99/1

LAND EAST OF SLEAFORD WOOD, SLEAFORD, LINCOLNSHIRE

Archaeological Geophysical Survey

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under the direction of

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SUMMARY

A geophysical evaluation programme comprising topsoil magnetic susceptibility mapping and selective gradiometer survey was carried out on a 15 ha area of arable farmland situated east and southeast of Sleaford Wood, on the northeastern outskirts of Sleaford, Lincolnshire (centred on NGR 507400 346900) in advance of a proposed power station.

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).

10 m topsoil magnetic susceptibility mapping revealed agricultural patterning, for the most part aligned with the existing drainage system. Some local increases in topsoil magnetic susceptibility suggest the incorporation of more magnetic material, perhaps derived from archaeological contexts.

Detailed magnetometer (gradiometer) survey (1.1 ha) recorded only weak magnetic anomalies, generally less than 1nT, with only suggestions of occasional linear features and possible pits. Localised flooding restricted the areas available for detailed gradiometer survey, and consequently not all of the higher topsoil magnetic susceptibility areas could be investigated.

1. INTRODUCTION

1.1 Geophysical survey was commissioned by Lindsey Archaeological Services on land immediately east and southeast of Sleaford Wood, on the northeastern outskirts of Sleaford, Lincolnshire in advance of a proposed power station. The fieldwork was carried out in January 1999.

1.2 The Survey Area (centred on NGR 507400 346900) comprises a roughly L-shaped block of land, some 15.1 ha in extent, in three fields (OS Fields 4700, 3981 and the eastern part of 0572), bounded on the west by the wood, on the north and east by substantial drains, and on the south by the embankment of a railway line. The location is shown on Fig. 1.

1.3 The geology is mapped as Oxford Clays and Kellaways Beds close to their junction with Cornbrash; surface observations of limestone brash have been recorded within the northern half of Field 4700, with silty clay predominating to the south (Tann 1996). The land is for the most part level (at c.12.5 m AOD), sloping gently southeastwards down towards the river, which lies some 750 m distant, although Field 0572 slopes northwards towards the wood. A slight natural topographic rise has been noted within the southwestern half of Field 3981 (Tann 1996). The northern field (Field 4700) had been ploughed, and the other two cropped, but unploughed. At the time of survey the land was extremely wet, with localised flooding, particularly within the eastern quarter of the survey area, restricting access for gradiometer survey.

1.4 The site is crossed by a series of underground (gas, sewer) service pipes and asbestos-cement land drains (Tann 1996). Two mains sewers cross Field 4700 (one running parallel and close to the southern boundary ditch, and the other extending from the northeastern angle of the field, where it is visible crossing the eastern boundary drain, southwestwards into Sleaford Wood at a point just south of centre along its western boundary). A gas main runs almost due south across the site from the extreme northeastern angle of the wood towards the railway embankment. A pattern of land drains, in 50 major pipe-runs spaced approximately 15 m apart, has been mapped on two major alignments: predominantly westsouthwest-eastnortheast in Field 4700, and on a perpendicular alignment within the extreme west of this and across the whole of the other two fields (Stratascan 1998).

1.5 It is unclear whether linear cropmarks recorded from the air within the most northerly of the fields (OS 4700) relate to the recent drainage pattern or more ancient activity (Tann 1996). The site of a Romano-British settlement/building lies immediately north of Sleaford Wood (centred on NGR 507150 347090: SMR No. 60458), and further cropmarks have been recorded upon land on the opposite (east side) of East Road, suggestive of a possible Romano-British settlement site alongside a Roman road (centred on NGR 507960 347050). The survey area is therefore believed to have some archaeological potential for the discovery of later prehistoric and Romano-British remains, although previous geophysical surveys on adjacent land have not

produced any significant magnetic evidence for the presence of extensive archaeological material (EAS 1997a., EAS 1997b & LRC 1997).

1.6 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. The objectives of the survey were twofold: to provide a time- and cost-effective means of locating and characterising archaeologically significant activity areas, and also to determine whether the techniques could precisely locate the network of known drains and underground services.

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 display 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 Four areas (totalling 1.1 ha) 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. 3) shows contours at a range of 10 SI intervals. Magnetometer data have been presented as grey scale, interpretation and stacked trace (raw data) plots (Figs.4 - 6).

2.6 Field numbers allocated by Lindsey Archaeological Services (LAS) in their desktop archaeological assessment of the site (Tann 1996) have been included in the following report.

3. SURVEY RESULTS

TOPSOIL MAGNETIC SUSCEPTIBILITY SURVEY (Fig. 3)

3.1 1509 *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 10 and 62 (x 10^{-5}) SI units. The mean for the survey was 33 SI units and the standard deviation calculated against the mean was 6.8 SI units.

3.3 The topsoil magnetic susceptibility map broadly reflects the agricultural/drainage pattern. There is a clear distinction between Field 4700, showing marked east-west trends which are, for the most part, aligned with the longitudinal axis of the field and its neighbours to the south (Fields 0572 & 3981), which display more 'block-like' orthogonal patterning on a general northnorthwest-southsoutheast alignment (i.e. perpendicular to the longitudinal axes of the fields). Areas showing stronger magnetic patterning in both Fields 4700 and 3981 coincide with topographically lower-lying areas within each of the fields which although partially flooded during the course of the survey were, prior to inundation, firm under foot and reasonably well-drained, the flooding having been caused by the overflow from a swollen and blocked drain.

Field 4700 (LAS Field No.2)

3.4 The majority of the topsoil magnetic susceptibility patterning visible within Field 4700 conforms with the multiple east-west drains (which cross the field at 15 m intervals). There is some suggestion that patterning on a southwest-northeast trend within the northeastern quadrant of the field may have been influenced by the presence of a modern sewer pipe at this location.

