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WHARRAM PERCY, North Yorkshire: Report on geophysical surveys, 1984-2002.

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Summary

Wharram Percy in the Yorkshire Wolds is indubitably the best-known example of a deserted medieval village in Britain. Its renown is due, in no small part, to the programme of excavations conducted by the Wharram Percy Research Project over forty years between 1950 and 1990. These excavations have revealed that the development of the medieval village was much more complex than was originally envisaged, with antecedents in the late Iron Age, Roman and Anglo-Saxon periods. Much information concerning this research has already been published but a synthetic volume is now in preparation that is intended to provide an overview of the project's findings (Wrathmell and Clark, Forthcoming).

The Archaeometry Branch has had a long history of involvement with the Wharram Percy Research Project and has provided geophysical surveys in advance of excavation over much of the site, the last work being carried out in 1989. However, these surveys have concentrated on the northern and central areas of the medieval village. On reassessing the geophysical evidence in preparation for the publication, it was realised that its conclusions could be strengthened if magnetometer survey coverage were extended to the southern part of the site. As previous magnetometer surveys had been carried out with less sensitive instruments and using several grid alignments, it was considered that the best way to achieve this end was to undertake a new survey that would cover all the open parts of the village site on a single survey grid. The Archaeometry Branch thus visited Wharram Percy in September 2002 for this purpose.

This fieldwork has resulted in a new magnetic map of Wharram Percy revealing an impressive range of anomalies likely to be of an archaeological origin. Where the 2002 survey covers areas surveyed in earlier years, it has successfully relocated the anomalies previously detected, often defining them with greater resolution. As these earlier results have not all been formally reported, they are included here for the purpose of comparison. Although features dating to all periods of occupation at the site have been detected, the survey has been most informative with regard to the pre-medieval settlement. In general, the pre-medieval features have not survived topographically and are often overlain by medieval earthworks. Hence, in unexcavated areas, magnetometer survey has revealed their presence for the first time. The opportunity has also been taken to test the potential of earth resistance and ground penetrating radar survey over small trial areas at the site. The results suggest that these techniques are also extremely responsive to the buried remains and can provide complementary evidence to that revealed by magnetic survey.

Keywords

Geophysics

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WHARRAM PERCY, North Yorkshire: Report on geophysical surveys, 1984-2002.

Introduction

Wharram Percy in North Yorkshire (NGR: SE 8583 6436) is unquestionably the best known example of a deserted medieval village in Britain. Its archaeological potential was first recognised by Maurice Beresford in 1948 on a visit to the site of the church of St. Martin's which was at that time neglected but still in occasional use. Since then the investigations of the Wharram Percy Research Project, a programme of survey, excavation and historical research, have brought the site to prominence, particularly amongst the archaeological community. These investigations continued over a period of forty years between 1950 and 1990 and the project was instrumental in helping to pioneer methodological advances such as 'landscape archaeology' and 'open area excavation'. As a result, the importance of Wharram Percy to the study of village development was recognised and the 15.4ha site placed in the guardianship of the Ministry of Public Buildings and Works in 1974, with the generous co-operation of the landowner, the 11th Baron Middleton. The site is also protected as a Scheduled Ancient Monument (RSM 13302) and is recorded in the Sites and Monuments Record for North Yorkshire and in the National Monuments Record (NMR) as SE 86 SE 4.

The Archaeometry Branch of the Ancient Monuments Laboratory (now part of the English Heritage Centre for Archaeology) has been involved with the Wharram Percy Research Project over much of its life. The first geophysical survey was undertaken in 1970 and visits to the site continued until 1989, prior to the final season of excavation. A full list of the 14 geophysical survey visits to Wharram Percy and surrounding areas (as contributions to the related Wharram Parish Project), is provided in Appendix 2. Results of all the surveys at Wharram Percy up until 1982 have been reported by David (1982). Subsequent visits were made in 1984, 1987 and 1989 in advance of summer campaigns of fieldwork (see Figure 2) but these results have not been formally reported before now.

To date, eight volumes of excavation results have been published as well as an English Heritage book giving an overview of the investigations (Beresford and Hurst, 1990). A further three volumes are being prepared to complete the reporting of individual excavations and present a synthesis of the findings of the project. The publication programme is being co-ordinated by Dr Stuart Wrathmell, who realised that the conclusions of the synthetic volume would be strengthened if magnetometer survey coverage were extended to the southern part of the plateau area which lies above the valley of Deep Dale, due west of St. Martin's church. This part of the site had not previously been surveyed and the extent of pre-medieval occupation there was unclear. To this end, he approached the Ancient Monuments Laboratory in 1997 to request that this additional survey work be undertaken as part of the publication programme.

Prompted by this request, previous geophysical survey work at Wharram Percy was reassessed. It was noted that over the nineteen years between 1970 and 1989, several generations of magnetometer had been used. Development of the technique over this period meant that the instrument used for the 1989 survey was 10 times more sensitive than those used earlier. Furthermore, digital recording of the magnetometer results had only been possible for the 1987 and

1989 surveys owing to advances in computer technology. Prior to this, measurements were recorded as a continuous paper trace using a portable chart recorder, making the results almost impossible to reanalyse quantitatively or to integrate with other surveys. Different grid alignments had also been used over the course of the project and combining the results of the various, often overlapping, survey areas would not be straightforward.

It was thus decided that the most desirable course of action would be to carry out a new magnetometer survey, using modern instruments, over all the open parts of the guardianship area where survey was practicable. Additionally, those areas of the arable fields adjacent to the guardianship area would also be covered, so that, where necessary, archaeological anomalies could be traced beyond the immediate area of the medieval village. This strategy offered the benefit of providing a complete magnetic map for all the open areas of Wharram Percy, referenced to a single survey grid, established to a high degree of accuracy, using modern satellite geographical positioning system equipment. As a result, the site was visited by members of the Archaeometry Branch between the 16th and 25th of September 2002, during which period the entire site was surveyed.

