Report on the Geophysical Survey at Bamburgh, Northumberland, July 2023

Compiled by K. Strutt and D. Barker

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Summary

This report presents the results of the geophysical survey undertaken at Bamburgh in Northumberland, between 11th and 19th July 2023. It specifies the survey methodology together with an interpretation discussion of the survey results. This report is further contextualised in the BRP's Interim Report on Work on the Outworks Beyond St Oswald's Gate 2023, available here.

The survey was conducted in the Cricket Ground to the west of Bamburgh Castle, and a GPR survey on the Inner Ward of the Castle was also undertaken. The results indicate the possible presence of a large ditch, some 45m across, immediately to the west of the outcrop, in addition to trackways, walls and other features in the survey area. The Inner Ward survey indicates the presence of structures to the north of the extant chapel, in the centre and east of the main part of the Ward.

1. Introduction

As part of the Bamburgh Research Project 2023 season, a geophysical survey was conducted by a team from the Department of Archaeology at the University of Southampton, between 11th and 19th July. The main focus of the survey was the Cricket Ground to the west of the castle, although a GPR survey was also carried in the Inner Ward. The principal surveyors were Dominic Barker and Kristian Strutt, who were ably assisted by volunteers and staff from the BRP team.

The reason for focusing on the Cricket Ground to the west of the castle was to locate the line of a potential ditch associated with the burg, in addition to any other archaeological features in the area. Results of the geophysical survey do seem to have located evidence for the ditch, and other anomalies.

The weather conditions during the survey, with alternating dry sunny weather followed by torrential rain did have an effect on the earth resistance results, and a limited impact on the GPR survey results. However, various features are clearly visible in the data.

1.1 Site Location and Background (Synthesised from the Bamburgh Village DBA and Young 2023)

Bamburgh Village lies adjacent to the coast in north-east Northumberland [NU180349] (Fig. 1). The village is centred on a triangular village green and extends for 740m north to south and 970m east to west with Bamburgh Castle marking the east side of the village. The village, in the parish of Bamburgh, lies within the area administered by Berwick upon Tweed Borough Council (Fig. 2). The earliest human activity in the Bamburgh area dates from the Mesolithic period (8,000 BC to 4,000 BC) that followed the end of the last ice age. The population during this early period is usually perceived as small numbers of hunter-gatherers occupying temporary camps, often to be found by the sea and along river or stream courses. Finds of Neolithic date within the area are not common and are represented by an axe head found near to Budle during the cutting of a trench and a further fragment of a shale axe identified immediately south of Glororum. It is far from certain that a settlement would have existed in the area of Bamburgh Village at this early time, but the rich farmland of the coastal plain of Northumberland would have been extensively exploited from that time. Evidence for early farming activity may well underlie the area of the present village. Finds of Bronze Age date (2,000 BC to 800 BC) within the area comprise the discovery of an arrowhead at Budle and part of a stone mould for a rapier discovered just north of Hoppen Hall. At Bamburgh, the presence of a round barrow and a second possible barrow both to the south of the Village attests to a Bronze Age presence in the village area of some status.

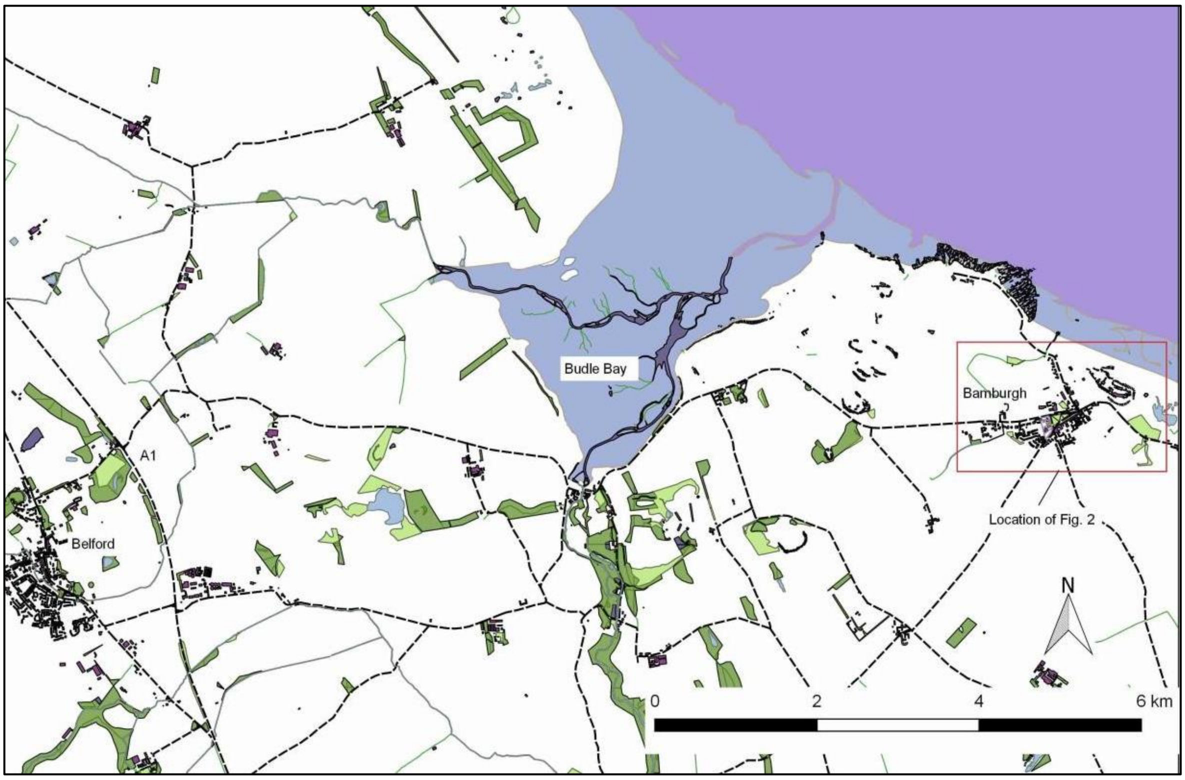

Figure 1. Location of Bamburgh and the surrounding area (Young 2023)

In the Iron Age, the castle site represented the focus of settlement activity at Bamburgh from at least that time if not earlier (Hope-Taylor 1960, 11). No further finds of Iron Age date are known from the village area.

Pottery of Romano-British date was recovered during the excavations by Dr Hope-Taylor within Bamburgh Castle, demonstrating occupation of the site in the Romano-British period. Although Bamburgh does not appear in the documentary record from this time it seems likely that native rulers or client chiefs occupied the site for at least part of this period. Evidence to predict the wider settlement landscape at Bamburgh for this period is not available at this time.

It is clear from documentary sources that an early medieval site of international importance lies beneath the castle. However, it appears almost certain that an early medieval site also lies in the area of the modern village. While references to Bamburgh in pre-conquest documents use the Latin term *urbs* (fortress) to denote the residence of the kings, Bede notes the existence of a separate but closely linked settlement nearby. St. Aidan is stated as having died within a church in a royal vill (*villa regis*) near to the *urbs* of Bamburgh. Royal vills were the centres of extensive estates, to which the local populace owed service and taxes (Campbell 1979, 44). The present parish church at Bamburgh (Fig. 3, item 2) is unique as the only known medieval dedication to St. Aidan. This, together with its position, strongly suggests that the church in which St. Aidan died was the predecessor of the present parish church, and that a royal vill or estate centre lies under the present village (Cambridge 1995, 136-8).

The potential scale of the Anglo-Saxon presence at Bamburgh as a whole is testified to by Bede's use of the terms *urbs* and *civitas* to describe the royal centres at Bamburgh. The combination of the two terms is used only rarely to describe sites of the importance of London and Canterbury (M. Welsh, 1992, 24-5).

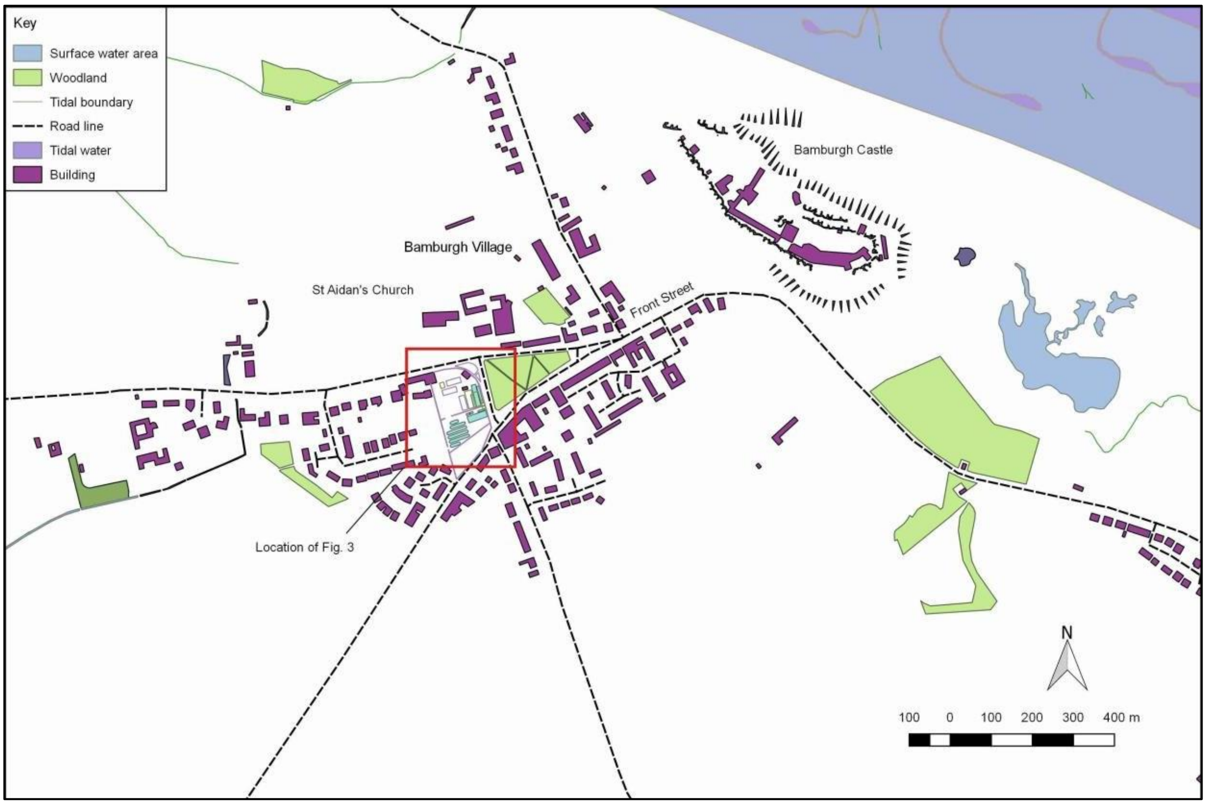

Figure 2. Map of Bamburgh village and Castle (Young 2023)

