STRATASCAN

Geophysical Survey Report

Kenilworth Castle, Warwickshire

For

English Heritage

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1 SUMMARY OF RESULTS

GPR and gradiometer surveys were carried out west of the proposed visitor centre at Kenilworth Castle. The gradiometer survey identified an area of linear magnetic disturbance in line with a series of bollards. A number of linear anomalies typical of services are present in the radar data within the area of magnetic disturbance, but the gradiometry survey was of limited overall success due to the high number of magnetic objects in and around the survey area. Large amplitude complex and discrete anomalies caused by the pathways are seen throughout the data. Anomalies located beneath the path suggest the presence of possible service routes. Few of the observed radar anomalies can be attributed to areas of archaeological activity with confidence. Two areas of complex response situated in the northeast of the survey area may represent areas of archaeological activity but may also be of modern origin as an inspection cover is thought to exist somewhere within the survey area.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned to undertake a geophysical survey of an area outlined for development including the laying of drainage and electrical services. This survey forms part of an archaeological investigation being undertaken by English Heritage.

2.2 Site location

The site is located to the west of the proposed visitor centre at Kenilworth Castle, a Scheduled Ancient Monument, in Warwickshire at OS NGR ref. SP 278 722.

2.3 Description of site

The site has been recently covered with gravel and has two pathways. One path runs along the northwestern edge of the survey area and is lined with bollards, whilst the other dissects the survey area in a southeast to northwest orientation. Scaffold poles cordoned off an area situated in the northeast of the site.

The underlying geology is Triassic Mudstones (British Geological Survey South Sheet, Fourth Edition Solid, 2001). The overlying soils are of the Hodnet association, which are stagnogleyic argillic brown earths. These have a reddish colour and consist of fine and coarse loamy soils with slowly permeable subsoils (Soil Survey of England and Wales, Sheet 3, Midland and Western England).

2.4 Site history and archaeological potential

Although no specific details were available to Stratascan, the archaeological potential is high because of the presence of the Scheduled Ancient Monument (SAM). The survey area is situated to the south of a former gatehouse tower situated in a low lying area that may well have served as a dock area for access to the formally flooded mere surrounding the castle. A service is thought to exist within the service area as a buried inspection cover was discovered in a previous investigation although the precise location is unknown.

2.5 Survey objectives

The objective of the survey was to locate any anomalies that may be of archaeological significance prior to development. A secondary objective was to locate a previous service run thought to exist within the survey area in an attempt to reuse the run for the proposed services.

2.6 Survey methods

A gradiometer survey was carried out to identify possible magnetic anomalies associated with services and possible features of archaeological origin. A ground penetrating radar survey (GPR) was carried out to identify features of archaeological origin and possible services with relative depth information.

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 2 days, on the 9th and 16th of November 2005 when the weather was dry.

3.2 Grid locations

The location of the survey grids has been plotted in Figure 2.

3.3 Description of techniques and equipment configurations

Gradiometry
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 (thermoremnant features). 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 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.

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

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*

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 0.798m/nsec which is typical for the type of sub-soils on the site. With a range setting of 70nsec this equates to a maximum depth of scan of 2.76m 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*

Magnetometry

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*

Magnetometry

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 has been carried out to further enhance the data:

Extreme high and low readings were removed from the data in an attempt to reveal additional subtle features.

Radar
The radar plots included in this report have been produced from the recorded data using Radan software. Filters were applied to the data to remove background noise.

3.5.2 <u>*Presentation of results and interpretation*</u>

Magnetometry
The presentation of the data for each site involves a print-out of the raw data both as greyscale (Figure 3) and trace plots (Figure 4 and 5), together with a greyscale plot of the processed data (Figure 6). Magnetic anomalies have been identified and plotted onto the 'Abstraction and Interpretation of Anomalies' drawing for the site (Figure 7).

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.

