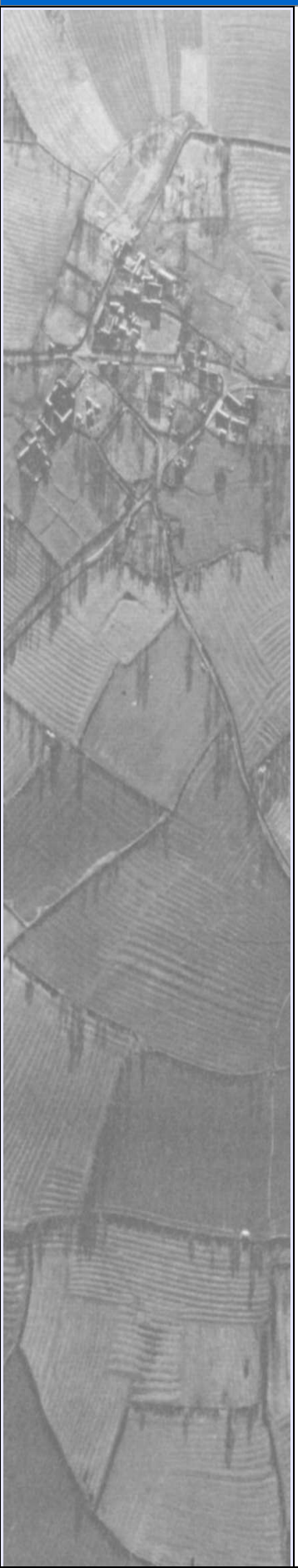

Royal High School
Playing Field
Bath

MAGNETOMETER SURVEY REPORT

for

Cotswold Archaeology

Kerry Donaldson & David Sabin

October 2015

Ref. no. 633

ARCHAEOLOGICAL SURVEYS LTD

Royal High School
Playing Field
Bath

Magnetometer Survey Report

for

Cotswold Archaeology

Fieldwork by David Sabin (Hons) MCIfA
Report by Kerry Donaldson BSc (Hons)
Report checked by David Sabin
Primary archive location - Archaeological Surveys Ltd, Yatesbury, Wiltshire

Survey date – 1st October 2015
Ordnance Survey Grid Reference – **ST 74068 67741**

Archaeological Surveys Ltd
1 West Nolands, Nolands Road, Yatesbury, Calne, Wiltshire, SN11 8YD
Tel: 01249 814231 Fax: 0871 661 8804
Email: info@archaeological-surveys.co.uk
Web: www.archaeological-surveys.co.uk

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SUMMARY

A detailed magnetometer survey was carried out by Archaeological Surveys Ltd, at the request of Cotswold Archaeology, on the site of the former Royal High School Playing Field on the northern edge of Bath. The results reveal positive linear and discrete anomalies that appear to relate to natural features such as joints, cracks and fissures within the underlying limestone geology. One positive discrete anomaly appears to relate to a pit-like feature larger than the majority of the natural features, and while it may also be natural, an anthropogenic origin is possible. Amorphous weakly positive or magnetically variable responses may indicate former quarrying; however, they may also be natural in origin.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by Cotswold Archaeology to undertake a magnetometer survey within the former Royal High School Playing Field near Lansdown on the northern edge of Bath. The site has been outlined for a proposed residential and primary school development. The survey forms part of an archaeological assessment of the site.

1.1.2 The geophysical survey was carried out in accordance with a Written Scheme of Investigation (WSI) produced by Archaeological Surveys (2015) and issued by Cotswold Archaeology to Richard Sermon, Senior Archaeological Officer for Bath & North East Somerset, prior to the commencement of the fieldwork.

1.2 Survey objectives and techniques

1.2.1 The objective of the survey was to use magnetometry to locate geophysical anomalies that may be archaeological in origin so that they may be assessed prior to development of the site. The methodology is considered an efficient and effective approach to archaeological prospection.

