PROPOSED AGRICULTURAL RESERVOIR
DONINGTON ON BAIN, LINCOLNSHIRE

Topsoil Magnetic Susceptibility & Magnetometer (Gradiometer) Survey

(Survey Ref : 2070100/DOL/LAS)

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Produced by

OXFORD ARCHAEOTECHNICS LIMITED

under the direction of

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Commissioned by

Lindsey Archaeological Services

OXFORD ARCHAEOTECHNICS

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Specialist Archaeological Field Evaluation

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SUMMARY

A geophysical evaluation programme comprising topsoil magnetic susceptibility mapping and gradiometer survey was carried out on 2.8 ha of land at Donington on Bain, Lincolnshire on the floodplain of the River Bain (centred on NGR 523600 381200) in advance of a proposed agricultural reservoir.

The survey was based upon the principle that past human activity and its associated debris usually creates slight but persistent changes in the local magnetic environment which can be sensed from the surface (using magnetic susceptibility measurement and magnetometry).

There was little magnetic evidence for extensive underlying deposits with obvious archaeological significance, nevertheless several discrete anomalies suggestive of former pits or hollows were detected, and the presence of a number of worked flints in the topsoil, together with superficially burnt deposits derived by hand augering from horizons immediately beneath ploughsoil depth suggest that the site has some potential for the discovery of prehistoric material.

1. INTRODUCTION

1.1 Geophysical survey was commissioned by Lindsey Archaeological Services on the site of a proposed agricultural reservoir on Stenigot Estates land situated c.1.5 km south of the village of Donington on Bain, Lincolnshire. The location is shown on Fig. 1. The fieldwork was carried out in January 2000.

1.2 The survey area (centred on NGR 523600 381200) lies upon the floodplain within a loop of the River Bain. Observation of a series of engineering test pits across the site showed only minimal depths of alluvial deposits: no features of obvious archaeological significance were observed within these test pits. The land was under arable cultivation at the time of survey, with bare soils providing good surface visibility. A substantial number of worked flints and flint flakes were observed on the lower slopes of the field, particularly on the northern margins of the proposed reservoir site. No ceramic material (of any period) was observed.

1.3 The geophysical survey comprised a combination of topsoil magnetic susceptibility field sensing and magnetometry. An explanation of the techniques used, and the rationale behind their selection, is included in an Appendix to the present report.

2. MAGNETIC SURVEY DESIGN

2.1 Survey control was established to the National Grid by EDM Total Station.

2.2 The equipment used for the direct topsoil magnetic susceptibility survey was a Bartington Instruments MS2 meter with an 18.5 cm loop.

2.3 *In situ* magnetic susceptibility readings were taken on a 10 m grid, an interval known to give a high probability of intersecting with dispersed horizons from a wide range of archaeological sites, particularly those associated with occupation and industrial activity from the later prehistoric period onwards. Soils over former occupation and industrial sites usually register as stronger patterning, frequently showing a marked focus. Agricultural activity helps to both generate (by ploughing casting up underlying deposits), and ultimately disperses the more magnetic soils over a wider area. Patterns recorded by 10 m magnetic susceptibility mapping tend to define zones of former activity rather than locate individual elements. Nevertheless, in some contexts, a focus of markedly stronger soil magnetic susceptibility (or markedly magnetically lower soils indicative of ploughed down earthworks) is occasionally found to relate to material dispersed from specific underlying features.

2.4 Routine scanning by gradiometer was undertaken at 25 m traverse intervals to check for any major concentrations of underlying archaeological features whose presence may not have been detected by the topsoil susceptibility survey. Three areas of enhanced topsoil magnetic susceptibility and gradiometer scanning anomalies were targeted for detailed gridded gradiometer survey with a Geoscan Research FM 36 Fluxgate Gradiometer (sampling 4 readings per metre at 1 metre traverse intervals in the 0.1 nT range). The nanotesla (nT) is the standard unit of magnetic flux (expressed as the current density), here used to indicate positive and negative deviations from the Earth's normal magnetic field.

2.5 The topsoil magnetic susceptibility colour shade plot (Fig. 2) shows contours at 10 SI intervals. Magnetometer data have been presented as grey scale, interpretative and stacked trace (raw data) plots (Figs. 3 & 4), and an overview of results is shown on Fig. 5.

3. SURVEY RESULTS

TOPSOIL MAGNETIC SUSCEPTIBILITY SURVEY (Fig. 2)

3.1 282 *in situ* magnetic susceptibility readings were recorded. Susceptibility is reported in SI:volume susceptibility units (x 10^{-5}), a dimensionless measure of the relative ease with which a sample can be magnetized in a given magnetic field.