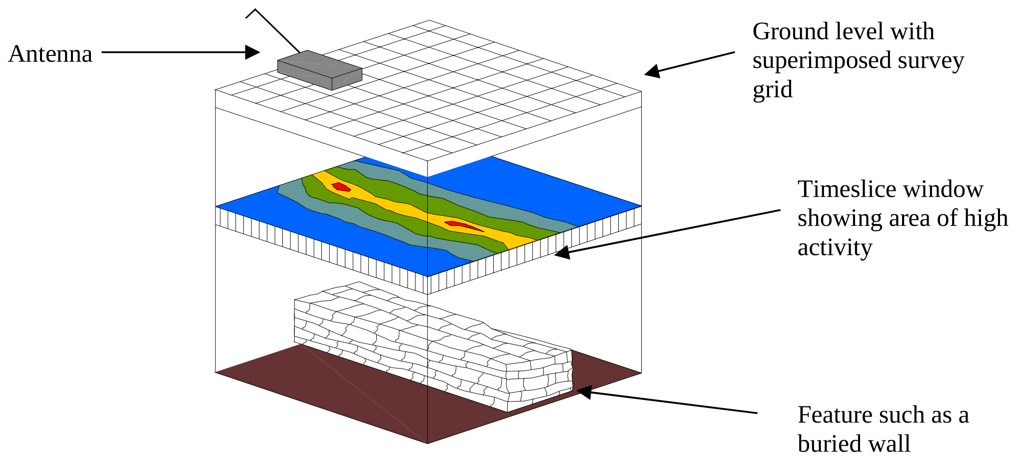
v. Planar returns.
These may be formed by a floor or some other interface parallel with the surface. These are subdivided into both strong and weak giving an indication of the extent of change of velocity across the interface which in turn may be associated with a marked change in material or moisture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

vi. Inclined events.
These may be a planar feature but not parallel with the survey surface. However, similar responses can be caused by extraneous reflections. For example, an “air-wave” caused by a strong reflection from an above ground object would produce a linear dipping anomaly and does not relate to any sub-surface feature. Normally this is not a problem as the antennae used are shielded, but under some circumstances these effects can become noticeable.

vii. Conductive surface.
The radiowave transmitted from the antenna has its waveform modulated by the ground surface. If this ground surface or layers close to the surface are particularly conductive a ‘ground coupled wavetrain’ is generated which can produce a complex wave pattern affecting part or all of the scan and so can obscure the weaker returns from targets lower down in the ground.

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 8 and 9). 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 8 and 9).

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 Gradiometer

The gradiometer survey has been of limited success due to the high levels of magnetic debris situated within and around the survey area. A linear magnetic anomaly is observed running in a northeast to southwest orientation (**a**) which may relate to the line of bollards situated along the northwestern edge of the survey area; however this may indicate a service running in a similar orientation. A discrete area of metallic disturbance situated in the northwest corner of the survey area (**b**) may represent the manhole cover thought to exist within the area. This also corresponds with an area of weak complex anomalies identified within the radar data (**27**); however the magnetic anomaly may also be associated with the nearby scaffold hoardings.

4.2 GPR

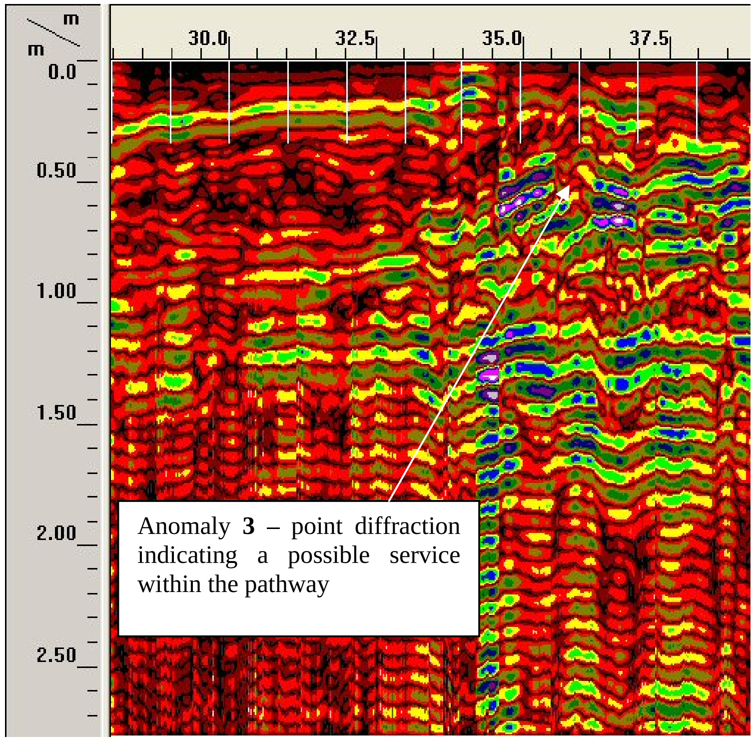
A wide range of anomalies have been identified within the radar data. The data is dominated by two linear anomalies likely to be associated with the two pathways present within the survey area; however additional features may be identified with complex area returns.

