STRATASCAN

Geophysical Survey Report

Hereford Cathedral Close, Hereford

For

Hereford Cathedral

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J2118

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1 SUMMARY OF RESULTS

A geophysical and utility mapping survey was carried out at Hereford Cathedral Close. The utility mapping results can be seen in Figures 4, 5 and 9. The geophysical survey has been successful in locating a number of features of possible archaeological origin. Discrete areas of high resistance may relate to structural debris or ground disturbance of possible archaeological origin. The gradiometry survey was of limited success due to the high levels of magnetic disturbances associated with an urban site. However areas of magnetic debris and discrete positive anomalies may relate to areas of archaeological activity. The GPR has identified a large number of services, confirmed documented structural remains and has identified further potential areas of archaeological interest. The continuation of the Saxon road and the possible extents of the mass graves partially identified in the 1993 library excavations can be seen within the GPR data with supporting evidence from the gradiometer and resistance surveys. The identification of individual burials has been difficult due to frequent ground disturbance and later landscaping activities. However, a small number of discrete anomalies seen across the survey area may represent individual burials within an area of graveyard activity.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned to undertake a geophysical survey of the Cathedral Close at Hereford prior to the regeneration of the Close. This survey forms part of an archaeological and underground utilities investigation being undertaken by Hereford Cathedral.

2.2 Site location

The site is located at Hereford Cathedral, Hereford at OS NGR ref. SO 512 398

2.3 Description of site

The site is Hereford Cathedral Close including the Lady Arbour (the cloister range). Ground probing radar (GPR) and radiodetection was carried out across the entire survey area, whereas the gradiometer and resistivity surveys covered all areas of soft landscaping (grass).

The underlying geology is Lower Old Red Sandstone including Downtonian (British Geological Survey South Sheet, Fourth Edition Solid, 2001). The overlying soils are likely to be river terrace gravels and typical argillic brown earths with a natural build up of soils from human occupation, however the site has not been extensively mapped due to its urban environment (Soil Survey of England and Wales, Sheet 2 Wales 1980).

2.4 Site history and archaeological potential

Archaeological evidence suggests the origins of the settlement at Hereford date to the Saxon period. Although Roman finds have been recovered in Hereford, direct evidence for a Roman settlement in the immediate vicinity of the city is very sparse (Stone and Appleton-Fox 1996). Based on the parish boundaries which emphasis the central position of the Cathedral, it is considered that the Saxon Cathedral is the oldest religious settlement, with a foundation date of in or before the late seventh century (Barrow 1992, 81, Barrow 1993).

Excavations elsewhere in the city demonstrate an established settlement beginning as early as the middle seventh century, with an established sequence of buildings between Victoria Street and Berrington Street by the early ninth century (Shoesmith 1982, 72-3). The road layout at this period would have related to the cathedral and the ford. By the ninth century the cathedral was at the city's centre and a planned layout had been established (Shoesmith 1982, 74).

Much of the Saxon road grid survives today and is based on a road leading north from the river (including Broad Street) and an east-west road. The two ends of this road survive as Castle Street and King Street, but the central part is now lost. The junction of these roads formed the central crossroad. This would have been an important commercial area and would have relativity substantial buildings. The Saxon cathedral must have been somewhere in the area to the southeast of the crossroads with a large part of the precinct being a cemetery. The precinct itself possibly extended south towards the river and bounded on the west by the road leading from the ford (Stone and Appleton-Fox 1996, 8-9).

The late eleventh century was a time of major change. The Earl of Hereford, William FitzOsbern was responsible for laying out a new market place and settlement for the Norman immigrants to the north of the Saxon defences. The conquest also dramatically affected the layout of the cathedral precinct.

Between 1079 and 1095 Bishop Lossinga built a two storey chapel to the south of the present cloisters. It northern wall was incorporated into the cloisters but the rest was demolished in 1737. When the chapel was built, the Saxon cathedral was presumably the main focus of the precinct.

During 1107 to 1115 a start was made on the construction of the new cathedral. It was laid to the north of the presumed Saxon cathedral and cut across the line of the main east-west road. This build would have been a vast undertaking, as foundation trenches were revealed to be 3.5 metres wide and were laid on natural gravels 2.1 metres deep (Willis 1841, 7). Other buildings (including residence for the clergy) were being constructed around the edges of the precinct throughout the medieval period.

The late twelfth century precinct had been greatly changed from the Saxon form. The precinct extended further north to its present boundary, incorporating properties that had been on the north of the east west road and effectively closing the road (Stone and Appleton-Fox 1996, 10).

During the Saxon period both the cathedral and St Guthlac's Church had burial rights but by 1108 documentary evidence states that the cathedral was claiming exclusive burial rights within the city. A large area was needed for the graveyard. By the late medieval period burial rights probably extended throughout the whole open area of the present Close (Stone and Appleton-Fox 1996, 10). Between 1180-86, Bishop Folliot ordered the Dean and Chapter to remove a house that had been built in the cemetery which used to belong to the archdeacon. In 1434 the Dean and Chapter were ordered to remove all trading and servile work and stop all animals entering the cemetery (Barrow 1992, 81, Morgan 1975, 15). The cemetery eventually became overcrowded and in 1791 the precinct was closed as a general burial ground (Stone and Appleton-Fox 1996, 12).

In 1760 the west range of the cloister was totally demolished and the chapter house demolished in 1769, revealing evidence that the fifteenth century cloisters were a replacement for an earlier one. Before the cloister demolition the area to the west of the range had been used as a garden and later a timber yard.

A music room was built in the place of the west range but was later demolished in 1835 and was replaced by the Dean Leigh Library in 1897. The new library built in 1993 now joins the western side of this building. In 1786 the Norman west front of the cathedral fell and was blandly rebuilt in 1793 and later redesigned in 1904.

A major landscaping project took place in 1850-1 that involved lowering the ground level in parts of the close by several feet. Therefore many of the burials that had originally been deeply interred are now just below the surface.

During 1935 the row of houses situated along the eastern side of Broad Street were demolished, the area was subsequently landscaped and two trees planted.

The excavation carried out prior to the library construction revealed continuous occupation from the Saxon period. Part of the cemetery associated with the Saxon cathedral and a late Saxon building including a stone basement fronting onto a Saxon cobbled road were revealed. A twelfth century pit was dug through earlier layers and filled with bone of approximately 5000 people. Late medieval cemetery activity was also identified, with over 1000 burials being excavated, of which 200 were retrieved from three mass grave pits that were likely to date from the Black Death (Stone and Appleton-Fox 1996).

