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FISKERTON, Witham Valley, Lincolnshire
Report on ground penetrating radar survey, January 2003

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Summary

A limited trial GPR survey was conducted over the suspected course of a wooden causeway buried within peaty soils close to the village of Fiskerton, Lincolnshire. Anomalies identified within the GPR data correlate directly with responses recorded by previous magnetic and earth resistance surveys conducted over the same area, although none of these are related to the location of the causeway itself. The failure of geophysical techniques to identify the timber causeway may be due either to the slight physical contrast between the organic remains and the surrounding peaty soil or, perhaps, the destruction of the monument through recent agricultural activity.

Keywords

Geophysics

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Introduction

Pilot magnetic and earth resistance surveys conducted in the vicinity of the Iron Age wooden causeway discovered at Fiskerton, Witham Valley, Lincs., failed to identify a geophysical anomaly that could be unequivically associated with the suspected course of this feature (Martin, 2002). This is, perhaps, unsurprising due to the subtle physical contrast expected between the surviving timber uprights of the causeway and surrounding peaty soil and the possible degradation of the monument through plough damage. However, recent excavation of the causeway, conducted by Pre-Construct Archaeology immediately N of the river Witham, recovered a large quantity of limestone bedding associated with the structure that may well present a suitable target for a Ground Penetrating Radar (GPR) survey (Field and Parker Pearson, 2001, J. Rylatt *pers comm*).

The aim of the current survey was to test the response of the site over an undisturbed area through which, from both excavation and surface recovery of ploughed-out timbers, the causeway is believed to pass. It was hoped that the presence of limestone bedding or, indeed, the causeway timbers themselves may form a suitable target for location through GPR survey (Clarke, *et al.*, 1999).

The site (TF 050 716) lies on peaty soils of the Adventurers' 2 association, with complex soil patterns locally (Soil Survey of England and Wales, 1983) developed over alluvial deposits underlain by Cornbrash (British Geological survey, 1973). At the time of the survey the field was in 'set-aside', though recent agricultural intervention to remove vegetation had left an uneven ground surface. Unclement weather conditions at the time of the survey resulted in surface pooling of water over the site and considerable difficulty in transporting the GPR equipment.

Method

The trial Ground Penetrating Radar (GPR) survey was conducted with a Pulse Ekko PE1000 console and antenna with centre frequencies of 450MHz and 225MHz. The 450MHz antenna was selected as the most suitable centre frequency for obtaining the optimum depth of penetration and lateral resolution required to image the known 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 ~0.075m/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 the trial survey area (Figure 1). Individual traces along each profile were separated by 0.05m and recorded the amplitude of reflections through a 60ns 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 (Figure 5).

Due 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 0.17m, assuming a centre frequency of 450MHz and a velocity of 0.075m/ns. 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 3 represents the areal variation of reflection strength through successive ~0.075m intervals from the ground surface.

In addition, a 225m NS transect was surveyed with both the 450 and 225MHz antenna (Figure 5). This transect ran parallel to the suspected course of the causeway off-set by ~10m to the E following the approximate orientation of a recent auger survey to establish the nature of subsurface soils and sediments across the site (J. Rackam *pers comm*).

Results

General response

The general response of the site to GPR survey was quite good with strong responses produced by subsurface reflectors from the surface to a variable depth of approximately 0.5 to 1.0m. Below this depth the GPR signal was attenuated more rapidly, possibly indicating a change in the soil type or the presence of the local water table. However, significant anomalies were still detected to a depth of 1.5m for the 450MHz antenna and to >2.0m for the 225MHz antenna (Figure 5A and 5B). Despite such favourable subsurface conditions transport of the GPR antenna proved most onerous over the uneven ground surface. This considerably reduced the rate of data acquisition to less than half the number of transects that would be expected from a site with better surface conditions or the possibility of vehicular access to tow the antenna.

Area survey

This survey was located approximately 60m N of the North Delph channel on the suspected course of the causeway in an area containing strong, linear magnetic anomalies caused by ceramic field drains (Figures 1 and 2). It was hoped that the field drains would provide suitable calibration targets to confirm the fidelity of the GPR response before continuing the survey S towards the North Delph where the location of the causeway had been proved through excavation. Regrettably, due to the poor surface conditions it only proved possible to survey a 60m $\times$ 22m grid.

