. Attempts to estimate the velocity of the radar wavefront in the subsurface through a common mid-point (CMP) velocity analysis conducted in the field suggested an average subsurface velocity of ~0.065m/ns. This latter velocity was adopted as a reasonable average value for processing the data from this site and for the estimation of depth to reflection events in the recorded profiles.

A series of parallel EW traverses separated by 0.5m were established over both survey areas (Figures 1 and 2). Individual traces along each profile were separated by 0.05m and recorded the amplitude of reflections through an 80ns time-window. 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 of the GPR transmitter with the ground to an approximate depth of $^{\lambda}/_{2}$, very near surface reflection events should only be detectable below a depth of 0.14m, if a centre frequency of 225MHz and a velocity of 0.065m/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 (David and Linford, 2000; Sensors and Software 1996). Each resulting time slice, illustrated as a greytone image in Figures 7 and 8 represents the variation of reflection strength through successive ~0.065m intervals from the ground surface.

In addition, an earth resistance survey was conducted over the site assisted by members of the Landscape Research Centre (LRC) using a Geoscan RM15 meter, MPX15 multiplexer and PA5 probe array (Figures 1 and 3). The Twin Electrode probe configuration was used and readings were taken, with a mobile probe spacing of 0.5m at a 0.5m x 1.0m over both Field 1 and Field 2. Additional deeper penetrating readings were collected in Field 1 at mobile probe spacings of 1.0m and 2.0m using 1.0m x 1.0m sampling interval. Both the resulting sets of raw data have been 'de-spiked' (to remove single high magnitude anomalous responses) and are illustrated as greyscale plots in Figures 4 and 5. A series of image processing algorithms have also been applied to the 0.5m mobile probe spacing data in an attempt to emphasise more significant anomalies. These include a contrast enhancing Wallis filter, a high-pass Gaussian filter to enhance linear anomalies >2m and an artificial shadow plot (Scollar*, et al.*, 1990; Figures 4(2), 4(3) and 4(4) respectively).

Results

Earth resistance survey

Figure 4(1) demonstrates the wide variation in earth resistance values recorded over the survey area, with a strong contrast between the high conductivity colluvium washed into the bottom of the dry valley and the sparsely covered chalk found on the higher ground. Despite this range of values the application of appropriate image processing algorithms has removed the regional background response and elucidated the presence of potentially more significant anomalies (e.g. Figures 4(2), 4(3) and 4(4)). This has proved particularly successful (Figure 4(2)) within the dry valley itself, where a linear band of high resistance [R1] continues along its length and encompasses a tentative rectilinear anomaly [R2] found within Field 1.

More obvious resistance anomalies are found in both Field 1 and Field 2. These include a strong ditch-type anomaly [R3] that appears to be associated with a ditched enclosure [R4] surrounding a local area of high resistance [R5]. The magnetometer survey conducted over the same area failed to identify any of the apparent ditch-type anomalies but did reveal an amorphous area of disturbance believed to be a former chalk quarry (J Lyall *pers. comm.*). Whilst anomalies [R3], [R4] and [R5] may well be of greater archaeological significance, their association with quarrying activity cannot be excluded.

Field 1 contains a number of more enigmatic, curvilinear earth resistance anomalies [R6] to [R15] all found within the areas of high resistance [R16] and [R17] on the higher ground to either side of the dry valley. The morphology of these latter anomalies does not immediately suggest an archaeological origin and their low resistance response may well be indicative of natural striations within the chalk. In theory, information regarding the relative depth of the target features producing these anomalies may be obtained from the earth resistance survey data collected with an increased mobile probe spacing. As the mobile probe spacing is increased the injected current is forced to travel deeper and the apparent resistance value is determined from a greater volume of subsurface. Whilst this increases the sensitivity of the electrode to more deeply buried targets the lateral resolution of the survey will also be reduced and may be further degraded by the use of a more coarsely spaced sample interval (see method above).

Figure 5 shows the three data sets, collected with mobile probe spacings of 0.5m, 1.0m and 2.0m over Field 1. As predicted, the lateral resolution of the data decreases as the mobile probe spacing is widened. However, the relative amplitude of certain anomalies does vary between the data sets, suggesting these responses occur from a range of depths. To better visualise the vertical separation of the anomalies an Hotelling transform was applied to the 0.5m and 2.0m mobile probe spacing data to indicate both the difference and the similarity between the two sets of survey results (Press*, et al.*, 1988, Gonzalez and Wintz, 1987). In this case, the difference between the 0.5m and the 2.0m mobile probe spacing survey may be due to near surface anomalies (Figure 5(4) and the similarity to deeper lying regional trends within the data (Figure 5(5)).

It is of interest to note that the majority of anomalies [R6] to [R15] decrease in amplitude significantly between Figures 4(4) and 4(5), suggesting they are due to comparatively near surface features although this appears more acute for the anomalies found to the W of the dry valley. Within the dry valley itself anomalies [R1] and [R2] are entirely absent from the probable deeper lying data (Figure 4(5)), perhaps lowering the expectation that these are due to the presence of significant archaeological remains, such as buried wall footings.

GPR Survey Field 1

Figure 7 shows the series of amplitude time slices produced from the GPR data collected in Field 1. The general response of the GPR in this area is highly similar to the earth resistance survey with a strong contrast between the colluvium within the dry valley and the near surface chalk to either side. Both areas of chalk on the higher ground to the E and W have produced high amplitude anomalies [GPR1] and [GPR2] that broadly reflect the distribution of enhanced earth resistance readings. There is no evidence of the curvilinear striations within the near-surface chalk apparent within the earth resistance data, although an area of lower amplitude reflections (Figure9; [GPR3]) is apparent from the 16-18ns (0.52 – 0.585m) time slice that correlates with an area of low resistance readings.

The GPR has proved more sensitive to very near surface features, such as the collapsed rabbit burrow [GPR4] that produced a high amplitude response from the initial time slice to a depth of ~0.6m. Indeed, the extensive network of rabbit warrens in this area may well account for the origin of the linear responses [GPR5] and [GPR6] found within the near surface amplitude time slices. However, the double linear anomaly [GPR5] may be of greater significance, as it would appear to share the orientation of the linear band of high resistance [R1] running along the dry valley (see [GPR11] below).

GPR Survey Field 2

Again, the GPR survey in this area has been adversely effected by very near surface features. In this case the anomalies are not, primarily, due to rabbit burrows but to cultivation patterns. The very near surface time slices (0 to 6ns) contain a palimpsest [GPR7] of NS and EW orientated plough patterns together with two arcuate anomalies due to the turning circle of an agricultural vehicle. The NS orientated pattern is less evident within the deeper lying time slices beyond 8ns. However, the EW orientation of ploughing apparently continues throughout the data set to the latest reflection times where the pattern replicates only the most substantial "tram lines" evident on the ground surface. It is highly unlikely that the ploughing actually continues to the apparent depth indicated by the anomalies within the GPR data. These responses are more readily explained through near surface "ringing" of the transmitted signal when the antenna pass over irregularities in the surface topography caused by the cultivation patterns (*cf* Conyers and Goodman, 1997; p78).

