ELI 441 SLI 35317 94/7

43/37 Med.

WOODHALL CHASE, WOODHALL SPA, LINCOLNSHIRE

Topsoil Magnetic Susceptibility and Gradiometer Survey

(Survey Ref : 0460694/WOL/LAS)

JUNE 1994

Produced by

OXFORD ARCHAEOTECHNICS LIMITED

under the direction of

A. E. Johnson *BA (Hons)*

Commissioned by

Lindsey Archaeological Services

on behalf of

Broadgate Builders (Spalding) Limited

Oxford Archaeotechnics

Specialist Field Evaluation

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CONTENTS

SUMMARY

A geophysical evaluation programme was carried out on land (centred at TF 1860 6290) north of Witham Road, Woodhall Spa, designated as Phase 1 of the Woodhall Chase building development by Broadgate Builders (Spalding) Limited.

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).

In the present case, the following features were identified: (a) patterns of enhancement derived from the modern (demolished) Witham Farm and (b) post-Medieval field boundaries (now removed but mostly already known from historical maps); and (c) weak anomalies which might be of agricultural origin. Topsoil magnetic susceptibility levels were generally low. There was no magnetic evidence for substantial archaeological occupation horizons or major 'cut' features. Any older archaeological sites, representing only brief episodes of 'clean' activity, might not have been located by magnetic survey. No ancient topsoil debris or artefact scatters were noted at any point within the survey area.

1. INTRODUCTION

1.1 A geophysical evaluation programme, comprising topsoil magnetic susceptibility field sensing and magnetometry, was commissioned by Lindsey Archaeological Services on behalf of Broadgate Builders (Spalding) Limited as part of an archaeological evaluation in advance of housing development (Woodhall Chase:Phase 1).

1.2 The survey area comprises an area of c. 4.8 ha situated on the western outskirts of Woodhall Spa, north of Witham Road (centred at TF 1860 6290) (Fig. 1).

1.3 The site lies within the floodplain of the River Witham at c. 6m OD. A test-pit commissioned by Broadgate Builders (Spalding) Limited showed a 35-40 cm depth of topsoil over sands and gravels above possible Kimmeridge Clay, with no evidence for widespread alluvial deposits, although some alluvium and peat was present in soil samples retrieved by Lindsey Archaeological Services.

1.4 The land was under arable cultivation, with a crop of wheat, at the time of survey. Until recently the western side of the survey area adjacent to the track (Viking Way) was occupied by the farm buildings of Witham Farm, rubble from which is still visible on the field surface.

1.5 The fieldwork was carried out in June 1994.

1.6 An explanation of the techniques used, and the rationale behind their selection, is included in an appendix to the present report.

1.7 Although no sites or finds of archaeological significance have been recorded within the survey area, a combination of several chance finds (prehistoric to Anglo-Saxon date) and some aerial photographic cropmark evidence from the vicinity serves to highlight its archaeological potential. The remains of a Medieval Cistercian abbey (Kirkstead Abbey) lie less than 1 km southeast of the survey area.

2. MAGNETIC SURVEY DESIGN

2.1 Survey control was established on 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 proven to give a high probability of intersection with the magnetic signal from a wide range of archaeological sites, particularly occupation sites of the later prehistoric, Roman or Medieval periods.

2.4 A 10 m resolution, although perfectly satisfactory for defining general areas of activity, will inevitably intersect locally with soils showing marked magnetic contrasts. It is more important to consider the general trend/pattern than to concentrate upon specific magnetically enhanced 'hotspots', even though many of the latter may subsequently prove to relate to the positions of underlying archaeological features.

2.5 Scanning of the whole site was undertaken on 25 m traverse intervals using a Geoscan Research FM 36 Fluxgate Gradiometer. Two areas which produced scanning anomalies were selected for detailed gradiometer survey in order to define the extent and geometry of any underlying cut/built features (Areas 1 & 2) in 30 x 30 m grids (sampling 4 readings per metre at 1 metre traverse intervals in the 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.

2.6 Field data were stored to 3.5-inch disks, and processed using Geoscan Research Geoplot and Oxford Archaeotechnics Geomath software.

2.7 Both grey shade and colour shade plots have been used to present the topsoil magnetic susceptibility data, which has been mapped at 5 SI intervals (Figs. 2 & 3).

