STRATASCAN

Geophysical Survey Report

Hopton Castle, Shropshire

For

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1 SUMMARY OF RESULTS

A geophysical survey was carried out at Hopton Castle, Shropshire. This consisted of a resistance survey and detailed magnetic survey over 3.2ha followed up by ground penetrating radar targeted on areas of interest.

The results show a complex set of anomalies, some of which correlate with surface earthworks. Others indicate the likely remains of stone structures and cut features which appear to occur extensively throughout the site.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned by the Hopton Castle Preservation Trust to undertake a geophysical survey of land surrounding Hopton Castle, Shropshire. This survey forms part of an archaeological study being undertaken by English Heritage in support of a Heritage Lottery Fund bid.

2.2 Site location

The site is located at Hopton Castle, Shropshire at NGR. SO 367 780.

2.3 Description of site

The site identified for geophysical survey covers 3.2ha of land surrounding the castle keep, and 32m^2 within the keep. Unfortunately at the time of the site work the small area within the keep was being excavated ruling it out of the survey. The remaining land is grass covered and encompasses a series of ditches and earthworks. It is currently used for grazing livestock.

The underlying geology is of the Ludlow formation (British Geological Survey, 2001) consisting of mudstones and siltstones (NERC, 2004). The soils are of the Rowton soil association. These consist of well drained fine silty and fine loamy soils, locally over gravels; with some fine silty over clayey soils with slowly permeable subsoils and seasonal waterlogging and some slowly permeable seasonally waterlogged fine silty over clayey soils (Soil Survey of England and Wales, Sheet 3 Midland and Western England).

2.4 Site history and archaeological potential

Hopton Castle is a Grade 1 listed building and a Scheduled Ancient Monument (SAM). It is uncertain exactly when the first castle at Hopton was constructed. Evidence suggests that it was converted from a motte and bailey earthwork to a stone structure and keep in 1276 (CastleUK.net, 2005) with further improvements taking place up until the 16th century (BBC, 2005). Throughout this time it is likely to have been involved in many Welsh raids across the Marches. Its most notorious day occurred in 1644 during the Civil War. Here Parliamentarian forces were besieged in the castle by Royalist soldiers. Eventually terms of surrender were agreed and the besieged army withdrew. It is unclear exactly what happened next but the outcome lead to the massacre of the Parliamentarians with some sources stating they were thrown in to the moat. Following this event the castle was abandoned and left to ruin.

The site currently consists of a stone keep structure with a basal area of approximately $100m^2$ and a wall around 10m high, surrounded by a series of earthworks. Further stone remains are just visible jutting out of the ground amongst the earthworks. This suggests the strong possibility that buried stone structures are present at the site.

Given this long history the potential for locating features of an archaeological origin is considered high.

2.5 Survey objectives

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

2.6 Survey methods

A resistance survey and detailed magnetic survey (gradiometery) were carried out across the entire 3.2 ha site. Based on these results six target areas were chosen to survey using ground penetrating radar (GPR). As previously mentioned the intended GPR survey within the keep was unable to proceed due to excavation workings.

More information regarding these techniques is included in the Methodology section below and Appendices at the end of the report.

3 METHODOLOGY

3.1 Date of fieldwork

The fieldwork was carried out over seven days from 12th September 2005 to 20th September 2005 during which the weather was warm and dry. A further one day site visit was made on 31st October 2005.

3.2 Grid locations

The locations of the survey grids and targeted GPR traverses have been plotted in Figure 2.

3.3 Survey equipment

3.3.1 Resistance survey

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 30m 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.

3.3.2 Detailed magnetic survey

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

3.3.3 Ground Penetrating Radar

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

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

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

Ground Penetrating Radar
Radar scans were carried out along traverses 0.5m apart on a parallel grid as shown in Figure 2. 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

Resistance survey
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 provides an appropriate methodology balancing cost and time with resolution.

Detailed magnetic survey
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.