Figure 3 shows amplitude time slices produced from the GPR data together with extracts of the same area from the previous magnetic and earth resistance surveys (Martin, 2002). A summary of significant GPR anomalies is provided in Figure 4 together with the known location of timbers from the causeway for reference.

The very near surface contains an area of disturbance [GPR01] following the approximate course of the causeway (0–2.0ns time slice). However, [GPR01] may be regarded as a highly tentative anomaly that is only evident within a single near-surface time slice. If this anomaly is indeed related to the timber causeway then it suggests the remains have been severely truncated with only scant traces surviving within the current topsoil. No further significant anomalies are detected until a depth of approximately 0.3m (6.0-8.0ns time slice) where a more substantial reflection [GPR02] is found continuing, in part, through the next two deeper time slices. A similar anomaly is found at the W end of the survey area that, apparently, forms part of [GPR05] and is better defined in the later time slices (see below). Anomaly [GPR02] is not replicated in either the magnetic or the earth resistance data and apparently lies slightly to the E of the known course of the timber causeway. Whilst a relationship to this feature cannot be entirely discounted, the limited extent of the anomaly within the current survey is not great enough to allow a confident interpretation.

The strong linear magnetic anomalies revealed by the magnetometer survey are replicated in the GPR data ([GPR03] and [GPR04]) at a similar depth to [GPR02] (8.0-14.0ns time slices). Indeed, [GPR04] cuts through [GPR02] and may be clearly identified as a distinct linear anomaly (10.0-12.0ns time slice), suggesting [GPR04] represents a more recent intervention. It is of interest to note that only [GPR03] was detected by the earth resistance survey confirming the suitability of the chosen GPR parameters for the location of physically quite subtle features.

One final high amplitude anomaly [GPR05] is partially described to the W of the GPR survey area between a depth of approximately 0.675 to 0.975m (16.0-24.0ns time slices). This latter anomaly lies some distance to the W of the causeway and seems unlikely to be related to this feature. However, [GPR05] does correlate with the edge of a pronounced band of high resistance and a diffuse magnetic response identified by the previous geophysical survey (Martin, 2002; Figure 5, Anomaly R4). A slight rise in the topography of the field at this point may, as Martin (2002) suggests, represent the location of significant rubble spread or, perhaps, the edge of a geomorphological feature such as the bank of a palaeochannel.

NS transect

Figure 5A and 5B shows the results of the NS GPR transect collected over the site with both the 450MHz and the 225MHz antenna. For comparison, the wider area magnetic survey is also shown with the location of significant anomalies identified from the GPR transect superimposed over both the 225MHz antenna GPR profile and the magnetic data (Figures 5C).

The higher frequency 450MHz antenna demonstrates more rapid signal attenuation with depth compared to the data collected with the 225MHz antenna. Despite this attenuation significant reflections have been recorded to a depth of >1.5m although these anomalies are recorded with a greater relative amplitude in the data collected with the lower frequency antenna (eg [GPR07]). Both GPR transects identify a band of high amplitude near-surface reflections [GPR06] from the ground surface to a varying depth between 0.5 to 1.0m. The base of this band may well indicate a significant interface between the peaty soils exposed at the surface and either a more compacted peat layer or, perhaps, the depth to the local water table. The nature of this response also varies from ~120-225m where the 225MHz data apparently indicates a higher amplitude of reflection from this apparent interface.

The 225MHz data also identifies three deeper lying reflections [GPR07], [GPR08] and [GPR09]. Anomaly [GPR07] is found at a depth of ~1.5m and as noted above, is present at a reduced amplitude within the 450MHz profile. A diffuse linear magnetic anomaly is found immediately to the S of [GPR07] and it is possible that this represents the response to a paleaochannel bank Alternatively, [GPR07] may represent a more significant target buried within the peat such as a buried timber or a rubble spread (*cf* Clarke, et al., 1999). Anomalies [GPR08] and [GPR09] appear with much reduced amplitude at a slightly greater depth of ~2.0m to the N of [GPR07] beyond the extent of the magnetometer survey. The reduced amplitude of [GPR08] and [GPR09] may well represent differing material properties of these target features compared to [GPR07] or, perhaps, greater signal attenuation due to a combination of the increased depth and the enhanced amplitude of reflection from the overlying interface layer [GPR06].