2.8 Magnetometer data have been presented as dot density and stacked trace (raw data) plots (Fig. 4).

3. SURVEY RESULTS

Topsoil Magnetic Susceptibility Survey

3.1 585 *in situ* topsoil 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; the lack of dimensions (a common situation in physical science) is an algebraic artefact (the actual units of measurement cancelling each other out in the formula for volume susceptibility) and in no way indicates subjectivity or lack of precision in the result.

3.2 *In situ* topsoil susceptibility measurements ranged between 2 and 142 (x 10^{-5}) SI units. (The mean for the survey area was 9.3 (x 10^{-5}) SI units and the standard deviation calculated against the mean was 10.4 (x 10^{-5}) SI units. However, these calculations are biased by the high readings from the vicinity of the former Witham Farm).

3.3 Over most of the survey area topsoil magnetic susceptibility levels were generally markedly low (less than 10 SI), with the exception of soils in the vicinity of former farm on the western boundary of the survey area, where locally readings of over 100 SI were recorded.

3.4 The topsoil magnetic susceptibility map (Figs. 2 & 3) reveals the former agricultural organisation of the landscape (smaller land parcels than the modern pattern), together with the position of an infilled pond (shown on the 1951 OS 1:10560 sheet).

3.5 With the exception of the former farm buildings, no strong magnetic patterns were revealed which might be indicative of former occupation sites of archaeological interest. The subtle variations in topsoil magnetic susceptibility seem to represent a fairly typical pattern of agricultural activity.

3.6 The majority of the magnetic contours lie orthogonal to the surviving land boundaries, with the exception of an area of low magnetic susceptibility soils on an (the most southerly blue zone on Fig. 3) on an east-west trend, lying some 100 m east of the former farmstead. This may represent the vestiges of an earlier cultivation pattern.

Magnetometer (Gradiometer) Survey

3.7 The survey area was scanned on 25m wide traverses by gradiometer, although it was clear that the generally low susceptibility levels would make it unlikely that any extensive strong anomalies representative of underlying 'cut' features would be detected .

3.8 Two locations (30 x 30 m) were selected for detailed gradiometer survey as a result of scanning anomalies. The location of the two survey areas is shown on Fig. 4.

Area 1

3.9 A 30 x 30 m survey grid was located on the axis of a former hedgeline, whose position is still partially visible as a slight topographic feature, in a position where a series of local anomalies detected during scanning suggested the presence of ferrous material. Although it was anticipated that these anomalies were probably associated with the hedge clearance, nevertheless gradiometer survey was conducted in order to eliminate any other (archaeological) source.

3.10 Detailed gradiometer survey showed the scanning anomalies detected to be the result of ferrous contamination (probably modern in date, derived from the former hedgerow); no other features of archaeological origin were observed..

Area 2

3.11 An area of 30 x 30m was located to investigate a number of subtle scanning anomalies suggestive of underlying 'cut' features.

3.12 The gradiometer plot (Fig. 4) suggests the presence of extremely weak lineations running predominantly on a southwest-northeast alignment. The two principal elements are parallel, some 15 m apart. The longer of the two is visible for at least 30 m, crossing the centre of the gradiometer survey area diagonally; the parallel linear to the southeast is visible for a distance of at least 10 m. There are indications of striations running orthogonal to these elements; again, they are extremely weak magnetically.

3.13 The alignment of these lineations/striations is very similar to the modern cultivation pattern, and it is possible that they reflect cultivation marks, perhaps former furrow bases, or subsoiling grooves. It is, however, unclear why they appear to be strongest in this particular locality, as they do not appear to lie within an area where topsoil magnetic enhancement is apparent.

4. CONCLUSIONS

4.1 Topsoil magnetic susceptibility levels on the site proved generally low and no further former areas of occupation were recorded by magnetic survey, apart from the site of a former (documented) farmstead. Some weak patterns of topsoil enhancement relate to former field layouts and the location of a former pond.

4.2 It should be stressed that such low levels of topsoil magnetic enhancement would not normally produce sufficient contrasts to register features such as simple ditch fills unless they were locally enhanced by the incorporation of more highly susceptible material (burnt clays, ceramic materials, tiles etc.). Only in one location (Area 2) were features recorded (albeit extremely weak). Their regularity and alignment is suggestive of patterns generated by agricultural activity. However, the possibility that they represent features of archaeological significance cannot be completely discounted. .