As might be expected, more significant anomalies become apparent within the data from a depth below the immediate plough soil. These include a rectilinear response [GPR8] of similar dimensions to the remains of the Roman shrine, constructed from compacted chalk rubble, revealed during previous excavation. However, comparison with the location of the shrine suggests the remains of this building lie approximately 15m W of [GPR8] and this anomaly may well relate to a second suspected structure, although this could not be verified during the 1995 excavation (J. Lyall *pers. comm.*).

A further anomaly, [GPR9], appears immediately S of [GPR8] through a similar range of time slices (from approximately 10 to 32ns). Unfortunately, the location of [GPR9] falls beyond the large area excavation and so the archaeological significance of this response remains questionable.

A more diffuse area of high amplitude reflections [GPR10] is found in the SE corner of the Field 2 that would appear to correlate with the recent quarrying activity revealed by the earth resistance survey (*cf* [R3], [R4] and [R5]). There is even a suggestion of the presence of the substantial ditch-type anomaly [R3] that apparently cuts through [GPR10], although this interpretation is hampered by the coincident orientation of [R3] with the EW plough pattern in the GPR data.

Finally, a linear anomaly [GPR11] is evident from the S of the survey area continuing N for ~50m. The significance of [GPR11] may be questioned by the similar alignment of the anomaly with respect to the NS agricultural pattern identified in the very near surface time slices. However, [GPR11] does not appear within the data until a depth of ~0.5m (16 to 18ns time slice) by which point the NS agricultural pattern has become almost entirely lost. Furthermore, [GPR11] is replicated within the earth resistance data at [R1] and shares both an alignment and an apparent double linear morphology with the more tentative GPR response [GPR5] located in Field 1 (*cf* Figure 6; 22 to 24ns time slice, Figure 7; 24 to 26ns time slice).

Unfortunately, the trial trench excavated before the geophysical survey in Field 2 was located to the E of [GPR11] and so no archaeological evidence is available to confirm the significance of this anomaly or its apparent continuation to the S. However, to the N [GPR11] terminates at the location of a small, curved remnant of standing wall associated with an area of compacted flooring (J. Lyall *pers. comm.*). A more significant interpretation of [GPR11] as, perhaps, a track way and/or drain feature passing through the bottom of the dry valley to this latter structure does not seem unreasonable.

Conclusion

As might be expected the site has produced a generally good correlation between the earth resistance and GPR data sets. However, the GPR data has been strongly influenced by near surface features, particularly the recent cultivation patterns found in Field 2. It is of interest to note that two separately orientated cultivation patterns have been recorded by the GPR data but only one of these may still be discerned in the surface topography of the site. Anomalies within the more extensive earth resistance data broadly reflect the contrast between the accumulation of soil within the dry valley and the exposed chalk found on the higher ground. The areas of exposed chalk contain linear earth resistance anomalies, although within Field 2 these might be associated with more recent quarrying activity, also evident in the previous magnetometer survey.

The GPR survey has identified a number of anomalies, possibly related to significant archaeological remains. Perhaps the most intriguing GPR response is the linear anomaly [GPR11] that extends from an excavated stone structure in Field 2 up the dry valley across the field boundary into Field 1. Trial trenching is recommended to confirm the significance of this anomaly and its potential for locating remains of the suspected Roman building within Field 1.

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Date of survey: 17-23/09/2002

Reported by: N Linford

Date of report: 25/06/2003

Archaeometry Branch,
English Heritage Centre for Archaeology.

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List of enclosed figures

Figure 1

WEST HESLERTON, NORTH YORKS.

Location of geophysical survey, September 2002

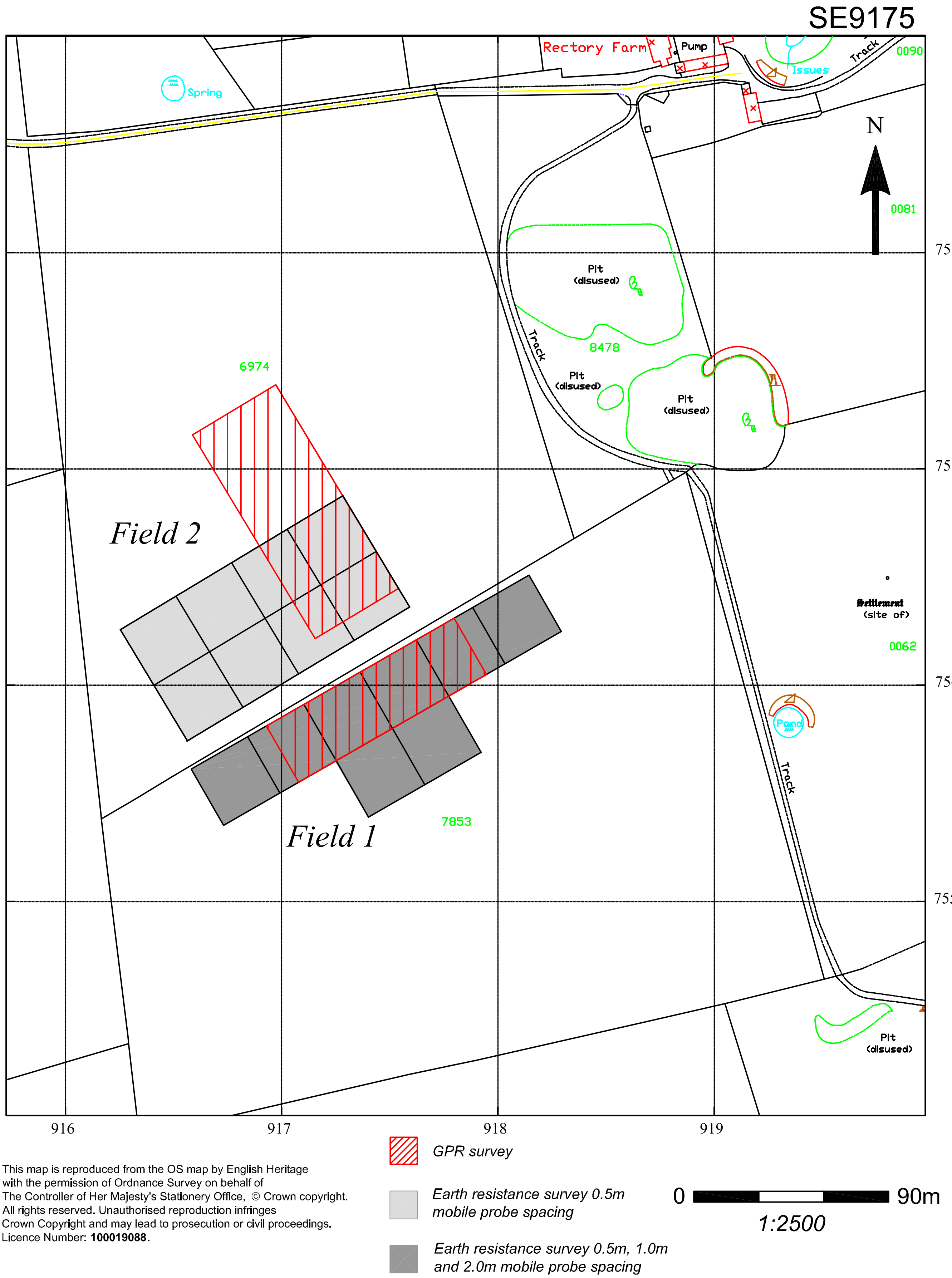


Figure 2

WEST HESLERTON, NORTH YORKS.

