Ancient Monuments Laboratory
Report 20/99

WHITEHALL FARM, KELK, E.RIDING. REPORT ON GEOPHYSICAL SURVEY, DECEMBER 1998

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Summary

A magnetometer survey was conducted over an area of 2.9ha containing cropmarks at Whitehall Farm, Kelk, East Riding and revealed a number of significant anomalies associated with a rectilinear enclosure of probable Roman date. This enclosure contained a group of apparently thermoremanent anomalies which may well represent some form of semi-industrial activity, such as pottery production. No evidence for the location of the reported 'lake dwelling' was found during the survey due, perhaps, to the subdued magnetic response over the lower lying wetland areas of the site noted in both the gradiometer data and values of topsoil magnetic susceptibility.

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WHITEHALL FARM, Kelk, East Riding.

Report on geophysical survey, December 1998

Introduction

A geophysical survey of 2.9ha was conducted over a series of linear crop mark anomalies (Fig 1) identified immediately S of the Gransmoor drain, Whitehall Farm, Kelk, in support of the ongoing Humber Wetlands archaeological survey. During the cutting of the drain in 1880, along the course of an old river channel, the site of a supposed 'lake dwelling' was revealed although few details of this discovery have been reported (Smith 1911). The site of the crop marks lies on an extensive area of raised till and it is possible that the 'lake dwelling' was a bridging point across the original stream serving a settlement on this higher ground.

The aim of the survey was to investigate the geophysical response of the crop marks on the raised till and examine the suspected site of the 'lake dwelling' on the lower ground adjacent to the current course of the Gransmoor drain. It was hoped that the survey results would inform the location of a limited excavation of the site.

The site (TA 108 601) lies on flat area of glacial till with some gravel outcrops raised above the level of the drain (British Geological Survey 1993). Fine loamy soils of the Holderness association have developed over this substrate with a narrow strip of clayey alluvial soil found in the lower lying areas of the site following the course of the Gransmoor drain (Soil Association of England and Wales 1993). At the time of the survey the field was lying fallow with the stubble remains of a previous cereal crop. Fragments of pottery recovered during the geophysical survey were spot dated to an apparently Roman age (W. Fletcher *pers. comm.*).

Method

Magnetometer survey

Magnetic survey was considered the most appropriate technique to apply due to the area of land to be covered and as a reasonable degree of success has been achieved with the method over similar drift geology in the region (*eg* Stephens 1995, Shiel 1995 and Noel 1996). The survey was conducted over all the numbered squares in Figure 1 using the standard method outlined in note 2 of Annex 1. The results are presented at a scale of 1:1250 in Plans A and B with a greytone image of the data superimposed over the base Ordnance Survey 1:2500 map in Figure 2. Plan A.1 shows a stacked trace plot of the raw data, the only correction to the measured values being to zero-mean each instrument traverse to remove heading errors. The greytone image of the data presented in Plan B.1 has been further enhanced to reduce the detrimental effects produced by surface iron objects through the application of a 2m by 2m thresholding median filter (Scollar *et al* 1990).

A graphical summary of significant anomalies discussed in the following text is provided in Plan B.2.

Topsoil magnetic susceptibility survey

Soil samples were recovered every 15m from a single NS transect across the site (Fig 1) chosen to traverse a concentration of magnetic anomalies noted during the magnetometer survey. Measurements of magnetic susceptibility were made in the laboratory at two frequencies (420Hz and 4200Hz) with a Bartington MS2 AC susceptibility meter and MS2B sensor. The dry mass of each sample was subsequently determined after air-drying at room temperature. Figure 3 shows the variation of both mass specific and frequency dependence of magnetic susceptibility over the site (Thompson and Oldfield 1986).

Results

General response and modern interference

Due to the location of the survey grid away from adjacent field boundaries little modern disturbance is evident beyond a scatter of near-surface ferrous responses most probably related to modern agricultural machinery. An anomalous area of magnetic disturbance is found at [1] in the vicinity of a spread of modern brick rubble in the topsoil and it seems likely that this represents the remains of an agricultural building or, perhaps, a recent midden.

