Holme Lane

Messingham

Geophysical survey

MISC333

December 2006

Client

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Executive Summary

Met Surveys was commissioned by Mr. William Foster-Thornton to carry out a combined magnetometry and resistance survey on land at Holme Lane, Messingham. The survey was undertaken to locate and characterise any sub-surface features of archaeological potential such that an informed assessment on the impact of any proposed development may be completed.

The survey area covers approximately 8ha and is located over pasture. There is considered to be high archaeological potential within the site, with widespread evidence of multi-period occupation and activity evidenced through cropmarks

A high-pressure gas main has been detected running through the southern part of the survey area. This service was identified by markers in adjacent fields.

Features which may relate to past palaeochannels or glacial scouring have also been discovered. A possible glacial moraine feature is located in the eastern part of the field, but does not fall within any survey area.

Very weak sub-rectangular and circular anomalies detected in Area 1 (Anomalies 1 and 2) may reflect soil-filled features such as ditches or gullies and possibly represent enclosures, although these could also result from animal disturbance.

Clusters of anomalies which may reflect pits have been detected in many of the survey areas. Some of these anomalies may reflect disturbance due to animal burrowing, however Anomalies 3 – 6 in Area 1 which seem to be associated with areas of dipolar magnetic enhancement (possible examples of thermoremanant magnetisation where materials heated above a certain temperature become remagnetised according to the prevalent magnetic field alignment upon cooling; usually this is the Earth's field in most archaeological cases) and clusters of intensely positive anomalies (Anomalies 17 and 18) in Area 4 are more likely to reflect significant features.

Linear and circular areas of high resistance detected in Area A may reflect subsurface features (Anomalies 21 and 22). Extreme waterlogging in this area has made interpretation difficult, and these features may reflect conventional high resistance features such as compacted areas or concentrations of stone; alternatively they may represent infilled features with deposits less conductive than the saturated topsoil.

Features detected in Area B are likely to reflect a combination of shallow features due to animal disturbance and possible geological effects. Linear low resistance features and a high resistance feature (Anomalies 25 and 26) may reflect significant subsurface features such as some form of banked ditch with Anomaly 24 and Anomalies 27-30 possibly reflecting areas of compaction, eroded banks or stony spreads; however they may equally be due to undulations in the natural bedrock or dumped glacial deposits.

The results and subsequent interpretation of data from geophysical surveys should not be treated as an absolute representation of the underlying archaeological and non-archaeological features. Features that do not produce a measurable geophysical response or those masked by other features may not be detectable. Confirmation of the

presence or absence of features can only be achieved by direct investigation of sub-surface deposits.

Features, especially linear features, may relate to underground utility apparatus such as pipes or gas tanks. <u>Always exercise caution when excavating.</u>

1. Introduction

1.1 Met Surveys was commissioned by Mr. William Foster-Thornton to carry out a combined magnetometry and resistance survey on land adjacent to Willow Springs Coarse Fishery, on Holme Lane, Messingham, in advance of a proposal for the construction of additional coarse fishing ponds.

1.2 The site is located in the parish of Messingham, approximately 1km to the northeast of the village, and lies on land to the east of the existing fisheries, to the north of Holme Lane (NGR centre: SE9027 0532). The site comprises a single unit of land that was once cultivated but is now under rough pasture.

1.3 The drift and solid geology of the survey areas comprises blown sand, leading to light and sandy soils, overlying the Scunthorpe mudstone formation. The land lies at approximately 20m AOD, with a gentle slope rising from the northeast to southwest. There is evidence of widespread animal burrowing across the site. The site is bounded by drains to the north and west sides, the road to the south and the existing ponds with their perimeter banks to the east.

1.4 The survey was undertaken to investigate the nature and extent of any sub-surface features of potential archaeological significance within the proposed development area, so as to enable an informed assessment of the archaeological impact of the development proposals.

1.5 In accordance with the brief, 4 areas totalling 4.98ha, were surveyed using a magnetic gradiometer and 2 areas, totalling 0.72ha, were surveyed using a resistance meter. The location of the site and individual survey areas is shown in drawings MISC333_LOC.dwg and MISC333_(1).dwg.

1.6 The site code is MISC333. The project archive is currently held by Met Surveys, and will be transferred to North Lincolnshire County archive. Met Surveys is registered with the **O**nline **A**ccess**S** to the **I**ndex of archaeological investigation**S** project (**OASIS**). The OASIS ID number for this project is **metsurve1-21411**.

2. Methodology and presentation

Survey Methodology

2.1 The survey was undertaken in accordance with a Project Design provided by Met Surveys, in adherence to a Brief prepared by North Lincolnshire Council Sites and Monuments Record Office (NLSMR), and following recommendations outlined in the English Heritage Research and Professional Services Guideline No.1: Geophysical survey in archaeological evaluation (David 1995); the Institute of Field Archaeologists Paper No.6: The use of geophysical techniques in archaeological evaluations (Gaffney et al. 2002) and the Archaeology Data Service: Geophysical data in archaeology: A guide to good practice (Schmidt 2001).

2.2 Survey grid baselines were established in each of the survey areas by means of a Leica TCR 705 total station. These baselines, together with field boundaries, were then tied in to semi-permanent stations established by Met Surveys Ltd. to allow comparison with Ordnance Survey mapping and enable the survey areas to be easily relocated.

2.3 Given the high potential for archaeological remains within the area, and in view of the site geology and soils, a combination of geophysical techniques was employed. A detailed magnetometer survey was carried out across all of the survey areas, with resistance survey used to target areas where cropmarks had been recorded.

2.4 Measurements of the vertical geomagnetic field gradient were taken using a Bartington Grad601-2 magnetic gradiometer with internal data logger. The instrument was checked for electronic and mechanical drift at regular intervals. Data were logged in 20m or 30m grid units, in a zig-zag traverse pattern with a traverse interval of 1m, at a sample interval of 0.25m and at a sensitivity of 0.1nT, resulting in a total of 1800 (for a 20m) or 3600 (for a 30m) readings per grid.

