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BRAUNCEWELL LIMESTONE QUARRY, LINCOLNSHIRE

Topsoil Magnetic Susceptibility and Gradiometer Survey

Commissioned by

Lindsey Archaeological Services

(Survey Ref: 3180108/BRL/LAS)

Site Code BCQ08

Accession No 2008.8

Produced by

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OXFORD ARCHAEOTECHNICS

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SUMMARY

A geophysical evaluation programme comprising topsoil magnetic susceptibility mapping and gradiometer survey was carried out on land immediately adjacent to the north and west of Brauncewell Limestone Quarry (centred on NGR 503200 352150) in advance of a proposed quarry extension.

Previous survey in 1996 in adjacent fields to the east and southeast had confirmed the presence of a triple ditch system (of probable later prehistoric date), and identified further zones of activity on its east side, subsequently identified by excavation as the result of prehistoric and Romano-British occupation, and ancient quarrying.

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.

The present survey identified a westward continuation of a broad band of highly magnetic soils, first identified in the 1996 survey, which appears to follow the course of ancient quarry pitting (containing soils locally enhanced by fire-setting the limestone). The presence of two parallel ditches hint at the presence of a trackway running into the centre of a c.0.5 ha block of land defined by 'cut' edges', tentatively identified as quarry sides.

A single NW-SE ditch is the only feature identified cutting across the pattern of topsoil magnetic susceptibility. There was no magnetic evidence for further areas unambiguously associated with former settlement.

1. INTRODUCTION

1.1 Geophysical survey was commissioned by Lindsey Archaeological Services on land adjacent to Brauncewell Limestone Quarry (centred on NGR 503200 352150) in advance of a proposed quarry extension. The quarry lies c. 0.5 km west of the A15 Lincoln to Sleaford road (7 km. north of Sleaford and 20 km south of Lincoln), and just over 1 km east of the small village of Brauncewell, Lincolnshire. The location is shown on Fig. 1. The fieldwork was carried out in January 2008.

1.2 The survey employed the same techniques (i.e. a combination of topsoil magnetic susceptibility field sensing and magnetometry, aimed to identify activity areas and characterise 'cut' features and structural remains of later prehistoric or subsequent periods) which had been used previously on land immediately to the east and southeast, which has subsequently been quarried (Johnson 1996). An explanation of the techniques used, and the rationale behind their selection, is included in an Appendix to the present report.

1.3 Over much of the area a shallow (c. 0.30 m) depth of topsoil overlies (Middle Jurassic) limestone brash and bedrock. A dry valley runs on a southwest-northeast trend across the southern half of the survey area. The land was under arable cultivation, and had been ploughed and disc-harrowed shortly before the survey. The bare soils had been softened by prolonged heavy rain, and were particularly soft in proximity to the quarry bunds marking the southern and eastern boundaries of the survey area. In practice, the impact of these adverse ground conditions on the topsoil magnetic susceptibility mapping proved negligible, although the detailed gradiometer plots were affected by highly magnetically susceptible soil adhering to the instrument and the operator's boots, which generated a much higher level of background magnetic 'noise' than normal. Although this has not seriously affected the overall response, more filtering and processing of the data was necessary, to a point where the magnetic subtleties are less conspicuous than those seen in the earlier survey work. The effectiveness was, however, not compromised, as can be seen by the fact that agricultural striations were clearly visible to the gradiometer.

1.4 The cropmark of a sinuous 'triple linear ditch system' has been observed from aerial photographs crossing the existing quarry c. 200 m east of the eastern boundary of the current survey area. Archaeological evaluation and excavation work in advance of the existing quarry by Lindsay Archaeological Services have investigated not only the triple ditch complex, (probably later prehistoric in date), but also detected a number of Romano-British quarry pits together with a variety of enclosures, burials, pits, postholes and agricultural features. The survey area lies just 4 km east of a major Roman arterial road (Ermine Street).

2. MAGNETIC SURVEY DESIGN

2.1 Survey control was established to a local (100m) grid using a baseline inset 20 m from the wall fronting the south side of Church Row Plantation. Survey details are shown on Fig. 8.

2.2 The equipment used for the 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 metre grid, an interval proven to give a high probability of intersection with the magnetic signal from a wide range of archaeological sites, particularly occupation sites of the later prehistoric, Roman or Medieval periods. However, under favourable conditions the survey technique is equally capable of locating earlier prehistoric features. The 10 m grid configuration also favours the detection of ploughed-out earthworks, which can occasionally be located as areas of more weakly magnetic soils.

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

2.5 Two areas showing significant enhanced topsoil magnetic susceptibility and which also produced gradiometer scanning anomalies were targeted for detailed gridded 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.

2.6 Field data were processed using Golden Software 'Surfer' and Geoscan Research 'Geoplot' software.

2.7 The topsoil magnetic susceptibility colour shade plots (Figs. 2 & 4) show soil magnetic contours at 20 SI intervals. Gradiometer data have been presented as grey scale, interpretative and raw data stacked trace plots (Figs. 5 - 7), and the results are summarised on Fig. 3. An overview of the results of both survey methods is shown on Fig. 4.

3. SURVEY RESULTS

TOPSOIL MAGNETIC SUSCEPTIBILITY SURVEY (Fig. 2)

3.1 A total of 686 *in situ* magnetic susceptibility readings were taken. 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 31 and 283 (x 10^{-5}) SI units; the mean for the survey was 91 SI units and the standard deviation calculated against the mean was 27 SI units.

3.3 The topsoil magnetic susceptibility map confirms the westward continuation of a broad band of magnetically enhanced soils previously recorded in the adjacent field to the east, within the dry valley running across the southern half of the present survey area. This pattern extends across the whole width of the survey area, with a marked focus visible close to the western boundary. The soils here contain a considerable amount of modern ferrous debris (e.g. discarded oil filters and other scraps of metal). Although this material accounts for the highest 'spot' focus of enhancement, strong patterning continues on a roughly east-west trend over a distance of almost 100 m, and it is evident that the soils themselves are displaying enhancement independent of the obvious modern focus.