Location of geophysical survey, September 2002

GPR 22 - 24ns (0.715 - 0.78m) Amplitude time slice

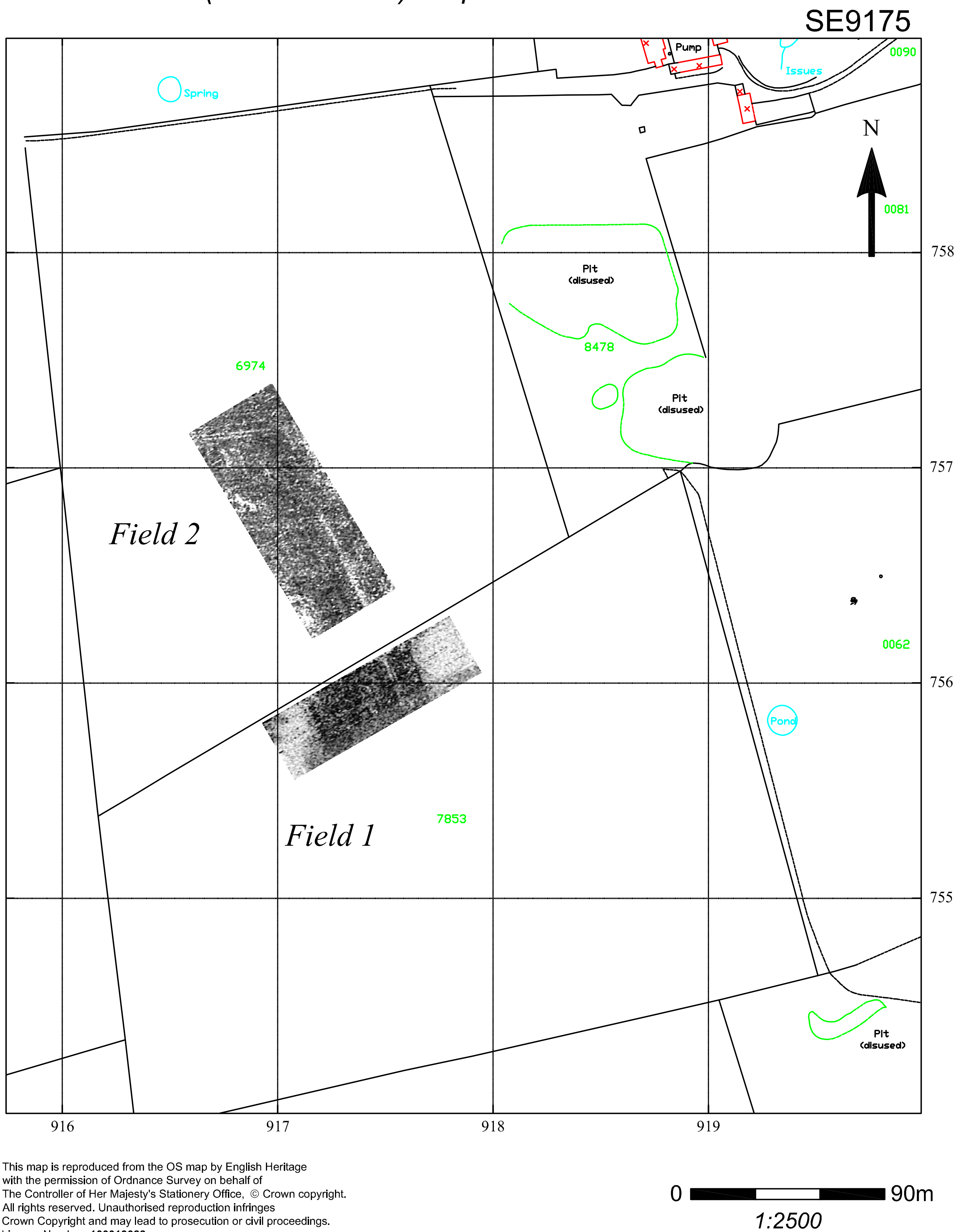


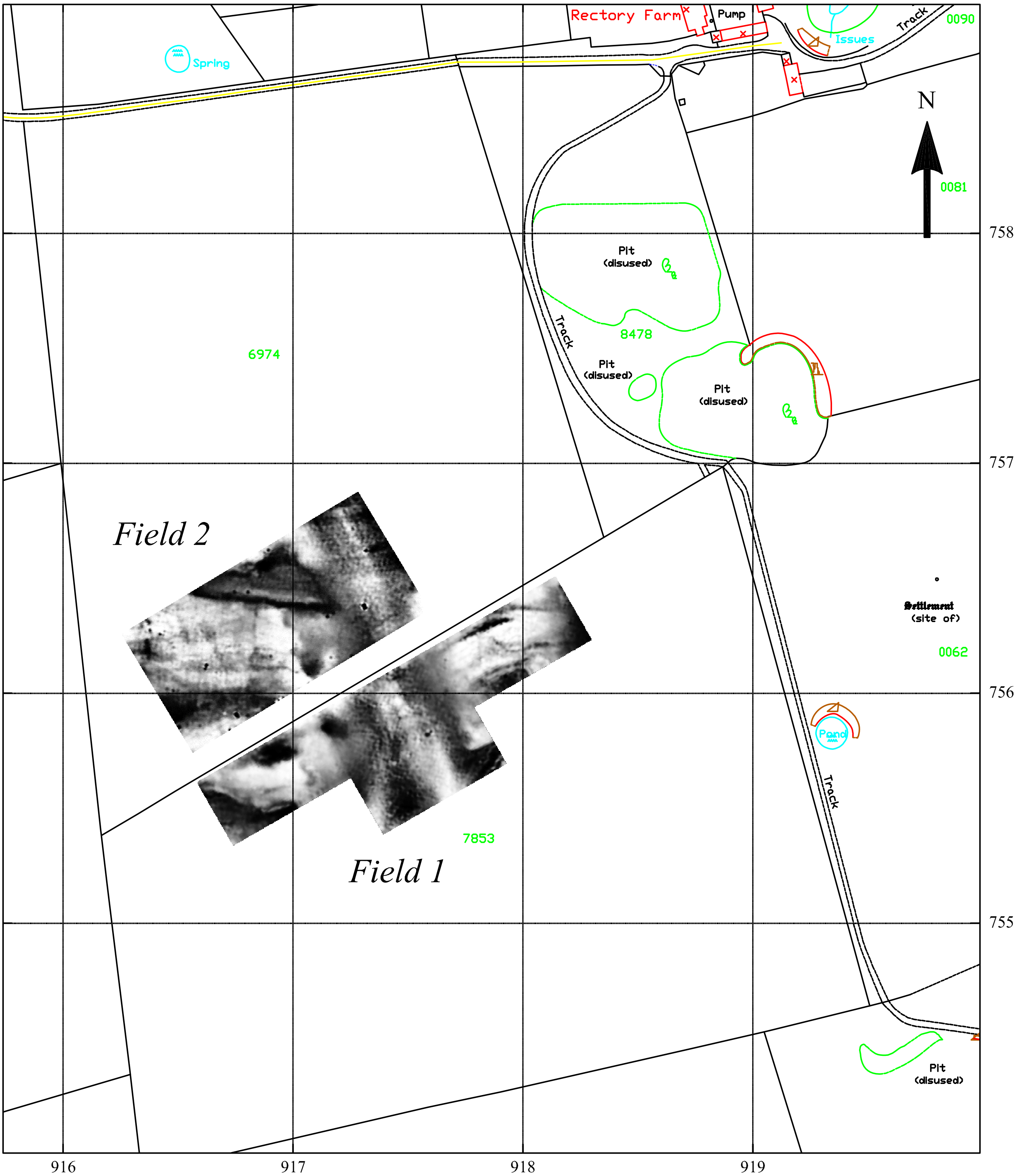
Figure 3

WEST HESLERTON, NORTH YORKS.

Location of geophysical survey, September 2002