Ground Penetrating Radar
The average velocity of the radar pulse is calculated to be 0.072m/ns which is typical for the type of sub-soils on the site. With a range setting of 60ns this equates to a maximum depth of scan of 2.17m, 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.

3.4.3 Data capture

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

Detailed magnetic survey
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.

Ground Penetrating *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

Resistance survey
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.

1.	*Despike*	*X radius = 1, Y radius = 1* *Spike replacement = mean*
2.	*High pass filter*	*X radius = 10, Y radius = 10* *Weighting = Gaussian*

Detailed magnetic survey
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* *X radius = 1, y radius = 1, threshold = 3 std. dev.*
Spike replacement = mean

2. *Zero mean traverse*
Least mean square fit = on , threshold = +/- 5

Ground Penetrating Radar
The radar plots included in this report have been produced from the recorded data using Radan software. A FIR filter has been applied to the data to removal background noise.

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

Resistance survey
The presentation of the data for the site involves a print-out of the raw data as a grey scale plot (Figure 4), together with a grey scale plot of the processed data (Figure 5). Anomalies have been identified and plotted onto the 'Abstraction of Anomalies' drawing (Figure 6).

Detailed magnetic survey
The presentation of the data for each site involves a print-out of the raw data both as greyscale (Figure 7) and trace plots (Figure 8 and 9), together with a greyscale plot of the processed data (Figure 10). Magnetic anomalies have been identified and plotted onto the 'Abstraction of Anomalies' drawing for the site (Figure 11).

Ground Penetrating *Radar*
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.

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.

4 RESULTS

The results have shown the site to be very complicated by defining detailed geophysical anomalies relating to both buried and surface features. To help simplify this an integrated interpretation plan of the site including the results from all techniques has been produced (Figure 18). Anomalies which coincide with visible surface expressions, such as ditches and earthworks, have been highlighted with a cross hatch pattern. The topographical evidence this is based on has been supplied by Mark Bowden, English Heritage.

4.1 Resistance survey *(Figures 4-6)*

The resistance survey defines many anomalies which can be associated with visible surface features. These mainly include cut ditches around the castle which are represented by low resistance readings. The castle motte is also defined by a circular area of low resistance. Some earthworks are associated with higher resistance areas which probably relate to stone remains.

The linear anomaly in the west of the site, running north-south, consists of low resistances and high resistances on its flanks. This coincides with the position of a track way marked on the 1st edition OS map (Bowden, 2005) and is probably related to it. This is also identified in the gradiometer data as a linear anomaly of magnetic debris which may be caused by disturbed ground possibly with a gravelled material.

On the far west edge of the survey area is a 'dog leg' shaped linear anomaly correlating in position with the leat. In places along it sides are higher resistance values suggesting it may have a stone lining. Separating this anomaly and a low resistance anomaly along the southern side of the survey area is a region where several low resistance anomalies appear to converge. While this area itself does not show particularly low readings it may represent a 'merging' area of several ditches, possibly related to water management.

Many other cut features identified (either as a surface expression or buried anomaly) seem to have associated high resistance readings along their banks. This is evidence indicating these cut features may be constructed with supporting stone sides.

The bailey area of the castle is defined by low resistance anomalies likely to be caused by defensive ditches. Within this area several higher resistance patches can be seen (three in the southern half, two in the northern half). It is possible these areas are associated with stone structural remains relating to former buildings. The topographical map also shows locations of possible building platforms in this area.

In between the northern side of the castle and the stream are several well defined anomalies. High resistance linear responses and low resistance responses indicate the presence of structural remains and cut features possibly relating to a former building. Further high resistance anomalies are observed east of the motte. Two high resistance areas seem to break with a well defined separating gap of around 4m. A corresponding gap between anomalies can also be seen continuing 5m further east. This 'pseudo' low resistance anomaly also manifests itself on the topography map suggesting it may be related to an access way in to the castle.

