

BONEMILL LANE, EAST ROAD, SLEAFORD, LINCOLNSHIRE

Topsoil Magnetic Susceptibility and Gradiometer Survey

(Survey Ref: 1570898/SLL/LAS)

NOVEMBER 1998

Produced by

OXFORD ARCHAEOTECHNICS LIMITED

under the direction of

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Commissioned by

Lindsey Archaeological Services

OXFORD ARCHAEOTECHNICS

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CONTENTS

	SUMMARY	1
1.	INTRODUCTION	2
2.	MAGNETIC SURVEY DESIGN	3
3.	SURVEY RESULTS	4
4.	CONCLUSIONS	6
	REFERENCES	7
	APPENDIX: Magnetic Techniques - General Principles	8
	FIGURES	

SUMMARY

A geophysical evaluation programme comprising topsoil magnetic susceptibility mapping and selective gradiometer survey was carried out on an 9 ha area of arable farmland at Bonemill Lane, East Road, on the northeastern outskirts of Sleaford, Lincolnshire (centred on NGR 508150 346900) in advance of proposed development.

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 some evidence for former patterns of landuse with some locally strong patterning across the northern third of the survey area (approaching Bonemill Lane) and further more subtle patterns of magnetic enhancement within the southern tip, whilst the majority of the remaining central part of the survey area proved unremarkable magnetically.

A total area of 0.9 ha was selected for detailed magnetometer (gradiometer) survey. Linear anomalies indicative of former ditches, together with a series of irregular anomalies suggesting the presence of pits (or pit-like features) were located within an area of topsoil magnetic enhancement in the northern part of the site, and further pits were also suggested within the extreme south.

Gradiometer scanning indicated no further concentrations of magnetic anomalies, although as the majority of anomalies recorded within the detailed survey areas were themselves weak and often diffuse, it is recognised that similar anomalies elsewhere would have been difficult to identify with confidence by scanning alone.

1. INTRODUCTION

- 1.1 Geophysical survey was commissioned by Lindsey Archaeological Services on land south of Bonemill Lane, just east of the A153 East Road, on the northeastern outskirts of Sleaford, Lincolnshire in advance of proposed development. The fieldwork was carried out in two stages, in August and October 1998.
- 1.2 The Survey Area (centred on NGR 508150 346900) comprises an elongated triangular block of land, some 9 ha in extent, divided into two fields (OS Fields 2100 and 0064) by an (east-west) agricultural drain, bounded on the west by a railway line, on the east by the New River Slea, and by Bonemill Lane on the north. The location is shown on Fig. 1.
- 1.3 The solid geology is mapped as Oxford Clay. The land is generally flat, at 11 - 12.5 m AOD.
- 1.4 Although no sites of archaeological significance have been recorded from the survey area itself, cropmarks of a possible Romano-British settlement site and Roman road have been recorded within the adjacent field to the west, on the opposite side of the railway line (centred on NGR 507960 347050), with further cropmark enclosures c.600 m to the north (centred on NGR 508500 347800), and the suspected site of a later prehistoric or Romano-British settlement revealed during an archaeological evaluation to the south of the survey area, within the angle formed by the railway line and the Old River Slea (LAS 1996).
- 1.5 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 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 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. Two areas (totalling 0.9 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 5 SI intervals. Magnetometer data have been presented as grey scale and stacked trace (raw data) plots (Figs. 4 & 5); an interpretation of results is shown on Fig. 6, and an overview on Fig. 7.

3. SURVEY RESULTS

TOPSOIL MAGNETIC SUSCEPTIBILITY SURVEY (Fig. 3)

- 3.1 913 *in situ* magnetic susceptibility readings were recorded. Susceptibility is reported in SI: volume susceptibility units ($\times 10^{-5}$), 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 7 and 73 ($\times 10^{-5}$) SI units. The mean for the survey was 22.1 SI units and the standard deviation calculated against the mean was 11.1 SI units.
- 3.3 For the most part the topsoil magnetic susceptibility map shows subtle variations which are typical of an arable landscape, much of the patterning being orthogonal to the existing agricultural alignments. However, an area of just over 1 ha along the extreme northern edge of the survey area, approaching Bonemill Lane, shows a marked increase in topsoil magnetic susceptibility, with soil levels measuring above 40 SI north of northing 347350, where the topsoil magnetic susceptibility map suggests a former east-west field boundary which would once have further subdivided the modern field (OS Parcel 2100). The strong patterning also extends southwestwards within a corridor some 60 - 70 m in width within the western third of this field, suggesting some further anthropogenic modifications to the soils, perhaps associated with a further former agricultural boundary.
- 3.4 Investigation of one of the stronger areas of topsoil magnetic enhancement by detailed magnetometer (gradiometer) survey (Area 1 below) demonstrated the presence of numerous linear anomalies (from former ditches). At least one of these linears coincides with an interface between magnetically enhanced topsoils noted to the southwest (see 3.3 above).
- 3.5 Subtle increases in topsoil magnetic susceptibility were also mapped within the southern tip of the site, although the apparent 'focus' visible at the extreme tip may be the result of more recent activity/clearance etc, which is often typical of an isolated/less accessible part of a field. Detailed gradiometer survey revealed a number of possible pit forms (Area 2 below).
- 3.6 The majority of the remaining central part of the survey area proved unremarkable magnetically.

MAGNETOMETER (GRADIOMETER) SURVEY (Figs. 4 - 6)

- 3.7 The survey area was scanned by gradiometer on 25 m traverses. Gridded gradiometer survey was carried out in two areas, totalling 0.9 ha; their location is shown on Fig. 2.