2.5 Measurements of electrical resistance were determined using a Geoscan RM15D resistance meter with automatic logging of the data. A zig-zag traverse scheme was employed and data were logged in 20m grid units. The instrument sensitivity was set to 0.1ohm, the sample interval to 1m and the traverse interval to 1.0m, thus providing 400 sample measurements per 20m grid unit.

Data Processing

2.6 Geoplot v.3 software was used to process the geophysical data from the resistance and gradiometer surveys and to produce both continuous tone greyscale images and trace plots of the raw data. The data had a zero mean traverse function (grid balancing) applied where necessary. The data was also clipped and despiked, then interpolated for presentation. Some grids had a low pass filter applied to enhance weaker features.

Interpretation

2.7 The geophysical data and interpretations are presented in drawings MISC333_(2) – (6). Trace (XYZ) plots of unprocessed data (except where data has been clipped for presentation purposes) are provided in Appendix III. In the greyscale images, positive magnetic or high resistance anomalies are displayed as dark grey and negative magnetic or low resistance anomalies as light grey. A palette bar relates the greyscale intensities to anomaly values in nT/m or ohm.

2.8 Colour-coded geophysical interpretation plans are provided. Anomaly types which may be distinguished in the data fall into these categories:

positive magnetic	regions of anomalously high or positive magnetic field gradient, which may be associated with high magnetic susceptibility soil-filled structures such as pits and ditches (*linear trends or areas of enhanced response*). Pedological variations or natural geomorphological features, such as palaeochannels or infilled natural features on certain geologies, can also produce areas of magnetic enhancement. Some naturally occurring geologies, for example igneous and metamorphic rock types, also give a strong positive response; fragments of such rocks in mixed deposits can sometimes result in discrete positive anomalies being detected.
negative magnetic	regions of anomalously low or negative magnetic field gradient, which may correspond to features of low magnetic susceptibility such as wall footings and other concentrations of sedimentary rock or voids (*linear trends or areas of enhanced negative response*).
dipolar magnetic	paired positive-negative magnetic anomalies, which usually reflect ferrous or fired materials (e.g. fences and service pipes) and/or fired structures such as kilns or hearths, as well as often signifying areas of disturbance involving fired and ferrous material e.g. building rubble (*isolated or concentrations of responses*).
high resistance	regions of anomalously high resistance, which may reflect foundations, tracks, paths and other concentrations of stone or brick rubble.
low resistance	regions of anomalously low resistance, which may be associated with soil-filled features such as pits and ditches.

2.9 A more detailed technical summary on the theory and survey methodology of resistance survey and magnetometry can be found in Appendices I and II.

The interpretative figures do not provide an exact representation of the sub-surface and they should be viewed in conjunction with the relevant discussion section and with the information contained in the Appendices.

3. Results and discussion

Magnetic Gradient (MISC333_(2).dwg / MISC333_(4).dwg)

3.1 Small, discrete dipolar magnetic anomalies have been detected in all of the survey areas. Most of these almost certainly reflect items of near-surface ferrous and/or fired debris, such as horseshoes and brick fragments. Only a sample of these anomalies has been shown on the geophysical interpretation.

3.2 Very weak linear negative magnetic anomalies, aligned roughly east-west, most apparent in Area 1 but also detected in Area 3, almost certainly result from a previous plough regime. These anomalies have not been shown on the geophysical interpretation figures for purposes of clarity; their alignment and general location is marked on the archaeological interpretation figure MISC333_(6).dwg.

3.3 Weak linear anomalies, usually positive magnetic, but occasionally detected as negative magnetic or linear chains of dipolar anomalies, are most likely to reflect land drains. These features are generally aligned northeast-southwest or northwest-southeast.

3.4 There is extensive animal burrowing across the entire site; this has caused a certain mottling of the magnetic background in areas, and may also be responsible for some of the positive magnetic linear and discrete features highlighted below.

Area 1

3.5 Very weak linear positive anomalies which may reflect soil-filled features have been detected in this area. These include one sub-rectangular (Anomaly 1) and one curvilinear feature (Anomaly 2), as well as a partial sub-rectangular feature (Anomaly 3).

3.6 Located within and around Anomaly 3 are two areas of positive magnetic enhancement (Anomaly 4) which may reflect soil-filled features such as pits and an area of fairly intense dipolar magnetic enhancement (Anomaly 5). This dipolar feature is polarised north-south which might indicate that this area has been subjected to heat and is an example of thermoremanant magnetism.

3.7 Thermoremanant magnetism is caused by weakly magnetised materials being heated above, and then allowed to cool through, the Curie Point. This is a specific temperature for different materials at which the heat results in the original magnetic orientation being wiped out. As it cools back through this point the material acquires a permanent magnetisation that is associated with the direction of the field in which it cooled (usually the Earth's). Thermoremanance allows such features as hearths and kilns to be readily identified due to their relatively high magnetic signature. This feature may therefore represent a hearth, kiln or similar, although it is also possible that this feature may reflect buried ferrous material, with the north-south orientation a matter of coincidence.

3.8 A similar area of enhanced dipolar magnetism to the west of Anomaly 5 is surrounded by a cluster of discrete positive magnetic anomalies (Anomaly 6). These features may reflect a collection of pits and a fired area, possibly the result of some form of industrial process, again however it is possible that this anomaly may have been caused by the break-up and burial of ferrous material.

3.9 A further cluster of discrete positive magnetic anomalies (Anomaly 7) has been detected in the southwest corner of Area 1. These may reflect pits or be caused by animal disturbance.

3.10 Two areas of positive magnetic enhancement (Anomaly 8) along the southern edge of Area 1 may reflect soil-filled features. Their form is similar to anomalies often observed around palaeochannels and areas once subjected to flowing water, these anomalies may reflect the remains of such features.

