The Old Sarum Landscapes Project
Research Report No. 1

Report on the Geophysical Survey at Old Sarum, Wiltshire March-April 2014

SREP 9/2014

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Archaeological Prospection Services of Southampton

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Report on the Geophysical Survey at Old Sarum, Wiltshire, March-April 2014

Summary

This report presents the results of the geophysical survey undertaken at Old Saruma, near Salisbury in Wiltshire, between 30th March and 11th April 2014. It specifies the survey methodology together with an interpretation discussion of the survey results. The survey was carried out across the inner and outer bailey of the scheduled ancient monument, incorporating topographic survey, magnetometer, earth resistance survey, GPR and ERT surveys. The preliminary results demonstrate an incredible number of features within the area of the outer bailey, showing the plan of the medieval city, and potentially earlier structures. The trial GPR in the inner bailey also demonstrated the presence of substantial medieval structures, together with possible remains predating the inner bailey. To date the results represent the first phase of a field project spanning three years, however, the potential for the application of these different techniques has been established at the site, and more intensive program of survey will hopefully allow the team to map the site and its environs.

1. Introduction

Between the 30th March and 11th April 2014 a geophysical survey was conducted at Old Sarum to the north of Salisbury in Wiltshire (Fig. 1). This formed the first season of survey work undertaken as part of a new project to investigate the archaeology of Old Sarum and Stratford-sub-Castle (Strutt et al. 2014). The survey was undertaken by staff and students from the University of Southampton with the permission of English Heritage. The work was directed by the authors with much of the survey work being conducted by undergraduate and postgraduate students from the Department of Archaeology at the University of Southampton.

1.1 Site Location and Background

The site of Old Sarum (Fig. 2) is located in Wiltshire some 3km to the north of Salisbury in the Avon Valley. The monument, number 1015675, includes a univallate Iron Age hillfort with evidence of Romano-British occupation and documentary evidence of a Saxon burh and mint (Bushe-Fox 1950; Richards 2010; List Entry Summary). The site was rebuilt as a royal motte and bailey castle including a cathedral and bishop's palace and extra-mural settlement. The remains of the castle and cathedral are Listed Grade I and the monument is in the care of the Secretary of State (Fig. 3). It is situated c.3km NNE of Salisbury, at the west end of a westward facing chalk spur overlooking the River Avon. The hillfort is roughly oval in shape, enclosing an area of c.12ha, with entrances at the east and west ends. Excavations within the hillfort have produced evidence of early Iron Age settlement and of later Iron Age and Romano-British occupation from the 1st to the 3rd centuries AD. Included within the scheduling is an area of Iron Age activity located outside the hillfort close to the eastern entrance. The site is the focus for a number of major Roman roads and the Roman town of Sorviodunum has been suggested as lying within the hillfort.

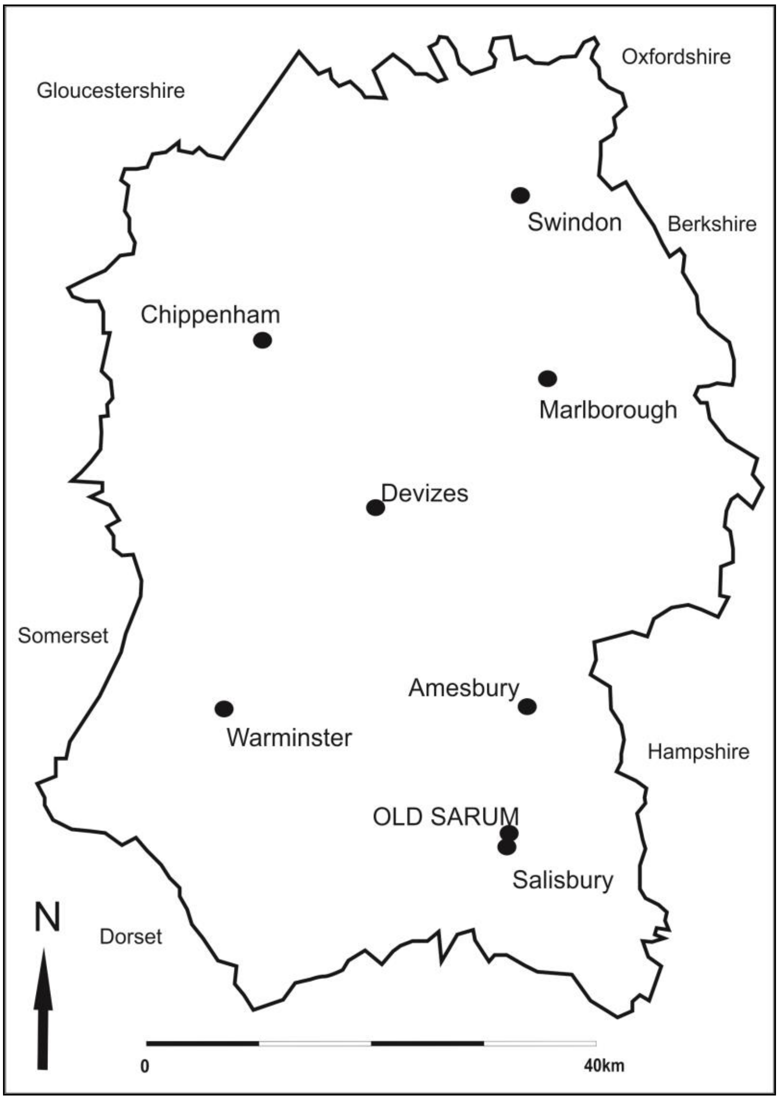

Figure 1 Map of the county of Wiltshire, showing the location of Old Sarum

There is, however, a lack of any substantial evidence for Romano-British occupation within the hillfort and current understanding does not allow this suggested location to be confirmed.

Documentary sources attest to the establishment of a Saxon burh, at the site. After the Norman Conquest in 1066 a royal motte and bailey castle was built within the hillfort. The defences of the hillfort were adapted to become those of the outer bailey while a mound was constructed in the centre of the hillfort.

The inner bailey, the entrance of which is on its eastern side, now contains the ruins of a series of stone buildings dating from c.1100 AD to the 13th century. The outer bailey of the medieval castle includes earthwork banks radiating from the motte to the outer defences. Those to the north east and south of the motte may have defined the outer bailey of the post-Conquest castle. The Norman town may have been established within the south western quadrant and the north western quadrant includes the ecclesiastical precinct within which lie the remains of the cathedral and other associated structures. The cathedral now survives as low walls and reinstated areas marking out the composite ground plan of its two phases of construction.

The first cathedral was built in 1078,, and consisted of a nave separated from two side aisles by eight great arches on each side. At the apsidal east end, the main altar and two side chapels in the transepts were also enclosed by semi-circular apses. This building was completed in 1092 and almost immediately largely destroyed. Rebuilding in the Norman style commenced in 1130 under Bishop Roger and involved the large scale levelling of this part of the hillfort interior. Outside the western limits of the defences aerial photographs show traces of what may be a contemporaneous suburb of Old Sarum. Although understanding of the extent, nature and survival of these remains is currently incomplete, artefacts recorded after cultivation immediately beyond the western hillfort entrance enable the eastern part of the possible settlement to be confirmed and included within the scheduling. Beyond the eastern limits of the defences, to the south of the main entrance, lie part of the remains of the east suburb, defined by surviving earthworks and by recorded finds dating from the 12th to the 14th centuries. Although understanding of the full extent of these remains is currently incomplete, and they have been considerably disturbed to the east of the Salisbury to Amesbury road, an area can be defined which is included within the scheduling.
Excavation has been conducted at the site in the 20th century, including Hope's work in the earlier part of the century (Hope 1911; 1914; 1916; 1917) and a number of trial excavations and archaeological mitigations prior to development in the area (for instance excavations on the trunk main replacement). Previous geophysical survey has been conducted at the site, with a survey of the supposed chapel site being conducted in 2003 (http://archaeologydataservice.ac.uk/archives/view/ehgsdb_eh_2011/fullrecord.cfm?id=2664), and resistivity survey of part of the monument in 2005 (http://archaeologydataservice.ac.uk/archives/view/ehgsdb_eh_2011/fullrecord.cfm?id=2804).

Figure 2 Orthorectified photographic image of Old Sarum (source: Google Earth)

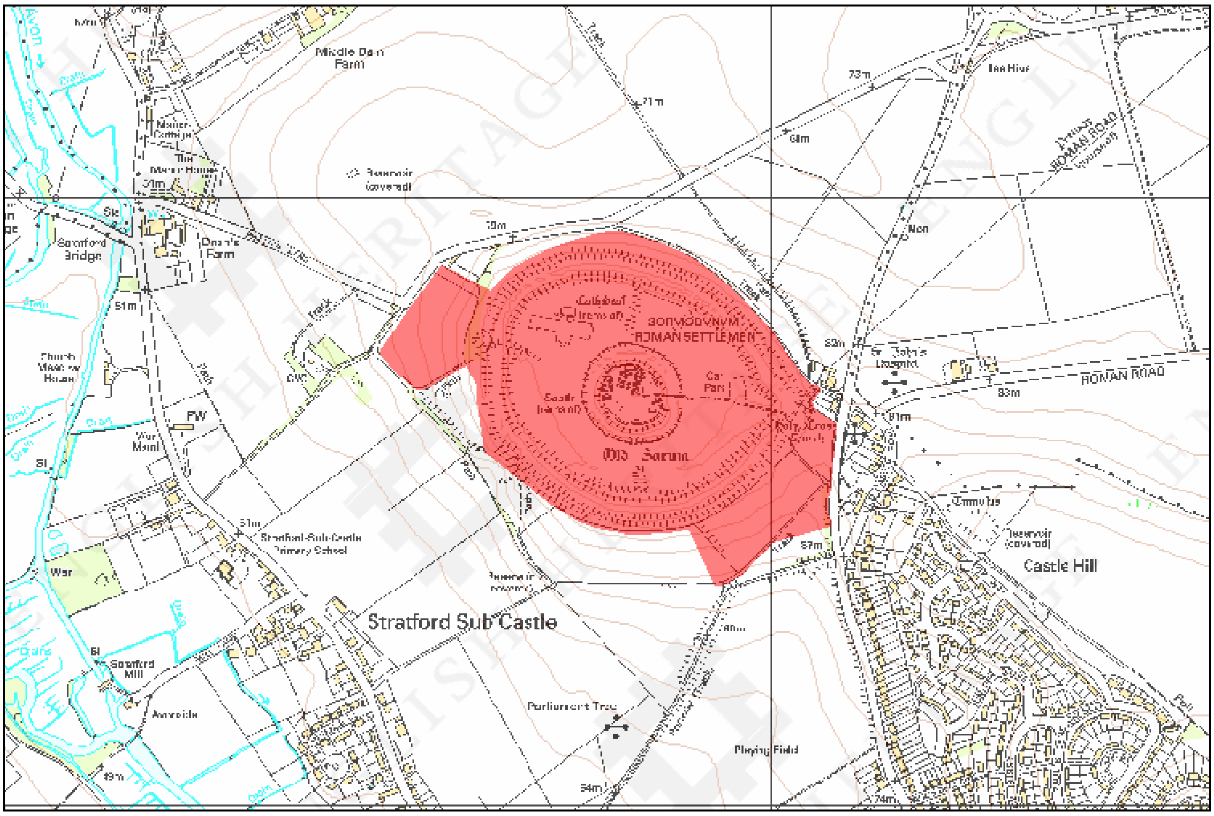

Figure 3 The scheduled area of Old Sarum and Stratford-sub-Castle

The Historic Environment Record for the monument and its environs (Fig. 2) and desk-based assessment for the monument and its environs (Richards 2010) indicates a palimpsest of archaeological material, including significant features from the Iron Age, Romano-British period, Saxon, Medieval and post-medieval periods. A detailed assessment of the archaeology is given in several other accounts, however a number of prominent areas exist in the landscape surrounding Old Sarum that would benefit from further non-intrusive investigation. The scheduled area of Old Sarum Castle contains multi-period evidence that would benefit from geophysical investigation. The exact layout of the medieval castle plan, and the Saxon Burg would merit attention. Although the location of possible Romano-British settlement has been noted, no actual evidence for occupation has been found.

The area immediately to the south of Old Sarum contains the remains of a Romano-British settlement, scheduled monument number 1004688, and geophysical investigation of the area would potentially provide a high resolution plan of the remains of the settlement.

In addition the area to the north-west contains the medieval settlement associated with the castle. Although much of the settlement appears to have been mapped from air photographic evidence, topographic and geophysical survey would potentially produce further information on the nature and extent of the site, and its relationship with the castle.

The site was taken over by the Royal Air Force in 1941 in order to provide defence for the airfield to the east of the site. The site was closed to the public and defended by extensive barbed wire belts on the outer ramparts. Some machine gun points, Nissen Huts for accomodation and cinder roads for access were built, all of which were removed after the war.

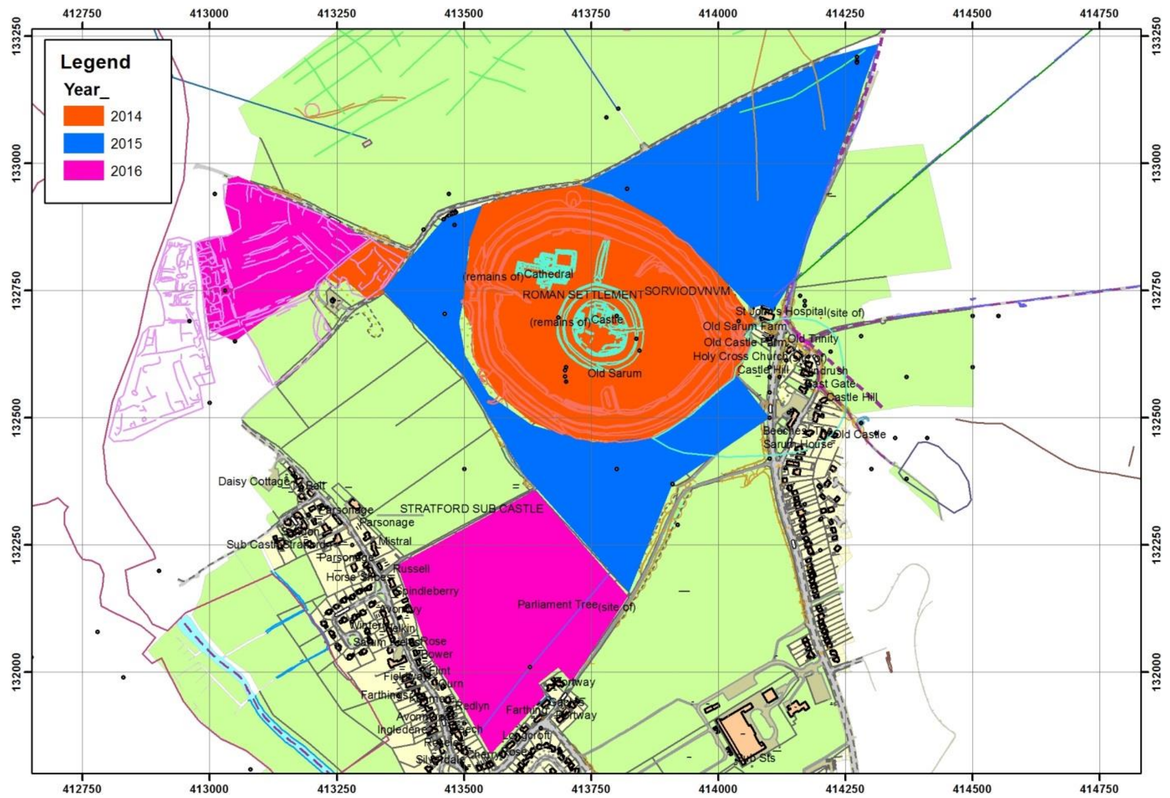

Figure 4 Proposed areas of survey for the duration of the project (from Strutt et al. 2014) (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

1.2 Geology at Old Sarum

Old Sarum is located on the Newhaven chalk formation which covers the area around Salisbury and Stratford Sub-Castle (Fig. 5).

