STRATASCAN

Geophysical Survey Report

Buckfast Abbey, Devon

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1 SUMMARY OF RESULTS

A trial of Ground Probing Radar (GPR) and resistance survey carried out at Buckfast Abbey, Devon, indicated that GPR was likely to be the more effective technique. Subsequent survey of approximately 0.5ha using GPR located discrete and complex responses likely to relate to structural features. Inclined events may relate to other former surface features such as ditches or depressions. Definition of possible structures is generally poor impeding detailed interpretation.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned to undertake a geophysical survey of an area of Buckfast Abbey prior to work replacing the sewerage system. This survey forms part of an archaeological investigation being undertaken by Stewart Brown on behalf of Buckfast Abbey.

2.2 Site location

The site is located at Buckfast Abbey, Devon at OS NGR ref. SX 742 673.

2.3 Description of site

The site is located within the Abbey precinct and is split into three areas. Area 1 south of the church, is approximately 1100m² covering a grassed area with formal garden and section of metalled surface. Area 2 between the leat and the River Dart covers a grassed area of approximately 1300m². Area 3, covering approximately 1400m², is located on grass to the south east of the church and to the west of the leat.

The underlying geology is Upper Devonian and Upper Old Red Sandstone (British Geological Survey South Sheet, Third Edition Solid, 1979). The overlying soils are Denbigh 1 soils which are typical brown earths. These consist of well drained fine loamy and fine silty soils over rock (Soil Survey of England and Wales, Sheet 5 South West England).

2.4 Site history and archaeological potential

A Saxon Benedictine monastery was founded at Buckfast in 1018. Major building and alterations occurred when the Cistercian Order was introduced in 1147. Further alteration and building was carried out through the medieval period although after the Dissolution the buildings fell into decline. The site was eventually offered back to the Cistercian community in the 19th century, after many years of decline a programme of restoration and rebuilding was carried out.

The archaeological potential of the survey areas is considered high as these are likely to cross the suspected position of buildings relating to the former medieval layout of the monastery. In addition it is possible that features relating to the original Saxon monastery, of which very little is known, may also be located.

2.5 Survey objectives

The objective of the survey was to locate any anomalies that may be of archaeological significance in order for them to be assessed prior to ground works associated with the laying of a new sewer pipeline.

2.6 Survey methods

From an initial trial survey of resistivity and GPR, the latter was considered to be more effective at locating known features at the time of survey. More information regarding both techniques is included in the Methodology section below.

3 METHODOLOGY

3.1 Date of fieldwork

The fieldwork was carried out over 5 days from the 29th to the 31st of March and the 4th and 5th of May.

3.2 Grid locations

The location of the survey grids has been plotted in Figures 2 and 6.

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 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.

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 200MHz 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.

Radar
Radar scans were carried out along traverses 1m 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 0.5m centres with a 0.5m probe spacing provides an optimum resolution for the technique.

Radar
The average velocity of the radar pulse varies from area to area. The following have been calculated for the site:

	Velocity [m/ns]	Max. depth of scan [m]
grass	0.0901	11
road	0.0999	12
area between leat and road	0.0712	9

With a range setting of 120 nsec the maximum depth of scan has also been calculated, 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).

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.

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.

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

Despike *X radius = 1*

Y radius = 1
Spike replacement

Radar
The radar plots included in this report have been produced from the recorded data using Radan software. Some of the data has been processed using an FIR filter to remove 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).

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.