3.2 *In situ* topsoil susceptibility measurements ranged between 4 and 132 (x 10^{-5}) SI units. The mean for the survey was 55 SI units and the standard deviation calculated against the mean was 23 SI units.

3.3 The topsoil magnetic susceptibility map shows a reasonably dynamic range reflecting primarily the interface between alluvium-rich soils and the more elevated parts of the field, but also showing some localised enhancement. The main patterning appears to reflect agricultural activity, although it is likely that the source of the higher topsoil magnetic susceptibility levels reflects marginally enhanced soils dispersed from burning events, or just possibly from underlying archaeological horizons.

MAGNETOMETER (GRADIOMETER) SURVEY (Figs. 3 & 4)

3.4 Three areas were selected for detailed gridded gradiometer survey on the basis of the topsoil magnetic susceptibility map, gradiometer scanning anomalies and topographic considerations: the choice of survey areas was somewhat restricted by the presence of test pits and spoil heaps from previous engineering investigations. The location of the gradiometer survey boxes is shown on Fig. 2.

AREA 1

3.5 A 60 x 30 m (0.2 ha) survey box was sited to investigate an area of enhanced topsoil magnetic susceptibility together with some weak gradiometer scanning anomalies.

3.6 The gradiometer plot is dominated by a group of parallel linears running on a NW-SE alignment, representing the locations of a series of clay land drains, and perhaps combined with associated drainage works such as mole draining. A single irregular linear anomaly on a WNW-ESE alignment runs contrary to this pattern. There is also a slight indication of a weak lineation running diagonally across the survey box perpendicular to the principal drainage alignment. These features all appear to be relatively modern in origin.

3.7 A series of magnetic anomalies recorded within the western side of the survey box indicate the presence of underlying material with contrasting magnetic susceptibility, whose overall patterning may indicate pockets of deeper topsoil or perhaps local geological variations, although the possibility of infilled hollows or pit forms with some archaeological significance cannot be discounted.

3.8 A light litter of ferrous material was recorded, consistent with a typical agricultural landscape.

AREA 2

3.9 This 30 x 30 m (0.1 ha) survey box was sited to investigate subtle (1 - 2 nT) magnetic anomalies recorded by gradiometer scanning.

3.10 The gradiometer plot shows similar drainage and agricultural striations to those recorded within Area 1, together with some weak positive anomalies which may indicate underlying hollows, scoops or pit forms. Hand augering of the anomaly situated closest to the centre of the survey box revealed slight traces of charcoal and burning just below the base of the ploughsoil.

AREA 3

3.11 A second 30 x 30 m (0.1 ha) was sited to investigate further gradiometer scanning anomalies.

3.12 The gradiometer plot again shows strong agricultural lineations, probably from clay drains and mole draining, together with more assertive positive anomalies suggesting deeper pockets of soil, or pits. The larger of these anomalies appears both from its geometry and alignment to fit within the general agricultural 'pattern'.

3.13 This survey box lies on the edge of a large and what appears to be an artificial 'scoop' in the river bank. Material associated with this feature produced a strong ferrous response, suggestive of buried iron debris, which has caused significant magnetic interference within the northwestern angle of the survey box. The area generally shows an above-average litter of ferrous material suggesting further relatively recent activity.

4. CONCLUSIONS

4.1 Topsoil magnetic susceptibility mapping and selective magnetometer (gradiometer) survey has suggested some limited potential for underlying archaeological features, possibly pits or hollows, an interpretation reinforced by a local scatter of worked flints. Hand augering demonstrated the presence of an apparently isolated patch of burnt material just below the ploughsoil in at least one location, although observation of approximately one dozen engineers' test pits on the site revealed no obvious 'cut' features.

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Topsoil magnetic susceptibility mapping and magnetometer survey by Oxford Archaeotechnics Limited under the direction of A.E. Johnson *BA(Hons)*, with: J. Porter *BSc*.

APPENDIX 1 - MAGNETIC TECHNIQUES: GENERAL PRINCIPLES

A1.1 It is possible to define areas of human activity (particularly soils spread from occupation sites and the fills of cut features such as pits or ditches) by means of *magnetic survey* (Clark 1990; Scollar et al. 1990). The results will vary, according to the local geology and soils (Thompson & Oldfield 1986; Gale & Hoare 1991), as modified by past and present agricultural practices. Under favourable conditions, areas of suspected archaeological activity can be accurately located and targeted for further investigative work (if required) without the necessity for extensive random exploratory trenching. Magnetic survey has the added advantages of enabling large areas to be assessed relatively quickly, and is non-destructive.