Conclusion

Despite poor field conditions, hampering the speed of data acquisition, the site has proved responsive to GPR survey. This is demonstrated by the detection of two linear anomalies [GPR03] and [GPR04] associated, perhaps, with recent ceramic field drains replicated in both the magnetic data and as a partial response within the earth resistance data. The penetration depth over the site has also proved to be adequate with significant reflections recorded to an approximate depth of >1.5m with the high frequency 450MHz antenna. It is, therefore, disappointing that the timber causeway has failed to be associated with a distinct GPR anomaly, beyond the highly tentative area of disturbance located in the very near surface time slice.

This may well be due to the material properties of the causeway within the limited trial area for the GPR survey, for example the absence of the limestone bedding revealed through excavation conducted further to the S in the vicinity of the North Delph. However, the possibility of severe truncation of the causeway through a combination of plough damage and deflation of the peat cannot be entirely dismissed (J. Rackham *pers. comm.*). Other anomalies identified by the GPR survey are, apparently, related to geomorphological features and support the presence of a wide palaeochannel crossing the site originally suggested during the interpretation of the previous magnetic and earth resistance surveys (Martin, 2002).

Comparison with the recently conducted auger survey following the line of the GPR NS transect may well allow for a more complete interpretation of this data and establish the degree of truncation that may have occurred across the site. This may also confirm the significance of the deeper lying GPR anomalies, [GPR07], [GPR08] and [GPR09]. However, it seems likely that a more intensive investigation through trial trenching is necessary to confirm the survival of the causeway along its proposed course N towards the present day village of Fiskerton. The results of the trial geophysical surveys, particularly with GPR, may then be reconsidered although further use of this latter technique cannot be recommended without first addressing the problems of data acquisition over the site.

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L Martin

Date of survey: 27-29/01/2003

Reported by: N Linford

Date of report: 25/04/2003

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Figure 2 Linear greytone plot of the 10 – 12ns (0.45 – 0.525m) GPR time slice superimposed over the previous fluxgate gradiometer survey data (1:2500).

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Figure 4 Graphical summary of significant GPR anomalies (1:500).

Figure 5 GPR profiles collected from the NS transect.

Figure 1

FISKERTON, WITHAM VALLEY, LINCOLNSHIRE.

Location of Ground Penetrating Radar survey, January 2003.