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ACKNOWLEDGEMENTS

Magnetic susceptibility and magnetometer survey by **Oxford Archaeotechnics Limited** under the direction of A.E. Johnson *BA(Hons)*, with C. Jenner *BSc(Hons)*, D. Chambers *BA(Hons)* and D. Grey *BA(Hons)*.

APPENDIX - Magnetic Techniques: General Principles

A.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.

A.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.

A.3 The tendency of most human activity is to locally increase soil magnetic susceptibility. 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.

A.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 modify the susceptibility of soils yet again 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.

A.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.

A.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, such as diurnal variation, these are cancelled out. In order to produce good results, the magnetic susceptibility contrast between features and their surroundings must be reasonably high and 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' within larger areas (where the operator directly monitors the changing magnetic field and pinpoints specific anomalies).

A.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.

A.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.

A.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 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).

A.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.

A.11 As well as locating specific sites, topsoil magnetic susceptibility survey frequently provides information regarding 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.

A.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

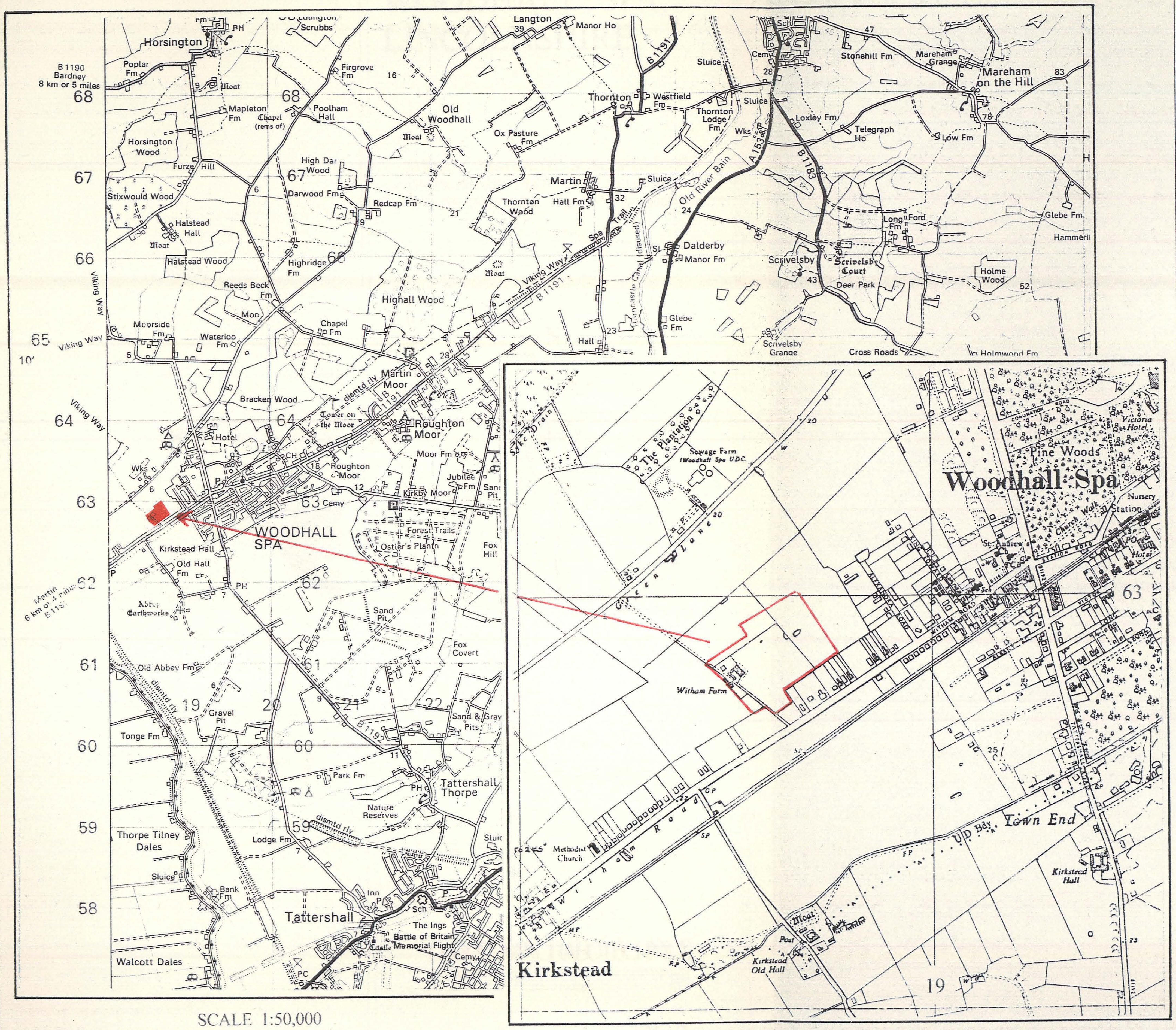
1. Location maps. Scale 1:50,000 and 1:10,000. Based upon OS Map 122 and 1:10,000 Sheet TF16SE.