A1.2 Topsoil is normally more magnetic than the subsoil or bedrock from which it is derived. Human activity further locally enhances the magnetic properties of soils, and amplifies the contrast with the geological background. The main enhancement effect is the increase of *magnetic susceptibility*, by fire and, to a lesser extent, by the bacterial activity associated with rubbish decomposition; the introduction of materials such as fired clay and ceramics - and, of course, iron and many industrial residues - may also be important in some cases. Other agencies include the addition and redistribution of naturally magnetic rock such as basalt or ironstone, either locally derived or imported.

A1.3 The tendency of most human activity is to increase soil magnetic susceptibility locally. In some cases, however, features such as traces of former mounds or banks, or imported soil/subsoil or non-magnetic bedrock (such as most limestones), will show as zones of lower susceptibility in comparison with the surrounding topsoil.

A1.4 Archaeologically magnetically enhanced soils are therefore a response of the parent geological material to a series of events which make up the total domestic, agricultural and industrial history of a site, usually over a prolonged period. Climatic factors may subsequently further modify the susceptibility of soils but, in the absence of strong chemical alteration (e.g. during the process of podzolisation or extreme reduction), magnetic characteristics may persist over millions of years.

A1.5 Both the magnetic contrast between archaeological features and the subsoil into which they are dug, and the magnetic susceptibility of topsoil spreads associated with occupation horizons, can be measured in the field.

A1.6 There are several highly sensitive instruments available which can be used to measure these magnetic variations. Some are capable, under favourable conditions, of producing extraordinarily detailed plots of subsurface features. The detection of these features is usually by means of a *magnetometer* (normally a fluxgate gradiometer). These are defined as passive instruments which respond to the magnetic anomalies produced by buried features in the presence of the Earth's magnetic field. The gradiometer uses two sensors mounted vertically, often 50 cm apart. The bottom sensor is carried some 30 cm above the ground, and registers local magnetic anomalies with respect to the top sensor. As both sensors are affected equally by gross magnetic effects these are cancelled out. In order to produce good results, the magnetic susceptibility contrast between features and their surroundings must be reasonably high, thereby creating good local anomalies; a generally raised background, even if due to human occupation within a settlement context, will sometimes preclude meaningful magnetometer results. The sensitive nature of magnetometers makes them suitable for detailed work, logging measurements at a closely spaced (less than 1 metre) sample interval, particularly in areas where an archaeological site is already suspected. Magnetometers may also be used for rapid 'prospecting' ('scanning') of larger areas (where the operator directly monitors the changing magnetic field and pinpoints specific anomalies).

A1.7 *Magnetic susceptibility measuring systems*, whilst responding to basically the same magnetic component in the soil, are 'active' instruments which subject the sample area being measured (according to the size of the sensor used) to a low intensity alternating magnetic field. Magnetically susceptible material within the influence of this field can be measured by means of changes which are induced in oscillator frequency. For general work, measuring topsoil susceptibility *in situ*, a sensor loop of around 20 cm diameter is convenient, and responds to the concentration of magnetic (especially ferrimagnetic) minerals mostly in the top 10 cm of the soil. Magnetically enhanced horizons which have been reached by the plough, and even those from which material has been transported by soil biological activity, can thus be recognised.

A1.8 Whilst only rarely encountering anomalies as graphically defined as those detected by magnetometers, magnetic susceptibility systems are ideal for detecting magnetic spreads and thin archaeological horizons not seen by magnetometers. Using a 10 m interval grid, large areas of landscape can be covered relatively quickly. The resulting plot can frequently determine the general pattern of activity and define the nuclei of any occupation or industrial areas. As the intervals between susceptibility readings generally exceed the parameters of most individual archaeological features (but not of the general spread of enhancement around features), the resulting plots should be used as a guide to areas of archaeological potential and to suggest the general form of major activity areas; further refinement is possible using a finer mesh grid or, more usually, by detailing underlying features using a gradiometer.

A1.9 Magnetic survey is not successful on all geological and pedological substrates. As a rule of thumb, in the lowland zone of Britain, the more sandy/stony a deposit, the less magnetic material is likely to be present, so that a greater magnetic contrast in soil materials will be needed to locate archaeological features; in practice, this means that only stronger magnetic anomalies (e.g. larger accumulations of burnt material) will be visible, with weaker signals (e.g. from the fillings of simple agricultural ditches) disappearing into the background. Similar problems can arise when the natural background itself is very high or very variable (e.g. in the presence of sediments partially derived from magnetic volcanic rocks).