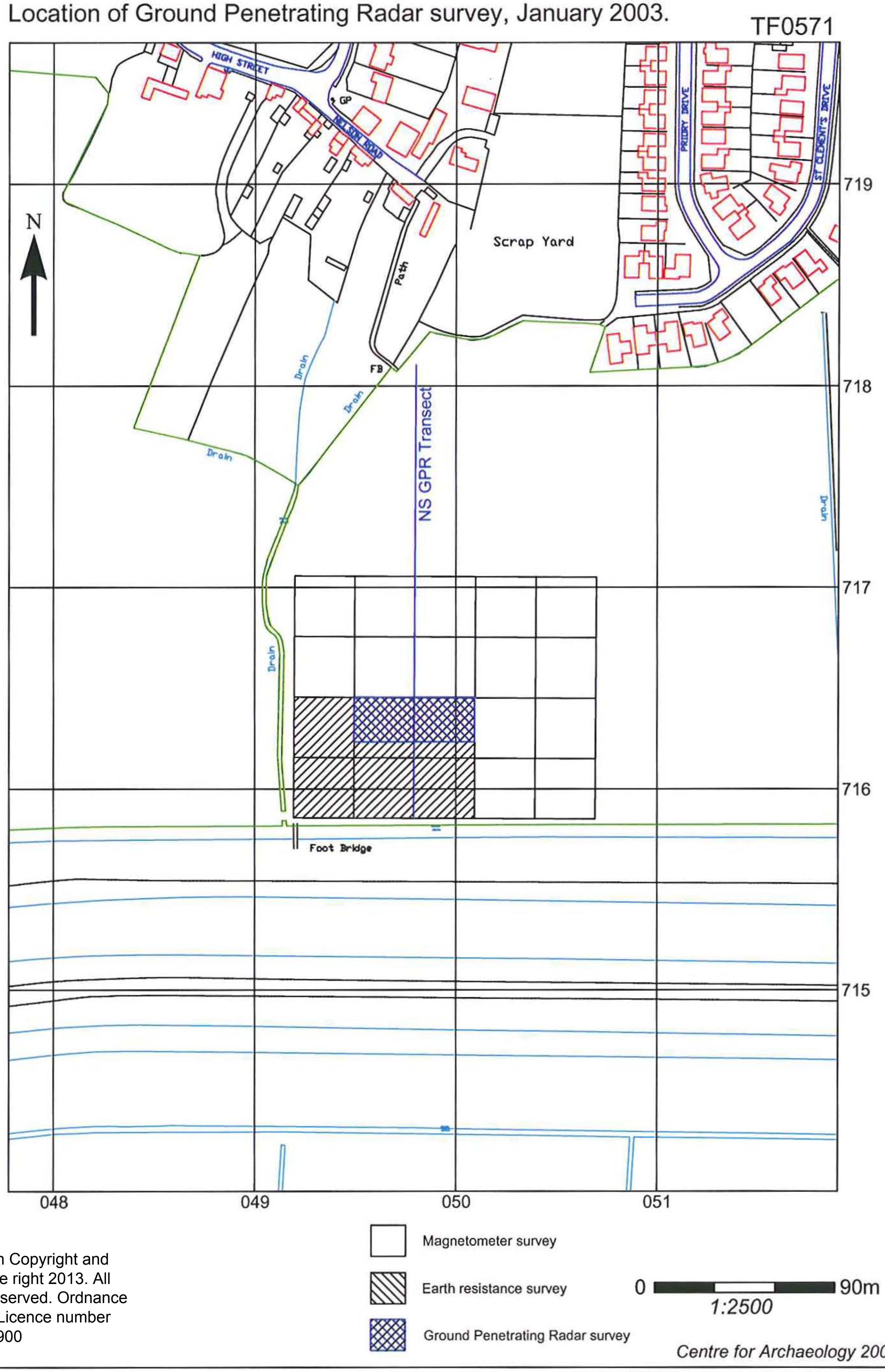

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Figure 2

FISKERTON, WITHAM VALLEY, LINCOLNSHIRE.

GPR survey superimposed over magnetometer data.