3.5 There is further patterning within the northeastern angle and alongside the eastern boundary, with several foci of topsoil enhancement exceeding 50 SI, which might indicate the presence of locally enhanced topsoils which may represent the product of the (agricultural) dispersal of magnetically enhanced horizons of possible archaeological significance. The largest focus, centred on NGR 507620 347060, may be associated with dispersed midden material (including oyster shells and animal bones and teeth) observed at this location on the field surface during the course of the survey work.

Field 3981 (LAS Field No.3)

3.6 The eastern half of the field displays more magnetically enhanced soils, with the stronger patterning aligned with the current field boundaries. The majority of the

readings taken in this part of the field were taken under a depth of 10 - 20 cm flood water, in extremely soft ground conditions.

3.7 The slight topographic rise within the southwestern half of the field (centred on NGR 507350 346750) displayed no topsoil magnetic enhancement.

Field 0572 (LAS Field No.4)

3.8 There is a marked local increase in topsoil magnetic susceptibility close to the eastern boundary of this field, with a small focus (centred on NGR 507150 346740) exceeding 50 SI. Otherwise the patterning is essentially agricultural.

MAGNETOMETER (GRADIOMETER) SURVEY

3.9 Much of the proposed programme of gradiometer scanning on 25 m traverses had to be abandoned because of flooding. Gridded gradiometer survey was carried out in 4 areas (totalling 1.1 ha), which were chosen on the basis of topsoil magnetic susceptibility contrasts, the availability of the land (restricted by localised flooding) for survey, and in one case (Area 3) to investigate a topographic rise. The location of the survey grids is shown on Fig. 2.

AREA 1 (Figs. 4 & 6)

3.10 A 60 x 30 m (0.18 ha) survey box was sited to investigate a small focus of increased topsoil magnetic susceptibility associated with what appeared to be a surface spread of midden material (see 3.5 above) within the northeastern part of Field 4700 (LAS Field No.2); the survey grid also encompassed a section of the pipeline and disturbance caused by a recent borehole, to test the possibility that underlying archaeological (magnetically enhanced) horizons may have been upcast into the topsoil as a result of their construction.

3.11 Both the pipeline and borehole location show graphically on the gradiometer plot. More subtle magnetic anomalies are visible beyond the influence of these dominant recent features. A series of weak disjointed anomalies visible approximately 10 m south of the borehole suggest a possible linear feature, together with several possible pits or hollows.

3.12 Horizontal banding on the plot marks the response of the gradiometer to plough furrows.

AREA 2 (Figs. 4 & 6)

3.13 A 120 x 30 m (0.36 ha) survey strip was sited on the first available dry land within the eastern part of Field 4700 (LAS Field No.2) in order to investigate the pattern of underlying field drains in an area of general topsoil magnetic patterning.

3.14 The large sewer pipe located in Area 1 was also recorded crossing the northern part of the survey grid.

3.15 A number of extremely subtle lineations, spaced approximately 15 m apart are visible on a westsouthwest-eastnortheast trend. A pair of weak anomalies running on a roughly north-south alignment may represent agricultural striations rather than drains.

3.16 Several weak anomalies detected within the southern 30 m of the survey grid suggest the presence of linears and possible pits (although the stronger pit-like anomalies are equally likely to represent deeply buried ferrous material). It is possible that these weak linear anomalies represent former ditches will fills containing material with relatively low magnetic susceptibility.

AREA 3 (Figs. 5 & 6)

3.17 A 60 x 60 m (0.36 ha) survey box was sited to cover a topographic rise within the southwestern half of Field 3981 (LAS Field No.3).

3.18 The eastern side of the survey grid is affected by its proximity to a gas pipeline which lies several metres east of the survey box, running on a north-south alignment and passing the northeastern angle of Sleaford Wood. Some magnetic effects from the railway line which forms the southern boundary of the field are also apparent.

3.19 The most obvious features visible within this survey grid are a series of at least three parallel linear anomalies, spaced 15 - 16 m apart, which appear to be modern drainage features.

3.20 No further features with obvious archaeological potential were recorded apart from a few possible hollows or pits.

AREA 4 (Figs 5 & 6)

3.21 A 60 x 30 m (0.18 ha) survey box was sited within Field 0572 (LAS Field No.4) and centred upon a small topsoil magnetic susceptibility focus, locally exceeding 50 SI.

3.22 No obvious underlying 'cut' features associated with the area of topsoil magnetic enhancement were identified by the gradiometer, although several weak magnetic lineations, suggesting agricultural striations or possible drains, were recorded.

4. CONCLUSIONS

4.1 The topsoil magnetic susceptibility response proved to be only moderate, and for the most part agriculturally patterned, although locally the topsoils reached levels which were capable of producing relatively graphic gradiometer plots (demonstrated by the way in which plough striations have been revealed at some locations). Amongst these 'enhanced' areas are a few which may be indicative of areas with archaeological potential, notably the northeastern angle of Field 4700 (LAS Field No.2) and the eastern half of Field 0572 (LAS Field No.4). The eastern half of Field 3981 (LAS Field No.3) displays some clear patterning, again with local 'hotspots', but as they were under water and soft ground at the time of survey, they could not be investigated by detailed magnetometry (gradiometer survey).