The deserted village is set on the western edge of Deep Dale, which for much of its length is a narrow dry valley typical of this part of the Wolds. However, a number of springs issue towards the southern end of the village. These feed a stream called The Beck which flows northwards to join the River Derwent. The majority of the surviving earthworks lie on the edge of the chalk plateau that overlooks this valley on its western side. Geologically, the plateau is composed of Cretaceous chalks of the Welton and Burnham formations above a thin layer of the Ferriby formation (British Geological Survey, 1993). In the valley below, underlying Jurassic clays are exposed. These are erroneously marked as being composed of Kimmeridge Clay on Geological Survey maps. However, ammonites within them, including one excavated from Site 30 at Wharram, demonstrate that they are of Oxfordian age, coeval with parts of the eastern midlands Ancholme Clay Group (Gaunt *et al.*, 1992, pp57-70). It is the outcropping of this impermeable clay layer lying beneath the porous chalk that gives rise to the springs in the valley.

Soils are of the ANDOVER1 association (Soil Survey of England and Wales, 1983, 343h) in the valley. These are deep calcareous and non-calcareous fine silty soils in valley bottoms. Over the chalk plateau the soils are well drained calcareous fine silty soils of the PANHOLES association (*ibid.* 511c). Such soils, developed over chalk uplands, typically produce good magnetic contrasts as a result of past anthropogenic activity. Previous magnetometer surveys at Wharram Percy and in the surrounding area attest to their extreme suitability for this method of archaeological prospecting. As the site of the deserted medieval village itself is under the protection of English Heritage, the land is not ploughed but cropped with grass used as pasture for grazing cattle. The well-drained calcareous soils of the surrounding fields are extremely fertile and are thus given over to arable cultivation. At the time of the survey, these fields had recently been harrowed and were in the process of being seeded.

Method

Magnetometer survey

The results of the magnetometer surveys carried out in 1984, 1987 (both using a Philpot fluxgate gradiometer) and 1989 (using a Geoscan FM36) are depicted in Figure 2, located on the 1:2500 Ordnance survey map of Wharram Percy. These surveys were located via taped offsets to the north and west boundary fences of the guardianship area.

For the 2002 survey, a grid of 30 metre squares was established over the site using a Trimble kinematic differential geographical positioning system as depicted in Figure 1. To minimise the number of incomplete squares, one axis of this grid was aligned parallel with the western boundary fence of the guardianship area, which runs approximately north-south. Magnetometer survey was conducted over this entire grid using the standard method outlined in note 2 of Appendix 1. Plots of the data set are presented as an X-Y traceplot at 1:2000 scale in Figure 4 and as a linear grey scale plot, superimposed on the 1:2500 Ordnance Survey map in Figure 3; the same plot is shown in Figure 5 at the larger scale of 1:1750. The only corrections made to the measured values were to first zero-mean each instrument traverse to remove heading errors, and then to replace with null readings any values with absolute magnitudes greater than 50nT. The latter operation reduces the visually distracting effect of large spikes in the traceplot. In addition, where necessary, a correction has been made for slight positional shifts between adjacent traverses due to the alternating direction of survey.

Earth resistance survey

A 30m by 30m earth resistance survey was carried out over part of the North Manor area in 1984. It is depicted, located on the Ordnance Survey 1:2500 map of Wharram Percy, in Figure 2. Resistance measurements were made with a Geoscan RM4 meter and recorded by hand. Readings were collected using the standard method outlined in note 1 of Appendix 1, with measurements taken at 1.0m intervals with a mobile electrode separation of 0.5m. The results were recorded digitally by typing the hand written measurements into a computer plain text file. The earth resistance results are depicted as a linear greyscale plot in Figure 11 at a scale of 1:750; no numerical processing was performed on these results.

Ground penetrating radar survey

The main purpose of the work in 2002 was to produce a complete magnetic map of the open parts of the Wharram Percy site. However, the opportunity was also taken to test the response of ground penetrating radar (GPR) to the village remains. GPR trials have previously been carried out on site 77 at Wharram Percy by York University in 1989 and 1990 (Stamper, 1990, p12; Stamper, 1991, p8; Milne and Richards, 1992, p16). No formal results of these tests appear to be available but subsequent excavation of the surveyed area seems to have indicated that much of the GPR response was caused by reflections from underlying natural deposits (Stamper, 1991, p8).

Nevertheless, it was felt that advances in GPR processing techniques in the last decade justified a further experiment. A 30m by 60m area covering tofts 12 - 15 was selected for the trial and this area is depicted in Figure 1. The methodology employed for the GPR survey and results obtained are more complex than those of the other techniques discussed in this report. Hence this survey is described separately by Neil Linford in Appendix 3.

Results

The focus of the discussion in this section is on the results of the 2002 magnetometer survey as this is by far the most extensive of the geophysical surveys carried out at Wharram Percy and it was the primary purpose of the fieldwork in September 2002. The magnetometer surveys carried out in 1984, 1987 and 1989 will not be discussed as their results have been superseded by the more recent work. A brief examination of the trial earth resistance survey over the North Manor site undertaken in 1984 is also included owing to the evident potential of the technique at Wharram Percy.

Magnetometer survey

The results of the fluxgate gradiometer survey are depicted as a greyscale plot in Figures 3 and 5 at 1:2500 and 1:1750 scales respectively. In the former case, they have been superimposed on the Ordnance Survey map of the area. A schematic plan of all significant geophysical anomalies is presented in Figure 6 and it is clear that many of these might potentially have an archaeological cause. In several places, multiple anomalies overlie one another and the resulting dense palimpsest is difficult to interpret. For this reason, an attempt has been made to group the geophysical anomalies into four units. Three of these approximately correlate with different periods of occupation at the site. The fourth identifies anomalies likely to have a non-archaeological cause. The groups are depicted separately in Figures 7-10 and the differentiation between anomalies has been based upon four criteria:

i) *Excavated evidence:* In many parts of the site, anomalies detected in the magnetometer survey clearly correspond with features discovered in excavation trenches. In particular, between 1985 and 1990, Dr. Julian Richards of York University undertook a series of excavations specifically to test the results of the 1984 and 1989 magnetometer surveys. Where such evidence is available, it is possible to date anomalies to a specific period with a high degree of confidence.