The general response of the site is quite subdued with significant ditch-type anomalies producing very modest responses <1nT. Under such conditions the identification of significant anomalies may often be hampered by a combination of soil and instrumental noise. A recent agricultural pattern is evident as subtle linear anomalies [2] in the SW part of the survey grid.

Significant anomalies

A group of broken linear anomalies apparently forms a rectilinear enclosure [3] in the vicinity of the recorded cropmarks. This enclosure appears to be truncated to the N where the plateau of gravel falls down to the lower-lying wetland which has a more subdued magnetic response [4]. It is unclear whether the enclosure was originally rectangular and has been eroded by the meandering course of the river channel (now contained within the Gransmoor drain) or whether it was a deliberate three-sided construction to allow access to the water supply. Activity within the enclosure is dominated by a group of intense anomalies [5] with a magnitude in excess of 30nT and a number of much weaker ditch and pit-type responses [6]. The intense anomalies [5] are suggestive of a thermoremanent origin and it is possible that the enclosure was associated with some form of semi-industrial process such as pottery production.

A number of linear anomalies [7] cross the survey grid S of [3] continuing towards the Gransmoor drain and the site of the reported 'lake dwelling'. It is possible that [7] represents the course of a former trackway serving the settlement and that the 'lake dwelling' may have been associated with a river crossing point or wooden causeway for crossing the wetland. Additional linear anomalies [8], [9] and [10] also run through the survey area but none of these are particularly convincing as evidence of former anthropogenic activity. Furthermore, the presence of the highly diffuse anomaly [11] is reminiscent of responses recorded over geomorphological features, such as deposits of alluvium (*cf* Cole 1998) and it is possible that other subtle anomalies in the data have a similar origin.

A scatter of pit-type anomalies occur sporadically throughout the survey area with more intense examples found at [12], [13] and [14]. No other linear anomalies or enclosures are evident beyond a single, arcuate anomaly [15] which may represent the location of ring ditch to the S of enclosure [3]. However, the response of this latter anomaly is extremely subtle and this interpretation should be regarded as highly tentative.

Topsoil susceptibility survey

Results of the magnetic measurements from the transect of topsoil samples crossing the site are presented as a barchart in Figure 3. Initial mass specific susceptibility (χ) reaches peak values in excess of ~100 × 10^{-8} m^3kg^{-1} over the location of anomaly [5] with background readings over the rest of the transect falling in the range of 20→45 × 10^{-8} m^3kg^{-1}. Susceptibility values to the N of the transect over the wetland area are lower than those from the gravel plateau correlating with the area of subdued magnetic response [4] noted during the gradiometer survey.

Figure 3B demonstrates that the frequency dependence of susceptibility ($\chi_{FD}\%$) displays an approximately linear relationship to χ for all samples other than the two extreme values measured in the vicinity of anomaly [5] ($R^2 = 0.827$). This suggests that variations in the magnitude of χ can, for the low susceptibility samples, be attributed to an increase in the concentration of fine superparamagnetic particles. Values of $\chi_{FD}\%$ for the two anomalously high samples may well be suppressed through particle-particle interactions (*eg* Maher 1988) although the enhancement of χ most probably reflects an increased proportion of ferrimagnetic minerals related to anthropogenic activity, such as the repeated use of fire within the enclosure.

Conclusion

Magnetometer survey at this site has successfully identified a number of significant anomalies apparently forming a rectilinear enclosure containing evidence for both settlement and semi-industrial activity. Whilst the substantial magnetic anomalies in the centre of the enclosure may be due to modern ferrous material the location of numerous pottery fragments from the site is suggestive of a more significant thermoremanent origin. Tentative evidence for a trackway serving the enclosure and continuing towards the approximate location of the reported 'lake dwelling' has also been revealed to the S. However, no significant magnetic anomalies are evident over the lower lying wetland areas of the site.

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P Linford
L Martin
A Payne

Date of survey: 10/12/98

Reported by: N Linford

Date of report: 23/3/99

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Acknowledgments

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References

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Thompson, R. and Oldfield, F. (1986). *Environmental Magnetism.* London: Allen and Unwin.

List of 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.