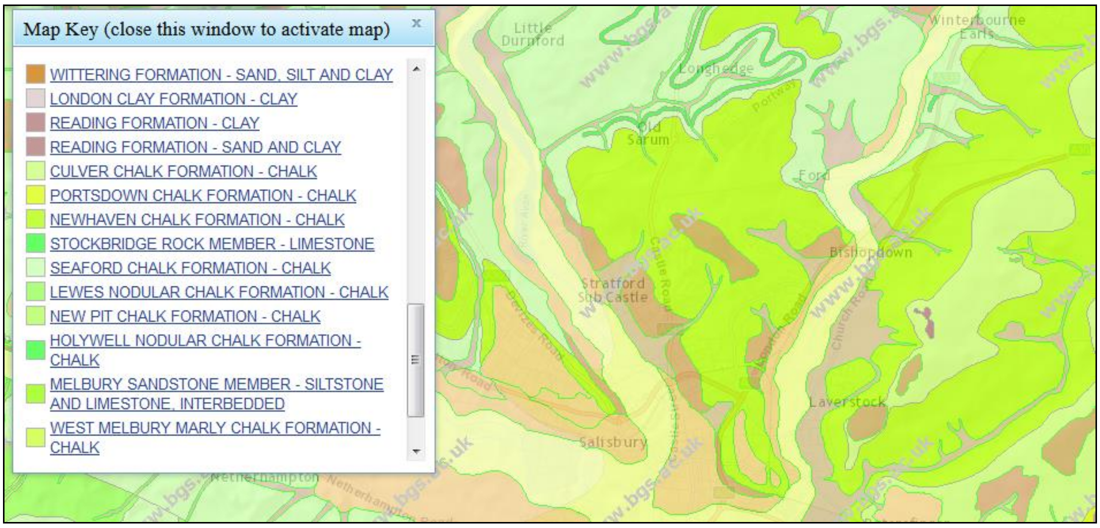

Figure 5 Geological map of the area of Old Sarum

1.3 Aims of the Survey

The objective of the survey project was primarily to provide an opportunity for training of archaeology students from the University of Southampton undertaking survey and geophysical survey modules of study, to produce new and extensive data for Old Sarum and its immediate environs using non-intrusive techniques of prospection (Fig. 4), and topographical survey methods to map the extant archaeological remains. The aims of the survey, in line with the project overview (Strutt et al. 2014) were to:

- To produce a new topographic interpretation for Old Sarum and Stratford Sub-Castle, integrating LiDAR data with on-site topographic survey of visible features.
- To produce a geophysical survey of the area, using an integrated strategy comprising different methods including earth resistance survey, magnetometry, Ground Penetrating Radar (GPR) and Electrical Resistivity Tomography (ERT).
- To create a dataset for use by researchers and management personnel at English Heritage and other interested organisations.
- To provide a framework for the training of Archaeology undergraduate and postgraduate students from the University of Southampton
- To potentially provide an opportunity for outreach by the Department of Archaeology at the University of Southampton, to local community organisations and archaeological groups.
- To potentially provide an opportunity for student involvement in other aspects of the archaeology at Old Sarum and Stratford Sub-Castle, for instance archive work as part of possible dissertation topics.

To that end, the field season in 2014 aimed to commence survey work, starting within the curtilage of the scheduled ancient monument, within the inner and outer baileys of the site.

2. Survey Methodology

For the survey at old Sarum a variety of techniques were applied, including magnetometry, earth resistance Ground Penetrating Radar (GPR) and Electrical Resistivity Tomography (ERT). 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 and ERT are based on the passing of an electrical current through the soil and measuring the resistance to the current. GPR survey utilizes an electromagnetic radar wave propagated through the soil to search for changes in soil composition and structures, measuring the time in nanoseconds (ns) taken for the radar wave to be sent and the reflected wave to return.

As part of the survey these techniques were applied to facilitate a comparison of their effectiveness. The underlying chalk geology, and the flint and masonry type of construction generally respond well to the use of earth resistance and GPR survey (Barker, Strutt and Sly 2005; Strutt, Sly, and Barker 2004; Strutt, Barker and Sly 2008). In addition the presence of possible pit features, burials, and burnt layers in the archaeological record, and the need for rapid survey over large areas, provided ideal conditions for magnetometry. In addition to these techniques ERT was applied to test the potential of the method for locating deeper potential archaeological features, and assessing the depth of archaeological deposits across the outer bailey at Old Sarum. Again similar project work at Bodiam Castle in East Sussex (Strutt 2010; Strutt, Sly and Barker 2012) had proven the potential for the use of this method.

2.1 Techniques of Geophysical Survey: Magnetometry, Earth Resistance, Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (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.

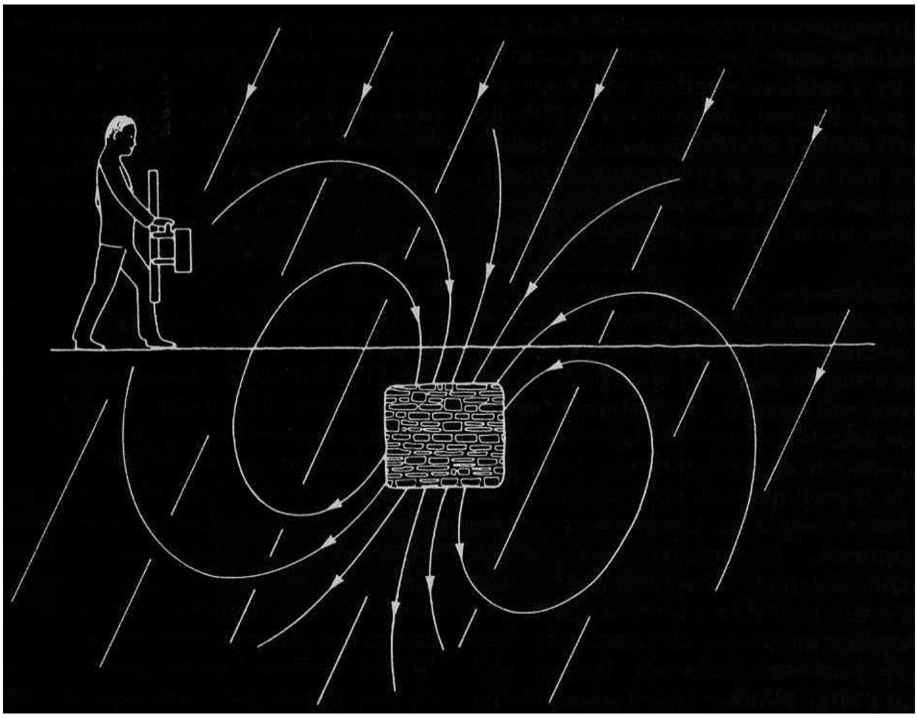

Figure 6 **Schematic diagram indicating the use of a magnetometer over archaeological remains, and the local magnetic field of the buried objects in relation to the earth's magnetic field (from Clark 1996)**

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.

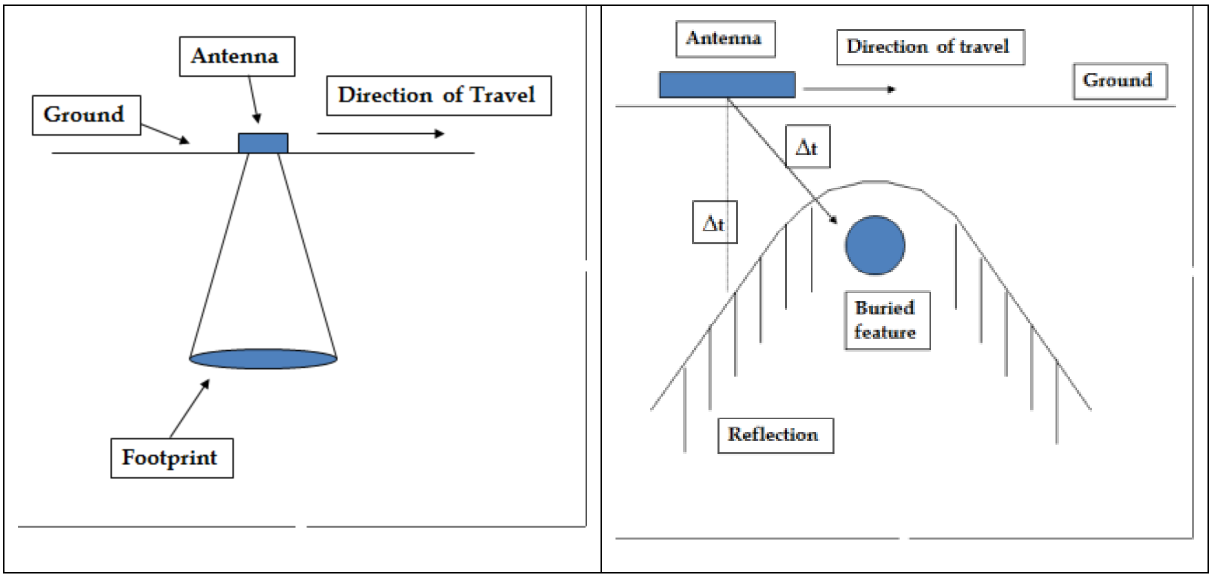

Figure 7 Diagram showing the footprint of a GPR radio signal and the response to a spherical object with the resulting hyperbola to demonstrate the propagation of the signal over distance and time (after Conyers and Goodman 1997)

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 (Gaffney et al. 2004, 207ff; Leckebusch 2001, 52ff; Nishimura and Goodman 2000; Neubauer et al. 2002).

Twin probe array 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 (Ω), whereas resistivity, the resistance in a given volume of earth, is measured in ohm-metres (Ωm). 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.

ERT, while similar to earth resistance in that it relies on the passing of an electrical current through the earth, takes a series of measurement at increased probe spacing intervals to build up a profile of the changing material below the surface of the ground (Fig. 8), measuring in varying apparent resistivity in ohm-metres (Ωm). This enables the archaeologist to detect localised anomalies and features at increased depth. A reading is taken at the centre of four probes chosen by the computer programme starting with probes 1, 2, 3 and 4 the reading is take at the centre of the probes. The depth at which measurements are taken corresponds approximately to half the distance between the individual probes, for example in P4 the probes were set at 3m spacing so that readings were taken every 3m horizontally and every 1.5m vertically below the ground ie at 1.5m, 3.0m, 4.5m, 6.0m … for 13 levels down to 19.5m. P6, which crosses the line of the dewatering trench, was set at 1m spacing for a higher resolution and thus readings were taken every 1m horizontally and every 0.5m vertically. At this resolution it is not possible to take readings as deep as when the probes are spaced further apart.

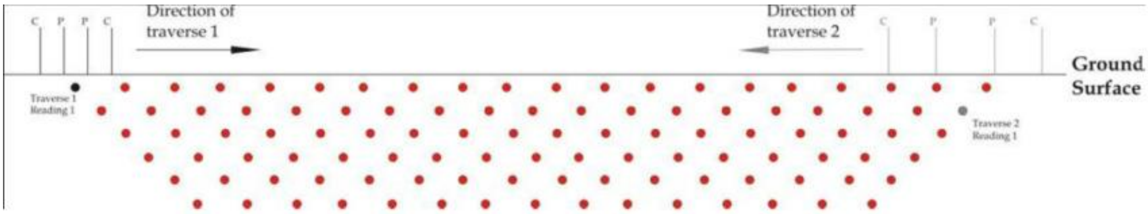

Figure 8 **Diagram showing the function of a multiprobe Electrical Resistivity Tomography (ERT) survey using Wenner array**

2.2 Survey Strategy

For the survey grid system was established using a Leica Viva Real Time Kinetic (RTK) GPS (Fig. 9) 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 together with the other landscape features and breaks of slope recorded during the topographic survey of the site.

Figure 9 Leica RTK GPS with Smartnet being used to grid out at Old Sarum (photo: K. Strutt)

Figure 10 Magnetometer survey being conducted using a Bartington Instruments Grad 601 fluxgate gradiometer (photo: K. Strutt)

The Leica GPS was also used to conduct a topographic survey of the different survey areas, with readings taken along traverses spaced c. 5m apart, at 1m intervals or where changes in elevation above 0.2m occurred within a 1m distance. Further detailed survey was carried out using a Leica TCR703XR and a TCR805 Power Total Stations, with data downloaded using LISCAD software.

The magnetometer survey was conducted using a Bartington Instruments Grad 601 dual sensor fluxgate gradiometer (Figs 10). 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 3.0 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.

Figure 11 GPR survey being conducted in the inner bailey using a GSSI 200 MHz antenna with SIR-3000 console (photo: K. Strutt)

The GPR survey in the inner bailey was conducted using a GSSI 200 MHz antenna with SIR-3000 console (Fig. 11). Profiles were positioned at 0.5m intervals with traces of data collected at 0.10m intervals. In addition a Sensors and Software Noggin Plus system with 500Mhz antenna and Smartcart (Fig. 14) in the outer bailey. Data were collected along traverses spaced 0.5m apart along the x direction of each survey grid across target areas of the sites in the northern, central and southern areas of the survey. 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 readings. The presence of hyperbola in the data were utilised to produce an estimation of signal velocity through the deposits at each site, facilitating a calculation of the depth of different features across each site. Profiles were then converted into grid data and were sliced horizontally to produce a series of time slices through each survey area.