1.2.2 The survey and report generally follow the recommendations set out by: English Heritage (2008) *Geophysical survey in archaeological field evaluation;* and Institute for Archaeologists (2002) *The use of Geophysical Techniques in Archaeological Evaluations*. The work has been carried out to the Chartered Institute for Archaeologists (2014) *Standard and Guidance for Archaeological Geophysical Survey.*

1.3 Site location, description and survey conditions

1.3.1 The site lies 180m north east of Lansdown Road, adjacent to the former MoD Ensleigh site on the northern edge of Bath. It is centred on Ordnance Survey

National Grid Reference (OS NGR) ST 74068 67741, see Figures 01 and 02.

1.3.2 The geophysical survey covers approximately 3.5ha within a single area of land formerly used as a playing field. It is surrounded by trees on three sides with tall metal fencing to the south and east. A pavilion building is located in the south eastern part of the area with a second small building located close to the south eastern corner.

Plate 1: Survey area looking south west

1.3.3 The ground conditions across the site were generally considered to be favourable for the collection of magnetometry data. Weather conditions during the survey were fine.

1.4 Site history and archaeological potential

1.4.1 An Archaeological Assessment has been carried out for the site (Watkins, 2014), which outlines that although there are no designated or undesignated heritage assets directly within the site, there are a number of archaeological sites and findspots in the surrounding area. These include Mesolithic flint scatters, several Bronze Age barrows, with one potentially recorded 40m to the south of the site, and Iron Age field systems. Lansdown Road is purported to be on the line of a Roman road with several Romano-British burials along it and a number of villas on the Lansdown plateau. A fragment of a 9th century stone cross, found 50m to the south east, may indicate early medieval activity in the area. During the medieval period the area was owned by the Prior of Bath Monastery and was used for sheep pasture. It continued as agricultural land until it became a playing field in the early 20th century. It lies immediately

adjacent to the former MoD Ensleigh site.

1.4.2 There is some potential for the site to contain evidence of possible prehistoric and/or Romano-British activity. There is always potential for the geophysical survey to locate anomalies that relate to previously unrecorded archaeological features should they be present within the site.

1.5 Geology and soils

1.5.1 The underlying solid geology across the site is Great Oolite Jurassic limestone from the Chalfield Oolite Formation (BGS, 2015).

1.5.2 The overlying soil across the survey area is from the Elmton 1 association and is a brown rendzina. It consists of a shallow, well drained, brashy, calcareous, fine, loamy soil over limestone (Soil Survey of England and Wales, 1983).

1.5.3 Magnetometry survey carried out across similar soils has produced good results, although there can be natural cracks and joints and other soil filled features within the underlying geology which at times can be difficult to distinguish from those with an anthropogenic origin. However, the underlying geology and soils are considered acceptable for magnetic survey due to the strong contrast between cut features and the material into which they are cut.

2 METHODOLOGY

2.1 Technical synopsis

2.1.1 Magnetometry survey records localised magnetic fields that can be associated with features formed by human activity. Magnetic susceptibility and magnetic thermoremnance are factors associated with the formation of localised fields. Additional details are set out below and within Appendix A.

2.1.2 Iron minerals within the soil may become altered by burning and the break down of biological material; effectively the magnetic susceptibility of the soil is increased, and the iron minerals become magnetic in the presence of the Earth's magnetic field. Accumulations of magnetically enhanced soils within features, such as pits and ditches, may produce magnetic anomalies that can be mapped by magnetic prospection.

2.1.3 Magnetic thermoremnance can occur when ferrous minerals have been heated to high temperatures such as in a kiln, hearth, oven etc. On cooling, a permanent magnetisation may be acquired due to the presence of the Earth's magnetic field. Certain natural processes associated with the formation of some igneous and metamorphic rock may also result in magnetic thermoremnance.

2.1.4 The localised variations in magnetism are measured as sub-units of the Tesla,

which is a SI unit of magnetic flux density. These sub-units are nano Teslas (nT), which are equivalent to 10^{-9} Tesla (T).