The north west of the site shows a 'U' shaped high resistance feature. It is possible this relates to stone remains. Two further high resistance anomalies are seen to the east which may also be caused by stone remains. To the west of the 'U' shaped anomaly is a curved low resistance area possibly caused by a cut feature.

4.2 Detailed magnetic survey *(Figures 7-11)*

As seen with the resistance data many magnetic responses can also be associated with visible surface expressions. This includes many of the more significant cut features.

Numerous positive magnetic anomalies are identified which are probably caused by cut features. Weak positive discrete responses may relate to infilled pits.

Two areas of magnetic debris have been identified. One located within the bailey and extending out to the north, and one to the east of the bailey. These areas consist of some variable and quite strong magnetic responses. This is indicative of ground disturbance combined with some magnetically enhanced material. The characteristics of the magnetically enhanced responses implies their cause may be ferrous objects and/or burnt material, suggesting areas of possible industrial activity of archaeological origin.

Other magnetically enhanced areas are observed which probably relate to modern interference from animal feeding troughs and metal fences.

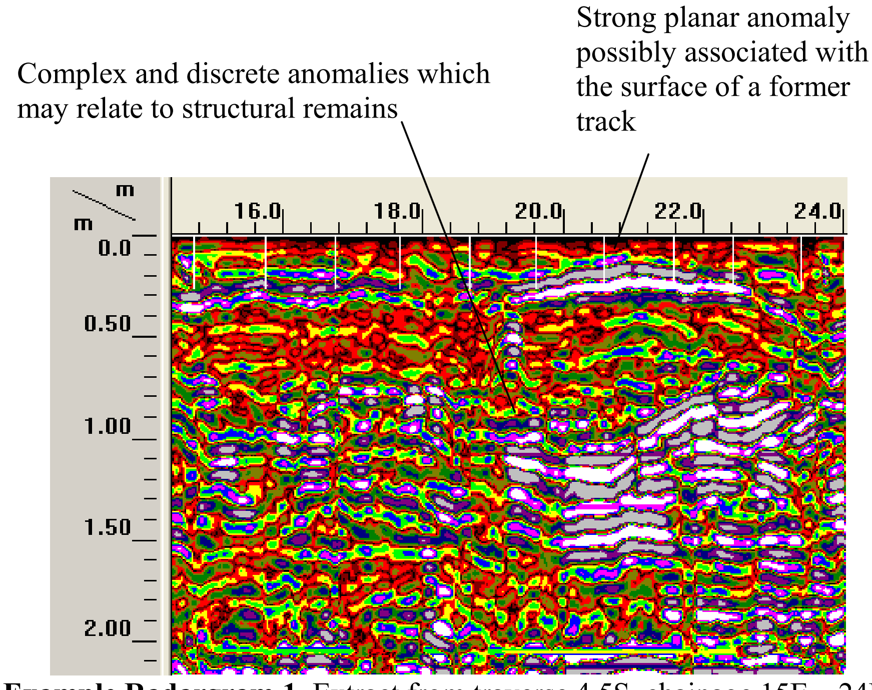
4.3 Ground Penetrating Radar *(Figures 12-17)*

Six areas have been selected for GPR survey based on the resistance survey and magnetic survey (Figure 2). The GPR grid is overlain on to the resistance data and magnetic data in Figures 12 & 13 respectively for comparison.

Area 1

Area 1 has been placed to cover the two limbs of the 'U' shaped high resistance anomaly described in section 4.2.