ii) *Geophysical character:* It may be noted that there is a distinct variation in the magnetic intensity of the detected anomalies. Those in the north-west of the survey area that appear to be related to the Iron Age and Roman settlement at the site, are more strongly magnetised than other magnetic anomalies at the site. These anomalies exhibit peak magnitudes that are typically around 5-10nT and sometimes much higher. This is despite the amount of subsequent occupation activity overlying them, as attested to by, often substantial, earthworks. By contrast, many of the anomalies that are clearly associated with extant medieval earthworks are typically only weakly magnetised, with peak magnitudes around 1-2nT. This variation in geophysical character is likely to reflect differences both in the form of the causative features and in the nature of the contemporary activities contributing to the enhancement of soil magnetisation.

iii) *Correlation with earthworks:* Many of the detected anomalies clearly correspond in position and shape with earthworks visible on the ground. Such anomalies have been grouped into the medieval unit. Conversely, those anomalies that appear to be cut by the earthworks have been grouped into one of the other two units on the assumption that they could not be contemporary with the medieval layout of the village reflected in the earthwork plan.

iv) *Alignment or contiguity:* Finally, where an anomaly is contiguous with, or on the same alignment as, anomalies that fall into one of the above classes, it has been assumed to be contemporary with it. Conversely, anomalies on different alignments or that overlie each other have been assumed to belong to different units.

The three archaeological units that result from this grouping are: "Iron Age and Roman settlement", "Medieval settlement" and "Other settlement evidence". The latter unit contains many anomalies that may result from occupation at Wharram prior to the late Iron Age/Roman settlement or in the Anglo-Saxon period but a post-medieval origin for some of these may also be considered. The title of the unit reflects the inherent uncertainty in ascribing an archaeological period to this group.

Such a scheme obviously has its shortcomings, not least because medieval occupation at the site persisted for over 500 years, during which time many changes to the layout of the village occurred.

Furthermore, it is likely that some geophysical anomalies have been misclassified. This is particularly likely in areas where alignments appear to have been preserved between periods, such as the superimposed Roman and medieval east-west roads to the north-west of the site. This route has been identified as Road 1 by Beresford and Hurst (1990, p74 fig. 55). Nevertheless, this classification clarifies the presentation of the geophysical results and provides a framework for their discussion.

In the text that follows, numbers in bold refer to annotated positions on the relevant interpretation figure. Plain numbers correlate with the revised site codes for excavation areas established by the Wharram Percy Research Project in 1983 (for example: **94** relates to the position of the York University excavations at Site 94 (Milne and Richards, 1992, p4 fig. 2)). Where geophysical anomalies occur in areas that cannot conveniently be identified in this way, additional numbers have been defined, all of which are prefixed with 'G' to distinguish them from the former numbering scheme (for example: **G01** identifying the pipeline at the eastern edge of the site in Figure 7).

Figure 7: Anomalies likely to have a non-archaeological cause

A number of features in the magnetic map of Wharram Percy are likely to have a non-archaeological cause. The most magnetically intense of these is the linear band of alternating high and low magnetisation running south-west from **G01**. This is clearly a modern pipeline, supplying water butts for cattle located in the fence line at the southern end of the marked anomaly.

At **G02** a weakly magnetised, broad, linear anomaly enters the survey area and bifurcates. Such an anomaly is likely to have a geological cause. It may represent the point at which the underlying clay outcrops from beneath the chalk formations of the Wold top (although the line of springs marked on the map suggests that this might be further down-slope to the east). A second possibility is that it represents periglacial scouring of the chalk surface, the scoured depression being filled with material of higher magnetic susceptibility. The southern branch of this anomaly continues towards the area of the North Manor excavations at Site **60** where it becomes indistinct amongst a confusing palimpsest of superimposed magnetic anomalies. However, one intriguing possibility suggested by Figure 3 is that it continues south along the line of the 'lynchet bank' (Oswald, 2003, section 5.3; Stamper and Croft, 2000, p19). Hence, it may be that this latter enigmatic feature is associated with an underlying geological change (see discussion of Figure 9 below).

Two anomalies similar to that at **G02** but even more diffuse have been marked near the centre of the western edge of the survey area.

Several areas have been marked in Figure 7 where intense changes in magnetic field gradient occur within a small area, the largest such is indicated at **G03**. These are likely to be caused by modern near-surface ferrous material. In many cases the origin is obvious, the metal signposts and information boards noted during the survey, create characteristic circular anomalies of this type about 5-10m in diameter. The larger, more linear, anomaly at **G03** has a less certain cause but appears to coincide with an old fence line. It is thus likely to be due to agricultural debris (a similar but less obtrusive anomaly occurs along the field boundary at the north-western corner of the survey area.

Excavation trenches have also been outlined in Figure 7. The magnetic map is unlikely to be reliable in such areas as the original fills of archaeological features will have been removed and replaced with mixed spoil. In some cases intense magnetic disturbance seems to have been caused by the archaeological investigation (for instance at Site **60** in the North Manor area) or where the positions of buildings have been marked in concrete (for example at Site **9**).

Finally a pattern of very faint, narrow, linear anomalies have been marked with dashed lines, running approximately east-west covering the north and north-western parts of the magnetic survey. It is tempting to associate these with medieval ridge and furrow, given that they appear to run approximately parallel to earthwork boundaries belonging to that period. However, in the field to the west of the guardianship area they run in an east-west direction whilst the surviving furrows that have been detect run north-south (Beresford and Hurst, 1990, p7 fig. 2). It is thus more likely that these anomalies are associated with the periglacial "parallel E-W striations in the natural Chalk caused by frost shattering and weathering" discovered at Site **98** (Stamper, 1991, p4). Similar features were also noted at Site **53**, north of the northern village boundary (Beresford and Hurst, 1990, p79).

Figure 8: Anomalies relating to Iron Age and Roman settlement

The most intense magnetic anomalies at Wharram Percy are those forming a conjoined series of rectilinear enclosures at the north-western corner of the guardianship area. Where these have been investigated by excavation (see below) they have been found to be enclosure ditches cut into the underlying chalk and relating to late Iron Age and Roman occupation at the site. This set of anomalies is not aligned over any of the earthworks visible on the ground and it is remarkable that they are still so clearly detectable given the extent of later occupation that has occurred in this area of the site.