A number of medieval features and sites are known to have been present in and around the site of the present village. The church of St Aidan located at the west side of the village contains structural work of the 12th, 13th and 14th centuries. Masonry believed to be a part of The Master of Bamburgh's Tower, first noted in 1415, is preserved within the east wall of the churchyard. A cell of Augustinian canons was founded at Bamburgh in AD 1121. Masonry remains now built into the farm buildings adjacent to Bamburgh Hall are noted as possibly representing part of the monastic buildings on the SMR. If this is the case then it clearly demonstrates that, as postulated for the early medieval church site, the boundary of St Aidan's in the medieval period was substantially larger than the present churchyard.

The post-medieval history of the village is dominated by its ownership by a series of great estates beginning with the purchase of the Castle and village by Nathaniel Crewe, Bishop of Durham, in the early 18th century. Lord Crewe's death prompted the foundation of the Bamburgh Trust, which functioned as an experiment in social welfare, providing opportunities for education for the local community and administering payments to the poor. A windmill constructed within the West Ward of the castle, in existence by the early 19th century was used to grind grain for the poor of the district. By the later 19th century the roll of the trust had been to a large extent taken over by national legislation. It was purchased by the first Lord Armstrong in 1888.

1.2 Geology at Bamburgh

Bamburgh Castle is located on an outcrop of the Great Whin Sill quartz-dolerite (Fig. 3). The surrounding area, including the Cricket Ground is situated on an Alston Formation of limestone, sandstone and mudstone bedrock, covered with blown sand (British Geological Survey Viewer).

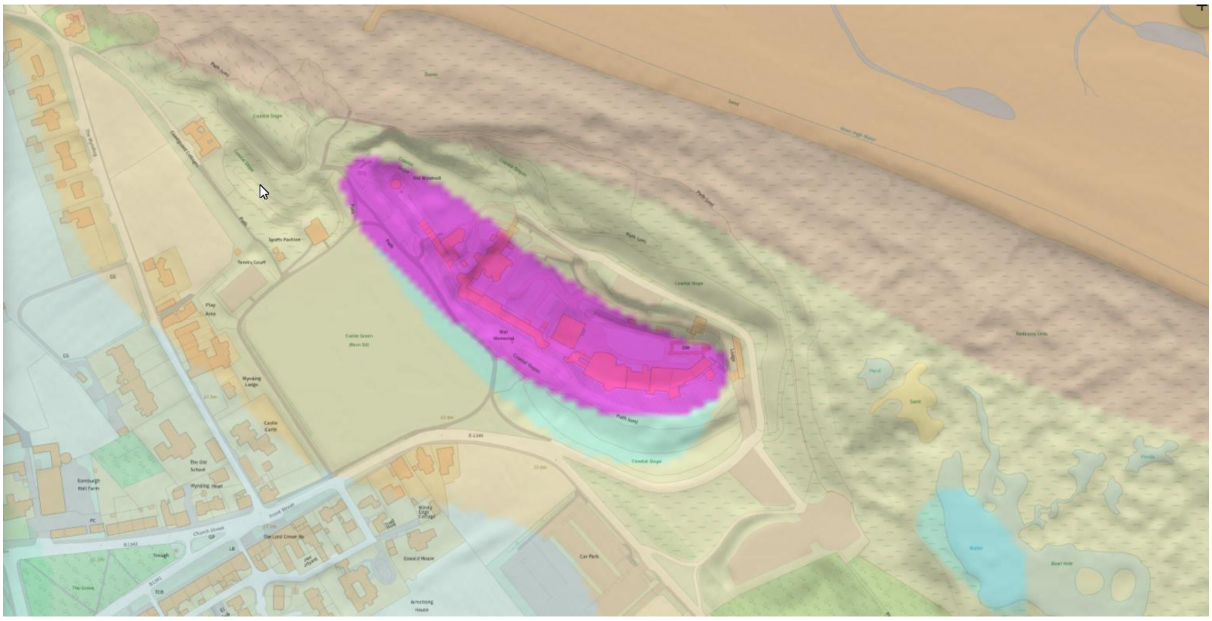

Figure 3. Geological map of the area of Bamburgh Cricket Ground (source: British Geological Survey Viewer)

1.3 Aims of the Survey

The objective of the 2023 survey was primarily to locate and map the extent of a potential ditch associated with Bamburgh Castle and its western defences. In addition, any evidence for archaeological deposits across the Cricket Ground (Fig. 4) would prove useful in assessing the nature of the site. A secondary objective was to map any possible deposits in the Inner Ward of the Castle.

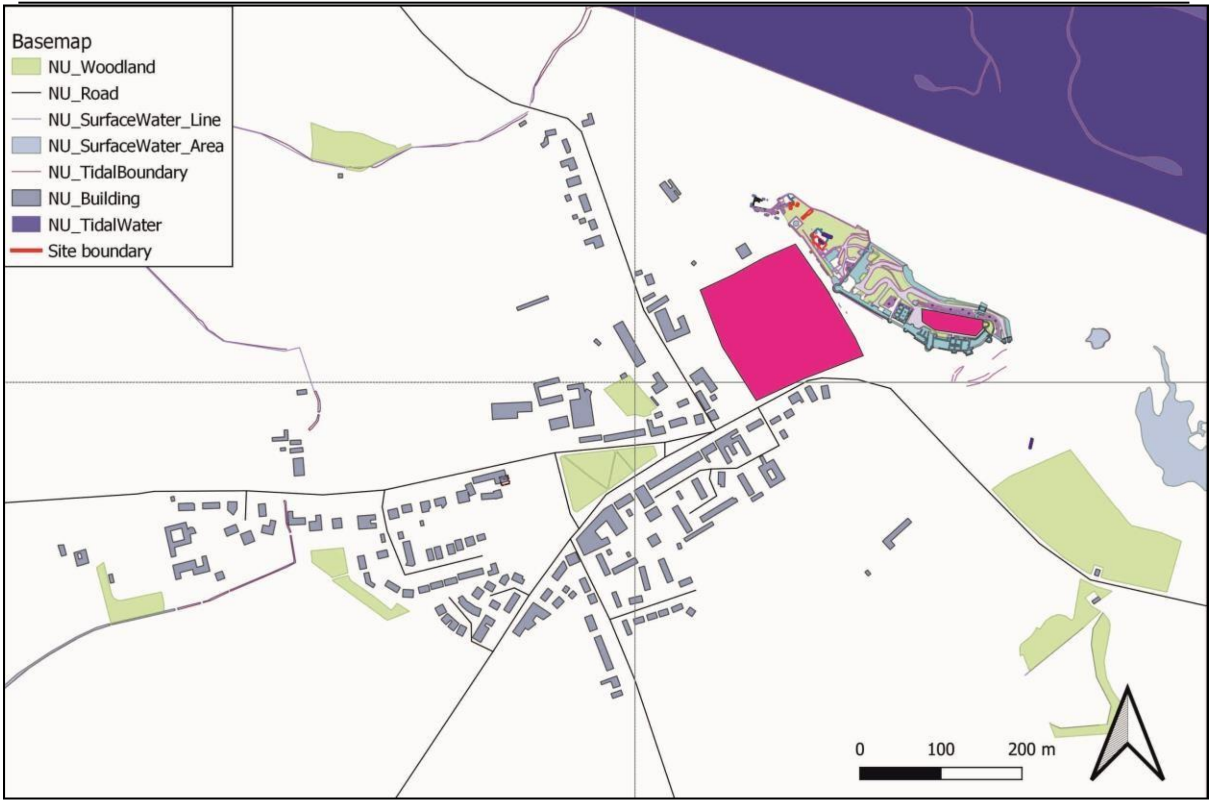

Figure 4. Survey areas from the 2023 season, showing the Cricket Ground and Inner Ward in purple

2. Survey Methodology

For the 2023 survey magnetometry, earth resistance and GPR (Ground Penetrating Radar) were applied. Results of these techniques are extremely dependent on the geology of the particular area, and whether the archaeological remains are derived from the same materials. Magnetometry is a passive technique which uses sensors to measure variations in the strength of the Earth's magnetic field in nanotesla (nT). Earth resistance is based on the passing of an electrical current through the soil and measuring the resistance to the current. GPR is based on the propagation of a radar wave into the ground and measuring the returned wave reflecting off buried objects and deposits.