AREA 1

- 3.8 Six contiguous 30 x 30 m (0.54 ha) survey boxes were sited to investigate an area of topsoil magnetic enhancement in an area where gradiometer scanning had also indicated a number of subtle magnetic anomalies.
- 3.9 The gradiometer revealed the presence of a number of silted linear features (former ditches), the majority on a southwest-northeast alignment which is not dissimilar from the present agricultural landscape.
- 3.10 Several further anomalies suggestive of small (generally 1 - 2 m diameter) pits are also present, although it is possible that a number of these may have been generated by more deeply buried ferrous material. There is a suggestion of some 'grouping' of magnetic anomalies within the area ringed on Fig. 6, situated immediately northwest of the electricity pole. Although the pattern is generally incoherent possible geometry, resembling enclosures, may be suggested by some of the weaker elements; the pattern is too disjointed to confidently suggest an area with archaeological potential.
- 3.11 Cultivation marks (ploughing striations) are visible running across the whole of the gradiometer survey area on a general east-west trend. A light litter of ferrous debris is visible across the survey area.

AREA 2

- 3.12 Two 60 x 30 m (0.36 ha) survey boxes were sited to investigate topsoil magnetic enhancement within the southern tip of the survey area.
- 3.13 With the exception of two southwest-northeast linears at the extreme southern edge of the survey area, which are clearly related to the modern agricultural regime (marked as the edge of cultivation on Fig. 6), no further evidence for linear 'cut' features was recorded. However, a number of magnetic anomalies were plotted which suggest the presence of pit-like features, showing some evidence for 'grouping' towards the north of the survey box.
- 3.14 There is a light litter of ferrous material, consistent with an arable landscape.

SURFACE OBSERVATION

- 3.15 A single Romano-British pottery sherd was observed on the field surface within the northern field during the course of the survey, at NGR 508200 346990.

4. CONCLUSIONS

- 4.1 A combination of topsoil magnetic susceptibility mapping and magnetometer (gradiometer) survey has revealed a series of intrusive features, principally linears (ditches) within the northern part of the survey area. Their alignments generally reflect those of the modern landscape, although they appear to have been long-established, as they reflect the former course of the River Slea, which runs parallel and 50 - 80 m distant from the eastern boundary of the survey area. It is possible that the persistence and regularity of these linears, apparently grouped in twos or threes, may indicate (on morphological grounds) a common agricultural origin. However, the presence of a series of extremely subtle anomalies clustered within the north of Area 1 could indicate an area of further (unrelated) activity; the potential for underlying archaeological horizons associated with subtle intrusions in this locality is reinforced by the evidence of the topsoil magnetic susceptibility map.
- 4.2 The southern tip of the survey area shows sporadic activity, mostly in the form of pits or pit-like features, although there is nothing in their pattern or distribution to suggest that they are necessarily associated with a pattern with archaeological significance.
- 4.3 Within the central part of the site, no further magnetic evidence was indicated by either topsoil magnetic susceptibility mapping or gradiometer survey (either scanning or more detailed survey) to indicate the presence of underlying occupation or settlement foci, although it is conceivable that features with weakly susceptible fills producing few magnetic contrasts may be present.

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ACKNOWLEDGEMENTS

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

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).