TF0571

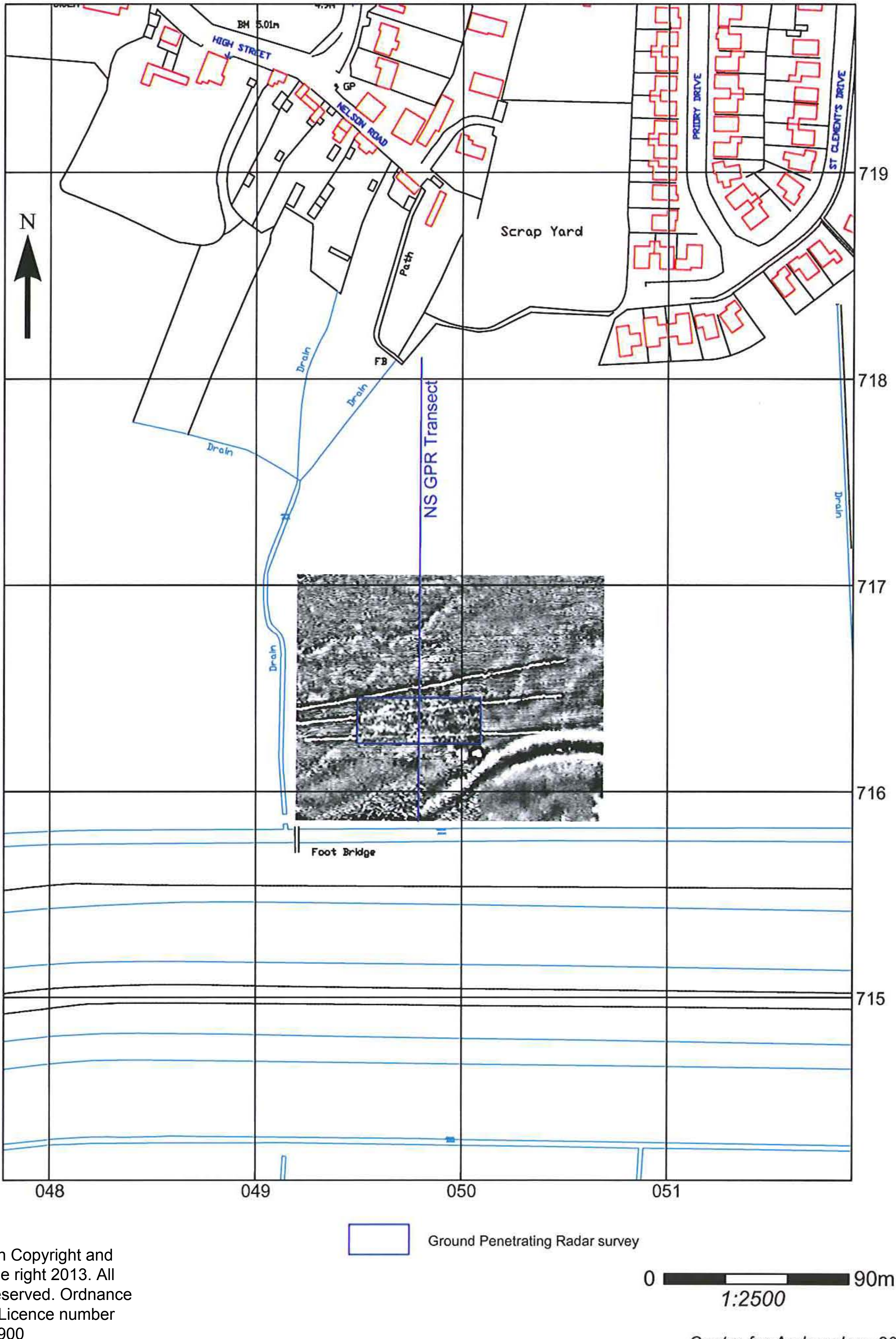

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Figure 3: FISKERTON, WITHAM VALLEY, LINCOLNSHIRE.
Ground Penetrating Radar survey, January 2002.

