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Burnfoot Farm, Longtown, Cumbria, Report on Geophysical Survey, August 2000

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Summary

Following the discovery of a Roman altar capital in about 1970 during gravel excavations on the banks of the River Esk near Longtown in Cumbria, a geophysical survey was carried out to try and establish whether crop marks visible in the adjacent field at Burnfoot Farm might be related to Roman occupation in the area. Unfortunately, only a very few anomalies were detected and it was not clear whether they relate to the crop marks. It is probable that this lack of success was due to the alluvial nature of the site.

Keywords

Geophysics

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BURNFOOT FARM, LONGTOWN, CUMBRIA

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Introduction

Following a lecture given by Alan Whitworth of the English Heritage Hadrian's Wall Co-ordination Unit to a group in Longtown, a member of the audience showed him a piece of Roman stonework that had been discovered in gravel workings thirty years previously. The stone appeared to be the capital of a very large Roman altar and had been excavated from the south bank of the River Esk near its confluence with the River Lyne between Longtown and Metal Bridge. Further investigation by Alan Whitworth uncovered aerial photographs of the area from 1951 (NMR 540/519 FR: 4211 and 4212) apparently showing a complex of crop marks in a field adjacent to the find spot at Burnfoot Farm. Hence, at the request of Tony Wilmott and Alan Whitworth, a geophysical survey was carried out to attempt to determine the extent of the crop marks and to better define the structures that they might represent. It was intended to excavate at the site after the geophysical survey was completed and it was hoped that the geophysical information could be used to inform the positioning of trenches.

The field at Burnfoot Farm in which the crop marks lie measures some 18ha and is under pasture (NY 364 660). It has not been ploughed during the tenure of the current farmer who has owned the land for over thirty years. Geologically the site lies on Permian and Triassic sandstones (Institute of Geological Sciences, 1979) but this is overlain with flood plain alluvium from the nearby River Esk (Geological Survey of Great Britain, 1969). The soils of the area are from the ALUN (561a) and ENBORNE (811a) associations, both being deep stoneless loamy soils developed over alluvial geology (Soil Survey of England and Wales, 1983). Magnetic response on such sites is expected to be poor, as alluvial soils typically have a very low magnetic susceptibility leading to very weak magnetic signals at the lower limits of instrument precision. Electrical response is also often complicated by the variable distribution and drainage of river gravels under the alluvium.

Method

Field Procedure

Owing to the short period of time available on site and the fact that it had only been possible to obtain unrectified aerial photographs the day before work commenced, it was decided to set out a grid of 30 metre squares 120m wide across the width of the field (see Figure 1). This strip was positioned in the hope of covering an area that appeared to contain strong crop marks in the aerial photographs (Figure 2). As the survey progressed, further 30m squares were added to the southwest of this strip in the hope of detecting other features visible in the crop marks.

As indicated in Figure 1, squares 1-4, 6-11, 15-18 and 21-28, comprising a strip across the field, were initially surveyed with a Geoscan FM36 fluxgate gradiometer according to the technique outlined in Annex 1; readings were taken at 0.25m by 1m intervals. The areas that were felt most likely to produce anomalies corresponding to the crop mark evidence were then surveyed with a Geoscan RM15 earth resistance meter with a mobile electrode separation of 0.5m. This electrode separation investigates only the top 0.75m of the subsurface on what could be a deeply alluviated site. However, it was felt that if archaeological features were showing up as crop marks on a site cropped with grass, then they were most likely to lie in this near-surface zone. Readings were taken at 1m by 1m intervals as outlined in Annex 1.

Two areas were also surveyed (see Figure 1) with repeated parallel traverses 1m apart using a Pulse-Ekko 1000 Ground Penetrating Radar (GPR) with a 225MHz antenna. Readings were taken at 10cm intervals along each traverse and distance measurement was controlled by an odometer wheel. Depth estimates were inferred from the two-way travel times of the impulse using the common midpoint method. In this method, successive measurements are taken with the GPR transmitter and receiver at increasing separations from each other, keeping the midpoint of the line between the two constant. The rate of change of the travel time of either the direct ground wave or a wave from a reflector beneath this midpoint is then measured against increasing transmitter/receiver separation. This measurement is used to deduce the average velocity of the impulse in the topsoil which at Burnfoot Farm was calculated to be ~0.073m/nS. It should be noted that the velocity of the impulse in the subsoil may differ from this estimate.