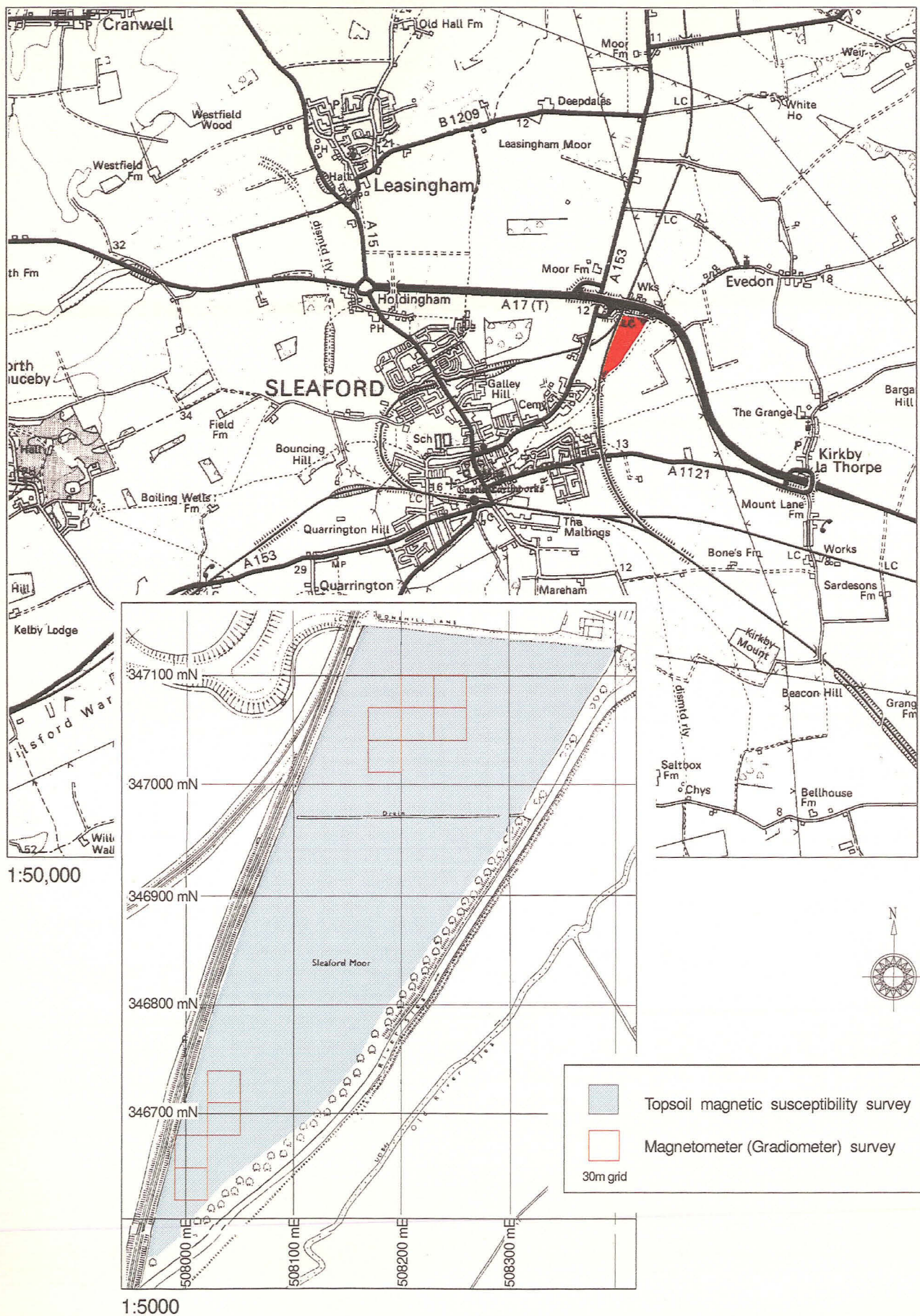
- A1.10 The precise physical and chemical processes of changing soil magnetism are extremely complex and subject to innumerable variations. In general terms, however, there is no doubt that magnetic enhancement of soils by human activity provides valuable archaeological information.
- A1.11 As well as 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 0846 & 0847.
- Figure 2. Location of survey grids. Based upon OS 1:2500 Sheets TF 0846 & 0847.
- Figure 3. Topsoil Magnetic Susceptibility Colour Shade Plot. Scale 1:2500.
- Figure 4. Magnetometer (gradiometer) survey. Areas 1 & 2: grey shade plots. Scale 1:1000.
- Figure 5. Magnetometer (gradiometer) survey. Areas 1 & 2: stacked trace (raw data) plots. Scale 1:1000.
- Figure 6: Magnetometer (gradiometer) survey. Areas 1 & 2: interpretation. Scale 1:1000.
- Figure 7. Topsoil magnetic susceptibility mapping and magnetometer (gradiometer) survey: overview. Scale 1:2500. Based upon OS 1:2500 Sheets TF 0846 & 0847.