Amplitude time slices - 450MHz antenna

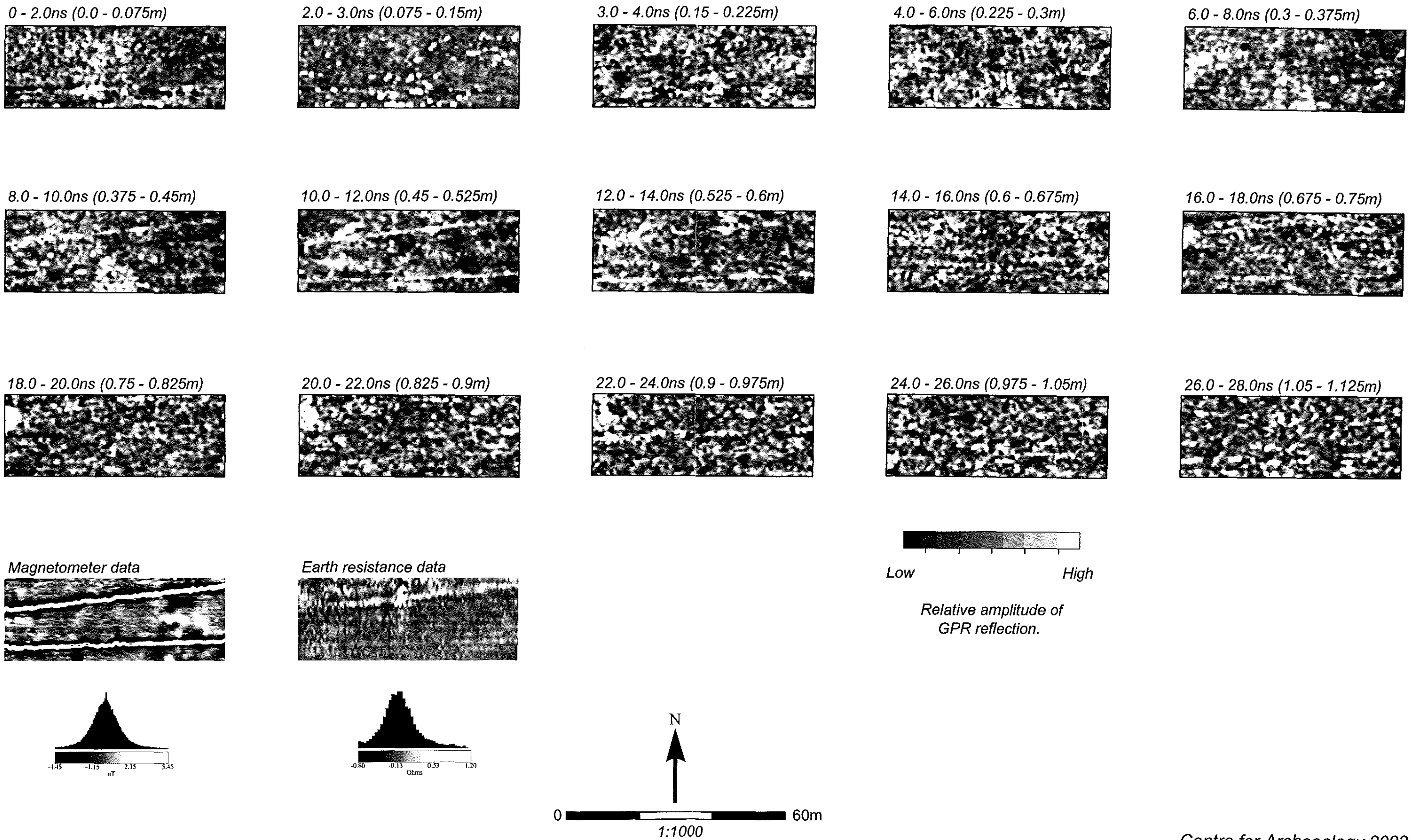

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Figure 4: FISKERTON, WITHAM VALLEY, LINCOLNSHIRE.
Summary of significant Ground Penetrating Radar anomalies.

