STRATASCAN

Geophysical Survey Report

Magdalen College, Oxford

For

John Steane

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1 SUMMARY OF RESULTS

A detailed magnetometry (gradiometery), resistivity and ground penetrating radar (GPR) survey were carried out at the cloisters of Magdalen College, Oxford. The resistivity and GPR survey produced interesting anomalies of possible archaeological origin. The magnetometer survey was of limited use due to the presence of metallic objects within and around the survey areas.

A possible buried structure of archaeological origin may have been identified within the centre of the cloisters, and can be best seen within the GPR timeslice data with supporting evidence from the resistivity data in the form of possible evidence of archaeological debris and cut features.

A number of services have been identified within all data sets.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned to undertake a geophysical survey within and around the Cloisters at Magdalen College, Oxford. This survey forms part of an archaeological investigation of the area.

2.2 Site location

The site is located at the cloisters of Magdalen College, Oxford at OS NGR ref. SP 522 063.

2.3 Description of site

The survey area includes the central grassed area of the Cloisters (Area A) and a grassed area situated between the outer east walls of the cloisters and the River Cherwell (Area B). The topography of both survey areas was flat. Area A contained a large service (a water main) running from a hydrant in the centre of the survey to the entrance of the cloisters situated towards the western edge of the survey area.

The underlying geology is Oxford Clay with overlying Alluvium (British Geological Survey South Sheet, Third Edition (Solid), 1979, British Geological Survey South Sheet, First Edition (Quaternary), 1977). Although the soils within the city of Oxford have not been mapped extensively due to the urban environment, the overlying soils are likely to be Pelo-alluvial Gley soils. These consist of stoneless clayey soils (Soil Survey of England and Wales, Sheet 6 Eastern England).

2.4 Site history and archaeological potential

By the Norman conquest Oxford was amongst the largest towns in England. The Anglo-Saxon town was established on a north to south axis down St Aldate's street to the Thames crossing. However, the curving street (not on the Anglo-Saxon alignment) leading eastwards (High Street) to the Cherwell crossing was well established when included into the late Saxon defences (www.oxfordshire.gov.uk).

William Waynflete, Bishop of Winchester, founded Magdalen College in 1458 after acquiring the site of the decayed Hospital of St John the Baptist in 1456. Some of the thirteenth century buildings were incorporated into the new foundations of Magdalen College (www.british-history.ac.uk). Construction of the cloisters began in 1474 (www.magd.ox.ac.uk).

Oxford Hospital of St John the Baptist was originally a hostel for entertaining travellers, which is first mentioned in Godstow Cartulary in 1180 (www.wantage.com). These buildings were greatly enlarged by Hugh Malaunay between 1191 and 1199 (www.british-history.ac.uk). The hostel was refounded as a hospital for the sick by Henry Ш in 1231 with a grant for a garden outside the eastern gate. Between 1232 and 1257 the hospital was completely rebuilt, work included progress on the chapel, kitchen, infirmary and a chamber for women in childbirth. In 1294 the brethren received permission to enclose a vacant plot to use as a burial ground (possibly a former Jewish cemetery). Part of the hospital burial ground was uncovered during renovation in 1976-7 (www.wantage.com)

During the foundation of Magdalen College most of the hospital buildings were demolished, however some buildings were incorporated. The infirmary block formed the north range of the college cloisters until 1822; the buildings to the north of it survived as college stables until 1733 and some rooms adjoining the kitchen served as lodgings until 1783. The Chapel survived almost intact until 1790, having been converted into a lecture room and alms-houses in the 16th century (www.british-history.ac.uk).

2.5 Survey objectives

The objective of the survey was to locate any anomalies that may be of archaeological significance.

2.6 Survey methods

Resistivity, detailed magnetometry (gradiometery) and ground penetrating radar (GPR) were carried out across the survey areas. More information regarding these techniques is included in the Methodology section below.

3 METHODOLOGY

3.1 Date of fieldwork

The fieldwork was carried out over four days from 20/12/04-22/12/04 and the 6/1/05 when the weather was mainly cold and dry with occasional showers.

3.2 Grid locations

The location of the survey grids and GPR traverses has been plotted in Figures 3 and 11.

3.3 Description of techniques and equipment configurations

Resistivity
This method relies on the relative inability of soils (and objects within the soil) to conduct an electrical current which is passed through them. As resistivity is linked to moisture content, and therefore porosity, hard dense features such as rock will give a relatively high resistivity response, while features such as a ditch which retains moisture give a relatively low response.