Area 2

3.11 A linear negative magnetic anomaly (Anomaly 9), aligned eastnortheast-westsouthwest, is situated within a linear depression observed during survey. This earthwork feature almost certainly represents the course of a former field boundary. The negative anomaly may reflect a field drain running within it, or may be an artefact of the sudden drop in ground when the instrument crossed this feature.

3.12 Towards the centre of Area 2, a positive magnetic anomaly (Anomaly 10) has been detected adjacent to Anomaly 9. This area of enhanced positive magnetic response may reflect a large pit or part of a ditch; however its form suggests it is more likely to reflect the remains of a palaeochannel.

3.13 Areas of negative magnetic and positive magnetic enhancement (Anomaly 11) may reflect the remains of former palaeochannels traversing this area.

3.14 Some discrete positive magnetic anomalies (Anomaly 12) detected may reflect pit features, but are more likely to represent disturbance caused by animal burrowing.

Area 3

3.15 A gas main (Anomaly 13) runs through the southern part of this survey area, resulting in intense dipolar magnetic readings which mask readings of subtler anomalies around it.

3.16 An area of dipolar magnetic enhancement of varying intensity reflects a waterlogged part of this survey area (Anomaly 14).

3.17 A linear dipolar magnetic anomaly passing through the waterlogged area (Anomaly 15) may reflect another service pipe or drainage.

3.18 Some discrete positive magnetic anomalies (Anomaly 16) detected may reflect pit features, but are more likely to represent disturbance caused by animal burrowing.

Area 4

3.19 The gas main running through Area 3 continues along the southern edge of Area 4.

3.20 Clusters of fairly intense positive magnetic anomalies (Anomaly 17 and 18) in this area reflect soil-filled features such as pits. Animal burrowing did not seem as extensive in this area so the likelihood of their being a result of animal disturbance is less than in some other areas.

3.21 Two areas of negative magnetic enhancement (Anomaly 19) may reflect areas of compaction, possibly surfaces or spreads of stony material; sometimes intense positive anomalies such as those detected in Anomalies 17 and 18 can give rise to a 'halo' effect of negative magnetic readings, and it may be this that has been detected in these areas.

Earth Resistance (MISC333_(3).dwg / MISC333_(5).dwg)

3.22 Earth resistance values differed greatly between the two areas surveyed. In Area A, waterlogging across much of the area gives rise to generally low resistance values, whilst in Area B, due to the very sandy soils and possible enhancement by voiding caused by animal burrowing, a much larger range of values has been measured. Area B is located to the south of a glacial moraine-like feature, and the ground is higher in this area compared to other parts of the survey area, so geological features may also be partly responsible for the observed differences in earth resistance between the two survey locations.

Area A

3.23 A linear feature of low resistance together with a linear feature of high resistance (Anomaly 20) along the southern edge of Area A may correspond to a trench or similar containing the gas main running through this area.

3.24 Areas of higher resistance in the northeast and northwest corners of the survey area correspond to higher ground with less waterlogging. There seems to be quite a well defined boundary between the areas of differing resistance, and it is possible that there may have been a pond or similar feature in this waterlogged area in the past.

3.25 Within the main body of the survey area, a region of low resistance corresponds to the waterlogged area, but within this there exists some anomalies defined by slightly higher earth resistance values. Anomaly 21 is a broad linear feature, aligned roughly northeast-southwest with some smaller linear anomalies located to the west of it at its southern extremity; and Anomaly 22 is a sub-circular feature, roughly 18m in diameter. High resistance features are often caused by concentations of stone or compacted areas, however due to the waterlogged nature of the topsoil in this area, these features may also be caused by deposits within ditches or similar which may be less conductive in comparison to the saturated topsoil.

Area B

3.26 A number of high and low resistance features have been detected within Area B. Area B was on higher ground, as previously mentioned, and was also subject to extensive animal burrowing. The gradiometer survey shows the gas main to pass through the southern part of Area B, although no sign of it has been detected in the resistance survey. The features discovered in the southern part of Area B (Anomaly 23) are most likely a result of animal burrowing and disturbance caused by the installation of the gas main.

3.27 Linear, curvilinear and large areas of high resistance, together with a two broad linear features of low resistance (Anomalies 24 - 30) may reflect sub-surface features. No corresponding features were detected in the magnetic survey apart from a mottling of the magnetic background, probably due to animal burrowing. These features are most likely caused by geological variations and animal disturbance; although it is possible Anomalies 25 and 26 may represent a double ditch with bank. Anomalies 24, 27, 28 and 29 may reflect other compacted areas, possibly eroded banks, or alternatively stone-filled ditches or similar. Anomaly 30 may reflect an area of compaction or stony spread, which may also be a continuation of Anomaly 24.

3.28 However, these features may all be caused by undulations in the geology or dumps of glacial material, or a combination of both. No characteristic features of archaeological significance have been detected and the interpretations within this report are merely possibilities rather than likelihoods.

3.29 No features corresponding to the recorded cropmark were discovered in this area by either resistance or magnetic survey. Resistance survey shows up features by detecting ground characteristics similar to those that result in cropmarks. It may be that the wet conditions may have saturated the soil to such an extent that there wasn't a sufficient contrast in earth resistance between the features which resulted in the cropmarks and the background resistance for these features to be detectable by our survey.

4. Conclusions

4.1 A high-pressure gas main has been detected running through the southern part of the survey area. This service was identified by markers in adjacent fields.

4.2 A number of anomalies which most likely relate to land drainage have also been detected across the survey area. These anomalies are shown on the archaeological interpretation figure as land drains.

4.3 Features which may relate to past palaeochannels have also been discovered. Glacial features are also visible within the survey area.

4.4 Very weak sub-rectangular and circular anomalies detected in Area 1 may reflect soil-filled features such as ditches or gullies and possibly represent enclosures (Anomalies 1 and 2), although these could also result from animal disturbance.