The anomalies have been classified into the following categories (see Figure 11):

- Linear anomalies possibly relating to services or structural remains of archaeological origin
- Strong discrete anomalies – possibly associated with the existing path or a service trench
- Broad crested anomalies **-** possibly associated with structural remains or a modern service
- Strong complex anomaly – area of ground disturbance or structural remains
- Strong planar anomaly – associated with path construction
- Weak complex anomalies – areas of disturbed ground
- Weak discrete anomalies – possible structural debris of archaeological origin

4.2.1 Linear anomalies possibly relating to services or structural remains of archaeological origin

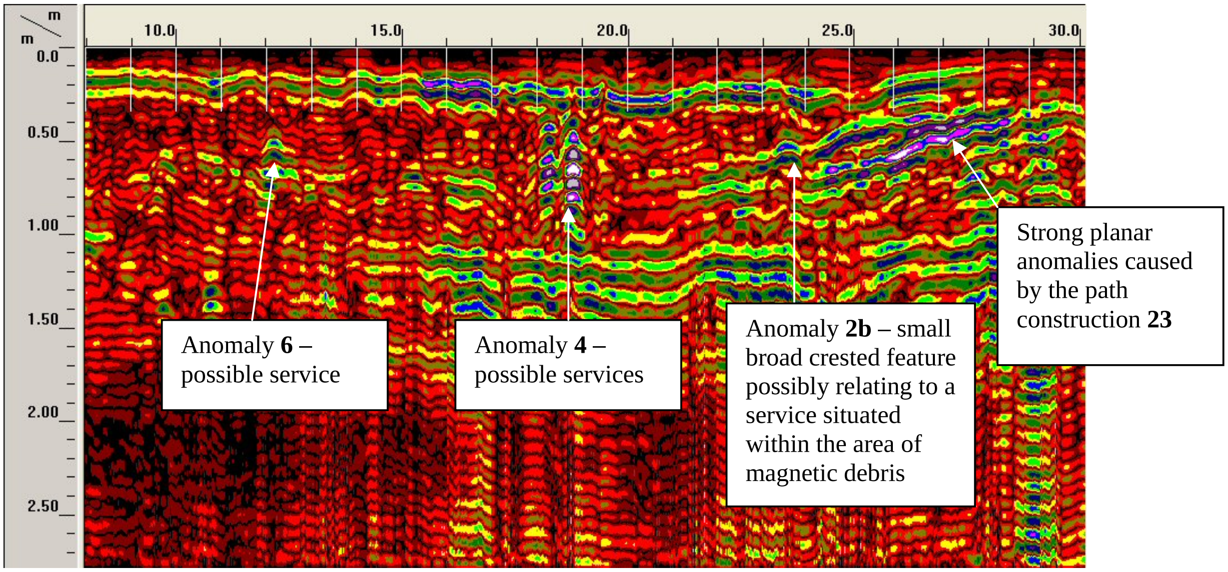
A large number of linear anomalies have been identified across the survey area in the form of point diffractions. These anomalies typically relate to services or discrete structural remains. Anomalies **1**, **2** and **3** may relate to a possible service identified within the western pathway; however these anomalies may also be caused by the construction of the pathway (Example Radargrams 1 and 3).