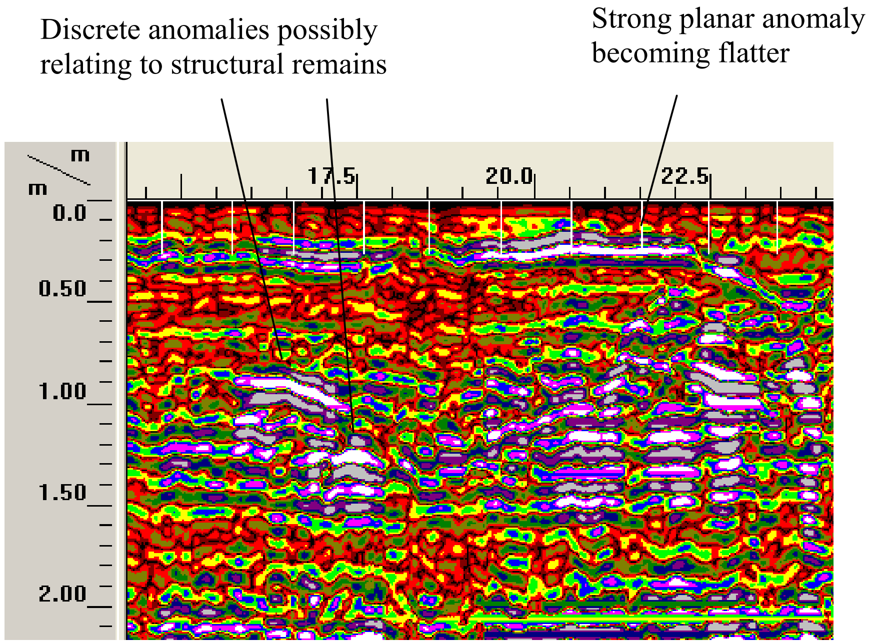
Over the eastern limb of the anomaly a series of strong planar responses has been detected at a depth of around 0.2m (Example Radargram 1). Some of these planar responses are slightly convex in appearance. Below these anomalies are strong complex and strong discrete anomalies at an average depth of 0.75m. The strong planar responses add evidence to support this as the location of a former track way as marked on the 1st edition OS map. They are likely to be caused by a planar (possibly slightly convex) feature around 3m wide. The complex anomalies beneath appear to be caused by a different feature. This may consist of structural stone remains.



Example Radargram 1. Extract from traverse 4.5S, chainage 15E – 24E.

Further south the shallow planar responses lose their convex nature and become flatter (Example Radargram 2). Discrete responses are also identified just to the west at depth of around 1m. It is possible that these are associated with structural remains.

There is little evidence in the GPR data of the western limb of the high resistance anomaly. This suggests that this may be caused by compacted and dry ground rather than solid structural remains.



Example Radargram 2. Extract from traverse 7S, chainage 14E – 24E.

Area 2

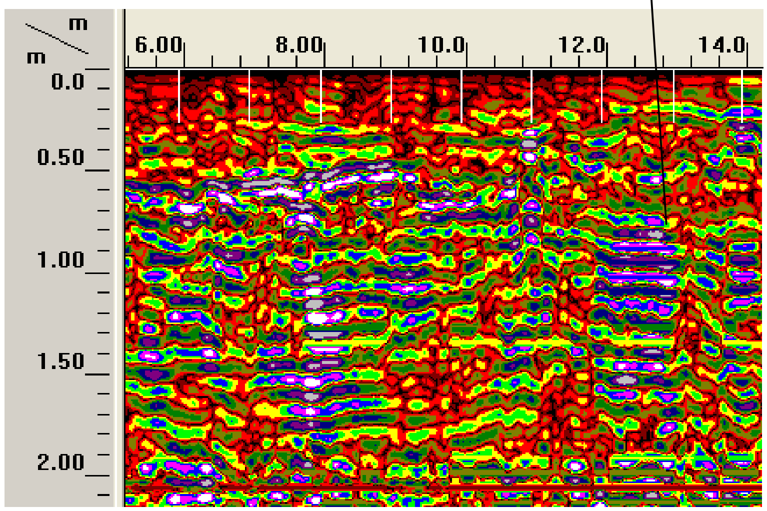
Area 2 is located on a high resistance anomaly east of the 'U' shaped feature. Three contiguous anomalous areas have been identified. Two correlate with high resistance values indicated possible structural remains. The third area is not associated with a resistance anomaly suggesting a more fragmented feature. Many other discrete and complex responses are observed (Example radargram 3) although these seem to occur sporadically, lacking any discernable pattern across traverses. This indicates that isolated stone remnants may be present without any structural continuity.

