Substrata Ltd.
Archaeological Geophysical Surveyors

Gradiometer survey at Welshbury Hillfort Gloucestershire NGR SO 6788 1554 SMR 5161

March 2005

A geophysical survey by Substrata Limited

Report R-WEL05-3105

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Contents

Figures

Tables

1. Survey Summary

Table 1: Survey Summary	
Name of Site: Welshbury Hillfort	**Grid Reference:** SO 6788 1554
Address of Site (including county): Gloucestershire	
Client: Environment Directorate, Gloucester County Council, Shire Hall, Gloucester GL1 2TH	
Substrata Survey No.(s): wel05-l1, wel05-l2a, wel05-l2b **Date (s) of Survey:** 31Jan05 to 11Feb05 **Author & Lead Surveyor:** Ross Dean	**Report Reference:** R-WEL05-3103 **Report Submitted:** 3rd April 2005 **Assistant Surveyor:** Colin Wakeham
Site Type: hillfort, thought to be Iron Age. **Description:** A large enclosure with and internal area of approximately 1.4 ha. defined by significant boundary earthworks and with a number of internal earthworks defining platforms and enclosures. The survey area is established woodland with naturally re-generated small leafed lime, oaks and beech predominating. At the time of survey, the undergrowth was relatively sparse with occasional dense patches of saplings and brambles. The monuments sits on a north-south prominent ridge with a gradient descending south to north and east to west with a relatively steep east-west decent at the south-western corner and a steep south-north descent at the north-eastern corner. **Known archaeological sites in survey area (SMR/NMR/appropriate other designation):** Gloucestershire SMR 5161: enclosure, surrounding earthworks and small finds	
Solid Geology: The geology comprises rocks of the Lower Old Red Sandstone Brownstones formation with strata dipping between 45 and 50 degrees west-south-west (BGS 1972). Generally these rocks comprise well sorted, fine to coarse grained, red and green sandstones with mudstones in the lower strata of the formation (Green 1992, 24).	
Survey Aims: This survey was a pilot study for The Forest of Dean Archaeological Survey and was commissioned as one of two surveys designed to investigate the potential of archaeological geophysical surveying for finding non-iron working features within the woodlands of the Forest of Dean. A two-tier survey strategy was recommended by Substrata as follows: **Level-One Survey Objectives:** To prospect and delimit non-iron working archaeological sites situated within relatively dense woodland using 1-metre by 1-metre sampling intervals. **Level-Two Survey Objectives:** To locate, record and provisionally classify potential archaeological features in areas highlighted by the level-one survey assuming approximately 12% of level 1 survey area and using 0.5-metre by 0.5-metre sampling intervals.	
Type (s) of Survey: Magnetometer **(**fluxgate gradiometer).	
Area Surveyed: level 1: 1.39 ha., level 2: 0.28ha.	
Survey Summary (detailed in section 3): The magnetic response across the site was low. The 'interference' of non-archaeological anomalies common to woodland environments inevitably reduced the quality of data collected but did not adversely affect the analysis. A number of potential archaeological structures were identified on the known earthworks in the north-east, south-east, south-west and north-west sections of the site along with a few potential archaeological structures not associated with recorded earthworks, including a potential platform and an associated structure. Three possible in-situ heating events were identified. Evidence was found for earlier phases of archaeological structures beneath the extant south-eastern earthworks along with evidence for the re-use of earlier earthworks as charcoal production areas. Some evidence for remnant ploughing was recorded in the north-western quadrant of the hillfort.	
Recommendations (detailed in section 4): Sufficient evidence of the extend and nature of the archaeology was gathered to facilitate the choice of sites for any future excavations or other archaeological investigations within the hillfort. The techniques adopted are recommended for any future archaeological magnetic surveys across similar terrain provided they are restricted to mature woodland sites with relatively sparse undergrowth. It is recommended that earthworks surveys should be considered in conjunction with geophysical surveys for archaeological assessments of woodland with extant features.	

Welshbury Hillfort
Gloucestershire
NGR: SO67881554
SMR: 5161

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See figure 2 for interpretation of anomalies within level 2 survey areas

L1-1
L1-2
L1-3
L1-4
L1-5
L1-6
L1-7
L1-8
L1-9
L1-10
L1-11
L1-12
L1-13
L1-14

tbm
tbm
tbm
tbm

0 10 50 metres
scale 1:500

Key

English Heritage earthworks survey re-drawn by Substrata

- ditches or earth fill
- cultivation traces
- pits and hollows
- stone or masonry
- earth and stone
- rubble or stony spread
- track or routeway
- uncharacterised archaeology
- quarry
- geological or geomorphological structure
- intense in-situ burning (e.g. furnaces, smithing hearths, ore roasting, kilns)
- less intense burning (e.g. hearths)
- buried ferrous objects (likely to be recent)
- ferrous pipes and cables
- service or drainage trench
- area not surveyed
- level 1 magnetometer survey limits
- level 2 magnetometer survey limits
- tbm survey marker
- 3 see section 2 of report for further explanation

Figure 1: gradiometer survey wel05-l1 interpretation of processed data over English Heritage earthworks survey

Welshbury Hillfort
Gloucestershire
NGR: SO67881554
SMR: 5161

GN

L2-1
L2-2
L2-3
L2-4
L2-5
L2-6
L2-7
L2-8
L2-9
L2-10
L2-11
L2-12
L2-13
survey wel05-l2a

survey wel05-l2b
L2-14
L2-15
L2-16
L217

0 10 50 metres
scale 1:500

Key

- filled ditches or earthen banks
- cultivation traces
- pits and hollows
- track or routeway
- intense in-situ burning (e.g. furnaces, smithing hearths, ore roasting, kilns)
- less intense burning (e.g. hearths)
- ferrous pipes and cables
- service or drainage trench
- buried ferrous objects (likely to be recent)
- tbm survey marker
- stone or masonry
- earth and stone
- rubble or stony spread
- uncharacterised archaeology
- quarry
- geological or geomorphological structure
- level 1 magnetometer survey limits
- level 2 magnetometer survey limits
- area not surveyed
- 3 see section 2 of report for further explanation

English Heritage earthworks survey re-drawn by Substrata

Figure 2:
gradiometer surveys wel05-l2a & wel05-l2b interpretation of processed data over English Heritage earthworks survey

2. Results

2.1 Level-one survey wel05-l1

Refer to figure 1 and figures 4 to 6 in appendix A. Specific anomalies and groups of anomalies are numbered left to right in figure 1.

L1-1 A set of anomalies that may represent archaeological structures associated with the earthworks recorded at this location.

L1-2 A group of anomalies likely to represent an in-situ burning event such a hearth. There are other magnetic anomalies in close proximity that are possibly of archaeological origin.

L1-3 A set of anomalies likely to represent filled pits and probably denoting the quarrying of the hillfort's inner bank.

L1-4 A set of anomalies likely to represent archaeology associated with the earthworks recorded in this vicinity. Some of these anomalies may represent filled pits but the data sample interval of 1-metre by 1-metre across soils with a low magnetic response may result in the creation of pit-like anomalies from more continuous earthen banks disrupted by tree growth and associated with the recorded earthworks.

L1-5 A set of anomalies associated with recorded earthworks that are likely to represent archaeological structures.

L1-6, L1-8, L1-13 and L1-14 The platforms recorded in the earthworks survey at L1-6, L1-8 and L1-14 have physical evidence for past charcoal production on the platforms in the form of charcoal deposits and all these platforms have a characteristic pattern of magnetic anomalies (see also L2-10 in section 2.1 below). A similar set of anomalies is present at L1-13 and while the geophysical survey team did not examine this platform for charcoal it is likely that this is also the site of former charcoal production. The pattern of anomalies makes it clear that material with a slightly higher response than the background soils has been deposited around the edges of the platforms. It is likely that the magnetic material is burnt soil and other burnt debris from the charcoal production process. Associated with the higher anomaly patterns, on and immediately beyond the edges of the platforms as recorded in the earthworks survey, are patterns of relatively low anomalies at locations L1-8, L1-13 and L1-14. A similar pattern may exist at L1-6 but his platform has been subject to relatively recent disturbance at tree-growth making a firm identification of a negative 'halo' difficult (see figure 5). Partial 'halos' of negative

anomalies around a core of positive patterns frequently occurs when burnt or heated material is deposited as a mass but in these particular instances there is some evidence for structures within the 'halos' and hence the characterisation of earth and stone archaeological structures defining the outer edges of the platforms shown in figures 1 and 2.

The anomalies at L1-8 include a likely in-situ heating event which is possibly the location of the last firing in the charcoal production process associated with this platform.

The platform at L1-14 on which charcoal production was undertaken is spatially associated with the platform at L1-11 (see below) for which no geophysical evidence for charcoal was found. This leads to the possibility that L1-14 represents the re-use for charcoal production of one of two earlier platforms.