4.5 Clusters of anomalies which may reflect pits have been detected in many of the survey areas. Some of these anomalies may reflect disturbance due to animal burrowing, however Anomalies 3 – 6 in Area 1 which seem to be associated with areas of dipolar magnetic enhancement (possible examples of thermoremanant magnetisation where materials heated above a certain temperature become remagnetised according to the prevalent magnetic field alignment upon cooling; usually this is the Earth's field in most archaeological cases) and clusters of intensely positive anomalies (Anomalies 17 and 18) in Area 4 are more likely to reflect significant features.

4.6 Linear and circular areas of high resistance detected in Area A (Anomalies 21 and 22) may reflect subsurface features. Extreme waterlogging in this area has made interpretation difficult, and these features may reflect conventional high resistance features such as compacted areas or concentrations of stone; alternatively they may represent infilled features with deposits less conductive than the saturated topsoil.

4.7 Features detected in Area B are likely to reflect a combination of shallow features due to animal disturbance and possible geological effects. Linear high resistance features and a low resistance feature (Anomalies 25 and 26) may reflect significant subsurface features such as some form of banked ditch with Anomaly 24 and Anomalies 27-30 possibly reflecting areas of compaction, eroded banks or stony spreads, however they may equally be due to undulations in the natural bedrock or dumped glacial deposits.

The results and subsequent interpretation of data from geophysical surveys should not be treated as an absolute representation of the underlying archaeological and non-archaeological features. Features that do not produce a measurable geophysical response or those masked by other features may not be detectable. Confirmation of the presence or absence of features can only be achieved by direct investigation of sub-surface deposits.

Features, especially linear features, may relate to underground utility apparatus such as pipes or gas tanks. <u>Always exercise caution when excavating.</u>

5. References

David, A, 1995 *Geophysical survey in archaeological field evaluation,* Research and Professional Services Guideline **1**, English Heritage

Gaffney, C, Gater, J & Ovenden, S, 2002 *The use of geophysical techniques in archaeological evaluations*, Technical Paper **6**, Institute of Field Archaeologists

Schmidt, A, 2001 *Geophysical Data in Archaeology: A Guide to Good Practice*, Archaeology Data Service, Arts and Humanities Data Service

Appendix I

Resistance Survey: Technical Information and Methodology

i. Soil Resistance

a. The electrical resistance of the upper soil horizons is predominantly dependant on the amount and distribution of water within the soil matrix. Buried archaeological features, such as walls or infilled ditches, by their differing capacity to retain moisture, will impact on the distribution of sub-surface moisture and hence affect electrical resistance. In this way there may be a measurable contrast between the resistance of archaeological features and that of the surrounding deposits. This contrast is needed in order for sub-surface features to be detected by a resistance survey.

b. The most striking contrast will usually occur between a solid structure, such as a wall, and water-retentive subsoil. This shows as a resistive high. A weak contrast can often be measured between the infill of a ditch feature and the subsoil. If the infill material is soil it is likely to be less compact and hence more water retentive than the subsoil and so the feature will show as a resistive low. If the infill is stone the feature may retain less water than the subsoil and so will show as a resistive high.

c. The method of measuring variations in ground resistance involves passing a small electric current (1mA) into the ground via a pair of electrodes (current electrodes) and then measuring changes in current flow (the potential gradient) using a second pair of electrodes (potential electrodes). In this way, if a structural feature, such as a wall, lies buried in a soil of uniform resistance much of the current will flow around the feature following the path of least resistance. This reduces the current density in the vicinity of the feature, which in turn increases the potential gradient. It is this potential gradient that is measured to determine the resistance. In this case, the gradient would be increased around the wall giving a positive or high resistance anomaly.

d. In contrast a feature such as an infilled ditch may have a moisture retentive fill that is comparatively less resistive to current flow. This will increase the current density and decrease the potential gradient over the feature giving a negative or low resistance anomaly.

ii. Survey Methodology

a. The most widely used archaeological technique for earth resistance surveys uses a twin probe configuration. One current and one potential electrode (the remote or static probes) are fixed firmly in the ground a set distance away from the area being surveyed. The other current and potential electrodes (the mobile probes) are mounted on a frame and are moved from one survey point to the next. Each time the mobile probes make contact with the ground an electrical circuit is formed between the current electrodes and the potential gradient between the mobile and remote probes is measured and stored in the memory of the instrument.

b. A Geoscan RM15 resistance meter was used during this survey, with the instrument logging each reading automatically at 1m intervals. The mobile probe spacing was 0.5m with the remote probes 15m apart and at least 15m away from the grid under survey. This mobile probe spacing of 0.5m gives an approximate depth of penetration of 1m for most archaeological features and so a soil cover of greater than 1m may mask, or significantly attenuate, a geophysical response.

Appendix II

Magnetic survey: technical information

i. Magnetic properties

a. The magnetic survey is based on the fundamental principle that all materials have magnetic properties (whether directly observable or not). There are two properties that are of importance in archaeology.

b. The property of most importance is magnetic susceptibility. This is generally an indicator of ferrous mineral concentration and it also determines how readily a material becomes magnetised when it is in the presence of a magnetic field.

c. Anthropogenic (human) activity can change the ferrous material that is present in soils into more magnetic forms (enhancement) and it can redistribute the ferrous material to create areas of lower or higher magnetic susceptibility. The presence or absence of anthropogenic activity can therefore be detected by measuring the background magnetic susceptibility of an area and looking for variations (anomalies) within it. The magnetism can be measured using a magnetic susceptibility meter or a magnetometer.

d. Natural enhancement of ferrous material can occur and this is also important in detecting archaeological features. Topsoil generally has a higher magnetic susceptibility than the subsoil and underlying geology because the ferrous material within it is oxidised into more magnetic compounds. Features associated with anthropogenic activity, such as pits or ditches, may become infilled by the more magnetic topsoil. It is the contrast between the magnetic susceptibility of the infill material and the magnetic susceptibility of the surrounding matrix that causes the magnetic anomaly.