2.1 Techniques of Geophysical Survey: Magnetometry, Earth Resistance and GPR

Magnetic prospection of soils is based on the measurement of differences in magnitudes of the earth's magnetic field at points over a specific area (Fig. 6). The iron content of a soil provides the basis for its magnetic properties, with the presence of minerals such as magnetite, maghaemite and haematite iron oxides all affecting the magnetic properties of soils. Although variations in the earth's magnetic field which are associated with archaeological features are weak, especially considering the overall strength of the magnetic field of around 48 Teslas (48,000 nanoTesla, or nT). It follows that these instruments are very sensitive indeed.

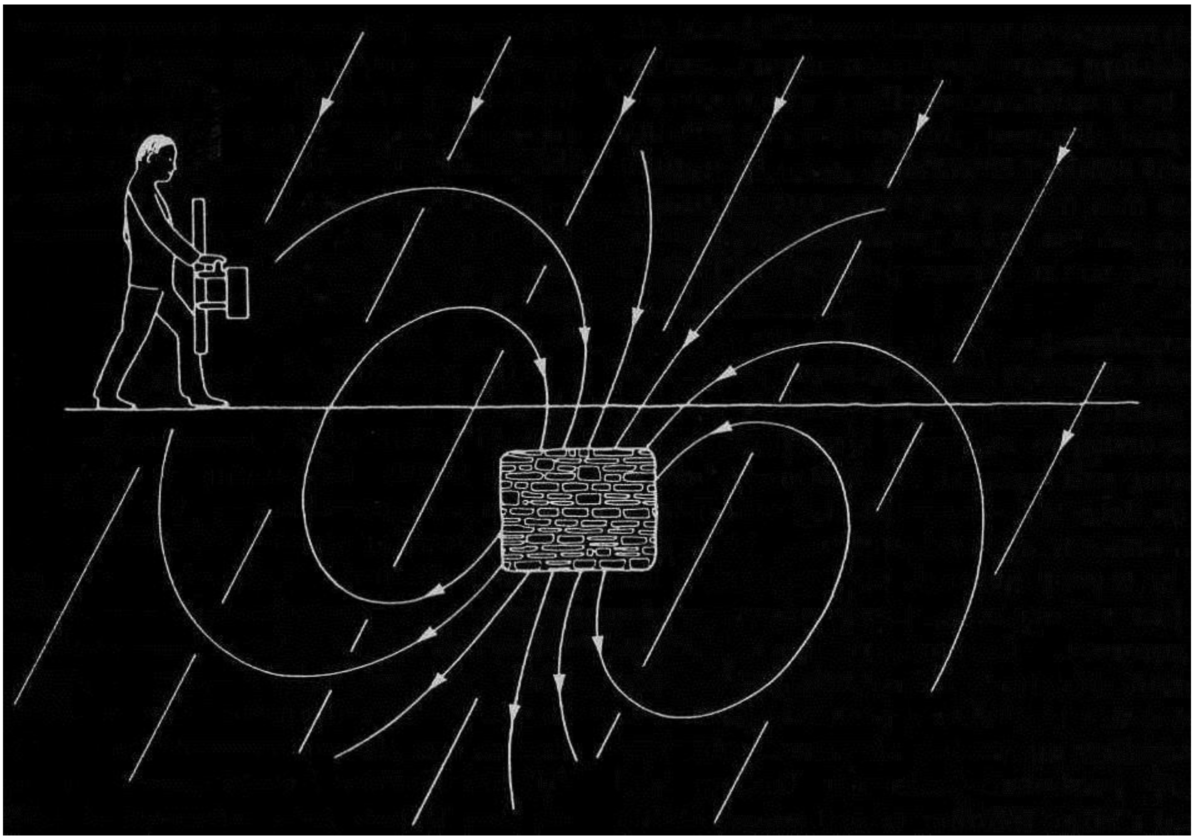

Figure 5. Schematic diagram indicating the use of a magnetometer over archaeological remains, and the local magnetic field of the buried objects in relation to the earth's magnetic field (from Clark 1996)

Three basic types of magnetometer are available to the archaeologist; proton magnetometers, fluxgate gradiometers, and alkali vapour magnetometers (also known as caesium magnetometers, or optically pumped magnetometers). Fluxgate instruments are based around a highly permeable nickel iron alloy core, which is magnetised by the earth's magnetic field, together with an alternating field applied via a primary winding. Due to the fluxgate's directional method of functioning, a single fluxgate cannot be utilised on its own, as it cannot be held at a constant angle to the earth's magnetic field. Gradiometers therefore have two fluxgates positioned vertically to one another on a rigid staff. This reduces the effects of instrument orientation on readings. Fluxgate gradiometers are sensitive to 0.5nT or below depending on the instrument. However, they can rarely detect features which are located deeper than 1m below the surface of the ground.

Archaeological features such as brick walls, hearths, kilns and disturbed building material will be represented in the results, as well as more ephemeral changes in soil, allowing location of foundation trenches, pits and ditches. Results are however extremely dependent on the geology of the particular area, and whether the archaeological remains are derived from the same materials. Around 1.5 hectares can be surveyed each day.

Earth resistance survey is based on the ability of sub-surface materials to conduct an electrical current passed through them. All materials will allow the passing of an electrical current through them to a greater or lesser extent. There are extreme cases of conductive and non-conductive material (Scollar *et al* 1990, 307), but differences in the structural and chemical make-up of soils mean that there are varying degrees of resistance to an electrical current (Clark 1996, 27). The technique is based on the passing of an electrical current from probes into the earth to measure variations in resistance over a survey area. Resistance is measured in ohms (), whereas resistivity, the resistance in a given volume of earth, is measured in ohm-metres (m). Four probes are generally utilised for electrical profiling (Gaffney et al. 1991, 2), two current and two potential probes. Survey can be undertaken using a number of different probe arrays; twin probe, Wenner, Double-Dipole, Schlumberger and Square arrays.

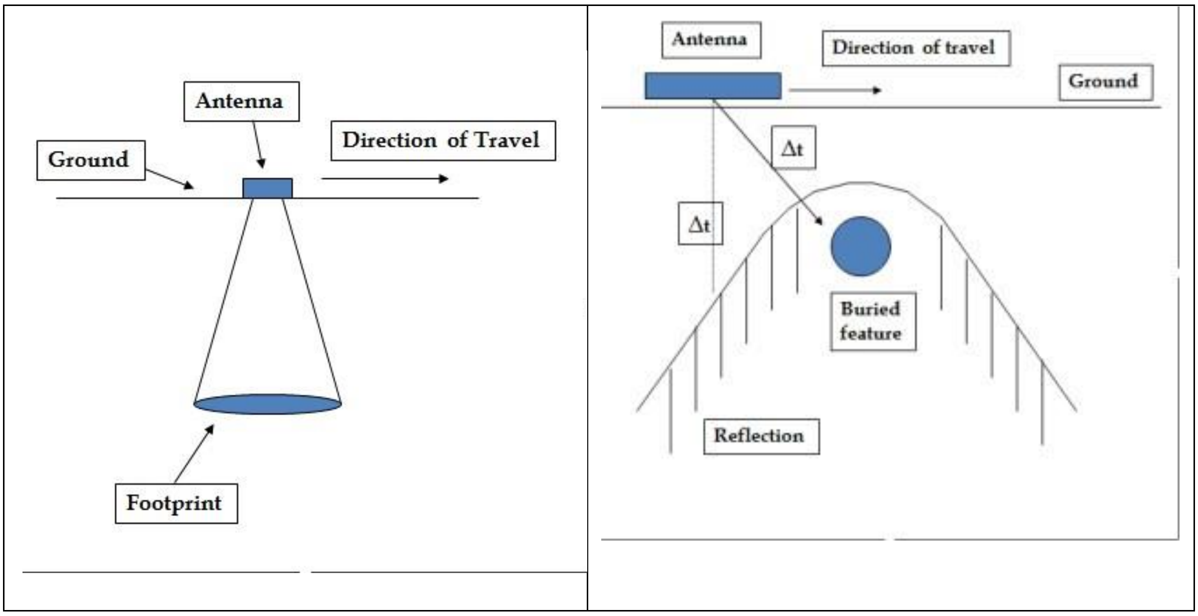

Figure 6. Diagram showing the footprint of a GPR radio signal and the response to a spherical object with the resulting hyperbola to demonstrate the propagation of the signal over distance and time (after Conyers and Goodman 1997)

Ground Penetrating Radar (GPR) uses an electromagnetic radar wave propagated through the soil to search for changes in soil composition and structures (Conyers and Goodman 1997, 23ff), measuring the time in nanoseconds (ns) taken for the radar wave to be sent and the reflected wave to return (Fig. 7). The variations in the Relative Dielectric Permittivity (RDP) in different deposits produces reflections in the profile data of the survey. Lower frequency survey antennae (50Mhz or 100Mhz) are generally used for geological survey, whereas higher frequency antennae (250Mhz, 500Mhz or 800Mhz) are utilised for archaeological surveys. The technique has been applied successfully on a range of archaeological sites, in particular over substantial urban archaeological remains (Leckebusch 2001, 52ff).

2.2 Survey Strategy

For the survey at Bamburgh, a grid system was established using a Leica Viva Real Time Kinetic (RTK) GPS (Fig. 7) utilising the Ordnance Survey coordinate system OSGB36. Wooden survey pegs and spray markers were set out at 30m by 30m intervals, and the grids for all areas were georeferenced with the OS grid system through the Smartnet function of the GPS.