Earth resistivity was carried out using a Geoscan Research RM15 resistance meter, with measurements taken at 0.5m intervals along traverses spaced 0.5m apart (Fig. 13). For the ERT an Allied Associates Tigre 64 probe resistivity system was used to take readings. Measurements were taken using an expanding Wenner array, with readings taken with the probes at differing intervals for each profile according to the length and depth required to answer the questions being asked. The data was processed and inverted using the Res 2D Inv software program.

Figure 12 Earth resistance survey being carried out using a Geoscan Resesarch RM15 (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.

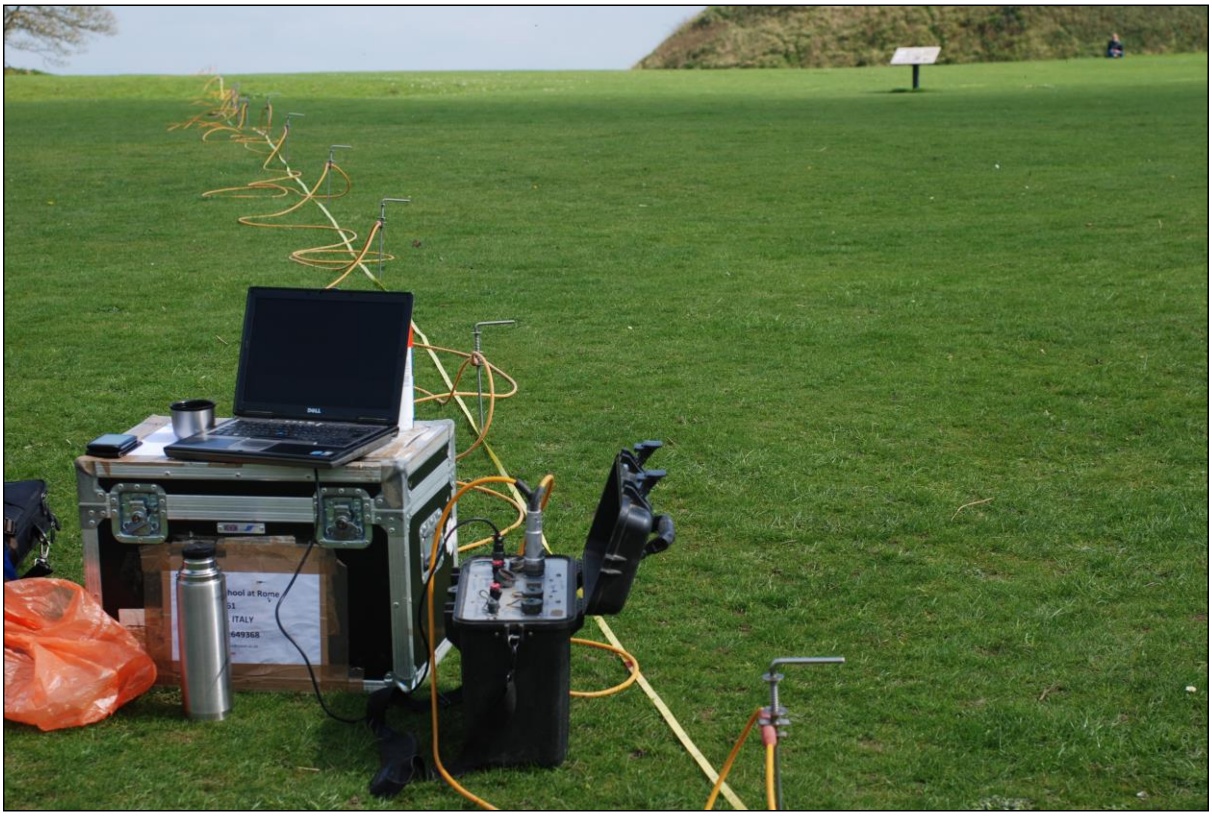

Figure 13 **ERT survey being undertaken across the inner bailey using an Allied Associates Tigre 64 probe system (photo: K. Strutt)**

Figure 14 **GPR survey being conducted in the outer bailey using a Sensors and Software Noggin Plus Smartcart with 500 MHz antenna (photo: K. Strutt)**

Figure 15 **Fluxgate gradiometer survey being carried out to the east of the cathedral (photo: K. Strutt)**

Figure 16 **Earth resistance survey under way with the spire of Salisbury Cathedral in the background (photo: K. Strutt)**

Figure 17 **GPR survey of the inner bailey (photo: K. Strutt)**

3. Survey Results

3.1 The Topographic Survey

Due to the possibility of accessing LiDAR data through the Environment Agency Geomatics department is was not necessary to conduct a micro-topography survey taking spot elevations across the site and surrounding area. Instead the topographic survey focussed on conducting a survey of breaks of slope within the scheduled ancient monument. The survey demarcated the bank and ditch of the inner bailey, the bank and ditch features sub-dividing the outer bailey, and the earthworks and extant remains associated with the cathedral and the curtain wall of the outer bailey (Figs 18 and 19).

3.2 The Magnetometer Survey

The magnetometer survey was focussed on the area of the outer bailey (Figs 20 – 25), as the potential depth of deposits and the quantity of modern structures and pathways within the inner bailey precluded a full survey using magnetometry. The results from the outer bailey indicate a substantial number of anomalies associated with the mediaeval settlement of Old Sarum.

In the north-west quadrant of the outer bailey a large number of anomalies relating to the medieval cathedral and city plan are visible. The area is dominated by a series of linear dipolar anomalies **[m1]**, **[m2]**, **[m3]** and **[m4]** marking the outline of the cathedral walls and columns as planned in the excavations in the area, presumably a response to modern metalling or similar materials used to demarcate the plan of the cathedral. Immediately to the south of the cathedral a number of negative linear anomalies **[m5]** and **[m6]** running from south-west to north-east indicate the presence of stone structures, probably medieval, but on a completely different alignment to the cathedral and its associated buildings. A north-south linear negative anomaly **[m7]** measuring some 20m in length marks a wall on the alignment of the cathedral, with a complex of rooms **[m8]** and **[m9]** immediately to the west. These structures continue northwards **[m10]**, **[m11]** and **[m12]** between the outer bailey curtain wall and the cathedral, and include a large structure measuring some 15m by 10m in size. A linear negative anomaly runs from north to south for a distance of 35m **[m13]** across the outer bailey, marking a possible wall or ditch. Several dipolar anomalies **[m14]** mark modern ferrous material on a north-south alignment to the west. Negative linear and discrete anomalies **[m15]** to the north mark a further possible medieval structure. A large dipolar anomaly and linear positive anomaly **[m16]** mark the presence of either a structure or deposit with modern ferrous material associated with it. To the east of this a rectilinear arrangement of faint negative anomalies **[m17]** marks a masonry structure, and a faint linear anomaly to the north **[m18]** indicates the line of the defensive wall of the bailey. Two further linear negative anomalies **[m19]** and **[m20]** mark structural remains, with a number of discrete dipolar anomalies to the north **[m21]** indicating modern ferrous material in the topsoil.

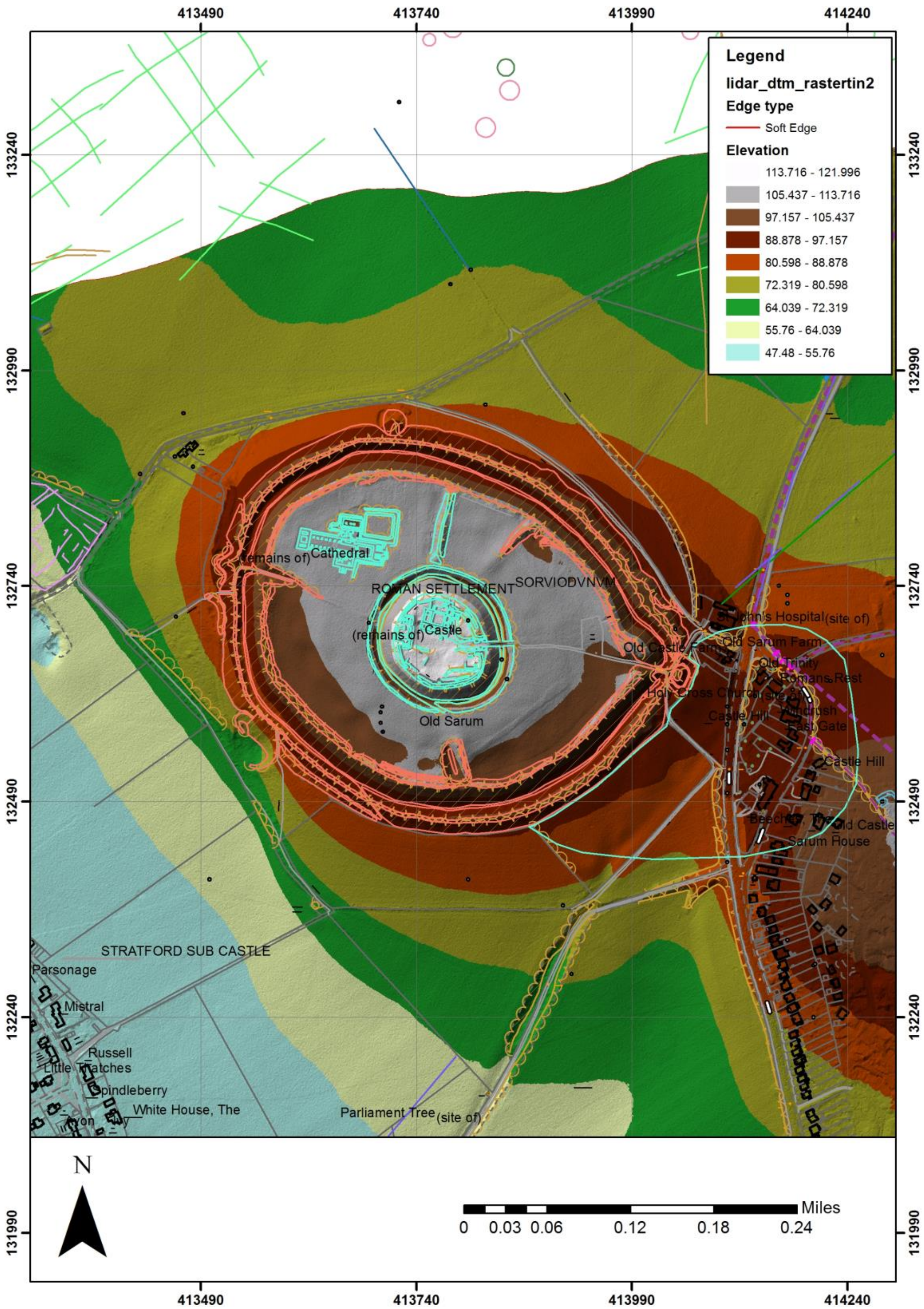

Figure 18 **Ordnance Survey data overlaid on the LiDAR data for the area of Old Sarum and Stratford-sub-Castle, with the break of slope survey data completed by undergraduate students during the fieldwork (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)**

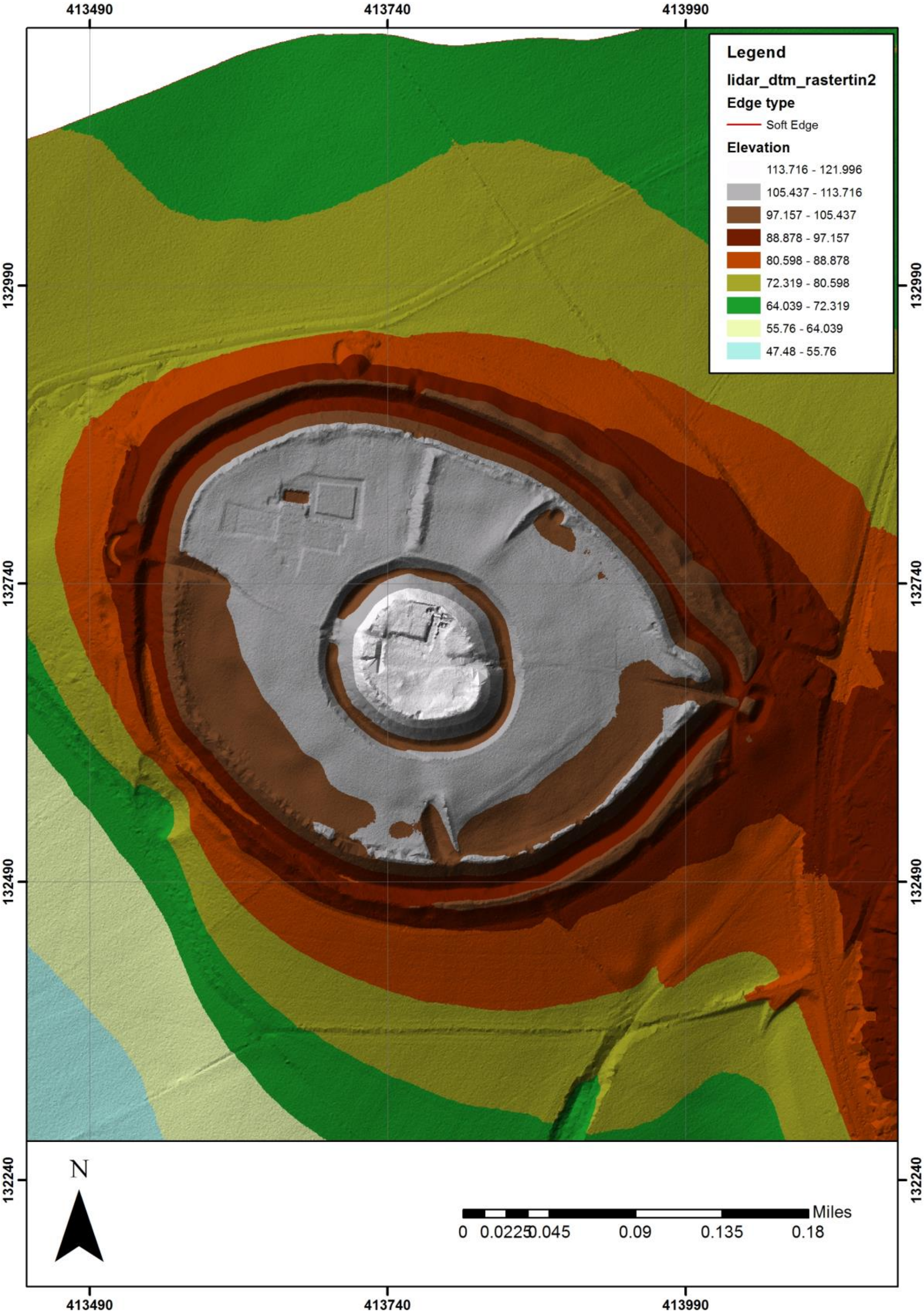

Figure 19 LiDAR DTM data showing the principal earthworks and topography for Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