4.2 The gradiometer plots show only weak indications of underlying features, but amongst these there are suggestions of what may be former ditches and pits. Those that may prove to be of archaeological significance have low magnetic susceptibility, and are unlikely to be associated with dense former occupation or industrial activity (such archaeological sites would normally be associated with more magnetic material. i.e. burnt and fired deposits, charcoal and ceramics, contributing to horizons and the fills of 'cut' features which would be more readily visible to the gradiometer). It is suggested, therefore, that these weak anomalies represent either outlying agricultural features (possibly ancient in origin) or elements of an earlier prehistoric landscape which are less likely to have incorporated 'magnetically grubby' material. Only at one location, in the northeastern corner of the northern field, was there any surface indication of the inclusion of material possibly derived from an occupation context (i.e. oyster shells, teeth and animal bone).

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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,* and M. Tomkins.

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.

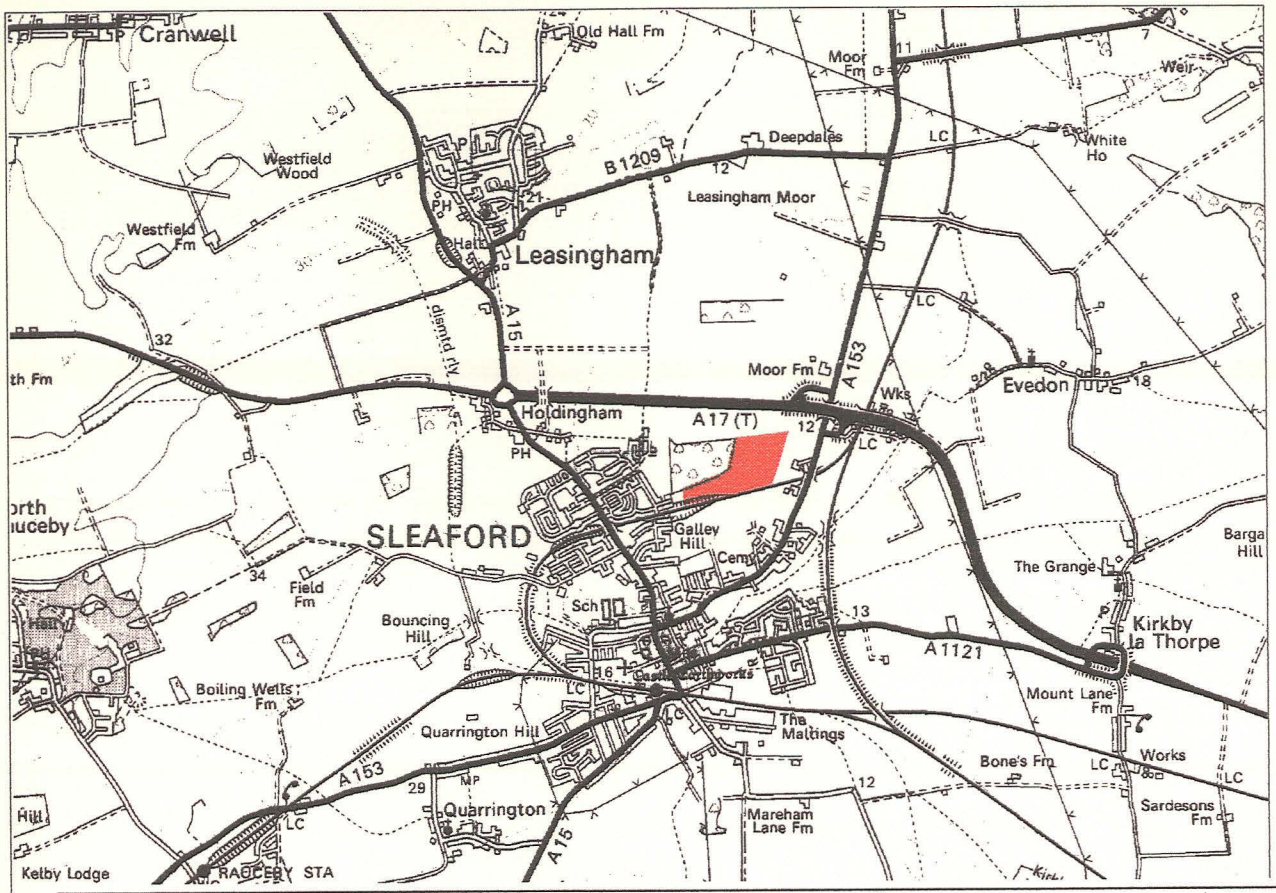
A1.12 Where a general spread of magnetically enhanced soils contained within a long-established boundary becomes admixed over a long period by constant ploughing, it can be diffused to such a point that the original source is masked altogether. Magnetically enhanced material may also be moved or masked 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