2. Topsoil magnetic susceptibility survey: grey shade plot. Scale 1:2500.

3. Topsoil magnetic susceptibility survey: colour shade plot. Scale 1:2500.

4. Magnetometer (gradiometer) survey. Location of survey grids, based upon OS 1:2500 Sheet TF1862. Areas 1& 2: dot density and stacked trace plots (Geoscan Research Geoplot Licence No. GPB 885-6). Scale 1:500.

TOPSOIL MAGNETIC SUSCEPTIBILITY SURVEY



SCALE 1:50,000

SCALE 1:10,000

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LOCATION

N

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FIG 1

TOPSOIL MAGNETIC SUSCEPTIBILITY SURVEY

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TOPSOIL MAGNETIC SUSCEPTIBILITY,
GREY SHADE PLOT. SCALE 1:2500
SHADE INTERVAL 5 (x 10^{-5}) SI UNITS

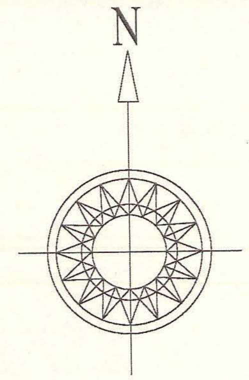

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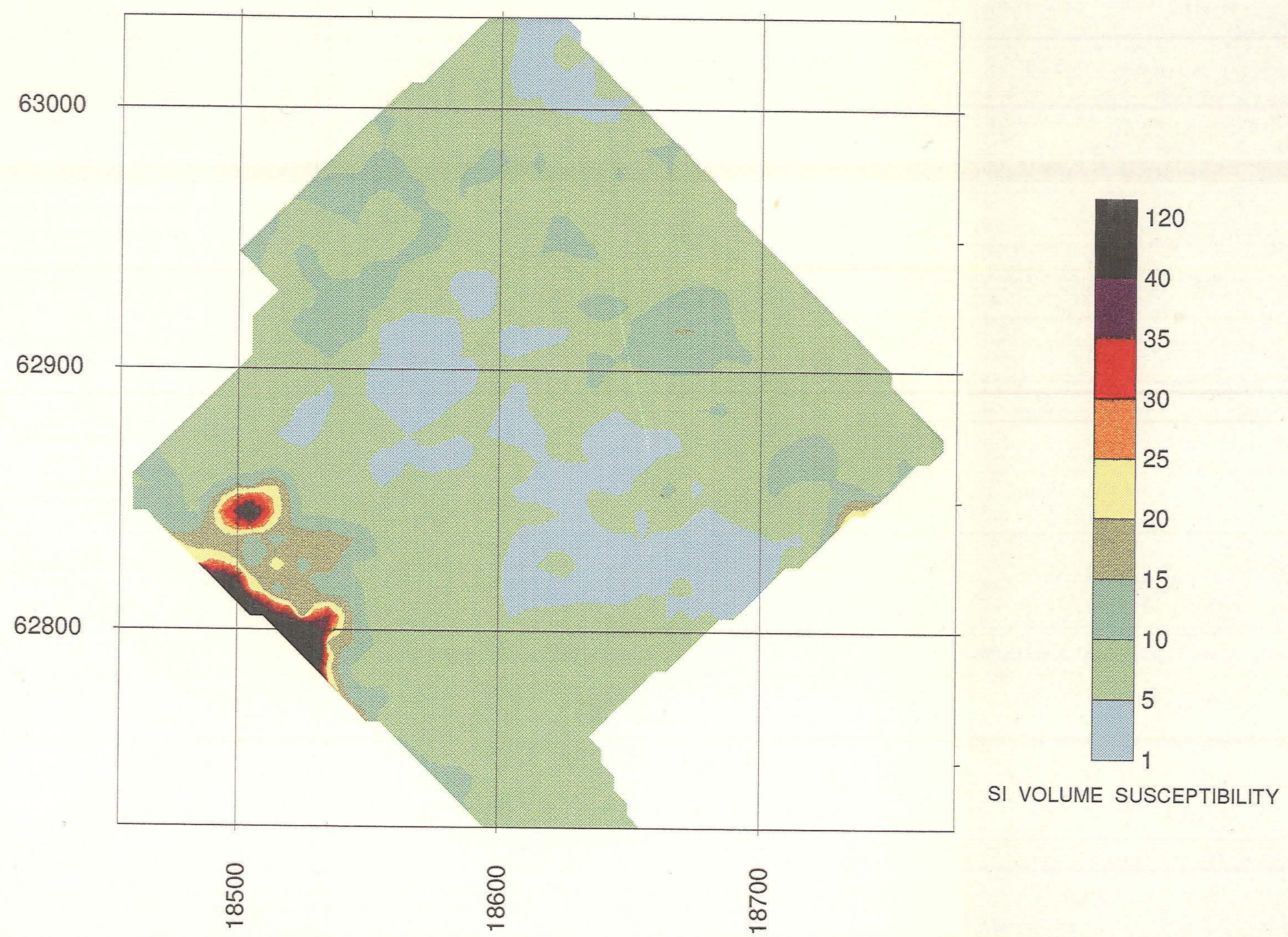
FIG 2