Most notable amongst these linear anomalies is the almost rectangular, north-westernmost enclosure where the peak strength of the magnetic anomaly is in excess of 10nT. This was first noticed as a crop-mark in aerial photographs (e.g.: NMR: SE8564/13 frame 149), although its significance was not recognised until the 1970s (Beresford and Hurst, 1990, p19 fig. 4). An excavation sectioning this ditch was carried out by Paul Herbert in 1989 and 1990 (Site **91**) (Stamper, 1990, pp2-3; Stamper, 1991, pp4-7). This revealed that the anomaly was caused by a ditch some 3.6 to 3.9m wide and about 1.8m deep. The ditch fill showed evidence of re-cutting and contained pottery dating from the Roman period. Removal of the original, magnetically enhanced, ditch-fill at Site **91** has caused the apparent break in the line of the ditch visible in the magnetometer survey.

The excavation results indicate that this ditch began life in the late C1st AD as a Roman military enclosure, perhaps surrounding a temporary camp or practice fortlet. By the late C2nd AD it appears to have been abandoned by the military and was being re-used as a farming enclosure. However, all the features within the area enclosed by the ditch seem to relate to the C4th AD and it has been suggested that these represent the outbuildings of a villa site, the main villa building being located towards the centre of the enclosure. With this conjecture in mind, it is instructive to compare the geophysical evidence with that from the nearby Roman villa site at Wharram le Street (David, 1980; Beresford and Hurst, 1990, p87 fig. 64). This site was excavated by Philip Rahtz (Rahtz *et al.*, 1986) and the villa building was found to be in the centre of a central square enclosure of similar dimensions to the one at Wharram Percy. Furthermore, the pattern of magnetic anomalies within the Wharram le Street villa enclosure is similar to that revealed by the present survey. Obviously, such a correlation does not prove the hypothesis but it certainly suggests that it might merit further consideration.

Unfortunately, the tenant farmer needed to sow the fields surrounding the guardianship area during the period of the geophysical fieldwork and it was not possible to revisit the central part of this enclosure after the initial magnetometer survey. It is here that the wall footings of the main villa building would be expected to be located and electrical or GPR prospecting techniques might directly detect buried masonry.

Immediately south of the enclosure just discussed, is evidence for the main Roman roadway through the settlement, running west to east from **G04** to **G05**. Confirmation of the date was discovered during excavations in the North Manor area (Site **60**). These indicated that the road was first laid out in the late Iron Age with modifications in the Roman period. Two Anglo-Saxon sunken-featured buildings were also found, dating from the 6^{th} to 8^{th} centuries AD (Beresford and Hurst, 1990, p71 and fig. 58). These were cut into a Roman metalled surface and one was in turn cut by the later medieval hollow way. It is interesting to compare the route of this Iron Age/Roman road with those of the later roadways in the medieval period (Beresford and Hurst, 1990, fig. 74). To the east, near **G05**, the Roman road runs along the route of the medieval Track 3 and would then appear to run down the gentlest part of the slope to join Road 2 where it enters the guardianship area. By the medieval period Track 3 is a cul-de-sac and travelling through the village from east to west requires a detour south into the centre of the village via Road 2. As the Iron Age/Roman road heads west from Site **60** to **G04**, it runs parallel to, but some 10-15m north of the later medieval Road 1 as delineated by the surviving earthworks. Furthermore the Iron Age/Roman road appears to continue almost due west as it leaves the survey area, after which it can be followed as a cropmark which eventually turns north in a gentle curve (Hayfield, 1987, p106 fig. 54). However, the medieval Road 1 turns sharply north to follow the, still extant, field boundary towards Malton. At **G04** it appears that one of the north-south linear ditch anomalies crosses the line of the road, suggesting some remodelling of the road layout even during the Roman period.

The easternmost of the Iron Age/Roman enclosures coincides with the southern courtyard of the medieval North Manor (Site **45**). Excavations here by York University have discovered a defensive Iron Age ditch with a gateway, suggesting that the main part of an aristocratic Iron Age settlement may lie beneath the later North Manor house (Beresford and Hurst, 1990, p71). Certainly the geophysical evidence for a complex series of interlinked rectilinear enclosures to the immediate north and north west would tend to support this inference. The York University excavations also show that this area continued to be utilised throughout the Roman period with a sequence of grain driers from the late Roman period being discovered. Further excavations by York University at Sites **88**, **89**, **92**, **94**, **95** and **98** have confirmed that the relevant sections of the ditches depicted in Figure 8 were in use during the Iron Age and Roman periods. This increases confidence in the map of Iron Age and Roman settlement that has been extrapolated from the geophysical evidence in Figure 8.

At **G06** a narrow north-south linear ditch forming one edge of an enclosure was detected in the 1987 magnetometer survey (see Figure 2) but was not detected in the 2002 survey (Figure 3). Traverses in the latter survey were orientated almost exactly parallel to the line of this anomaly, so its disappearance is likely to be a survey orientation or processing artefact rather than due to any physical change in the causative feature. For this reason the line of the ditch has been traced from the 1987 survey and included in the interpretation.

As a final comment on Figure 8 it may be noted that, to the south of **G04**, a number of the boundary ditches continue westwards out of the survey area, parallel to the main Iron Age/Roman road. It is thus possible that the remains detected represent the eastern end of an east-west aligned ladder settlement similar to that detected by air photography along the Gypsey Race at Wharram le Street (Hayfield, 1987).

Figure 9: Anomalies relating to medieval settlement

The anomalies presumed to be due to medieval features are generally less strongly magnetised than the Iron Age and Roman anomalies just discussed, despite the fact that they often correlate in position with quite substantial surviving earthworks. This is perhaps because the causative features are often upstanding rather than cut features capable of holding large volumes of magnetically enhanced backfill. Furthermore, in the case of depressions and ditches dating from the medieval period, the soil backfill may have been subject to less anthropogenic enhancement of magnetic susceptibility, as occupation at the site diminished after the medieval period. Many of the more imposing medieval remains have also been excavated, reducing their potential for detection by geophysical methods.