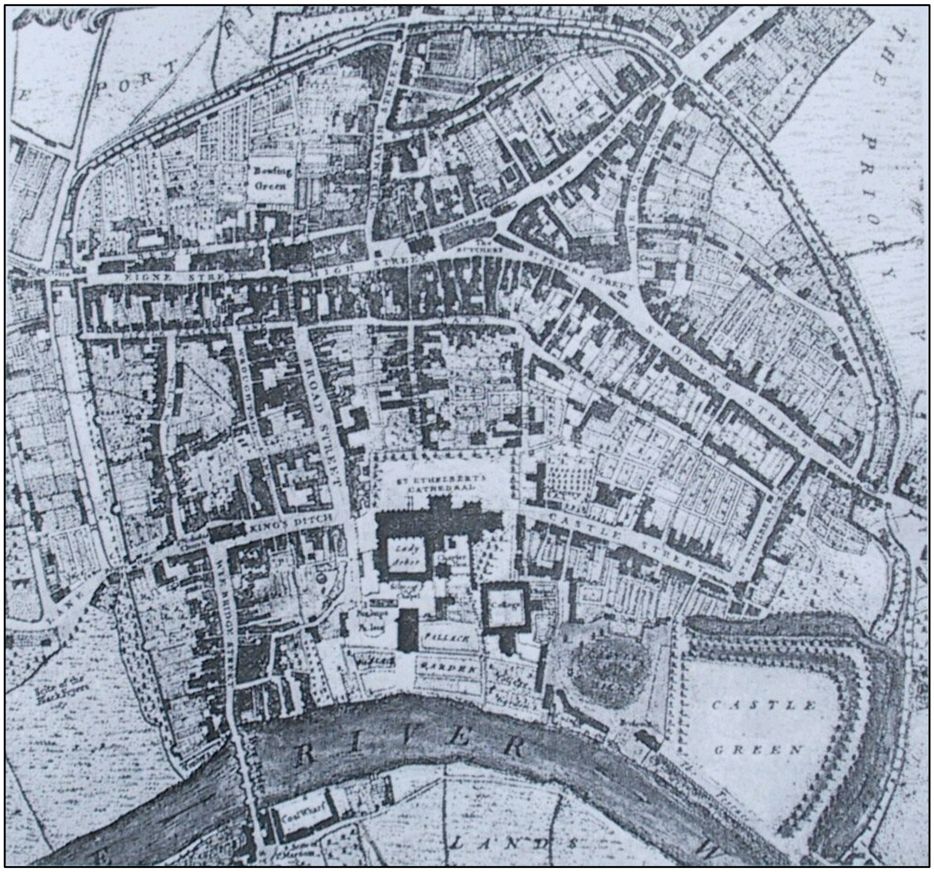


Plate 1: Taylor's map of Hereford (1757)

Over the past 25 years there have been many excavations and watching briefs across all parts of the Cathedral Close. Excavations have shown that burials can be encountered very close to the surface. The removal of turf and topsoil to a depth of 0.2m will often reveal articulated human remains (Shoesmith 2005, 7). Structural remains may also be present within the Close as the layout of the Close before the mid 18th century is virtually unknown. The canonical houses may have included grounds which have since been incorporated into the close (Shoesmith 2005, 7).

2.5 Survey objectives

The objective of the survey was to locate any anomalies that may be of archaeological significance and the identification of underground utilities prior to a regeneration and development of the Cathedral Close.

2.6 Survey methods

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 20 days from the 6^{th}- 24^{th}, 29^{th}- 31^{st} March and the 3^{rd}- 4^{th} April 2006 when the weather was variable.

3.2 Grid locations

The location of the survey grids has been plotted in Figure 1.

3.3 Description of techniques and equipment configurations

3.3.1 Gradiometer

Although the changes in the magnetic field resulting from differing features in the soil are usually weak, changes as small as 0.2 nanoTesla (nT) in an overall field strength of 48,000nT, can be accurately detected using an appropriate instrument.

The mapping of the anomaly in a systematic manner will allow an estimate of the type of material present beneath the surface. Strong magnetic anomalies will be generated by buried iron-based objects or by kilns or hearths. More subtle anomalies such as pits and ditches can be seen if they contain more humic material which is normally rich in magnetic iron oxides when compared with the subsoil.

To illustrate this point, the cutting and subsequent silting or backfilling of a ditch may result in a larger volume of weakly magnetic material being accumulated in the trench compared to the undisturbed subsoil. A weak magnetic anomaly should therefore appear in plan along the line of the ditch.

The magnetic survey was carried out using a dual sensor Grad601-2 Magnetic Gradiometer manufactured by Bartington Instruments Ltd. The instrument consists of two fluxgates very accurately aligned to nullify the effects of the Earth's magnetic field. Readings relate to the difference in localised magnetic anomalies compared with the general magnetic background. 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.

3.3.2 Resistance Meter

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.

3.3.3 Radiodetection

A survey of the detectable underground services involves the use of active and passive radio detection methods. An active signal is a signal that has been artificially generated by an external source. Active radiodetection methods can allow different services, for example, telecom, BT and electric to be individually identified. A passive signal is a signal that occurs ‘naturally’ on a buried conductor. Passive radiodetection methods will provide an indication only that services are present underground.

The active radiodetection method used for this survey was an RD433 high power transmitter. The transmitter can either be used for direct connection or for induction. Direct connection involves the application of an active signal to a conductor using a clamp. Induction involves a signal being radiated from the internal antenna of the transmitter which is induced to any conductors in the vicinity and re-radiated. Since not all the services are accessible via an inspection chamber both direct connection and induction techniques are used on the site. As there was access to a number of manholes on site rodding a sonde through ducts was another way of tracing services

An RD400 electromagnetic cable and pipe locator was used in both passive (radio and power modes) and active (8, 33 or 65Hz) applications. The cable locator has three locating modes:

- Power – detects 50-60Hz energy present on most buried conductors
- Radio – detects re-radiated radio energy if present on conductors
- 8/33/65Hz – detects conductors radiating the applied transmitter signal

Moving the locator from side to side it is possible to follow the line so that an audible signal is heard over the conductor and not at either side. The response from the conductor can suddenly reduce or disappear due to a curve, tee connection, break, termination or depth change of the conductor.

3.3.4 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 400 and 200MHz antenna. These mid-range frequencies offer 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

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

Resistivity
Readings were taken at 1.0m centres along traverses 1.0m apart. This equates to 900 sampling points in a full 30m x 30m grid. All traverses were surveyed in a “zigzag” mode.

Radiodetection
The survey areas were scanned in the passive mode of the locator. The line of any services detected from this scan were then traced across the survey area until they became undetectable or exited the survey area. Active radiodetection was used on several services that could be clamped onto or where rodding a sonde was possible.

Radar
400MHz radar scans were carried out along traverses 0.5m apart on a parallel grid as shown in Figure 1. 200MHz radar scans were carried out along traverses 5m apart on an orthogonal grid as shown in Figure 1. 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*

Gradiometer
The Grad 601 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 0.5m centres provides an appropriate methodology balancing cost and time with 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 0.5m probe spacing provides an appropriate methodology balancing cost and time with resolution.

Radiodetection
The pipe and cable locator is able to detect services up to a typical maximum depth of some 3m.

Radar
The average velocity of the radar pulse is calculated to be 0.073/nsec which is typical for the type of sub-soils on the site. With a range setting of 60 and 150ns this equates to a maximum depth of scan of 2.18 and 5.44m 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

Gradiometer
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.

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.

Radiodetection
No data capture is required for the radiodetection technique apart from marking detected targets on the ground surface with paint. The location of these markings are added to the site plan using a Leica TCR705auto total station.

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

Gradiometer
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:

Zero mean grid	*Threshold = 0.25 std. dev.*
Zero mean traverse	*Last mean square fit = off*
Despike	*X radius = 1 Y radius = 1*
	Threshold = 3 std. dev.
	Spike replacement = mean

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

Radiodetection
No processing was required for the information gained using the radiodetection technique.