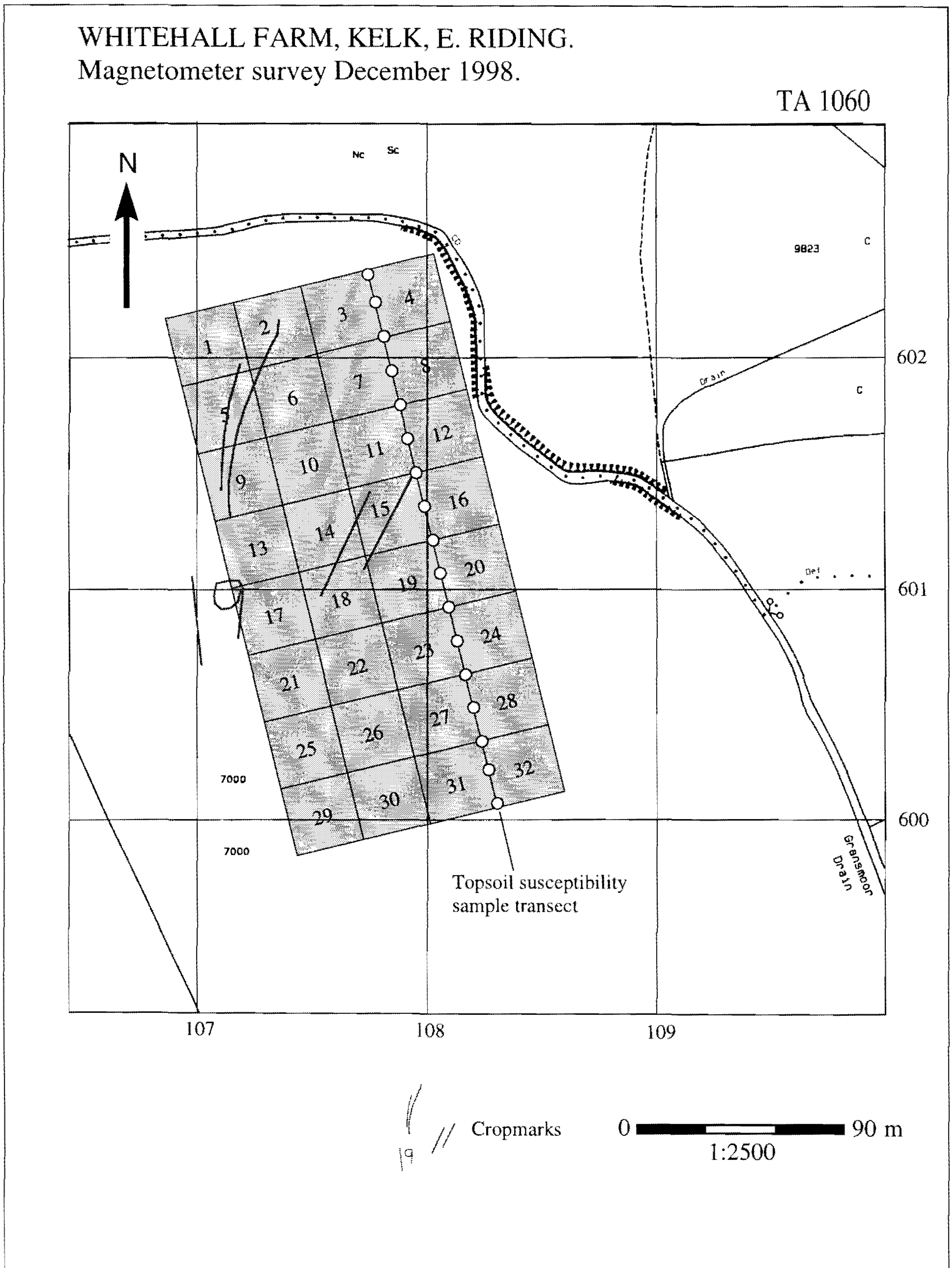


Figure 1; Whitehall Farm, Kelk, E. Riding, *Location of magnetometer survey, December 1998.*