e. The second magnetic property that is of importance in archaeology is thermoremanant magnetism. This is caused by weakly magnetised materials being heated above, and then allowed to cool through, the Curie Point. This is a specific temperature for different materials at which the heat results in the original magnetic orientation being wiped out. As it cools back through this point the material acquires a permanent magnetisation that is associated with the direction of the field in which it cooled (usually the Earth's). Thermoremanance allows such features as hearths and kilns to be readily identified due to their relatively high magnetic signature. It can, however, also cause problems for magnetic surveys over some igneous geologies as these can have a strong thermoremnant magnetisation that masks any changes caused by the magnetically weaker archaeological features.

ii. Measurement of the Magnetic Field

a. Instruments that are used to measure a magnetic field are called magnetometers. The fluxgate magnetometer is the most suitable to use in rapid surveys to detect archaeological features. This magnetometer consists of high magnetic permeability cores that have coils wrapped around them. As an alternating current is passed through the cores they are driven in and out of magnetic saturation. Every time they come out of saturation an external field causes an electric pulse proportional to the field strength that affects them.

b. Although this is a cyclic measuring system the whole process takes milliseconds and is therefore effectively continuous for archaeological survey purposes. The major problem with it is that it is highly direction sensitive as it only measures the magnetic field component parallel to its axis. This means that any tilt in the sensor leads to a change in the reading. This is compensated for by using a gradiometer system, where two sensors are used, and by fine-tuning the detector alignments at each individual site to achieve the minimum direction sensitivity. The fluxgate gradiometer is the standard magnetometer used in archaeological surveys.

c. Magnetic data that is measured in the field in a regular grid system is called detailed survey. This technique generally involves taking readings at predetermined points on a grid. The readings are stored in the memory of the instrument and are later downloaded to computer for processing and interpretation. Met Surveys uses a Bartington Grad601-2 system to collect its geomagnetic data, which currently represents state-of-the-art technology for archaeological prospection.

d. The Bartington Grad601-2 is a dual sensor instrument, incorporating two Grad-01-1000 gradiometers set at a distance of 1m apart. The sensors within each gradiometer are also spaced 1m apart, rather than the 0.5m found in most fluxgate gradiometers. The configuration of the Grad601-2 provides an increased depth penetration and weaker anomalies are detected with greater resolution, as well as reducing both the time taken and distance walked compared to a conventional fluxgate gradiometer survey.

e. The Grad-01-1000 sensor is a high-stability fluxgate gradient sensor with a resolution of 0.1nT/m when used on the 100nT/m range and 1nT when used on the 1000nT range. The exceptional temperature stability of this sensor ensures minimal drift during surveys and reduces the need for adjustment and consequently survey time.

iii. Magnetic Anomalies

a. The overall geomagnetic field intensity in Britain is about 48000 nanoTeslas (nT). When the magnetic field is measured across a site the reading varies depending on the average magnetic susceptibility of the pedology and geology. Archaeological features can cause changes in this background measurement that range from about 500nT for thermoremanant magnetic features to as little as 0.2nT for features with a low magnetic contrast to the surrounding matrix. Comparing these values it can be seen that very sensitive equipment is needed to measure these changes.

b. All anomalies will have a positive and negative magnetic component relative to the background geomagnetic field. The responses from material with a higher magnetic susceptibility than the background will have usually have a larger positive component and can generally be described as a positive anomaly. As discussed above the majority of archaeological features have a higher magnetic susceptibility than the background and will therefore be observed as positive anomalies. Features that have thermoremanant magnetism will also have a positive response.

c. Some features can manifest themselves as a negative anomaly, which conversely means that the response is negative relative to the mean magnetic background. Such negative anomalies are often very faint and are commonly caused by modern, non-ferrous, features such as water pipes or drains. Infilled natural features may also appear as negative anomalies across certain geology.

d. Material that has a high ferrous content can have very strong positive and negative components. This type of response is called a dipolar anomaly.

e. The responses mentioned above can be further sub-divided and a possible interpretation can be made based on the anomaly type and morphology. There are often difficulties in interpreting the origin of anomalies and so anomalies are generally described as probable, possible or unknown. It should be noted that anomalies that are interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.

f. The general categories and morphologies of magnetic anomalies are:

i) Dipolar Magnetic

- *Isolated dipolar responses* ('Iron spikes')

  This response is characterised by a rapid positive / negative variation in the magnetic response resulting in a 'spike' profile. These anomalies are typically caused by ferrous material either on the surface or in the topsoil. A near-surface archaeological artefact could produce an iron spike response but the vast majority of these anomalies, even on archaeological sites are caused by modern ferrous material and so little importance is usually given to them.

- *Areas of magnetic disturbance* (a concentration of dipolar responses)

  This type of anomaly is characterised by an area of very strong, 'spiky' variations in the magnetic background. These anomalies can have several causes, from concentrations of near-surface ferrous or fired material to surface features such as ferrous fencing or tipped material. A modern origin is again usually assumed unless there is other supporting information.

ii) Positive Magnetic

- *Areas of magnetic enhancement* (positive isolated or areas of positive response)

  These responses do not have the characteristic spike of the dipolar anomalies but instead are characterised by a general increase in the magnetic background over a localised area. Pedological variations or natural geomorphological features, such as palaeochannels or infilled natural features on certain geologies, can produce areas of magnetic enhancement, as can infilled discrete archaeological features, such as pits or post holes, or areas of anthropogenic activity. Kilns and other industrial features can produce strong areas of magnetic enhancement, with the former often being characterised by a strong, positive double peak response. Modern ferrous material in the subsoil can also give a similar response. Magnetic enhancement can therefore be associated with natural or anthropogenic processes and it can often be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

iii) Negative Magnetic

- *Areas of reduced magnetic response*(isolated or areas of negative response)

  These are usually regions of anomalously low or negative magnetic field gradient, which may correspond to features of low magnetic susceptibility such as wall footings and other concentrations of sedimentary rock or voids. Pedological variations or natural geomorphological features, such as palaeochannels or glacial scouring can also give rise to areas of negative magnetic response.

iv) Morphology

- *Discrete* (positive, negative or dipolar magnetic anomalies)

  Isolated or small area responses caused by near-surface objects or small-scale features.