A1.10 The precise physical and chemical processes of changing soil magnetism are extremely complex and subject to innumerable variations. In general terms, however, there is no doubt that magnetic enhancement of soils by human activity provides valuable archaeological information.

A1.11 As well as locating specific sites, topsoil magnetic susceptibility survey frequently provides information relating to former landuse. Variations in the soils and subsoils, both natural and those enhanced by anthropogenic agencies, when modified by agriculture, give rise to distinctive patterns of topsoil susceptibility. The containment of these spreads by either natural or man-made features (streams, hedgerows, etc.) gives rise to a characteristic chequerboard or strip pattern of varying enhancement, often showing the location of former field systems, which persist even after the physical barriers have been removed. These patterns are often further amplified in fields containing underlying archaeological features within reach of the plough. More subtle landuse boundaries and indications of former cultivation regimes are often suggested by topsoil magnetic susceptibility plots.

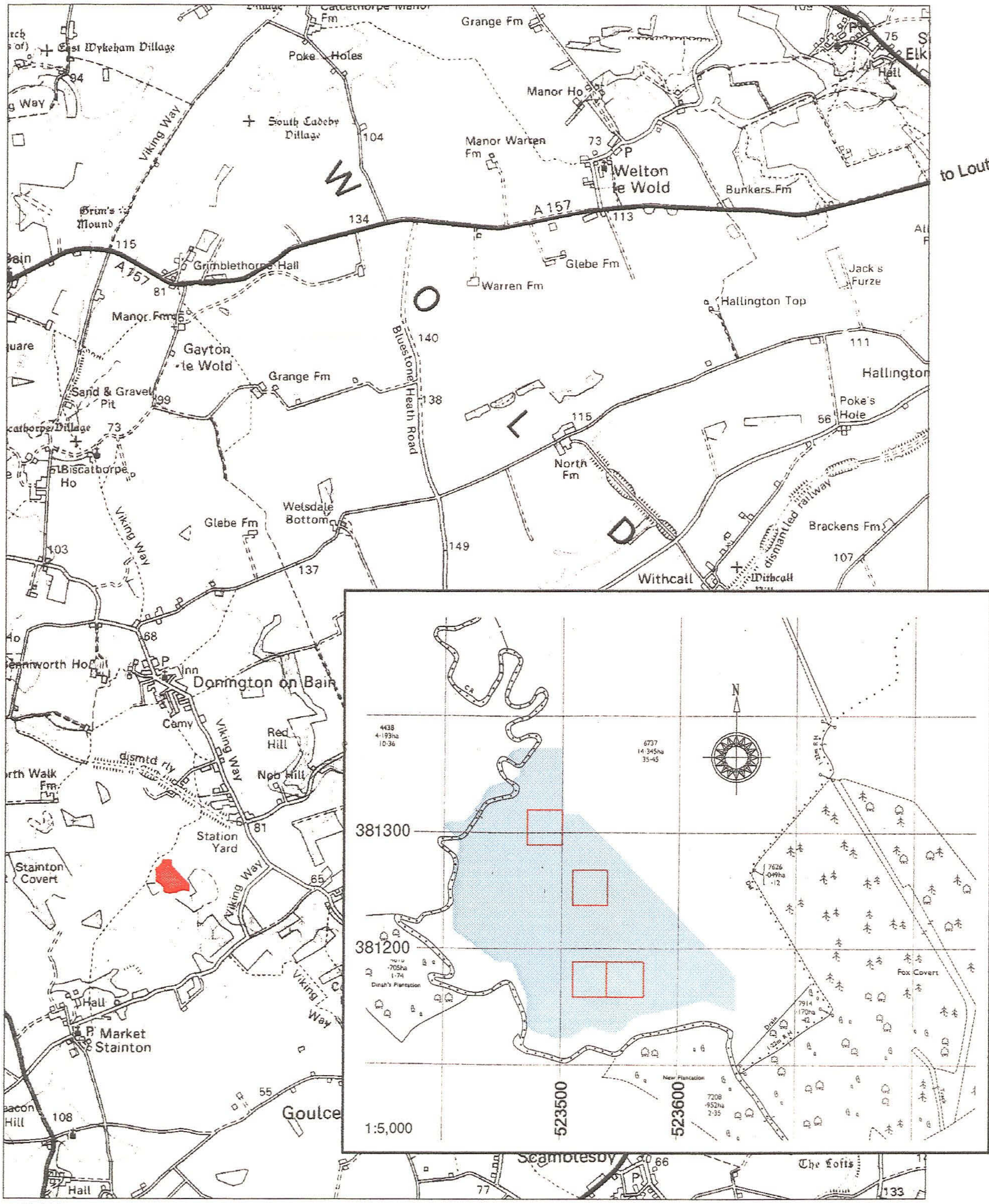
A1.12 Where a general spread of magnetically enhanced soils contained within a long-established boundary becomes admixed over a long period by constant ploughing, it can be diffused to such a point that the original source is masked altogether. Magnetically enhanced material may also be moved or masked by natural agencies such as colluviation or alluviation. Generally, it appears that the longer a parcel of land has been under arable cultivation, the greater is the tendency for topsoil susceptibility to increase; at the same time there is increasing homogeneity of the magnetic signal within the soils owing to continuous agricultural mixing of the material. Some patterns of soil enhancement derived from underlying archaeological features are, however, apparently capable of resisting agricultural dispersal for thousands of years (Clark 1990).