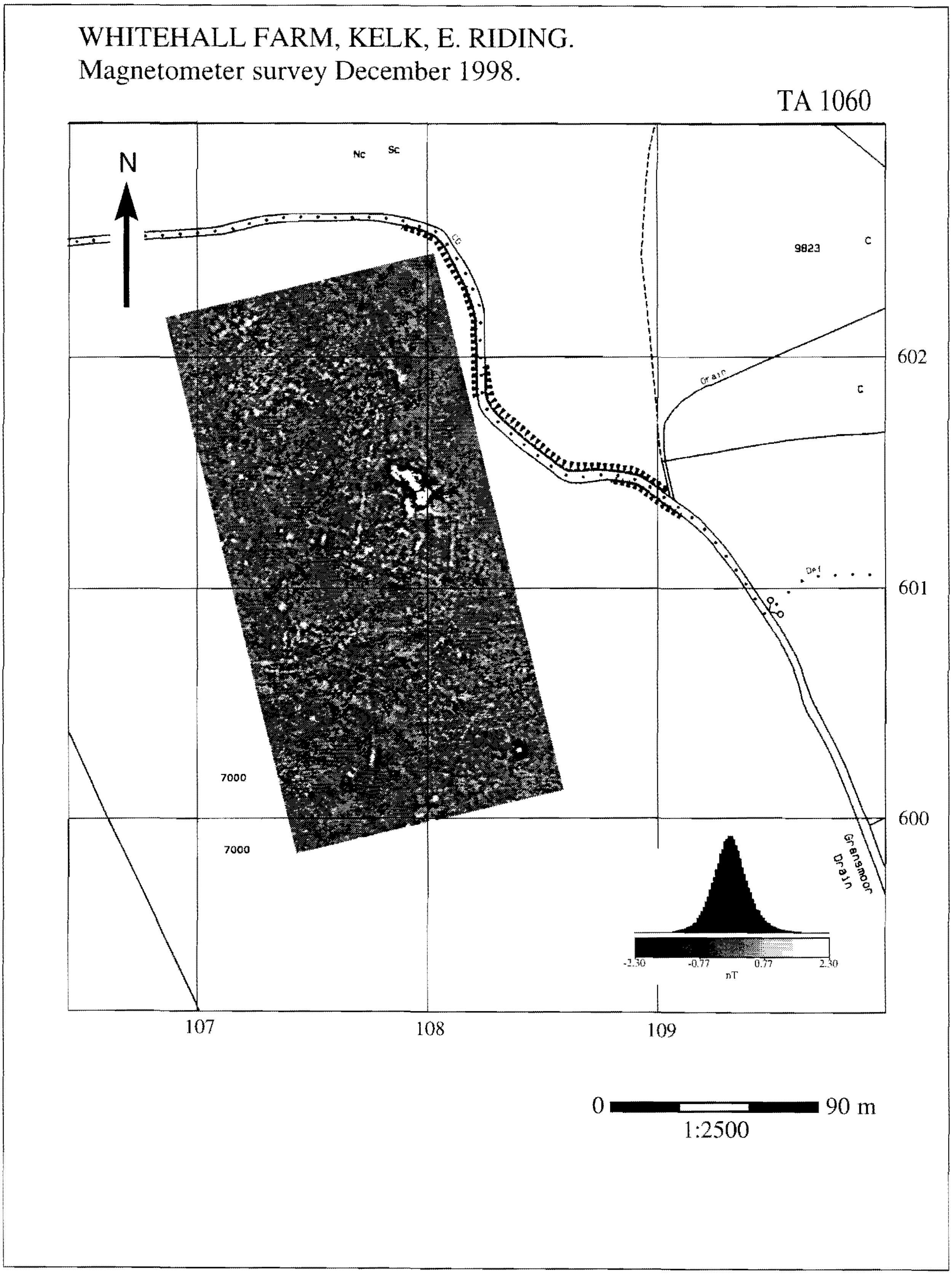


Figure 2; Whitehall Farm, Kelk, E. Riding, *Greytone of magnetometer data superimposed over base OS map.*