Area 3

This area is positioned south of Area 1 on the same area of high resistance. Three areas of contiguous discrete responses across adjacent transects are observed (Example Radargram 4). These may relate to structural remains. It is noticeable that taken together the three areas form a rudimentary right angled shape giving the suggestion of a building outline.

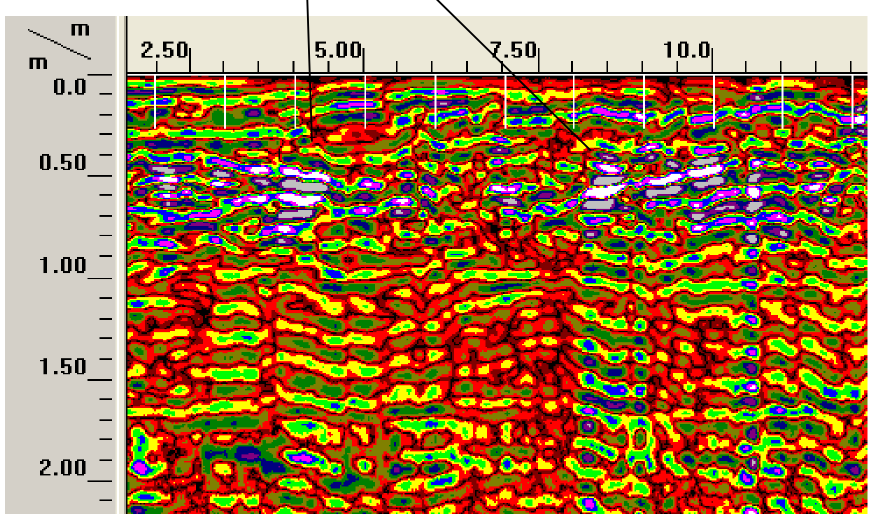
Despite being located on the continuation of the same anomaly as Area 1 there is no evidence of the shallow planar and deeper complex anomalies as seen in the east of that area. This perhaps suggests that the former track is better preserved in Area 1, and that the possible structural remains beneath are localised. The continuation of the resistance anomaly may be explained by either compacted earth or slight soil variations which are not being picked up by the GPR antenna.

Strong discrete anomaly seen in isolation across traverses



Example Radargram 3. Extract from traverse 0.5N, chainage 5E – 14E.

Strong discrete anomalies seen in adjacent traverses



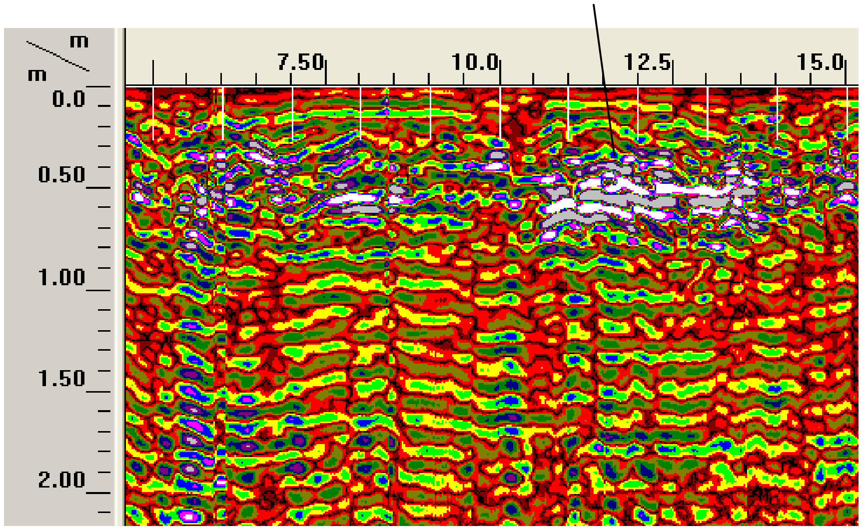
Example Radargram 4. Extract from traverse 4N, chainage 1.5E – 12E.