- *Linear trend* (positive or negative anomalies)

  This is usually a weak or broad linear anomaly of unknown cause or date. An agricultural origin, either ploughing or land drains is a common cause

- *Linear and curvilinear anomalies* (positive, negative and dipolar)

  These anomalies have a variety of origins. They are commonly caused by agricultural practice, such as former field boundaries, ploughing, both modern and earlier ridge and furrow regimes or land drains. Modern features generally cause negative and dipolar anomalies.

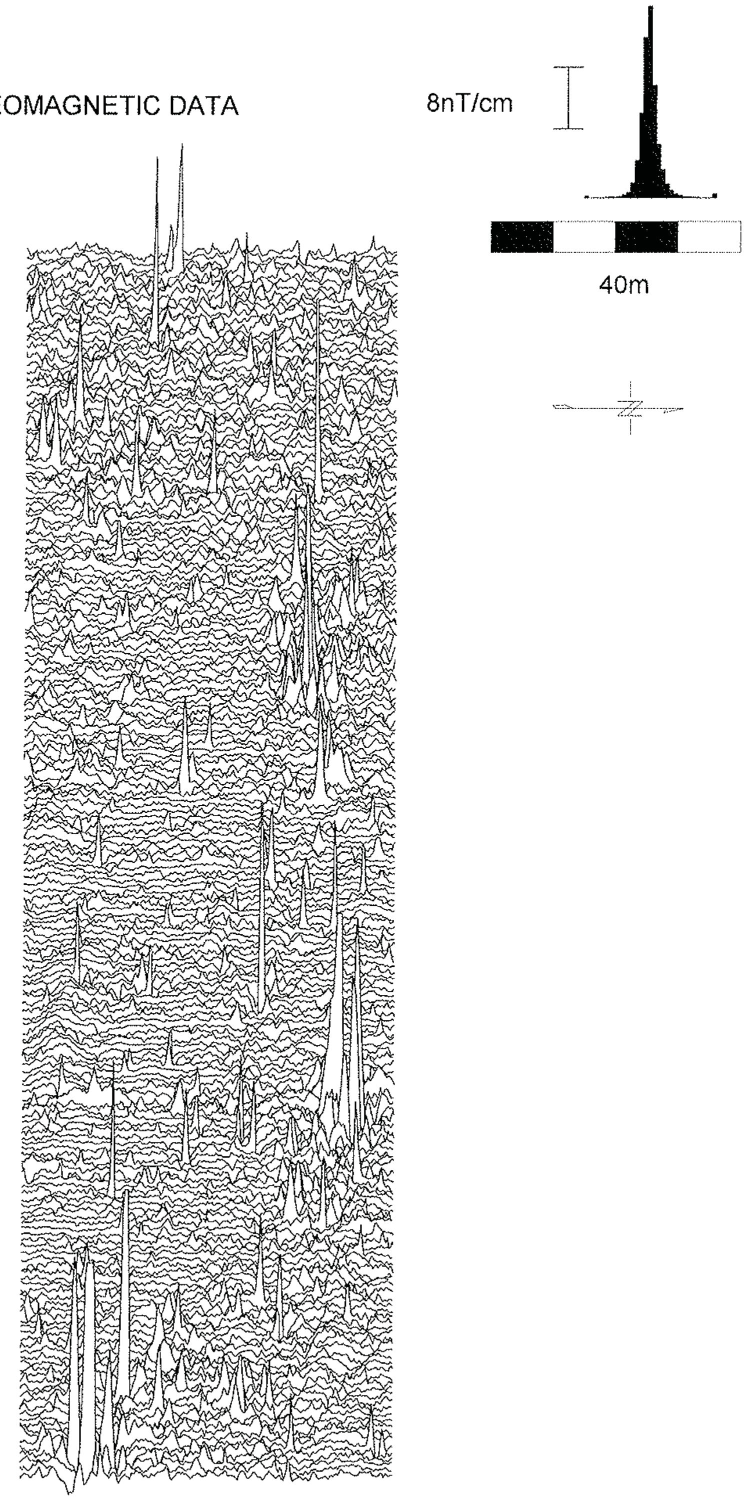
  Infilled archaeological ditches usually produce a positive anomaly and so if a pattern can be seen in the linear or curvilinear anomalies that correspond to the morphology of an archaeological field system or settlement then it is often possible to identify archaeological sites.