The earthworks at L1-13 are relatively complex when compared to those at the other charcoal production areas discussed above and it is likely that this represents the re-use for charcoal production of an earlier structure. The possible re-use of L2-10 is discussed in section 2.2 below.

L1-7 There are two directional trends in the data in the area around L1-7 running northeast-southwest and northwest-southeast. They are relatively clear in this area and in the vicinity of L2-12 (see section 2.2) and similar disrupted trends appear elsewhere in the survey area (see figures 4 and 5). Directional trends like these can be the result of processing of data collected in areas with a low magnetic response such as this site but in the area around L1-7 there is a possibility that these trends are linear anomalies representing the remnants of old ploughing.

L1-9 The area around L1-9 has a number of magnetic anomalies likely to be the result of woodland conditions. Those shown in figure 1 have patterns more likely to be related to archaeology, the character of which is uncertain. Some of these anomalies may represent filled pits but the data sample interval of 1-metre by 1-metre across soils with a low magnetic response may be leading to the creation of pit-like anomalies from more continuous earthen banks.

L1-10 A group of anomalies representing earthworks and now buried archaeological features associated with a partially filled old saw pit. The reflection of the shape of earthworks to the east of the saw pit in the pattern of anomalies found raises the possibility that the saw pit was dug into an older feature, possibly a ditch, associated with the earthworks.

L1-11 The anomalies at L1-11 are likely to represent earthen banks defining a platform and a

linear bank. The proximity of L1-11 to L1-14 is discussed above.

L1-12 A number of magnetic anomalies are situated within this area of recorded earthworks on uneven, rubble-strewn ground. Some of the anomalies are conformant with the pattern of extant earthworks and rubble mounds while others represent deposits of rubble probably associated with the destruction of earlier features. A third group of anomalies are linear with one of two northeast-southwest or northwest-southeast trends. A similar pattern of anomaly trends is discussed above in relation to possible remnant ploughing (L1-7) but given the location of these anomalies on uneven terrain at the highest part of the hillfort, remnant ploughing is an unlikely cause in this case. It is possible that this third group of anomalies represents an earlier group of platforms.

2.2 Level-two surveys wel05-l2a and wel05-l2b

Refer to figure 2 and figures 7 to 9 in appendix A. Specific anomalies and groups of anomalies are numbered left to right in figure 2.

L2-1 The trend of this group of linear anomalies is similar to that of an extant bank immediately up-hill to the south-east and recorded in the English Heritage earthworks survey. They probably denote the edge of a similar bank and the continuation of the archaeology represented by the earthworks.

L2-2 A set of anomalies that possibly represent in-situ burning. This may relate to metal working such as smithing hearths or ore roasting but without supporting archaeological evidence these are only speculative examples of possible causes of the anomaly pattern. There also appears to be an anomaly, partially masked by the burning anomaly, representing a stony structure, possibly a retaining wall, on the northern edge of the platform.

L2-3, L2-4, L2-5, L2-6, L2-7 and L2-8 A group of anomalies that are likely to reflect structures on the earthwork platforms mapped by English Heritage. Anomaly patterns in the vicinity of L2-3, L2-4 and L2-6 appear to define to sub-rectangular structures but with the data set available this conclusion must remain tentative.

L2-9 There are a number of anomalies in the area of L2-9 but most appear to be related to the woodland environment rather than archaeology. The potential earthen or earth-filled structure at L2-9 is, however, more likely to be of archaeological origin.

L2-10, L2-11 and L2-13 The platform recorded in the earthworks survey at L2-10 has physical evidence for past charcoal production on the platform in the form of charcoal deposits. In this regard it is similar to other platforms recorded during the level-one survey at

L1-6, L1-8, L1-13 and L1-14 and has the characteristic pattern of magnetic anomalies discussed in section 2.1 above.

The magnetic anomaly patterns at L2-10 are complicated by those of L2-11 and L2-13 and this gives rise to the possibility that the earthworks visible at L2-10 are part of an earlier more complex structure modified for charcoal production.

L2-11 comprises a outer semi-circular structure, likely to be a filled ditch or the remnants of an earthen bank, within which is situated a possible earth and stone structure. It is may be that L2-11 represents the remains of a platform and associated building.

L2-13 is a set of linear anomalies situated on the boundary of a survey grid and orientated along the line of the survey. As such, there remains a possibility that these anomalies are the results of errors in data collection. On balance, however, the anomalies are likely to represent a linear archaeological feature such as a filled ditch or earthen bank. It could be an extension of earthworks to the south and appears to influence the shape of the rear of the platform at L2-10.

L2-12 As discussed in section 2.1 L1-7, there are two directional trends in the data in the area around L2-12 running northeast-southwest and northwest-southeast. Directional trends like these can be the result of processing of data collected in areas with a low magnetic response such as this one but in the area around L2-12 there is a possibility that these trends are linear anomalies representing old ploughing.

L2-14 A series of linear anomalies that, while in the direction of survey and therefore possibly the result of data collection errors, are likely to denote archaeology in the form of the base of an earthen bank or filled ditch and the slightly eroded, stony traces of a trackway still in use today. A number of groups of anomalies representing deposits of rubble were recorded that do not correspond to mapped earthworks. It is possible that these reflect the destruction of earlier features.

L2-15 A set of linear anomalies that have a similar trend to those discussed in section 2.1, L1-12 above and which may represent an earlier phase of structures.

L2-16 and L2-17 These anomalies represent patterns of rubble that correspond closely to mounds recorded by the English Heritage earthworks survey. These anomalies confirm the recorded earthworks which were difficult to discern on the ground at the time of the geophysical survey.

3. Conclusions

3.1 General Considerations

The magnetic response across the site was low. This inevitably means fewer magnetic anomalies to analyse and a reduction in the archaeological interpretation of those identified magnetic anomalies. The “interference” of non-archaeological anomalies caused by tree boles, burrows and other features common to woodland environments was a factor in the analysis but, while such anomalies inevitably reduced the quality of data when compared to open-country surveys, their main impact was in the time taken to assess and reject them during data analysis and interpretation.

3.2 Objectives and Results

Two surveys were completed; a ‘level-one’ survey across the internal extent of the Hillfort using one-metre by one-metre sample density, and a ‘level-two’ survey across two areas selected after reviewing the level-one survey and using a half-metre by half-metre sample density. Both surveys were successful in that a number of potential archaeological features were identified and classified both within and without the areas of earthworks mapped by English Heritage . The methodology performed to the objectives stated in section 1.

3.3 The Level-One Survey

The level-one survey was useful in gaining a general understanding of potential archaeological structures across the site and in defining areas likely to yield further results using a level-two survey. In particular, a number of potential archaeological structures were identified on the known earthworks in the north-east, south-east, south-west and north-west sections of the site along with a few potential archaeological structures not associated with recorded earthworks. Magnetic anomalies recorded over the difficult terrain of the highest, south-eastern corner of the hillfort were suggestive of earlier phases of archaeological structure beneath the extant earthworks. Evidence was found for quarrying of the inner side of the western bank. Patterns of distribution of magnetically detectable material around five known charcoal production platforms were mapped and deviations in this pattern around three of the platforms (L1-13, L1-14 and L2-10 in figures 1 and 2) led to the conclusion that they were part of earlier structures later re-used as charcoal production areas. A possible site of an in-situ burning event was recorded on one of the platforms with evidence for charcoal production (L1-8 in figure 1). There was some evidence for remnant ploughing patterns on the more level areas of the hillfort in the north-western quadrant of the hillfort.

3.4 The Level-Two Surveys

Level-two surveys were carried out across two areas shown by the level-one survey to have a number of magnetic anomalies which could in the main be characterised as archaeological features and which were apparently associated with extant earthworks (see figures 1 and 2). Potential structures around the charcoal platform L2-10 (figure 2), including a potential platform and associated structure not defined in the earlier earthworks survey, were defined in greater detail. A number of potential structures on the north-eastern platforms were better defined, some being provisionally identified as sub-rectangular. A possible in-situ heating event was identified on the edge of one of the north-eastern platforms. Evidence suggesting that the extant earthworks in the north-eastern corner of the hillfort extended further down-slope to the extant inner bank (L2-1 in figure 2). As with the level-one survey, some evidence for remnant ploughing was recorded in the north-western quadrant of the hillfort. The presence of a small rubble mound and adjacent structures recorded during the English Heritage earthworks survey was confirmed by the geophysical survey (L2-16 in figure 2) and further supporting evidence was found for earlier phases of archaeological structures in the south-eastern corner of the hillfort.

4. Recommendations

4.1 The survey achieved the objectives set out in section 1 and sufficient evidence of the extend and nature of the archaeology has been gathered to facilitate the choice of sites for any future excavations or other archaeological investigations within the hillfort.