Bonemill Lane, East Road, Sleaford, Lincolnshire

Topsoil magnetic susceptibility & magnetometer survey: location



Bonemill Lane, East Road, Sleaford, Lincolnshire

Magnetometer (Gradiometer) survey: location

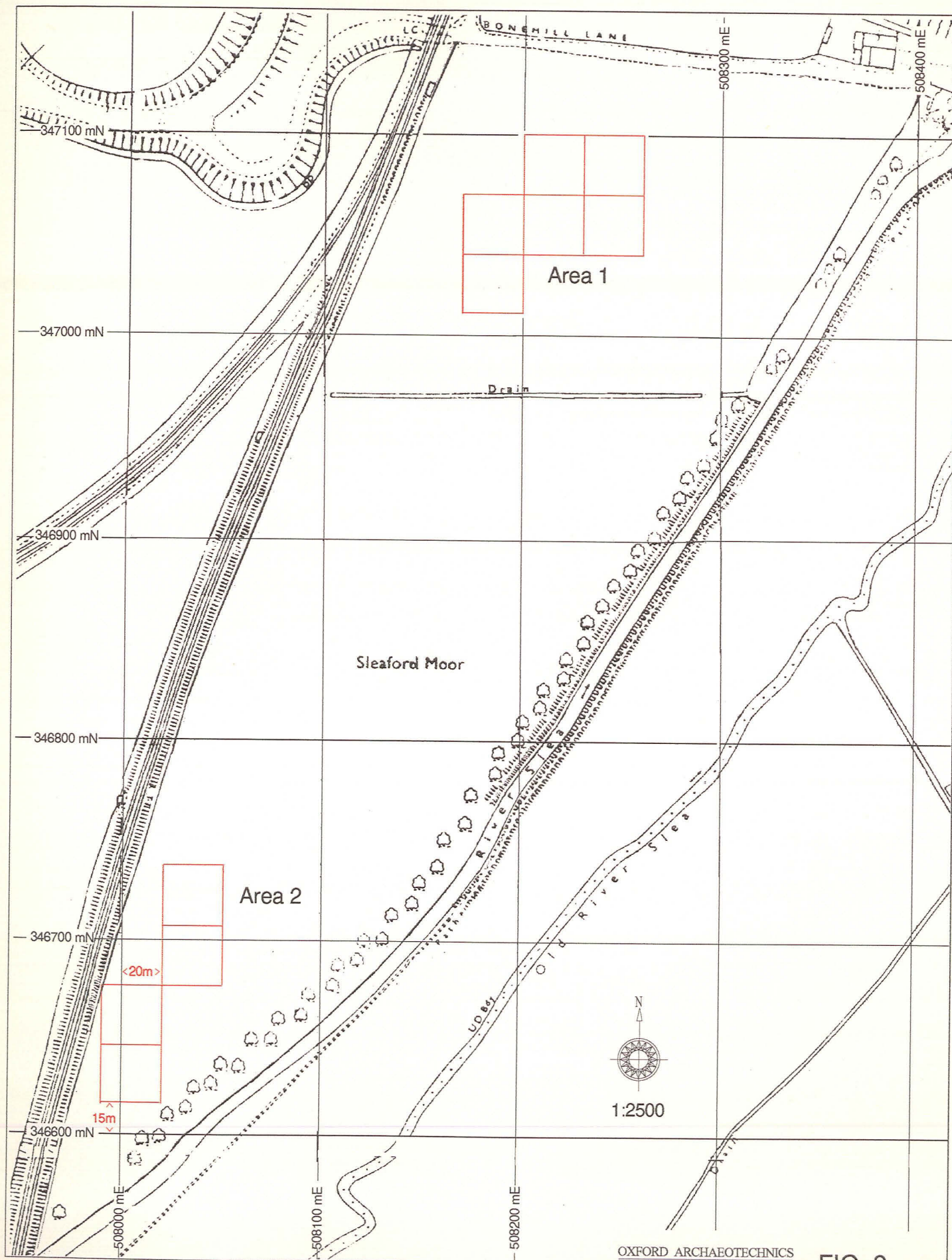
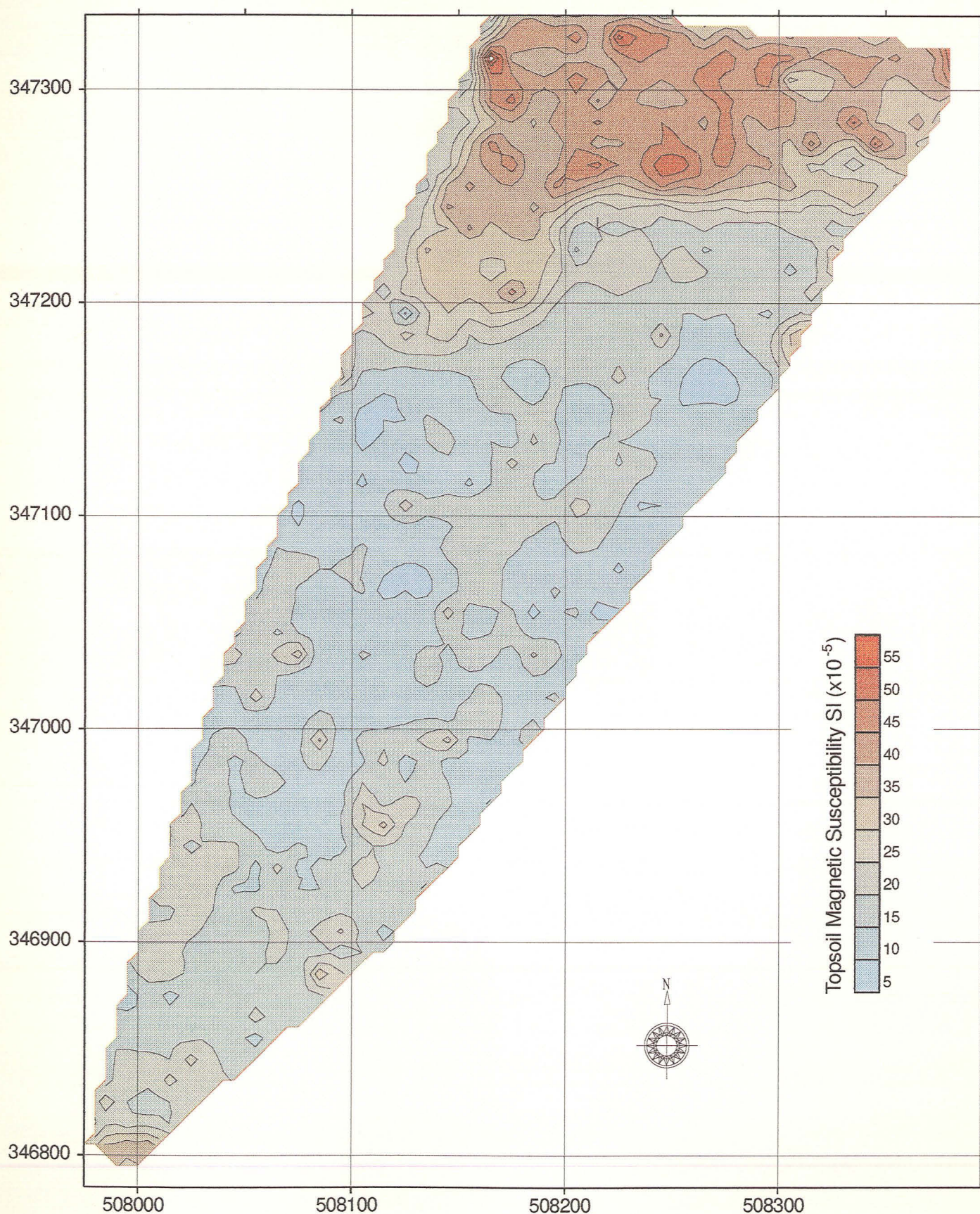


