# LAND AT BRACEBRIDGE HEATH, LINCOLN

*Topsoil Magnetic Susceptibility and Gradiometer Survey*

(Survey Ref : 1490498/BRL/HEL)

APRIL 1998

Produced by
**OXFORD ARCHAEOTECHNICS LIMITED**

under the direction of
**A.E. Johnson *BA(Hons)***

Commissioned by
Heritage Lincolnshire

on behalf of
Westbury Homes

OXFORD ARCHAEOTECHNICS

# Specialist Archaeological Field Evaluation

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# CONTENTS

## *SUMMARY*

*A geophysical evaluation programme comprising topsoil magnetic susceptibility mapping and gradiometer survey was carried out on 1.8 ha area of land at Bracebridge Heath, Lincoln (centred on NGR 498250 367500) in advance of proposed residential 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 survey suggested some patterns of former landuse and a single focus of increased topsoil magnetic susceptibility which appears to be related to a probable (relatively recent) burning episode associated with a concentration of ferrous material. Detailed gridded magnetometer (gradiometer) survey located two probable pits, together with a series of weak lineations, probably of agricultural origin.*

## 1. INTRODUCTION

1.1 Geophysical survey was commissioned by Heritage Lincolnshire on behalf of Westbury Homes on land situated on the northeastern outskirts of the village of Bracebridge Heath, east of Sleaford Road, approximately 4 km south of Lincoln, in advance of proposed residential development. The fieldwork was carried out in April 1998.

1.2 The proposed development area (centred on NGR 498250 367500) comprises a single rough pasture field (1.8 ha in extent) to the south of St. John's Hospital. The location is shown on Fig. 1.

1.3 Although no sites or finds of archaeological significance have been recorded from the survey area, several findspots of Roman material (coins, pottery & tile, burials and a possible kiln) have been recorded from the village of Bracebridge Heath, suggesting the site of a Romano-British settlement. The course of a major Roman road (Ermine Street) runs through the village less than 300 m west of the survey area.

1.4 The survey area lies upon a Jurassic limestone escarpment. Topsoils (Elmton 1 Association) were generally shallow (c.25 cm in depth), interfacing abruptly with the underlying limestone bedrock. The land was level, at c.72 m AOD.

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 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 Gradiometer scanning confirmed an area of approximately 1 ha to be relatively free from modern ferrous disturbance, which was 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. 2B) shows contours at 10 SI intervals. Magnetometer data have been presented as grey scale and stacked trace (raw data) plots (Figs. 3 & 4), and an interpretation of results is shown on Fig. 5.

## 3. SURVEY RESULTS

### TOPSOIL MAGNETIC SUSCEPTIBILITY SURVEY (Fig. 2B)

3.1 173 *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 17 and 128 (x $10^{-5}$) SI units, the higher readings reflecting dispersed modern debris. The mean for the survey was 38 SI units and the standard deviation calculated against the mean was 14 SI units.

3.3 Marked increases in topsoil magnetic susceptibility within western and southwestern periphery of the survey area are probably attributable to the incorporation into the topsoils of material dispersed from adjacent modern sources, particularly footpaths.

3.4 A small focus of magnetic enhancement situated close to the northern boundary of the survey area exceeding 50 SI units was shown by subsequent gradiometer survey to lie within an area containing quantities of ferrous material, indicative of probable relatively recent disturbance.

3.5 Within the core of the survey area, which showed little obvious evidence for modern disturbance, more subtle anthropogenic modifications relating to former landuse are visible, producing patterns which appear to relate to former cultivation, or possibly former field/property boundaries.

## MAGNETOMETER (GRADIOMETER) SURVEY

3.6 Gridded gradiometer survey was carried out in an area measuring 150 x 60 m with an additional 60 x 30 m area appended to its northwest corner (1.1 ha); the location is shown on Fig. 2A.

3.7 The resulting plot is generally unremarkable, the majority of the magnetic anomalies being weak lineations suggestive of former agricultural activity scarring the underlying bedrock.

3.8 At one location, two anomalies suggesting the presence of more substantial 'pit-like' intrusions were recorded. These features appear to contain no ferrous or other obviously recent magnetic debris and may therefore be regarded as having some archaeological potential.