Figure 7. Volunteers from the Bamburgh Research Project using the GPS to establish a survey grid in the Cricket Ground (photo: K. Strutt)

Figure 8. Dominic Barker using the Bartington Grad 601-2 instrument on the Cricket Ground (photo: K. Strutt)

The magnetometer survey was conducted using a Bartington Instruments Grad 601 dual sensor fluxgate gradiometer (Fig. 8). Measurements were taken at 0.25m intervals on 0.5m traverses, with data collected in zig-zag fashion. The survey data were processed using Geoplot 4.0 software. The processing of data was necessary to remove any effects produced by broad variations in geology, or small-scale localised changes in magnetism of material close to the present ground surface. Magnetometer data were despiked to remove any extreme magnetic values caused by metallic objects. A zero mean traverse function was then applied to remove any drift caused by changes in the magnetic field. A low pass filter was then applied to remove any high frequency readings, and results were then interpolated to 0.5m resolution across the traverses.

Earth resistivity was carried out using a Geoscan Research RM15 resistance meter, with measurements taken at 1.0m intervals along traverses spaced 1.0m apart (Fig. 9).

The Ground Penetrating Radar (GPR) survey was carried out using an Impulse Raptor 8-channel system, set up to collect data and establish location using a the RTK GPS (Fig. 10). The spacing between channels was 0.125m with traces initiated at every 0.05m along each traverse. Data were processed using GPR Slice software. The different survey profiles were presented in their relative positions, and all profiles were then processed to remove background noise. A bandpass filter was applied to each profile to remove all high and low frequency reading, and a Hilbert Transform was also applied to increase the strength of responses when the data were sliced.

Figure 9. Earth resistance survey being carried out by BRP volunteers (photo: K. Strutt)

Figure 10. GPR survey under way across the Cricket Ground using an Impulse Raptor 8-channel system and GPS (photo: K. Strutt)

The data from each survey were exported as a series of bitmaps, and were imported into and georeferenced in a GIS, relating directly to other salient spatial information such as AutoCAD maps of the site and relevant air photographic imagery. An interpretation layer of archaeological and modern features was digitized deriving the nature of different anomalies in the survey data from their form, extent, size and other appropriate information. As no direct chronological information can be derived from the geophysical survey data, much of this had to be inferred from the morphology of anomalies, and the relationships between different features.

3. Survey Results

The magnetometer, earth resistance and GPR surveys in July 2023 covered 2.1, 1.0 and 1.1 hectares respectively in the Cricket Field. The survey was designed to map the nature and extent of buried features in the area related to a potential ditch and other features.

3.1 The Magnetometer Survey

The magnetometry covered the largest area in total (Figs. 11 and 12), almost the entire extent of the Cricket Ground, some 2.3 hectares in size. The results indicate a number of modern utility pipes **[m1]**-**[m5]** in the north of the area. These are matched by similar anomalies **[m6]** and **[m7]** in the south-west corner of the Cricket Ground. A series of strong magnetic anomalies seem to indicate the area of the castle ditch **[m8]**, measuring up to 45m across. Dipolar anomalies of considerable size were located within the area **[m9]** and **[m10]**, ranging from 10m to 20m in size. There is a rectilinear pattern to these, and perhaps they suggest cuttings made into the bedrock along the line of the ditch. Two fainter positive linear anomalies **[m11]** and **[m12]** in the south of the area suggest the lines of two trackways, with a further linear anomaly indicating the line of a wall **[m13]**, matched by a number of possible wall features in the south **[m14]** and west **[m15]** and **[m16]** of the area.

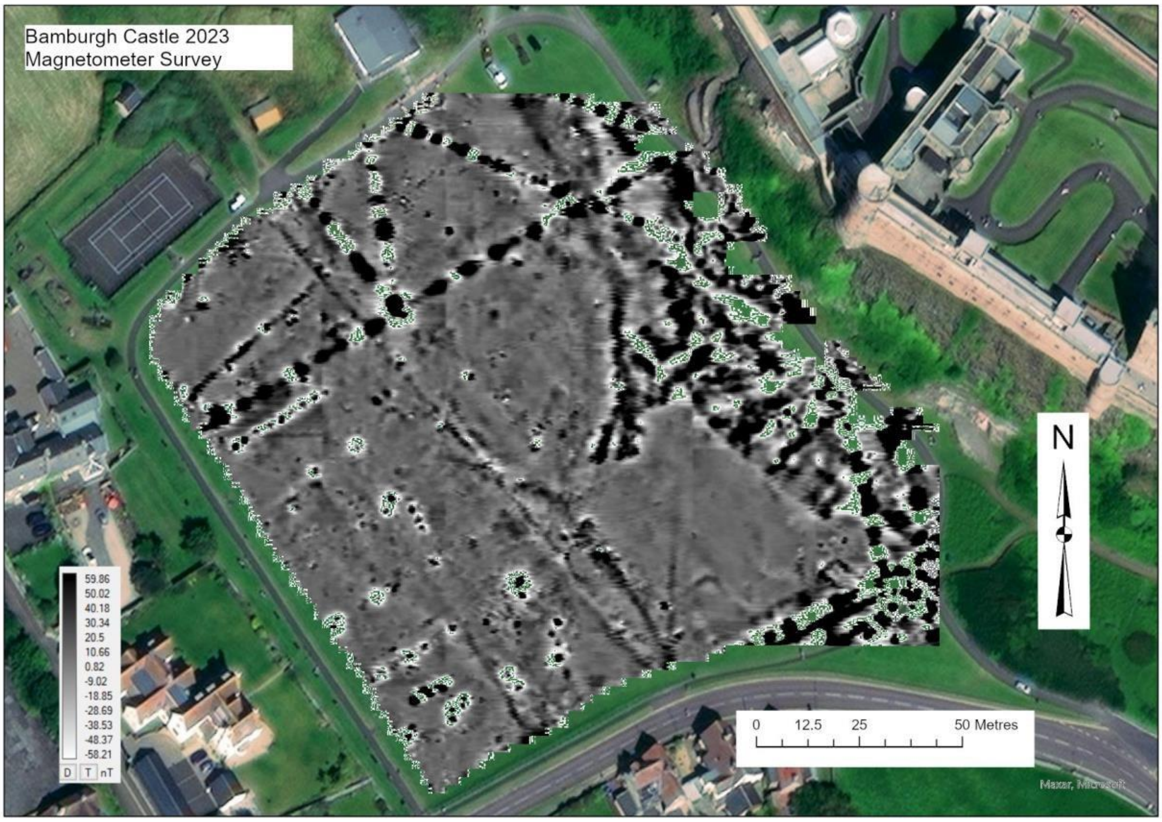

Figure 11. Results of the magnetometer survey

Figure 12. Interpretation plot for the magnetometer survey

3.2 Earth Resistance Survey

A smaller area of earth resistance survey was conducted during the season (Figs. 13 and 14), and with a 0.5m twin probe array being utilised, provides a relatively shallow set of data for the area. The results are dominated by the low resistance responses of the modern cricket square **[r1]** caused by the difference in the shallow deposits across the cricket square, and presumably from the maintenance and treatment of the square over many years. Evidence for the castle ditch, and high resistance deposits to the west **[r2]** and **[r3]** are evident, presumably the latter caused by sandy material. The two trackways are evident **[r4]** and **[r5]** as two low resistance linear anomalies. The wall associated with one of the trackways **[r6]** is also visible as a high resistance linear feature.