Radar
The radar plots included in this report have been produced from the recorded data using Radan software. No processing was undertaken.

3.5.2 Presentation of results and interpretation

Gradiometer
The presentation of the data for the survey involves a print-out of the raw data as grey scale (Figure 10) and a colour plot demonstrating the amplitude of responses (Figure 11), together with a grey scale plot of the processed data (Figure 12). Magnetic anomalies have been identified and plotted onto the 'Abstraction and Interpretation of Anomalies' drawing for the site (Figure 13).

Resistivity
The presentation of the data for the site involves a print-out of the raw data as a grey scale plot (Figure 14), together with a grey scale plot of the processed data (Figure 15). Anomalies have been identified and plotted onto the ‘Abstraction and Interpretation of Anomalies’ drawing (Figure 16).

Radiodetection
The locations of any buried services detected at the site are marked on the ground in paint. As well as marking lines on the ground, the locations of any buried services detected at the site by the radiodetection equipment were added to the schematic site plan.

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.

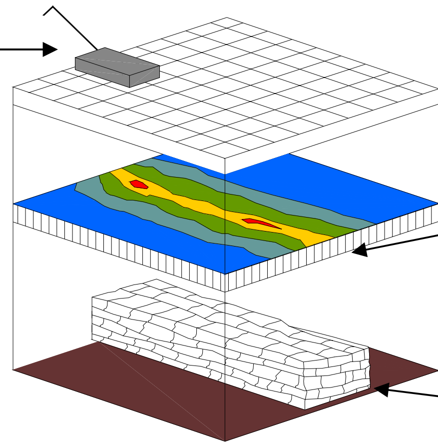
ii. Complex reflectors.
These would generally indicate a confused or complex structure to the subsurface. An occurrence of such returns, particularly where the natural soils or rocks are homogeneous, would suggest artificial disturbances. These are subdivided into both strong and weak giving an indication 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 17-23). 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 17-23).

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

The results of the radiodetection survey can be seen within Figure 4, with the final utility mapping survey results seen in Figure 9. The following section will concentrate on the geophysical anomalies of possible archaeological origin identified within each survey technique.

4.1 Gradiometry

The gradiometer results were dominated by areas of strong magnetic anomalies due to high levels of magnetic debris and modern activity. Despite large areas of the data being obscured by the strong magnetic responses, discrete positive anomalies and areas of magnetic debris have been identified that may relate to features of archaeological origin.

A number of services have also been identified within the gradiometer data in the form of positive or bipolar linear anomalies. A number of positive anomalies with associated negative responses have been identified across the survey area. These anomalies are likely to represent near surface ferrous objects.

Three discrete ‘strips’ of magnetic debris can be seen north of the library (**a**, **b** and **c**). Anomalies **a** and **c** may represent discrete areas of structural remains, with anomaly **c** possibly associated with the previous cloister range or music hall. Anomaly **b** may identify the continuation of the cobbled Saxon road uncovered during the library excavations in 1993.

A large area of magnetic disturbance can be seen along the western and northern edge of the cloister range (**d**). This area anomaly may represent structural debris associated with the previous west range of the cloisters. The five discrete low magnetic readings running in line along the western edge of the cloisters (see Figure 11) may represent the foundation remains situated between the windows of the music hall or the west cloister range eastern wall.

Anomalies **e**, **f** and **g** represent further areas of magnetic disturbance possibly associated with the demolished row of buildings that previously fronted onto Broad Street and the subsequent landscaping. The eastern end of anomaly **e** (**e1**) may also represent the possible continuation of the Saxon road (anomaly **b**), which has been suggested to run along the back of the demolished buildings along Broad Street and join Widemarsh Street to the north (Stone and Appleton-Fox 1996).

Anomaly **h** represents a linear magnetic anomaly possibly associated with service routes identified within this area. A faint positive linear anomaly can be seen in the centre north of the survey area (**i**). This anomaly may provide weak evidence for a cut feature of archaeological origin.

Three areas of discrete positive anomalies have be identified, one within the area of the cloisters (**j**) and two across the northeast and west of the survey area (**k** and **l**). Further discrete positive anomalies may be present across the survey area but are obscured by the large areas of magnetic disturbance and debris. These anomalies may indicate discrete areas of ground disturbance possibly relating to cut features associated with landscaping or burial activity.

4.2 Resistivity

Discrete areas of high and low resistance have been identified across the survey area that may indicate cut features and areas of structural remains of archaeological origin. However, the vast landscaping in the mid 19th century and the demolition and later landscaping of the buildings along Broad Street may create areas of high and low resistance and therefore be of relatively modern origin. The resistivity anomalies have been identified into the following categories:

- Low resistance linear anomaly – possibly associated with a service
- High resistance area anomalies – possible areas of structural debris
- High resistance area anomalies – possible areas of structural debris and landscaping actives
- Low resistance area anomalies – possible cut features of archaeological origin
- Low resistance area anomalies – cut features possibly associated with demolition and landscaping activities
- Low resistance area anomalies – possibly associated with nearby trees
- High resistance area anomalies associated with nearby buildings
- Possible service trenches

Low resistance linear anomaly – possibly associated with a service
A low resistance linear anomaly can be seen crossing a section a grass near the main entrance to the cathedral. This anomaly coincides with a number of service lines identified within the GPR and therefore is likely to be associated with services.

High resistance area anomalies – possible areas of structural debris
A number of discrete high resistance area anomalies can be seen within the cloister range (**12**). These anomalies may represent discrete areas of structural debris or ground disturbance of modern or archaeological origin. A substantial drainage system is known to exist within the cloisters and converge at its centre (see Figure 2). High resistance anomaly **13** may be associated with the surface water drainage system.

Situated to the west of the cathedral are a further number of discrete high resistance anomalies (**14** and **15**). These may represent areas of structural debris of possible archaeological origin.

High resistance anomalies **19** and **20** situated in the northwest of the survey area may represent further areas of structural remains and debris of possible archaeological origin. Areas anomalies **20-22** represent moderate high resistance anomalies, identifying further areas of ground disturbance and possible structural debris in a northeast to southwest orientation. Anomaly **23** may indicate a service trench associated with an electric service seen within record drawings and GPR.

Anomalies **24** and **25** represent areas of moderate high resistance. Area anomalies **24** are in close proximity to the tarmac pathways and may to some extent be of modern origin. Anomaly **25** may represent an area of ground disturbance and corresponds with an area of strong magnetic response seen within the gradiometer data.
Anomaly **26** represents two discrete areas of high resistance situated in the northeast of the survey area. A number of grave markers lay within the high resistance areas. These anomalies may represent large areas of ground disturbance and possible structural debris of archaeological origin.

High resistance area anomalies – possible areas of structural debris and landscaping actives
High resistance area anomalies **16-18** may represent a combined response from structural remains and debris from the former properties along Broad Street and the subsequent landscaping that took place.

Low resistance area anomalies – possible cut features of archaeological origin
The majority of the low resistance area anomalies can be identified in the west of the survey area. Three distinct low resistance area anomalies have been identified around the area of the library. Anomalies **1** and **3** may represent cut features of archaeological origin, possibly identifying the extents of the three mass graves identified along the western edge of the library excavations in 1993. Area anomaly **2** is of similar size and orientation to that of the previous music hall and therefore may be associated with the destruction of the hall in 1835.