Earth resistance data (0.5m mobile probe spacing)

SE9175



0 90m

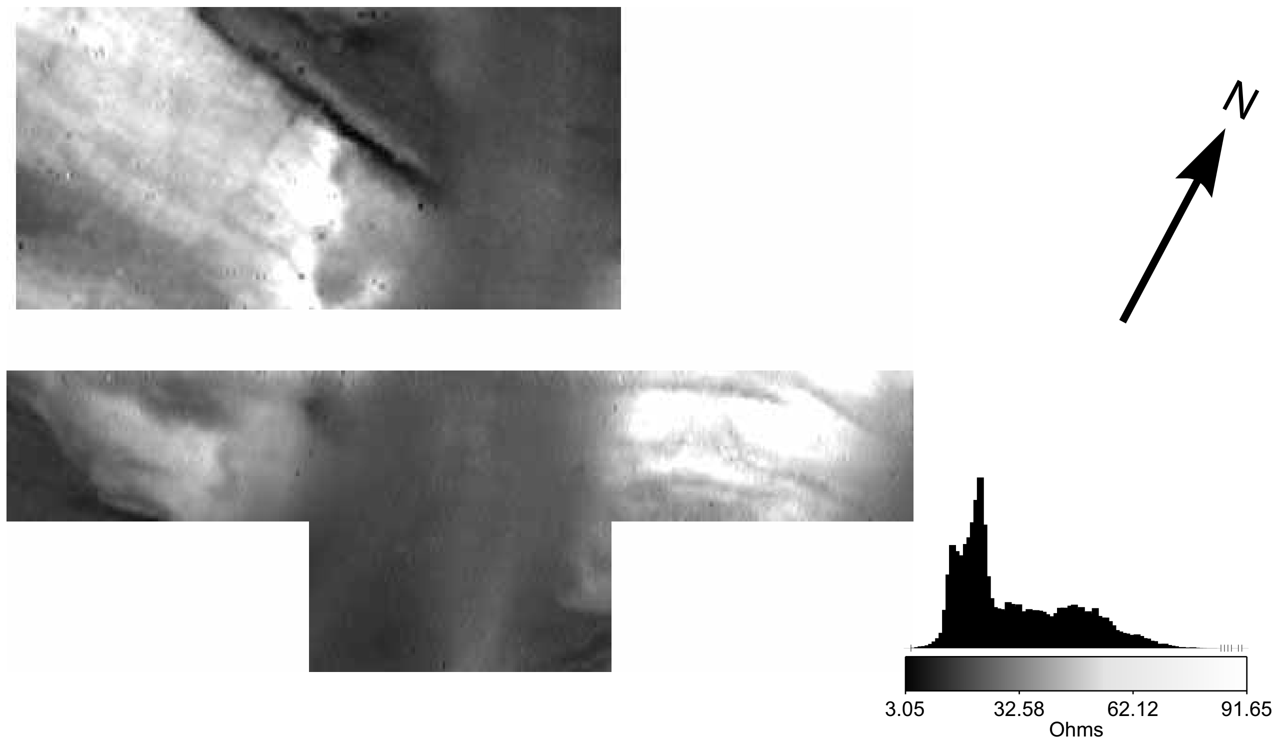
1:2500

WEST HESLERTON, NORTH YORKS.

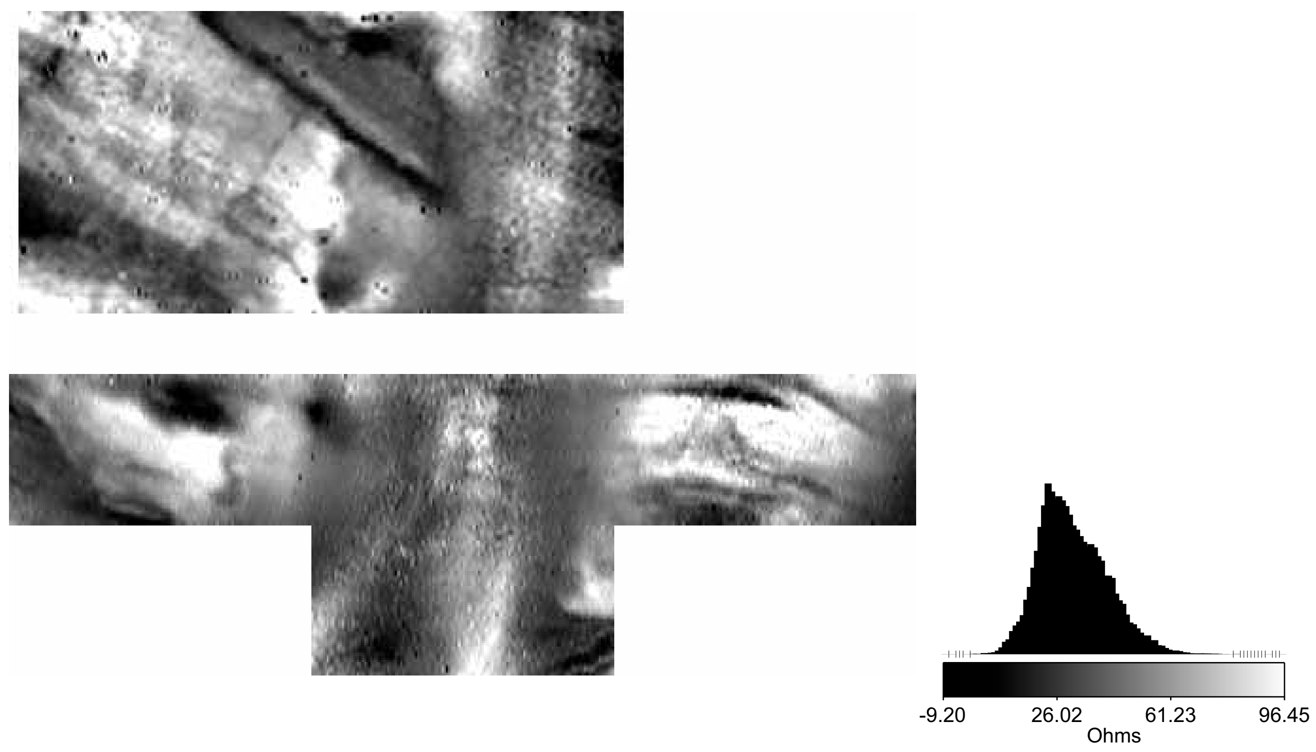
0.5m mobile probe spacing Earth Resistance data