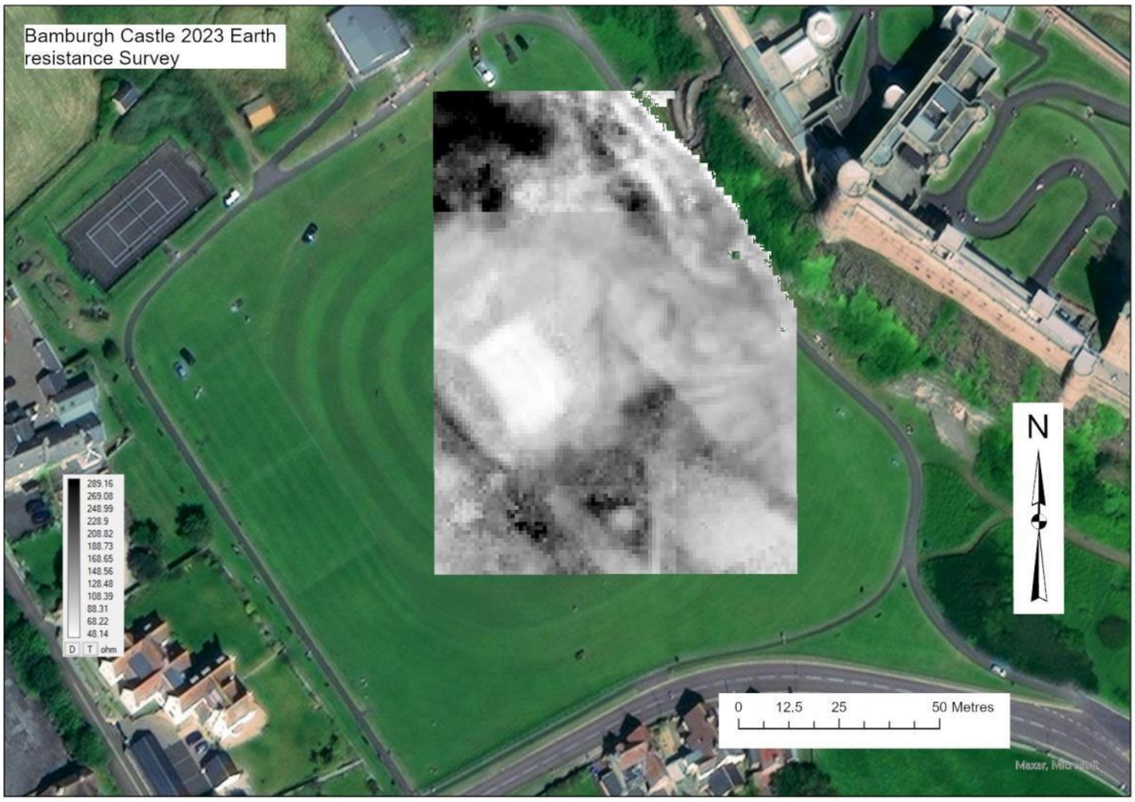

Figure 13. Results of the earth resistance survey

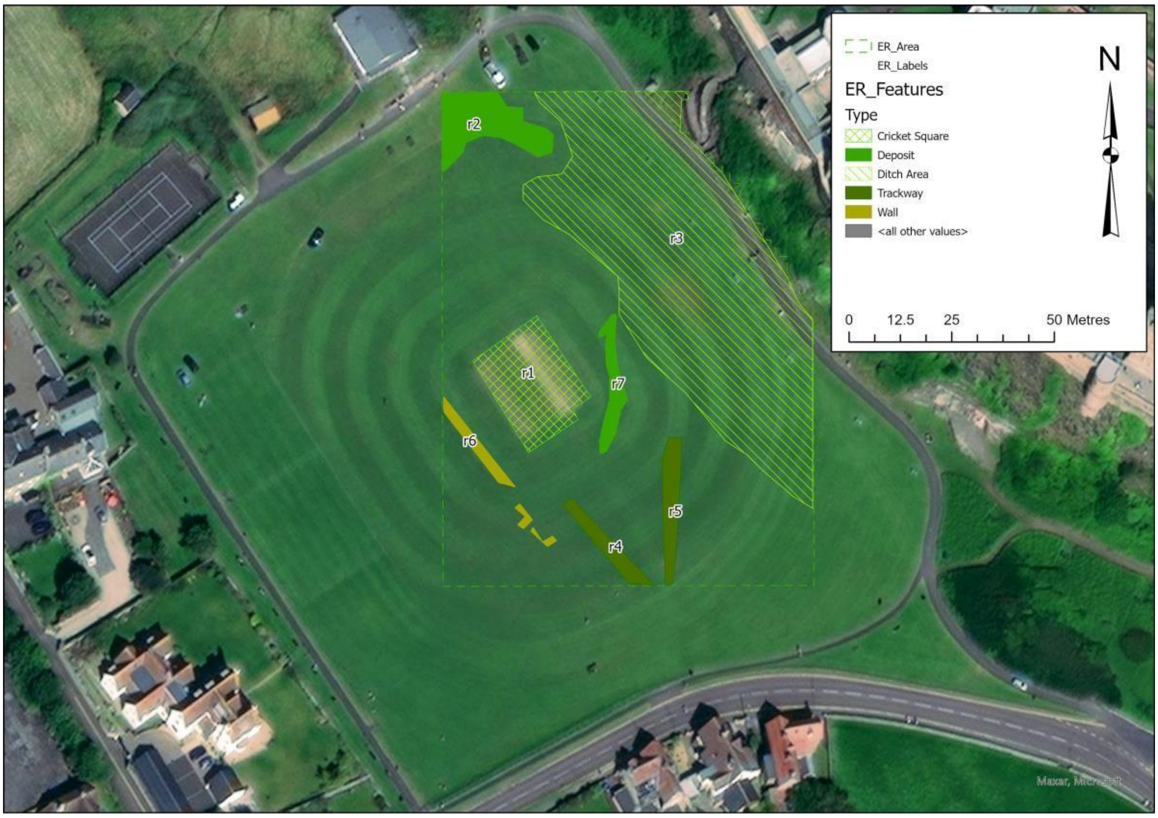

Figure 14. Interpretation plot for the earth resistance survey

3.3 Ground Penetrating Radar Survey

The results of the GPR survey (Figs. 15 and 16) indicate anomalies that match the utilities mapped in the magnetometry **[g1]** – **[g3]**. In addition, the area of the castle ditch is clearly visible as a low amplitude area **[g4]** measuring over 45m in width. What is interesting is that the cut of the ditch is not clearly represented in the data, but there is a contrast in the subsoil between the ditch area and the rest of the survey area that defines the feature. The ditch is also defined slightly by the line of a possible trackway **[g5]** and **[g6]** that in the data runs up to the edge of the ditch, but is then not visible further to the north. The trackway visible in the earth resistance can also be seen **[g7]** running north-west, together with two further linear anomalies **[g8]** and **[g9]** suggesting possible surfacing or trackways.

Figure 15. Results of the Ground Penetrating Radar (GPR) Survey

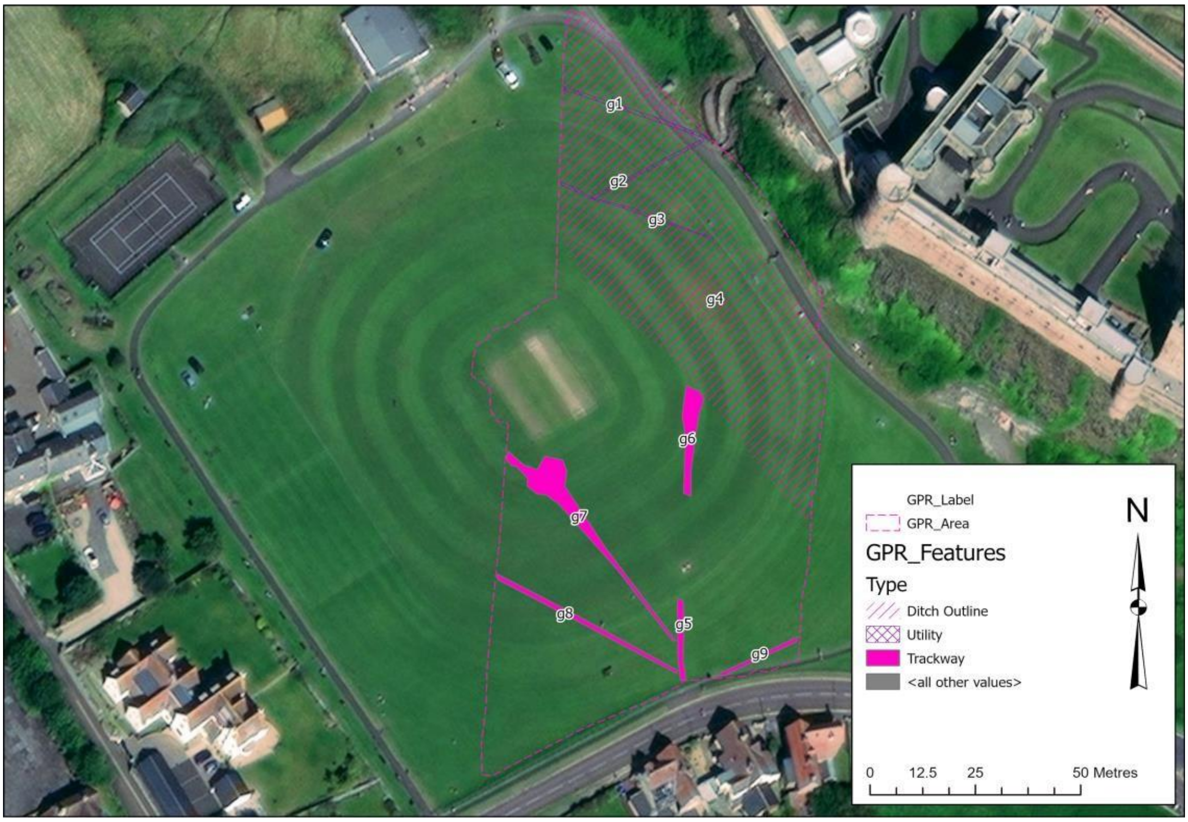

Figure 16. Interpretation plot for the Ground Penetrating Radar (GPR) Survey

3.4 The GPR Survey of the Inner Ward

A small GPR survey was also conducted in the area of the Inner Ward and chapel as part of the 2023 season. The Impulse Raptor was used with the same settings as for the Cricket Ground. The results (Figs. 11 and 12) indicate the presence of linear anomalies within the chapel running at a tangent to the extant walls, and possibly marking utilities. Possible walls of structures are also visible in the main part of the Inner Ward at 0.5m depth (Fig. 11).