The resistance meter used was an RM15 manufactured by Geoscan Research incorporating a mobile Twin Probe Array. The Twin Probes are separated by 0.5m and the associated remote probes were positioned approximately 15m outside the grid. The instrument uses an automatic data logger which permits the data to be recorded as the survey progresses for later downloading to a computer for processing and presentation.

Though the values being logged are actually resistances in ohms they are directly proportional to resistivity (ohm-metres) as the same probe configuration was used through-out.

Detailed magnetometry (gradiometry)
The magnetic survey was carried out using a dual sensor Grad601-2 Magnetic Gradiometer manufactured by Bartington Instruments Ltd. The Grad601-2 consists of two high stability fluxgate gradiometers suspended on a single frame. Each sensor has a 1m separation between the sensing elements giving a strong response to deep anomalies, so enhancing the response from weaker anomalies.

Radar
Two of the main advantages of radar are its ability to give information of depth as well as work through a variety of surfaces, even in cluttered environments and which normally prevent other geophysical techniques being used.

A short pulse of energy is emitted into the ground and echoes are returned from the interfaces between different materials in the ground. The amplitude of these returns depends on the change in velocity of the radar wave as it crosses these interfaces. A measure of these velocities is given by the dielectric constant of that material. The travel times are recorded for each return on the radargram and an approximate conversion made to depth by calculating or assuming an average dielectric constant (see below).

Drier materials such as sand, gravel and rocks, i.e. materials which are less conductive (or more resistant), will permit the survey of deeper sections than wetter materials such as clays which are more conductive (or less resistant). Penetration can be increased by using longer wavelengths (lower frequencies) but at the expense of resolution (see 3.4.2 below).

As the antennae emit a "cone" shaped pulse of energy an offset target showing a perpendicular face to the radar wave will be "seen" before the antenna passes over it. A resultant characteristic *diffraction* pattern is thus built up in the shape of a hyperbola. A classic target generating such a diffraction is a pipeline when the antenna is travelling across the line of the pipe. However it should be pointed out that if the interface between the target and its surrounds does not result in a marked change in velocity then only a weak hyperbola will be seen, if at all.

The Ground Probing Impulse Radar used was a SIR2000 system manufactured by Geophysical Survey Systems Inc. (GSSI).

The radar surveys were carried out with a 400MHz antenna. This mid-range frequency offers a good combination of depth of penetration and resolution.

3.4 Sampling interval, depth of scan, resolution and data capture

3.4.1 Sampling interval

Resistivity
Readings were taken at 0.5m centres along traverses 0.5m apart. This equates to 3600 sampling points in a full 30m x 30 grid. All traverses were surveyed in a “zigzag” mode.

Detailed magnetometry (gradiometry)
Readings were taken at 0.25m centres along traverses 1m apart. This equates to 3600 sampling points in a full 30m x 30m grid.

Radar
Radar scans were carried out along traverses 0.5m apart on a parallel grid as shown in Figure 3. Data was collected at 40 scans/metre. A measuring wheel was used to put markers into the recorded radargram at 1m centres.

3.4.2 Depth of scan and resolution

Resistivity
The 0.5m probe spacing of a twin probe array has a typical depth of penetration of 0.5m to 1.0m The collection of data at 1m centres with a 0.5m probe spacing provides an optimum resolution for the technique.

Detailed magnetometry (gradiometry)
The Grad601-2 has a typical depth of penetration of 0.5m to 1.0m. This would be increased if strongly magnetic objects have been buried in the site. The collection of data at 0.25m centres provides an appropriate methodology balancing cost and time with resolution.

Radar

The average velocity of the radar pulse is calculated to be 0.06m/ns which is typical for the type of sub-soils on the site. With a range setting of 80nsec this equates to a maximum depth of scan of 2.39m respectively but it must be remembered that this figure could vary by ± 10% or more. A further point worth making is that very shallow features are lost in the strong surface response experienced with this technique.

Under ideal circumstances the minimum size of a vertical feature seen by a 200MHz (relatively low frequency) antenna in a damp soil would be 0.1m (i.e. this antenna has a wavelength in damp soil of about 0.4m and the vertical resolution is one quarter of this wavelength). It is interesting to compare this with the 400MHz antenna, which has a wavelength in the same material of 0.2m giving a theoretical resolution of 0.05m. A 900MHz antenna would give 0.09m and 0.02m respectively.