FIG. 2

Bonemill Lane, East Road, Sleaford, Lincolnshire

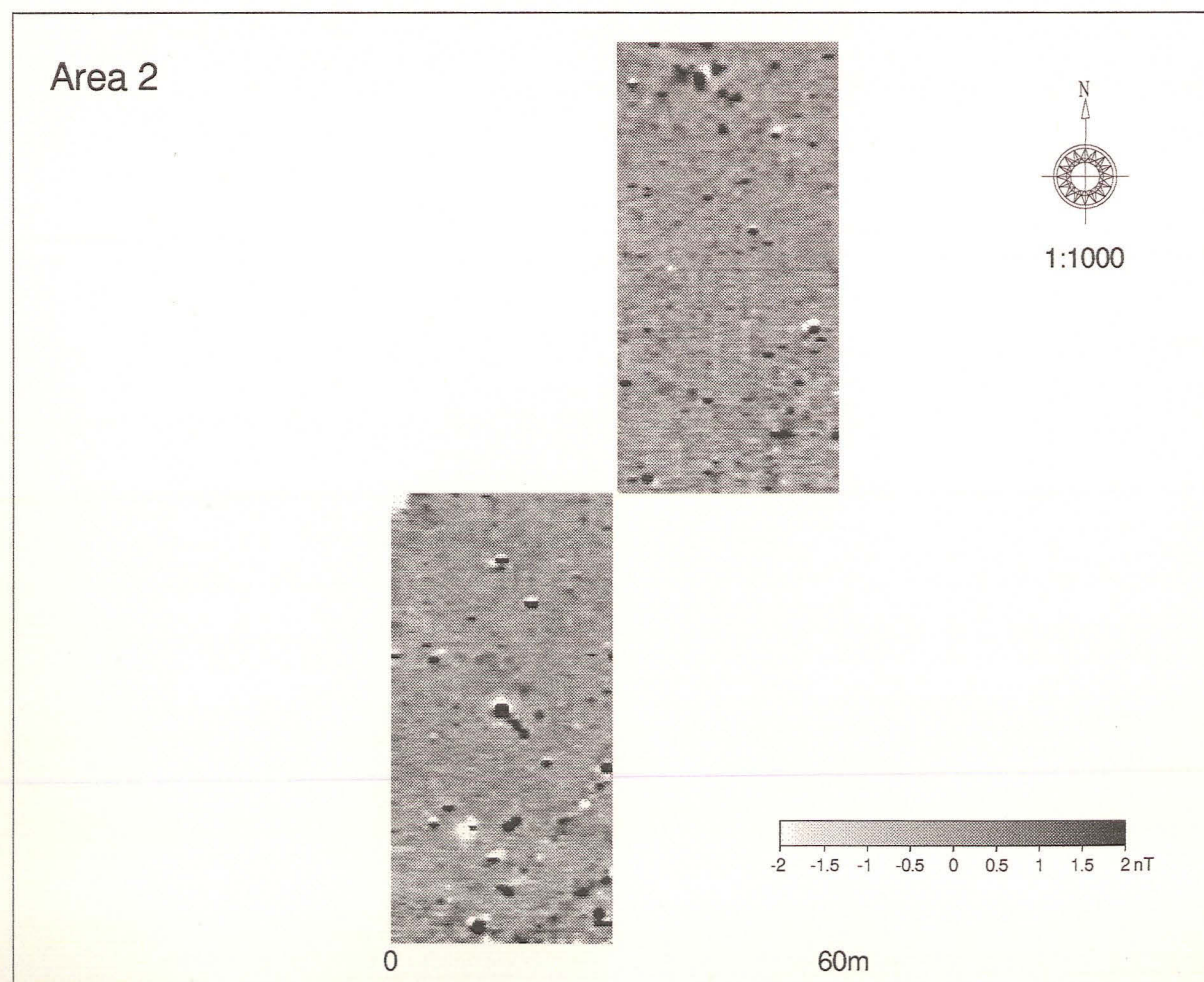
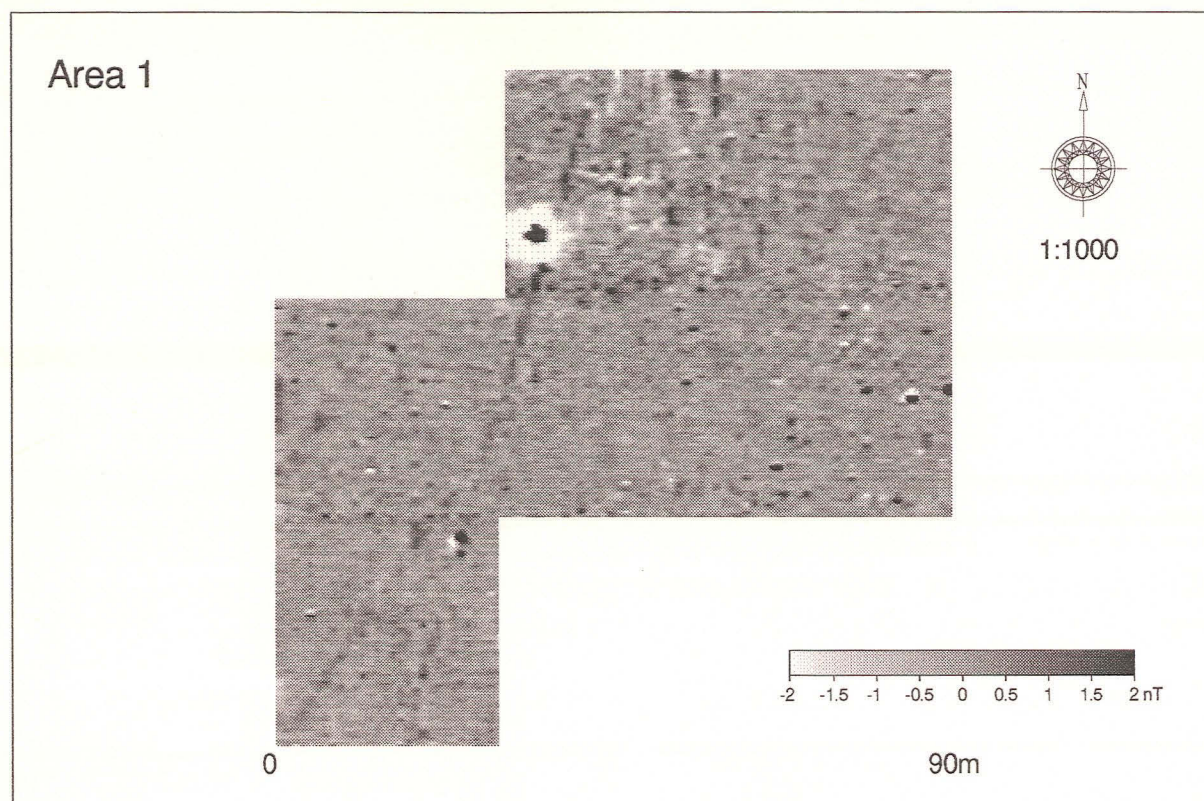
Topsoil Magnetic Susceptibility Colour Shade Plot