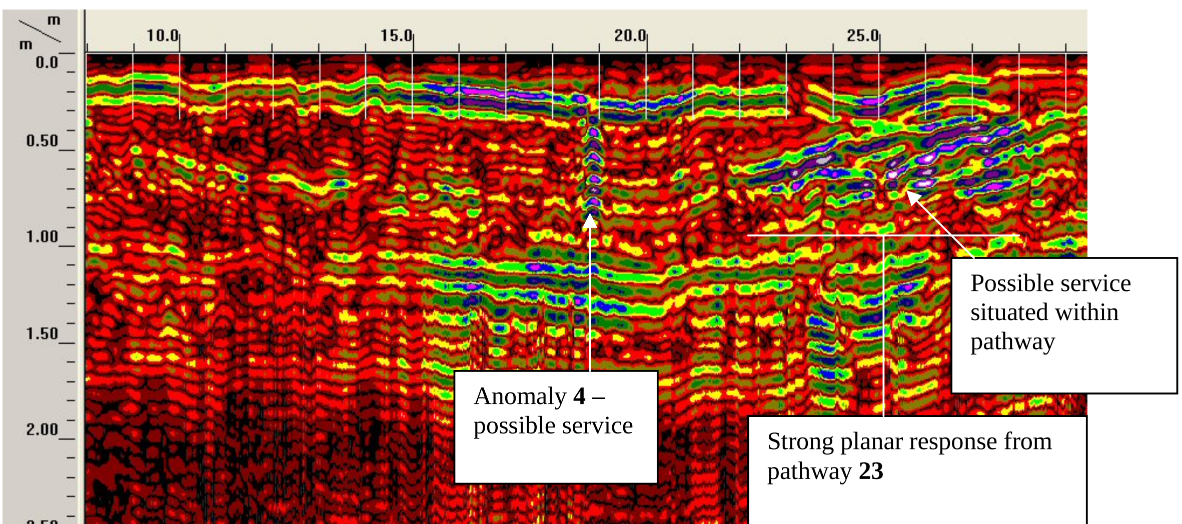
Example Radargram 1: Traverse 31.5N, 28-30.5W. Possible service situated within pathway

A linear anomaly in the form of a low energy return is observed in the timeslice data at a depth of 0.3m. This corresponds with the linear magnetic disturbance identified within the gradiometer survey. These anomalies may indicate a possible service trench.

A small number of point diffractions identified within the linear low energy return could represent a service running along the line of magnetic debris (**2a** and **2b**). However these anomalies are somewhat disjointed and therefore it is difficult to identify a linear alignment with confidence. Additional isolated point diffractions could represent service lines (**4**, **5-5b**, **6-9**) but intrusive investigation would be required to identify the nature of these anomalies (Example Radargrams 2 and 3 and Figures 10 and 11).



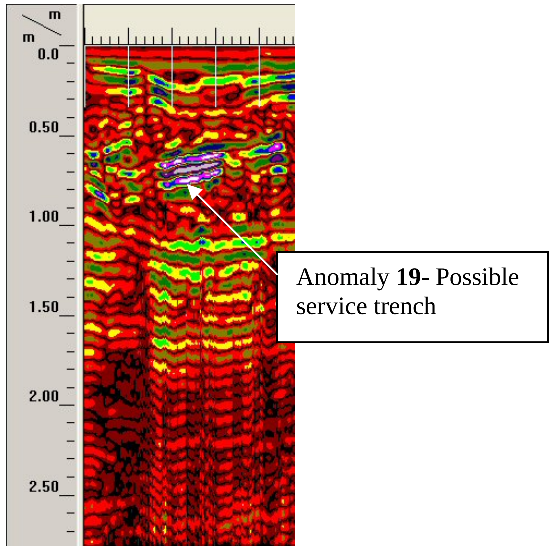
Example Radargram 2: Traverse 24N, 8-30W. Showing a number of point diffractions that may relate to services



Example Radargram 3: Traverse 23.5N, 8-29.5W. Showing the strong planar response from the pathway and a possible service

4.2.2 <u>Strong discrete anomalies – possibly associated with the existing path or a service trench</u>

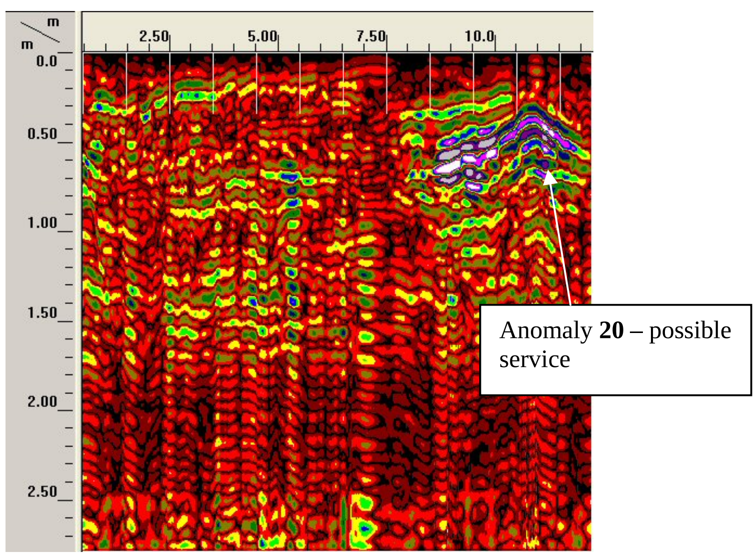
Areas of strong discrete responses can be identified throughout the survey area. The majority of these responses can be attributed to the construction of the pathway (anomalies **10-14** and **16**). Anomalies **17** and **19** may represent a possible service trench due to the features well defined edges (Example Radargram 4). Anomaly **15** may correspond to structural remains of modern or archaeological origin.