2.2 Equipment configuration, data collection and survey detail

2.2.1 The detailed magnetic survey was carried out using a SENSYS MAGNETO®MXPDA 5 channel cart-based system. The instrument has 5 fluxgate gradiometers spaced 0.5m apart with readings recorded at 20Hz. The gradiometers have a range of recording data between 0.1nT and 10,000nT. The system is linked to a Leica GS10 RTK GPS with data recorded by SENSYS MAGNETO®MXPDA software on a rugged computer.

2.2.2 Data are collected along a series of parallel survey tracks wherever possible. The length of each track is variable and relates to the size of the survey area and other factors including ground conditions. A visual display aids accurate placing of tracks and their separation.

2.2.3 Data are not collected within fixed grids and data points are considered to be random even though the data are collected in a systematic manner covering all accessible areas (Aspinall, Gaffney and Schmidt, 2009).

2.3 Data processing and presentation

2.3.1 Magnetic data collected by the MAGNETO®MXPDA cart-based system are initially prepared using SENSYS MAGNETO®DLMGPS software. Survey tracks are analysed and georeferenced raw data (UTM Z30N) are then exported in ASCII format for further analysis and display using TerraSurveyor.

2.3.2 The data are collected between limits of ±10000nT and clipped for display at ±5nT. Data are interpolated to a resolution of effectively 0.5m between tracks and 0.15m along each survey track. A zero median traverse function is required in order to remove fixed offset values present within the sensors which do not undergo a zeroing procedure in the field. The approach ensures that the gradiometer sensors are very accurately aligned and fixed to the vertical magnetic field and are not influenced by localised magnetic fields or disturbed by vibration. Although a zero median traverse algorithm can remove anomalies aligned with the survey tracks, in practice this rarely occurs due to the use of long traverses, high resolution measurement and variability within the magnetic susceptibility of long linear features.

2.3.3 Appendix C contains metadata concerning the survey and data attributes and is derived directly from TerraSurveyor. Reference should be made to Appendix B for further information on any processes, such as clipping, carried out on the data.

2.3.4 A TIF file is produced by TerraSurveyor software along with an associated world file (.TFW) that allows automatic georeferencing (OSGB36 datum) when using GIS or CAD software. The main form of data display used in the report

is the minimally processed greyscale plot.

2.3.5 The raster images are combined with base mapping using ProgeCAD Professional 2014, creating DWG (2010) file formats. All images are externally referenced to the CAD drawing in order to maintain good graphical quality. The CAD plots are effectively georeferenced facilitating relocation of features using GPS, resection method, etc.

2.3.6 An abstraction and interpretation is also drawn and plotted for all geophysical anomalies located by the survey. Anomalies are abstracted using colour coded points, lines and polygons. All plots are scaled to landscape A3 for paper printing.

2.3.7 A brief summary of each anomaly, with an appropriate reference number, is set out in list form within the results (Section 3) to allow a rapid and objective assessment of features within the survey area.

2.3.8 A digital archive is produced with this report, see Appendix D below. The main archive is held at the offices of Archaeological Surveys Ltd.

3 RESULTS

3.1 General assessment of survey results

3.1.1 The detailed magnetic survey was carried out over 3.5ha within a single land parcel.

3.1.2 Magnetic anomalies located can be generally classified as positive and negative anomalies of an uncertain origin, anomalies with a natural origin, areas of magnetic debris and strong discrete dipolar anomalies relating to ferrous objects. Anomalies located within the survey area have been numbered and are described in 3.4 below.

3.2 Statement of data quality

3.2.1 Data are considered representative of the magnetic anomalies present within the site. There are no significant defects within the dataset.

3.3 Data interpretation

3.3.1 The list of sub-headings below attempts to define a number of separate categories that reflect the range and type of features located during the survey. A basic explanation of the characteristics of the magnetic anomalies is set out for each category in order to justify interpretation, a basic key is indicated to allow cross referencing to the abstraction and interpretation plot. CAD layer names are included to aid reference to associated digital files (.dwg/.dxf). Sub-headings are then used to group anomalies with similar

characteristics within the survey area.