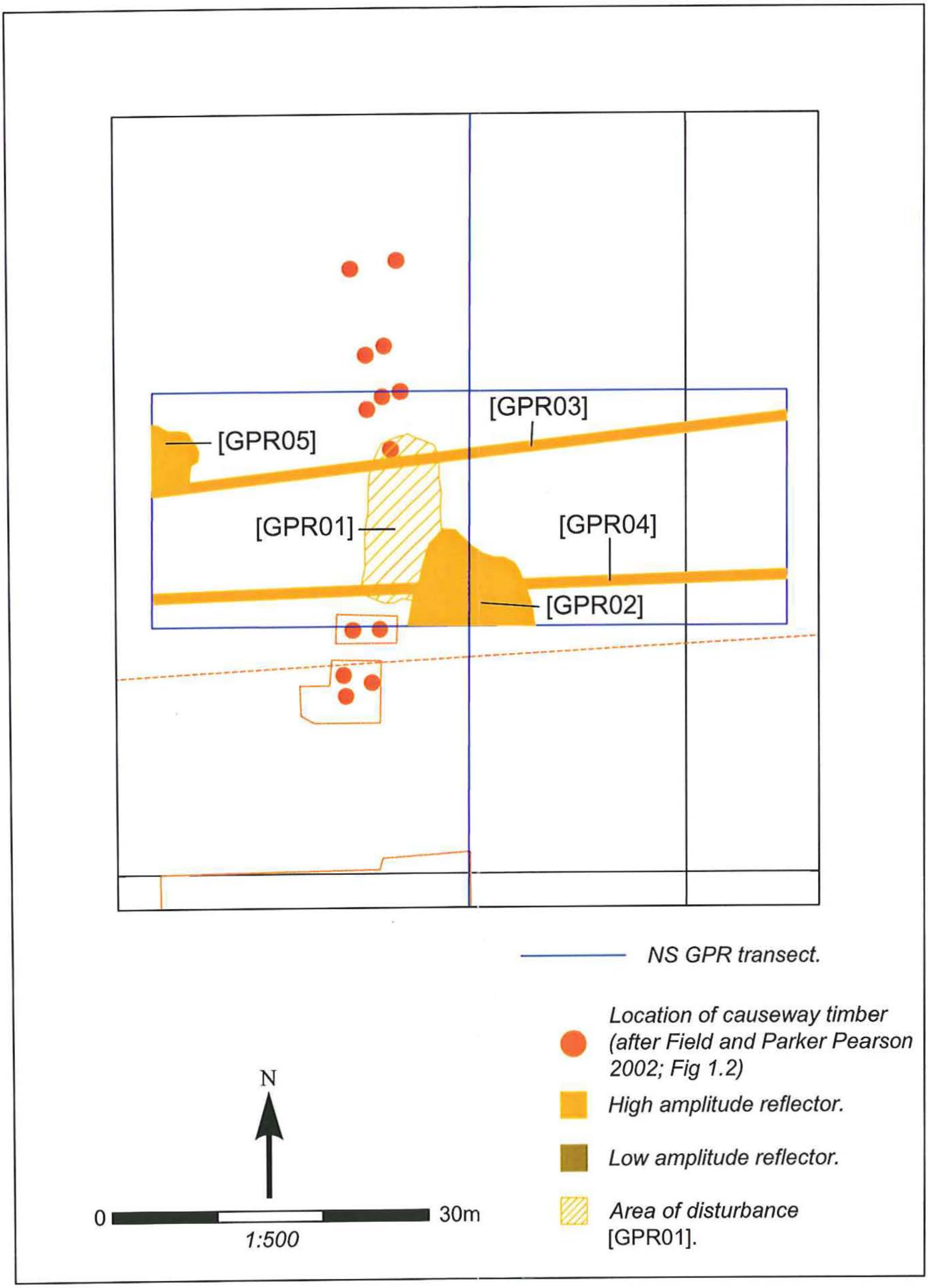

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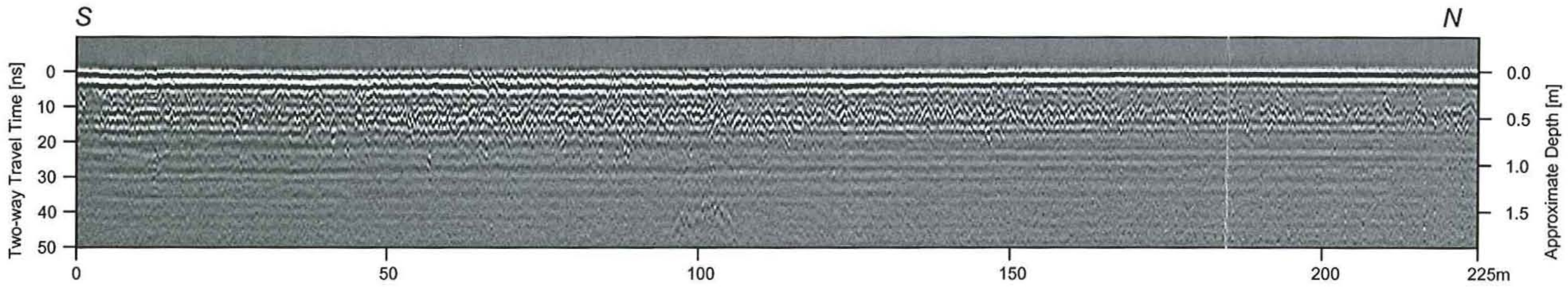
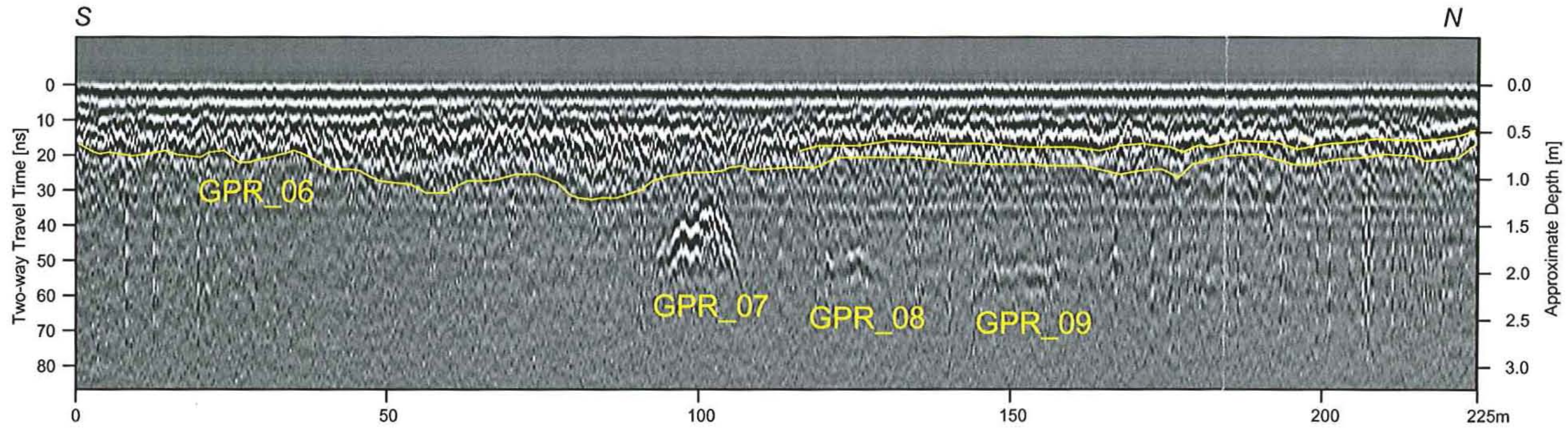
Figure 5: FISKERTON, WITHAM VALLEY, LINCOLNSHIRE.
Ground Penetrating Radar survey, January 2002.