3.4.3 Data capture

Resistivity

The readings are logged consecutively into the data logger which in turn is daily down-loaded into a portable computer whilst on site. At the end of each job, data is transferred to the office for processing and presentation.

Detailed magnetometry (gradiometry)

The readings are logged consecutively into the data logger which in turn is daily down-loaded into a portable computer whilst on site. At the end of each job, data is transferred to the office for processing and presentation.

Radar

Data is displayed on a monitor as well as being recorded onto an internal hard disk. The data is later downloaded into a computer for processing.

3.5 Processing, presentation of results and interpretation

3.5.1 Processing

Resistivity

The processing was carried out using specialist software known as *Geoplot 3* and involved the 'despiking' of high contact resistance readings and the passing of the data though a high pass filter. This has the effect of removing the larger variations in the data often associated with geological features. The nett effect is aimed at enhancing the archaeological or man-made anomalies contained in the data.

The following schedule shows the processing carried out on the processed resistance plots.

Despike	*X radius = 1* *Y radius = 1* *Spike replacement*

High pass filter *X radius = 10*
Y radius = 10
Weighting = Gaussian

Detailed magnetometry (gradiometry)
Processing is performed using specialist software known as *Geoplot 3.* This can emphasise various aspects contained within the data but which are often not easily seen in the raw data. Basic processing of the magnetic data involves 'flattening' the background levels with respect to adjacent traverses and adjacent grids. 'Despiking' is also performed to remove the anomalies resulting from small iron objects often found on agricultural land. Once the basic processing has flattened the background it is then possible to carry out further processing which may include low pass filtering to reduce 'noise' in the data and hence emphasise the archaeological or man-made anomalies.

The following schedule shows the basic processing carried out on all processed gradiometer data used in this report:

1. *Despike* (useful for display and allows further processing functions to be carried out more effectively by removing extreme data values)

   Geoplot parameters:
   X radius = 1, y radius = 1, threshold = 3 std. dev.
   Spike replacement = mean

2. *Zero mean grid* (sets the background mean of each grid to zero and is useful for removing grid edge discontinuities)

   Geoplot parameters:
   Threshold = 0.25 std. dev.

3. *Zero mean traverse* (sets the background mean of each traverse within a grid to zero and is useful for removing striping effects)

   Geoplot parameters:
   Least mean square fit = off

In addition the following processing the removal of very high and low values caused by large metallic objects has been carried out to further enhance the data.

Radar
The radar plots included in this report have been produced from the recorded data using Radan software. A high pass filter (220MHz) has been applied to the data to removal background noise.

3.5.2 *Presentation of results and interpretation*

Resistivity
The presentation of the data for the site involves a print-out of the raw data as a grey scale plot (Figure 3), together with a grey scale plot of the processed data (Figure 4). Anomalies have been identified and plotted onto the ‘Abstraction and Interpretation of Anomalies’ drawing (Figure 5).

Detailed magnetometry (gradiometry)
The presentation of the data for each site involves a print-out of the raw data both as greyscale (Figure 6) and trace plots (Figure 7 and 8), together with a greyscale plot of the processed data (Figure 9). Magnetic anomalies have been identified and plotted onto the 'Abstraction and Interpretation of Anomalies' drawing for the site (Figure 10).

Radar
Manual abstraction
Each radargram has been studied and those anomalies thought to be significant were noted and classified as detailed below. Inevitably some simplification has been made to classify the diversity of responses found in radargrams.

i. Strong and weak discrete reflector.
These may be a mix of different types of reflectors but their limits can be clearly defined. Their inclusion as a separate category has been considered justified in order to emphasise anomalous returns which may be from archaeological targets and would not otherwise be highlighted in the analysis.

ii. Complex reflectors.
These would generally indicate a confused or complex structure to the subsurface. An occurrence of such returns, particularly where the natural soils or rocks are homogeneous, would suggest artificial disturbances. These are subdivided into both strong and weak giving an indication of the extent of change of velocity across the interface, which in turn may be associated with a marked change in material or moisture content.