Report sub-heading CAD layer names and plot colour	Description and origin of anomalies
Anomalies with an uncertain origin AS-ABST MAG NEG LINEAR UNCERTAIN AS-ABST MAG POS DISCRETE UNCERTAIN AS-ABST MAG POS UNCERTAIN 	The category applies to a range of anomalies where there is not enough evidence to confidently suggest an origin. Anomalies in this category may well be related to archaeological features, but equally relatively modern features, geological/pedological features and agricultural features should be considered. Positive anomalies are indicative of magnetically enhanced soils that may form the fill of 'cut' features or may be produced by accumulation within layers or 'earthwork' features; soils subject to burning may also produce positive anomalies. Negative anomalies are produced by material of comparatively low magnetic susceptibility such as stone and subsoil.
Anomalies with a natural origin AS-ABST MAG LINEAR NATURAL AS-ABST MAG DISCRETE NATURAL	Naturally formed magnetic anomalies are are caused by localised variability in the magnetic susceptibility of soils, subsoils and/or solid geologies. They can relate to joints, cracks, fissures and gulls within the solid geology. They can be linear, rectilinear, curvilinear, discrete and amorphous. It can be difficult to distinguish linear and rectilinear anomalies from those with an anthropogenic/archaeological origin.
Anomalies associated with magnetic debris AS-ABST MAG DEBRIS AS-ABST MAG STRONG DIPOLAR 	Magnetic debris often appears as areas containing many small dipolar anomalies that may range from weak to very strong in magnitude. It often occurs where there has been dumping or ground make-up and is related to magnetically thermoremnant materials such as brick or tile or other small fragments of ferrous material. Strong discrete dipolar anomalies are responses to ferrous objects within the topsoil.

Table 1: List and description of interpretation categories

3.4 List of anomalies

Area centred on OS NGR 374068 167741, see Figures 03 & 04.

Anomalies with an uncertain origin

(1) - A discrete positive anomaly with a response of 10nT is larger, at 4.6m by 6.3m, and slightly stronger than the majority of other positive discrete anomalies within the site (5). It is possible that it relates to a natural feature; however, an anthropogenic origin should also be considered.

(2) - Two negative linear anomalies can be seen in the western part of the survey area. It is not clear if they are directly associated.

(3) - A small number of amorphous weakly positive or magnetically variable responses can be seen within the site. Although an association with quarrying is possible, they may relate to natural features within the underlying limestone geology.

Anomalies with a natural origin

(4) - The survey area contains a large number of positive linear responses. These have a general north west to south east and north east to south west trend, although there are variations within. Most have a response of 1-6nT, with one anomaly in the east peaking at over 15nT. The morphology indicates that they relate to soil filled natural joints and cracks within the underlying limestone geology.

(5) - A number of discrete positive responses appear as pit-like features with a response of 5-6nT and dimensions of 1.5-2m across. There is no coherent pattern and they are likely to relate to naturally formed features.

Anomalies associated with magnetic debris

(6) - A small patch of magnetic debris at the south eastern corner of the area is likely to relate to material associated with the use of the site as a playing field.

(7) - The site contains a number of discrete, strong, dipolar anomalies. These relate to ferrous and other magnetically thermoremnant objects within the topsoil. Many will relate to the use of the site as a playing field.

4 CONCLUSION

4.1.1 The detailed magnetometer survey located anomalies predominantly associated with naturally formed features within the underlying limestone geology. One pit-like response was larger and stronger than the majority of the anomalies and although a natural origin is possible, an anthropogenic origin should be considered. Several amorphous responses are evident, and while they may be associated with quarrying a natural origin is possible. Two negative linear anomalies have also been located, but it is not possible to determine their origin.

5 REFERENCES

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Appendix A – basic principles of magnetic survey

Iron minerals are always present to some degree within the topsoil and enhancement associated with human activity is related to increases in the level of magnetic susceptibility and thermoremnant material.