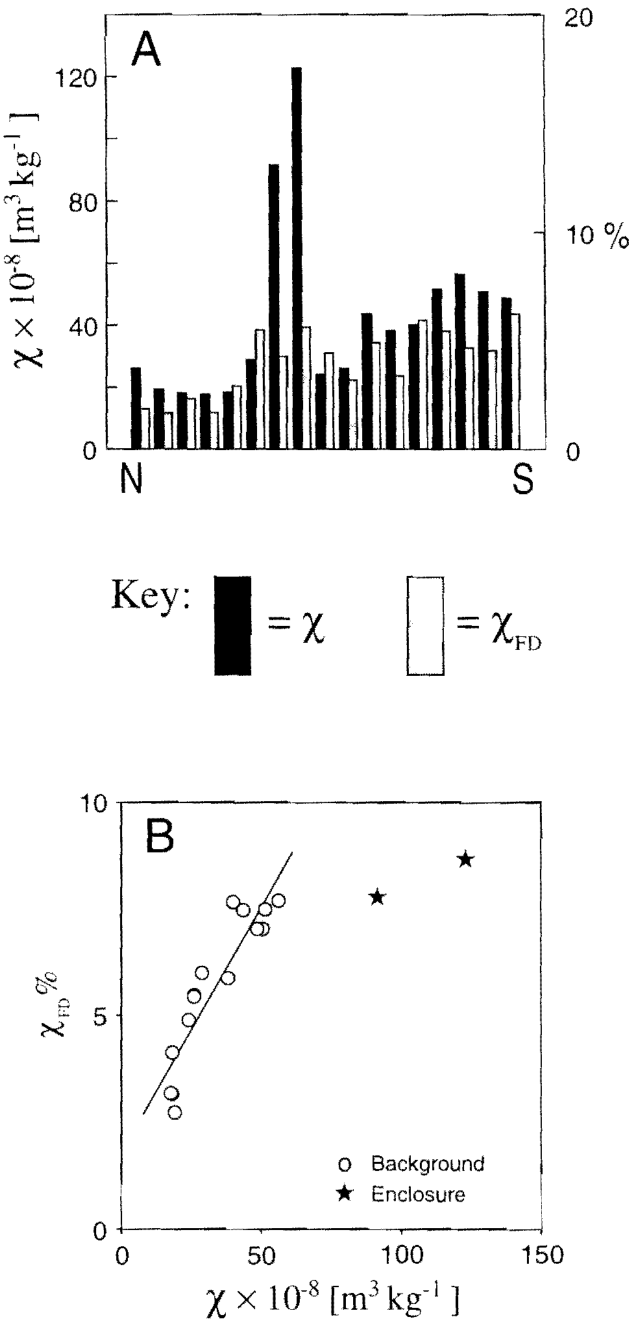