Appendix III: Trace Plot Data

HOLME LANE, MESSINGHAM

AREA 1

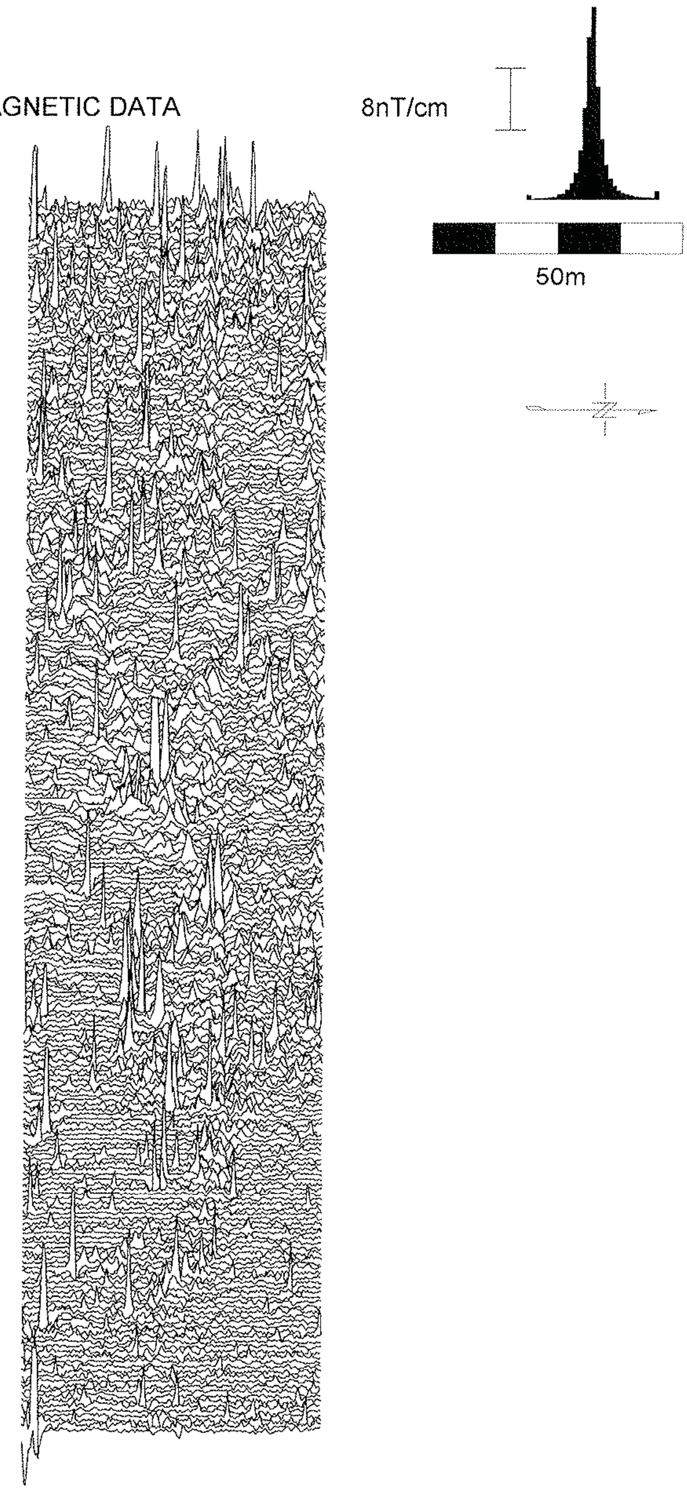
TRACE PLOT OF GEOMAGNETIC DATA



HOLME LANE, MESSINGHAM

AREA 2

TRACE PLOT OF GEOMAGNETIC DATA



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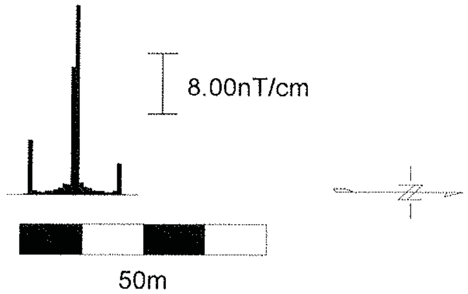
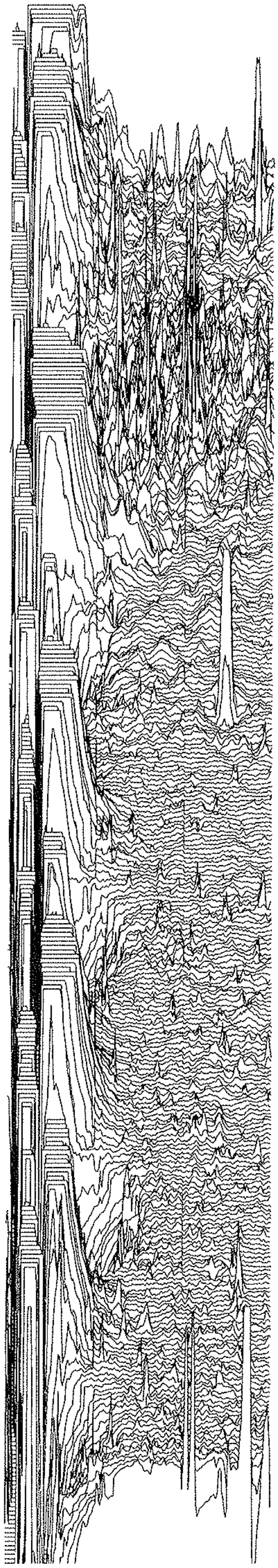
AREA 3