TOPSOIL MAGNETIC SUSCEPTIBILITY SURVEY



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TOPSOIL MAGNETIC SUSCEPTIBILITY, COLOUR SHADE PLOT. SCALE 1:2500
SHADE INTERVAL 5 (x 10^{-5}) SI UNITS

N

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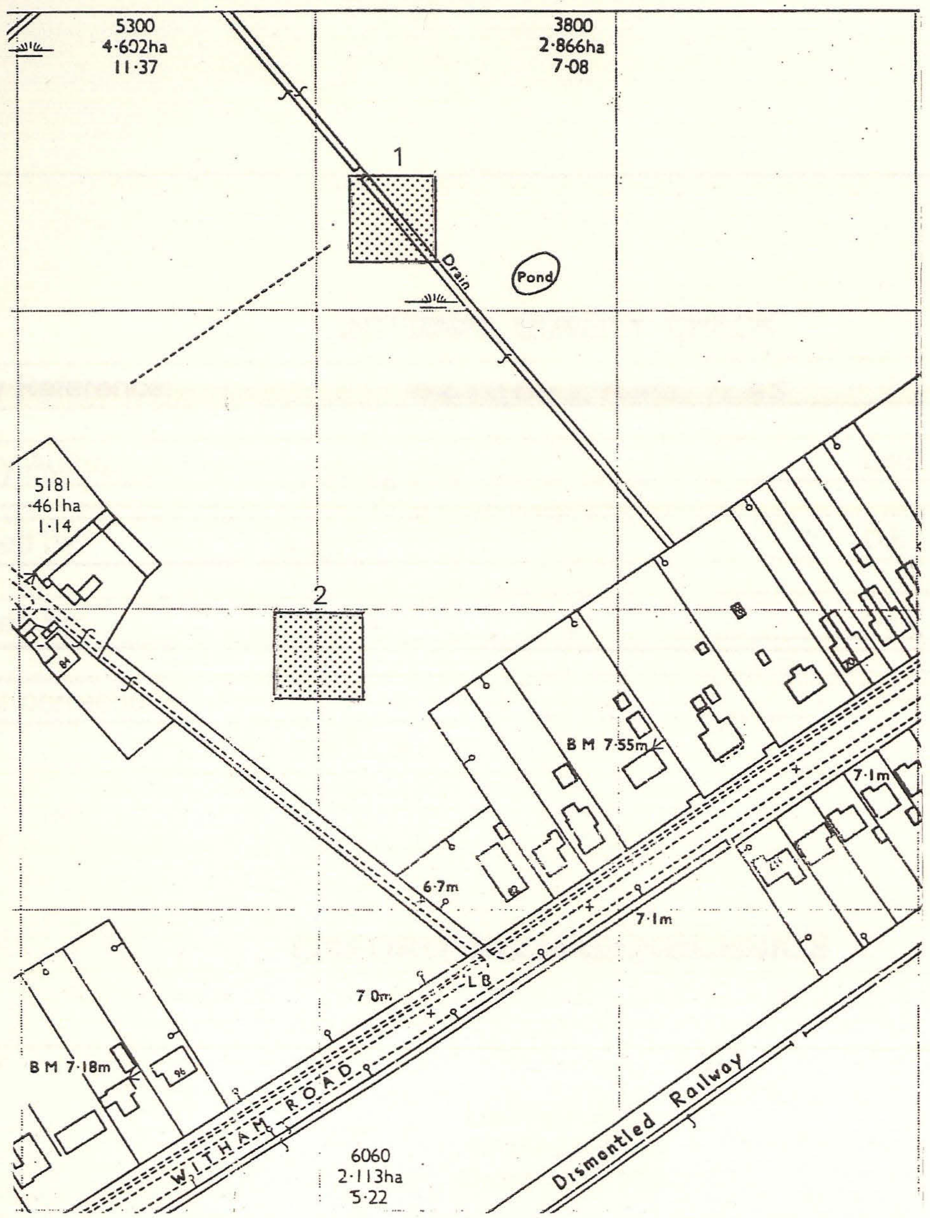
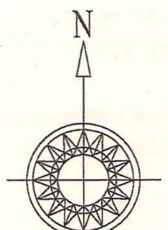
FIG 3