3.9 A litter of ferrous debris was recorded over much of the site, with some local concentrations perhaps suggesting areas of superficial disturbance. The greatest concentration was recorded in the vicinity of the area of increased topsoil magnetic susceptibility at the northern edge of the site, contained within a roughly circular area some 2.5 m in diameter; there is a suggestion of a shallow curvilinear anomaly which may mark the easternmost 'containment' of this concentration of material. It should be noted that the topsoil magnetic susceptibility increase at this location is essentially unrelated to the ferrous material, and is more likely to be the result of a former burning episode. The combination of ferrous material and increased soil susceptibility would tend to favour a relatively recent date, although the possibility of the presence of material having some archaeological significance cannot be entirely discounted.

## 4. CONCLUSIONS

4.1 The combination of magnetic techniques (topsoil magnetic susceptibility mapping and magnetometer survey) has not indicated the presence of any substantial 'cut' features of potential archaeological significance, and in general, the magnetic evidence suggests a low level of archaeological potential on the site. Apart from two probable pit forms, and perhaps an associated area of disturbance, the majority of the magnetic anomalies appear to relate to the former cultivation pattern.

4.2 As topsoil magnetic susceptibility mapping indicated locally good magnetic contrasts between the topsoils and the underlying limestone, it is anticipated that had any significant concentrations of underlying features been present which might represent a former focus of activity or settlement site (particularly of later prehistoric or Romano-British date), they should have been visible to the gradiometer, although it should be noted that magnetically 'clean' features containing little or no anthropogenically enhanced material such as prehistoric burial sites, or insubstantial limestone wall footings, would generally prove more elusive.

## REFERENCES


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GALE, S.J. & HOARE, P.G. 1991. *Quaternary Sediments: petrographic methods for the study of unlithified rocks.* Belhaven Press: London (see Section 4.7, pp.201-229, "The magnetic susceptibility of regolith materials").

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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: F. Eckardt *BSc, PhD.*

## 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 1:10,000. Based upon OS 1:50,000 Map 121, and OS 1:10.000 Sheet SK 96 NE.

Figure 2. A: Location of magnetometer (gradiometer) survey grids.
B: Topsoil magnetic susceptibility map. Scale of both, 1:2500.