FIGURE CAPTIONS

Figure 1.	Location maps. Based upon OS 1:50,000 Map 122 and OS 1:2500 Sheet TF 2381 reduced to 1:5,000 scale.
Figure 2.	Topsoil magnetic susceptibility survey: colour contour plot and location of gradiometer survey grids. Based upon OS 1:2500 Sheet TF 2381. Scale 1:2500.
Figure 3.	Magnetometer (gradiometer) survey. Areas 1 -3: grey scale and interpretative plots. Scale 1:1000.
Figure 4.	Magnetometer (gradiometer) survey. Areas 1 - 3: stacked trace plots (raw data). Scale 1:1000.
Figure 5.	Magnetometer (gradiometer) survey: overview. Based upon OS 1:2500 Sheet TF 2381. Scale 1:2500.

Donington on Bain, Lincolnshire

Topsoil magnetic susceptibility & magnetometer (gradiometer) survey



1:50,000

Location

Topsoil magnetic susceptibility survey

Magnetometer survey area (30m grids)

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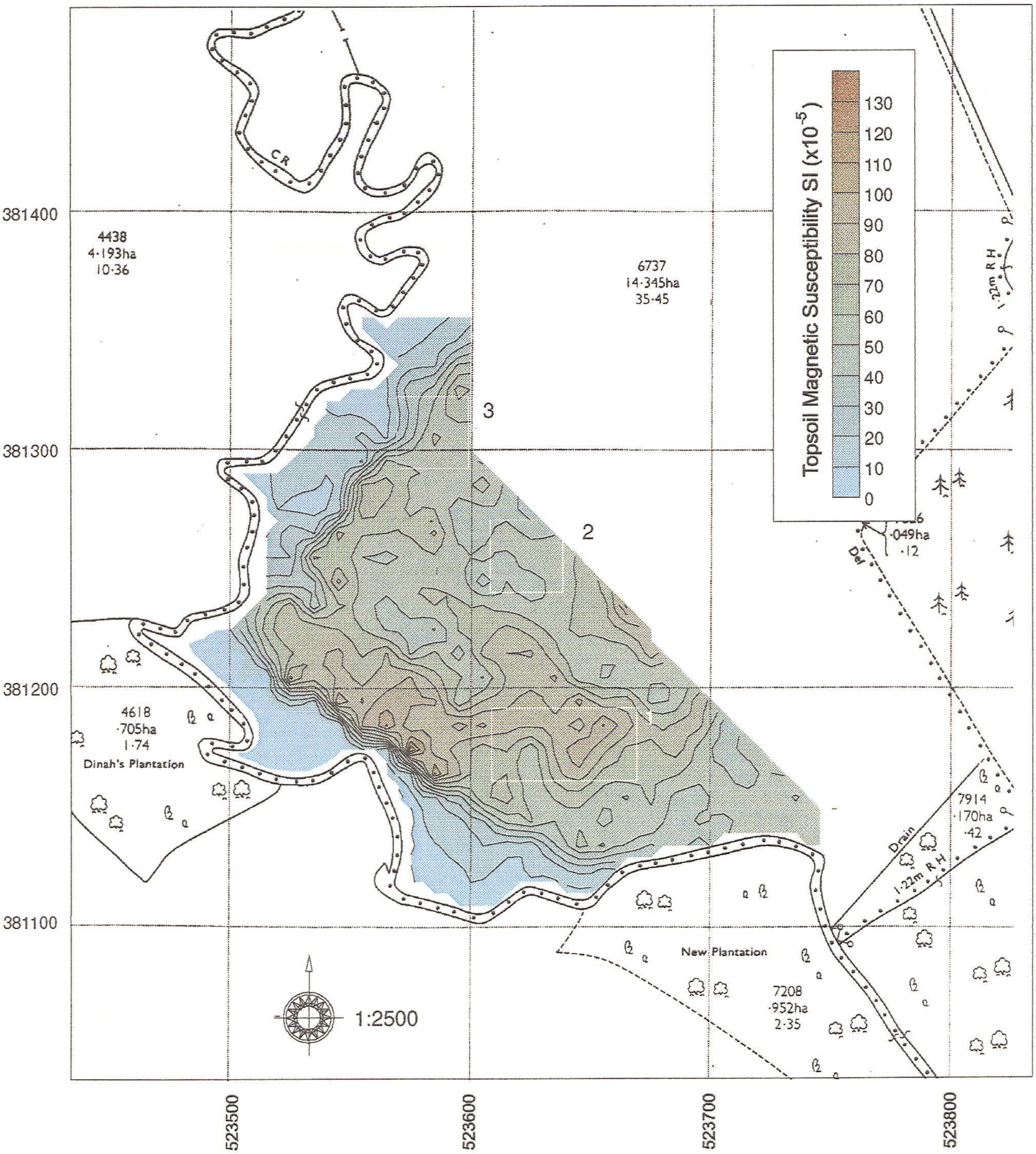
Fig. 1