North - South GPR transects

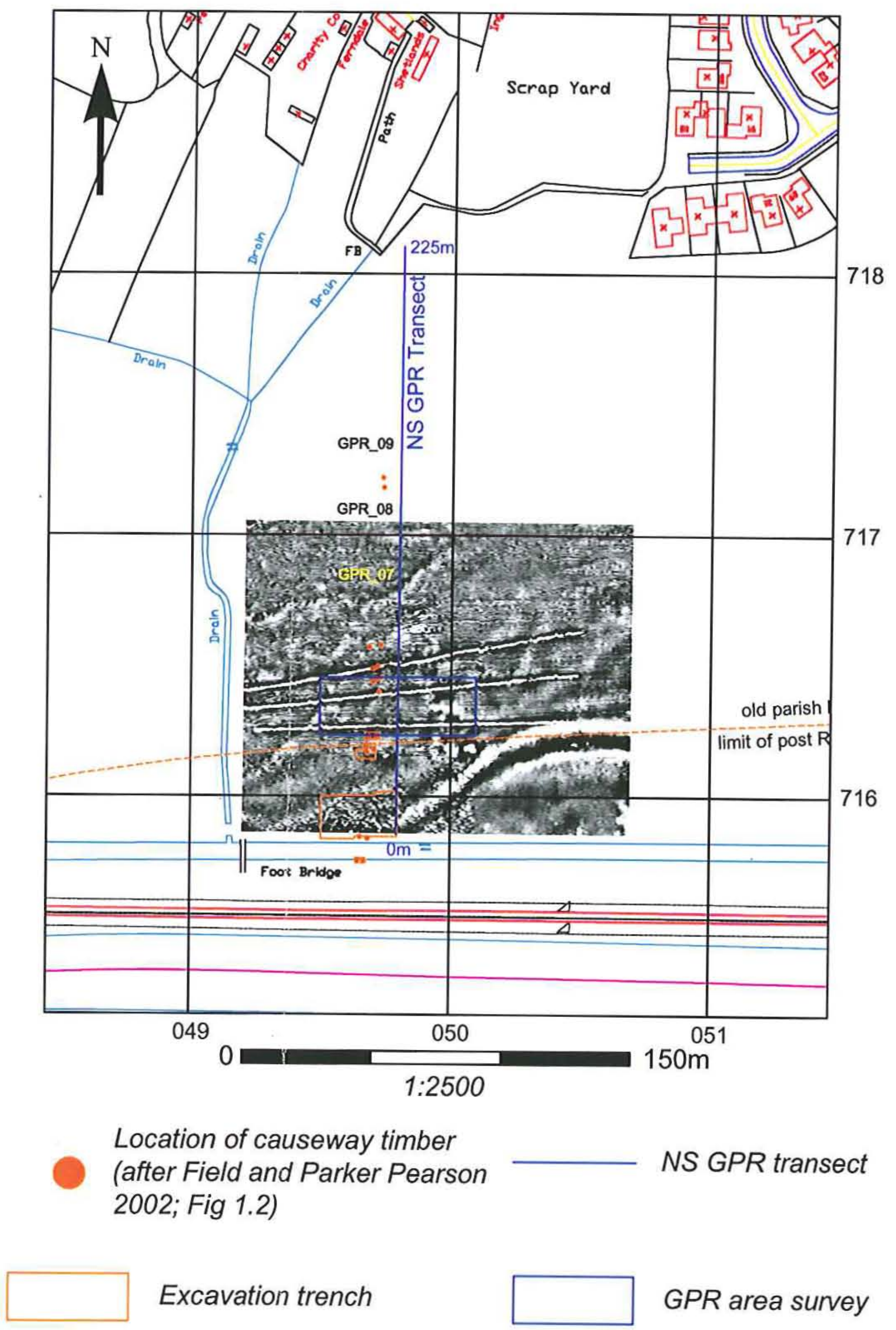
(A) 450MHz Transect



(B) 225MHz Transect



(C) Location of GPR transect superimposed over magnetic data



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