Anomalies **4** and **5**, situated close to the pathways within the cloister range may represent cut features possibly associated with the laying of services or landscaping activities.

Anomaly **6** situated to the west of the cathedral represents an area of discrete low resistance. This anomaly may indicate a large cut feature of archaeological origin. Identified to north of the cathedral entrance is a well defined low resistance area anomaly (**9**). This anomaly may represent a cut feature of archaeological origin.

A low resistance area anomaly has been identified around the Elgar statue situated in the northwest corner of the survey area (**10**). This anomaly is likely to be associated with the preparation and instalment of the statue.

A large area of low resistance can be seen in the southwest corner of the survey area (**11**) and is sited within an area of large magnetic debris seen with the gradiometer data. This anomaly may be associated with landscaping and modern activity.

Low resistance area anomalies – cut features possibly associated with demolition and landscaping activities
Situated to the northwest of the cathedral are three areas of low resistance (**7** and **8**). These anomalies may represent cut features associated with the demolition and landscaping that took place during the mid 1930's. The southern extent of area anomaly **7** may represent a section of trench relating to an electric service. This area of varied

response coincides with an area of magnetic debris seen within the gradiometer data (**e** and **f**).

Low resistance area anomalies – possibly associated with nearby trees
Several areas of low resistance have been identified within close proximity to a number of trees situated along the pathways of the survey area. These anomalies are therefore likely to be associated with the trees.

High resistance area anomalies associated with nearby buildings
A number of high resistance responses can be identified in close proximity to the cathedral. These anomalies are likely to be associated with the nearby structures and their foundations.

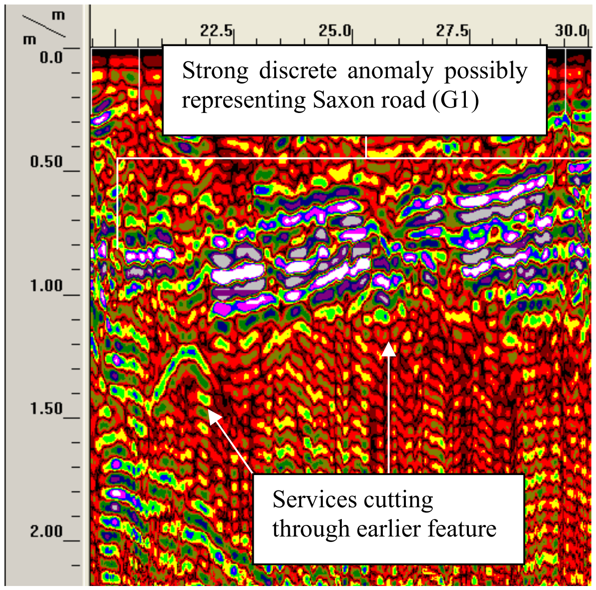
Possible service trenches
Three possible service trenches have been identified within the eastern end of the survey area in the form of high and low linear area anomalies. The two trenches positioned around the eastern end of the cathedral may relate to the gas main known to exist within the area and is supported by a number of possible services identified within the GPR. The service trench running diagonally towards a manhole is likely to relate to the foul water drainage.

4.3 GPR
The GPR data has proved very successful in locating a large number of services and a number of features that may be of archaeological origin. From historical and archaeological documentation it can be assumed that the Cathedral Close is likely to have a high concentration of burials, for the cathedral precinct was used as a graveyard from Saxon times up until the late 18th century. The major landscaping activities of the early 1850's has dramatically changed the topography of the close, many of the burials that had originally been deeply interred are now just below the surface, possibly suggesting that near surface GPR anomalies may be of archaeological origin rather that of modern activity. The GPR anomalies have been identified into the following categories:

- Anomalies associated with the Saxon road (**G1**)
- Structural remains associated with the music hall (**G2**)
- Structural remains possibly associated with the west cloister range (**G3**)
- Structural remains relating to the cathedral frontage (**G4**)
- Structural debris relating the Broad Street buildings (**G5**)
- Discrete and complex responses possibly relating to structural debris and remains (**G9** and **G10**)
- Discrete GPR anomalies possibly indicating burials (e.g **G13**)
- Evidence for mass graves (**G15** and **G14**)

Anomalies associated with the Saxon road
A Saxon road was uncovered during the library excavations in 1993 and was seen exiting the northwestern corner of the trench in a northerly direction. A series of strong discrete anomalies have been identified within the projected area of the Saxon road and can be clearly seen within the timeslice data (Figures 20-22). These anomalies may

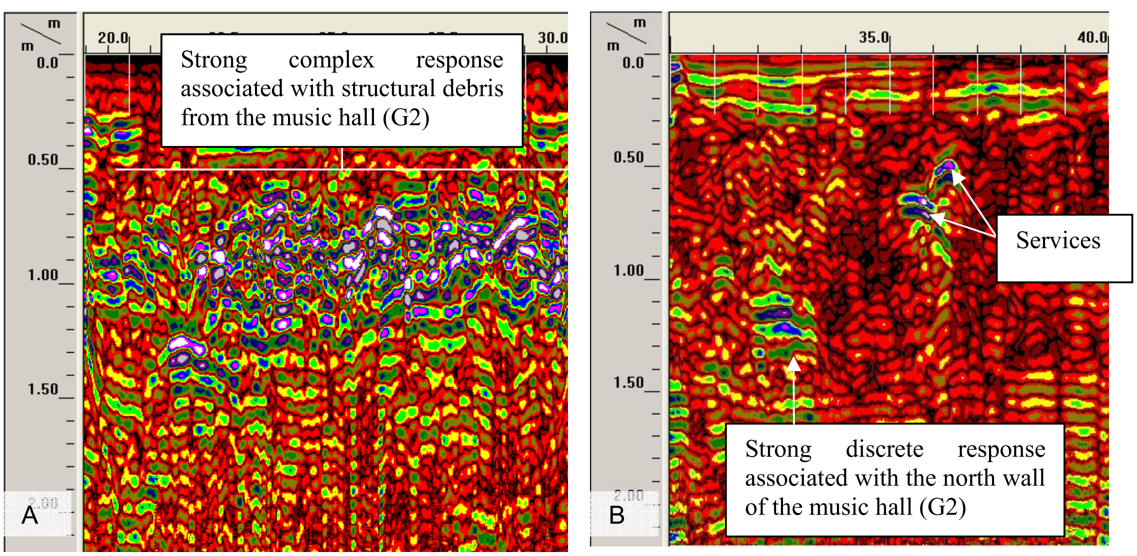
represent the cobbled surface of the Saxon road continuing northwards across the grass in front of the library (**G1**) (Example Radargram 1). The feature abruptly stops at the tarmac pathway. The continuation of the roadway may have been destroyed during the laying of the pathways and major landscaping during the 1850's.