3.4 A second band area of increased magnetic susceptibility c. 10 m wide is visible approximately 50 m south of the principal band of enhancement, extending for a distance of c.80 m.

3.5 Within the southeast angle of the field, the magnetic susceptibility locally increases and then drops away markedly. A similar 'break in continuity' identified in the 1996 survey corresponded with the course of the known triple ditch system, seemingly due to the dispersal of diamagnetic limestone rubble from the former earthworks becoming incorporated into the local soils, and effectively weakening the overall soil (volume) magnetic susceptibility.

3.6 There may be some significance in the fact that that magnetic trends over the majority of the survey area run on a roughly east-west alignment, following the topography, whilst within the southeastern angle there is a suggestion of magnetic patterning on a NW-SE trend (shown on Fig. 4), which may be relics of earlier landscape features.

MAGNETOMETER (GRADIOMETER) SURVEY (Figs. 5 – 7)

3.7 Gridded gradiometer survey was carried out in two areas (totalling 1 ha in area) which were sited to investigate enhanced topsoil magnetic susceptibility and gradiometer scanning anomalies.

AREA A

3.8 A block measuring 90 x 60, with a 30 m square extension to the south was sited over the strongest focus of topsoil magnetic susceptibility, taking in the outlying band of enhancement to the south.

3.9 The gradiometer identified several pockets of magnetically enhanced soils which suggest underlying broad silted 'cuts', either infilled ditches or just possibly pockets of soil marking the scarped edges of former quarry pits.

3.10 Almost central to the survey block is a pair of parallel and slightly curving linear anomalies on a WSW-ENE trend, which appear to define a track-like feature some 6 -7 m in width, which become less distinct as they approach the high magnetic susceptibility focus. This is contrary to what would normally be expected, suggesting that these features may have become less visible to the gradiometer because they are increasing in depth beneath the modern ground surface.

3.11 Within the southern extension of the survey area, central to the zone of higher topsoil magnetic susceptibility, a slightly curving anomaly, again seemingly a silted 'cut' or ditch, was identified.

3.12 The magnetic image gives the impression that the northernmost cut, although interrupted by the focus of modern ferrous material, may conceivably have turned southwards, possibly connecting with the southern ditch, defining the margins of a feature measuring at least 75 x 60 m, whose centre is occupied by the pair of relatively well-defined parallel ditches. There are some suggestions that within this area there are additional pockets of deeper soils which may possibly represent pits, and that some attenuation of the magnetic signal due to depth of burial may be producing a less distinct signal than would normally be anticipated.

3.13 Strong agricultural striations were recorded. There is a light litter of ferrous material dispersed throughout the topsoil, apart from the strong area of debris of seemingly modern origin. There may possibly also be some magnetic evidence due to *in situ* burning at this location, although the principal response is from ferrous metal.

AREA B

3.14 A second survey block measuring 60 m square was sited to investigate the eastern extremity of the broad zone of magnetic patterning. At the time of the survey this was the wettest part of the site, with drainage impeded by the presence of quarry bunds to the south and east.

3.15 A relatively poorly-defined sinuous anomaly crosses the centre of the survey block from east to west, following the overall trend shown by the topsoil magnetic susceptibility map. This anomaly is locally strong and weak alternately, suggesting naturally silted hollows, but with concentrations of higher susceptibility soils which in places reach levels comparable with those recorded in Area A to the west. There are slight suggestions of deeper pockets of soil or pit-like intrusions similar to those recorded in Area A, but only one can be identified with any degree of confidence, lying on the same trend as the sinuous linear, which may be no more than a pocket of magnetically enhanced soils within the cutting.

3.16 A linear anomaly representing a silted ditch crosses the western side of the survey block from its northwest angle on a NNW-SSE trend, changing to a NW-SE alignment approaching the southern edge of the survey.

3.17 Strong agricultural striations are visible. There is a light litter of ferrous material in the topsoil.

4. CONCLUSIONS

4.1 The application of topsoil magnetic susceptibility mapping and gradiometer survey, using the same methods which were employed in previous survey work at Brauncewell Quarry, have proved successful, suggesting that a high degree of confidence can be placed in their ability to identify principal areas of archaeological activity on this site.

4.2 Unlike the previous survey, no strong isolated foci lay outside the principal zones of topsoil magnetic enhancement. The anomalies which have been identified relate to broad band of magnetic enhancement within the topographically low zone crossing the southern half of the field, and there is no magnetic evidence for archaeological activity further north. The sinuous magnetic anomalies identified by the gradiometer which broadly mark the edges of this enhancement seem to correspond with Romano-British quarry pits excavated by Lindsey Archaeological Services in the adjacent field to the east which involved some fire-setting of the limestone (pers. comm. Naomi Field). Within these infilled quarries broad areas containing deeper pockets of soil infilling hollows retain a high magnetic signature, and pockets of enhanced soils on the edges of the cuttings are visible to the gradiometer. The presence of a pair of parallel ditches running down the centre of one of these features suggests some formal organisation to this activity.

4.3 The only anomaly which breaks this trend is a single ditch running on a NW-SE trend, identified in Area A within the southeastern part of the field.

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The survey was carried out by Oxford Archaeotechnics under the direction of A.E. Johnson *BA*, assisted by Dr. B. Gilmour.

The project was co-ordinated by A.P. Johnson *BA, PhD, MIFA.*

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 2000; Scollar et al. 1990; Gaffney & Gater 2003; Walden, Oldfield and Smith 1998). 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 thousands 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.