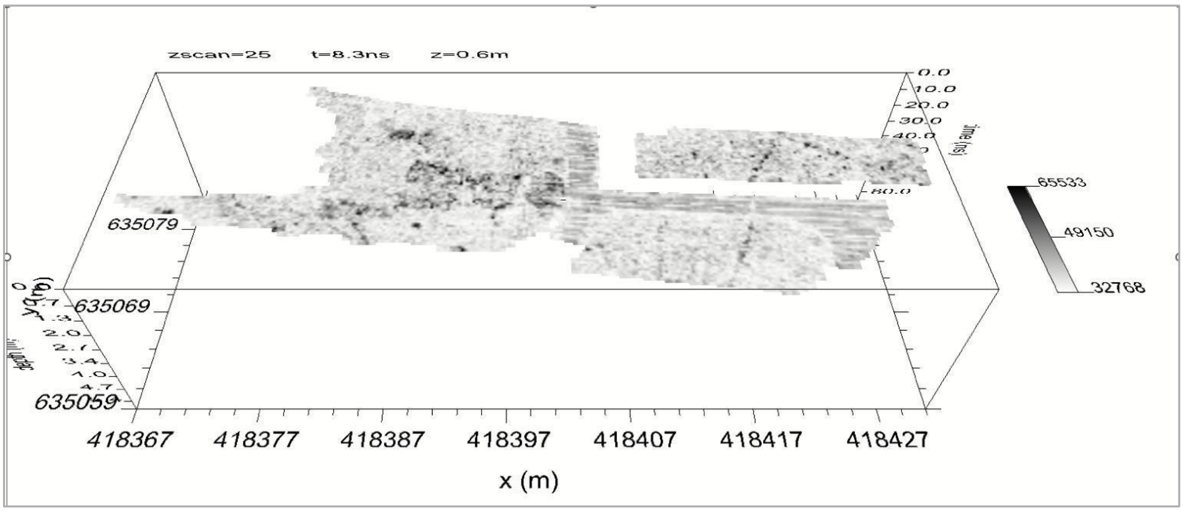

Figure 17 Results of the GPR survey in the Inner Ward at c. 0.5m depth

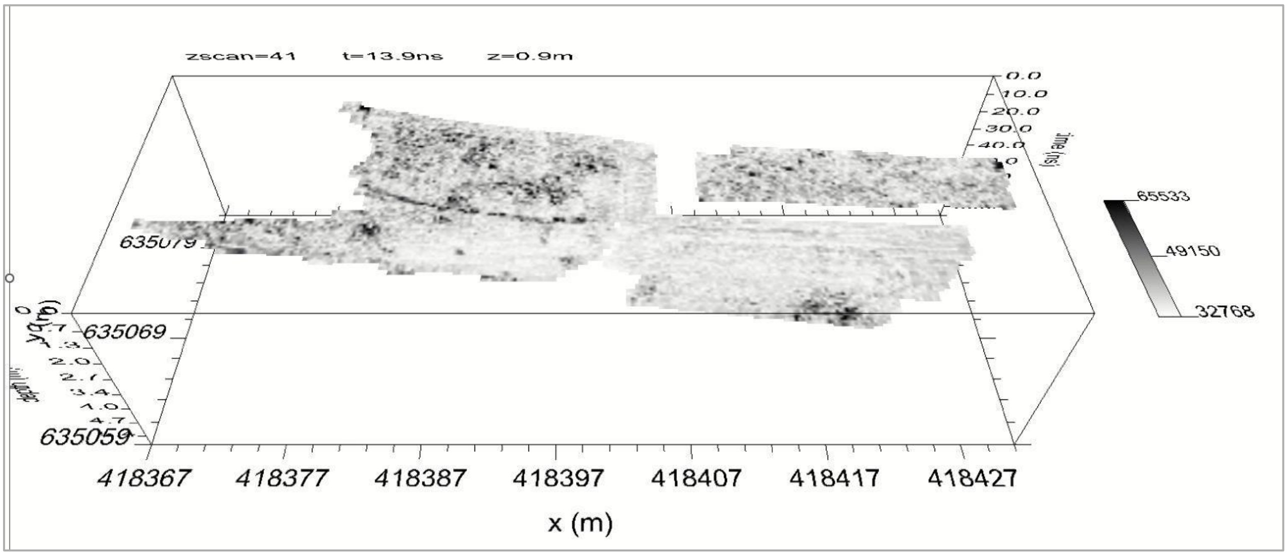

Figure 18. Results of the GPR survey in the Inner Ward at c. 1.0m depth

At 1.0m depth (Fig. 12) a possible utility pipe or wall appears to run across the length of the Inner Ward, and a series of possible structural remains are visible closer to the eastern wall of the Ward. Further analysis of the data will be necessary to draw any firm conclusions.

4. Discussion

In spite of the variable weather conditions during the season, and the effect on the earth resistance and GPR data (see the varying grids in the earth resistance and the more subtle variations in the GPR data), the survey results seem to have successfully located the ditch running along the western side of the rock outcrop at Bamburgh. This is particularly apparent in the transparency overlays produced from maps of the different techniques (Figs. 19 and 20) and the overlaid interpretation plots (Fig. 21).

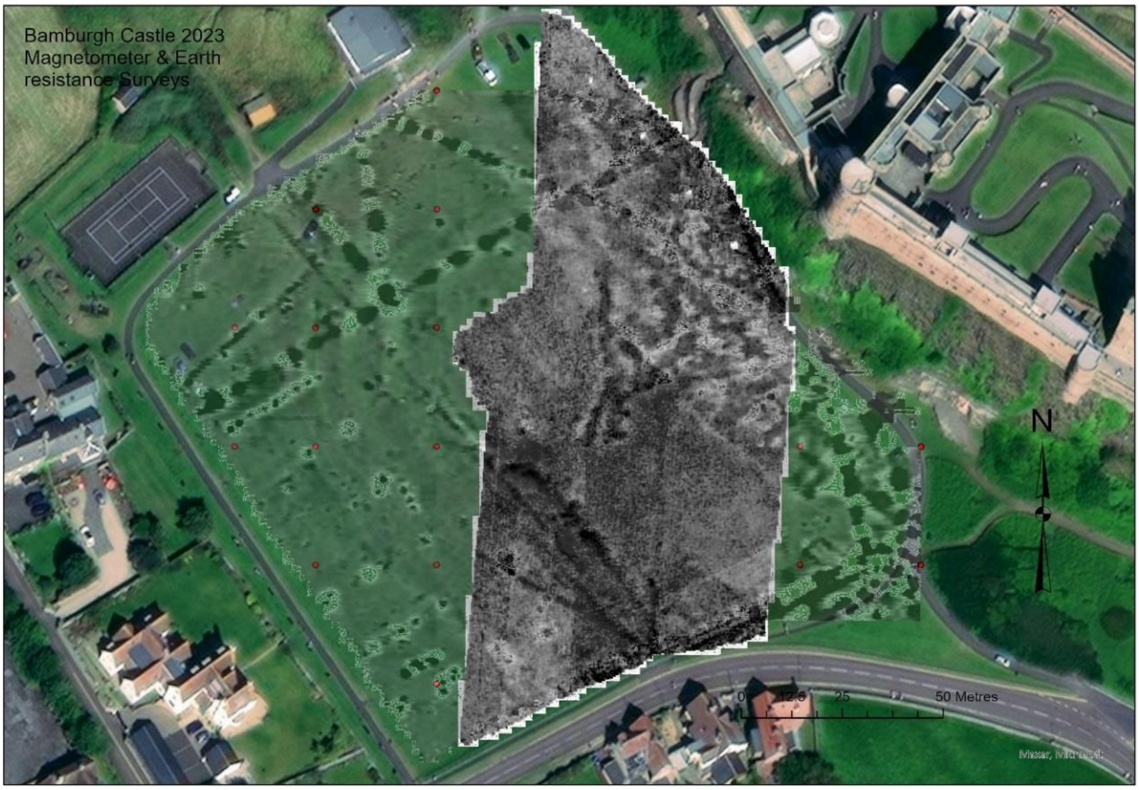

Figure 19. Overlaid transparencies of the magnetometer and GPR results

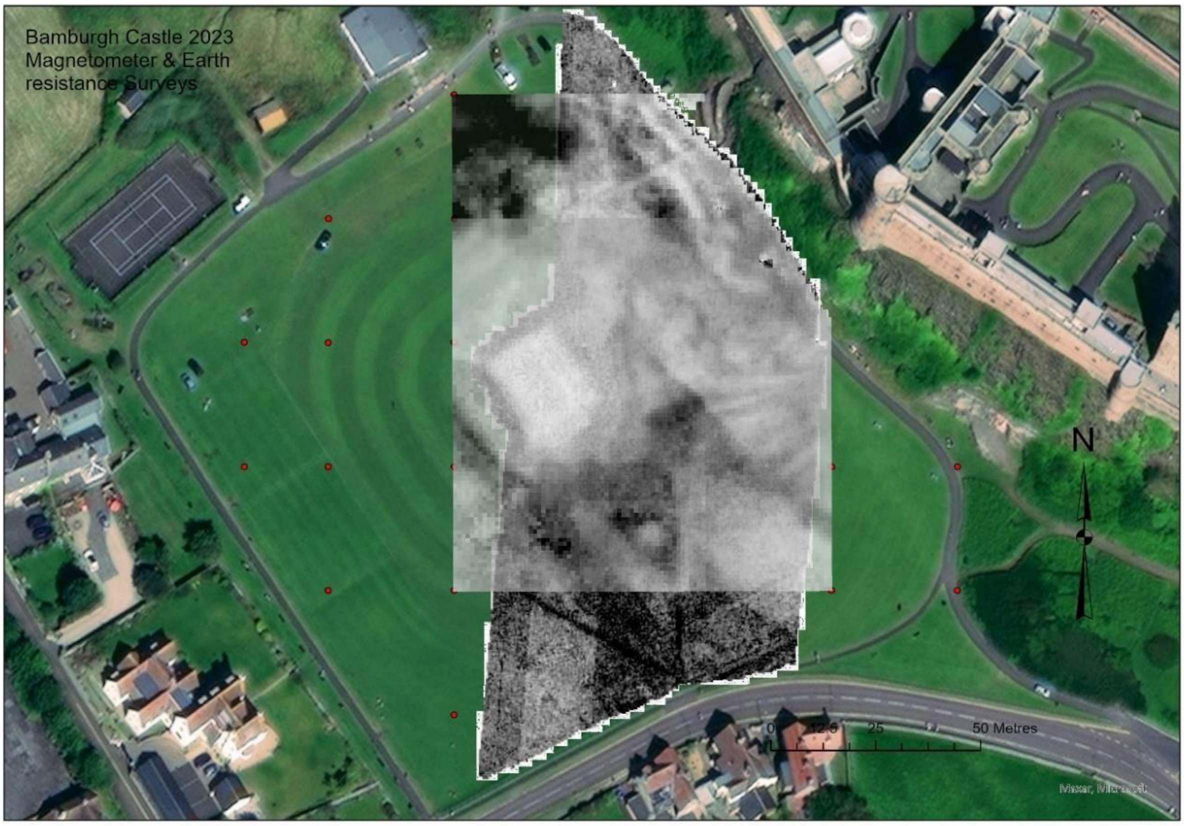

Figure 20. Overlaid transparencies of the earth resistance and GPR results

The GPR results suggest a large ditch, some 45m across at its largest extent, and 40m at its narrowest, comparing with the extant remains of the ditch to the east of the cricket ground which measure c. 36m across. The feature seems to be at least 2.5m deep at the centre, and possibly much deeper as the GPR signal attenuated before picking up the base of the feature. The GPR results, while indicating the extent of the ditch, show very minor changes in terms of background measurements, suggesting a degree of homogeneity in the form of the sub-soil and the back-filling of the ditch. This is also apparent in the earth resistance survey, in which the 0.5m twin probe array, giving shallow readings, shows limited contrast between the ditch fill and the surrounding area. Crucially the greatest contrast for both methods shows where near-surface anomalies to the west and south of the ditch provide clear evidence for the edge of the feature. In the earth resistance and GPR (Fig. 20) the edge of the feature seems relatively smooth. However, in the magnetometry (Fig. 19) the strong magnetic anomalies show a more irregular form, potentially due to their representing deeper magnetic deposits, or cutting into underlying bedrock.