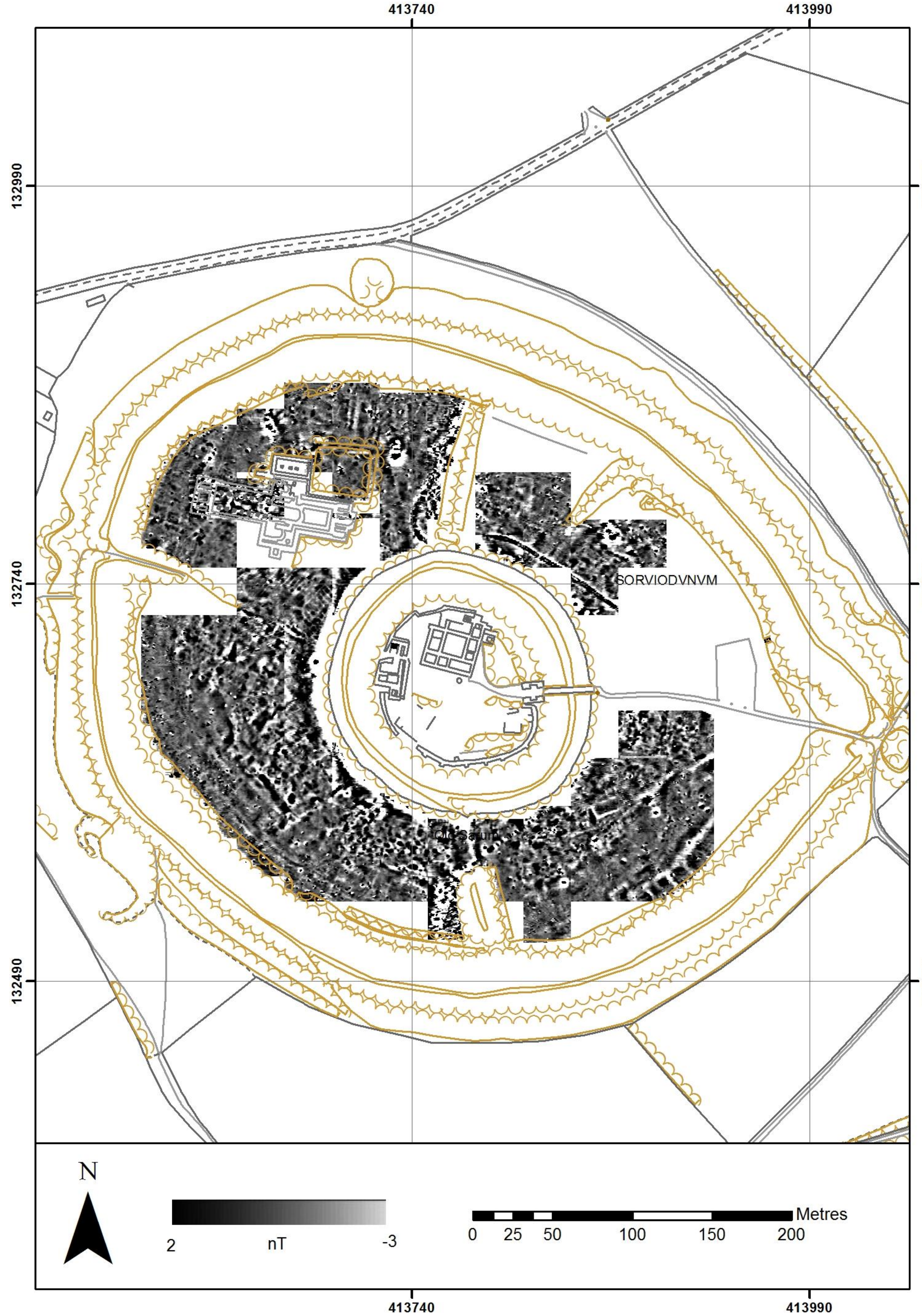

Figure 20 Greyscale image of the magnetometer survey at Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

Figure 21 **Greyscale image of the magnetometer survey for the western part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)**

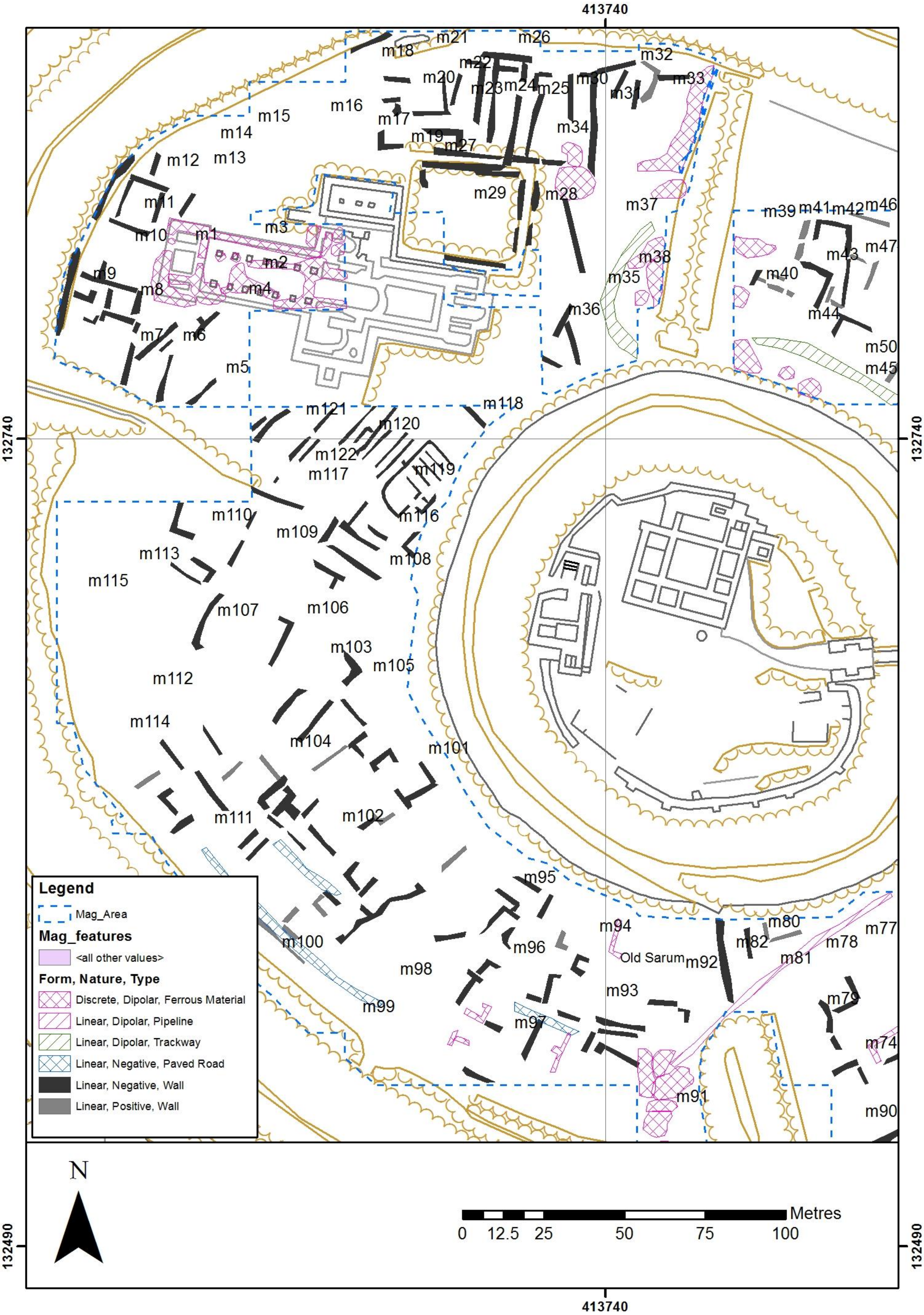

Figure 22 Interpretation plot derived from the results of the magnetometer survey for the western part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

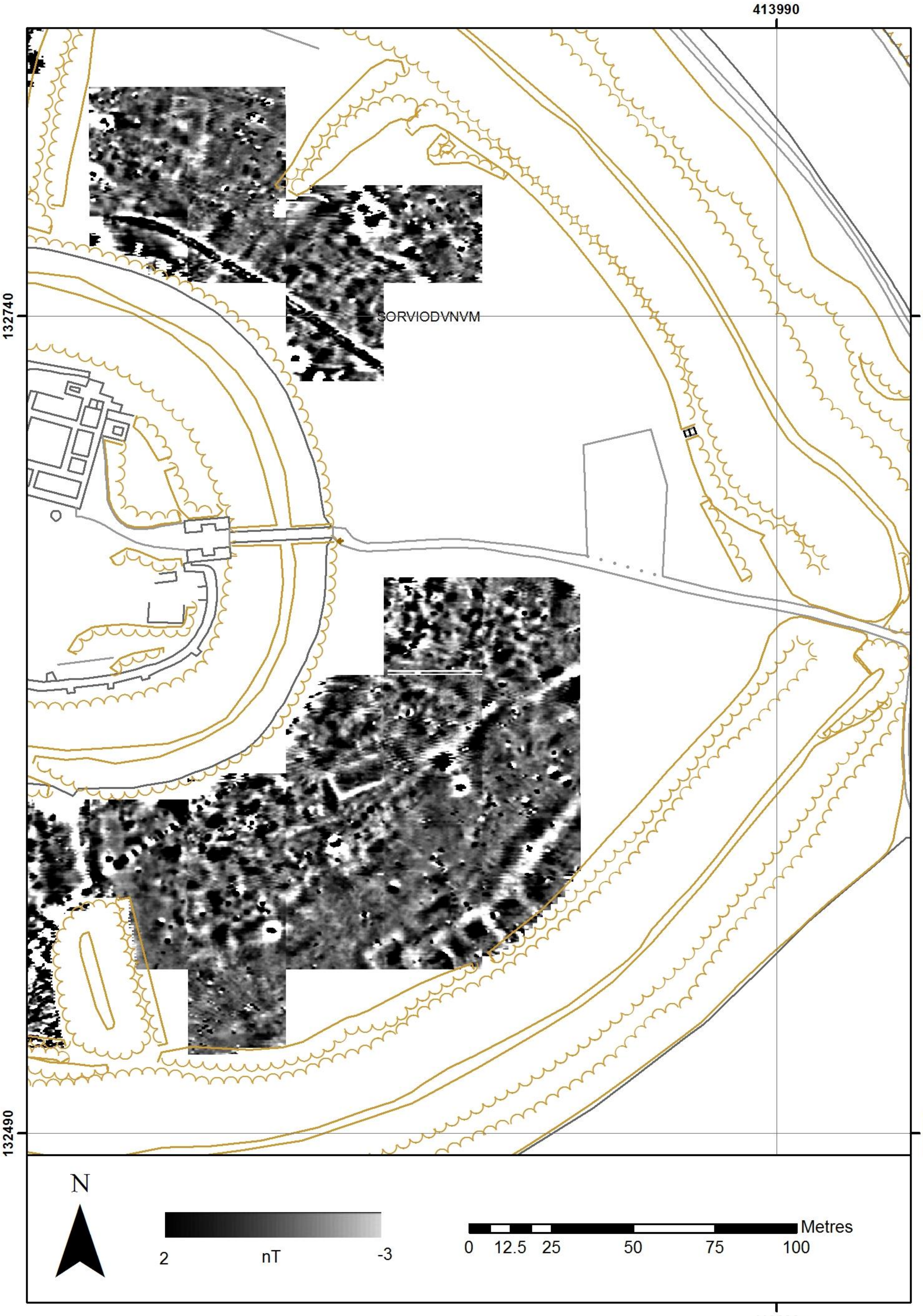

Figure 23 **Greyscale image of the magnetometer survey for the eastern part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)**

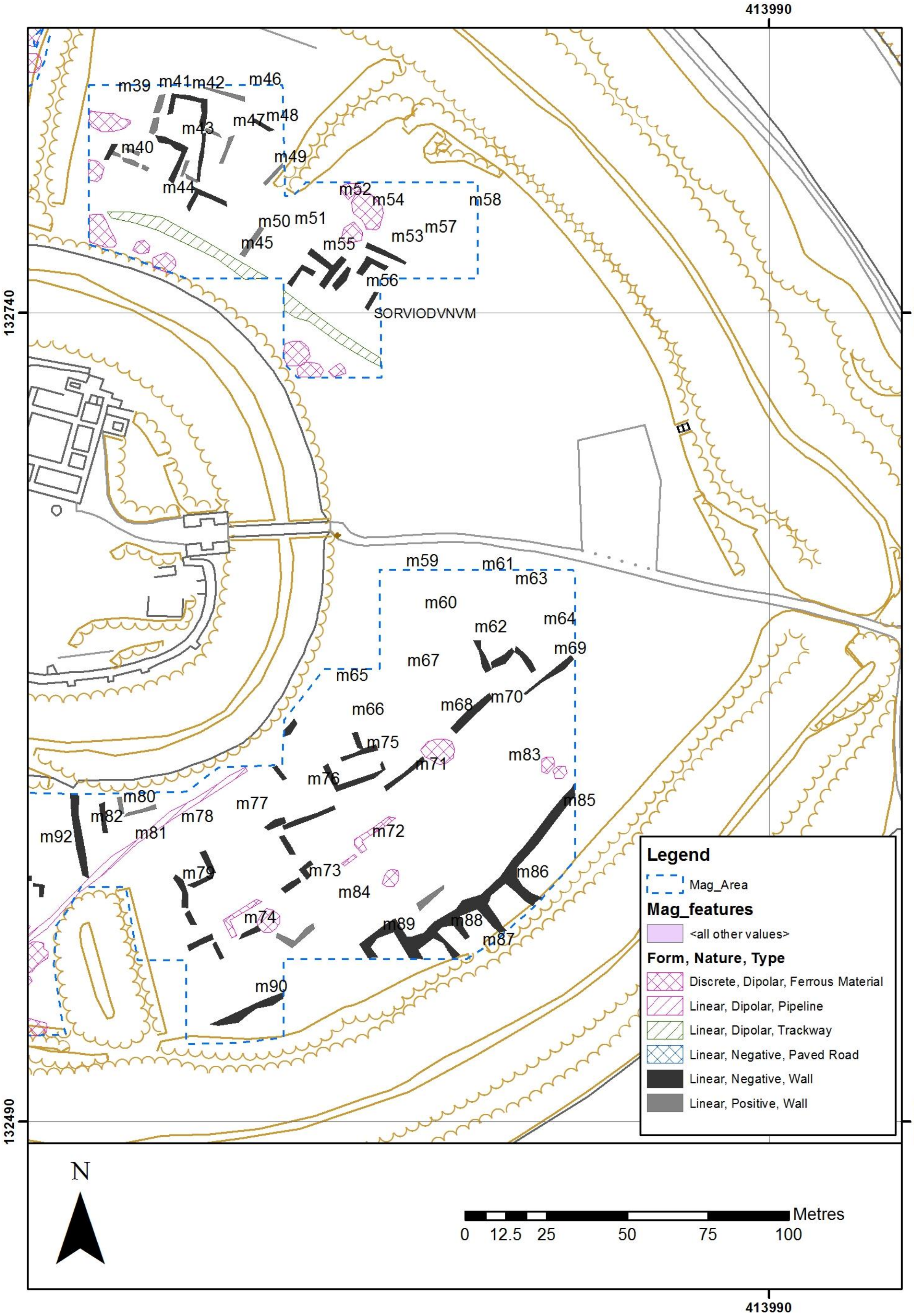

Figure 24 Interpretation plot derived from the results of the magnetometer survey for the eastern part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