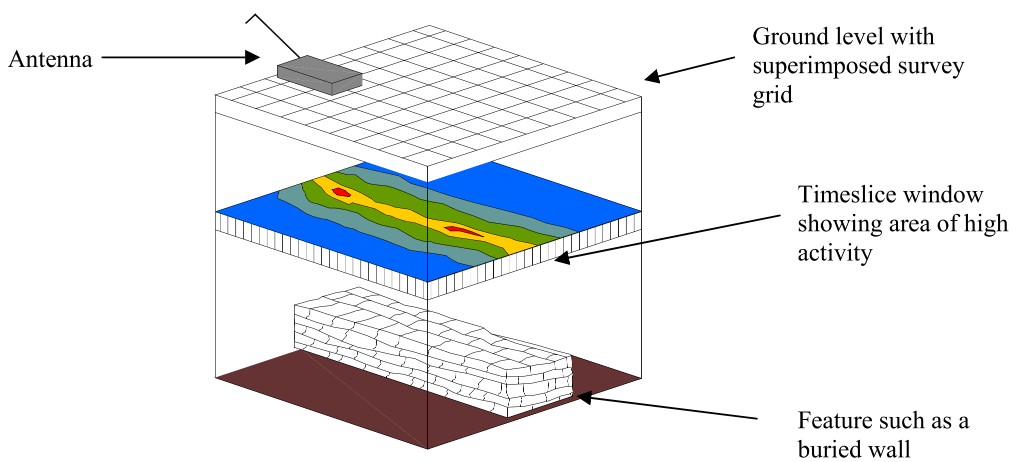
iii. Point diffractions.
These may be formed by a discrete object such as a stone or a linear feature such as a small diameter pipeline being crossed by the radar traverse (see also the second sentence in 4. below).

iv. Convex reflectors and broad crested diffractions.
A convex reflector can be formed by a convex shaped buried interface such as a vault or very large diameter pipeline or culvert. A broad crested diffraction as opposed to a point diffraction can be formed by (for example) a large diameter pipe or a narrow wall generating a hybrid of a point diffraction and convex reflector where the central section is a reflection off the top of the target and the edges/sides forming diffractions.

v. Planar returns.
These may be formed by a floor or some other interface parallel with the surface. These are subdivided into both strong and weak giving an indication of the extent of change of velocity across the interface which in turn may be associated with a marked change in material or moisture content.

Timeslice plots

In addition to a manual abstraction from the radargrams, a computer analysis was also carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots (Figures 12-15). In this way it is easy to see if the high activity areas form recognisable patterns.



The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within range. The data was then modelled to produce activity plots at various depths. As the radar is actually measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Based on an average velocity calculations have been made to show the equivalent depth into the ground. The data was sampled between different time intervals effectively producing plans at different depths into the ground.

The weaker reflections in the time slice windows are shown as dark colours namely blues and greens. The stronger reflections are represented by brighter colours such as light green, yellow, orange, red and white (see key provided in Figures 12-15).

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as foundations or surfaces within the soil matrix.

4 RESULTS

4.1 *Resistivity* (Figures 3-5)

A wide range of anomalies have been identified across both survey areas and can be divided into the following categories:

- High resistance linear anomalies – indicating a possible service
- Areas of high resistance – possible structural remains of archaeological origin
- Areas of low resistance – cut features of possible archaeological origin
- Areas of very low resistance – cut features of possible archaeological origin

High resistant linear anomalies

Three high resistant linear anomalies have been identified within survey Area A. One is known to be caused by the presence of a water main, running from an inspection cover in the centre of the survey area to the western cloister doorway. It is likely that the other two linears also represent services, which the radar data appears to confirm (see Figures 3-5 and 16-17).

Areas of high resistance

A large number of high resistance area anomalies have been identified across both survey areas. No obvious structural plans can be determined from the data. This suggests these anomalies may represent areas of structural debris of possible archaeological origin (see Figures 4-5).

Areas of low resistance

A number of low resistance area anomalies have been identified in both survey areas. In survey area A, a low resistance anomaly runs around the southwestern edge of the survey area, parallel to the cloisters. This anomaly is likely to be associated with a feature of the cloisters due to its similar orientation (Figures 3-5).

Further areas of low resistance appear in the northern sections of both survey areas, although once again no well-defined structure can be identified. These anomalies may represent cut features of archaeological origin or indicate previous structures that have later been robbed out.

Areas of very low resistance

Two areas of very low resistance anomalies can be identified towards the north west corner of survey Area A and on the western edge of survey Area B. Both of these anomalies may represent cut features of archaeological origin, although the anomaly in Area B may be artificially enhanced due to its close proximity to the cloister wall and nearby services (identified within the magnetometry and radar data, see Figures 5 and 17).