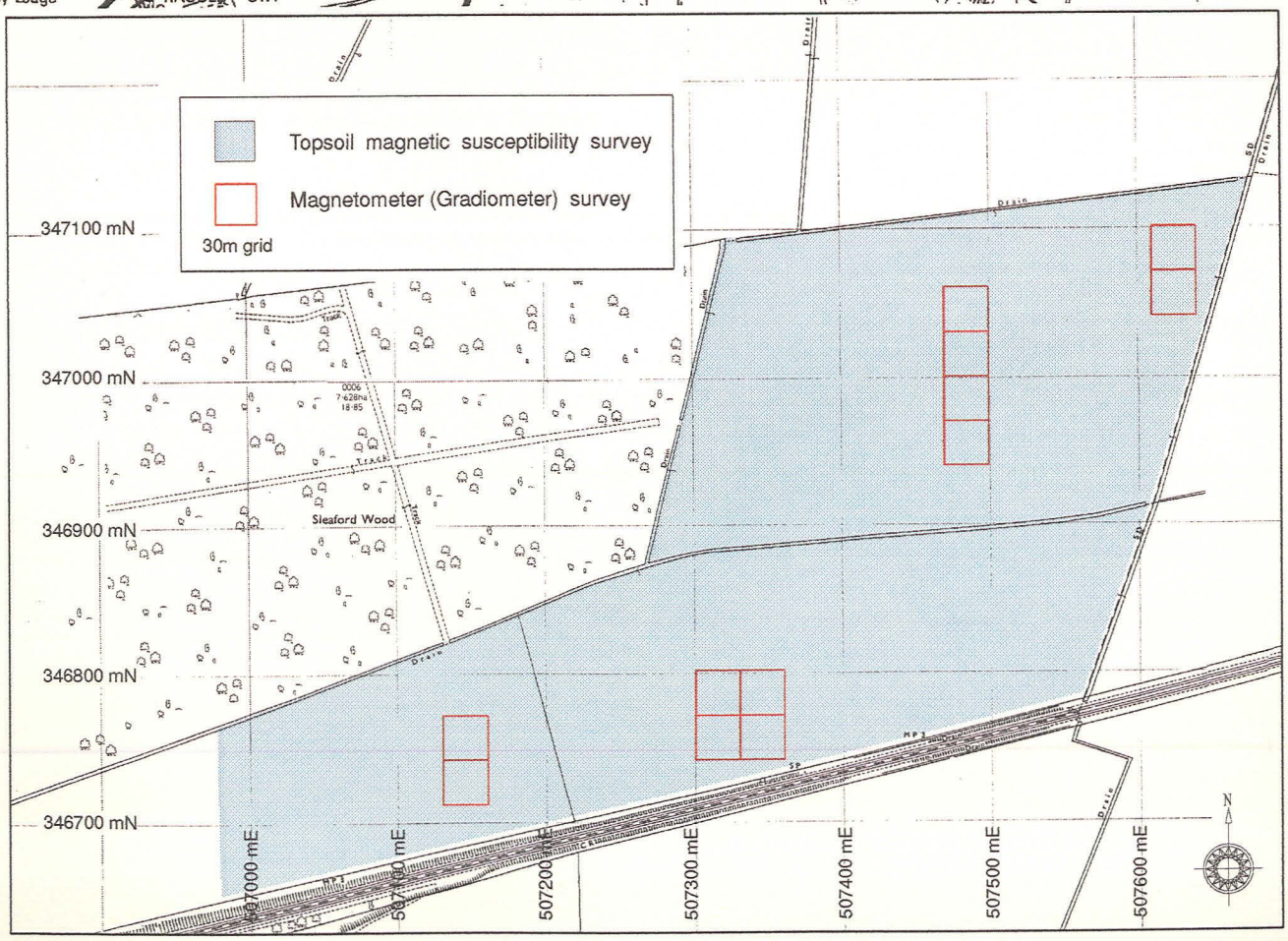
Figure 1.	Location maps. Scale 1:50,000 and 1:5,000. Based upon OS 1:50,000 Sheet 130 and OS 1:2500 Sheets TF 0746 & 0747.
Figure 2.	Location of survey grids. Based upon OS 1:2500 Sheets TF 0746 & 0747. Scale 1:2500.
Figure 3.	Topsoil magnetic susceptibility survey: colour shade plot. Based upon OS 1:2500 Sheets TF 0746 & 0747. Scale 1:2500.
Figure 4.	Magnetometer (gradiometer) survey. Areas 1 & 2: grey shade plots and interpretation. Scale 1:1000.
Figure 5.	Magnetometer (gradiometer) survey. Areas 3 & 4: grey shade plots and interpretation. Scale 1:1000.
Figure 6.	Magnetometer (gradiometer) survey. Areas 1 - 4: stacked trace (raw data) plots. Scale 1:1000.