Magnetic susceptibility is an induced magnetism within a material when it is in the presence of a magnetic field. This can be thought of as effectively permanent due to the presence of the Earth's magnetic field.

Thermoremnant magnetism occurs when ferrous material is heated beyond a specific temperature known as the Curie Point. Demagnetisation occurs at this temperature with re-magnetisation by the Earth's magnetic field upon cooling.

Enhancement of magnetic susceptibility can occur in areas subject to burning and complex fermentation processes on biological material; these are frequently associated with human settlement. Thermoremnant features include ovens, hearths, and kilns. In addition thermoremnant material such as tile and brick may also be associated with human activity and settlement.

Silting and deliberate infilling of ditches and pits with magnetically enhanced soil can create an area of enhancement compared with surrounding soils and subsoils into which the feature is cut. Mapping enhanced areas will produce linear and discrete anomalies allowing an assessment and characterisation of hidden subsurface features.

It should be noted that areas of negative enhancement can be produced from material having lower magnetic properties compared to the topsoil. This is common for many sedimentary bedrocks and subsoils which were often used in the construction of banks and walls etc. Mapping these 'negative' anomalies may also reveal archaeological features.

Magnetic survey or magnetometry can be carried out using a fluxgate gradiometer and may be referred to as gradiometry. The SENSYS gradiometer is a passive instrument consisting of two fluxgate sensors mounted vertically 65cm apart. The instrument is carried about 10-20cm above the ground surface and the upper sensor measures the Earth's magnetic field as does the lower sensor but this is influenced to a greater degree by any localised buried field. The difference between the two sensors will relate to the strength the magnetic field created by the buried feature.

There are a number of factors that may affect the magnetic survey and these include soil type, local geology and previous human activity. Situations arise where magnetic disturbance associated with modern services, metal fencing, dumped waste material etc., obscures low magnitude fields associated with archaeological features.

Appendix B – data processing notes

Clipping

Minimum and maximum values are set and replace data outside of the range with those values. Extreme values are removed improving colour or greyscale contrast associated with data values that may be archaeologically significant. It has been found that clipping data to ranges between ±5nT and ±3nT often improves the appearance of features associated with archaeology. Different ranges are applied to data in order to determine the most suitable for anomaly abstraction and display.

Zero (destripe) Median/Mean Traverse

The median (or mean) of each traverse is calculated ignoring data outside a threshold value, the median (or mean) is then subtracted from the traverse. The process is used to equalise differences between the baseline value of gradiometer sensors.

High Pass Filtering

A mathematical process used to remove low frequency anomalies relating to survey tracks and modern agricultural features.

Appendix C – survey and data information

```
COMPOSITE
Filename:              J633-mag-proc.xcp
Description:           Imported as Composite from: J633-mag.asc
Instrument Type:       Sensys DLMGPS
Units:                 nT
UTM Zone:              30U
Survey corner coordinates (X/Y):OSGB36
Northwest corner:      373944.274735143, 167847.851825519 m
Southeast corner:      374182.474735143, 167634.851825519 m
Collection Method:     Randomised
Sensors:               5
Dummy Value:           32702

Source GPS Points:     895400

Dimensions
Composite Size (readings):  1588 x 1420
Survey Size (meters):       238 m x 213 m
Grid Size:             238 m x 213 m
X Interval:            0.15 m
Y Interval:            0.15 m

Stats
Max:                   5.53
Min:                   -5.50
Std Dev:               1.64
Mean:                  0.11
Median:                0.00
Composite Area:        5.0737 ha
Surveyed Area:         3.4757 ha

PROGRAM
Name:                  TerraSurveyor
Version:               3.0.23.0

Processes:    1
  1   Base Layer

GPS based Proce4
  1   Base Layer.
  2   Unit Conversion Layer (Lat/Long to OSGB36).
  3   DeStripe Median Traverse:
  4   Clip from -5.00 to 5.00 nT
```

Appendix D – digital archive

Archaeological Surveys Ltd hold the primary digital archive at their offices in Wiltshire. Data are backed-up onto an on-site data storage drive and at the earliest opportunity data are copied to CD ROM for storage on-site and off-site.