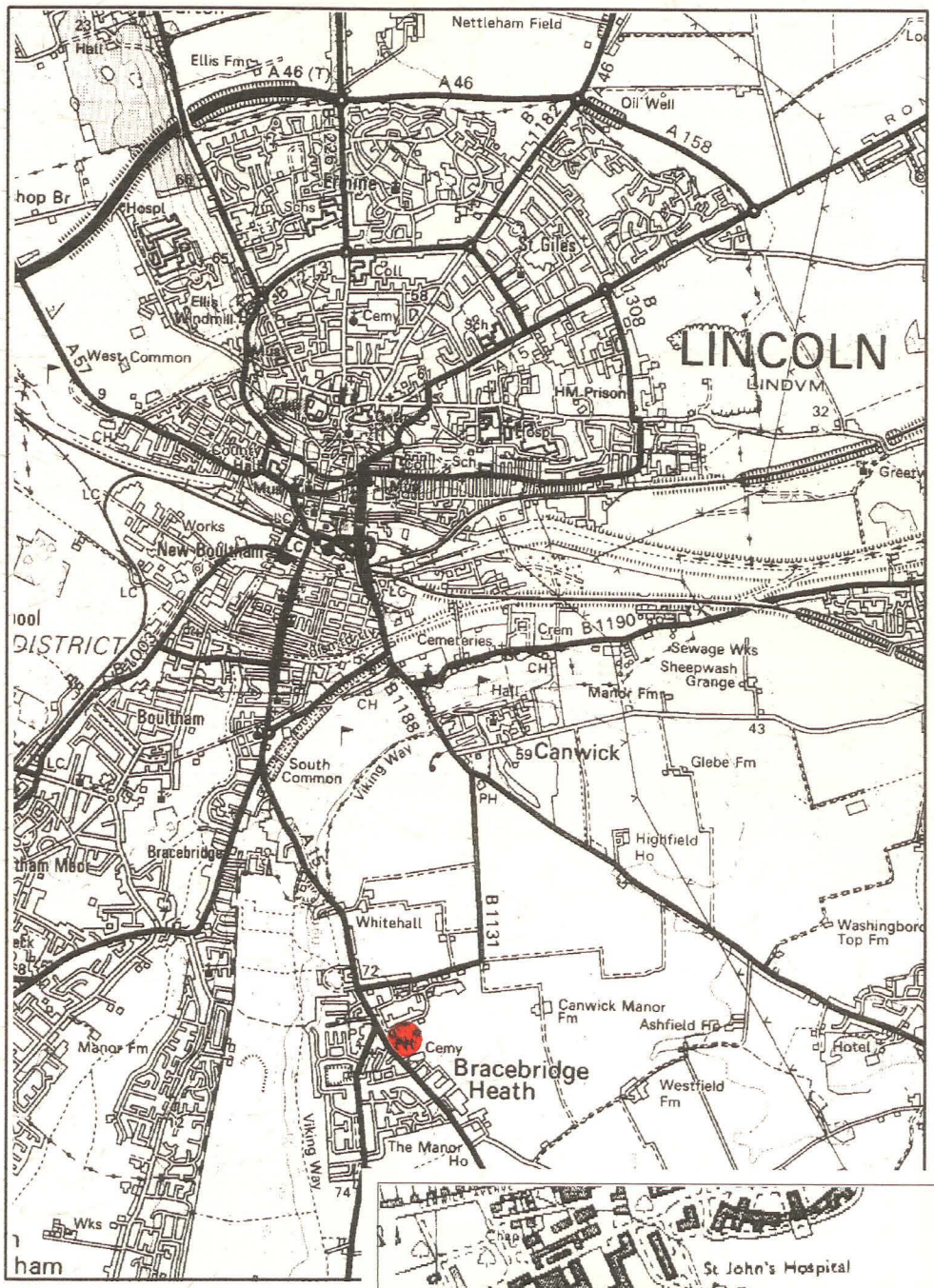
Figure 3. Magnetometer (gradiometer) survey: grey shade plot (Geoscan Research Geoplot Licence No. GPB 885-6). Scale 1:1000.

Figure 4. Magnetometer (gradiometer) survey: stacked trace plot: raw data (Geoscan Research Geoplot Licence No. GPB 885-6). Scale 1:1000.

Figure 5. Magnetometer (gradiometer) survey: interpretation (Geoscan Research Geoplot Licence No. GPB 885-6). Scale 1:1000.

# Land at Bracebridge Heath, Lincoln

Archaeological geophysical investigation (topsoil magnetic susceptibility & magnetometer survey)

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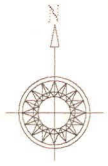
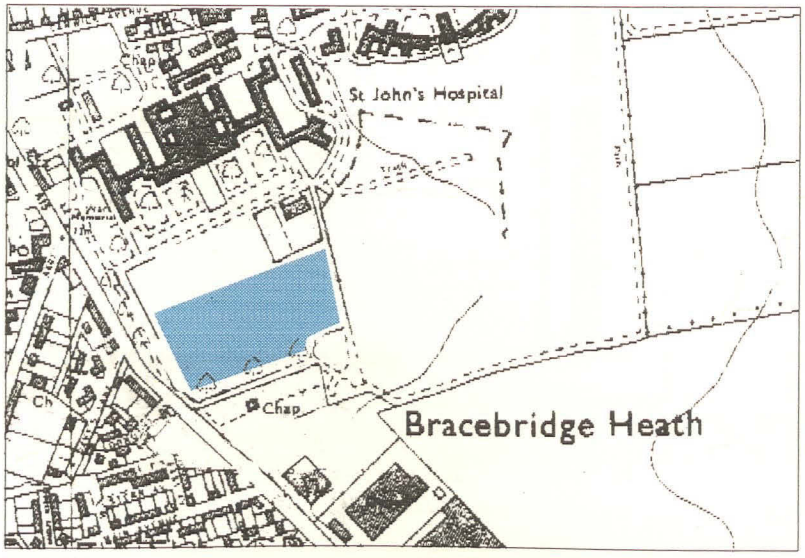