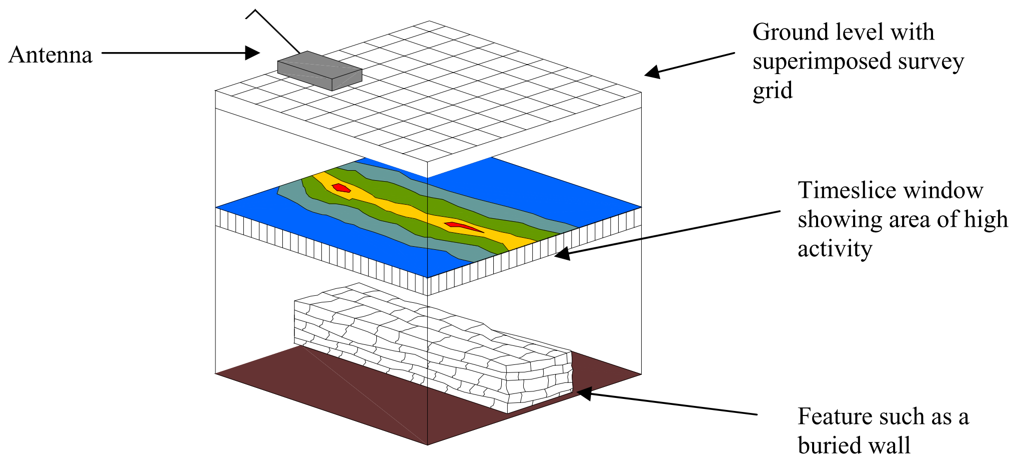
ii. Complex reflectors.
These would generally indicate a confused or complex structure to the subsurface. An occurrence of such returns, particularly where the natural soils or rocks are homogeneous, would suggest artificial disturbances. These are subdivided into both strong and weak giving an indication 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 7 - 10). 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 7 - 10).

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

An initial trial of resistance and GPR indicated that the latter technique was likely to provide a more effective survey. Resistance carried out across Area 1 failed to provide anomalies relating to areas of known archaeology and services in contrast to GPR that effectively produced reflections from these areas.

Resistance survey

The resistance survey has been categorised into three relatively different area anomalies; high, moderate and low. High to moderate may represent structural remains or rubble, low resistance anomalies are created from areas having increased water content and may represent former cut features although within the small area surveyed these areas possibly represent less disturbed ‘natural’ soil and subsoil conditions.

There are two areas of high resistance. The area in the north west of the survey is likely to be structural remains associated with a previous building. The area parallel to the current leat is possibly a former course backfilled with stone and rubble although a track way may cause a similar response.

Other area anomalies are poorly defined precluding accurate abstraction and interpretation although it should be considered that archaeological remains may be represented

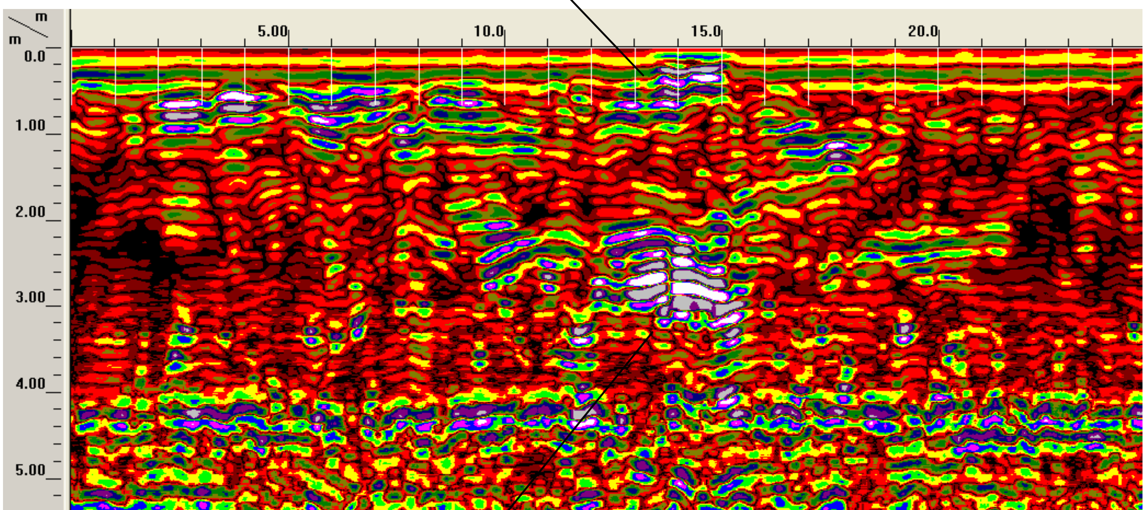
GPR survey

Area 1

The area is separated by a paved path into a western and eastern section, strong and weak complex anomalies are formed by reflections from this modern feature.