Donington on Bain, Lincolnshire

Topsoil magnetic susceptibility & magnetometer (gradiometer) survey

Topsoil magnetic susceptibility: shaded contour plot

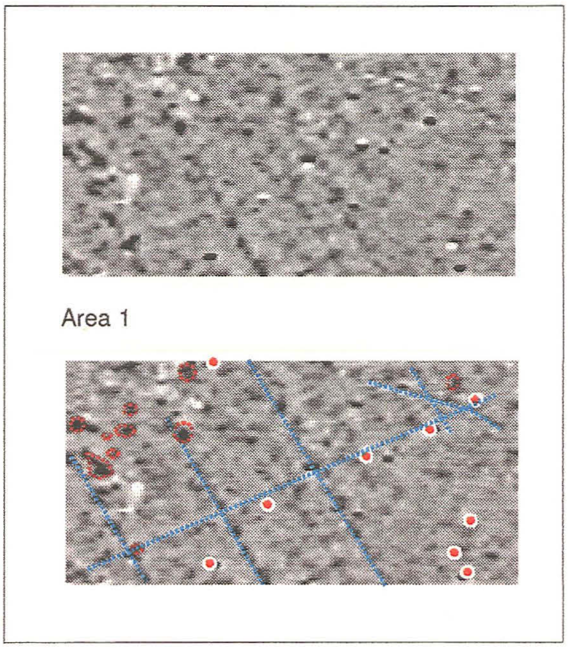


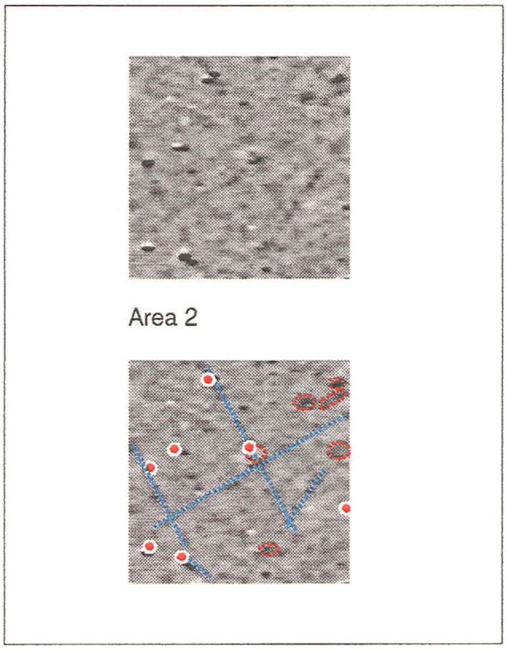
Gradiometer Survey Areas Shown In White Outline