Example Radargram 1: 400MHz 19.5E, 19.5-30N. Showing strong discrete anomaly possibly representing Saxon road cut by two services

Structural remains associated with the music hall

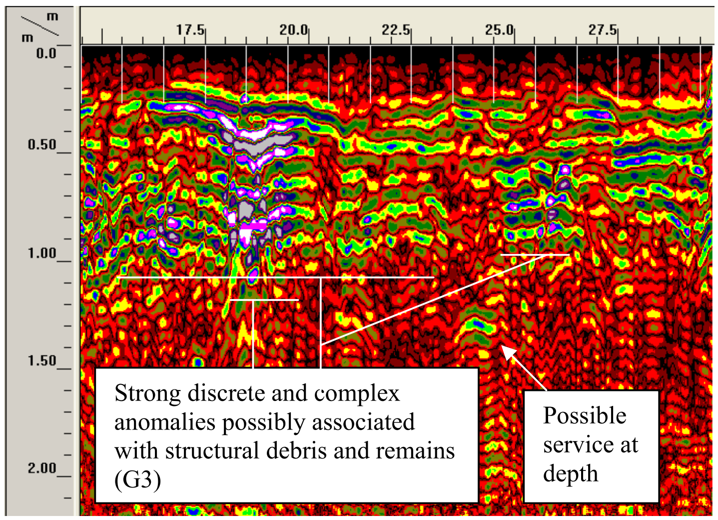
The foundation trench associated with the music hall has been identified by a series of complex and discrete responses and can be clearly seen within the timeslice data between 0.8-1.2m deep (**G2**) (Figures 21-23 and Example Radargram 2). However, the eastern wall foundation has not been so clearly identified.



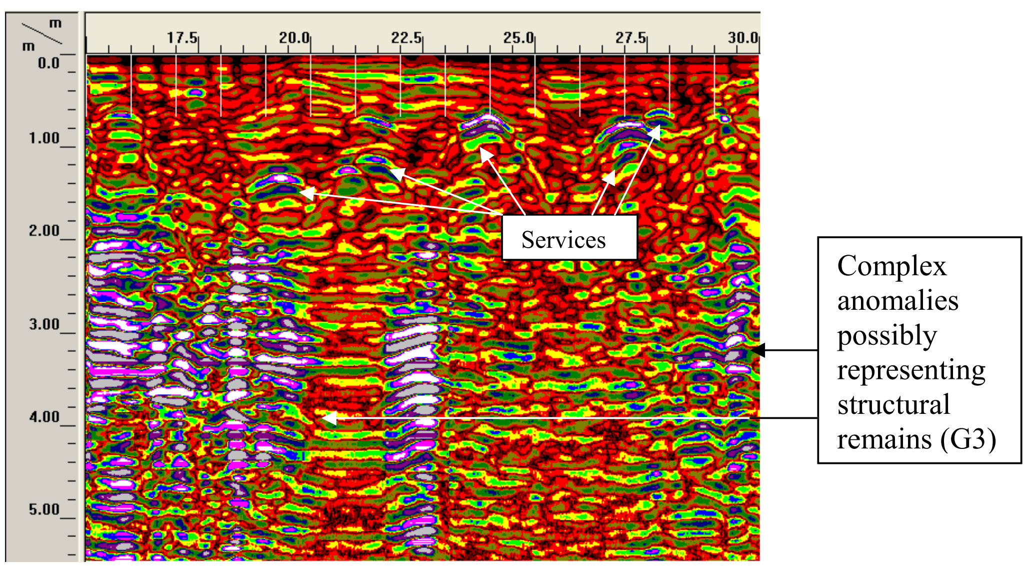
Example Radargram 2: 400MHz (a) 23.5E, 19-30N, (b) 24.5E, 30-40N. Showing complex and discrete responses associated with the music hall

Structural remains possibly associated with the west cloister range

A small number of complex areas have been identified within the vicinity of the west cloister range. These areas of complex and discrete responses may be associated with the structural remains of the west cloister (**G3**). The absence of a coherent foundation may be due to the subsequent robbing and demolition of material and the redevelopment of the area from 1760 onwards. Structural debris and remains have been identified within both the 200 and 400MHz data (Example Radargrams 3 and 4).



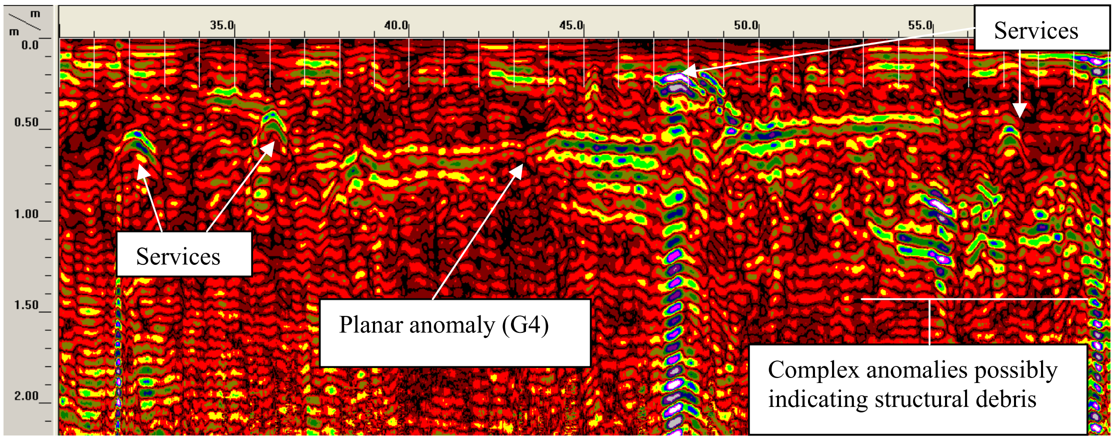
Example Radargram 3: 400MHz along traverse 28.5E, 14.5-30N. Showing complex and discrete anomalies possibly associated with structural debris and remains from the west cloister range



Example Radargram 4: 200MHz along traverse 35E, 15-30N. Showing strong complex anomalies at depth possibly associated with structural debris and remains

Structural remains relating to the cathedral frontage

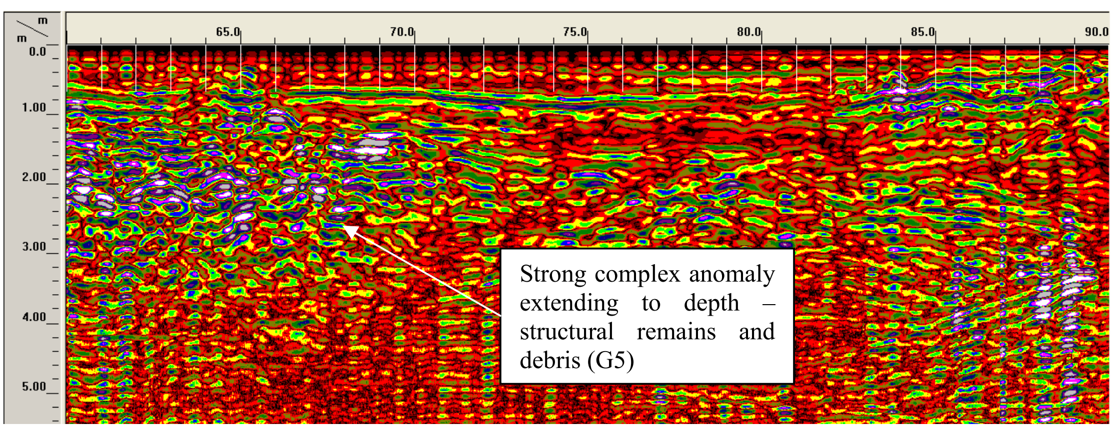
A series of weak planar and complex anomalies have been identified within the area of the original cathedral frontage (**G4**). These anomalies are somewhat weaker than what would be expected from an area of masonry debris. Little evidence for structural debris can be found toward the southern corner of the frontage. This may be due to the removal of material and the modern ground disturbance from the laying of two services identified within the area (see Figure 6 and Example Radargram 5).