Location




1:10,000

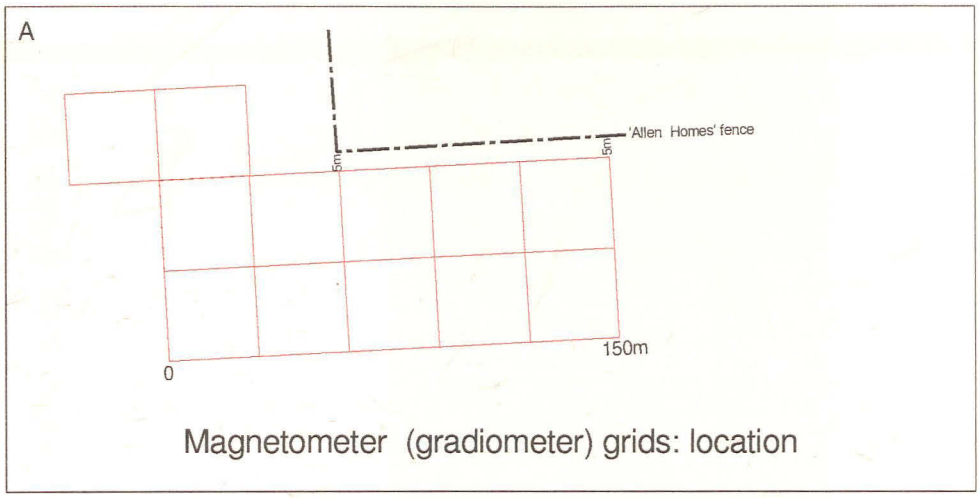
OXFORD ARCHAEOTECHNICS FIG. 1

# Land at Bracebridge Heath, Lincoln

Archaeological geophysical investigation (topsoil magnetic susceptibility & magnetometer survey)

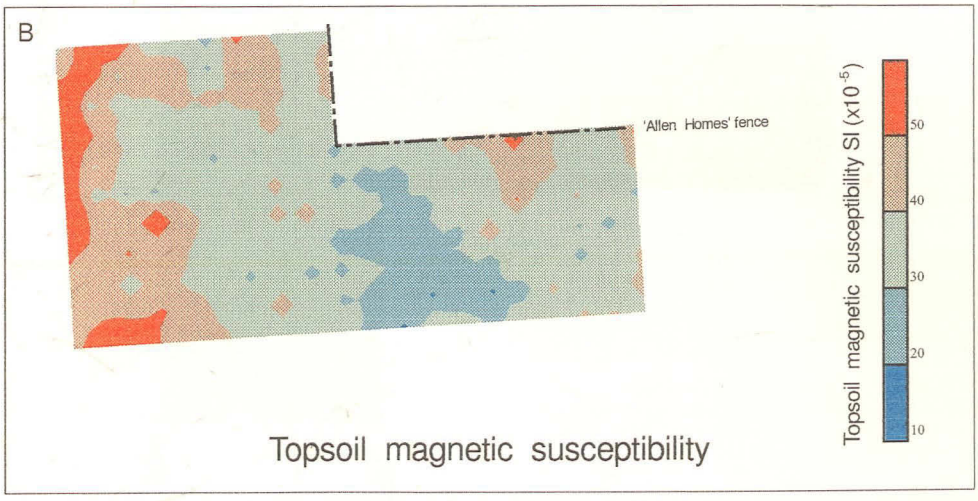
A: Magnetometer (gradiometer) survey: location

B: Topsoil magnetic susceptibility map





Scale 1:2500




OXFORD ARCHAEOTECHNICS FIG. 2

# Land at Bracebridge Heath, Lincoln

Archaeological geophysical investigation (topsoil magnetic susceptibility & magnetometer survey)