The large, strong angular maculaic and rectangular anomalies in the magnetometry seem to map a strong magnetic response within the area of the ditch **[m6]**, **[m9]** and **[m10]**, possibly marking cuts into the bedrock within the ditch, or alternatively marking strongly magnetic deposits in the deeper ditch fill. Further investigation of these deposits, possibly through auger survey, would be beneficial to establish the nature of the deposits.

There are also some variable anomalies running from the line of the ditch in the magnetometry and earth resistance **[r7]**. To the south a series of trackways seem to run from a point along the southern side of the Cricket Ground. One of these **[g6]**, **[m12]** seems to represent a pathway and embankment running north to meet with an access point on the rock outcrop of the castle, that is visible on the 1st edition Ordnance Survey maps. A wall and trackway also run across the centre of the Cricket Ground

[m13], **[g7]** matching a wall and track shown in Historic England photos of the site from the 19th century (Historic England Photograph Website: Reference OP05279). A series of linear features along the western part of the survey area seem to indicate further walls or garden boundaries associated with Bamburgh village. These anomalies could relate to either post-medieval or even medieval walls in the layout of the village, with a trackway running north-south, joining the fence line and an extant trackway running alongside the dunes to the west and north-west of the Castle.

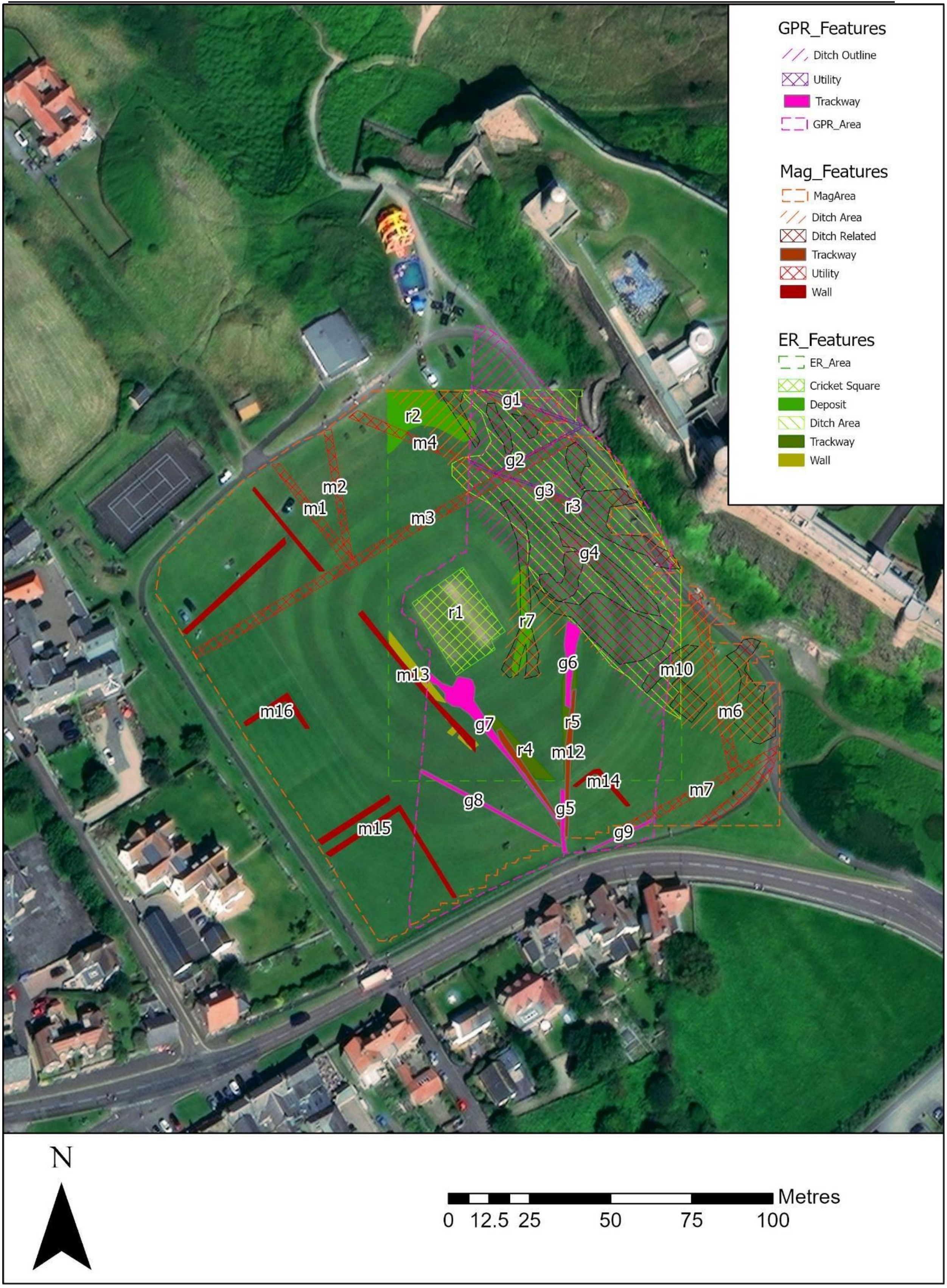

Figure 21. Interpretation plot of all three surveys, labels link to the text

5. Conclusions

The geophysical survey at Bamburgh has successfully located evidence of a possible ditch running along the western side of the outcrop at Bamburgh Castle. The feature appears to be substantial, with a width of 40-45m, and a potential depth of 2.4m or greater. The feature seems to have been cut through a mixture of sandy subsoil, and possibly bedrock along the side of the dolorite outcrop that the Castle is situated on. The generally homogenous nature of the background readings for the ditch fill and sub-soil to the south seems to indicate backfilling by material similar to the sub-soil, presumably sandy soil deposits. The responses to the magnetometer survey seem to indicate a pattern of large dipolar anomalies that fit within the possible outline of the ditch feature. These may indicate areas where bedrock has been cut into, or deposits within the ditch of sediment and rock with highly magnetic properties. Further investigation of the infill of the ditch, possibly through an auger transect, should be a priority to ascertain the nature of the deposits.

In addition, a number of features, including trackways, walls and other anomalies associated with the Bamburgh village were located in the western half of the Cricket Ground. These may mark tracks walls and boundaries associated with the post-medieval or even medieval layout of the village. A trackway also cuts across the Cricket Ground from north to south suggesting an access route running towards the location of the Castle mill. This feature does not, however, show within the area of the ditch.

Results from the Inner Ward suggest the presence of modern features, possibly utilities, but also structural remains in the main part of the Ward.

6. Recommendations

- Bearing in mind the results of the survey it is recommended that an intrusive excavation or auger survey of the possible ditch is undertaken. This should take the form of an auger traverse to examine the depth and nature of deposits across the ditch. Evaluation trenches could also be excavated over other features found in the results of the survey.
- The results of the magnetometer, earth resistance and GPR surveys successfully indicate the nature and extent of archaeological features under the Cricket Ground. It is recommended that an integration of different techniques should be applied, including GPR, earth resistance and magnetometry to continue to map features associated with Bamburgh, including in the fields to the west and north of the Cricket Ground.
- On the basis of the 2023 results, it is recommended that the remaining fields in the area should be surveyed using magnetometry, with targeted GPR or earth resistance where appropriate.

7. Statement of Indemnity

Whilst every effort has been made to ensure that interpretation of the survey presents an accurate indication of the nature of sub-surface remains, any conclusions derived from the results form an entirely subjective assessment of the data. Geophysical survey facilitates the collection of data relating to variations in the form and nature of the soil. This may only reveal certain archaeological features, and may not record all the material present. It must be stressed that accurate interpretation of responses within small areas can prove difficult.

Acknowledgments

Considerable advice and assistance were received from a number of sources in the completion of this survey. Primarily, thanks go to Graeme Young and Joanne Kirton for commissioning the survey. Thanks are also due to the Castles Trust for funding the work through a grant to the Bamburgh Research Project, enabling the work to take place.

On site the kind assistance and advice of Constance Durgeat and other members of the BRP team was instrumental in the successful completion of the survey. The work would have been impossible without the dedication of the BRP students and volunteers.

Finally, thanks are extended to Bamburgh Cricket Club and the Bamburgh Estate for kind permission to undertake the survey on the Cricket Ground and the Inner Ward.

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Appendix 1: Details of Survey Strategy

Dates of Survey: July 2023

Site: Bamburgh, Northumberland

Surveyors: Department of Archaeology, University of Southampton

Personnel: Dominic Barker, Kristian Strutt, staff and volunteers of the Bamburgh Research Project.