Bonemill Lane, East Road, Sleaford, Lincolnshire

Topsoil magnetic susceptibility & magnetometer survey

Magnetometer (gradiometer) grey shade plots

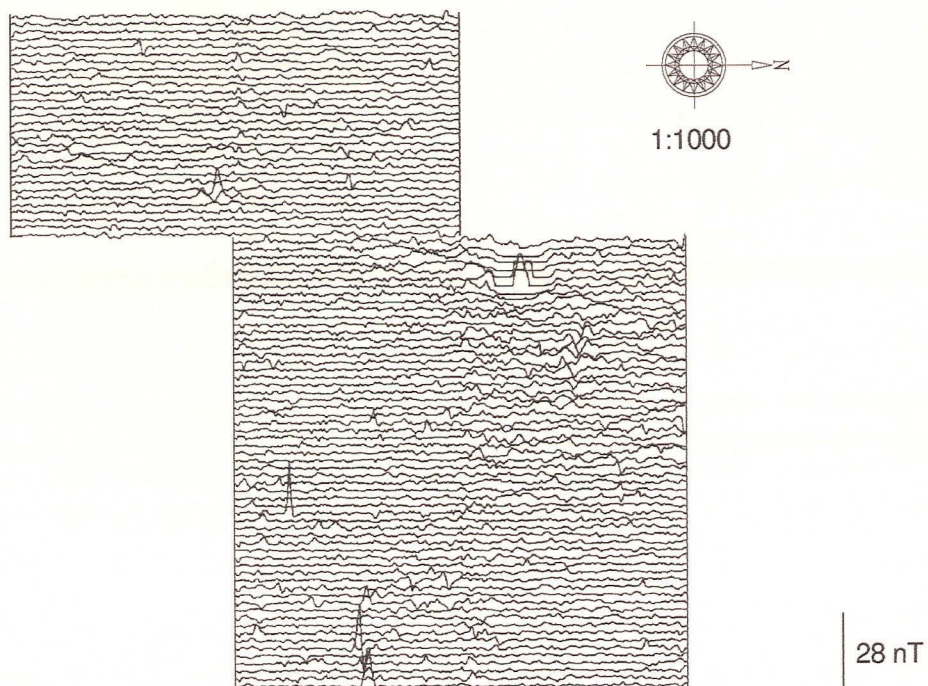


Bonemill Lane, East Road, Sleaford, Lincolnshire

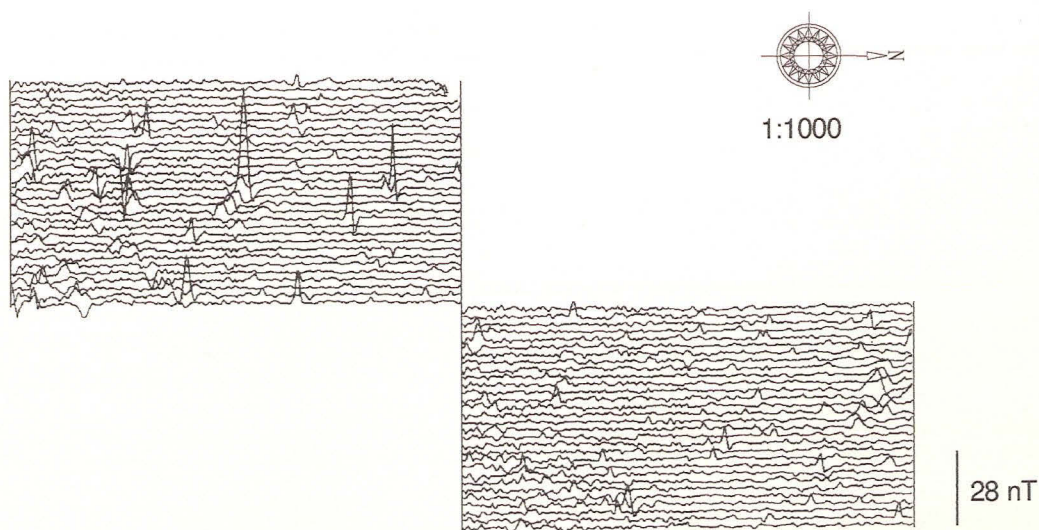
Topsoil magnetic susceptibility & magnetometer survey

Magnetometer (gradiometer) stacked trace plots (raw data)