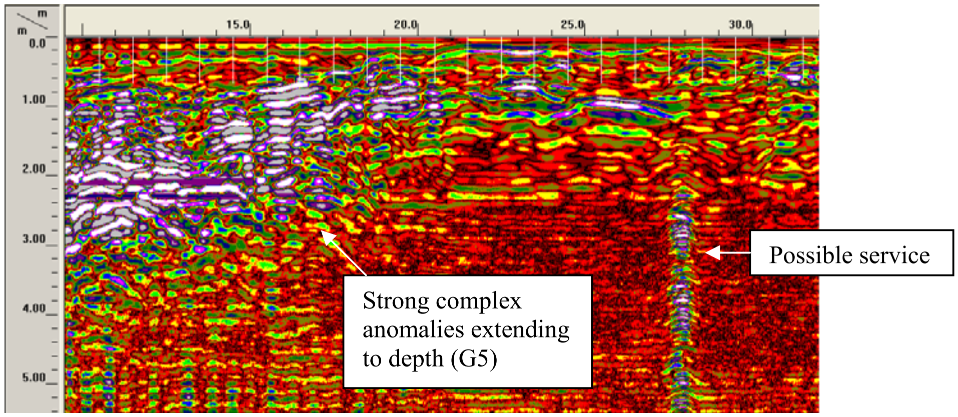
Example Radargram 5: 400MHz along 28E, 30-60N. Showing weak complex and planar responses possibly associated with the original cathedral frontage

Structural debris relating the Broad Street buildings

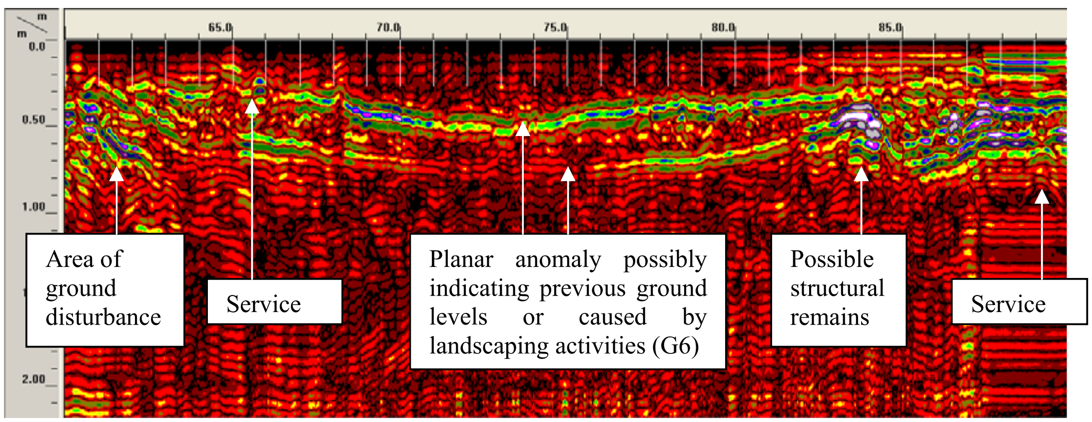
Large areas of strong complex anomalies extending to depth can be seen within the 200MHz and parts of the 400 MHz radar data (**G5**). These anomalies are likely to be associated with the structural remains and debris from the former buildings along Broad Street. A number of the complex anomalies extend to depth; this could suggest the presence of subsurface structures, such as basements or cellars (Example Radargram 6 and 7). The possible identification of the ground surface prior to the landscaping activities in the late 1930s can be seen as inclining planars (as the radar follows the contours of the rising man made surface, the previous ground level inclines downwards) (example Radargram 8).



Example Radargram 6: 200MHz along 10E, 60-90N. Showing strong complex anomalies extending to depth



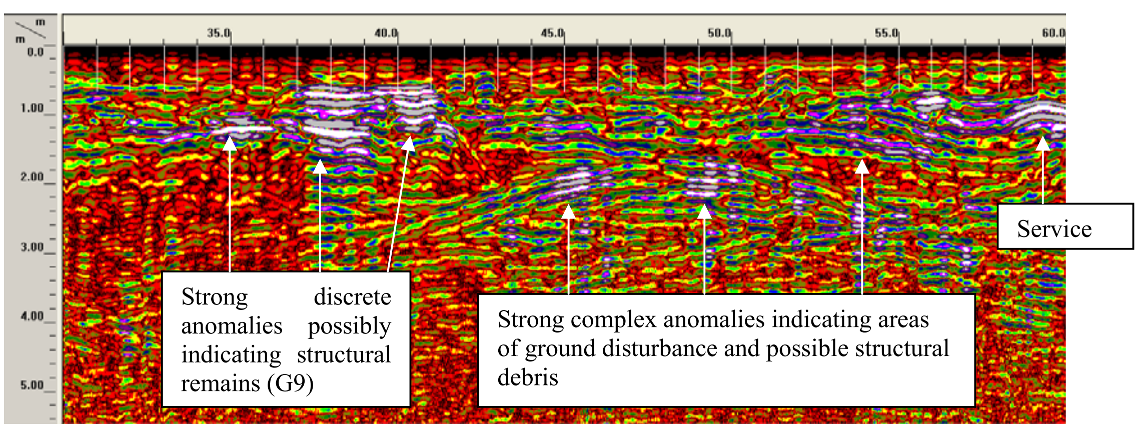
Example Radargram 7: 200MHz along 60N, 9.5-32E. Strong complex anomalies extending to depth possibly associated with subsurface structures



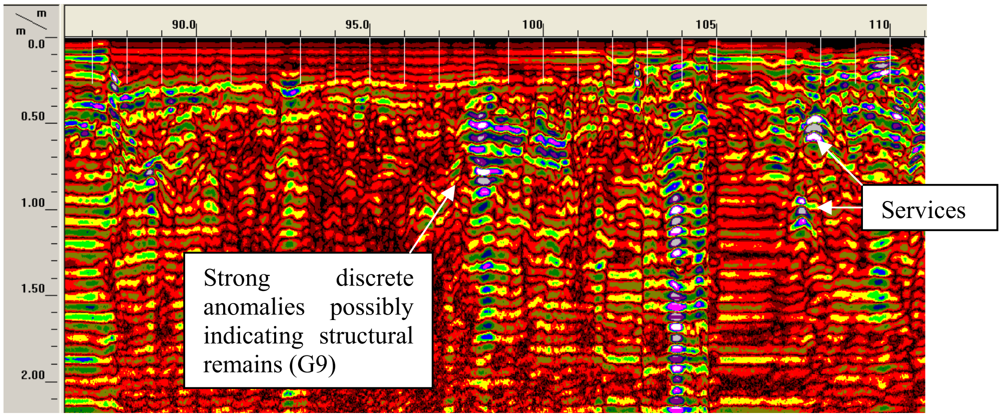
Example Radargram 8: 400MHz along 19E, 60-90N showing inclining planar anomalies possibly associated with a previous ground level and landscaping activities

Discrete and complex responses possibly relating to structural debris and remains

Situated to the north of the cathedral a number of strong discrete anomalies have been identified within both the 400 and 200MHz data (**G9** and **G10**). These anomalies may represent structural remains of archaeological origin (Example Radargrams 9 and 10).