FIGURE CAPTIONS

Brauncewell Limestone Quarry, Lincolnshire: Proposed Extension

Archaeological Geophysical Survey: location

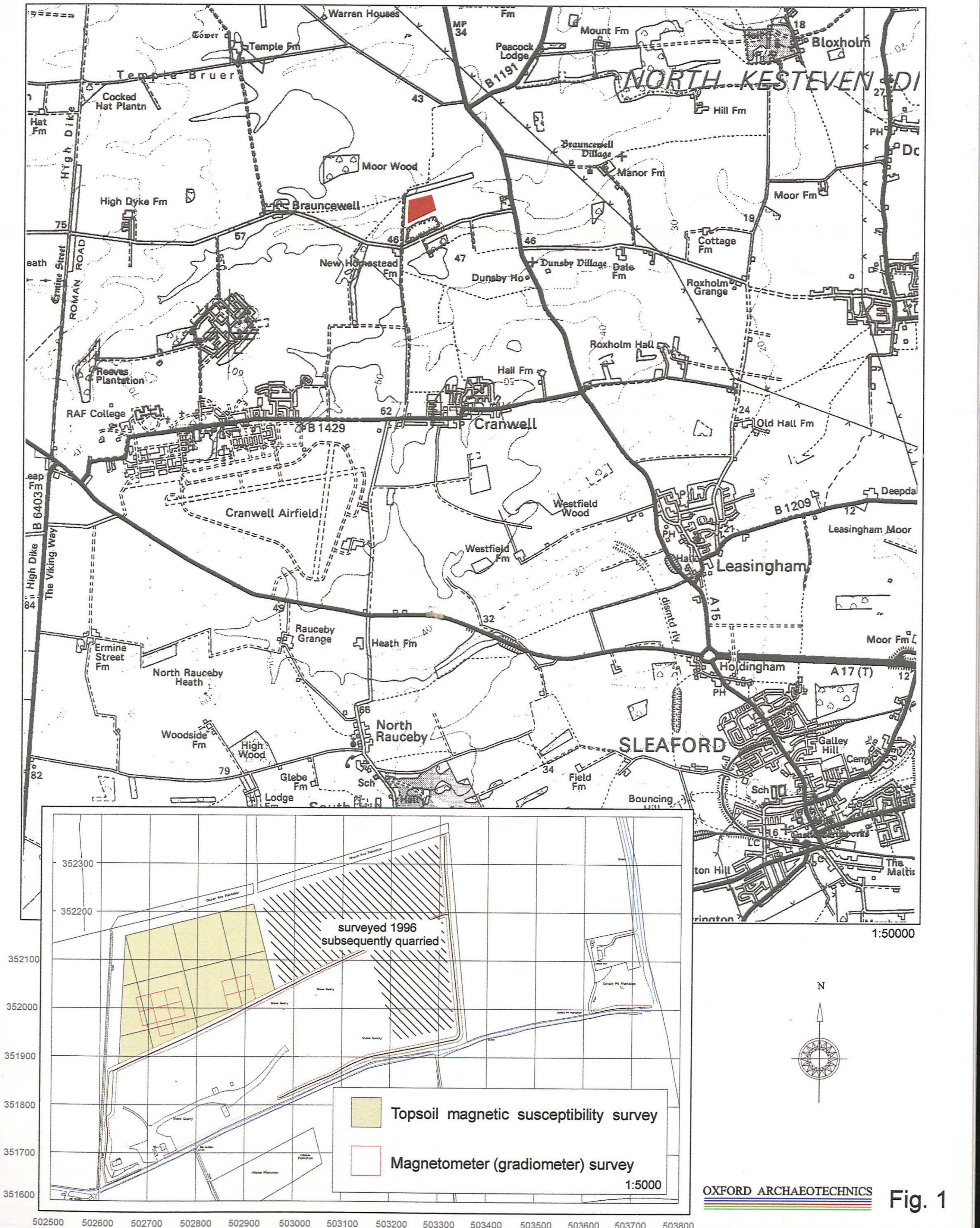

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Fig. 1

Braunceweli Limestone Quarry, Lincolnshire: Proposed Extension

Topsoil Magnetic Susceptibility

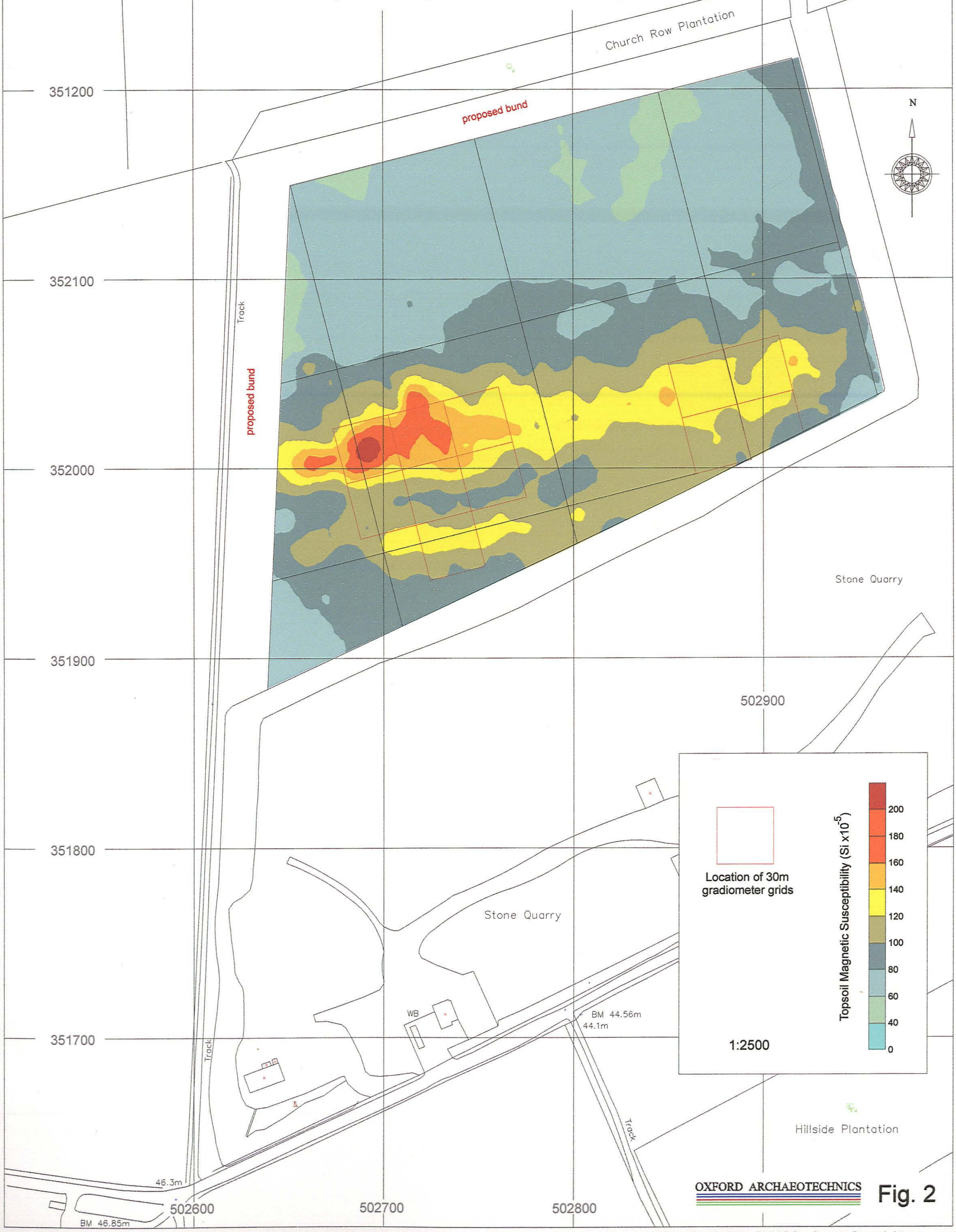
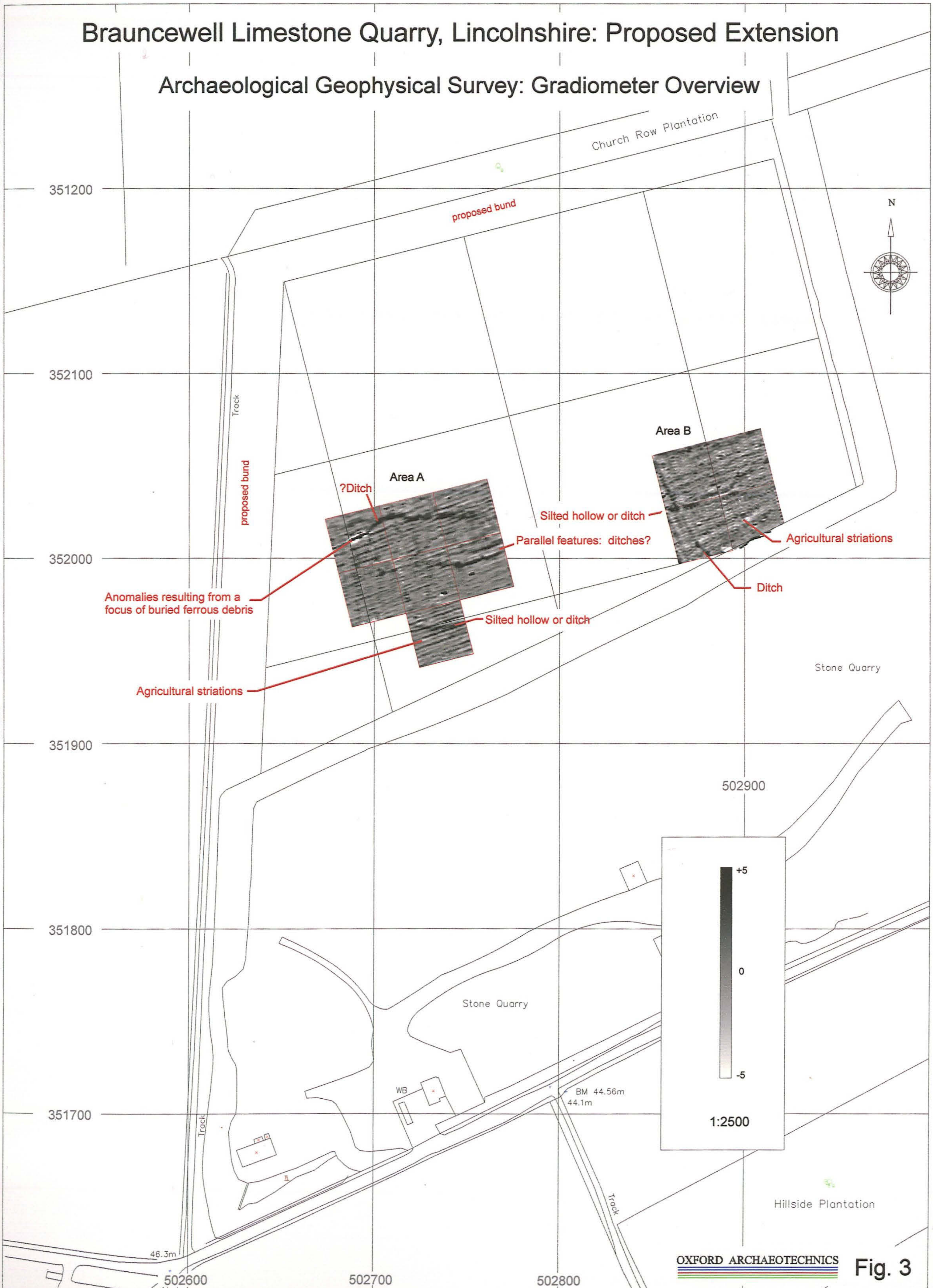


Fig. 2


Brauncewell Limestone Quarry, Lincolnshire: Proposed Extension
Archaeological Geophysical Survey: Gradiometer Overview
Church Row Plantation
proposed bund
N
351200
352100
352000
351900
351800
351700
Track
proposed bund
Area A
Area B
?Ditch
Silted hollow or ditch
Parallel features: ditches?
Agricultural striations
Ditch
Anomalies resulting from a focus of buried ferrous debris
Silted hollow or ditch
Agricultural striations
Stone Quarry
502900
+5
0
-5
1:2500
Stone Quarry
WB
BM 44.56m
44.1m
Track
Track
Hillside Plantation
46.3m
502600
502700
502800
OXFORD ARCHAEOTECHNICS
Fig. 3