Nevertheless, the magnetic survey has detected many medieval features at Wharram Percy. One notable example is the hollow way running west out of the village and labelled Road 1 by Beresford and Hurst (1990, p74 fig. 55). The banks to either side of this thoroughfare have been detected where they survive as earthworks. These run from Site **60** in the east, where the road was investigated by excavation, to a point some 30m south of Site **91** in the west. However, the peak magnitude of the magnetic anomalies is much weaker (~2-3nT) than those created by the parallel ditches running just north of the original Iron Age road (~7-10nT).

Immediately north of Site **45** the magnetometer survey has detected anomalies caused by the remains of the complex of medieval buildings identified as the North Manor. It has been possible to distinguish these anomalies from those caused by earlier Iron Age and Roman enclosure ditches, upon which they are superimposed, owing to differences in alignment and peak anomaly strength. The magnetic anomalies from this area are shown, compared with the surviving earthworks in Figure 11c. Although fragmentary, many features of the manor complex are distinguishable in the magnetic survey.

To the east of the North Manor complex at **G07** a number of faint linear magnetic anomalies have been marked. They appear to run approximately east-west on an alignment similar to that of the manor complex. The surviving earthworks (Beresford and Hurst, 1990, p49 fig. 34) indicate the north-south aligned crofts behind the North Row of medieval dwelling in this area. However, the magnetic map suggests another pattern of land division in this area, perhaps during the late medieval period when it was incorporated into the North Manor complex (Beresford and Hurst, 1990, p81 fig. 60).

The enclosure bank running round the west and north sides of the North Manor *curia* has been detected in the magnetic map as two narrow linear, anomalies of positive magnetic field gradient separated by a band of slightly negative magnetic field gradient. The form of the magnetic anomaly over these banks reflects, at least in part, the topographic shape of the earthwork rather than differences in the magnetic susceptibility of subsurface features. A diminution in the magnetic gradient would be expected on the crest of an upstanding earthwork bank even if it were composed of soil of homogenous magnetic susceptibility (Linington, 1973).

Several other earthworks to the south also exhibit a similar magnetic signature. These include the 'lynchet bank' near **G08**, the western boundary of crofts 12-17 near **G09** and the boundaries of the South Manor *curia* (particularly the northern boundary running between **G08** and **G09** and the western boundary running south from **G09**). These boundaries have been interpreted as originating in the prehistoric or Roman periods (Atkin and Tompkins, 1986, p10; Beresford and Hurst, 1990, p72 fig. 53). However, the magnetometer survey has detected only anomalies likely to result from the medieval earthworks rather than any strongly magnetised linear ditch responses like those exhibited by the features discussed above. It is possible that pre-medieval ditches do underlie the visible earthworks but that their original magnetic soil fill has been disturbed or replaced by later remodelling. Results of excavations at Sites **36** and **37**, if available, may throw further light on this matter.

The feature known as the 'lynchet bank', running south from Site **60**, past **G08** and through the South Manor excavation Sites **81** and **90**, is particularly puzzling. The date of this feature is uncertain (Stamper *et al.*, 2000, p19); archaeological survey suggests a prehistoric origin (Oswald, 2003, section 5.3), whilst no excavated evidence predates the medieval period (Stamper et al., 2000, p38). The magnetic map shows an anomaly similar to that of the North Manor *curia* boundary earthwork running south from about 40m south of Site **60** to **G08**. This then appears to turn west to run along the northern boundary of the South Manor *curia*, whilst the southern continuation of the 'lynchet bank' through Sites **81** and **90** is effectively invisible to the magnetometer. Thus magnetic survey suggests that the earthwork may be composed of at least two different components along its length. However, no strongly magnetised linear anomalies similar to the Iron Age and Roman boundary ditches are apparent. Hence, the geophysical survey cannot offer any evidence to support a prehistoric origin for this boundary, or for any Iron Age ladder settlement features to its east (Oswald, 2003, section 5.3). It is, of course, possible that medieval activity in these areas has disturbed the magnetised fills of earlier remains.

Three access tracks, Beresford and Hurst's, Tracks 5, 6 (**G10**) and 10 (**G11**) (1990, p74 fig. 55), have been clearly detected as strong linear anomalies of negative magnetisation, with flanking positive magnetic anomalies to either side (these latter often being weak and fragmentary). However, recent archaeological survey (Oswald, 2003, section 5.2), suggests that these tracks, in fact, originate more recently than the medieval period.

The medieval arrangement of croft boundaries had been detected most clearly on the Northern Glebe Terrace immediately south of **G01** as a series of parallel linear anomalies, about 15m apart, approximately perpendicular to the eastern boundary fence of the guardianship area. Seven separate crofts can be distinguished. Also, a very faint linear anomaly of negative magnetisation can be discerned running perpendicular to the croft boundaries beside their north-western ends (along the line running from **G01** to **G11**). Comparison with the trackway anomalies just mentioned, suggests that this may indicate the former presence of an access track running between the tofts and crofts of the East Row.

In the fields outside the guardianship area a number of linear anomalies have been indicated that are conjectured to be medieval enclosure boundaries. To the west, these anomalies appear to be continuations of features discernible as earthworks further east. It is on the basis of this continuity of alignment that they have been assumed to be medieval. At **G12** one such anomaly cuts across one of the characteristically strongly magnetised ditch anomalies of the Iron Age and Roman settlement (**G12** is also marked in Figure 6 with all the geophysical anomalies). Certainly this suggests that this anomaly, and the others in the western fields with a similar geophysical signature, are not contemporary with the Iron Age or Roman settlement.

In the field to the north of the guardianship area, a number of linear anomalies have been identified that appear to run approximately parallel to the northern boundary earthwork of the North Manor *curia*. The longest and broadest of these, identifiable in air photography (Beresford and Hurst, 1990, p19 fig. 4), cuts across the boundary ditch of the main Iron Age and Roman enclosure at the north-west of the site and so cannot have been contemporary with this period of occupation. For these reasons these anomalies have been classified as potential medieval boundary ditches. However, they appear to run parallel to the faint linear anomalies described above under Figure 7 (depicted as dashed lines) that were attributed to natural striations in the chalk surface. It is thus possible that these stronger and broader anomalies also have a natural, geological origin.