The level-one and level-two phases of survey worked well in allowing a faster prospection survey, using a one-metre by one-metre sampling interval with hand-triggered sampling, to be followed up by a detailed survey using half-metre by half-metre sampling across selected areas across a mature woodland environment. This technique, detailed in appendix B, is recommended for any future archaeological magnetic survey across similar terrain.

4.2 The relatively coarse sample intervals chosen in recognition of the difficult surveying environment proved to be acceptable but even these were difficult to implement across some areas of undergrowth. It is recommended that the surveying strategy adopted be limited to mature woodland with relatively sparse undergrowth.

4.3 The geophysical survey complemented and extended the existing earthworks survey and together the surveys provide a useful assessment of the archaeological potential of the site. It is recommended that earthworks surveys should be considered in conjunction with geophysical surveys for archaeological assessments of woodland with extant features.

5. Disclaimer

Every effort has been made to provide accurate descriptions and interpretations of the geophysical data described in this report. The nature of archaeological geophysical surveying is such, however, that interpretations based on geophysical data can only be provisional and so cannot be taken as conclusive evidence for significant archaeological features. Geophysical surveys are one step in the multi-phase process that is archaeology.

6. Acknowledgements

We would like to thank Jon Hoyle, Senior Project Officer, Gloucester County Council Environment Department Archaeology Service, for commissioning Substrata to complete this survey and for his efficient and knowledgeable project management .

7. Standards

The standards used to complete this survey are defined in David (1995), English Heritage (1991, 1999) and Schmitt (2002).

8. References

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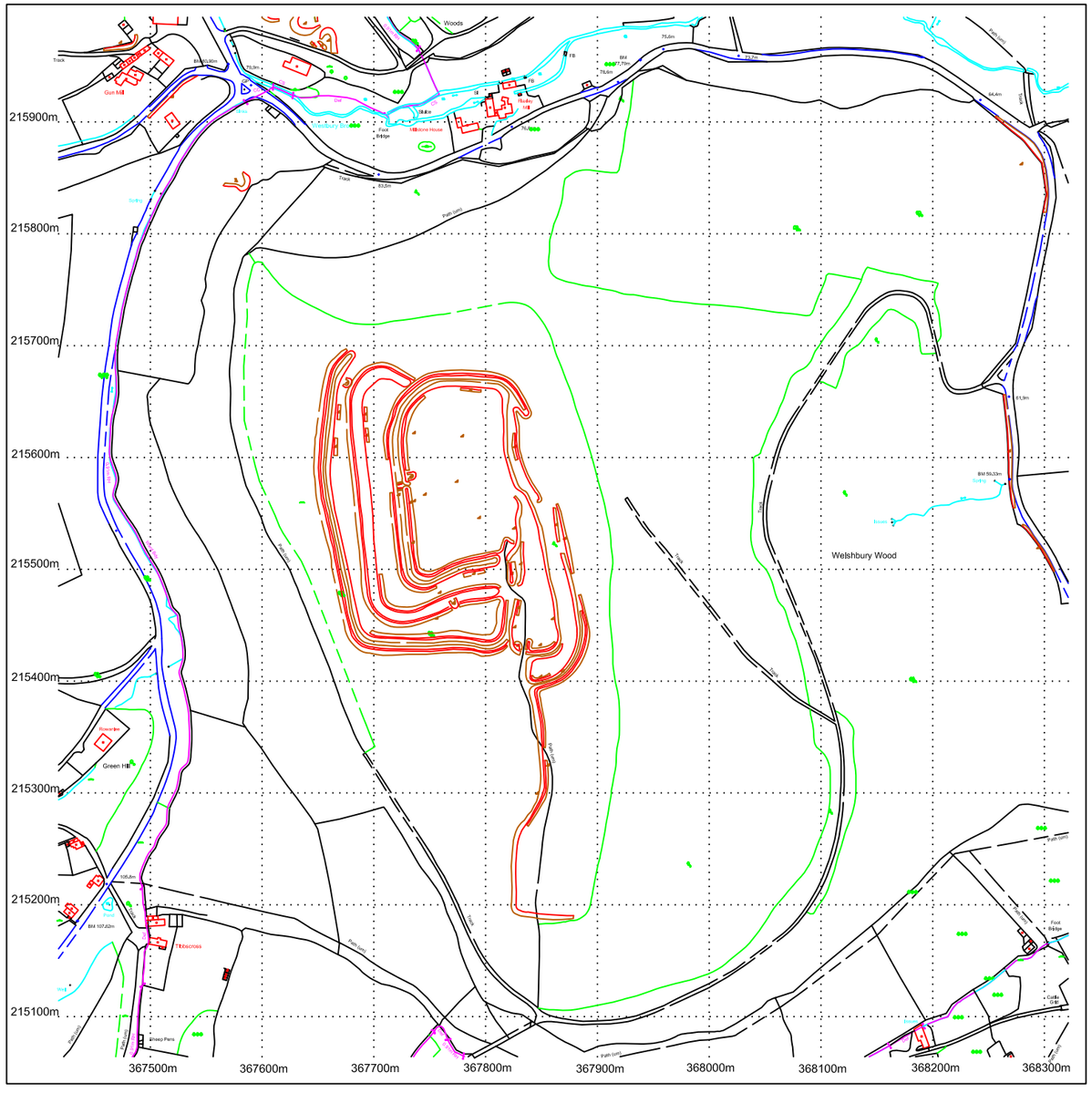
Appendix A: Survey Plots

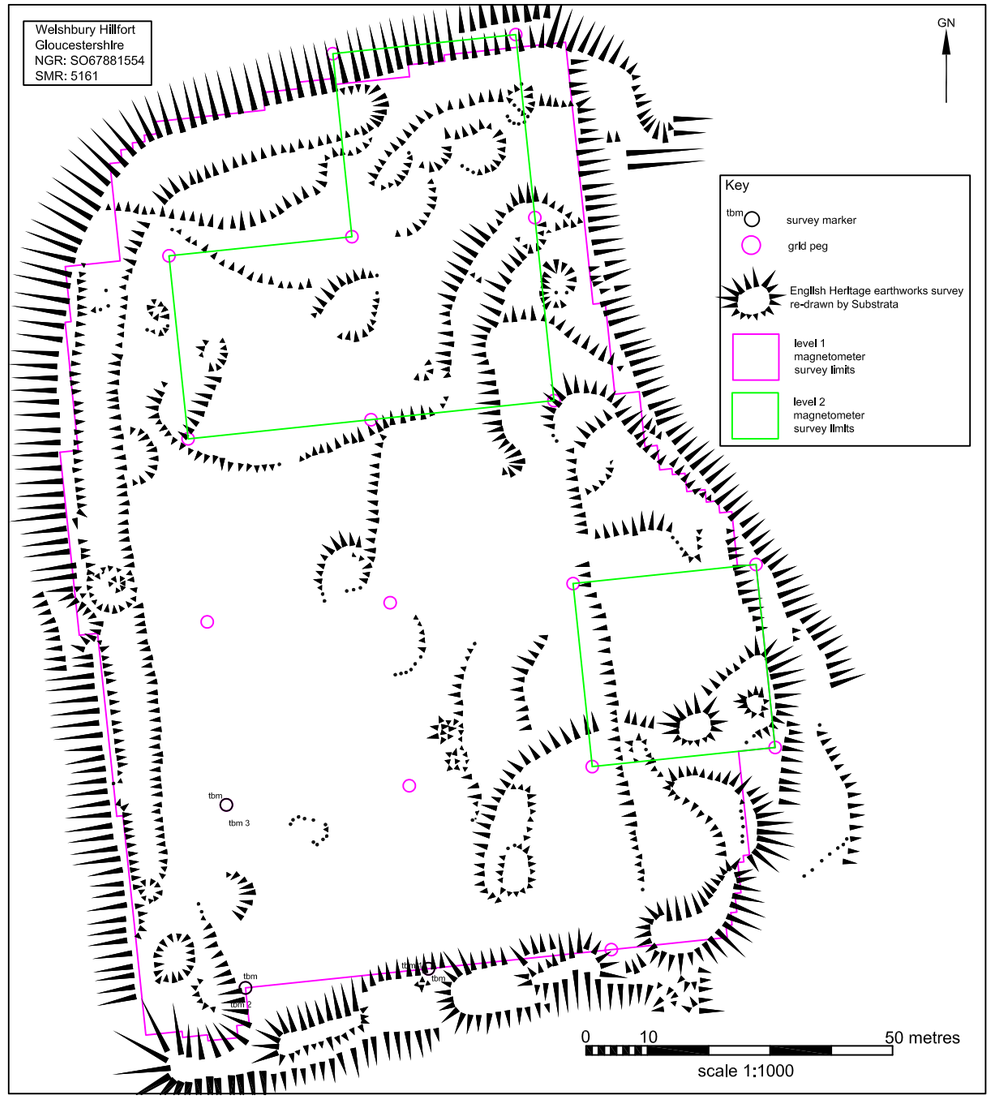
A1 General Guidance

The anomalies represented in the survey plots provided in this appendix are magnetic anomalies. The apparent sizes of the such anomalies and anomaly patterns are likely not to correspond exactly to the dimensions of any associated archaeological features.