TRACE PLOT OF GEOMAGNETIC DATA





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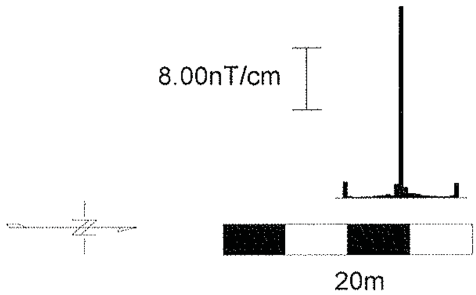
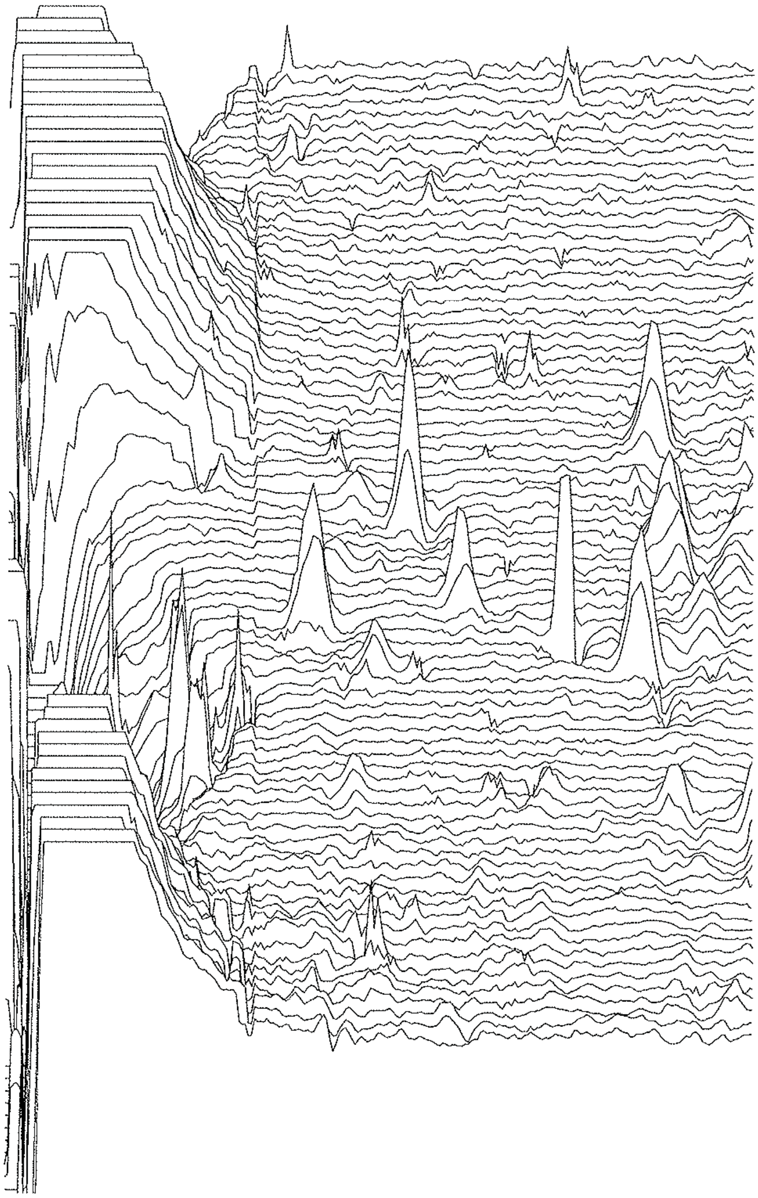
AREA 4

TRACE PLOT OF GEOMAGNETIC DATA





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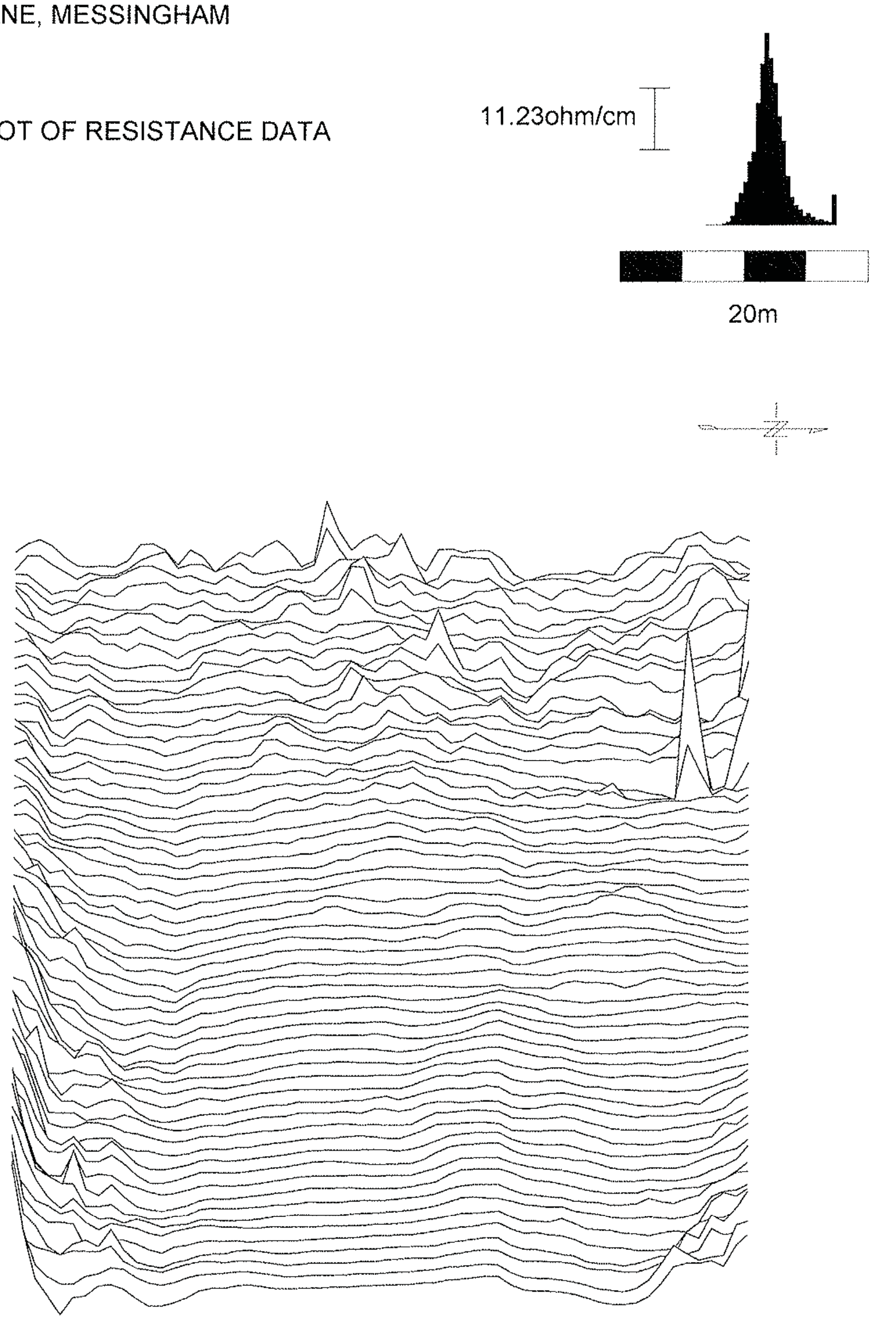
AREA A

TRACE PLOT OF RESISTANCE DATA



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AREA B

TRACE PLOT OF RESISTANCE DATA