Beneath the path there is a strong complex response indicative of structural remains, this occurs at a depth of 2.2m, see Figure 13.

Response from current path at ground level



Deeper complex response

Figure 13. Radar transect from Area 1, -18N from –0.5E to 24.5 E.

Weak complex responses form possible linear elements immediately to the west of the central pathway running through Area 1. These may be associated with nearby strong discrete anomalies and are best seen in the timeslice plot, Figure 07.

A series of weak discrete responses to the east of the pathway appear to link inspection chambers and are likely to be related to services. A strong discrete anomaly at the western edge of the survey area may be related to nearby buildings.

Area 2

There is a large area of complex response towards the north of Area 2. In places the continuity between adjacent transects is broken but in general linear elements are formed. This suggests a possibility of structural remains which may have been partially removed.

Adjacent to the above anomalies is a series of inclined events typical of a response to a ditch, depression or some other buried inclined surface (Figure 14). It would therefore suggest some re-modelling of a former surface.

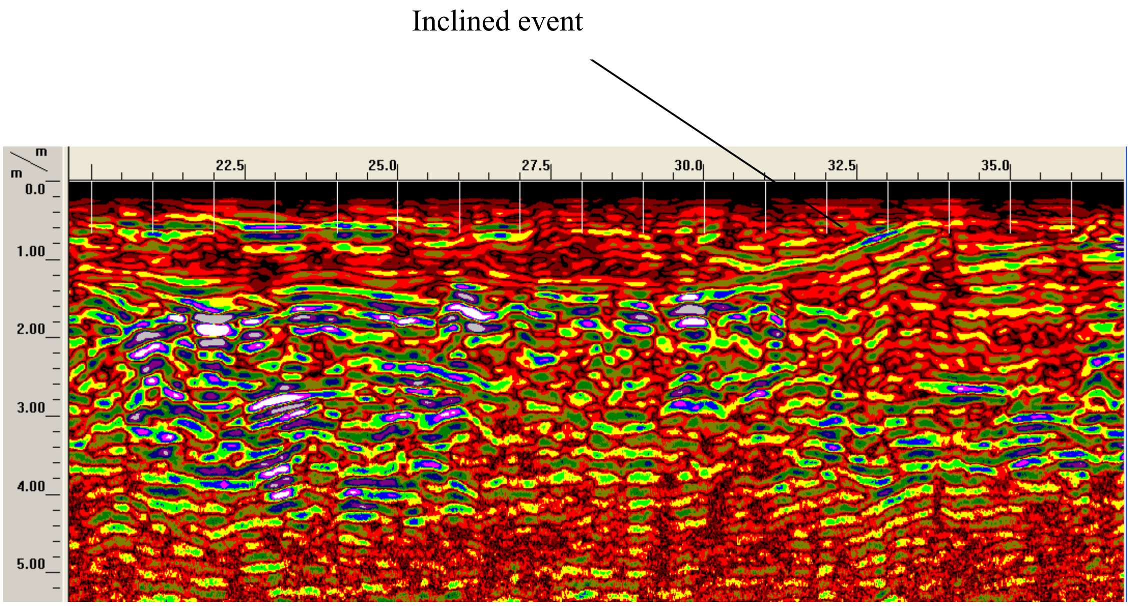


Figure 14. Transect 17E. Inclined event possibly relating to former surface.

Other areas of complex response to the south of Area 2 may also suggest linear elements having an archaeological origin although these are not defined well enough to allow detailed assessment.