A rough guide for interpreting the dimensions of magnetic anomalies is that the width of an anomaly at half its maximum reading is equal to the width of the buried feature, or its depth if this is greater (Clark 2000, 83). Caution must be applied when using this rule as it depends on the anomalies being clearly identifiable and distinct from adjacent anomalies. In northern latitudes the position of the maximum of a magnetic anomaly will be displaced slightly to the south of any associated physical feature.

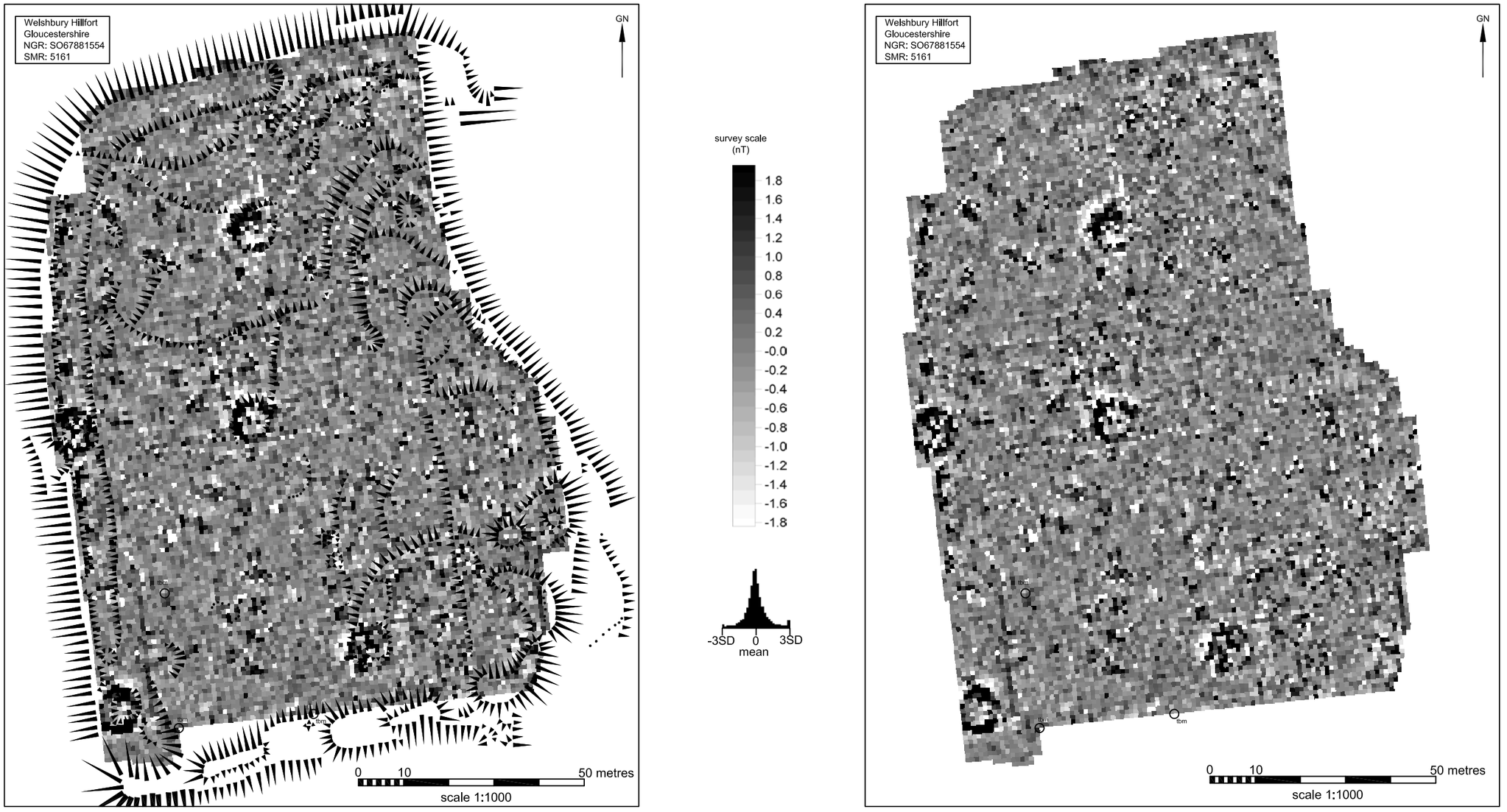


a: Ordnance Survey map of area at scale 1:5000



b: location of survey grids over part of an English Heritage earthworks survey (earthworks survey re-drawn by Substrata)

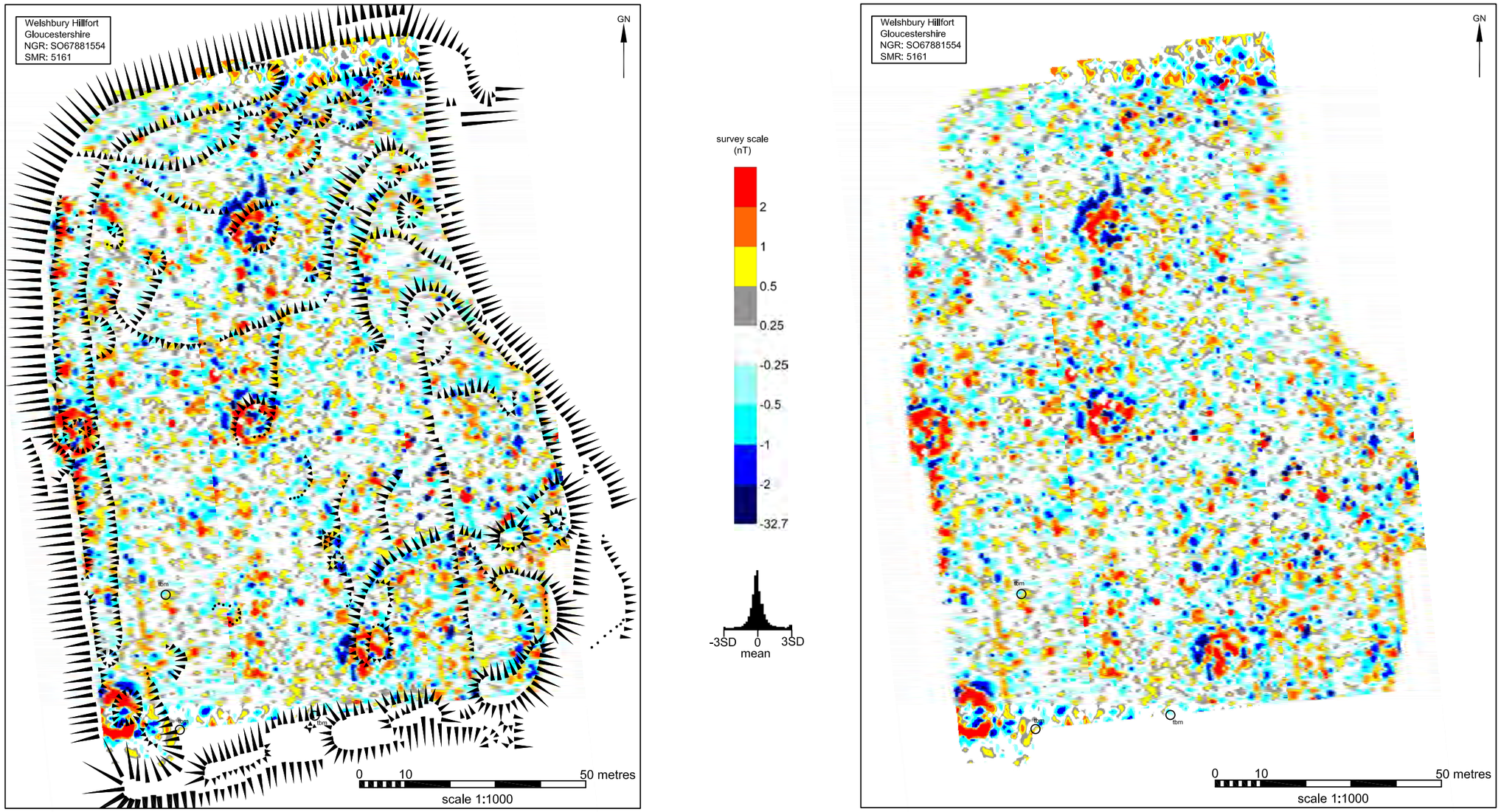
Figure 3: location of survey



a: gradiometer survey wel05-l1 shade plot of processed data over English Heritage earthworks survey