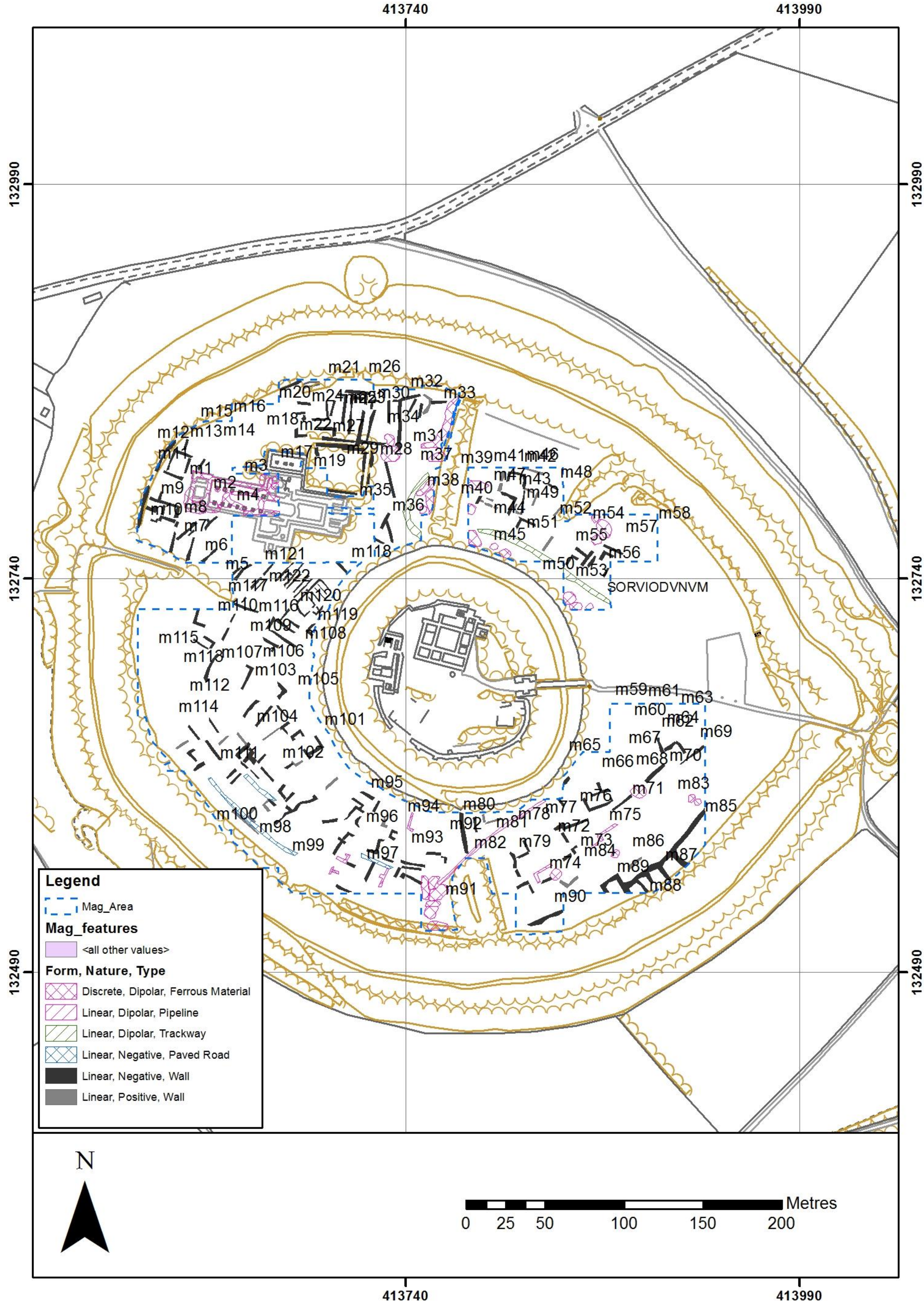

Figure 25 Interpretation plot derived from the results of the magnetometer survey for Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

A series of parallel linear negative anomalies to the east **[m22]**, **[m23]**, **[m24]** and **[m25]** measuring up to 30m in length and running from north to south, mark medieval masonry walls, presumably associated with the cathedral. Several positive discrete anomalies to the north **[m26]** mark possible post or pit features. Two sets of parallel linear negative anomalies **[m27]** and **[m28]** mark the corridor of the cloister associated with the cathedral with a discrete dipolar anomaly **[m29]** marking a feature in the centre of the cloister itself. A strong linear anomaly **[m30]** marks the eastern extent of these features, possibly suggesting the limit of the cathedral area. Several linear negative anomalies **[m31]** and **[m32]** to the east of this indicate further structures, but on a different alignment to those associated with the cathedral. Several large dipolar discrete anomalies in the area **[m33]** and **[m34]** mark modern ferrous material, possibly associated with the excavations in the area. A large curvilinear dipolar anomaly **[m35]** marks the line of a modern pathway or track with metalling. A number of discrete dipolar anomalies **[m37]** and **[m38]** also mark modern material, with linear and discrete anomalies to the west marking medieval pits and walls.

In the north-east quadrant of the outer bailey the area is also marked by buried structural remains and other possible pits and discrete anomalies. Several discrete dipolar anomalies **[m39]** mark modern disturbance, however, a series of negative linear and rectilinear anomalies **[m40]**, **[m41]** and **[m42]** mark medieval walls, with a large structure **[m43]** measuring some 15m by 10m in the centre of the survey area. A second rectilinear anomaly **[m44]** marks a structure closer to the inner bailey ditch. A broad linear dipolar anomaly **[m45]** marks the continuation of a metalled modern track running for a distance of 95m alongside the inner bailey ditch. A series of shorter negative linear anomalies **[m46]**, **[m47]** and **[m48]** mark walls in the north-eastern part of the area mark further structures, with two strong linear anomalies **[m49]** and **[m50]** running from north-east to south-west also showing walls. A linear arrangement of positive discrete anomalies **[m51]** marks possible occupation deposits. To the north of these a large dipolar anomaly **[m52]** marks possible modern ferrous material, with a negative linear anomaly and positive anomalies **[m53]** and **[m54]** indicating a possible masonry wall and associated deposits. Two sets of parallel negative anomalies **[m55]** and **[m56]** mark walls of buildings, and a series of positive discrete anomalies to the north-east **[m57]** and **[m58]** indicate possible pits or deposits.

To the south of the modern parking area is also marked with a series of positive and dipolar discrete anomalies suggesting deposits or features **[m59]** with linear negative anomalies indicating further structural remains **[m60]**. These anomalies extend across the outer bailey **[m61], [m62]** and **[m64]** immediately to the south of the modern entrance to the inner bailey. A linear negative set of anomalies **[m63]** marks the presence of a structure and a series of positive and negative anomalies close to the inner bailey ditch **[m65]**, **[m66]** and **[m67]** mark structures and possible occupation deposits. A line of negative anomalies **[m68]** and **[m69]** and a broad positive anomaly **[m70]** mark the southern edge of what appears to be an intensively occupied area close to the ditch of the inner bailey. This series of anomalies continues to the south and west **[m71]**, **[m72]**, **[m73]** and **[m74]** presenting an irregular set of structures, some measuring 10m by 6m in size with the area to the north populated by a large number of negative and positive anomalies, including a rectilinear feature **[m75]** measuring 16m by 12m, with a band of positive readings along its south-west side **[m76]**, and a pattern of negative and positive anomalies **[m77]** and **[m78]** marking masonry walls and other deposits. A possible structure is visible at the western extent of these features

[m79] and other anomalies mark walls close to the inner bailey ditch **[m80]** and **[m82]** cut by a linear dipolar anomaly **[m81]** marking a modern pipeline or drain.

A broad area with relatively few anomalies **[m83]** and **[m84]**, measuring 30m across and almost 100m in length, runs around this part of the outer bailey. Some modern dipolar anomalies and linear anomalies suggesting earlier structures are present, but there is a marked contrast between this and the area closer to the ditch of the inner bailey. The southern edge of this area is demarcated not by the defensive wall of the outer bailey, but by a series of impressive negative linear and rectilinear anomalies **[m85]**, **[m86]**, **[m87]**, **[m88]** and **[m89]** marking a number of large masonry structures with walls over 2m thick, and rooms over 10m across, abutting the wall of the outer bailey. The anomalies continue to the west and south **[m90]** up to the extant feature to the west.

The eastern edge of the south-west quadrant of the outer bailey is marked by a series of large dipolar responses **[m91]** caused by modern disturbance and ferrous material. A line of positive features stretches from north to south **[m92]** marking possible occupational deposits or an infilled ditch measuring 32m in length. To the west of this a series of small negative linear anomalies and positive discrete anomalies mark the walls of buildings and associated deposits **[m93]**, **[m94]**, **[m95]** and **[m96]** ranging alongside the ditch of the inner bailey. A large rectilinear arrangement of negative anomalies to the south **[m97]** measuring some 17m across marks a possible buried structure. A slightly more open area **[m98]** marked with several discrete positive and dipolar anomalies leads to a broad linear negative anomaly **[m99]** and **[m100]** measuring some 74m in length and marking a possible paved street, or the foundations of a massive wall, measuring some 3m across. Several large adjacent structures **[m101]**, **[m102]**, **[m103]** and **[m104]**, each measuring between 13m and 15m across, indicate a substantial built-up area in the south-west area of the outer bailey, again with the characteristic negative anomalies denoting walls, with occupational deposits and other features showing as discrete positive responses. A substantial rectilinear positive anomaly **[m105]** located adjacent to the inner bailey ditch indicates a possible structure. A collection of rectilinear features to the west **[m106]**, **[m107]**, **[m108]**, **[m109]** and **[m110]** also mark remains of large buildings, all on a north-west to south-east alignment, one **[m107]** suggesting a large chamber some 22m across, a room some 20m in length **[m108]** and a structure along the edge of the current results **[m110]** measuring 19m across.

Walls of possible structures are also ranged more closely to the defensive wall of the outer bailey **[m111]**, **[m112]**, **[m113]**, **[m114]** and **[m115]**, a mix of negative and positive linear anomalies indicating masonry walls and more rudimentary structures. To the north a series of discrete positive anomalies **[m116]** and **[m117]** mark possible pits or rubble material. A short negative linear anomaly **[m118]** marks a wall running up to the inner bailey ditch. Two areas of small linear negative anomalies suggest two different structures **[m119]** and **[m120]** on a north-east to south-west alignment, marking a strange arrangement of features with narrow walls and corridors. To the north-west of these a more regular pattern of structures is visible **[m121]** and **[m122]**.

3.3 Earth Resistance Survey

The earth resistance survey in the outer bailey (Figs 26 – 31) indicated the presence of structures on a similar pattern to those in the magnetometry. In the area of the cathedral three strong high resistance linear anomalies **[r1]**, **[r2]** and **[r3]** demarcate the walls of a cloister measuring 40m by 32m in size. A sub-circular high resistance anomaly is visible in the centre of the cloister **[r4]** marking a possible feature. Several high resistance anomalies to the south **[r5]** and **[r6]** mark the hard standing used to demarcate the plan of the excavated cathedral. A linear high resistance anomaly **[r7]** and **[r12]** runs in a north-east to south-west direction, marking a wall some 67m in length. To the west of this wall a series of small linear anomalies and areas of rubble **[r8]**, **[r9]**, **[r10]** and **[r11]** mark structures.

A rectilinear high resistance anomaly **[r13]** close to the northern circuit of the defensive wall of the outer bailey marks a possible building abutting the wall, measuring 7m across. A linear high resistance anomaly **[r14]** measuring 30m in length with a break in it marks a wall closing off the area to the north-west of the cloister. A further possible structure **[r15]** is also visible to the north of this, and several smaller linear anomalies **[16]** and **[r17]** mark walls of a large structure to the east. Two large high resistance anomalies to the east **[r18]** and **[r19]** mark possible rubble deposits, with a further linear anomaly **[r20]** marking a possible wall or rubble filled ditch forming a rectilinear annex on the east side of the cloister. A further broad high resistance band of readings **[r21]** running from west to east marks a possible rubble deposit with a wall **[r22]** at its eastern end. Several linear and discrete high resistance anomalies to the north **[r23]**, **[r24]** and **[r25]** mark the remains of masonry structures.

In the north-east quadrant of the outer bailey two areas of high resistance mark possible building rubble **[r26]** and **[r27]**. A faint linear high resistance anomaly **[r28]** marks a wall running from north to south, with a second shorter wall **[r29]** running from east to west and a short linear of high resistance to the west **[r30]** running parallel with **[r28]**. An area of high resistance **[r31]** marks possible rubble, with a strong rectilinear high resistance anomaly **[r32]** marking a building measuring 17m by 12m. A second fainter rectilinear anomaly comprising two high resistance linear anomalies **[r33]** and **[r34]** mark a further building measuring some 17m by 10m in size. The line of the defensive wall around the outer bailey is also visible in the results **[r35]** to the north.