Figure 4

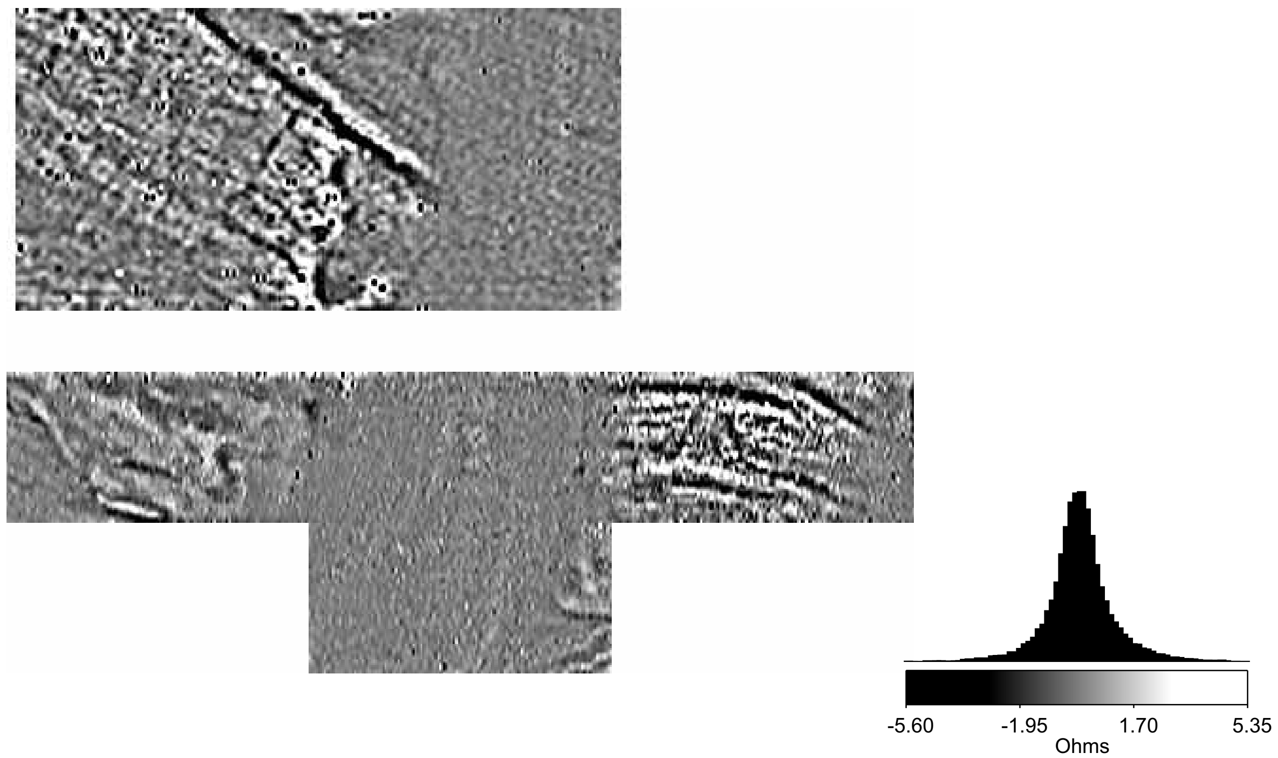
(1) Linear greyscale image of despiked data



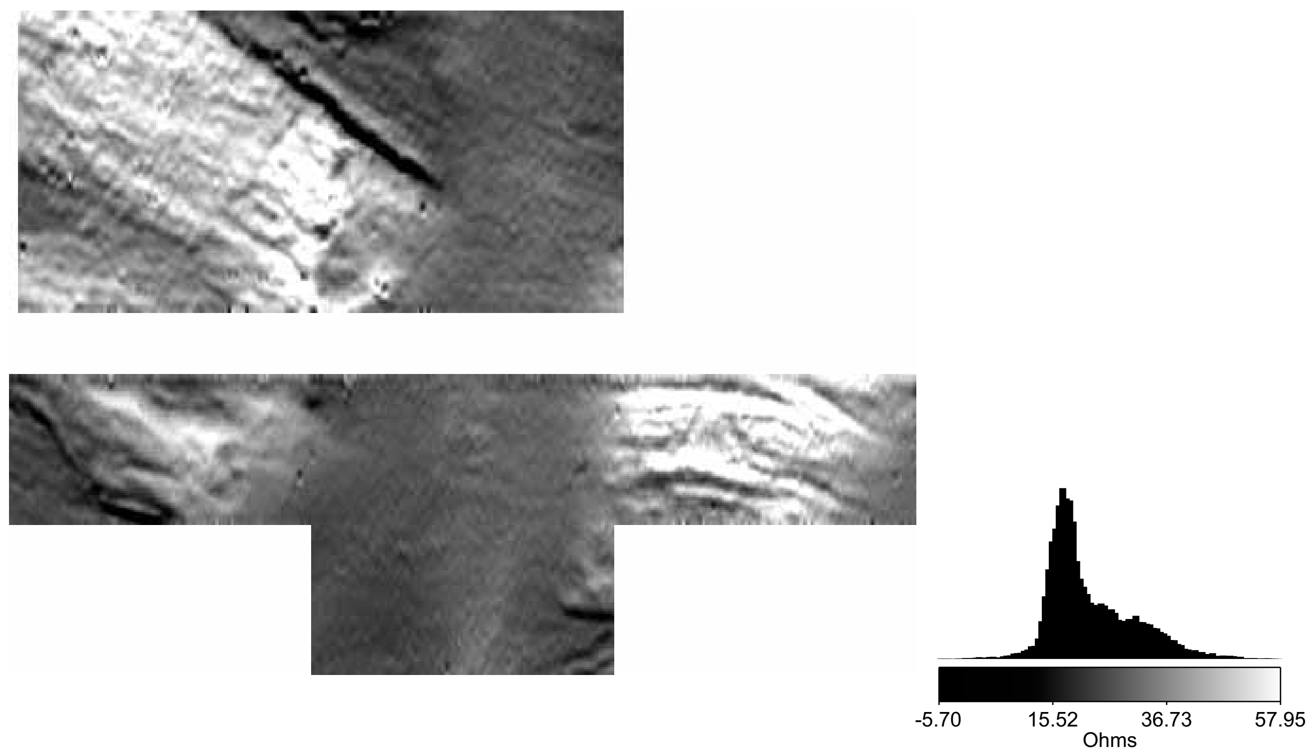
(2) Linear greyscale of contrast enhanced data

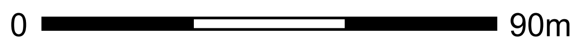


(3) High pass filtered data to enhance linear anomalies >2m



(4) Artificial shadow plot





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WEST HESLERTON, NORTH YORKS.