Area 4

Area 4 has been positioned within the bailey over an area of high resistance and magnetic debris.

As previously seen in Area 2 there are many isolated strong responses perhaps indicating remnants of stone remains. There are also five areas of anomalies which are continuous across several adjacent traverses. The clearest example of this is the area in the east which extends out beyond the limit of the other traverses. This is composed mainly of strong complex responses (Example Radargram 5), which are likely to represent stone structural remains.

Strong complex response – likely structural remains



Example Radargram 5. Extract from traverse 5N, chainage 5E – 15E.

Area 5

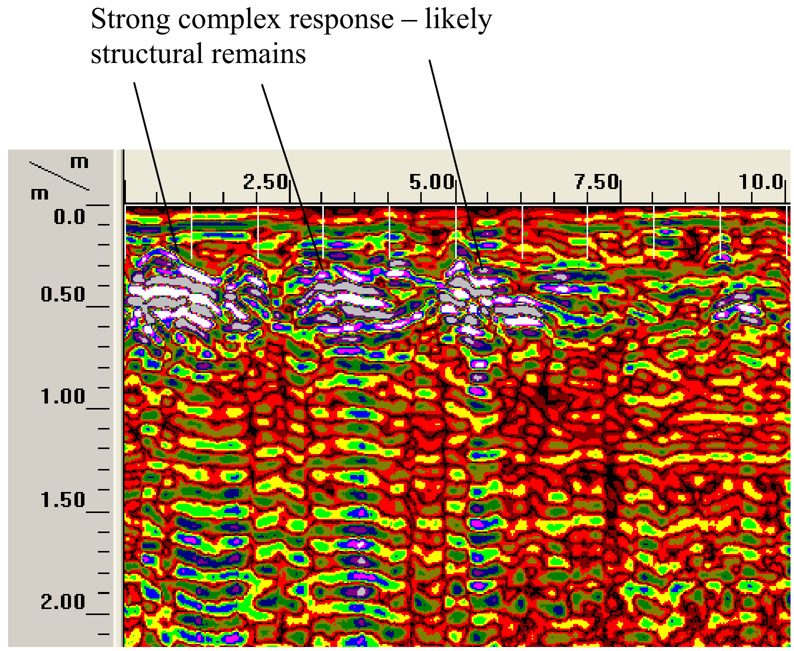
Area 5 is located north east of the keep over the series of detailed anomalies identified in the resistance survey.

The GPR responses appear to follow the outline of the high resistance anomaly. They range in depth from around 0.1m to 0.4m and seem fragmentary in appearance, which suggests that structural remains within this area are not continuous as the resistance data indicates. This may be explained by the higher resolution of GPR compared to resistance techniques.