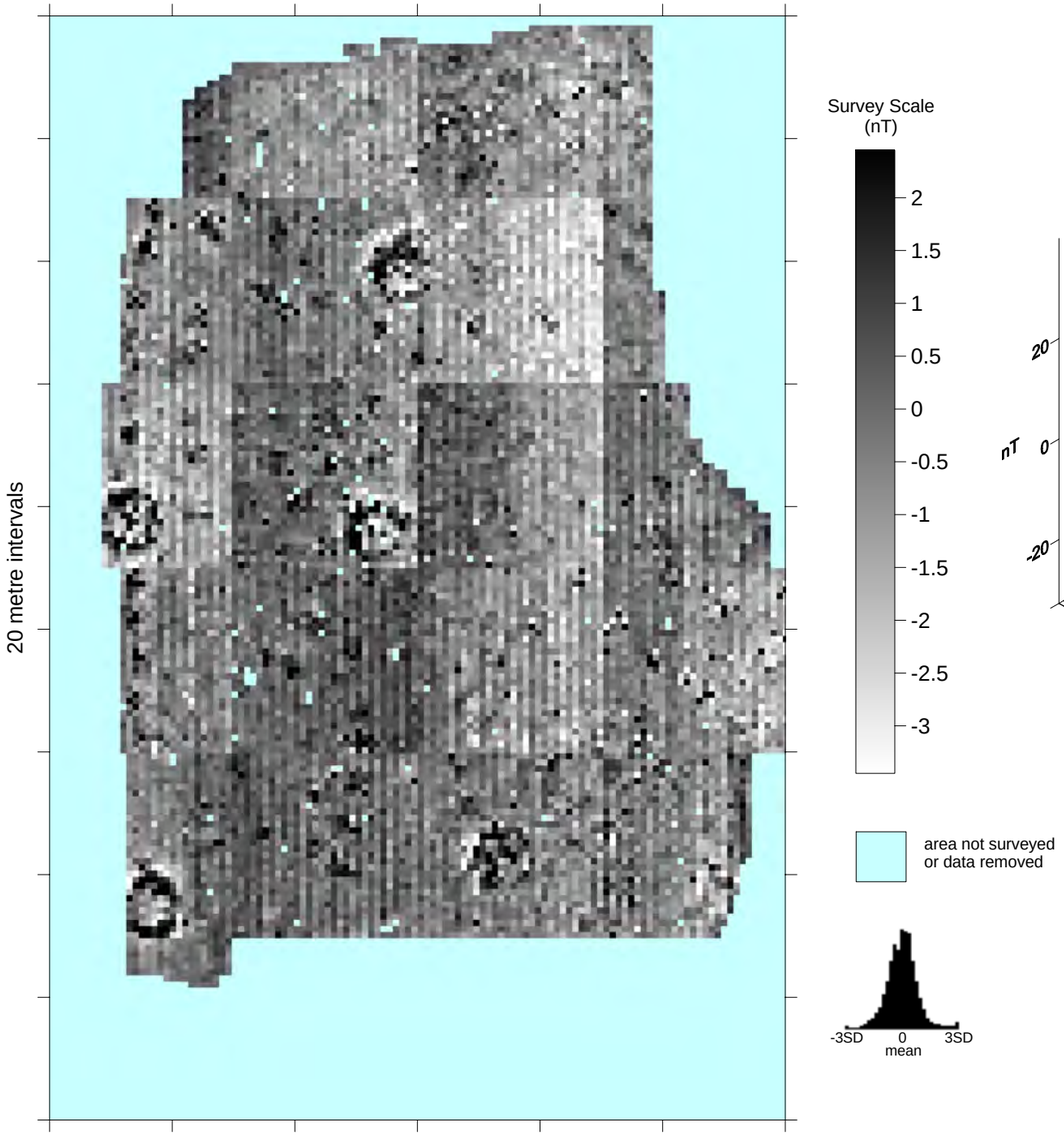
b: gradiometer survey wel05-l1 shade plot of processed data

Figure 4: gradiometer survey wel05-l1 shade plot of processed data over English Heritage earthworks survey (data range -5.12 to 5.12 nT, mean = 0.06 nT, sd = 0.95)
(Earthworks survey re-drawn by Substrata)

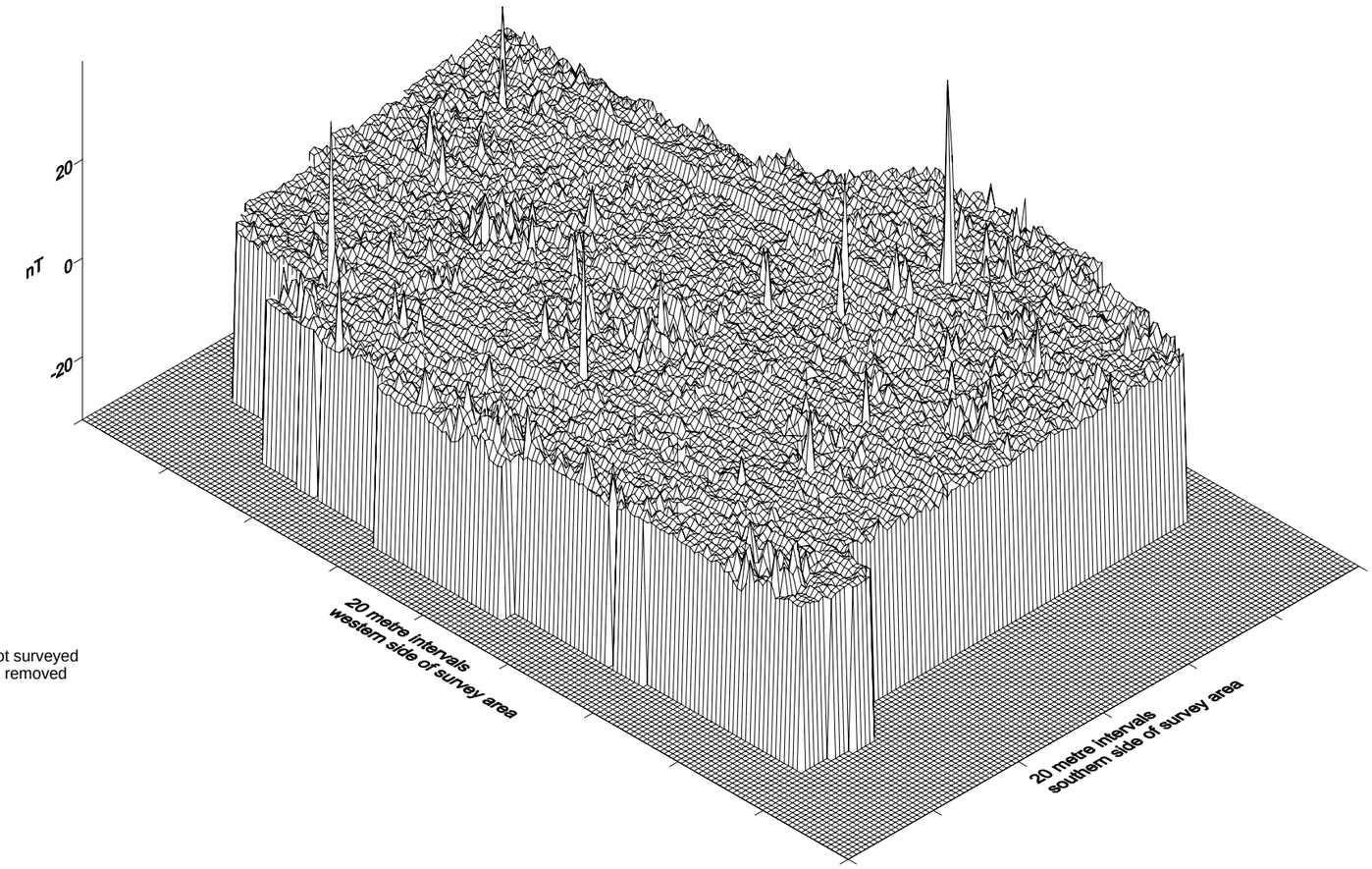


a: gradiometer survey wel05-l1 contour plot of processed data over English Heritage earthworks survey

Figure 5: gradiometer survey wel05-l1 contour plot of processed data over English Heritage earthworks survey (data range -32.7 to 39.9 nT, mean = 0.07 nT, sd = 1.28)
(Earthworks survey re-drawn by Substrata)



a: shade plot of unprocessed data for survey weo05-l1



b: wireframe plot of unprocessed data for survey wel05-l1
(scale 1:1000)