Brauncewell Limestone Quarry, Lincolnshire: Proposed Extension

Archaeological Geophysical Survey: Overview

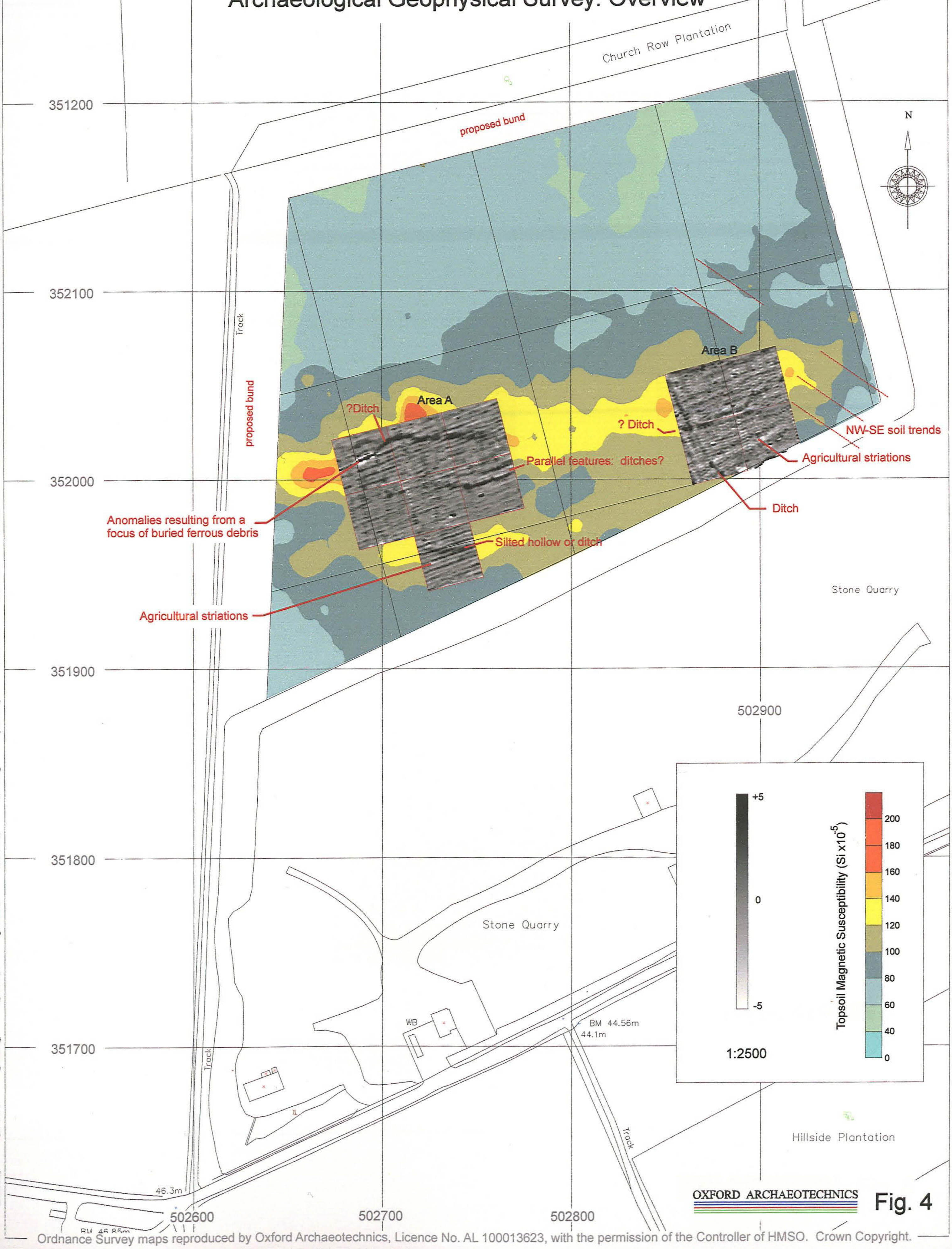


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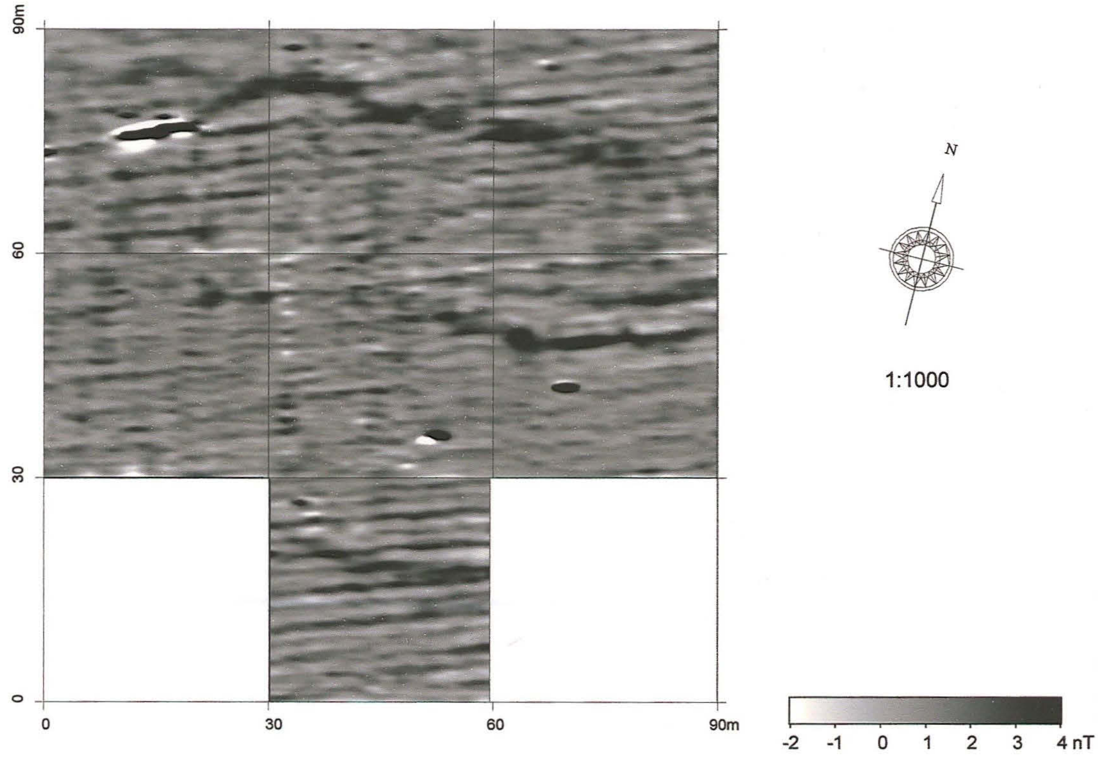
Fig. 4