Comparison of 0.5m, 1.0m and 2.0m mobile probe spacing Earth Resistance data

Figure 5

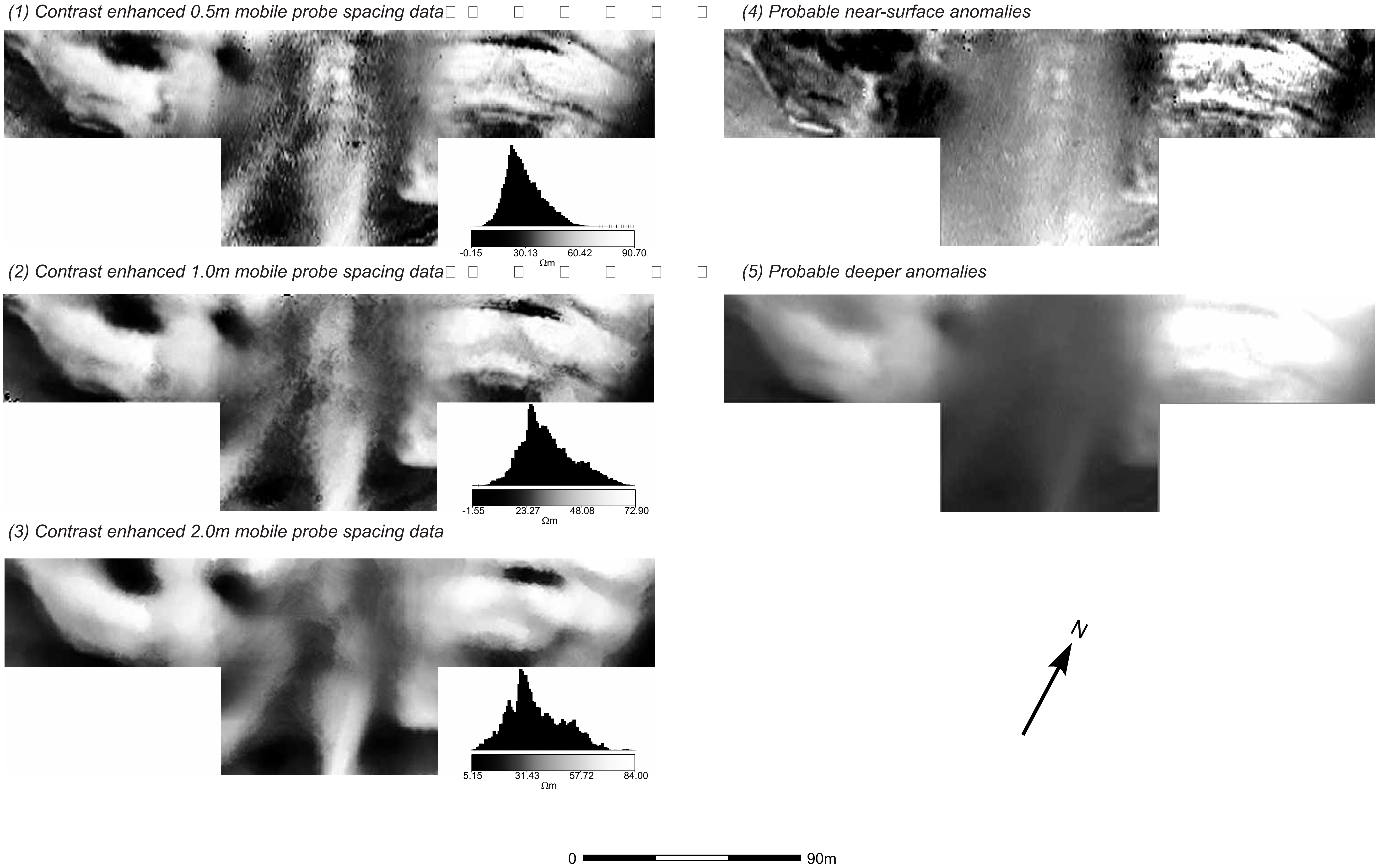

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Figure 6: WEST HESLERTON, NORTH YORKS.
Summary of significant Earth Resistance anomalies.