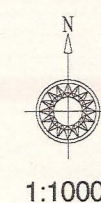
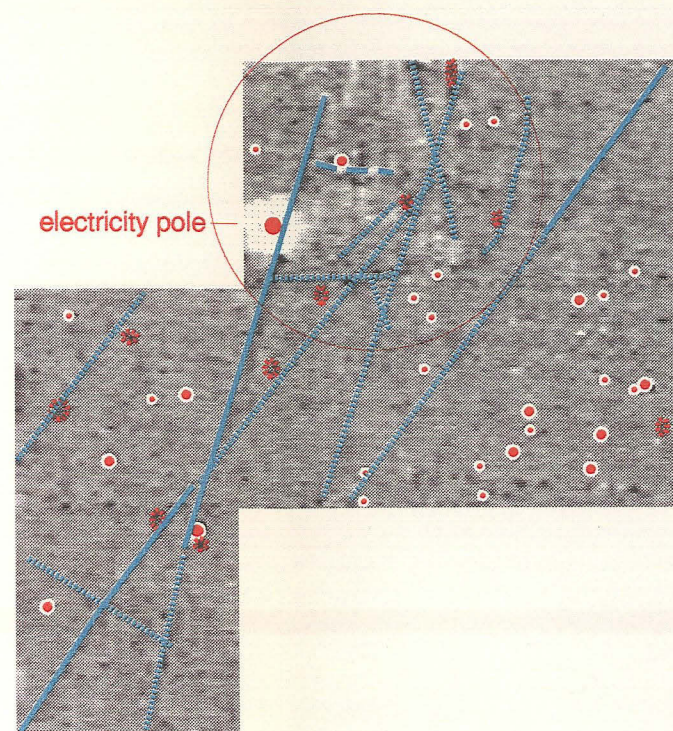
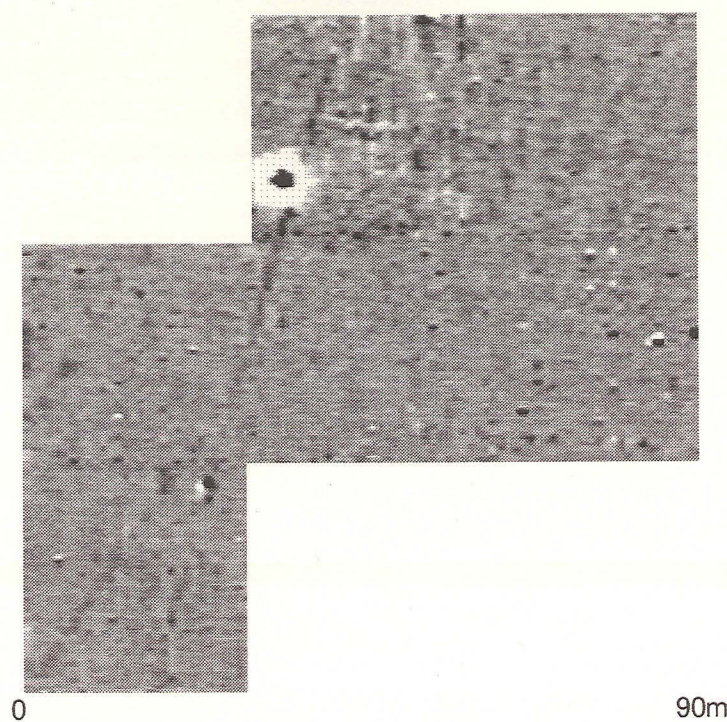
Area 1



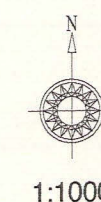
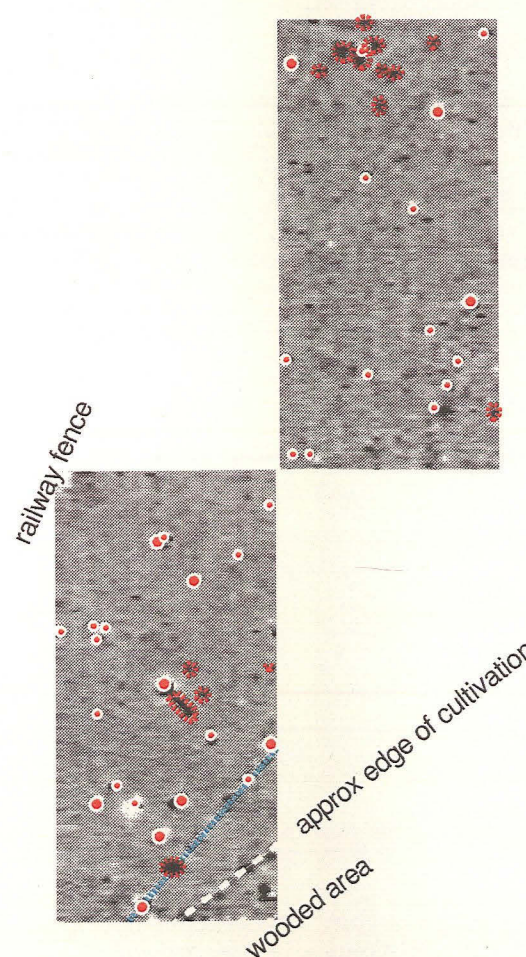
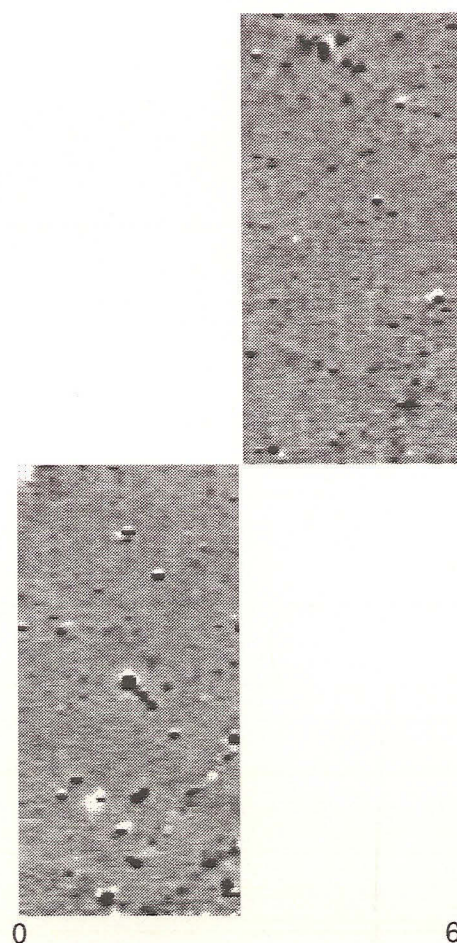
Area 2