Data Processing and Presentation

The unprocessed magnetometer measurements were treated with an adaptive thresholding median filter to replace measurements of extreme magnitude, caused by surface iron, with a local median calculated over a 1m by 1m rectangular window. The results after this operation are depicted at 1:1000 scale as both trace and linear greyscale plots in Figure 3.

Figure 4 shows trace and greyscale plots of the unprocessed resistivity survey also at 1:1000 scale. However, it should be noted that in the greyscale plot (4b) the data has been processed with the same median filter as above to remove extreme values caused by contact resistance. Figure 5 shows the same data after the application of a 0.75m smoothing Gaussian convolution mask and the application of the Wallis contrast enhancement algorithm with a rectangular window size of 10m. This enhancement was intended to accentuate smaller archaeological scale anomalies whilst suppressing larger scale regional variations.

The ground penetrating radar data profiles were treated with appropriate gain functions to equalise response down the profiles and were then stacked together and sliced horizontally to produce a series of plan views of the results at different depth (“time-slices”) as greyscale plots. The results from area 1 are depicted in colour in Figures 6 at 1:1250 scale and in Figure 7 at 1:1000 scale. Those from area 2 are depicted in Figure 8 at 1:1000 scale.

Results

The anomalies described below are depicted at 1:1000 scale on the interpretation plan in Figure 9.

The magnetometer survey

It is immediately clear from Figure 3 that the magnetic response from the site was extremely low. 95% of the measurements in the survey fell within a range of +/- 0.86nT which is barely above the level of instrument noise for the FM36 when being carried in the normal survey mode. Thus, unsurprisingly, inspection of Figure 3 reveals very few anomalies. However, in the north-western part of the survey area (the top in the figures) a linear anomaly has been detected some 35m long and 4m wide. Some possible associated pit-like anomalies have also been indicated in Figure 9. The edge of a palaeochannel of the river Esk, visible in the air photographs, has also been faintly detected and the linear anomaly appears to be in this palaeochannel. Unfortunately, the alignment of these features does not appear to correspond with any of the crop marks.

The ground penetrating radar survey

Scrutiny of Figures 6-8 again reveals few anomalies. However, in Figures 6 and 7, a linear anomaly is visible running across Area 1 in the near surface data (0-8nS). This anomaly has also been detected as a high resistance feature by the earth resistance survey (see below) so is likely to be composed of consolidated material such as stone or compacted soil. The top of the features is likely to be some 15-30cm below the surface. It is possible that this anomaly is on the same alignment as the linear features visible in the aerial photographs (Figure 2).

At the northwestern end of Area 1, a second, broader anomaly is visible in the 16-24nS time slice cutting diagonally across a corner of the survey area. This is 8m wide and is detected as a low amplitude anomaly with no corresponding anomaly visible in the magnetic or resistivity surveys. It does not seem to project into Area 2 and does not appear to correspond with any feature visible in the aerial photographs. The measurements indicate that it is about 50-85cm below the surface and study of the vertical profiles for this area suggests that it cuts through the layer of gravel underlying the near surface alluvium. For this reason it has been indicated as a cut feature, possibly a ditch.

In the shallowest time slices of both Areas 1 and 2, some faint linear anomalies can be discerned running southeast-northwest (parallel to the longest edge of Area 1). These are likely to be an artefact of recent cultivation and have also been detected by the resistivity survey.

Whilst some other anomalies are visible in Area 2 it is likely that these reflect variations in the natural disposition of underlying river gravels in this area.

The resistivity survey

One of the most noticeable features in Figures 4 and 5 is the series of parallel linear low resistance features running south-west to north-east across the survey area. These are suggestive of ridge and furrow, possibly indicating the medieval utilisation of the land. Signs of more recent cultivation running perpendicular to these are also visible as faint low resistance linear anomalies in places. These have been noted in the ground penetrating radar survey also (see above).