## Magnetometer (gradiometer) survey: grey shade plot

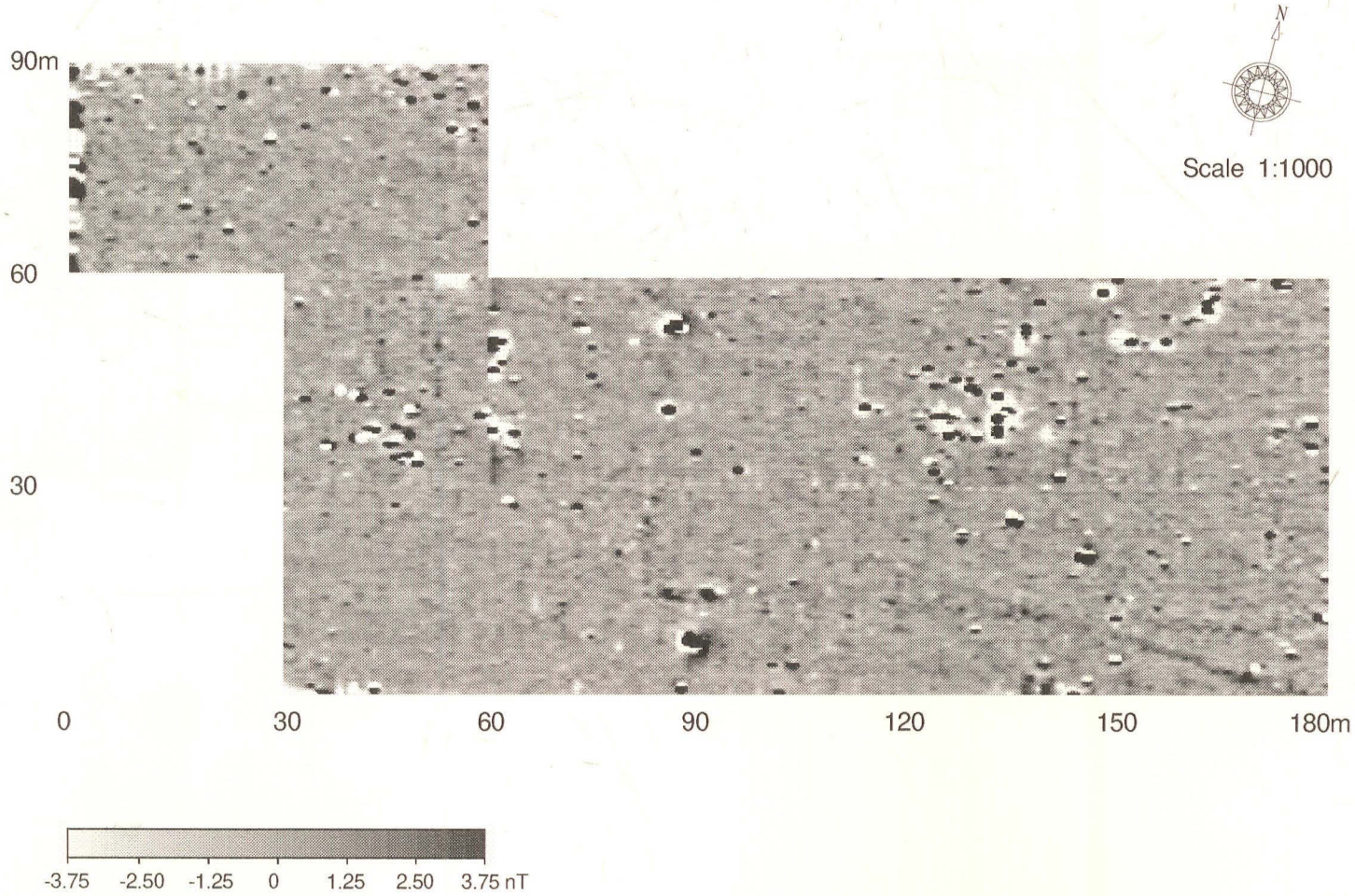



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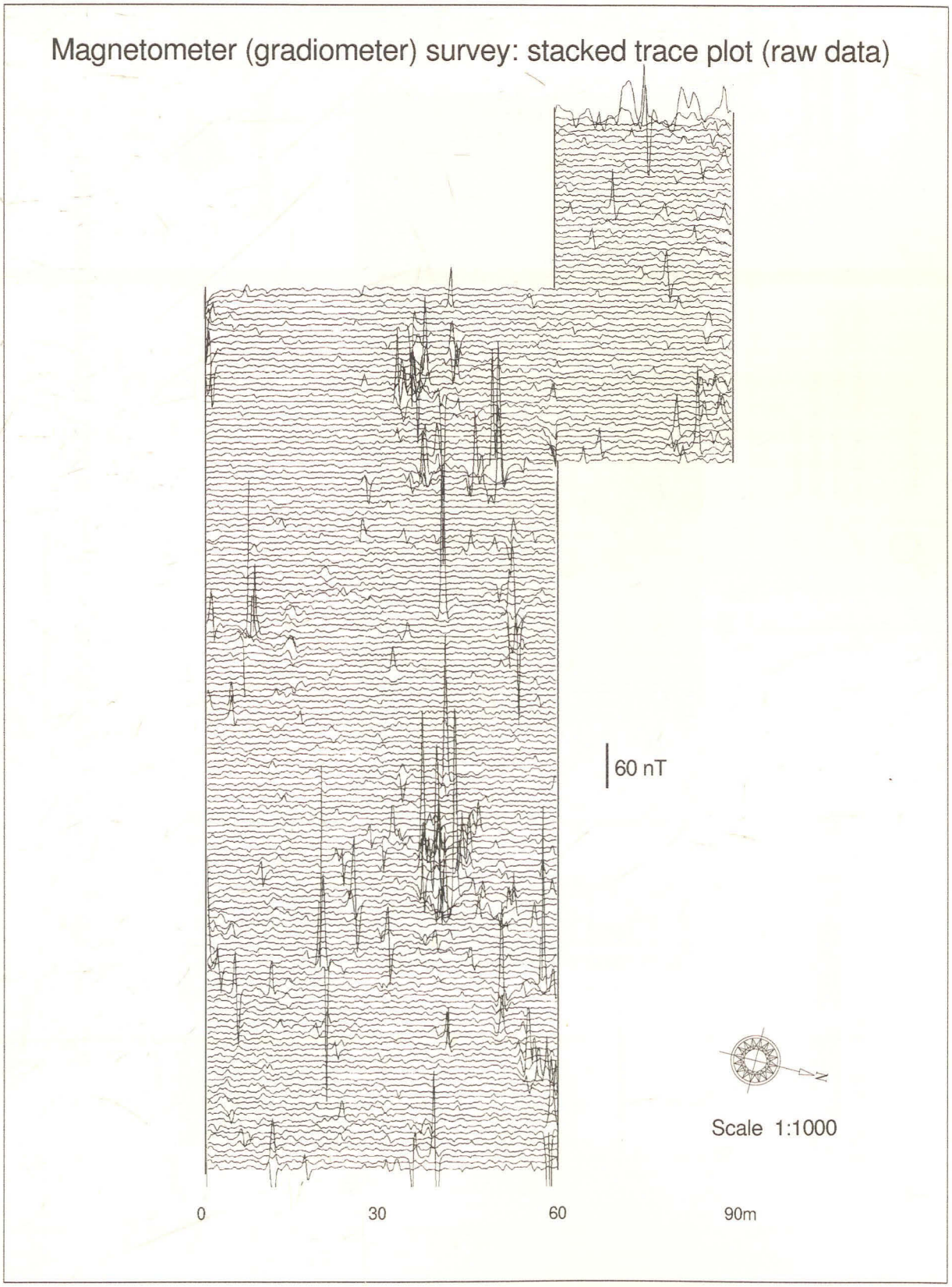
FIG. 3

# Land at Bracebridge Heath, Lincoln

Archaeological geophysical investigation (topsoil magnetic susceptibility & magnetometer survey)




OXFORD ARCHAEOTECHNICS FIG. 4

# Land at Bracebridge Heath, Lincoln

Archaeological geophysical investigation (topsoil magnetic susceptibility & magnetometer survey)