Area 1



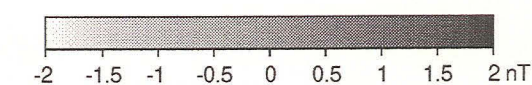
Area 2



Bonemill Lane, East Road Sleaford, Lincolnshire Gradiometer interpretation

Interpretation

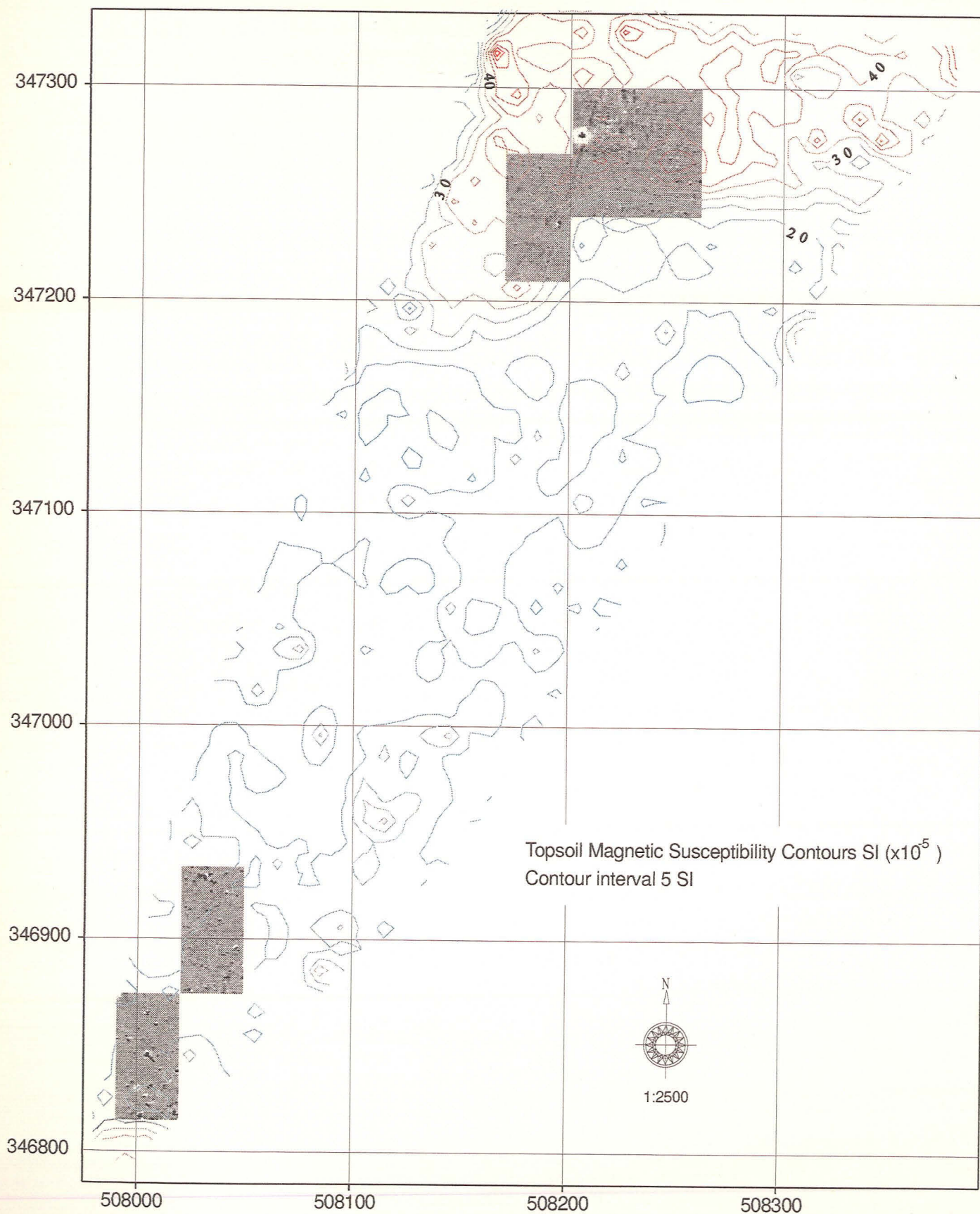
- Linear and curvilinear features
 - Positive anomaly
 - Negative anomaly
- Possible pits
- Weak linear and curvilinear features, including agricultural striations
- Ferrous material (main concentrations)
- Irregular areas of disturbed ground and pitting



Bonemill Lane, East Road, Sleaford, Lincolnshire

Topsoil Magnetic Susceptibility and Gradiometer Survey

Overview



INTERNAL QUALITY CHECK

Survey Reference	1570898 / SLL / LAS	
Primary Author	AG	Date 23/11/98
Checked By	APJ	Date 23.11.98
Checked By		Date
Further Corrections		Date

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