Brauncewell Limestone Quarry, Lincolnshire: Proposed Extension

Archaeological Geophysical Survey: Gradiometer Gray Shade Plots

Area A



Area B

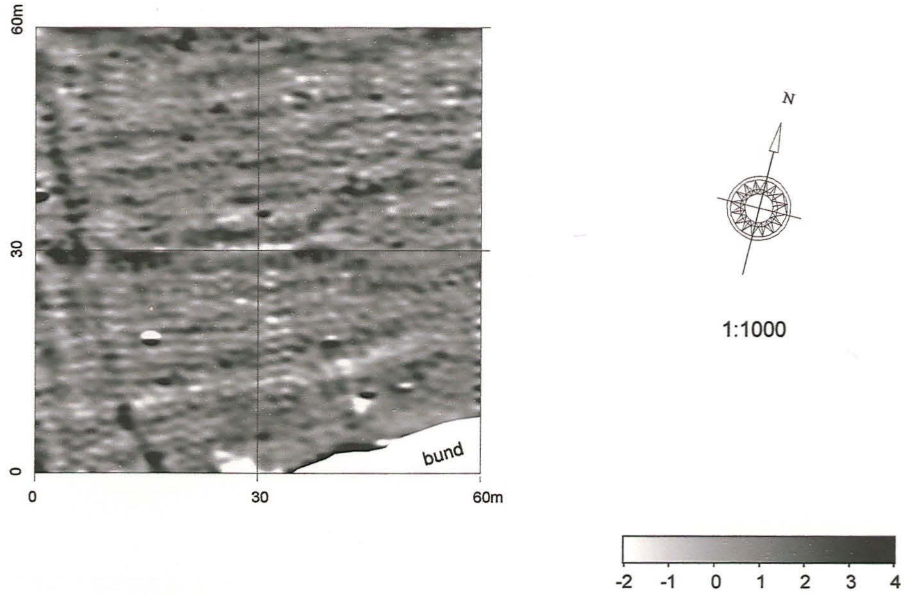


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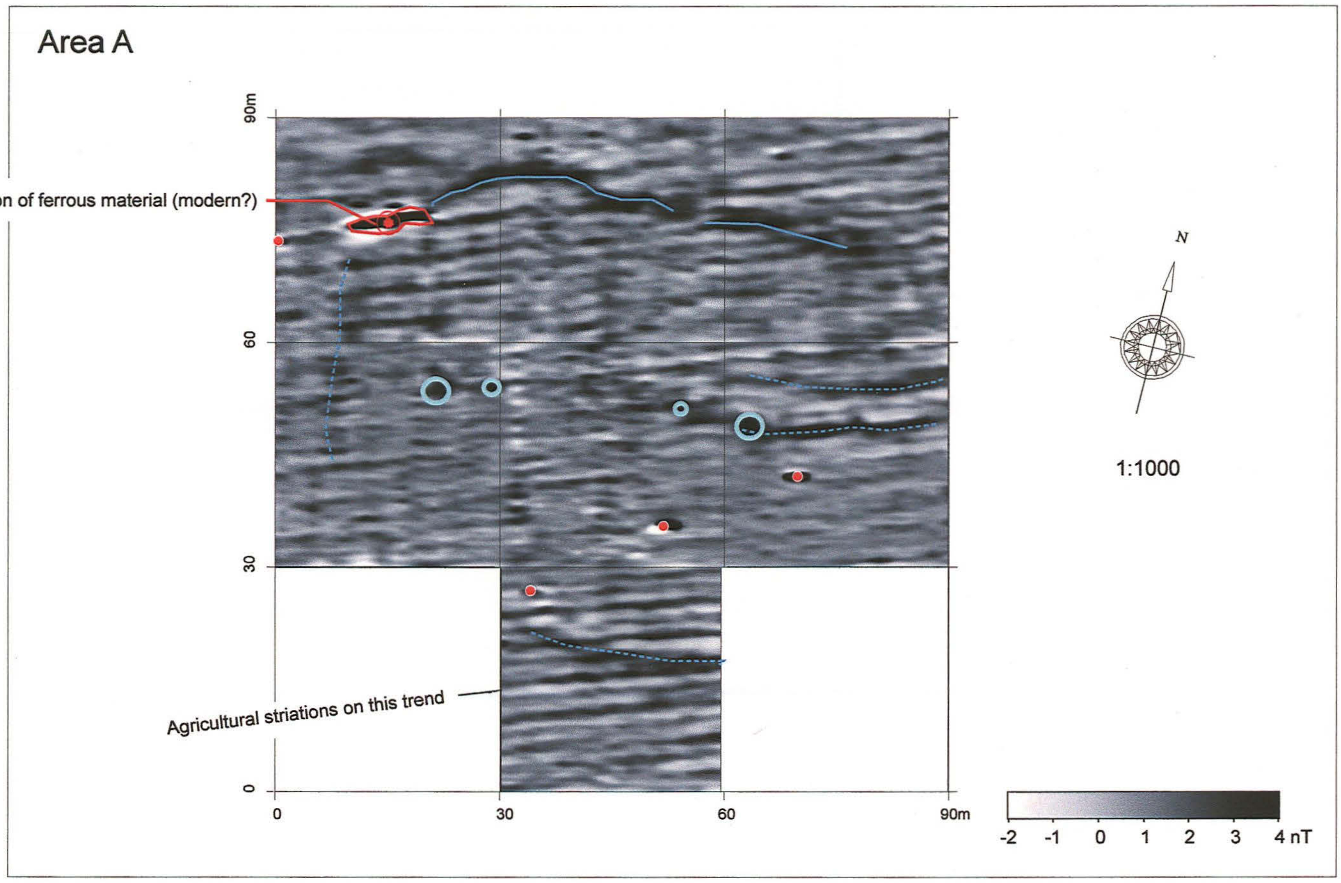
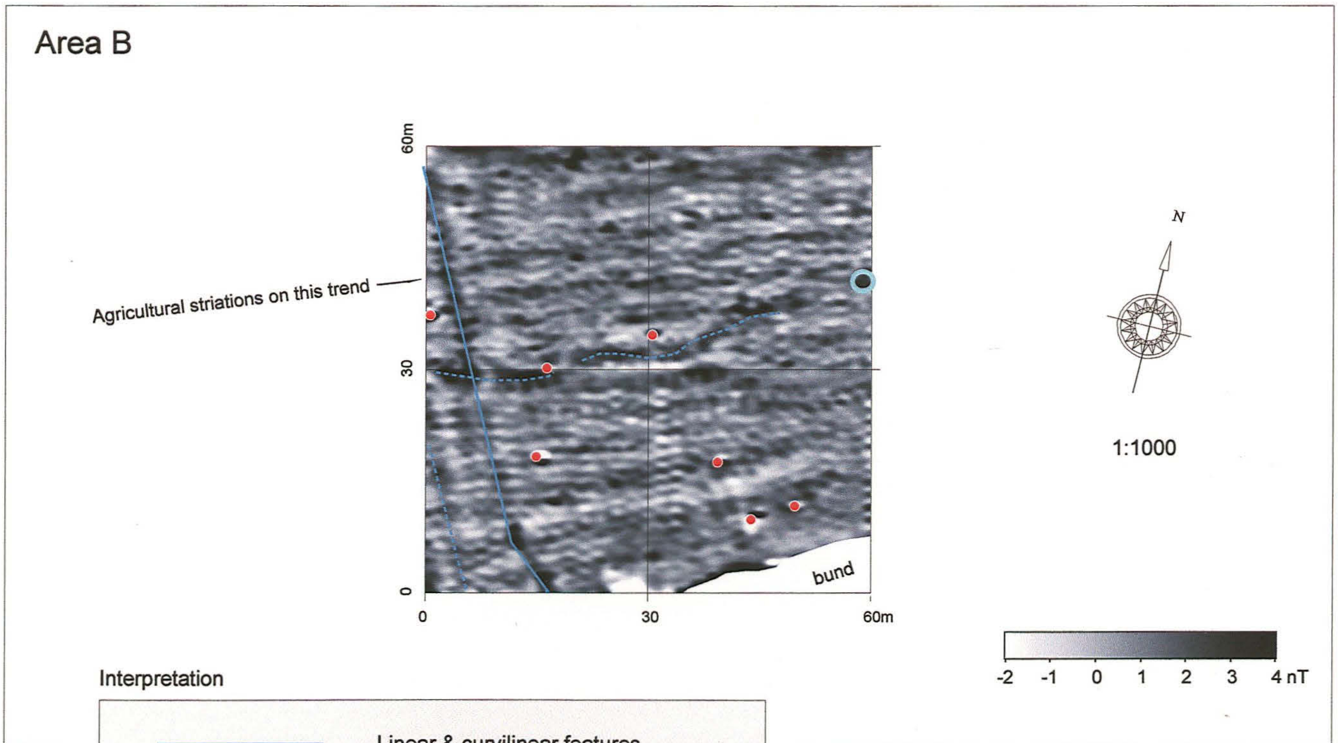
Fig. 5