Land East of Sleaford Wood, Sleaford, Lincolnshire

Topsoil magnetic susceptibility & magnetometer survey: location



1:50,000



1:5000

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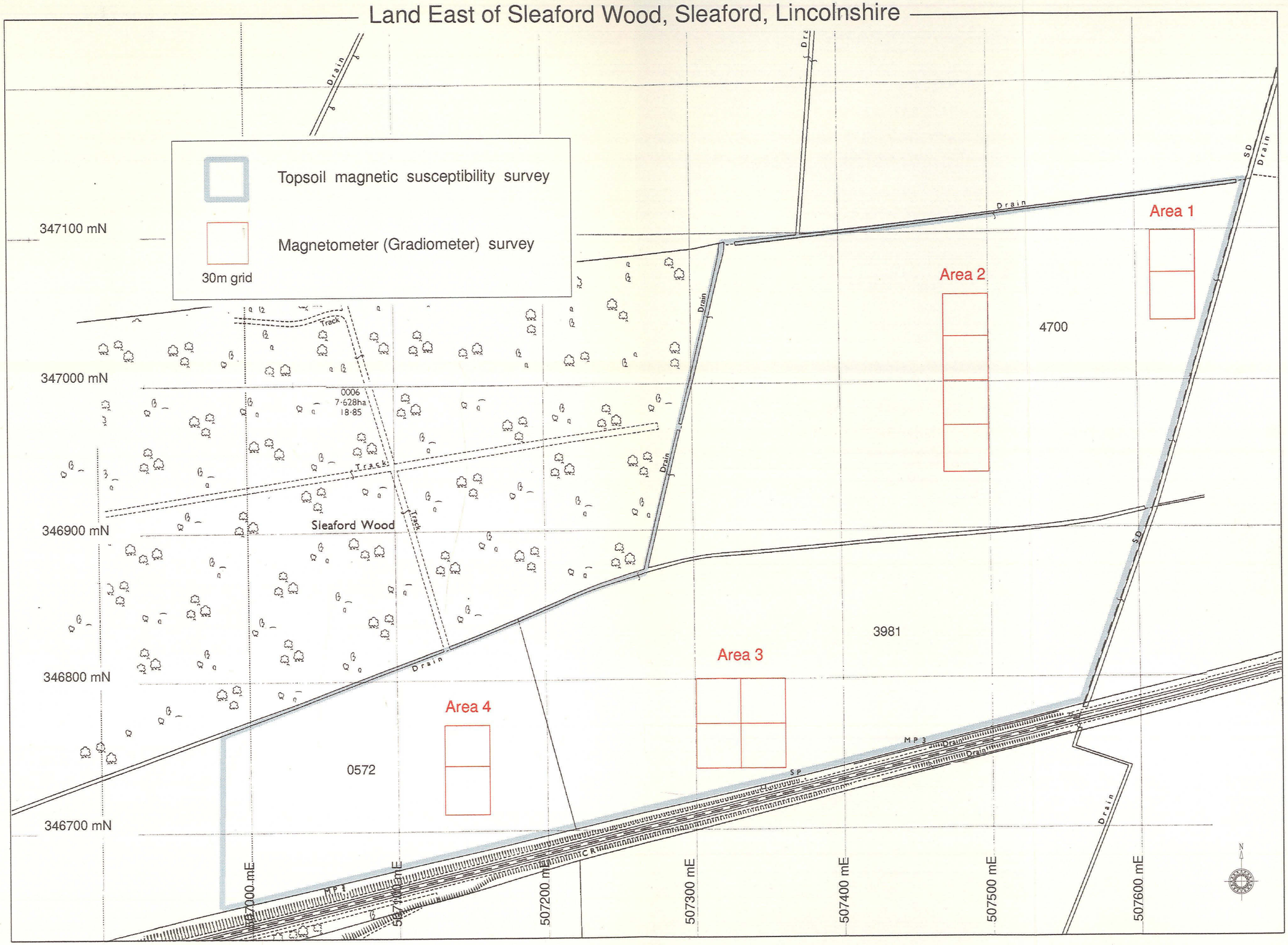
FIG. 1

Land East of Sleaford Wood, Sleaford, Lincolnshire



Topsoil magnetic susceptibility & magnetometer survey: location. 1:2500

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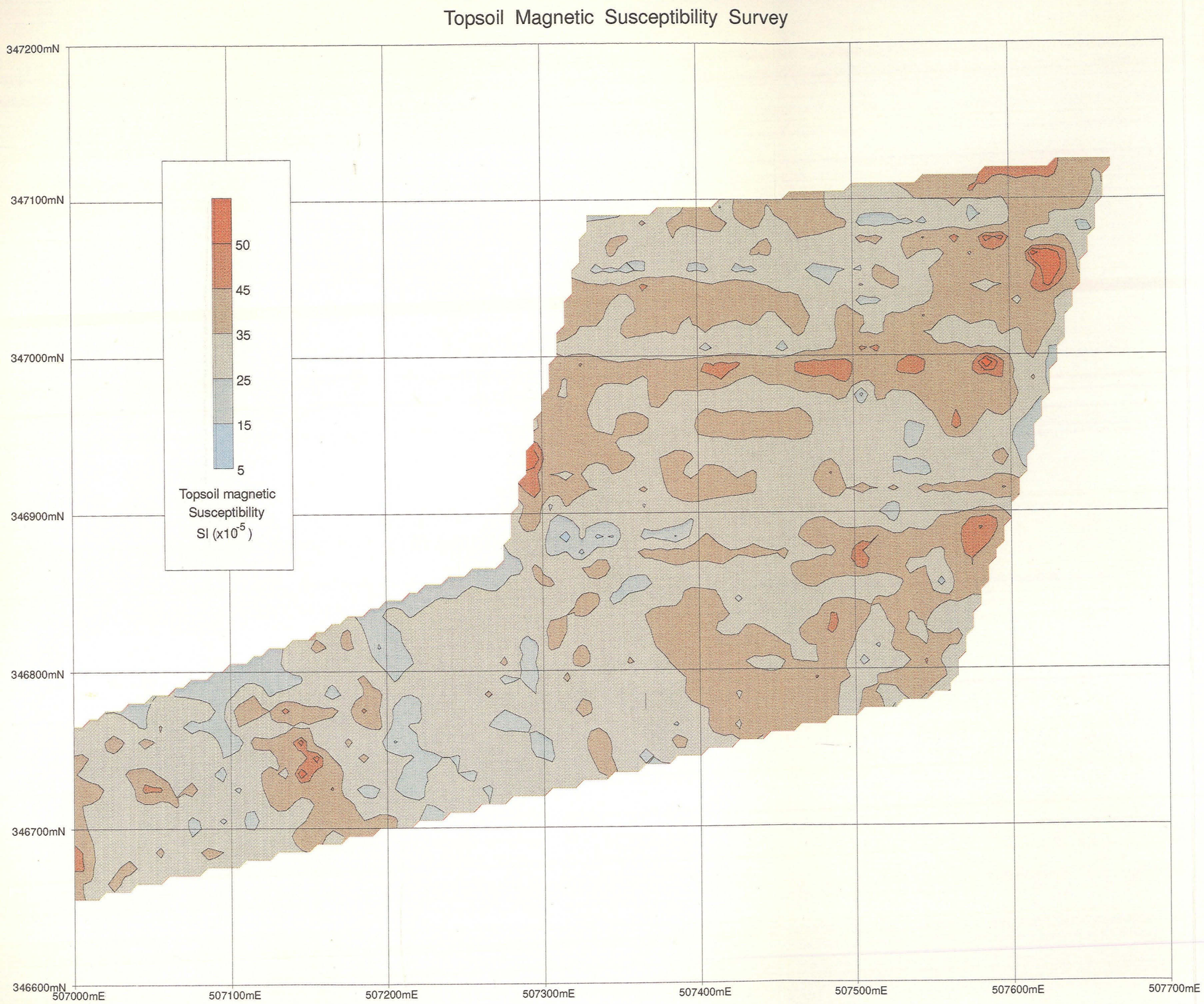
FIG. 2