## Magnetometer (gradiometer) survey. Grey shade plot: interpretation

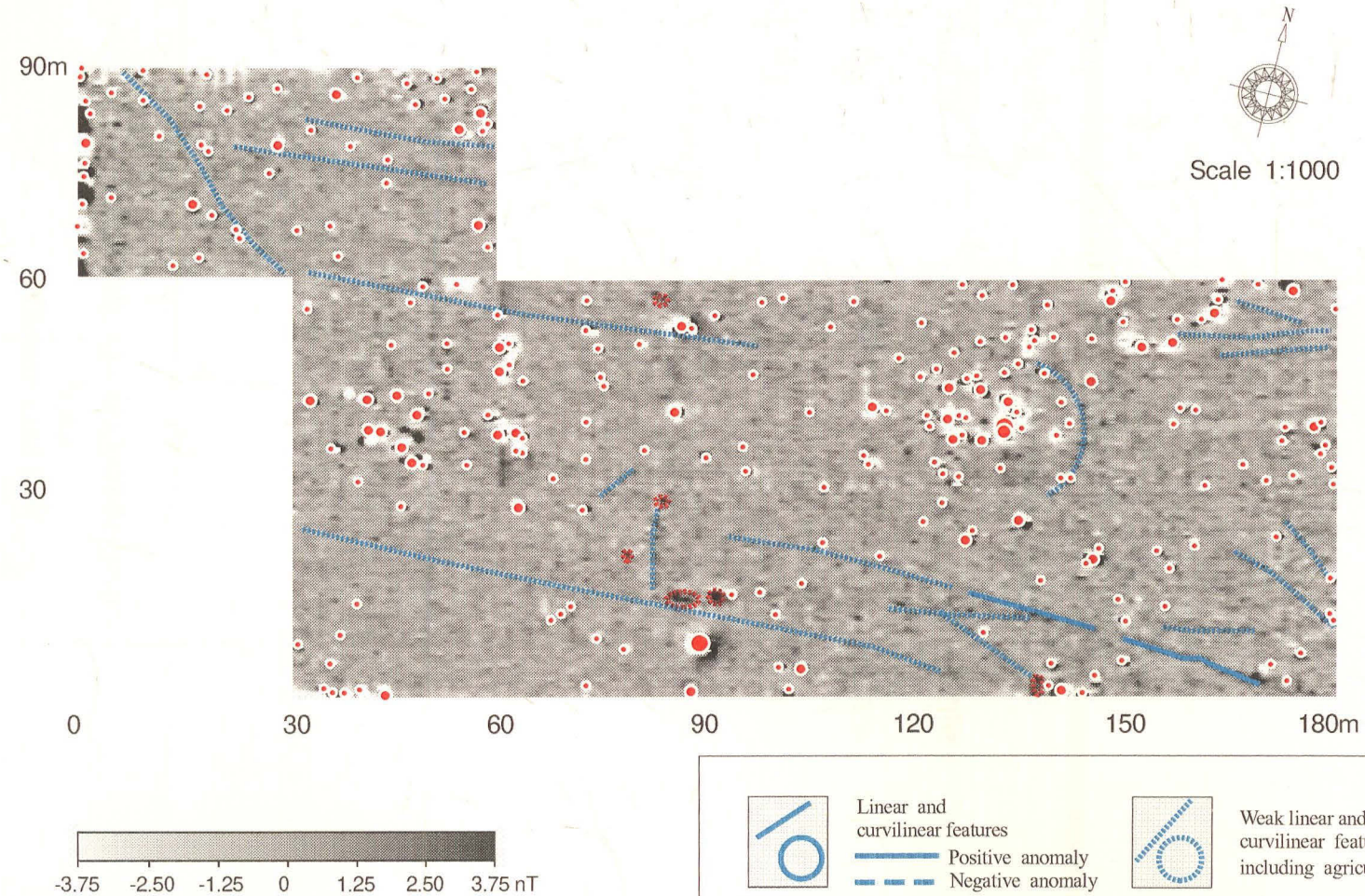



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FIG. 5

# INTERNAL QUALITY CHECK

| | | | |
|---|---|---|---|
| Survey Reference | 1490498 / BRL / HEL | | |
| Primary Author | | Date | |
| Checked By | APJ | Date | 23-4-98 |
| Checked By | | Date | |
| Further Corrections | | Date | |

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