A copy of the report in PDF format will be supplied to the Bath & North East Somerset Historic Environment Record, with printed copies available on request. The report will also be uploaded to the Online AccesS to the Index of archaeological investigationS (OASIS).

Archive contents:

Geophysical data - path: J633 Bath\Data				
Path and Filename	**Software**	**Description**	**Date**	**Creator**
ensleigh1\MX\ .prm .dgb .disp	Sensys MXPDA	Proprietary data formats representing magnetometer survey traverses logged to a PDA.	01/10/15	D.J.Sabin
ensleigh1\MX\J633-mag.asc	Sensys DLMGPS	ASCII CSV (tab) file representing survey Area 1 in eastings, northings (UTM Z30N), magnetic measurement, traverse file and sensor number.	02/10/15	K.T.Donaldson
Mag\comps\J633-mag.xcp	TerraSurveyor 3.0.23.0	Composite data file derived from ASCII CSV.	02/10/15	K.T.Donaldson
Mag\comps\J633-mag-proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file (zmt and clipping to ±5nT).	02/10/15	K.T.Donaldson
Graphic data - path: J633 Bath\Data				
Mag\graphics\ J633-mag-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a minimally processed greyscale plot clipped to ±5nT.	02/10/15	K.T.Donaldson
Mag\graphics\ J633-mag-proc.tfw	TerraSurveyor 3.0.23.0	World file for georeferencing TIF to OSGB36.	02/10/15	K.T.Donaldson
CAD data - path: J633 Bath\CAD				
J633 version 1.dwg	ProgeCAD 2014	CAD file for creating plots of greyscales, abstraction, interpretation and mapping. Grid coordinates as OSGB. AutoCAD 2010 format.	29/09/15	K.T.Donaldson
Text data - path: J633 Bath\Documentation				
J633 report.odt	OpenOffice.org 3.0.1 Writer	Report text as an Open Office document.	02/10/15	K.T.Donaldson

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Survey location

N

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Geophysical Survey
Royal High School
Playing Field
Bath

Map of survey area

Survey location

Site centred on OS NGR
ST 74068 67741

SCALE 1:25 000

0m 500m 1000m

SCALE TRUE AT A3

FIG 01

Archaeological Surveys Ltd

Geophysical Survey
Royal High School
Playing Field
Bath

Referencing information

Referencing grid to OSGB36 datum at 50m intervals

Data collected at 20Hz and georeferenced to ETRS89 zone 30 with conversion to OSGB36 using OSTN02

374000 167800

SCALE 1:2000

0m 20 40 60 80 100m

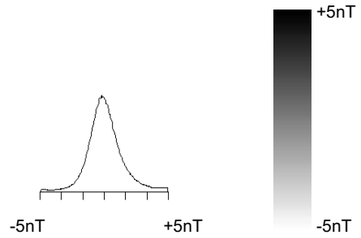
SCALE TRUE AT A3

FIG 02

Archaeological Surveys Ltd

Geophysical Survey
Royal High School
Playing Field
Bath

Greyscale plot of minimally processed magnetometer data



SCALE 1:1000

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 03

Archaeological Surveys Ltd

Geophysical Survey
Royal High School
Playing Field
Bath

Abstraction and interpretation of magnetometer anomalies

- Negative linear anomaly - material of low magnetic susceptibility
- Positive linear anomaly - of natural origin
- Discrete positive response - possible pit-like feature
- Discrete positive response - of natural origin
- Positive anomaly - weakly magnetically enhanced material
- Magnetic debris - spread of magnetically thermoremnant/ferrous material
- Strong dipolar anomaly - ferrous object

N

1
2
3
4
5
6
7

SCALE 1:1000

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 04