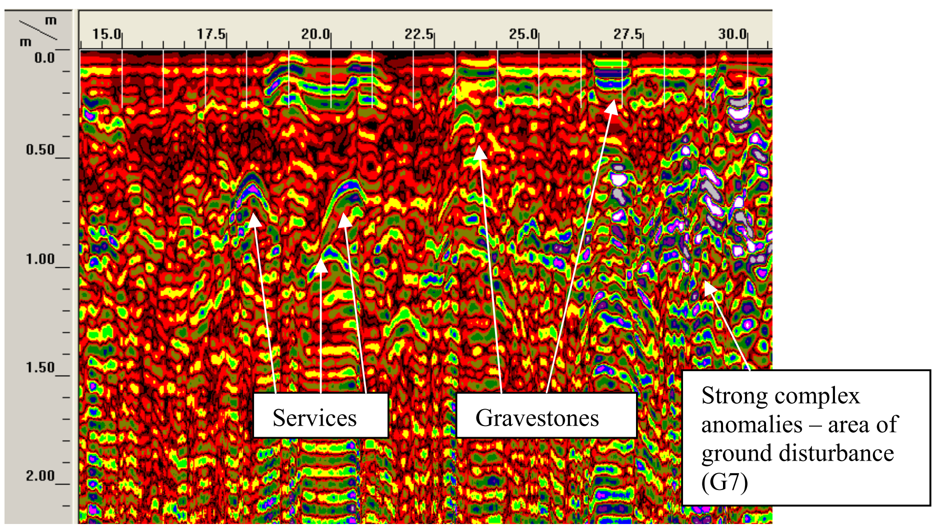


Example Radargram 9: 200MHz along 100N, 30-60E showing strong discrete and complex anomalies possibly associated with structural remains



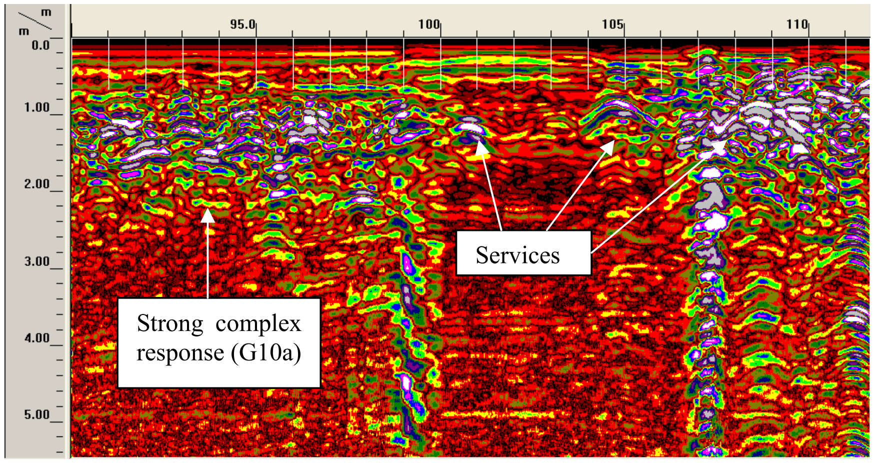
Example Radargram 10: 400MHz along 37.5E, 86-111N showing strong discrete anomalies possibly indicating structural remains

Large areas of complex anomalies have been identified in a number of places within the cloister range (**G7** and **G8**). These areas of complex response may represent areas of structural debris. However, a number of services have been identified running within or nearby the areas of complexity, suggesting these anomalies represent areas of ground disturbance of possible modern origin.



Example Radargram 11: 400MHz along 58.5E, 14-30N. Showing a number of services and an area of strong complex response indicating an area of ground disturbance of possible modern origin

A band of complex response has been identified only within the 200MHz radar (Figure 7) (**G10a**). This anomaly may indicate an area of general ground disturbance at depth, possible of archaeological origin.



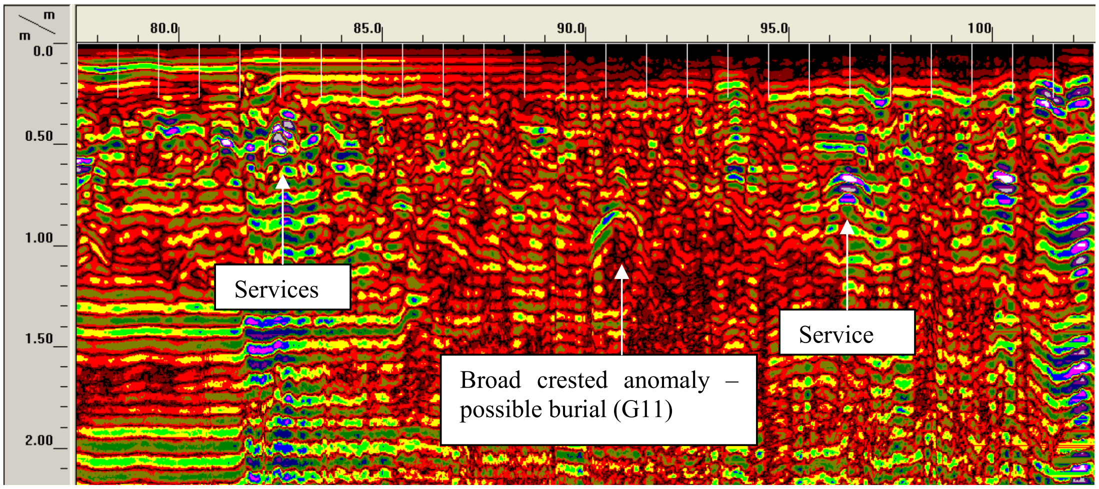
Example Radargram 12: 200 MHz along 70E, 90-111N. Showing an area of strong complex responses indicating possible structural debris and ground disturbance

Little evidence can be seen of the structural remains relating to the previous buildings situated near the Castle Street entrance (Taylor 1757). The laying of the pathways and services within this area may obscure or have removed the structural debris associated with these buildings.