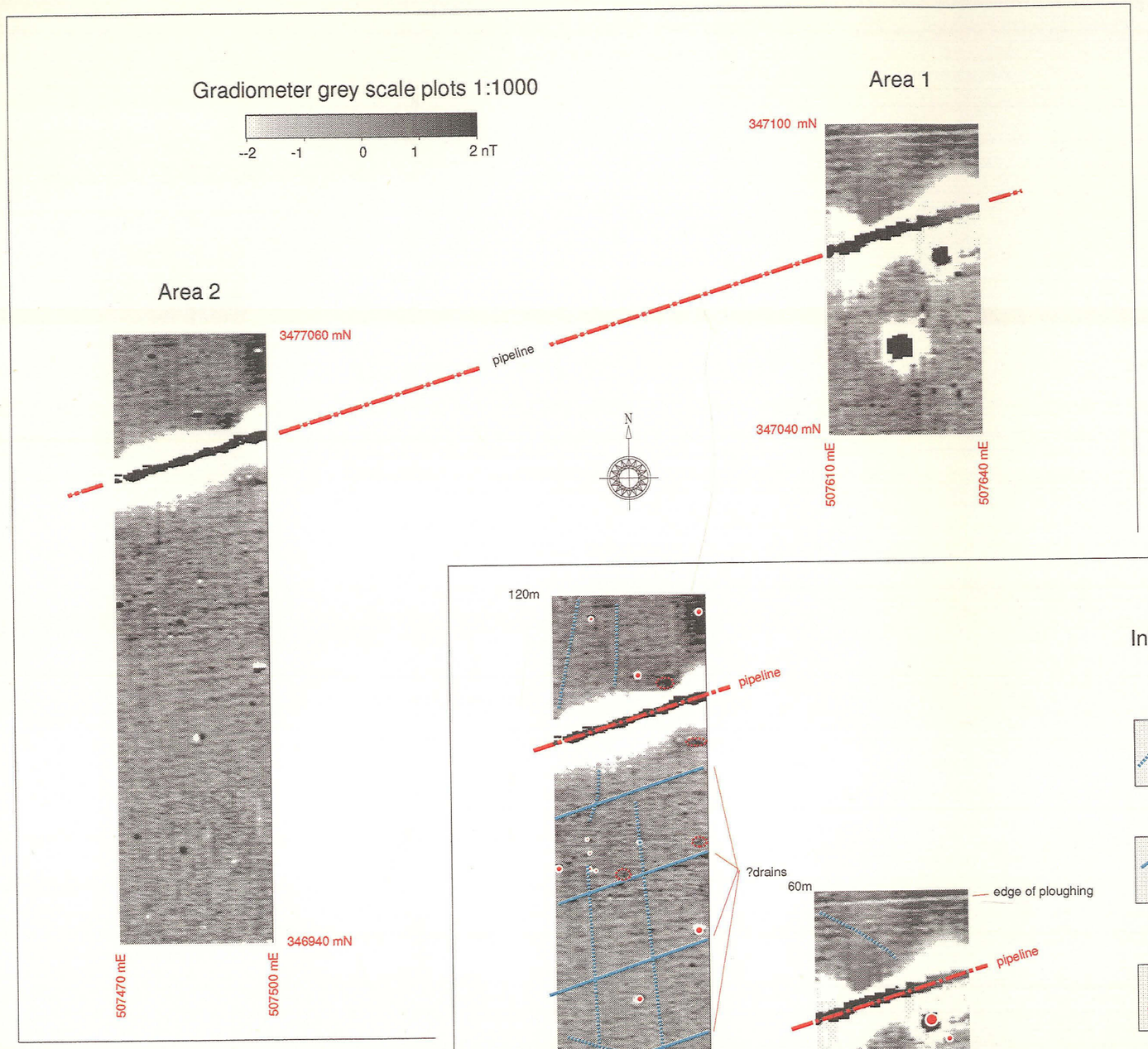


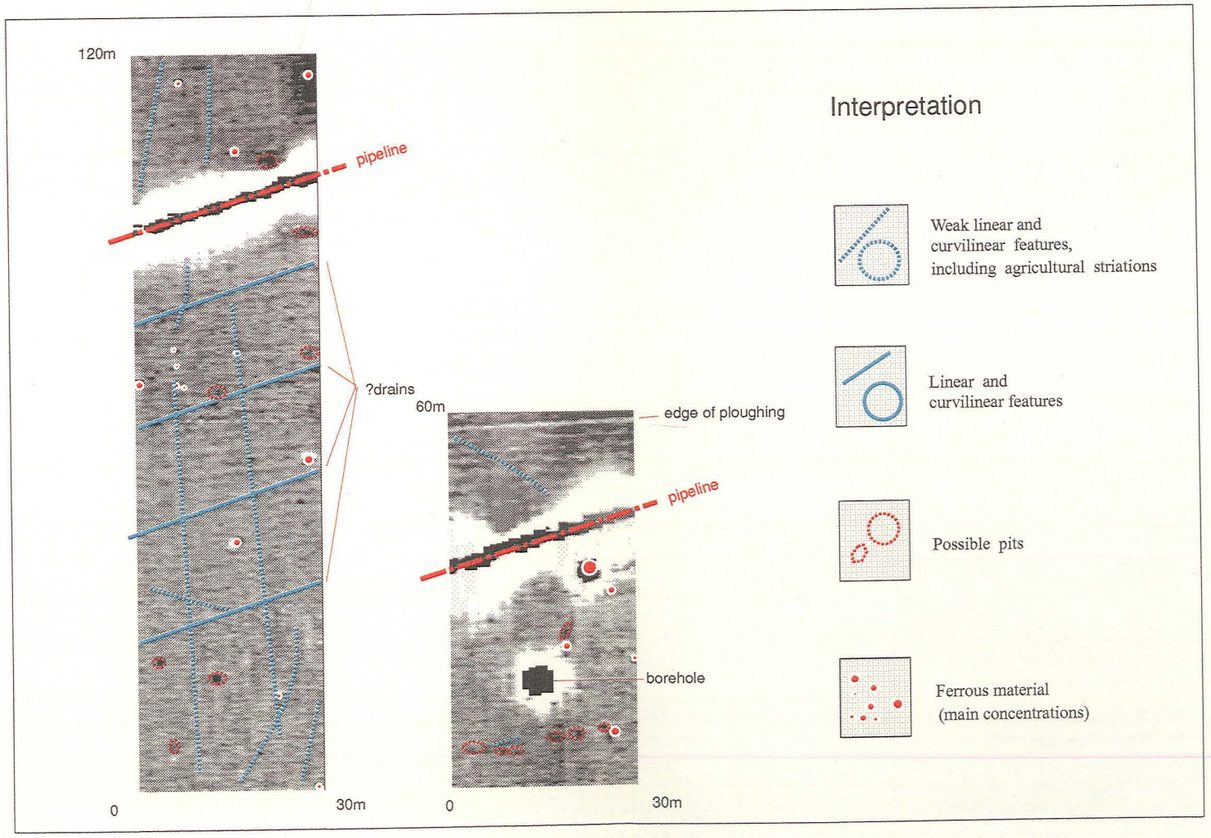
Land East of Sleaford Wood,
Sleaford, Lincolnshire

Archaeological Geophysical Survey

OXFORD ARCHAEOTECHNICS FIG.3

Magnetometer (gradiometer) survey: grey scale plots





Land East of Sleaford Wood, Sleaford, Lincolnshire

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OXFORD ARCHAEOTECHNICS FIG. 4

Magnetometer (gradiometer) survey: grey scale plots

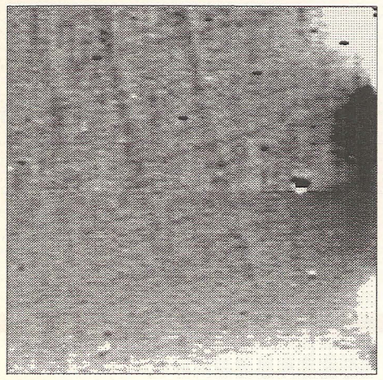
Area 3

507300 mE

507360 mE