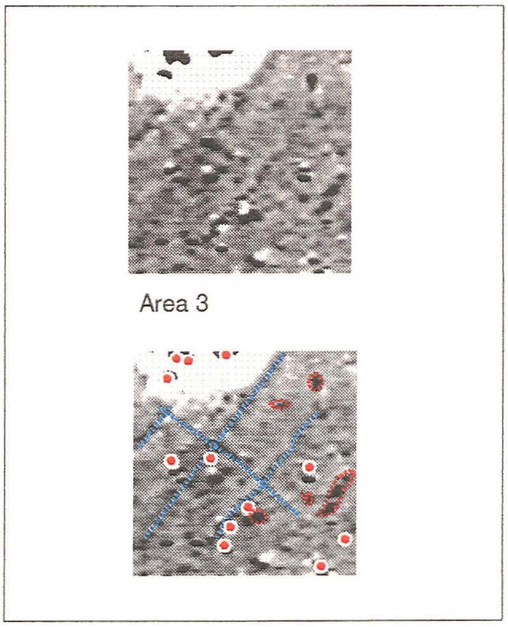
Donington on Bain, Lincolnshire

Topsoil magnetic susceptibility & magnetometer (gradiometer) survey

Magnetometer (gradiometer) Grey Shade plots







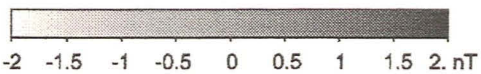
Interpretation

Possible pits

Ferrous material
(main concentrations)

Linear and
curvilinear features

Weak linear and
curvilinear features,
including agricultural striations



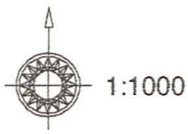


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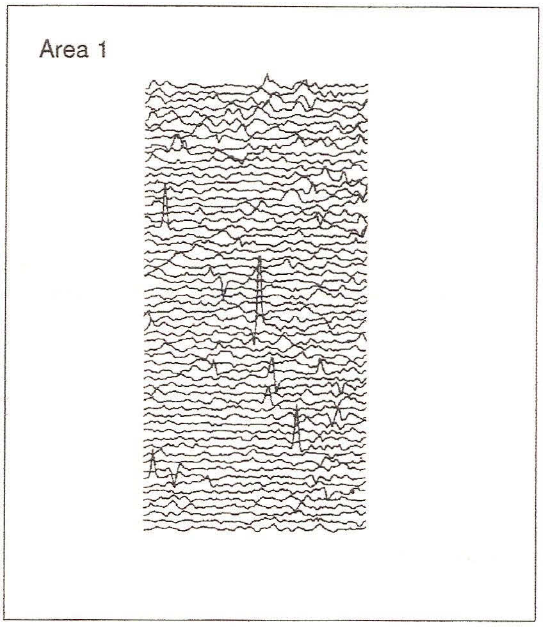
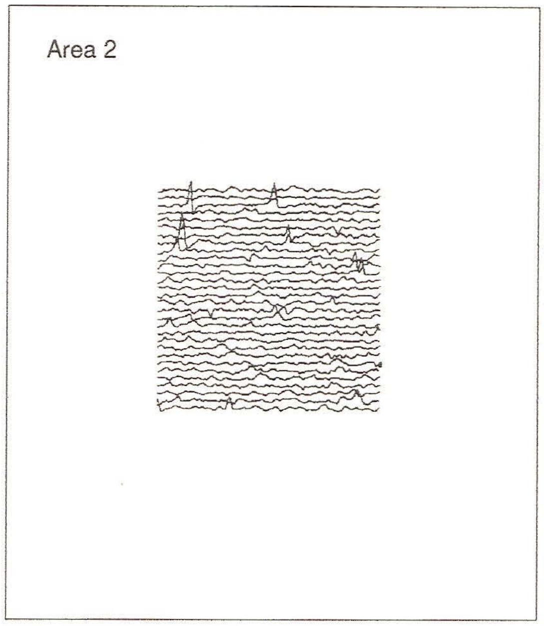
Fig. 3

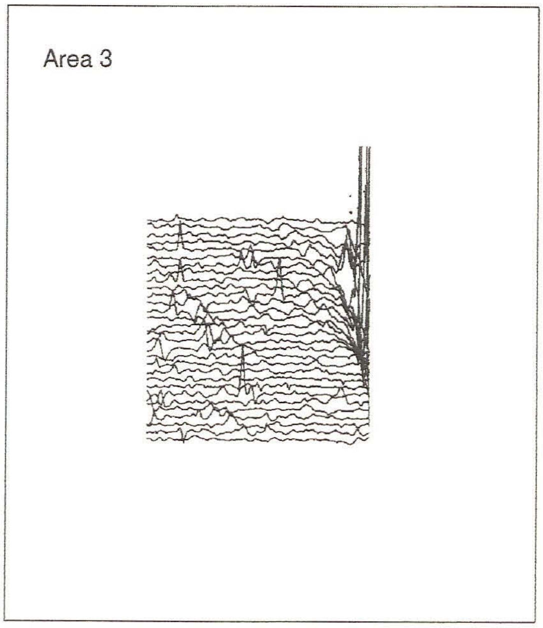
Donington on Bain, Lincolnshire

Topsoil magnetic susceptibility & magnetometer (gradiometer) survey

Magnetometer (gradiometer) Stacked Trace Plots (raw data)