Geology: Dolerite and Sandstone

Survey Type 1: Magnetometer

Approximate area: 2.1 hectares

Grid size: 30m

Traverse Interval: 0.5m

Reading Interval: 0.25m

Instrument: Bartington Instruments *Grad601-2* Dual Array Twin Fluxgate Gradiometer

Resolution: 0.1 nT

Trigger: *Grad-01* Data Logger

Survey Type 2: Earth resistance

Approximate area: 1.0 hectares

Grid size: 30m

Traverse Interval: 1m

Reading Interval: 1m

Instrument: Geoscan Research Resistance Meter RM15

Survey Type 3: GPR

Approximate area: 1.1 hectares

Grid size: None

Traverse Interval: 0.125m

Reading Interval: 0.05m

Instrument: Impulse Raptor 8-channel System

Appendix 2: Archaeological prospection techniques utilised by Department of Archaeology, University of Southampton

The following appendix presents a summary of prospection methods, implemented by the Department of Archaeology at the University of Southampton to determine the extent and nature of sub-surface archaeological structures, remains and features. The methodology usually applied places an emphasis on the integration of geophysical, survey to facilitate a deeper understanding of a particular site or landscape.

Geophysical Prospection

A number of different geophysical survey techniques can be applied by archaeologists to record the remains of sub-surface archaeological structures. Magnetometer survey is generally chosen as a relatively time-saving and efficient survey technique (Gaffney *et al*. 1991: 6), suitable for detecting kilns, hearths, ovens and ditches, but also walls, especially when ceramic material has been used in construction. In areas of modern disturbance, however, the technique is limited by distribution of modern ferrous material. Resistivity survey, while more time consuming is generally successful at locating walls, ditches, paved areas and banks, and the application of resistance tomography allows such features to be recorded at various depths. We also implement topographic surveys over areas of prospection, to record important information concerning the location of the site. A summary of the survey techniques is provided below.

Resistivity Survey

Resistivity survey is based on the ability of sub-surface materials to conduct an electrical current passed through them. All materials will allow the passing of an electrical current through them to a greater or lesser extent. There are extreme cases of conductive and non-conductive material (Scollar *et al*. 1990, 307), but differences in the structural and chemical make-up of soils mean that there are varying degrees of resistance to an electrical current (Clark 1996, 27).

The technique is based on the passing of an electrical current from probes into the earth to measure variations in resistance over a survey area. Resistance is measured in ohms (□), whereas resistivity, the resistance in a given volume of earth, is measured in ohm-metres (□/m).

Four probes are generally utilised for electrical profiling (Gaffney *et al*. 1991, 2), two current and two potential probes. Survey can be undertaken using a number of different probe arrays; twin probe, Wenner, Double-Dipole, Schlumberger and Square arrays.

The array used by the Department utilises a Geoscan Research RM15 Resistance Meter in twin electrode probe formation. This array represents the most popular configuration used in British archaeology (Clark 1996; Gaffney *et al*. 1991, 2), usually undertaken with a 0.5m separation between mobile probes. Details of survey methodology are dealt with elsewhere (Geoscan Research 1996).

A number of factors may affect interpretation of twin probe survey results, including the nature and depth of structures, soil type, terrain and localised climatic conditions. Response to nonarchaeological features may lead to misinterpretation of results, or the masking of archaeological anomalies. A twin probe array of 0.5m will rarely recognise features below a depth of 0.75m (Gaffney *et al*. 1991). More substantial features may register up to a depth of 1m. With twin probe arrays of between 0.25m and 2m, procedures are similar to those for the 0.5m twin probe array.

Although changes in the moisture content of the soil, as well as variations in temperature, can affect the form of anomalies present in resistivity survey results, in general, higher resistance features are interpreted as structures which have a limited moisture content, for example walls, mounds, voids, rubble filled pits, and paved or cobbled areas. Lower resistance anomalies usually represent buried ditches, foundation trenches, pits and gullies. In addition to the normal twin electrode method of survey, a Geoscan Research MPX15 multiplexer can be utilised with the Resistance Meter, allowing multiple profiles of resistivity to be recorded simultaneously, or resistance tomography to be carried out up to a depth of 1.5m. We generally survey, as with the twin electrode configuration, to a resolution of 1 or 0.1Ω, with readings every metre or half metre.

Magnetic Survey

Magnetic prospection of soils is based on the measurement of differences in magnitudes of the earth's magnetic field at points over a specific area. Principally the iron content of a soil provides the basis for its magnetic properties. Presence of magnetite, maghaemite and haematite iron oxides all affect the magnetic properties of soils. Although variations in the earth's magnetic field which are associated with archaeological features are weak, especially considering the overall strength of the magnetic field of around 48,000 nanoTesla (nT), they can be detected using specific instruments (Gaffney *et al*. 1991).

Three basic types of magnetometer are available to the archaeologist; proton magnetometers, fluxgate gradiometers, and alkali vapour magnetometers (also known as caesium magnetometers, or optically pumped magnetometers). Fluxgate instruments are based around a highly permeable nickel iron alloy core (Scollar *et al*. 1990, 456), which is magnetised by the earth's magnetic field, together with an alternating field applied via a primary winding. Due to the fluxgate's directional method of functioning, a single fluxgate cannot be utilised on its own, as it cannot be held at a constant angle to the earth's magnetic field. Gradiometers therefore have two fluxgates positioned vertically to one another on a rigid staff. This reduces the effects of instrument orientation on readings.

Archaeological features such as brick walls, hearths, kilns and disturbed building material will be represented in the results, as well as more ephemeral changes in soil, allowing location of foundation trenches, pits and ditches. Results are however extremely dependent on the geology of the particular area, and whether the archaeological remains are derived from the same materials. For fluxgate gradiometer survey, the Bartington Grad601-2 is used. This is a twin array probe, so carries two fluxgate gradiometers which work simultaneously to increase the speed of a survey. Survey is carried out at 0.1nT resolution, with readings taken every 0.5m by 0.25m. In flat and open territory around 1 hectare per day can be surveyed by each instrument.

Ground Penetrating Radar Survey

Ground Penetrating Radar (GPR) survey is based on the use of an electromagnetic radar wave propagated through the soil to search for changes in soil composition and the presence of structures, measuring the time in nanoseconds (ns) taken for the radar wave to be sent and the reflected wave to return. The propagation of the signal is dependent on the Relative Dielectric Permittivity of the buried material.

This technique has been applied successfully on a range of archaeological sites, in particular over substantial urban archaeological remains. Use of GPR is more time consuming than using magnetometry. It is more appropriate to apply this method to target particular areas of interest at an archaeological site where magnetometry or resistivity have already been applied, or where there is a potential for deeper archaeological deposits.

We operate a Sensors and Software radar system, configured for use with a Smartcart frame and console. This utilises a 500 Mhz antenna, which allows propagation of radar waves down to a depth of approximately 3-4m depending on the nature of the sub-surface materials. We also use an Impulse Raptor 8-channel system, linked to GPS, that collects very high resolution data, with channels spaces at 0.125m intervals.

Integrated Survey Methodology

The survey work carried out by our team is always produced as part of an integrated survey strategy, designed to affiliate all of the geophysical survey techniques to the same grid system, which would be used for geochemical soil sampling and surface collection. Surveys are normally based on an arbitrary grid coordinate system, tied into a national system or to a series of hard points on the ground corresponding to points on a map. A set of 30m grids are then set out to provide the background for the magnetometry, resistivity, and other survey techniques which will complement the results, for instance fieldwalking and geochemical sampling.

Bibliography

Barker, D., Strutt, K. and Sly, T. 2005, *Report on the Geophysical Survey at Netley Abbey*. Unpublished Survey Report.

Bowden, M. (ed.) 1999, *Unravelling the Landscape: an inquisitive approach to archaeology.* Stroud; Tempus.

Cambridge E. 1984, The Early Church in County Durham', in *Journal of the British Archaeological Association*, Vol. 137, 65-85.

Cambridge E. 1995, Archaeology and the Cult of St. Oswald in Pre-Conquest Northumbria'. in (eds.) Stancliffe C. and Cambridge E. *Oswald. Northumbrian King to European Saint,* Stamford, 1995, 128-63.

Campbell J. 1979, Bede's Words for Places, in (ed.) P. H. Sawyer *Names, Words and Graves: Early Medieval Settlement.* Leeds 1979, 34-51.

Clark, A. 1996, *Seeing Beneath the Soil: Prospecting Methods in Archaeology*. London; Batsford.

Conyers and Goodman 1997, *Ground Penetrating Radar: An Introduction for Archaeologists*.

Walnut Creek; Altamira.

English Heritage 2008, *Geophysical Survey in Archaeological Field Evaluation*. English Heritage Publishing.

Gaffney, C., Gater, J. and Ovendon, S. 1991, *The Use of Geophysical Survey Techniques in Archaeological Evaluations*. Institute of Field Archaeologists Technical Paper No. 9.

Hope-Taylor B. Excavation Committee, report for 1960, Bamburgh, in *University of Durham Gazette*, Vol. VIII (New Series), No. 2, 1960, 11-12.

Hope-Taylor B. Excavation Committee, report for 1961, in *University of Durham Gazette*, Vol. IX (New Series), No. 4, 1962, 5-7.

Hope-Taylor B. *Yeavering. An Anglo-British centre in early Northumbria*, HMSO, London, 1977.

Leckebusch, J. 2001, Dreidimensionale Prospektion mit Hilfe von Bodenradar (GPR) in Augusta Raurica (insulae 34, 35, 36, 40, 41 and 42). In *Jahresberichte aus Augst und Kaiseraugst* 22, 51-70.

Scollar, I., Tabbagh, A., Hesse, A. and Herzog, I. 1990, *Archaeological Prospecting and Remote Sensing*. Cambridge University Press.

Welch M. 1992, *Anglo-Saxon England,* London.

Young, G. 2023, The Gardens Radcliffe Road, Bamburgh, Northumberland. Archaeological Monitoring Written Schedule of Investigation. Unpublished Report.

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