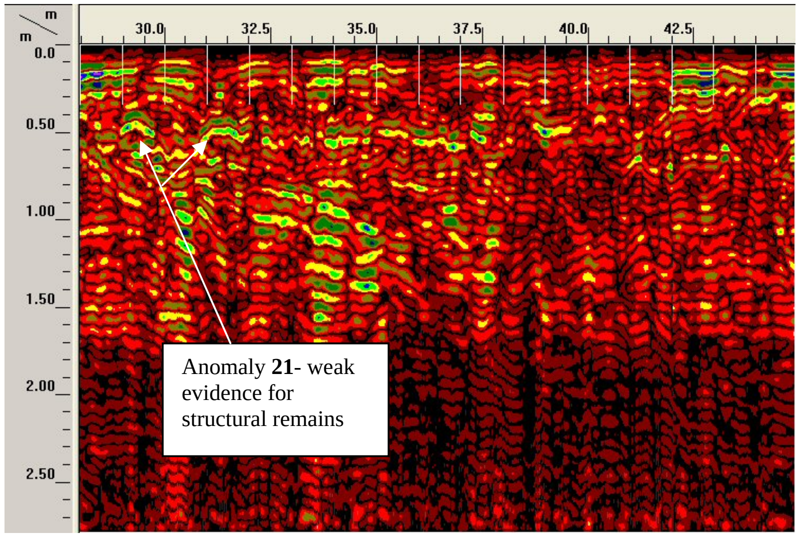
Example Radargram 4: Traverse 38.5N, 7-12W. Showing a strong discrete anomaly possibly relating to a service trench

4.2.3 Broad crested anomalies - possibly associated with structural remains or a modern service

Two discrete broad crested anomalies have been identified within the survey area (**20** and **21**). Anomaly **20** may indicate a possible service situated within the pathway at an approximate depth of 0.3m (Example Radargram 5). Anomaly **21** may represent weak evidence for structural remains (Example Radargram 6).



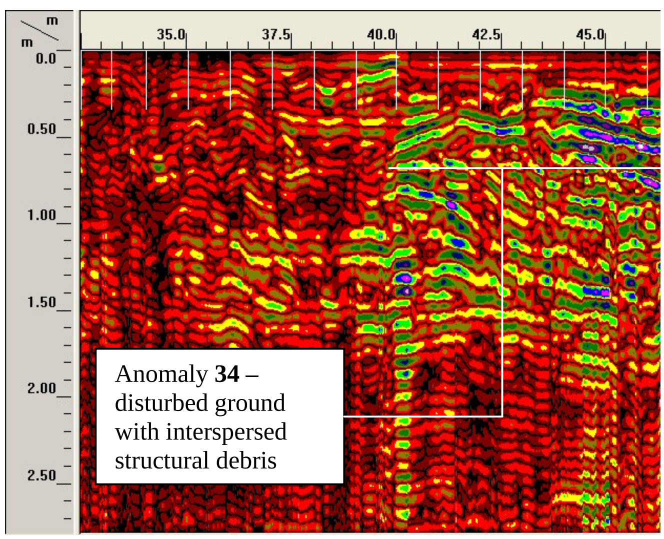
Example Radargram 5: Traverse 5.5N, 0.5-12.5E. Showing a broad crested anomaly possibly relating to a service



Example Radargram 6: Traverse 42.5N, 28-44.5W. Showing weak broad crested anomalies, possible weak evidence for structural remains

4.2.4 Strong complex anomaly – area of ground disturbance or structural remains

An area of strong complex anomalies (**34**) is situated in the north of the survey area. This anomaly is likely to be caused by the pathway but may also indicate areas of structural debris (Example Radargram 7).