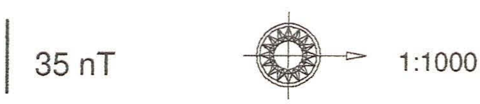


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Fig. 4

Donington on Bain, Lincolnshire

Topsoil magnetic susceptibility & magnetometer (gradiometer) survey

Overview

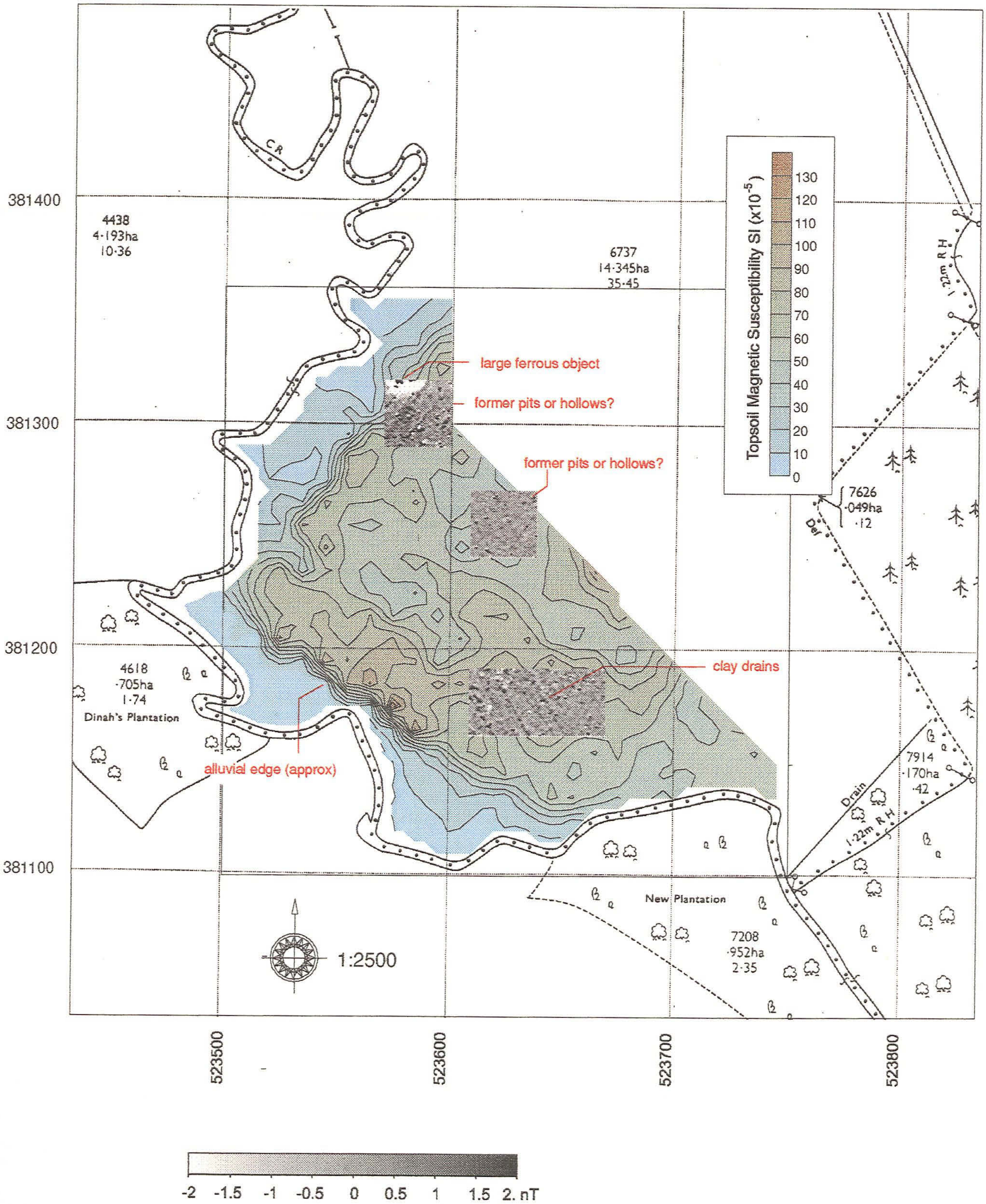

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Fig. 5

Specialist Archaeological Field Evaluation

INTERNAL QUALITY CHECK

Survey Reference	2070100 / DOL / LAS	
Primary Author		Date
Checked By	APJ	Date 10.02.00
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Further Corrections		Date

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