The continuation of the extant bank in this part of the site can be seen **[r36]** and **[r37]** running from north-west to south-east, and measuring 30m by 7m, with a break in its southern end close to the outer bailey ditch. A low resistance linear anomaly **[r38]** and **[r39]** to the east of this demarcates the area into a quitter zone **[r40]** with some possible walls **[r41]** and areas of rubble, and a noisier area with more substantial anomalies including high resistance walls **[r42]**, **[r43]** and **[r44]** and a low resistance linear anomaly **[r45]** and **[r46]** marking a possible ditch feature. Again the wall of the outer bailey is visible **[r47]**.

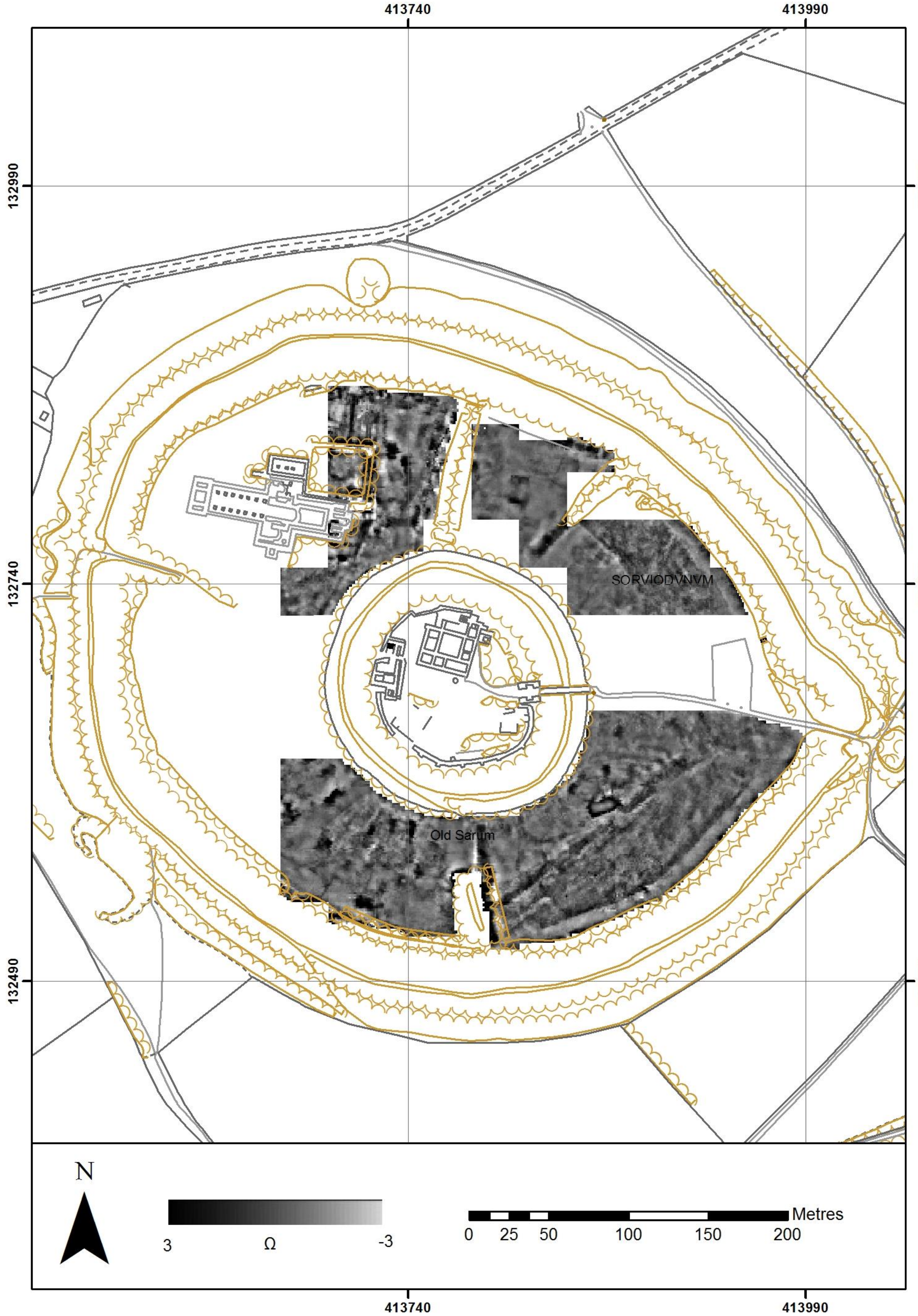

Figure 26 Greyscale image of the earth resistance survey at Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

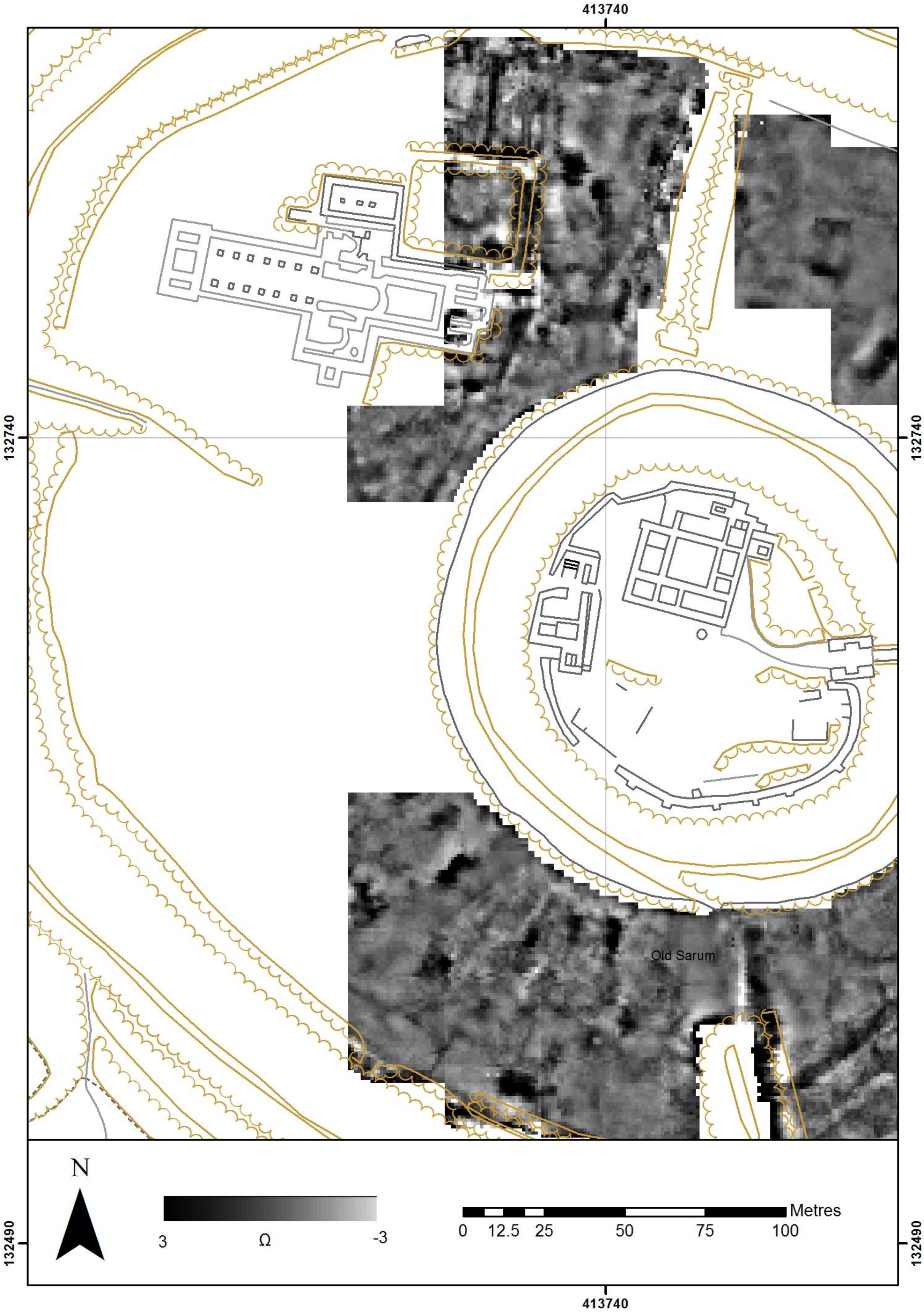

Figure 27 Greyscale image of the earth resistance survey for the western part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

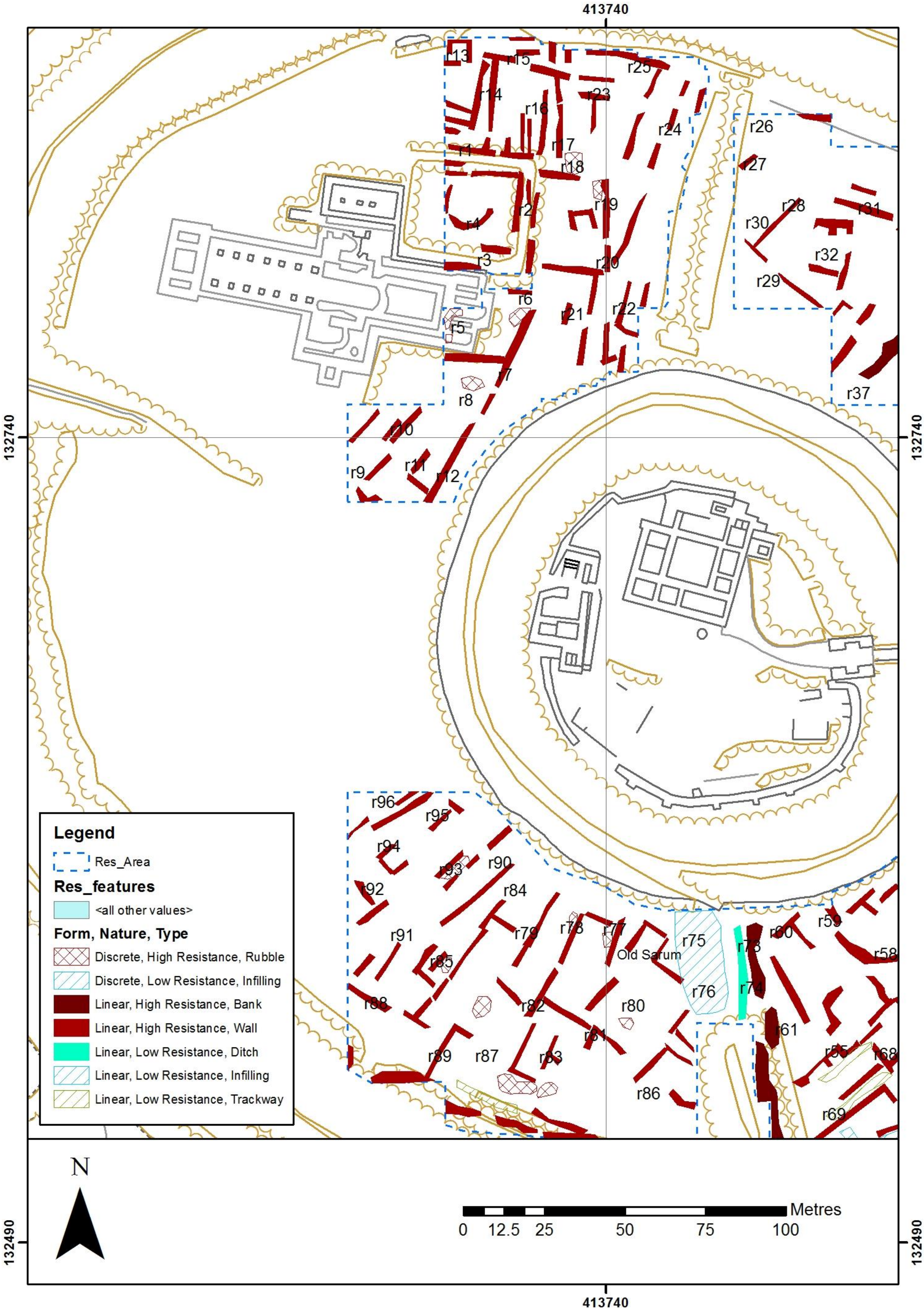

Figure 28 Interpretation plot derived from the results of the earth resistance survey for the western part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

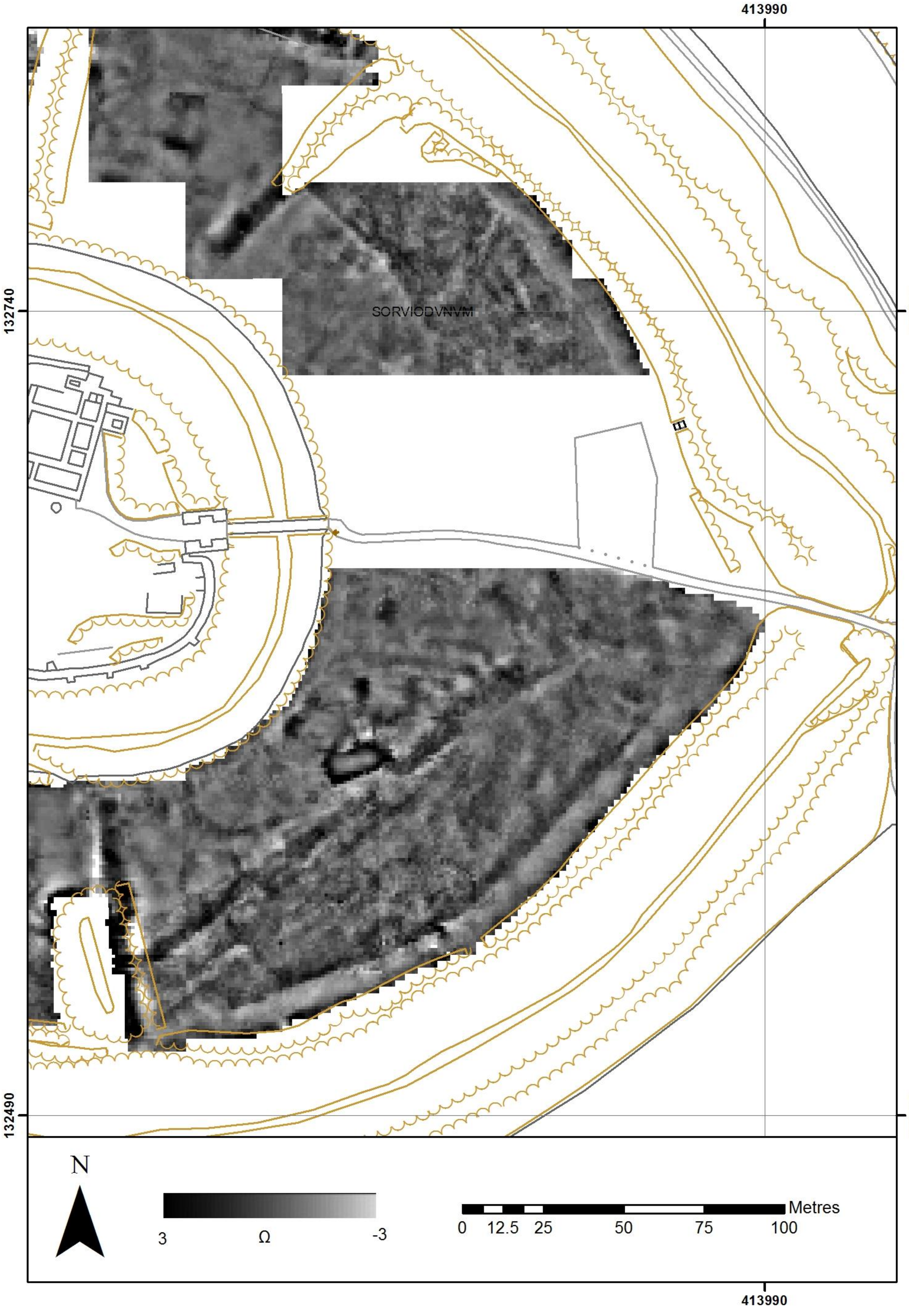

Figure 29 Greyscale image of the earth resistance survey for the eastern part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