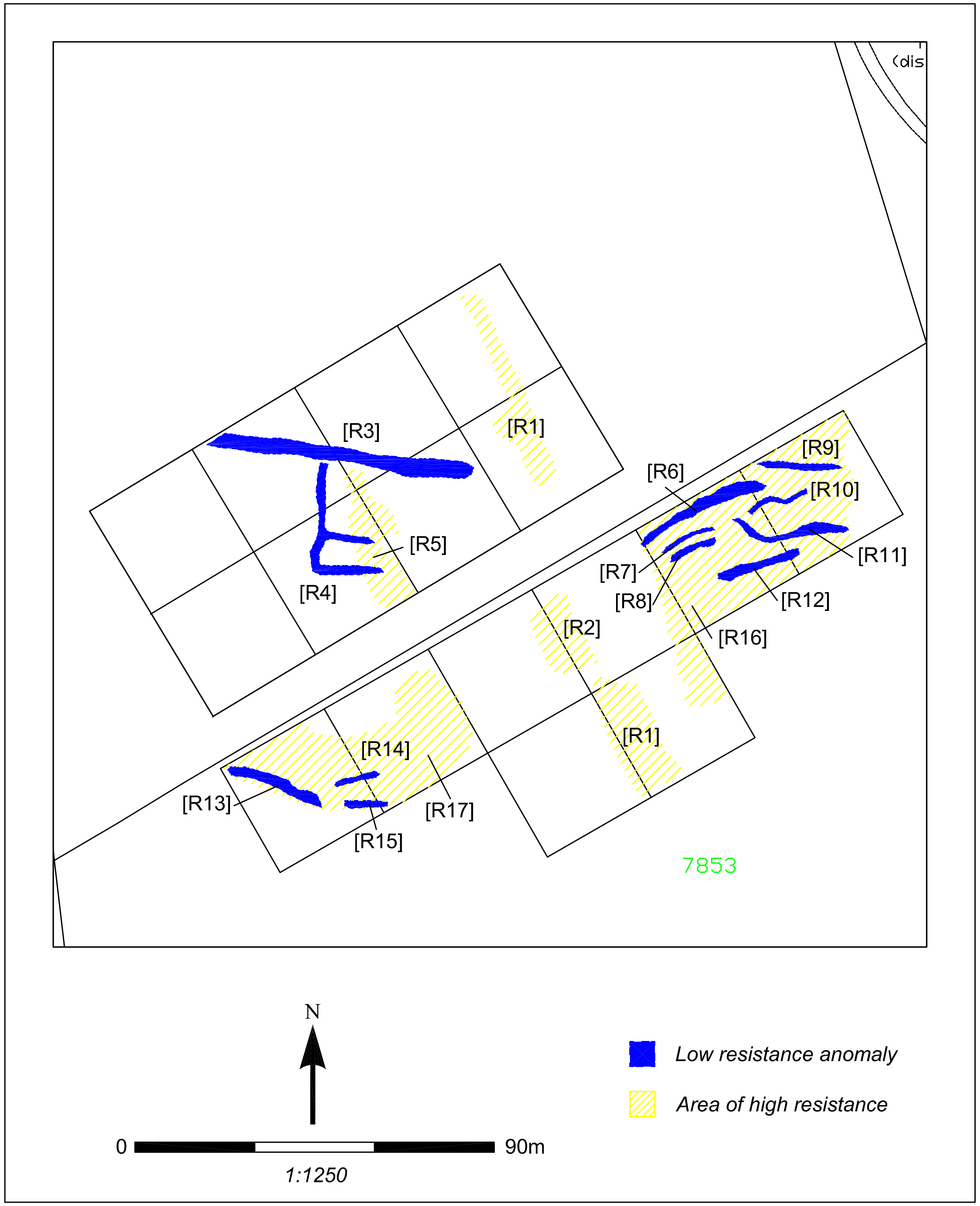

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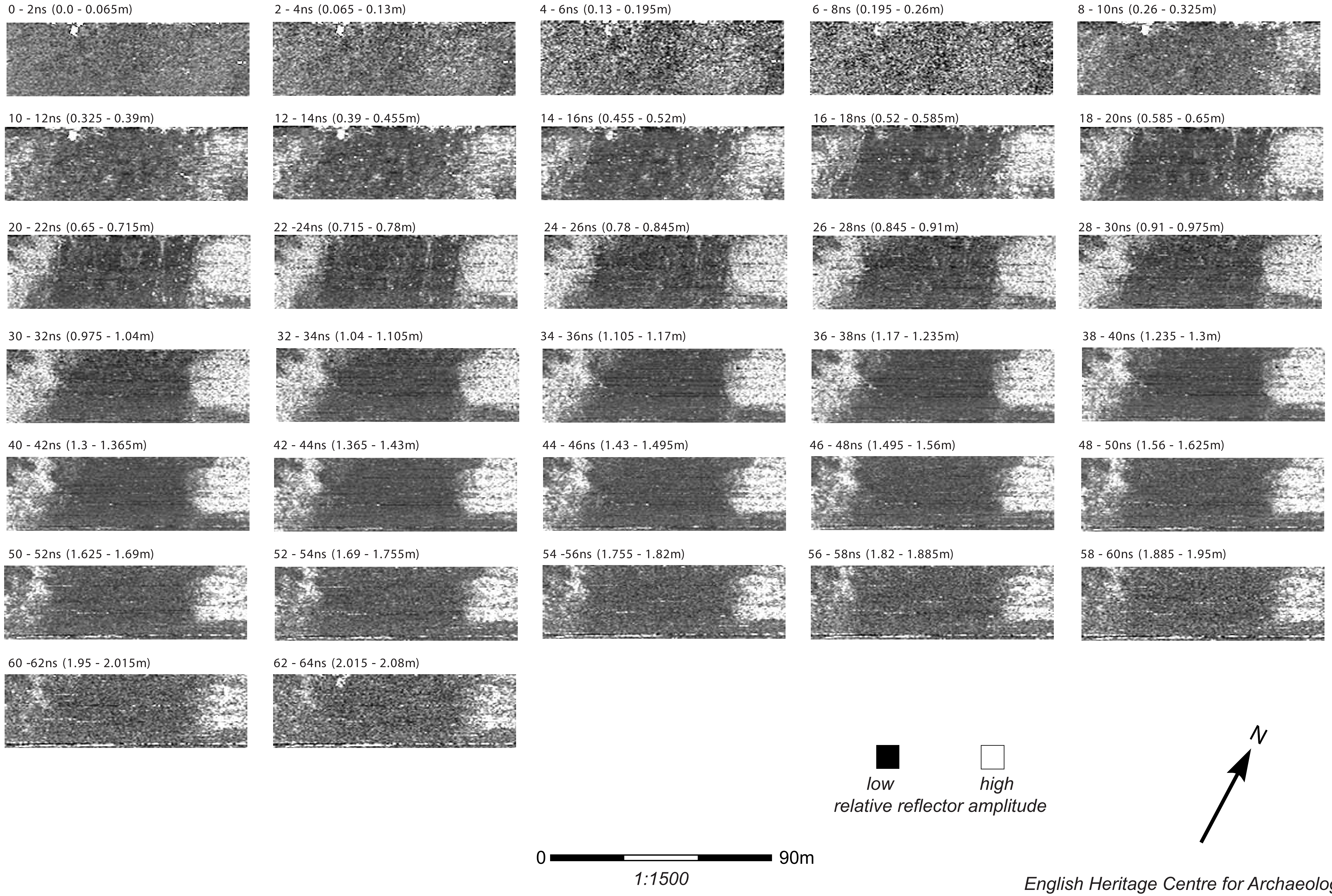
Figure 7

WEST HESLERTON, NORTH YORKS.

GPR Amplitude Time Slices Field 1



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WEST HESLERTON, NORTH YORKS.