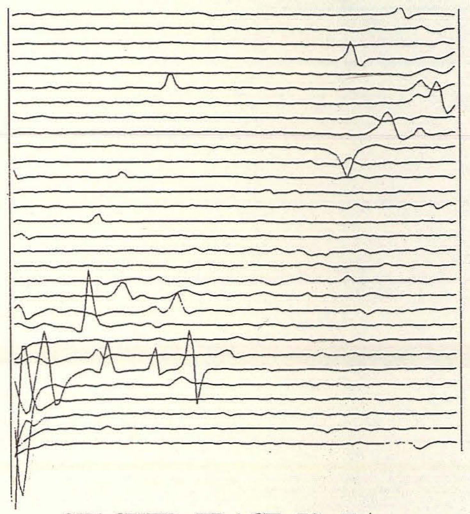
GRADIOMETER SURVEY

LOCATION OF 30M SURVEY GRIDS

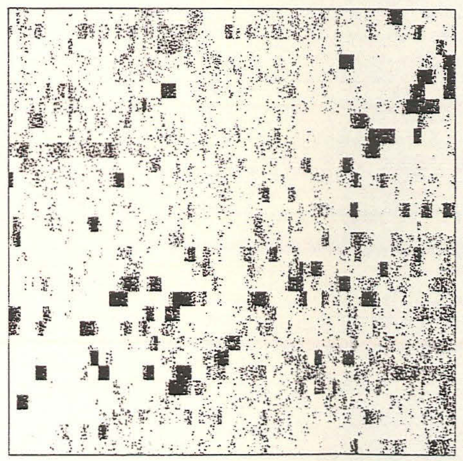




AREA 1

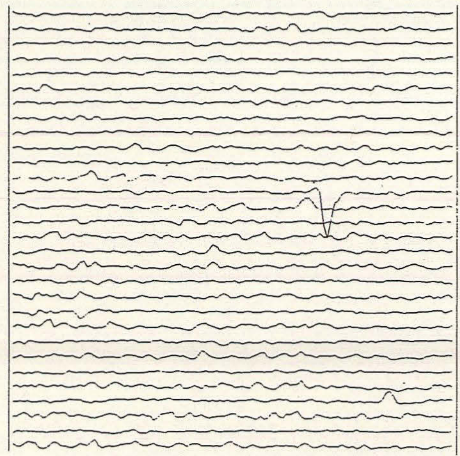


STACKED TRACE 70 nT / cm

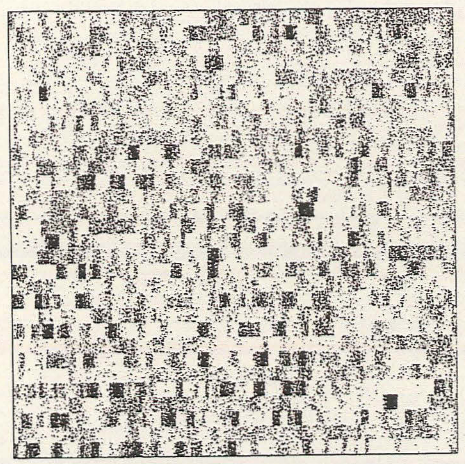


DOT DENSITY -2 to +4 nT

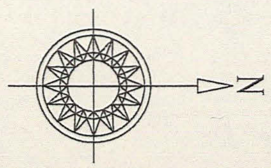
AREA 2



STACKED TRACE 35 nT / cm



DOT DENSITY -2 to +4 nT



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MAGNETOMETER (GRADIOMETER) SURVEY

SCALE
LOCATION : 1:2500
SURVEY AREAS : 1:500

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FIG 4

INTERNAL QUALITY CHECK

Survey Reference:	0460694/WOL/LAS		
Primary Author:		Date:	11-7-94
Checked by:	APJ	Date:	11-7-94
Checked by:		Date:	
Further corrections:		Date:	

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PLEASE ANSWER *ALL* THE FOLLOWING QUESTIONS BY RINGING THE ANSWER OPTION WHICH MOST CLOSELY MATCHES YOUR DESIRED RESPONSE (SPECIFY OTHERWISE IF NECESSARY)

(1) *What is your interest in this particular site/project?* [ring two categories if necessary]

[direct involvement] Client Client's Agent Curator Other Archaeologist Local Public Other

[observer] Developer Developer's Agent Curator Other Archaeologist General Public Other

(2) *How would you qualify this report with respect to overall presentation, lay-out and graphic material?*

very poor poor middling good very good

(3) *How would you qualify this report with respect to overall clarity of argument?*

very poor poor middling good very good

(4) [where applicable as judged from the viewpoint of individual readers] ***How would you qualify this report with respect to clarity of technical explanation?***

very poor poor middling good very good not applicable in my case

(5) *How would you qualify this report with respect to completeness of reference to relevant data?*

very poor poor middling good very good unable to comment

PLEASE TURN OVER