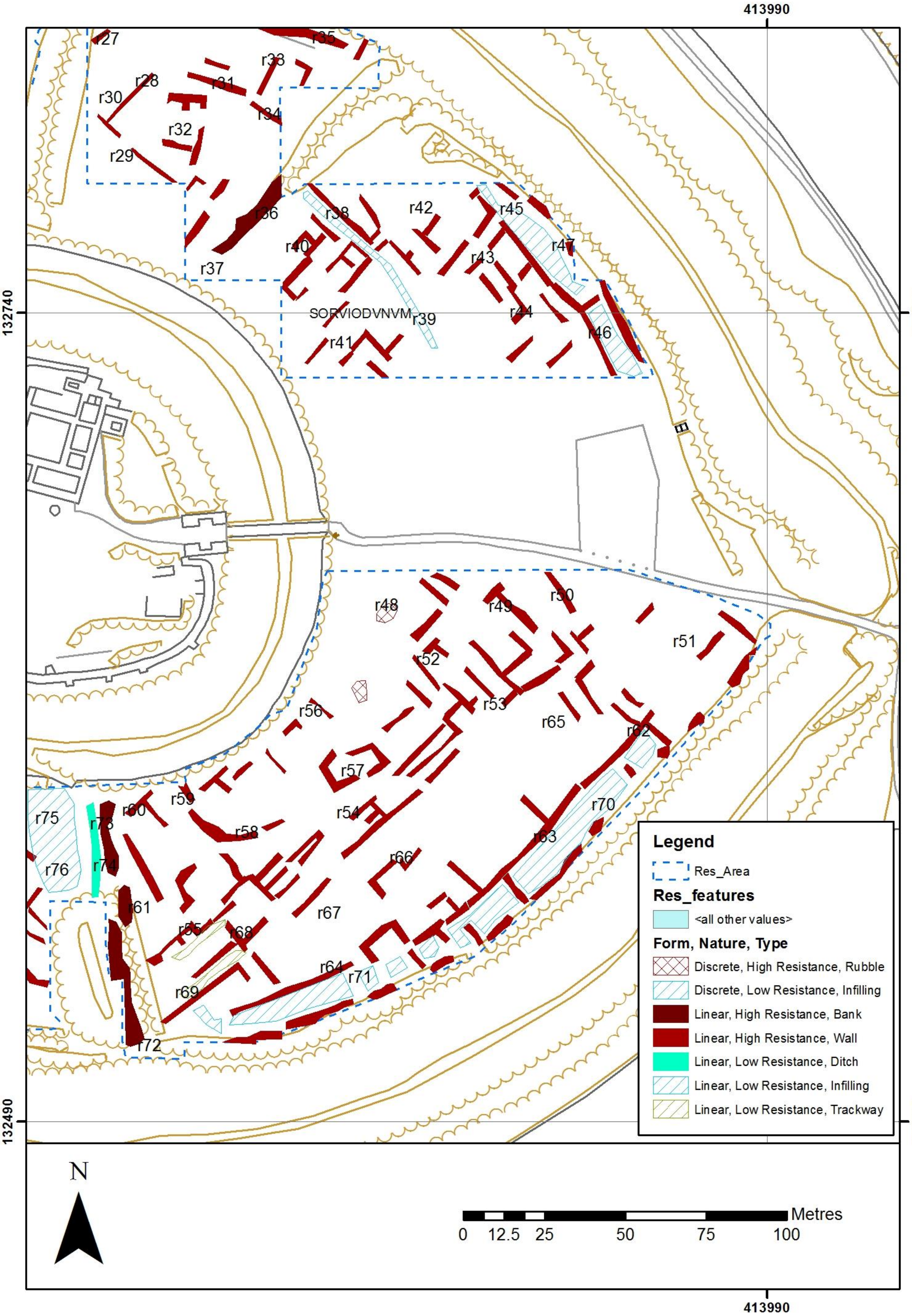

Figure 30 Interpretation plot derived from the results of the earth resistance survey for the eastern part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

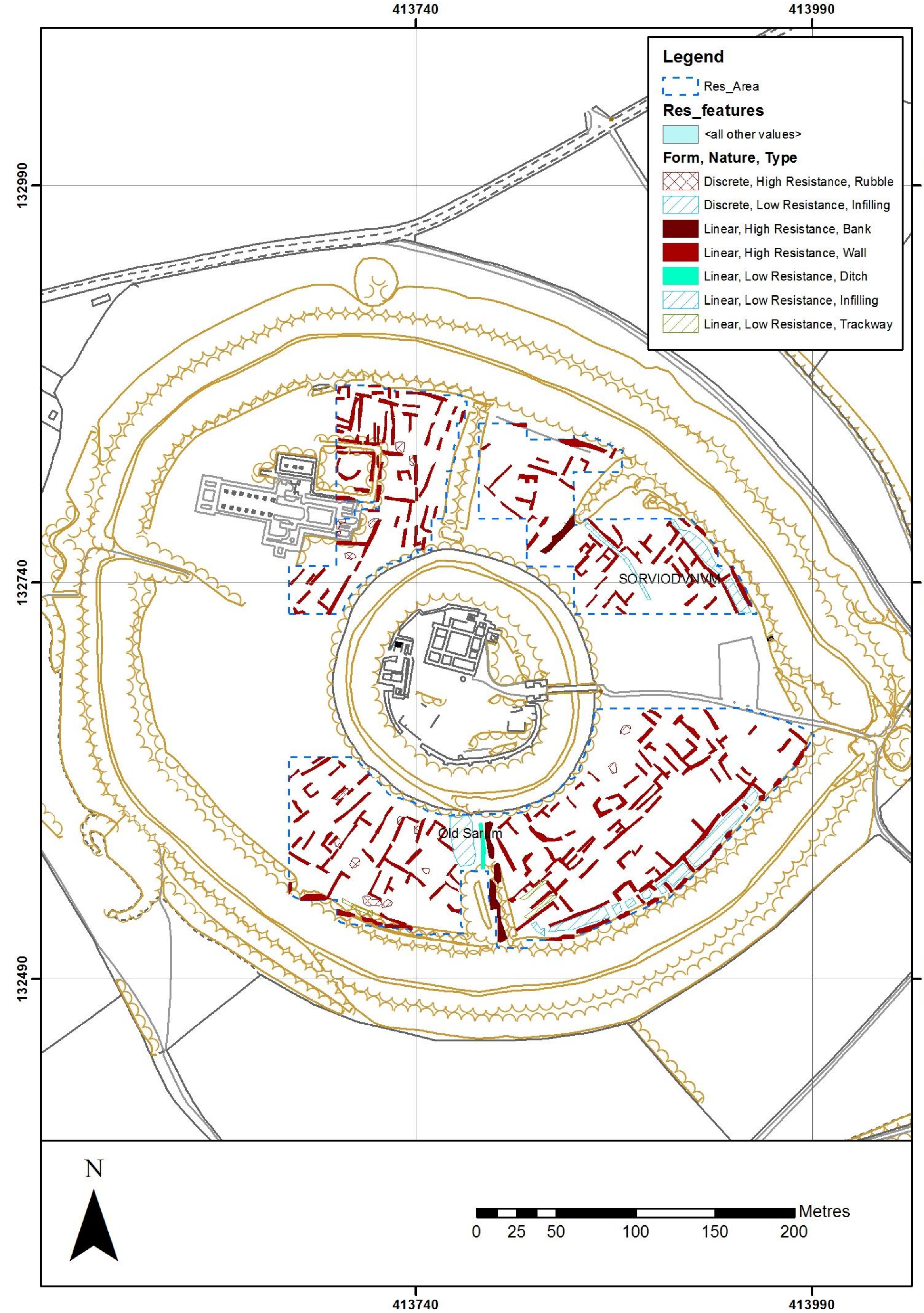

Figure 31 Interpretation plot derived from the results of the earth resistance survey for Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

To the south of the modern parking area a series of discrete high resistance anomalies **[r47]**, **[r48]**, **[r49]** and **[r50]** mark rubble deposits, with large structural remains **[r51]** close to the line of the outer bailey wall. A number of linear high resistance anomalies **[r52]** and **[r53]** mark structures in this portion of the outer bailey with a band of high resistance readings **[r53]**, **[r54]** and **[r55]** marking rubble and associated structural remains stretching for a distance of over 150m. High resistance readings close to the outer bailey ditch **[r56]** indicate a structure, and a high resistance rectilinear anomaly **[r57]** measuring 18m by 10m indicates remains of a building. A curvilinear anomaly **[r58]** and **[r59]** marks a possible wall enclosing a small area of the outer bailey. Fainter high resistance anomalies to the west **[r60]** and **[r61]** also mark structures. A linear high resistance anomaly ranging alongside the outer bailey wall **[r62]**, **[r63]** and **[r64]** indicates the presence of a substantial wall and a series of buildings stretching for a distance of over 160m.

A more open area with traces of possible high resistance features **[r65]**, **[r66]** and **[r67]** is located to the north of the long wall ending in a linear anomaly **[r68]** showing the location of a wall, with a second wall **[r69]** abutting it to the west with a low resistance band of readings, possibly suggesting a defensive wall with gate and roadway. A band of low resistance readings **[r70]** and **[r71]** indicates the area of the interior of the buildings ranged along the outer wall. High resistance and low resistance anomalies **[r72]** and **[r73]** run from north to south forming a bank and ditch cutting off the south-western quadrant of the outer bailey. A quiet area in the results **[r75]** and **[r76]** is located immediately to the west of **[r73]** perhaps indicating a continuation of the large excavated area to the south in the modern topography. A series of high resistance linear anomalies **[r77]**, **[r78]** and **[r79]** radiate out from the ditch of the inner bailey, indicating remains of structures. Similar smaller anomalies **[r80]**, **[r81]**, **[r82]** and **[r83]** also indicate buried building remains. Two further linear high resistance anomalies **[r84]** and area of possible rubble **[r85]** mark walls. To the south there is an open area close to the outer bailey wall **[r86]** then the continuation of structures **[r87]**, **[r88]** and **[r89]** ranged along the defensive wall of the outer bailey. A break in the structural features **[r90]** and **[r91]** measuring 60m by 14m is also visible. Structures then continue to the edge of the resistance survey **[r92]**, **[r93]**, **[r94]**, **[r95]** and **[r96]**, comprising high resistance linear anomalies and discrete anomalies suggesting rubble material.

3.4 Ground Penetrating Radar

A trial geophysical survey was undertaken in the inner bailey using GPR (Figs 32 and 33). The results indicated the remains of several structures associated with the bailey and the already excavated remains.

The GPR results for c. 1m depth show the corner of structural remains to the west of the gatehouse **[g1]** and the line of hard standing for the modern pathway **[g2]**. An open courtyard area is visible to the south **[g3]**, and an irregular masonry structure is positioned to the east formed from three high amplitude linear anomalies **[g4]**, **[g5]** and **[g6]** measuring some 15m across. A rectilinear structure **[g7]**, **[g8]** and **[g9]** measuring 13m by 10m is located along the southern side of the inner bailey, and a series of smaller linear anomalies **[g10]**, **[g11]** and **[g12]** mark the remains of a building abutting the wall of the inner bailey.

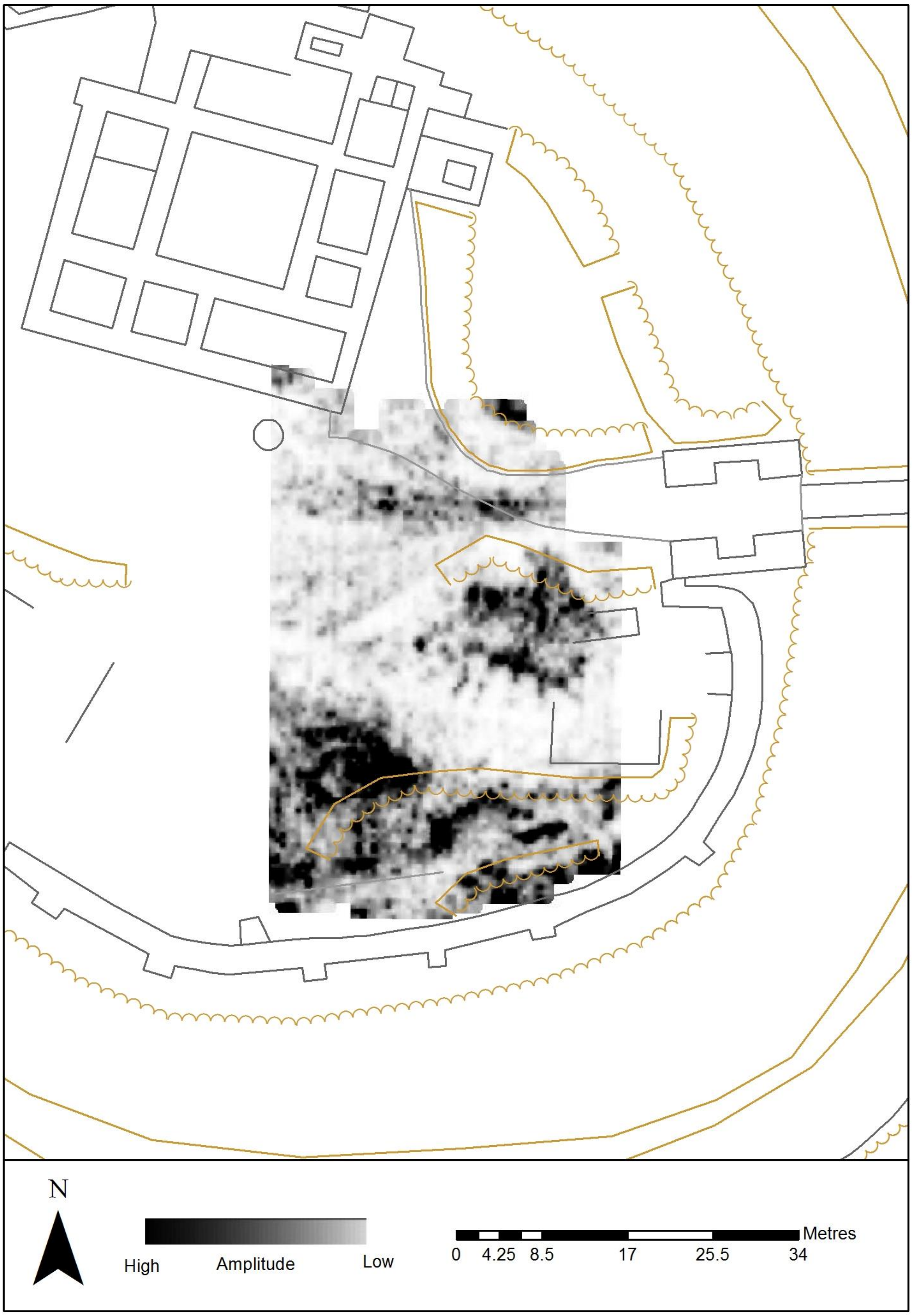

Figure 32 Greyscale image of the GPR results from the inner bailey for a depth of c. 1m (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