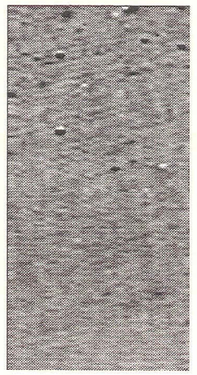
346800 mN

346740 mN



Area 4

346770 mN

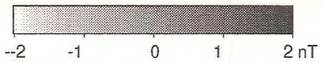


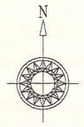
346710 mN

507130 mE

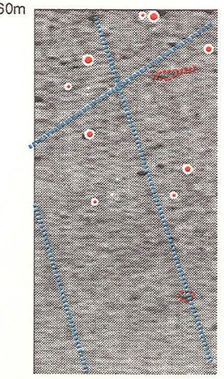
507160 mE

Gradiometer grey scale plots 1:1000





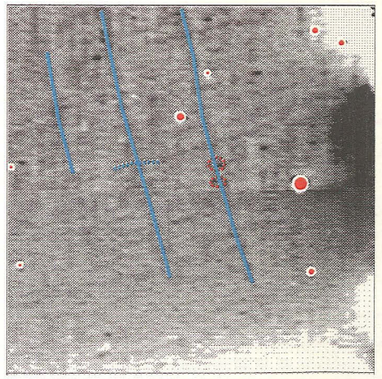
60m



0m

30m

60m



0m

30m

Interpretation

Weak linear and curvilinear features, including agricultural striations

Linear and curvilinear features

Possible pits

Ferrous material (main concentrations)