4.2 *Detailed magnetometry (gradiometry)* (Figures 6-10)

Due to large number of nearby metal objects within the survey areas (such as the water main in Area A and metal lawn edgings in Area B) any weak anomalies that may be present have been distorted by large areas of magnetic disturbance (see Figures 6-10). After processing the magnetometer data to reduce the effects of the magnetic disturbance, a faint positive linear anomaly can be identified running approximately in an east to west orientation in the centre north of survey Area A for a length of up to 17m. This anomaly may be of archaeological origin (see Figures 9-10).

A possible service has been identified running along the outer east wall of the cloisters. The series of strong discrete positive anomalies with negative returns situated across survey Area A are typical of responses caused by near surface ferrous objects (Figures 9-10).

4.3 *Radar* (Figures 11-17)

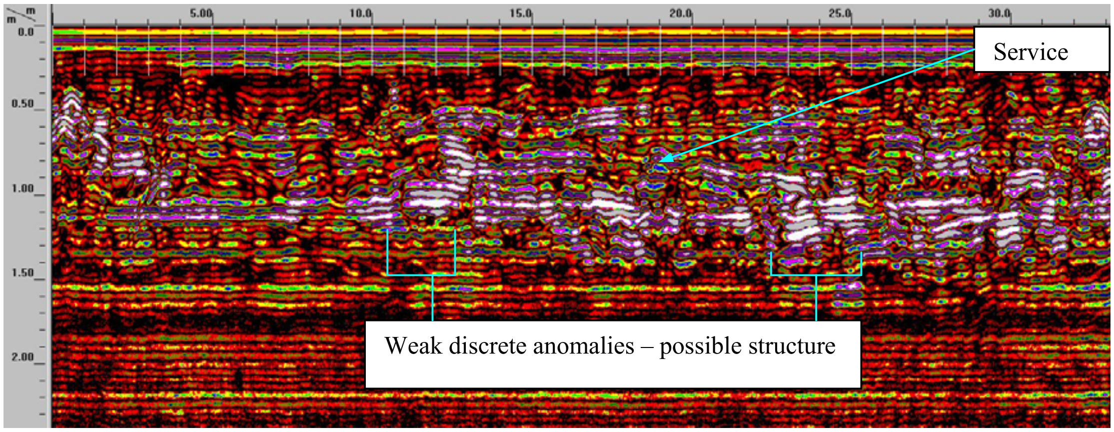
Wide ranges of anomalies have been identified across both survey areas. An area of higher complexity has been identified towards the north of survey Area A, with evidence of structural remains of archaeological origin. This is best seen in the timeslice data (Figures 12-15). Area B appears to be a more ‘quiet’ area, with a few discrete anomalies mainly concentrated in the north west of the survey area.

The anomalies observed can be grouped into eight categories:

- Possible evidence for a buried structure of archaeological origin
- A large area of complex returns at a depth of 1-1.2m of possible archaeological origin
- Areas of complex returns of possible archaeological origin
- Areas of strong discrete returns of possible archaeological origin
- Areas of weak discrete returns of possible archaeological origin
- Areas of ‘negative’ response
- Possible drain
- Services

Evidence for a buried structure

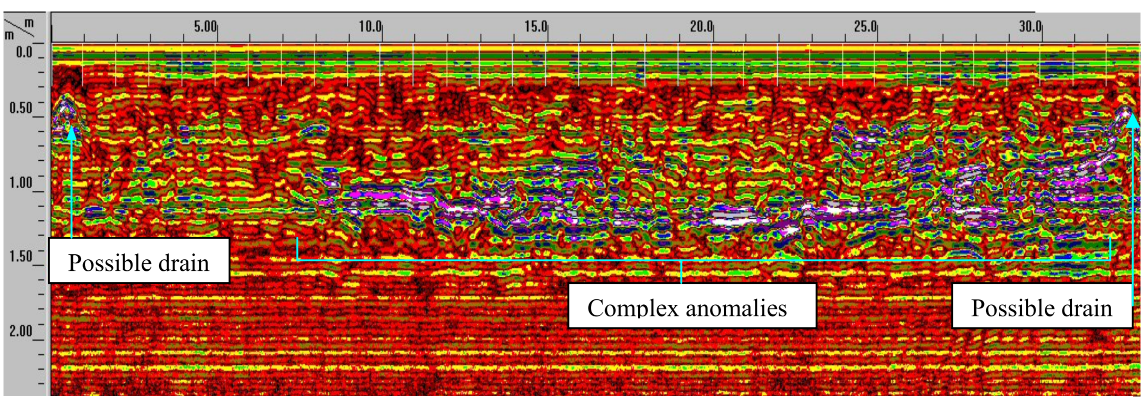
The strongest evidence indicating a possible structure comes from the examination of the radar timeslices (Figures 12-15). The structure appears to be rectilinear in shape, approximately 18.5m wide and up to 30m long, and can be seen at a depth of 0.6m-0.9m. When examining the individual radar transects, the evidence for a buried structure comes in the form of weak discrete anomalies (see Example Radargram 1 and Figure 16). This may indicate a less substantially built structure or that the construction material were later robbed out.