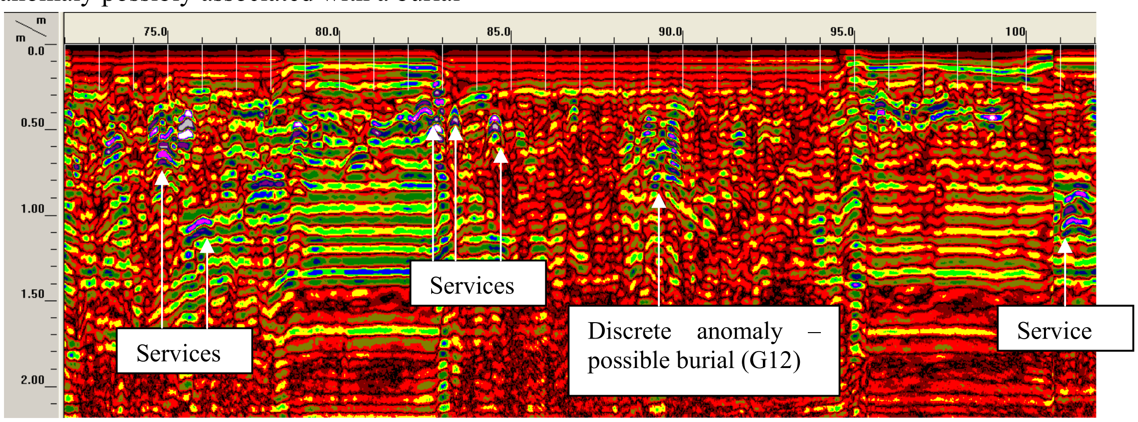
The same can be said for any potential remains of archaeological origin running along the northern pathway and the southeast of the Cathedral Close. Areas of complex response have been identified; however these anomalies may be associated with the laying of services and other modern activities and could obscure potential archaeological features.

Discrete GPR anomalies possibly indicating burials

With documentary evidence suggesting overcrowding of the graveyard, the subsequent closure of the precinct to burials in 1791 and the 1993 excavation findings (Stone and Appleton-Fox 1996, 12), it can be assumed that the Cathedral Close contains a large number of burials, although the graveyard boundary is unknown. In an area of frequent ground disturbance and the later landscaping activities of the 1850's it has been difficult to identify individual graves with confidence. However, a small number of discrete anomalies have been identified across the survey areas that may represent burials (Figures 6 and 8 and Example Radargrams 13 and 14). The identification of the extents of the burial ground is also difficult to distinguish, although areas of fewer GPR anomalies can be identified possibly suggesting the limits of burial activity. A higher concentration of discrete anomalies can be seen in the northeast of the survey (**G13**). This may represent a high concentration of burials or indicate an area of better preserved burials after the 1850s landscaping.



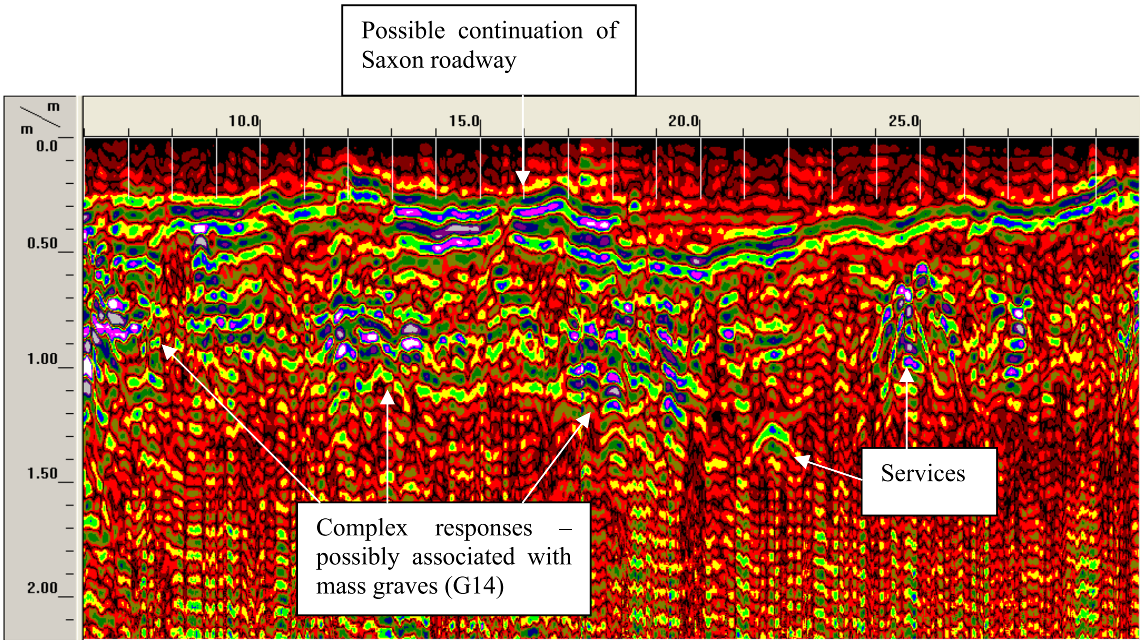
Example Radargram 13: 400MHz along 55.5E, 77.5-102.5N showing a broad crested anomaly possibly associated with a burial



Example Radargram 14: 400MHz along 82E, 72-102N showing a discrete anomaly possibly associated with a burial

Evidence for mass graves

During the 1993 archaeological excavation of the new library building three mass graves were uncovered along the eastern extents of the trench. The partially uncovered mass graves appear to continue into the present survey area along the western edges and northwest corner of the library building. The timeslice data at a depth of 0.45m (Figure 19) shows a large area of high energy returns running along the western edge of the survey area (**G14**). These responses may represent the ground disturbance associated with the mass graves. A discrete area of high energy response can also be seen within the timeslice data at a depth of 0.6m (Figure 20). This area anomaly may represent the extent of the northernmost mass grave reveal in 1993 (**G15**) (Example Radargram 15).



Example Radargram 15: 400MHz along 14E, 6-30N. Showing areas of complex response possibly associated with the 1993 mass graves

4.4 Underground utility mapping (UUM) survey

Overall, the UUM survey has been successful in confirming a number of documented service routes and identifying previously unknown services. There are a number of concentrated areas of service activity, possibly suggesting the reusing of service trenches. A large percentage of surface water drainage gullies could not be sonded due to the levels of silt deposits. The GPR abstraction within the Lady Abour suggests an alternative drainage system to that of the record drawings, but has been difficult to identify with confidence. The surface water drainage appears to converge at the stone marker in the approximate centre of the cloisters. To achieve a better understanding of the drainage it is recommended to clean all gullies and gully connections of silt and investigate under the marker stone in the Lady Abour to allow a thorough investigation of the services.

Small scale intrusive investigations will help confirm and identify unknown services seen within the GPR data. Suggested excavation positions can be seen within Figure 24.

5 CONCLUSION

The geophysical survey undertaken at Hereford Cathedral has been successful in locating a number of features of possible archaeological origin. The resistivity survey has identified a number of discrete areas of high resistance that may relate to structural debris or ground disturbance of possible archaeological origin. The gradiometry survey was of limited success due to the high levels of magnetic disturbances associated with an urban site. However areas of magnetic debris and discrete positive anomalies may relate to areas of archaeological activity, with a number of anomalies comparable to those identified within the resistivity and GPR. The GPR survey has been successful in identifying a large number of services, in confirming documented structural remains and identifying further potential remains of archaeological origin. The continuation of the Saxon road can be seen within the GPR and gradiometry data and the possible extents of the mass graves identified within the GPR and resistivity. It can be assumed by documentary and archaeological records that the Cathedral Close has a high concentration of burials. In an area of frequent ground disturbance and later landscaping activities, the identification of individual burials is very difficult. However, a small number of discrete anomalies have been identified across the survey area that may represent individual burials within an area of graveyard activity.

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