(6) ***Drawing on your own knowledge, how many significant inaccuracies does this report appear to contain?***

very many many some few none unable to comment

(7) ***How would you qualify this report with respect to fulfilment of the brief and/or specification?*** [observers cf. introductory chapter]

very poor poor middling good very good unable to comment

(8) ***On the basis of criteria you yourself judge the most important, how would you describe the apparent overall quality of this report?***

very poor poor middling good very good unable to comment

(9) [direct involvement] ***How would you qualify the supporting service (in terms of ease of communication, punctuality, quality of response, readiness with explanation, preparedness, reasonableness, etc.) surrounding the circumstances of this report?***

very poor poor middling good very good not applicable

(10) [Client and Client's Agent only] ***How would you qualify this report and the supporting service with respect to value for money?***

very poor poor middling good very good not assessed not applicable

REPORT TITLE:

REPORT DATE:

RESPONDENT NAME: **RESPONSE DATE:**

Please feel free to add comments on any point (including the actual structure of the questionnaire) if desired and to encourage any other interested persons to fill out further copies. Note that the primary addressee of this copy of the report will receive a loose copy of the questionnaire and a stamped-addressed envelope; another copy of the questionnaire is bound into the back of the report as a model for further responses. The completed questionnaire(s) (marked with identification of the report in question, the name of the respondent and the response date) should be posted to: OAA Ltd., Lawrence House, 2 Polstead Road, Oxford OX2 6TN. Dr. Simon Collcutt will be happy to reply to any queries on 0865 310209.

THANK YOU FOR YOUR KIND AND VALUABLE ASSISTANCE