Example Radargram 1: Along transect 12.5S (survey Area A) showing discrete anomalies, possibly indicating a buried structure (please note: plotting parameters adjusted to enhance weaker anomalies)

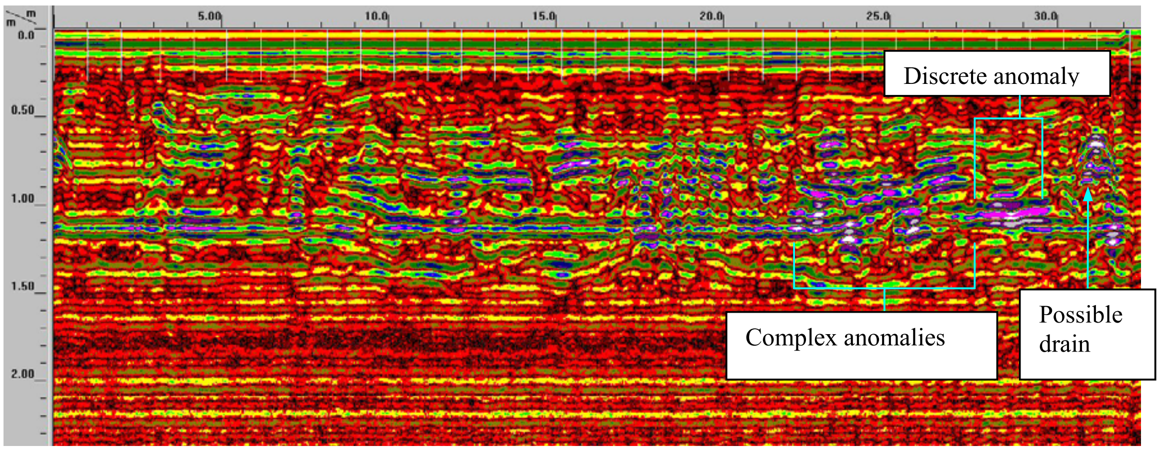
A large area of complex returns at depth (1-1.2m)

A large area of complex anomalies appear at depth situated across the northern section of Area A. The complex area starts to emerge at an approximate depth of 1m and can be clearly seen in the timeslice data (see Figures 15-16 and Example Radargram 2). This anomaly appears to have comparatively well defined edges, possibly suggesting a feature of archaeological origin.



Example Radargram 2: Along transect 8S (survey Area A) showing a large area of complex anomalies and two possible drainage features

An area of complex returns of possible archaeological origin
Situated towards the south east corner of survey Area A (27-30.5S) is an area (approximately 7m x 5m) of complex returns. The anomaly is at an approximate depth of 0.8m and can be clearly seen in the timeslice data (see Figure 14). Although no discrete features can be identified within the area, this anomaly could be of archaeological origin, possibly indicating areas of structural debris and a site of a former building (see Example Radargram 3).

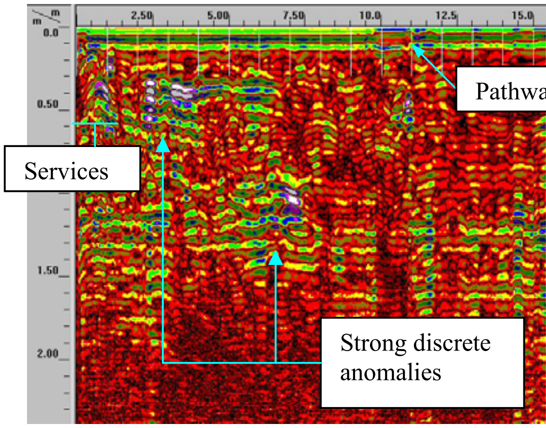


Example Radargram 3: Along transect 28S (survey Area A) showing an area of complex anomalies indicating an area of possible archaeological interest