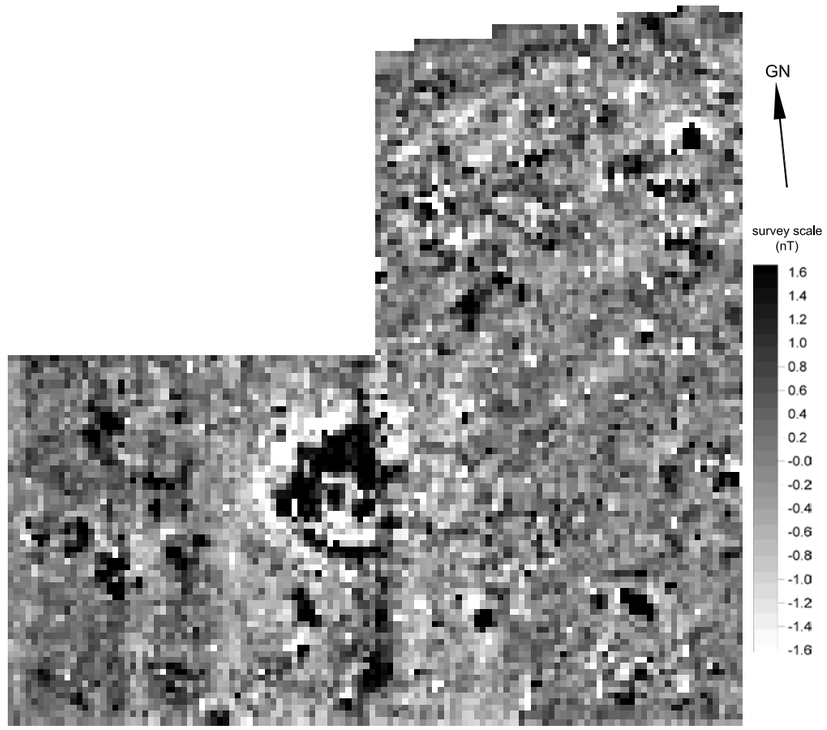
Figure 6: plots of unprocessed data for survey wel05-l1 (data range -32.7 to 39.9 nT, mean=0.50 nT, sd=1.48)

Welshbury Hillfort
Gloucestershire
NGR: SO67881554
SMR: 5161

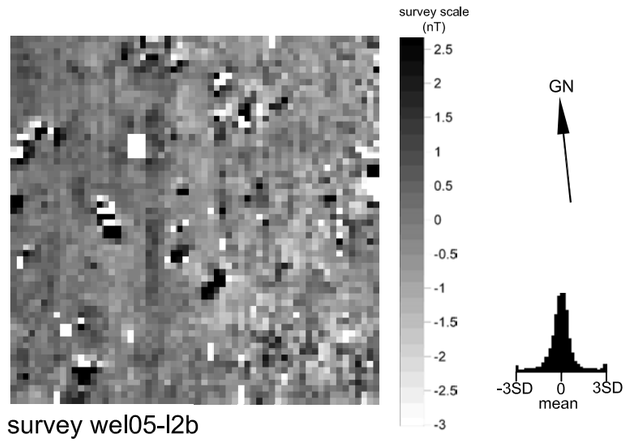
GN

survey wel05-l2a

survey wel05-l2b



survey wel05-l2a
(data range -3.89 to 3.72 nT, mean = 0.02 nT, sd = 0.82)



survey wel05-l2b
(data range -10.5 to 10.5 nT, mean = 0.18 nT, sd = 1.43)

Figure 7:
gradiometer surveys wel05-l2a and wel05-l2b
shade plots of processed data
over English Heritage earthworks survey
(Earthworks survey re-drawn by Substrata)

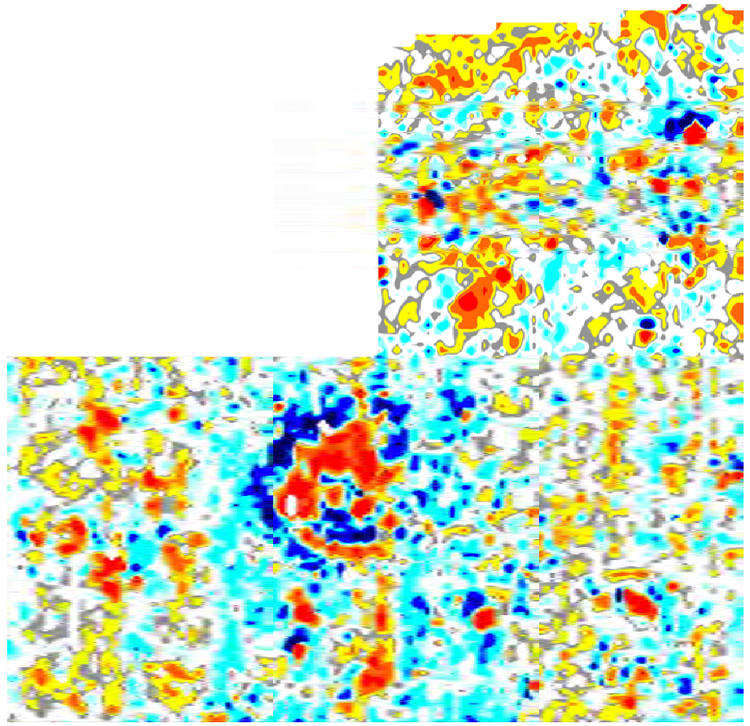
0 10 50 metres
scale 1:500

Welshbury Hillfort
Gloucestershire
NGR: SO67881554
SMR: 5161

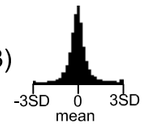
GN

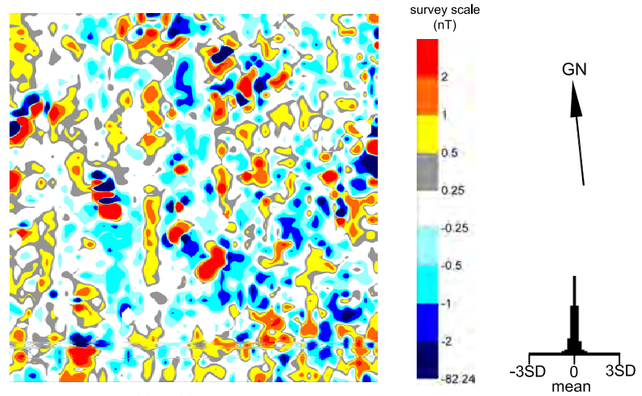
survey wel05-l2a

survey wel05-l2b



survey wel05-l2a
(data range -34.58 to 58.35 nT, mean = 0.52 nT, sd = 1.13)