Figure 10: Anomalies relating to other settlement

This figure depicts anomalies that are likely to be archaeological in origin but that cannot be confidently ascribed to any particular archaeological period. The difficulty may be illustrated by considering the arcing, linear anomaly running north-westwards through Site **94** where it crosses the east-west boundary ditch of the Iron Age and Roman settlement (see also Figure 6). Its northern end is extremely close to the end of a second similar anomaly that arcs south-west to cross the same Iron Age and Roman boundary ditch in Site **98**. It is tempting to assume that these two curving anomalies are caused by the same underlying feature, the slight break between them being simply due to limitations in the resolution of the magnetometer. However, upon excavation, it was discovered that the anomaly in Site **94** was cut by the Roman ditch and was thus concluded to date from the Iron Age, whilst the anomaly in Site **98** cuts it, suggesting an Anglo-Saxon date (Stamper, 1991, p4). Further examination of the excavation evidence may shed more light on the matter but it seems likely that the gap between the two anomalies in the magnetometer plot is real and that two separate causative features exist. Furthermore, these results demonstrate that two anomalies with very similar magnetic signatures can have quite different archaeological dates.

The area to the south of the sites just discussed exhibits further concentrations of similar curvilinear anomalies stretching almost all the way down to Drue Dale and lying both within and outside the guardianship area. These anomalies do not align with any of the medieval features visible as earthworks and, in some cases, cross them. Excavation evidence from Sites **94** and **98** suggests that such anomalies could be due to features that range in date from the late prehistoric to the Anglo-Saxon period. Trenches excavated further south, in advance of tree planting, seem to confirm this. At Sites **70** and **78** evidence for a Romano-British farm was discovered along with a complex sequence of Anglo-Saxon occupation continuing into the C12th AD (Beresford and Hurst, 1990, pp78-9). Some of these anomalies might thus represent boundaries of the original Roman farmstead in this area, whilst the remainder may be caused by Anglo-Saxon features.

A number of discrete features have also been indicated and these tend to cluster close to the curvilinear anomalies just discussed, particularly in the southern part of the survey area. Some of these anomalies have dimensions and magnetic signatures consistent with an interpretation as Anglo-Saxon sunken featured buildings. Such buildings have been discovered by excavation at Sites **95** and **39** (Milne and Richards, 1992), as well as at Site **60** (Beresford and Hurst, 1990, pp71-72). However, given the density of anomalies possibly caused Anglo-Saxon structures in the southern part of the geophysical survey, it might be conjectured that the examples just discussed, lying to the north, are outliers from a main centre of settlement that developed on the plateau further south. This hypothesis is leant some weight by the extensive middle Saxon remains discovered in the **South Manor Sites** (Beresford and Hurst, 1990, p82; Stamper et al., 2000, pp27-37). However, little Anglo-Saxon evidence was found in Site **12** (Milne, 1979), so any such settlement would have to have been situated further west, away from the edge of the plateau.

Along the eastern edge of the plateau, a number of magnetic anomalies suggestive of quarrying pits have been marked. Where these have been excavated (e.g. at Site 9 - (Wrathmell, 1989, p21) this is indeed what they have turned out to be. Much of this quarrying appears to have taken place in the C13th AD to provide stone for toft construction. However, there is some evidence for quarries dating from the Roman and Saxon periods, hence the anomalies have been marked on this figure rather than Figure 9.

At the far north of the survey area a linear anomaly has been detected that is suggestive of a field boundary (**G13**). However, it is not aligned with any of the other anomalies or visible features on the site and it crosses the supposed medieval boundary anomalies in this area. Thus its interpretation and date remain enigmatic.

Earth resistance survey, 1984

During the 1984 geophysical survey, a trial earth resistance survey was conducted over a 30m by 30m area in the North Manor complex. The results of this are plotted in Figure 11, superimposed on the earthwork survey of the area carried out by R. T. Porter, G. L. Worsley and W. J. Hopkins. The relevant portion of the magnetometer survey is also depicted for comparison. It is immediately clear that the earth resistance anomalies do not correspond with those detected by the magnetometer. However, a number of linear, high resistance anomalies have been very clearly detected by the earth resistance meter and these are indicated in Figure 11c. These anomalies correlate closely with the upstanding earthworks and they are likely to be caused by buried masonry within them. This is one of the most striking instances of complementarity between magnetic and electrical surveys that has occurred in a survey undertaken by the Ancient Monuments Laboratory. Each instrument has very clearly detected a different set of features: the magnetometer has responded to the Iron Age and Roman ditches, whilst the earth resistance meter has detected medieval wall footings of the North Manor.

Further earth resistance survey by York University is mentioned in an interim excavation report on Site 95 (Stamper, 1991, p3) but the author has not seen the results of this work.

Conclusions

Magnetometer survey at Wharram Percy has been extremely successful in detecting anomalies likely to be of archaeological origin. Furthermore, the differing structures of features from various archaeological periods, along with differences in the occupation activities enhancing the magnetisation of the soil, have resulted in anomalies with distinctive magnetic signatures. It has thus been possible to produce an approximate phasing for the archaeological anomalies as depicted in Figures 8-10. As a result, it can be seen that the magnetic survey has produced a great deal of information concerning pre-medieval occupation at the site. In particular the Iron Age and Roman ladder settlement to the north has been clearly mapped as have a complex series of possible prehistoric and Anglo-Saxon features in the south. These remains have not survived as topographic features and it has thus not been possible to detect them using topographic survey within the guardianship area (although the principal boundaries have been detected in aerial photographs (Stoertz, 1997, map 1)). In the field outside the north-west corner, the Iron Age and Roman ditch system has been detected as a crop mark in air photographs. However, it has been mapped in greater detail by the magnetic survey.

Conversely, the magnetometer has responded only weakly to anomalies corresponding to extant topographic features, whilst oblique air photography and topographic survey have mapped features surviving as even slight earthworks in great detail. These features appear to relate almost exclusively to medieval settlement at the site and so the magnetic map has contributed relatively little new information to the understanding of occupation in this period. In this way, the magnetometer survey complements the information gained from other survey techniques at Wharram Percy.