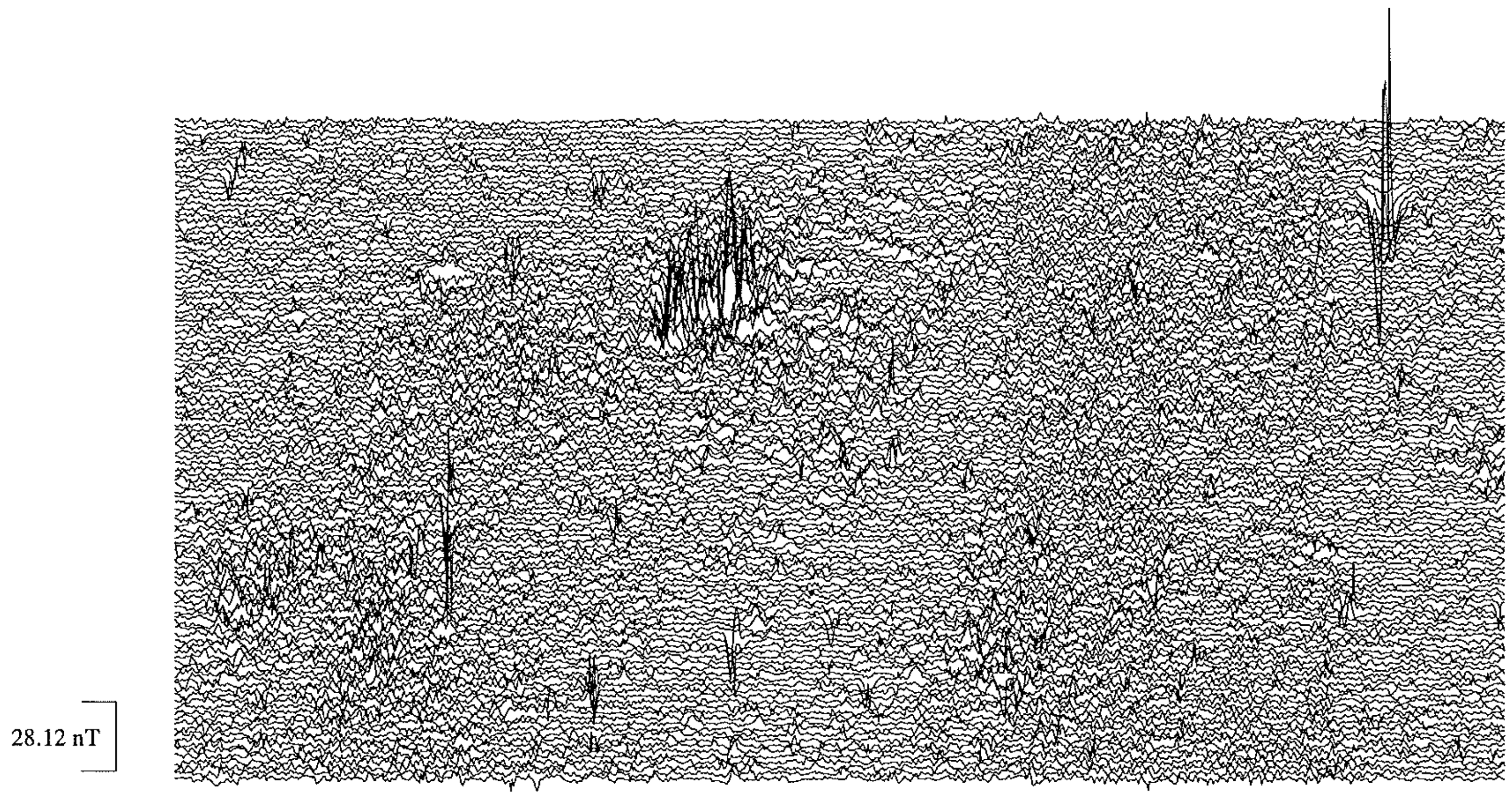