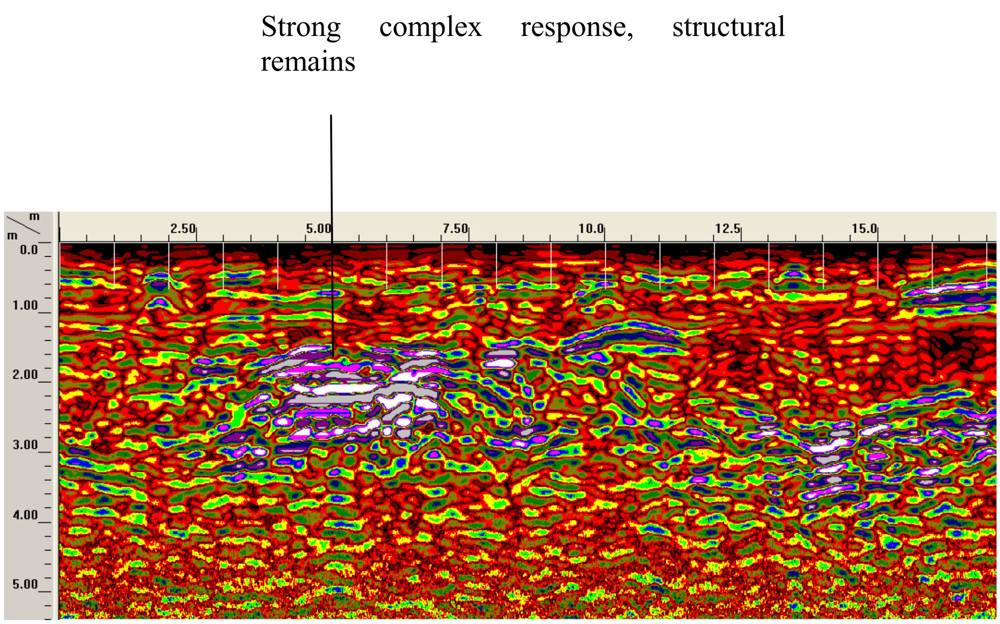


Figure 15. Transect 27E. Shows the typical response expected from structural remains and walls.

Area 3

A region of complex reflections in the north west corner of Area 3 suggests structural remains. The area is bisected by a linear shallow planar response that has correlation to an area of low resistance, this would tend to suggest a modern feature such as a service trench backfilled with damp clay for example.

Shallow planar response running parallel to the existing leat correlates with high resistance areas mentioned above. The response may suggest a track way or former course to the leat. Comparison of timeslices for relatively shallow and deep responses, Figures 7 and 9, suggest that the feature extends from near surface to depth, however, it is likely that the deeper responses are some 'ringing' of the reflected signal from near surface changes. This would tend to support interpretation of the anomaly as relating to a track way or path fairly close to the present ground surface. Inclined events close to the south western edge of the area may be associated and probably indicate some landscaping of a former more undulating surface.

Generally complex response towards the south western corner of Area 3 suggests possible structural remains in this area. There is a correlation to areas of moderately high resistance also supporting possible structural features.

Complex responses with adjacent shallow inclined events are located towards the northern end of area, these are not well defined although within the resistance survey a clear change from high to low resistance was located in the same area. Low resistance areas show some correlation to the inclined events suggesting damp soil within an in-filled ditch or depression, high resistance correlating to the complex response may be associated with rubble or structural remains.

5 CONCLUSION

GPR has located anomalies possibly suggesting structural remains and other archaeological features, these are summarised below:

Area 1

- a strong complex return beneath the paved area (structural)
- weak complex anomalies and strong discrete anomalies to the west of the paved area (structural)

Area 2

- large complex responses towards the north of the area possibly forming linear elements (structural)
- inclined events adjacent to the above (ditch/depression or former surface characteristics)

- complex responses towards the south of the area also possibly forming linear elements (structural)

Area 3

- complex reflections to the north west of the area adjacent to current buildings (structural)
- shallow planar response parallel to the current leat (possible track way)
- complex response towards the south west corner of the area (structural)
- complex response and inclined events to the north of the area (structural and ditch/depression)

Detailed interpretation from the results of the survey is problematic due to the characteristics of the radar response. This may suggest that buried structures are fragmentary or of slight construction. In addition the location of inclined events may suggest that there has been some re-modelling of former land surfaces with possible consequences for structural remains.