Other geophysical techniques have only been tested on small areas at the site. Nevertheless, the results of these trials suggest that the well drained soils of the western plateau offer good potential for both earth resistance and GPR surveying. In both surveys, buried masonry wall footings, likely to date to the medieval period, have been detected clearly. They contrast with the magnetic survey in this regard as the magnetometer appears to have responded to cut features such as ditches rather than upstanding buried wall footings. GPR survey offers the additional benefit of providing relative depth information for the anomalies it detects. This has been demonstrated in the present instance through the detection of a second, deeper building platform associated with toft 13 indicating multiple phases of occupation during the medieval period. Although some evidence of buried wall footings has emerged from aerial photographs of parch marks (Wrathmell, 1989, p43 fig. 30), it is likely that electrical and GPR surveying could provide a more complete picture.

The list of geophysical surveys at Wharram Percy given in Appendix 2, represents in microcosm the history of development of geophysical survey techniques at the Ancient Monuments Laboratory. These developments have benefited immensely from the unique combination of exceptionally clear geophysical results and the feedback from extensive archaeological excavation afforded by the Wharram Percy Research Project. Nevertheless, the foregoing report demonstrates that, despite the large amount of magnetometer survey already carried out at the site, the potential for further discoveries to be made by geophysical survey with other techniques has perhaps not yet been exhausted.

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Dates of survey: 16th-25th September 2002

Reported by: P. Linford & N. Linford

Date of report: 3rd March 2003

Archaeometry Branch,
English Heritage Centre for Archaeology.

List of enclosed figures

Appendix 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 resistivity 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. However, the magnetometer is always kept facing in the same direction, regardless of the direction of travel, to minimise heading error.

   Unless otherwise stated the measurements are made with a Geoscan FM36 fluxgate gradiometer which incorporates two vertically aligned fluxgates, one situated 0.5 metres above the other; the bottom fluxgate is carried at a height of approximately 0.2 metres above the ground surface. The FM36 incorporates 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).

Appendix 2: Previous geophysical surveys at Wharram Percy and its environs

Listed below are the geophysical survey visits made by the Ancient Monuments Laboratory to Wharram Percy and the surrounding area, as recorded on the English Heritage Geophysical Survey Database (http://www.eng-h.gov.uk/SDB). The index numbers on the left are survey visit numbers - the survey visit number is a reference used by the database to uniquely identify each specific survey visit. Results from visits 355-7 are included in this report, earlier results from visits 350-354 have previously been reported by David (1982).

Visits to Wharram Percy itself

350) WHARRAM PERCY, North Yorkshire [23-NOV-82 to 25-NOV-82]: Magnetometer survey in advance of proposed excavation.

351) WHARRAM PERCY, North Yorkshire [08-JUL-70 to 11-JUL-70]: Magnetometer survey to test for presence of western boundaries to the site.

352) WHARRAM PERCY, North Yorkshire [05-JUL-71 to 09-JUL-71]: Magnetometer survey to further define the western boundary ditches and locate evidence for croft enclosures.

353) WHARRAM PERCY, North Yorkshire [07-JUL-75 to 10-JUL-75]: Resistivity traverses across the main earthworks at the western boundary bank.

354) WHARRAM PERCY, North Yorkshire [17-MAY-76 to 21-MAY-76]: Further geophysical survey in advance of continuing excavations in the north-western part of the site.

355) WHARRAM PERCY: NORTH MANOR, North Yorkshire [15-MAY-84 to 18-MAY-84]: Continuing geophysical survey to define settlement plan in the North Manor area of the village.

356) WHARRAM PERCY, North Yorkshire [23-FEB-87 to 10-APR-87]: Continuing magnetometer survey at north-west corner of the village to examine the area around the Roman enclosure.

357) WHARRAM PERCY, North Yorkshire [17-APR-89 to 21-APR-89]: Continuing magnetometer survey at Wharram to define underlying archaeology of the medieval village.

Geophysical survey contributions to the Wharram Parish Project

282) BIRDSALL, WHARRAM PARISH, North Yorkshire [18-SEP-84 to 21-APR-84]: Geophysical survey of an extensive cropmark site, as part of the Wharram Parish survey project.

312) WHARRAM GRANGE, North Yorkshire [31-OCT-77 to 04-NOV-77]: Magnetometer survey to define the extent and nature of a probable Roman site located by field walking and aerial photography.

313) WHARRAM GRANGE, North Yorkshire [23-NOV-82 to 25-NOV-82]: Further survey at Wharram Grange to define the boundaries of the Roman settlement.

358) WHARRAM PARISH: TUNNEL TOP FARMSTEAD, North Yorkshire [28-JAN-91 to 01-FEB-91]: Magnetometer survey to determine nature and extent of possible Roman farmstead site.

359) WHARRAM PARISH: RAISTHORPE WOLD FARMSTEAD, North Yorkshire [28-JAN-91 to 01-FEB-91]: Magnetometer survey to determine nature and extent of possible Roman farmstead site.

429) WHARRAM-LE-STREET, North Yorkshire [17-OCT-78 to 21-OCT-78]: Magnetometer survey to define the character and extent of a large villa-like complex seen on aerial photographs.

Appendix 3: Trial ground penetrating radar survey over tofts 12-15

By Neil Linford

Method

A trial ground penetrating radar (GPR) survey was conducted with a Pulse Ekko PE1000 console and 450MHz centre frequency antenna. The 450MHz antenna was selected as the most suitable centre frequency for obtaining the optimum depth of penetration and lateral resolution required. The velocity of the radar wavefront in the subsurface was estimated through a common mid-point (CMP) velocity analysis conducted in the field and a constant velocity test subsequently performed on extracts of the data (Leckebusch, 2000). Both methods suggested that a velocity of 0.0714 m/ns was a reasonable average value to adopt, both for processing the data from this site and for the estimation of depth to reflection events in the recorded profiles.