GPR Amplitude Time Slices Field 2

Figure 8

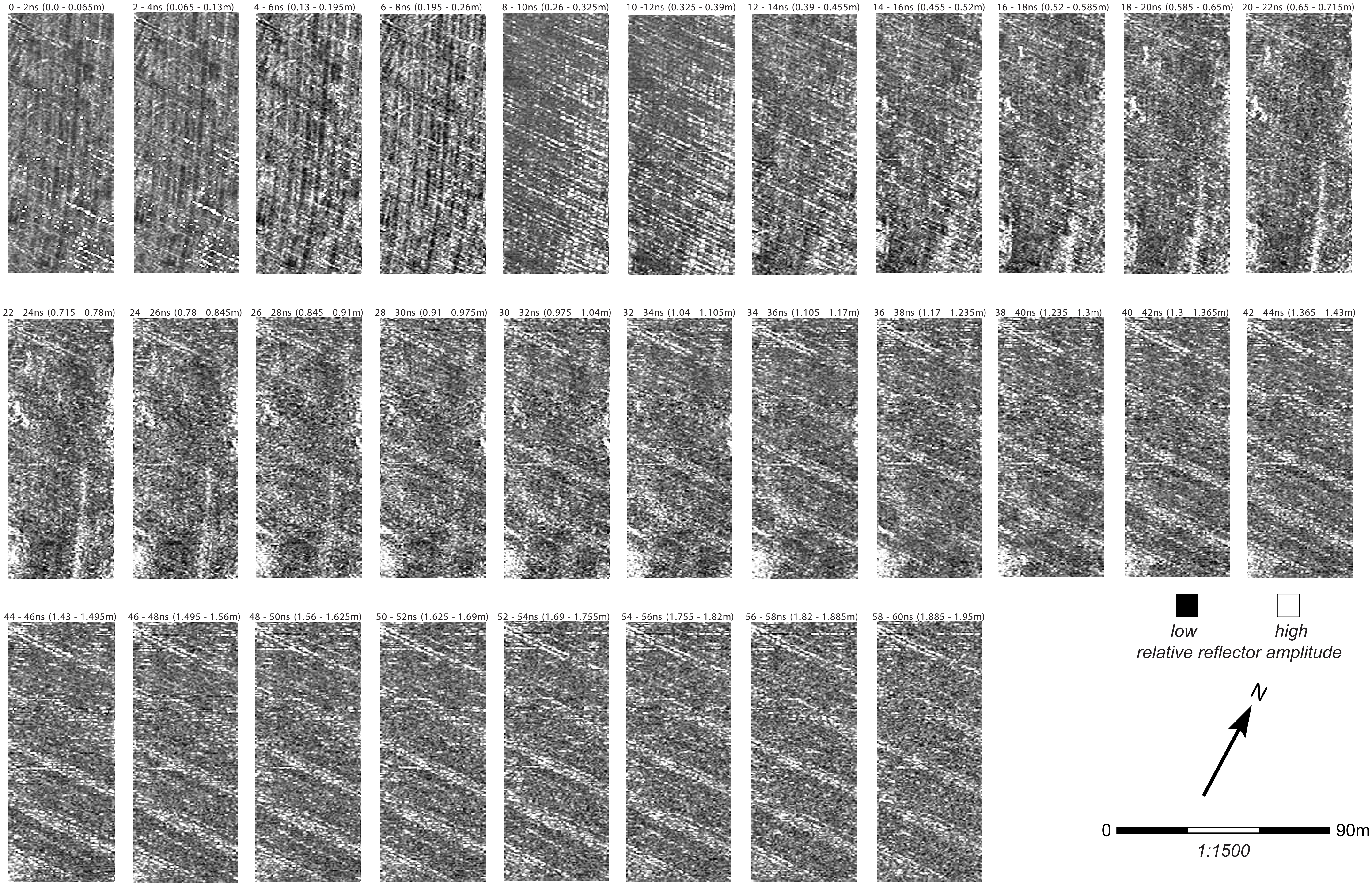

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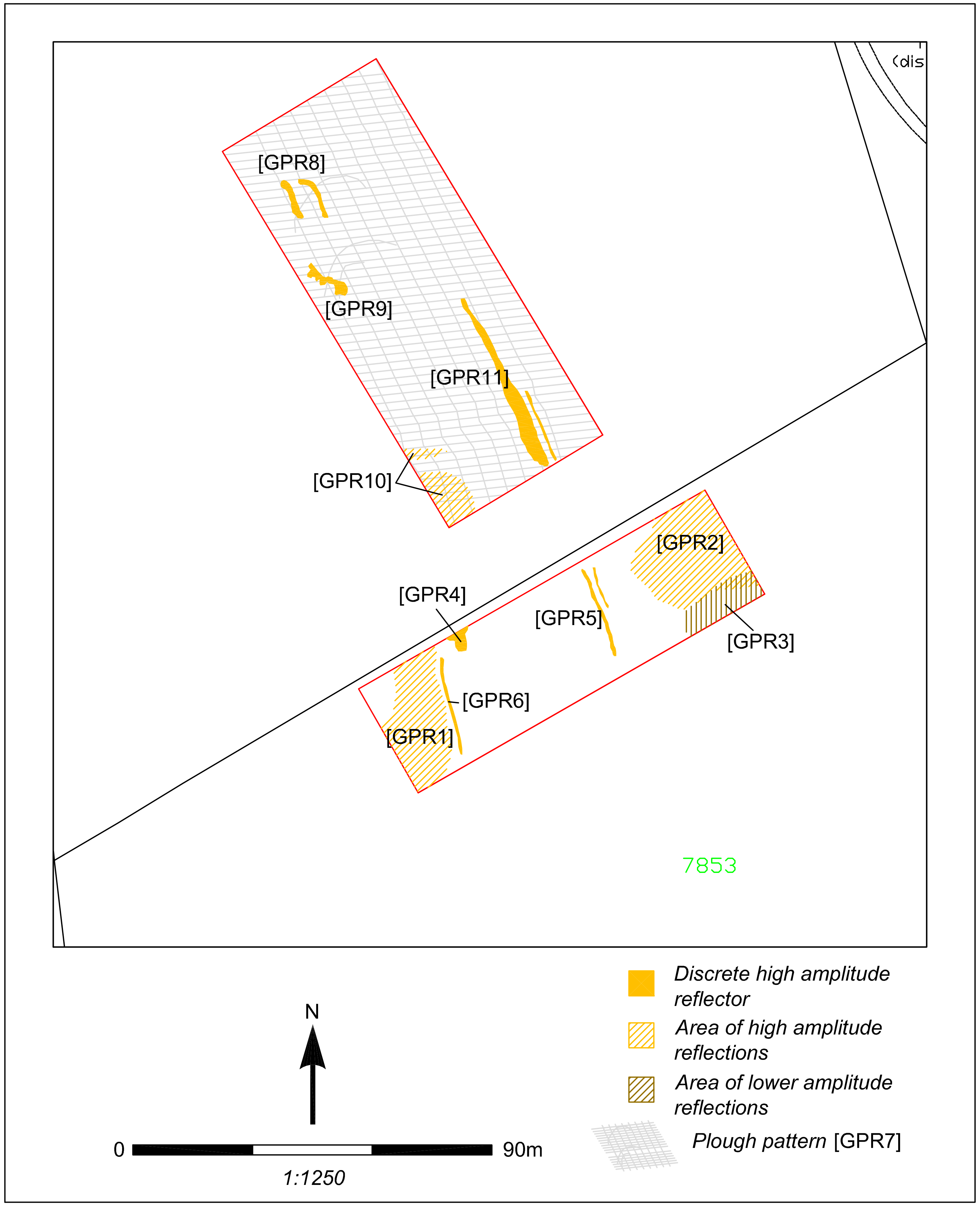
Figure 9: WEST HESLERTON, NORTH YORKS.
Summary of significant GPR anomalies.



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