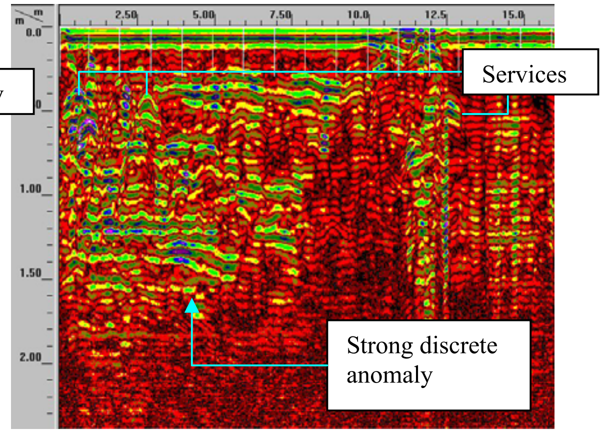
Areas of strong discrete returns of possible archaeological origin
A total of nine areas of strong discrete anomalies have been identified across both survey areas, seven of which are situated in survey Area A. A number of discrete anomalies have been identified along 30E, from 24.5S to 32S at an approximate depth of 0.9m (see Figures 15-17). This area appears to be bissected by a possible service trench (examined later in *4.3.8*); therefore indicating this anomaly may predate the possible service (See Figure 15-17 and Example Radargram 3).

Three areas of strong discrete anomalies situated towards the southwestern corner of survey Area A may indicate possible linear anomalies of archaeological interest, but may also represent service trenches (see Figures 15-17).

Three areas of strong discrete anomalies have been identified in the northeast corner of survey Area A at an average depth of 0.9m. These anomalies may be areas of archaeological interest, possibly indicating areas of previous structural remains.
The two areas of strong discrete anomalies identified within survey Area B are located in the northwest corner of the survey area. Between transects 10-12S a discrete anomaly is observed at a depth of 1.26m that may represent an area of archaeological interest (see Example Radargram 4a). To the north appears a linear discrete anomaly at an approximate depth of 0.35m, this may be of archaeological origin, although it represent a service trench due to its shallow depth (see Figures 15-17 and Example Radargram 4a).



(a) *Example Radargram 4a*: Along traverse 3S (survey Area B) showing strong discrete anomalies and services



(b) *Example Radargram 4b*: Along traverse 10.5S (survey Area B) showing strong discrete anomalies and services

Areas of weak discrete anomalies of possible archaeological origin

A small weak discrete area anomaly can be identified at 11E, 16.5-17.5S in survey Area A. It appears at a depth of 0.9m and could be of archaeological origin. A larger area of weak discrete anomalies can be identified within survey Area B, approximately situated between 7S-10.5S at a depth of 0.3m, this area may also be of archaeological origin (see Figures 12-17).

Areas of 'negative' response

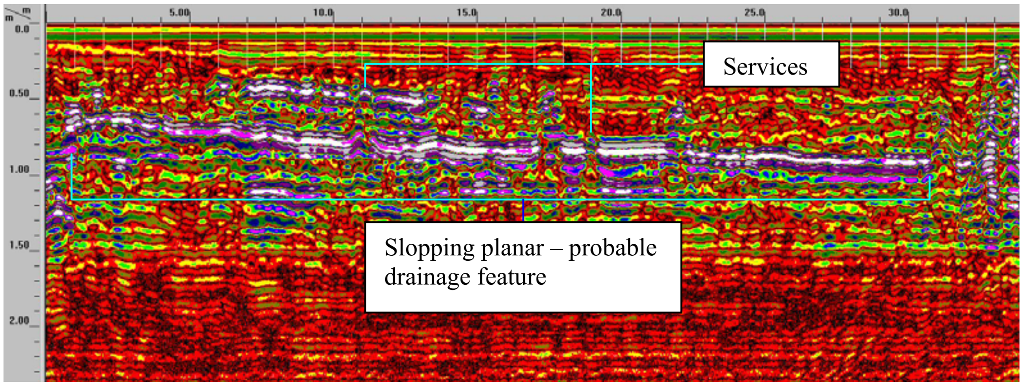
Three areas of 'negative' response (comparatively quiet areas within the radar data) can be identified within survey Area A. An area situated to the south west of the survey area (27.5S-33S) and can be clearly seen in the timeslice data (Figure 15) and appears to 'cut through' an area of complex returns (see Figure 16). This is likely to be a service trench associated with an identified service at approximately 1m deep.

A further area of negative response can be clearly seen in the timeslice data at a depth of 0.87m (Figure 14). This is possibly indicative of an area of relative 'quiet' archaeological activity. Another area can be identified at a depth of 1.1m (see Figure 15), marking the lateral extent the area of strong complex anomalies to the north of the survey area.