Land East of Sleaford Wood, Sleaford, Lincolnshire

Archaeological Geophysical Survey

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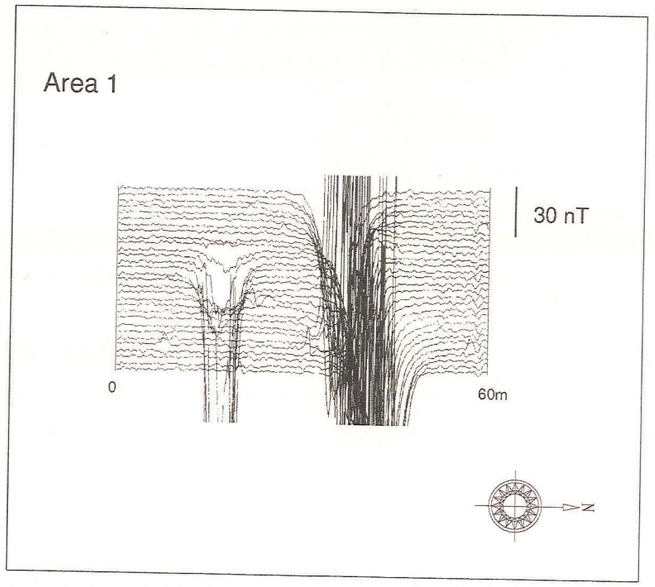
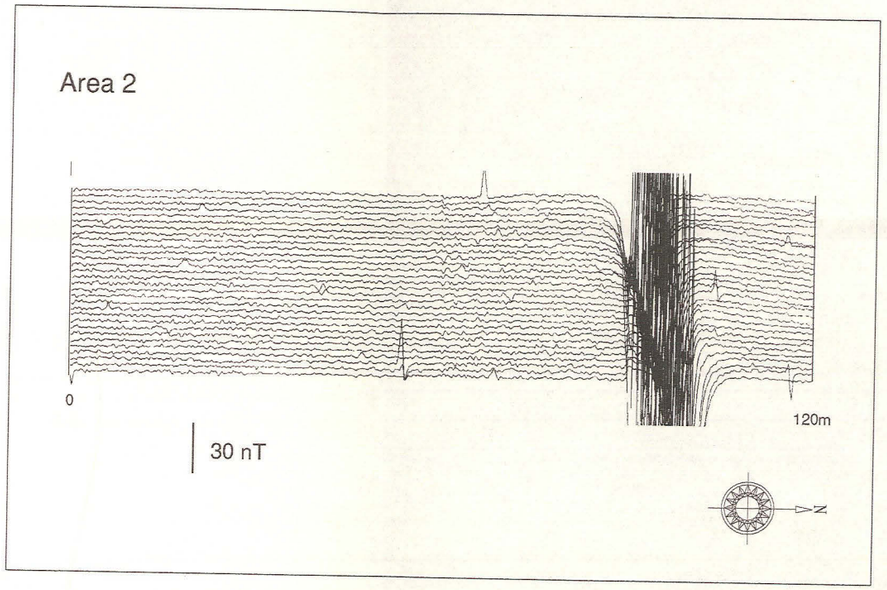
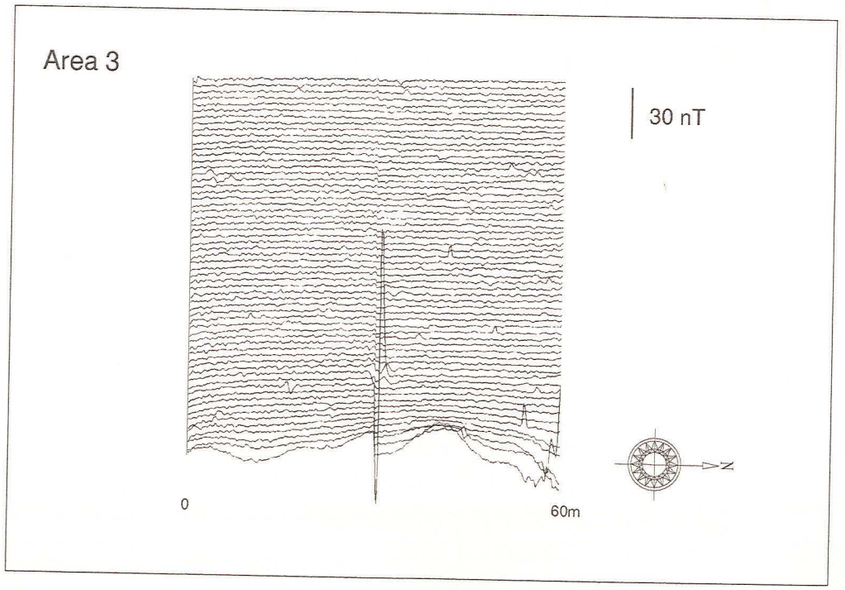
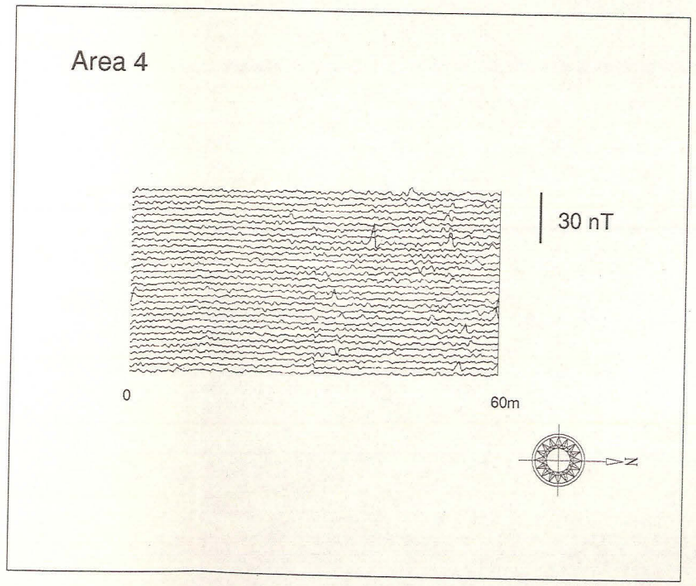
FIG. 5

Magnetometer (gradiometer) survey: stacked trace plots (raw data)









1:1000

Land East of Sleaford Wood,
Sleaford, Lincolnshire

Archaeological Geophysical Survey

OXFORD ARCHAEOTECHNICS

FIG. 6

INTERNAL QUALITY CHECK

Survey Reference	1730199 /SWL/LAS		
Primary Author	MJ	Date	22/1/99
Checked By	APJ	Date	22.01.99
Checked By		Date	
Further Corrections		Date	

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