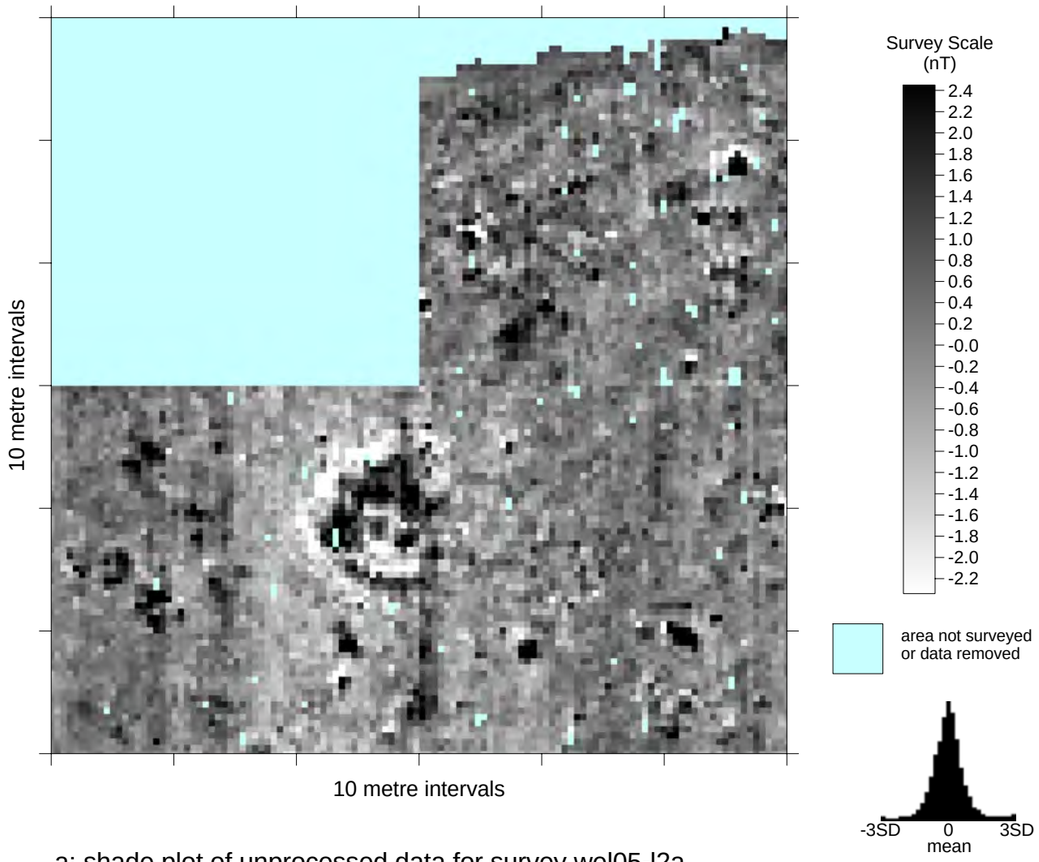




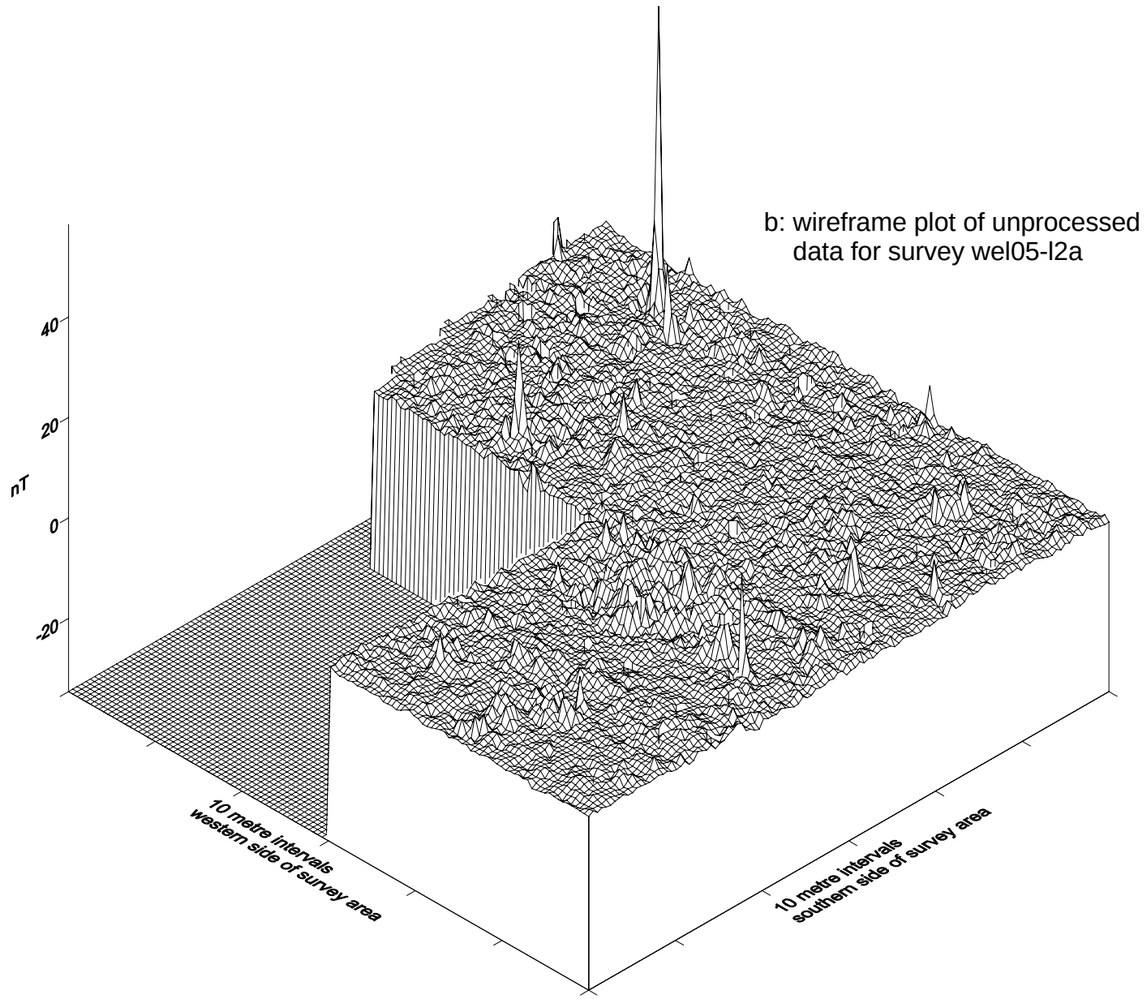
survey wel05-l2b
(data range -82.24 to 117.58 nT, mean = 0.18 nT, sd = 3.45)

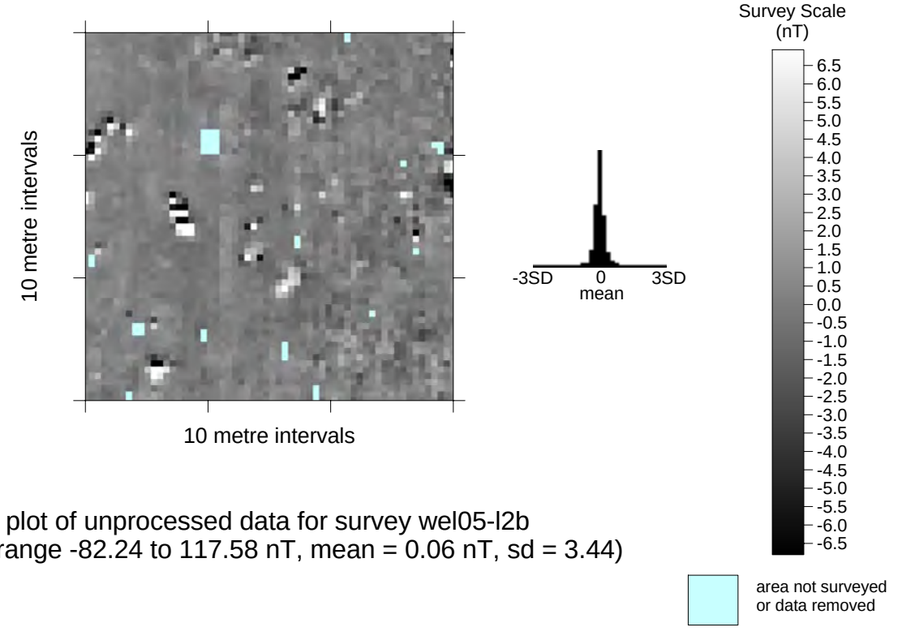
Figure 8:
gradiometer surveys wel05-l2a and wel05-l2b
contour plots of processed data
over English Heritage earthworks survey
(Earthworks survey re-drawn by Substrata)

0 10 50 metres
scale 1:500



a: shade plot of unprocessed data for survey wel05-l2a
(data range -34.56 to 58.35 nT, mean = 0.06 nT, sd = 1.20)





c: shade plot of unprocessed data for survey wel05-l2b
(data range -82.24 to 117.58 nT, mean = 0.06 nT, sd = 3.44)

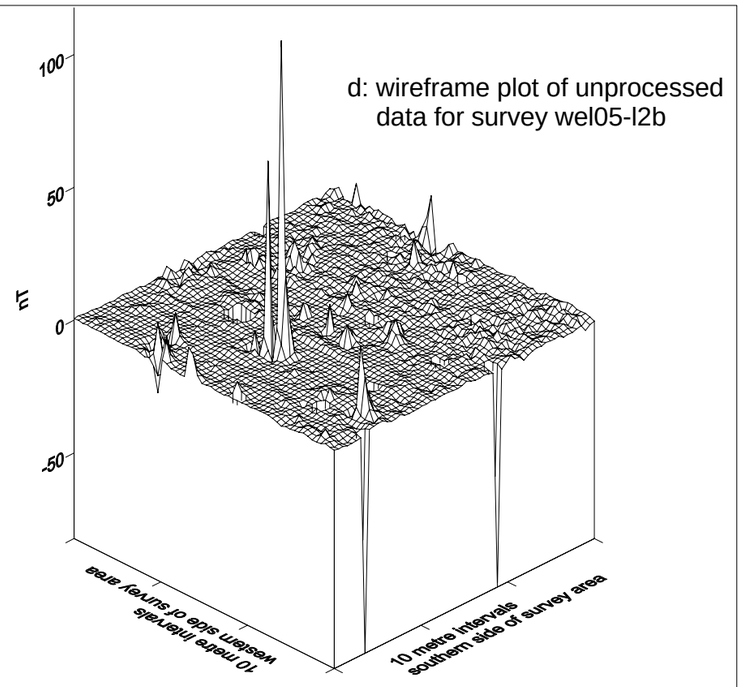


Figure 9: plots of unprocessed data for surveys wel05-l2a and wel05-l2b

Appendix B: Methodology

<table>
<tr><th colspan="2">Table 2: Gradiometer Survey Methodology</th></tr>
<tr><td colspan="2">Grid:
Method of Fixing: total station layout tied to previously mapped earthworks.
Composition: survey wel05-l1, wel05-l2a and wel05-l2b: 30-metre by 30-metre grids
Recording:
On to Ordnance Survey digital map tiles and recorded using Autodesk's AutoCAD 2002. An English Heritage earthworks survey was placed best-fit over the Ordnance Survey digital map and the total station survey of the survey grid and re-surveyed sections of the earthworks was placed best fit to the resulting composite map.</td></tr>
<tr><td>Equipment:
Instrument:
Geoscan Research FM36 with manual trigger
Instrument resolution: 1 nT</td><td>Data Capture:
Survey wel05-l1
Sample Interval: 1 metre
Traverse Interval: 1 metre
Traverse Method: zig-zag
Traverse Orientation: GN 354