In survey Area B towards the eastern side of the survey there appears to be a general lack of radar anomalies. This may indicate a general absence of archaeological material and therefore suggest the eastern limit of any previous occupation of this site (see Figures 12-17).

Possible drain

Running around the parameter of survey Area A are linear broad crested features that are likely to represent drainage. The services appear to incline towards the southwest corner of the survey area, starting at a depth of 0.3m and sloping down to a depth of 0.9m (see Figures 12-17 and Example Radargram 5).

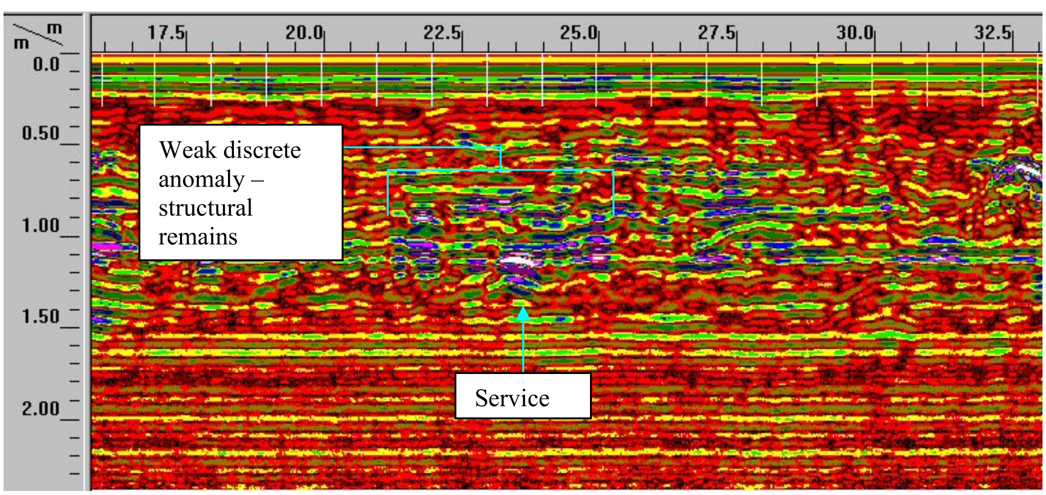


Example Radargram 5: Along transect 40.5S (survey Area A) showing sloping a planar, indicating drainage

Services

Several services have been identified in both survey areas. A minimum of seven services have been identified within Area A. A known water main has been identified running from an inspection cover in the centre of the survey area to a doorway in the western range of the cloisters, at a depth of 0.6m. A service has been identified running down the centre of the survey area approximately 0.8m deep. Two services appear from the southern edge of the survey area, running in the direction of the western doorway at an approximate depth of 0.5m (see Example Radargram 5). A number of small sections of a possible continuous service run parallel with the probable drainage feature running along the eastern edge of the survey area (see Figures 16-17).

A large service has been identified at depth (approximately 1.1m deep) running northwest to southeast down the survey area, curving off to the southeast corner of the cloisters. There appears to be little evidence of a service trench cutting through the possible buried structure (mentioned in *4.3.1*) (see Example Radargram 6), therefore suggesting this service predates the structure. This service therefore may be of archaeological origin, possibly associated with previous buildings on this site.



Example Radargram 6: Along transect 27.5S (16-33E) Area A, showing a service and weak discrete evidence for structural remains

A number of services have been identified in survey Area B, all of which appear to run parallel along the length of the outer eastern wall of the cloisters. A small number of point diffractions (characteristically the response caused by the presence of services) have been identified running under the pathway (identified as a conductive surface anomaly), suggesting a number of services are likely to run under the present pathway (see Example Radargram 4a and b).

5 CONCLUSION

The radar and resistivity data have produced a number of interesting anomalies that may be of archaeological origin. The magnetometry survey met with limited success due to metallic debris in the surroundings.

A possible structure has been identified and is most visible within the radar timeslice data (Figures 12-15). A number of high and low resistance anomalies and the single positive linear anomaly identified within the magnetometry appear to correspond with this possible structure.

A well-defined area of deep complex anomalies (approx 1m) situated to the north of survey Area A identified within the radar data may possibly represent an area of structural debris of archaeological origin.

Several services have been identified across both survey areas. A drainage feature associated with the cloisters runs around the perimeter of survey Area A.