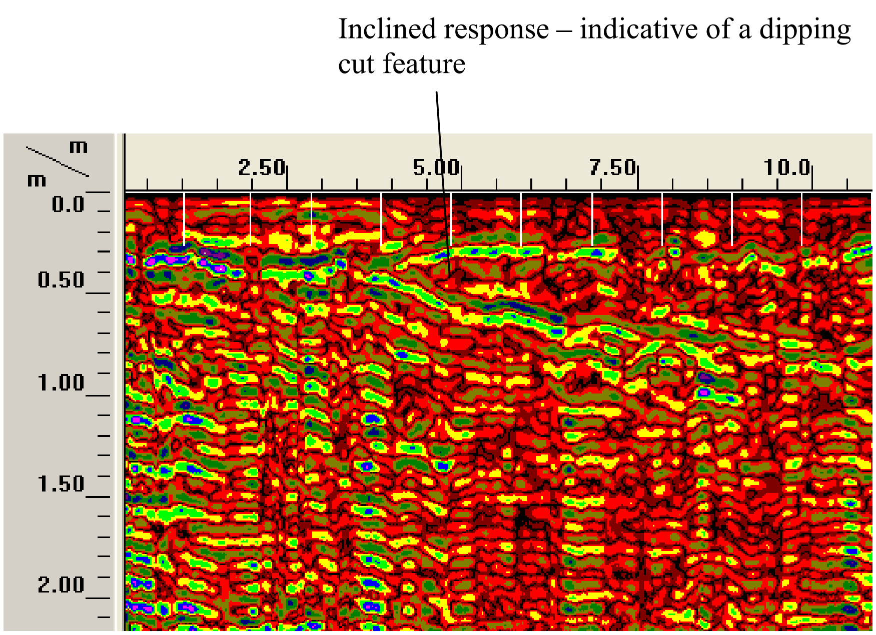
Area 6

Located to the south east of the keep, Area 6 defines anomalous areas which may relate to structural remains and the position of cut features.

Example Radargram 6 shows the nature of the complex responses taken from traverse 6N which are likely to be caused by structural stone remains. A possible cut feature is defined by several inclined planar responses seen in adjacent radargrams which correlate with a low resistance anomaly (Example Radargram 7).



Example Radargram 6. Extract from traverse 6N, chainage 0E – 10E.



Example Radargram 7. Extract from traverse 6N, chainage 0E – 10E.

5 CONCLUSION

The geophysical survey shows a complex set of anomalies surrounding the castle. Many of these are associated with visible surface features of ditches and earthworks. It seems likely there are areas of buried stone remains across the site with numerous cut features as well. Some of these may relate to former buildings, particularly the areas within the bailey which may have been used for an industrial purpose given the levels of magnetic noise recorded. The area north of the keep may also contain structures of an industrial nature.

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APPENDIX A – Basic principles of resistance survey

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 resistance is linked to moisture content, and therefore porosity, hard dense features such as rock will give a relatively high resistance response, while features such as a ditch which retains moisture give a relatively low response.

APPENDIX B – Basic principles of magnetic survey

Detailed magnetic survey can be used to effectively define areas of past human activity by mapping spatial variation and contrast in the magnetic properties of soil, subsoil and bedrock.

Weakly magnetic iron minerals are always present within the soil and areas of enhancement relate to increases in *magnetic susceptibility* and permanently magnetised *thermoremnant* material.

Magnetic susceptibility relates to the induced magnetism of a material when in the presence of a magnetic field. This magnetism can be considered as effectively permanent as it exists within the Earth's magnetic field. Magnetic susceptibility can become enhanced due to burning and complex biological or fermentation processes.

Thermoremnance is a permanent magnetism acquired by iron minerals that, after heating to a specific temperature known as the Curie Point, are effectively demagnetised followed by re-magnetisation by the Earth's magnetic field on cooling. Thermoremnant archaeological features can include hearths and kilns and material such as brick and tile may be magnetised through the same process.

Silting and deliberate infilling of ditches and pits with magnetically enhanced soil creates a relative contrast against the much lower levels of magnetism within the subsoil into which the feature is cut. Systematic mapping of magnetic anomalies will produce linear and discrete areas of enhancement allowing assessment and characterisation of subsurface features. Material such as subsoil and non-magnetic bedrock used to create former earthworks and walls may be mapped as areas of lower enhancement compared to surrounding soils.

Magnetic survey is carried out using a fluxgate gradiometer which is a passive instrument consisting of two sensors mounted vertically either 0.5 or 1m apart. The instrument is carried about 30cm above the ground surface and the top sensor measures the Earth's magnetic field whilst the lower sensor measures the same field but is also more affected by any localised buried field. The difference between the two sensors will relate to the strength of a magnetic field created by a buried feature, if no field is present the difference will be close to zero as the magnetic field measured by both sensors will be the same.

Factors affecting the magnetic survey may include soil type, local geology, previous human activity, disturbance from modern services etc.

APPENDIX C – Basic principles of ground penetrating 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. 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.

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.