The 30m × 60m trial survey grid was surveyed with parallel east-west traverses separated by 0.5m resulting in a total of 120 recorded GPR profiles collected from the survey area shown in Figure 1. Individual traces along each profile were separated by 0.05m and recorded the amplitude of reflections through a 50ns 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 12).

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 0.08m, assuming a centre frequency of 450MHz and a velocity of 0.0714m/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 3ns (two-way travel time) windows (David and Linford, 2000; Sensors and Software, 1996). Each resulting time slice, illustrated as a greyscale image in Figure 13, represents the variation of reflection strength through successive ~0.11m intervals from the ground surface.

Results

Figure 12 shows three representative GPR profiles collected over the survey area prior to the application of a 2-D migration algorithm. In general, the response to GPR survey has been most favourable, with strong near-surface reflections recorded to a two-way travel time beyond 20ns (~0.7m). Reflections from a range of features have been identified including the response to raised, chalk rubble walls and at least one discrete anomaly demonstrating a more complex stratigraphy. The GPR response to the wall footings is quite varied producing either a semi-continuous layer (e.g. [GPR06] on Figure 12; Profile 15) or a group of multiple point reflections produced, no doubt, from individual chalk rubble blocks (eg [GPR03] on Figure 12; Profile 50).

The amplitude time slices (Figure 13), generated from all the collected profiles, confirm the presence of significant reflections at the very near-surface (0–1.5ns time slice), although the majority of linear anomalies within the survey area become apparent from approximately 0.5m from the ground surface. A strong correlation between the GPR anomalies (Figure 14b) and the combined plan of recorded earthworks together with buildings identified from aerial photographs is evident (Wrathmell, 1989, p43 fig. 30) and may be compared, together with the corresponding magnetometer data, in Figure 14. Indeed, all the major medieval buildings within the trial survey area produce a detectable response including elements of toft 15 at [GPR01], toft 14 at [GPR02], toft 13 at [GPR03] and toft 12 at [GPR04].

The GPR anomalies do not replicate either the recorded earthwork survey or the evidence for buried walls derived from aerial photography directly (Figure 14a), suggesting a more complex relationship between the subsurface geophysical response and the obvious topographic variation encountered in the field. For example, the GPR survey suggests some additional structure to the west of building 14 including a series of wall-type anomalies [GPR05] subdividing the toft enclosure together with a distinctive, low reflection strength anomaly [GPR06]. The rectilinear nature of [GPR06] together with evidence for a gently sloping reflector bounding the anomaly to the north (Figure 12, Profile 15) suggest some form of building platform, although the apparent absence of stone-built wall footings may well be indicative of a less permanent, timber built structure. An enhanced magnetic anomaly, of similar size and shape, is found to correlate with the location of [GPR06] and it is possible that the geophysical response may be due to a compacted floor-layer of organic material or clay.

Immediately to the S, in the vicinity of toft 13, a sub-circular topographic anomaly is replicated by a GPR response, [GPR07], of similar morphology. Again, this correlates directly with the location of an enhanced magnetic anomaly that would appear, from the GPR response (Figure12; Profile 41), to be of 'U' shaped section with a definite 'floor layer' extending to a depth of ~1.0m from the current ground surface. However, this apparent profile may be misleading due to the extant topography of the site that, if corrected, may reduce [GPR07] to a horizontally continuous subsurface layer (cf Linford, 2001). Despite these reservations, it does not seem unreasonable to suggest that [GPR07] represents a discrete feature, such as an oven or kiln, that would explain the correlation with an enhanced magnetic response or, perhaps, a stone-lined well back-filled at a later date with some form of magnetically enhanced material. In addition, evidence is found for a high-amplitude, rectilinear reflection [GPR08] abutting the walls of the building within toft 13 immediately to the north. This latter anomaly appears at a greater depth than the majority of reflections from the medieval buildings (e.g. Figure 12, Profile 50; Figure 13, time slice 10.5 – 12.0ns onwards) but is distinct from the general area of deeper disturbance, [GPR09], illustrated by hatching on Figure 14b. Whilst [GPR08] may be directly associated with the building within toft 13, it remains possible that this response is due to an earlier phase of construction sharing a broadly similar orientation.

As has been noted above, to the south of the trial GPR survey area only part of the building within toft 12 has, apparently, been replicated by a GPR response, [GPR04]. However, a number of GPR anomalies are found between the location of the buildings in tofts 12 and 13, in part, following the evidence for wall-footings revealed through aerial photography [GPR10]. Additional anomalies, [GPR11], immediately to the west appear within the wider enclosure of toft 12, that is apparently devoid of either topographic anomalies or evidence for wall footings recovered from aerial photographs. Unfortunately, magnetic data from this area is partially obscured by surface ferrous interference but the GPR results certainly suggest a more complex subdivision of the enclosure and possible extension of wall footings towards the main building structure within toft 13.

Discussion

The trial GPR survey has proved highly successful, producing a high resolution data set that complements the archaeological information inferred from the standing earthworks, aerial photography and the magnetometer surveys. A number of additional wall alignments have been revealed through the GPR survey together with two rectangular anomalies, possibly representing building platforms or enclosures, that have not been previously recognised. One of these, [GPR08], abuts the building within toft 13 but is found at a greater depth from the current ground surface, suggesting an earlier phase of occupation and later reuse.

GPR survey with a lower centre frequency would, no doubt, increase the penetration depth beyond the ~1.2m achieved with the 450MHz antenna used during this trial. However, the amplitude time slices (Figure 13) demonstrate that the majority of linear anomalies, related to the presence of buried wall footings, appear <1.0m from the current ground surface. Below 1.0m the GPR data records an area of deeper-lying disturbance that is more likely to be associated with either a change of soil type or striations within the underlying chalk geology. It is possible, therefore, that repeat survey with a lower centre frequency (deeper penetrating) antenna would not recover much additional archaeological information.

Further GPR survey would benefit from topographic correction and anomaly modelling to separate responses due to significant buried reflectors from those created by the undulating site terrain. Thus, any additional coverage with this technique should be conducted in concert with a topographic survey to establish a full Digital Terrain Model for the site during the subsequent processing and visualisation of the GPR data set.

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