***Figure 3; Whitehall Farm, Kelk, E. Riding**, (A) bar charts showing the variation of topsoil mass specific (χ) and frequency dependence (χ_{FD}%) of magnetic susceptibility and (B) plot of χ vs χ_{FD} %.*

PLAN A

WHITEHALL FARM, KELK, EAST RIDING OF YORKSHIRE.
Magnetometer survey December 1998.

A.1 Traceplot of raw magnetometer data



4	8	12	16	20	24	28	32
3	7	11	15	19	23	27	31
2	6	10	14	18	22	26	30
1	5	9	13	17	21	25	29

0 90m

1:1250

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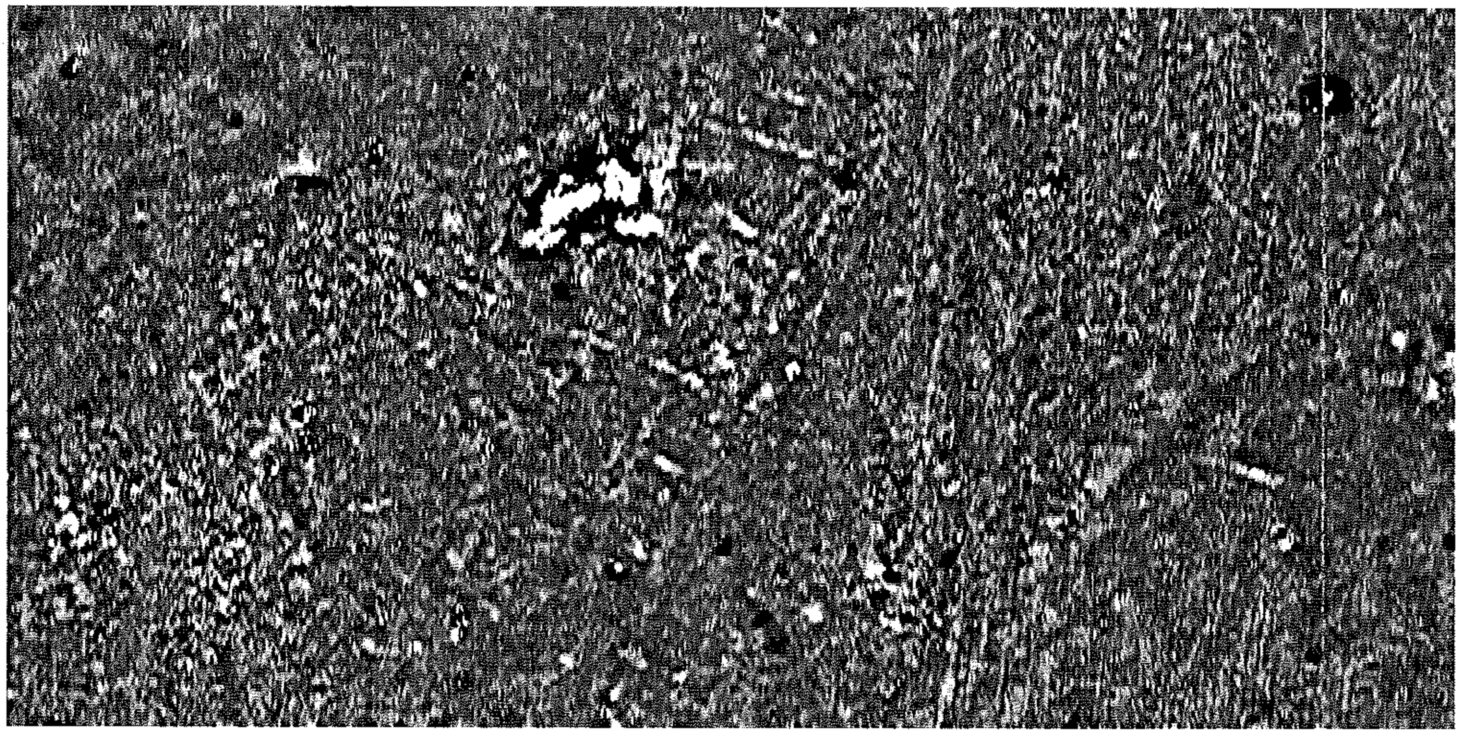
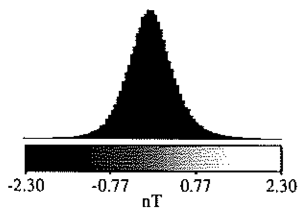
PLAN B

WHITEHALL FARM, KELK, EAST RIDING OF YORKSHIRE.
Magnetometer survey December 1998.

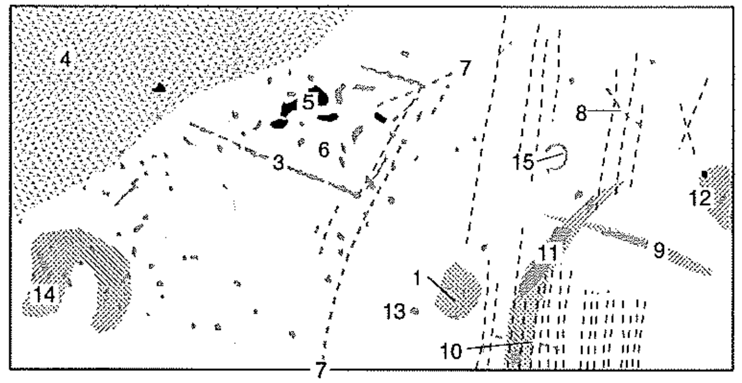
N

B.1 Greytone of magnetometer data





B.2 Summary of significant anomalies



+ve magnetic anomaly

intense magnetic anomaly

amorphous magnetic disturbance

ploughing [2]

subdued response over wetland [4]

4	8	12	16	20	24	28	32
3	7	11	15	19	23	27	31
2	6	10	14	18	22	26	30
1	5	9	13	17	21	25	29

0 90m
1:1250

Ancient Monuments Laboratory 1998.