A low resistance ditch-like anomaly has also been indicated as a dashed black line running south-east to north-west across the survey area (Figure 8). However, this anomaly was not detected by the magnetometer or GPR. At its north-western end is an apparently amorphous area of very high resistance. The magnitude of this anomaly is remarkable, with measured resistance values of up to 322 ohms in places, when the average background reading for the site was 92 ohms. It should be borne in mind that this anomaly could, in part, be caused by instrument problems encountered owing to the dry conditions during August when the survey was carried out. Nevertheless, problems with extremely dry, resistive ground were only encountered in this localised area suggesting some underlying cause in the ground itself. It may represent an area where the underlying gravel lies closest to the surface. However, a similar response might be expected from a spread of masonry rubble from a collapsed building, hence it is indicated on the interpretation plan. Contrast enhancement of the data, depicted in Figure 5, reveals that the very highest readings in this area form a linear band running along the edge of the palaeochannel visible on the aerial photographs. It is thus possible that the anomaly represents either some sort of revetment or other structure associated with the palaeochannel.

Several other areas are indicated where resistance readings were higher than the background level. Once again, these might represent regions where the river gravel is nearer the surface but could also represent rubble spreads. Towards the south-western edge of the survey, some approximately rectilinear areas of slightly higher resistance have been identified in the contrast enhanced data (Figure 5). Whilst possibly significant, their interpretation as anthropogenic anomalies is tentative given their extremely faint response.

Conclusions

As anticipated, the alluvial nature of the site has limited the efficacy of geophysical methods. The magnetic response was largely confined to the range of instrument noise and only one anomaly of possible archaeological significance has been detected. Although the resistivity survey has been more successful, it has not detected with certainty any of the features visible in the aerial photographs of the field. The GPR survey successfully detected the interface between the alluvium and underlying gravel deposits but few anomalies likely to be of anthropogenic rather than natural origin.

In the time available, only ~15% of the 18ha field in which the crop marks appear could be sampled. The lack of correlation between the geophysical data and cropmark evidence is disappointing. However, previous experience on this type of site suggests that geophysical techniques are often unsuccessful even when, on excavation, archaeological features are in abundance. Hence the negative evidence of the survey may not necessarily indicate an absence of archaeology at the site.

Surveyed by:	P. Cottrell N. Linford P. Linford L. Martin	Dates:	7th to 11th August 2000
Report by:	P. Linford & N. Linford	Date:	12th April 2001

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(Sheet 1) Legend for the 1:250,000 Soil Map of England and Wales.

Enclosed Figures and plans

Annex 1: Notes on standard procedures

1) **Resistivity Survey:** Each 30 metre square is surveyed by making repeated parallel traverses across it, all aligned parallel to one pair of the 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 square edge. Readings are taken along each traverse at 1 metre intervals, the first and last readings being 0.5 metres from the nearest 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 Ancient Monuments Laboratory using desktop workstations.

2) **Magnetometer Survey:** Each 30 metre square is surveyed by making repeated parallel traverses across it, all parallel to that pair of 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 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 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 Ancient Monuments Laboratory 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).

3) **Resistivity Profiling:** This technique measures the electrical resistivity of the subsurface in a similar manner to the standard resistivity mapping method outlined in note 1. However, instead of mapping changes in the near surface resistivity over an area, it produces a vertical section, illustrating how resistivity varies with increasing depth. This is possible because the resistivity meter becomes sensitive to more deeply buried anomalies as the separation between the measurement electrodes is increased. Hence, instead of using a single, fixed electrode separation as in resistivity mapping, readings are repeated over the same point with increasing separations to investigate the resistivity at greater depths. It should be noted that the relationship between electrode separation and depth sensitivity is complex so the vertical scale quoted for the section is only approximate. Furthermore, as depth of investigation increases the size of the smallest anomaly that can be resolved also increases.

Typically a line of 25 electrodes is laid out separated by 1 or 0.5 metre intervals. The resistivity of a vertical section is measured by selecting successive four electrode subsets at increasing separations and making a resistivity measurement with each. Several different schemes may be employed to determine which electrode subsets to use, of which the Wenner and Dipole-Dipole are typical examples. A Campus Geopulse earth resistance meter, with built in multiplexer, is used to make the measurements and the Campus Imager software is used to automate reading collection and construct a resistivity section from the results.