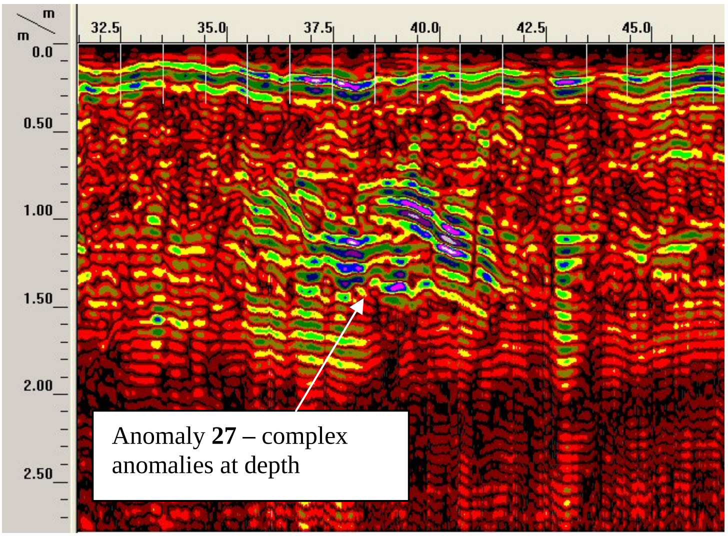
Example Radargram 7: Traverse 35.5N, 32.5-48W. Showing strong complex anomalies caused by the pathway with possible interspersed structural debris

4.2.5 Strong planar anomaly – associated with path construction

Strong planar anomalies have been identified along sections of the two pathways that are likely to be directly related to their construction (**22-24**) (Example Radargram 2 and 3).

4.2.6 Weak complex anomalies – areas of disturbed ground

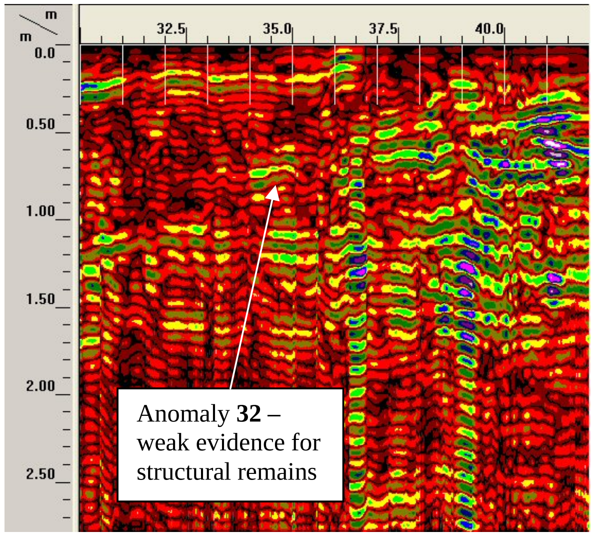
Weak complex anomalies **25** and **26** have been identified along two sections of the pathways and can be attributed to the construction of the path or modern activity. Anomalies **27** and **28** situated in the northeast of the survey area may represent an area of ground disturbance of possible archaeological origin. It is worth noting that an inspection cover was discovered within this area during a previous investigation, therefore it is possible that these anomalies may be of modern origin (example Radargram 8).



Example Radargram 8: Traverse 38.5N, 31.5-46W. Showing complex anomalies of possible archaeological or modern origin at depth

4.2.7 Weak discrete anomalies – possible structural debris of archaeological origin

A number of weak discrete anomalies have been identified across the survey area (**29-33**). Anomaly **29** is possibly associated with a nearby earthen bank. Anomalies **30-33** may indicate weak evidence for structural remains of archaeological origin. As these anomalies are weak and infrequent they may represent natural changes within the subsurface material (Example Radargram 9).



Example Radargram 9: Traverse 33N, 30-41W. Showing a weak discrete anomaly indicating possible structural remains

5 CONCLUSION

A number of linear GPR anomalies have been observed within the area of magnetic disturbance identified by the gradiometry survey that may indicate a service route. The radar data has been dominated by complex and discrete responses caused by the two pathways present within the survey area. Possible services and a service trench may be situated within these pathways; however these anomalies may also be caused by the construction of the pathway and general modern activity.

Few radar anomalies can be attributed to areas of archaeological activity with confidence. Two areas of complex response situated in the northeast of the survey area may represent an area of archaeological activity but may also be of modern origin as an inspection cover is thought to exist somewhere within the survey area.