Surveys wel05-l2a & wel05-l2b
Sample Interval: 0.5 metres
Traverse Interval: 0.5 metres
Traverse Method: parallel
Traverse Orientation: GN 354</td></tr>
<tr><td colspan="2">Data Processing, Analysis and Presentation Software:
Geoscan's Geoplot 3.00p, Golden Software Inc.'s Surfer 8, Autodesk's AutoCAD 2002, Microsoft Corp.'s Office Publisher 2003.</td></tr>
</table>

Appendix C: Data Processing

Table 3: Fluxgate Gradiometer Survey Data Processing	
	All data processing was completed using Geoscan's Geoplot 3.00p.
Survey wel05-l1	
Figure 4	• Zero-mean traverse (all grids, LMS on, threshold = +/- 5nT) • Cut and combine to restore data compromised by zero mean traverse (34, 25 - 66, 26 from unprocessed data to 34, 25; 37, 81 - 60, 83 from raw data to 37, 81; 35,111 - 60, 114 to 35, 111) • Clip min at +/- 5.12 nT
Figure 5	• Zero-mean traverse (all grids, LMS on, threshold = +/- 5nT) • Cut and combine to restore data compromised by zero mean traverse (34, 25 - 66, 26 from unprocessed data to 34, 25; 37, 81 - 60, 83 from raw data to 37, 81; 35,111 - 60, 114 to 35, 111)
Survey wel05-l2a	
Figure 7	• Search and Replace to tidy traverse lengths at northern edge of survey • Edge Match (grid 1, bottom) • Clip min at +/- 3.53 nT • Zero-mean traverse (LMS on, threshold = +/- 5nT, grids 6, 7, 8)
Figure 8	• Search and Replace to tidy traverse lengths at northern edge of survey • Edge Match (grid 1, bottom)
Survey wel05-l2b	
Figure 7	• Edge Match (grid 1, bottom) • Clip min at +/- 10.5 nT
Figure 8	• Edge Match (grid 1, bottom)
	Complete data processing details are provided in the survey electronic data archive.

Appendix D: Geophysical Surveying Techniques

D1 Introduction

Substrata specialises in magnetometry (gradiometer) and resistance surveying. The particular method or combination of methods used depends on local soil conditions and the survey requirements. Magnetometry and resistance surveying are frequently complementary. In large geophysical surveys it is good practice to assess an area with a magnetometer survey and then selectively apply resistance surveys to areas identified as being likely to contain building remains and other buried archaeology.

The geophysical surveying equipment Substrata uses is specifically developed for archaeological surveying and is the latest generation of proven technology. When used in conjunction with software designed to analyse and present the recorded data, these systems are capable of delivering fast and accurate assessments of the archaeology of both large and small sites. If excavation is required, the geophysical assessment can be used to place trenches over potential archaeological features. The gradiometers (a type of magnetometer) and resistance meters employed are sensitive to depths of between 0 and 3 metres below ground level, with maximum sensitivity at depths of 1.5 metres or less. Most surveys are designed to work within the 0 to 1.5 metre range.

D2 Magnetometry Scanning and Area Surveying

General Concepts

Magnetometry surveying is used to detect and map small changes in the earth's magnetic field caused by magnetised materials buried beneath the surface. While these differences are too small to affect a compass needle, they can be detected and mapped by sensitive field equipment. During surveys the different magnetic properties of topsoils, subsoils, rocks and archaeological features are recorded as variations against a background value. Subsequently magnetic anomalies resulting from potential archaeology can be identified and interpreted. Identifiable archaeological features include areas of occupation, hearths, kilns, furnaces, ditches, pits, post-holes, ridge-and-furrow, timber structures, wall footings, roads, tracks and similar buried features.

Surveying Instruments

A gradiometer is an instrument sensitive to relatively small changes in the earth's magnetic field. Substrata uses two types of gradiometer both specifically designed for field use by archaeologists. Our primary surveying instruments are Bartington *Grad*601-2 (dual sensor) flux-

gate gradiometers with automatic data loggers. We also use a Geoscan FM36 fluxgate gradiometer with an automatic and manual sampling triggers. The Bartington gradiometers provide the latest proven technology in archaeological magnetic surveying and offer fast, accurate set-up and survey rates. The Geoscan FM36 provides an effective solution when surveys are required in difficult terrain such as woodland. More technical details can be provided as required.

Magnetic Scanning Surveys

When speed and general assessment are key requirements, scanning with gradiometers facilitate fast, on-site data analysis. This method allows rapid assessment of large areas of land such as proposed main communications routes, pipeline routes and significant commercial developments. Scanning is useful in complementing aerial surveys across wooded areas or fields under permanent pasture. This technique can also be effectively used in exploring suspected archaeological sites found during field walking surveys.

Magnetic Area Surveys

These are detailed area surveys employing a greater density of traverses and readings across the area of interest compared to scanning surveys. The current typical sampling interval for detailed area surveys is 0.25 metres on traverses 1.0 metre apart.

Typically, area surveys are undertaken when archaeological features are expected to be relatively concentrated or when a comprehensive survey is required. They are used to clarify areas of archaeological interest and to enable decisions to be made on the location of features to be preserved or excavated. Recent developments in the speed of surveying equipment such as the *Grad*601-2 system means that area surveys are often cost-effective alternatives to scanning surveys.

D3 Resistance Area and Linear Surveying

General Concepts

This method measures changes in the electrical resistance of the ground being surveyed. In practice, differences in the electrical resistance of materials facilitates the detection and interpretation of masonry and brick foundations, paving and floors, drains and other cavities, large pits, building platforms, robber trenches, timber structures, ditches, graves and similar buried features.

Resistance to electrical current flow in the ground depends on the moisture content and structure of the soil and other materials buried beneath the surface. For example, the higher the moisture content of a soil, the less resistant it is to electrical current flow. A ditch completely

buried beneath the present ground surface is likely to have an infill soil different to that surrounding the ditch in terms of compactness and composition. As a result, the soil filling the buried ditch will retain moisture in a different way to the surrounding soil which means it will have an electrical resistance at variance with the surrounding environment. By passing a small current through the ground it is possible to detect, record, plot and interpret such changes in electrical resistance.

Surveying Instruments

For resistance surveying Substrata uses the Geoscan Research RM 15 multi-probe resistance meters and purpose-built automatic data-loggers. The MPX 15 multi-probe facility can be used to speed up standard surveys and it is also useful when simultaneous multiple-depth analysis is required.

Resistance area surveys

Resistance area surveys are excellent tools for the detailed planning of likely archaeological sites and particularly useful in the surveying of areas likely to contain building footings or similar structures.

Resistance linear surveys

Resistance linear surveys are useful when searching a large area for buried buildings or roads and similar large linear archaeological features.

A reading interval of 1.0 metres by 1.0 metres is standard for both area surveys and the linear surveys.

D4 Other methodologies offered: Magnetic Susceptibility Surveying

Human activities such as burning, rubbish accumulation, fertilisation and animal husbandry enhance the magnetic susceptibility of topsoils. This means some archaeological sites having no remaining buried features can still be detected by examining modern topsoils for patterns of susceptibility that indicate likely past human activity. Sampling intervals for this type of survey are usually 20 metres or less.

Magnetic susceptibility surveys using a portable field system and data-logger are sometimes used to prospect for areas of higher magnetic susceptibility that may indicate the presence of archaeological structures. Such portable systems are also used explore the extent of suspected sites during archaeological field walking surveys.

Magnetic susceptibility surveys using sample collection and laboratory analysis are useful when there is a need to examine topsoil that is no longer *in situ* but has been deposited in, for example, lake sediments or alluvium. Analysis of such sediments in cores and sections can detect traces of past activities such as land clearance and cultivation.

In most cases, magnetic susceptibility surveys of *in situ* topsoils are best undertaken in conjunction with partial sampling using other geophysical survey techniques (such as fluxgate gradiometer surveys across selected areas of at least 60 metres by 60 metres) to provide an acceptable degree of positional and interpretative analysis.