Braunceswell Limestone Quarry, Lincolnshire: Proposed Extension

Archaeological Geophysical Survey: Gradiometer Grey Shade Plots





Interpretation

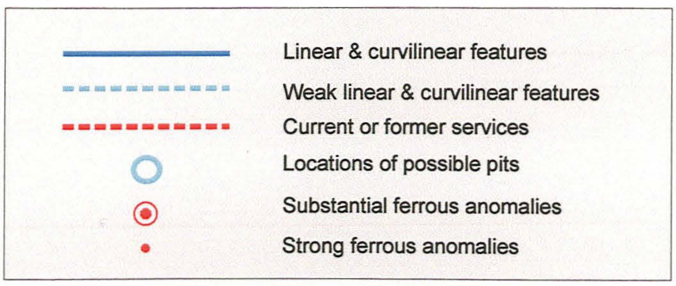


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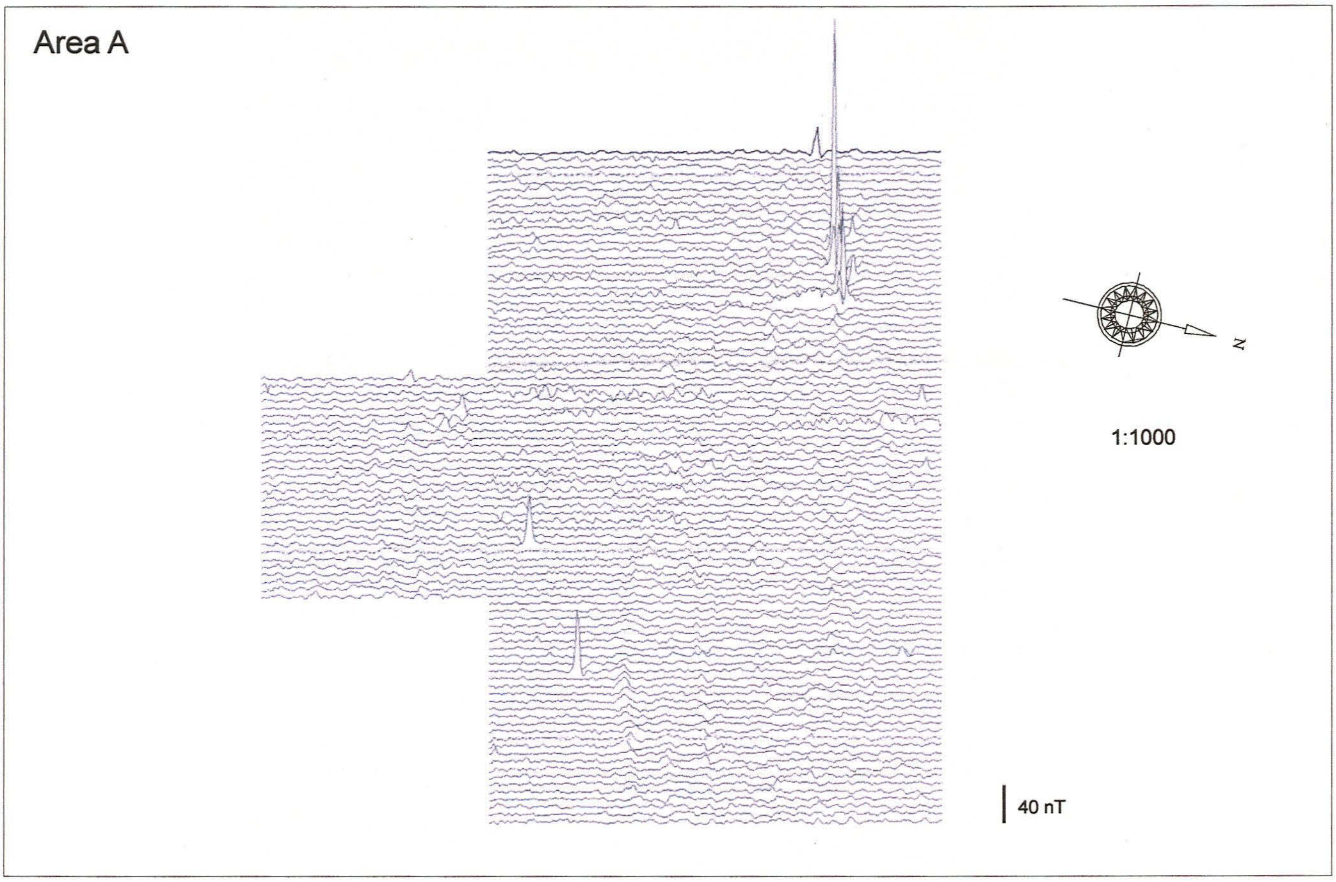
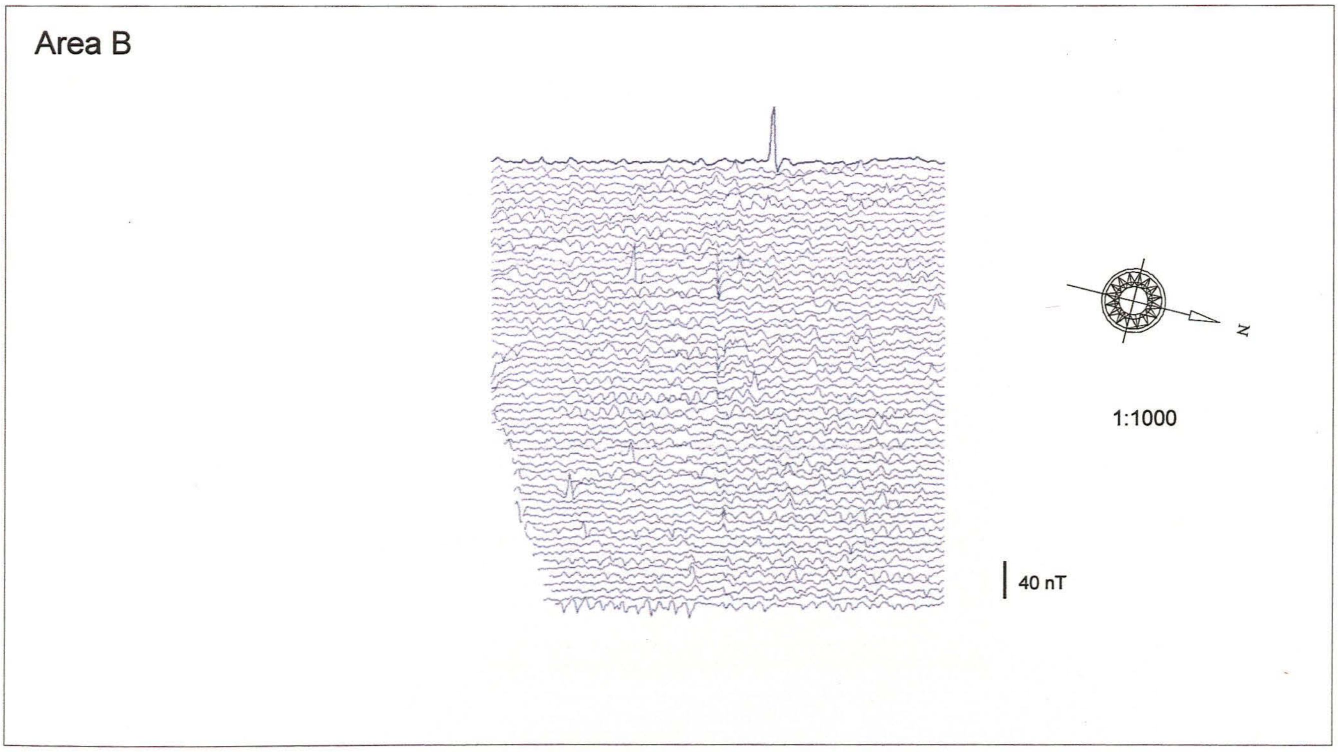
Fig. 6

Braunceewell Limestone Quarry, Lincolnshire: Proposed Extension

Archaeological Geophysical Survey: Gradiometer Stacked Trace Plots (raw data)





Brauncewell Limestone Quarry, Lincolnshire: Proposed Extension

Archaeological Geophysical Survey. Gradiometer Grids: Survey Details

1:2500

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2: 502760.60 E 352043.00 N	8: 502893.70 E 352004.30 N
3: 502688.00 E 351962.90 N	9: 502651.30 E 352149.50 N
4: 502775.20 E 351984.80 N	10: 502845.20 E 352198.40 N
5: 502850.00 E 352055.20 N	11: 502700.10 E 351955.60 N
6: 502908.20 E 352069.90 N	12: 502753.50 E 351948.40 N