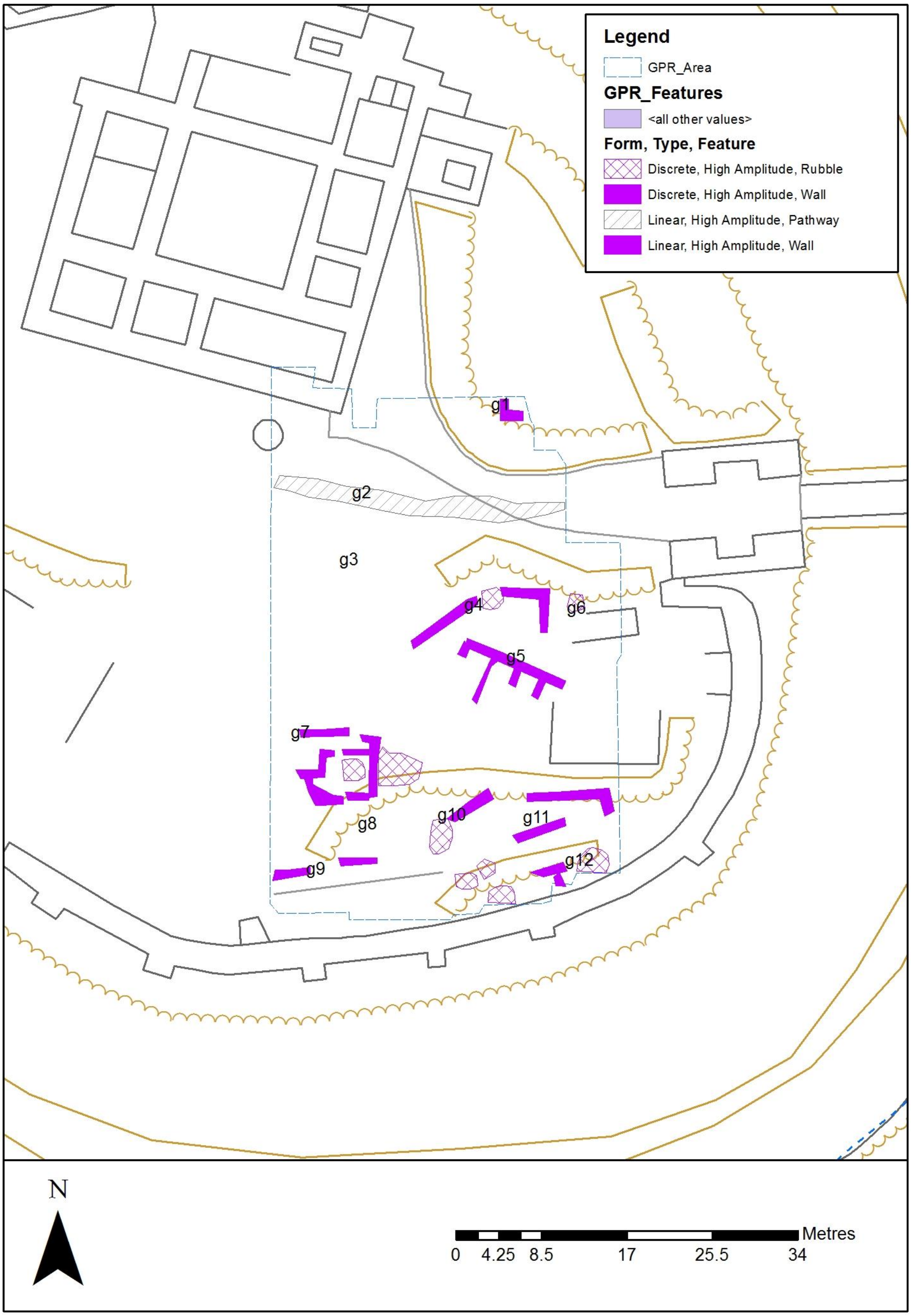

Figure 33 Interpretation plot for the GPR survey results from the inner bailey (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

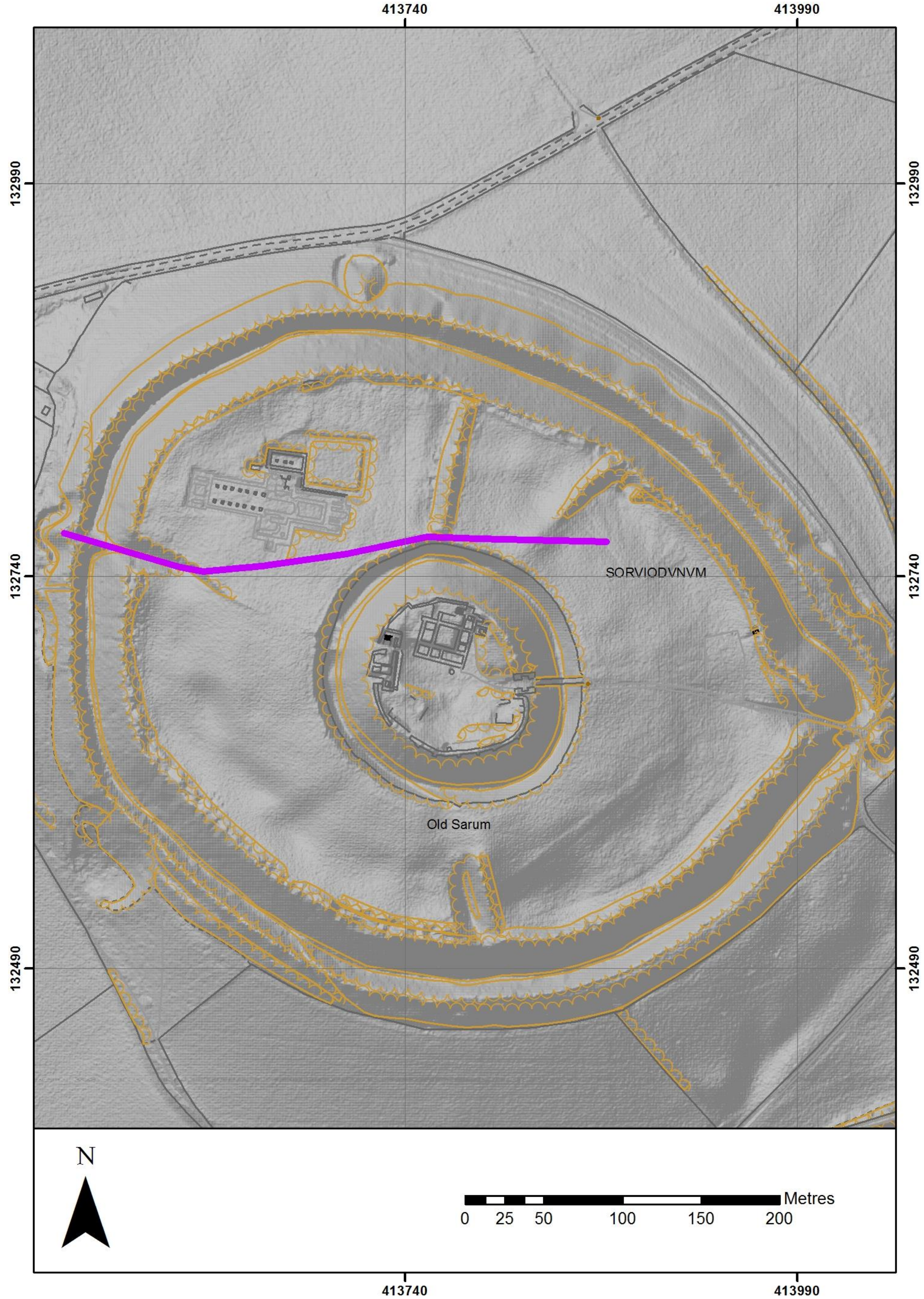

Figure 34 Map showing the location of the ERT profile across the outer bailey (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

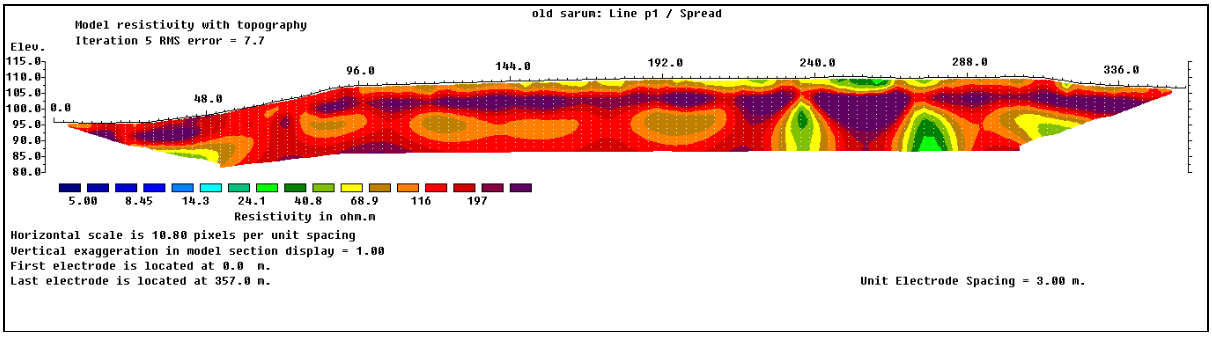

Figure 35 Results of the ERT profile across the outer bailey of Old Sarum

In addition to the GPR survey in the inner bailey, a further small survey was carried out of a trial 30m by 30m square in the outer bailey, principally as a training exercise. The data was clear and features did show in it, however the area is so small that this will be processed together with data that will be collected using the same equipment and methodology in the coming seasons of work.

3.4 Electrical Resistivity Tomography Survey

The ERT profile conducted across the outer bailey (Figs 34 and 35) was undertaken primarily to assess the effectiveness of the technique in assessing the archaeological deposits and natural geological strata of the site. Results of the survey (Fig. 35) indicate high resistivity deposits in the western (left hand) portion of the profile, corresponding with the western entrance to the site, most probably cut into the underlying chalk. At c. 100m along the profile, on the edge of the cutting through the ramparts of the site, low resistivity deposits are indicated close to the surface, some 1m in depth, increasing to 2.5m depth some 150m along the profile, then continuing to c. 220m along the profile. This series of low resistivity readings seems to indicate archaeological deposits overlying the natural chalk, and suggests quite deep stratification in the outer bailey, something that was also noted in the magnetometry (see discussion section below). A higher resistivity band in the profile occurs close to the surface around 220-230m along the profile, suggesting either bank material associated with the extant bank sub-dividing the outer bailey to the north, or the natural chalk rising to the surface. Low resistivity shallow readings are then apparent from 230m – 280m along the profile. From 280m to the end of the profile shallow readings are dominated by high resistivity, suggesting perhaps very shallow archaeological stratigraphy in this part of the site. A few small low resistivity anomalies occur, most notably at c. 310m along the profile, possibly indicating shallow (c. 1m deep) pit or ditch features.

The deeper portion of the profile indicates high resistivity from near the surface down to a depth of c. 10-12m, representing the underlying chalk. At 230m to 300m along the profile these high resistivity readings deepen, with underlying low resistivity responses, perhaps suggesting deep changes in the geology, possibly from chalk to underlying Reading Bed clays, or a possible underground spring or stream. Lower resistivity responses also occur along the entire profile, and in the western portion of the profile there is an increase in resistivity towards a depth of 16m and below, possible suggesting further chalk strata. The geological nature of the site was very much outside the scope of this survey, but the results of this work indicate that further investigation and research into the nature of the geology at the site may be useful.

4. Discussion

The geophysical survey at Old Sarum provided evidence of the development of the site and the nature of settlement at the site with, unsurprisingly, an emphasis on the medieval city in the data. A significant portion of the outer bailey was covered using magnetometry and earth resistance survey, with an ERT profile conducted across the northern part of the outer bailey. In addition the GPR survey of the inner bailey provided some evidence for the medieval plan of the area.

Data from the outer bailey (Figs 36 to 38) presents for the first time a plan of the medieval city of Old Sarum, demonstrating that the area, now an undulating area of pasture, was once a thriving settlement. The outer wall of the outer bailey is visible in the some sections of the data making its course around the bailey perimeter. A series of massive structures are ranged along the southern part of the bailey abutting the outer wall **[r62]**, **[r63]**, **[r64]**, **[m85]** – **[m90]**, **[r88]**, **[r89]**. This suggests that, for the southern part of the site at least, large structures for storage. It would seem unlikely that, in the outer bailey, these represented high status dwellings. In fact they abut the defensive walls of the settlement, and as such may indicate buildings of a military or defensive nature. An area to the north of these structures, certainly in the south-east quadrant, seems to have been kept open **[r65]**, **[r66]** and **[r67]**, **[m83]**, **[m84]**, whether for mustering of people or resources, or purely as part of a circular route through the city is unclear.

A north-east to south-west frontage of structures in located to the north of this open area **[m70]** – **[m74]**, **[r53]**, **[r54]**, **[r55]** with a series of masonry walls and deposits indicating a possible residential quarter between this and the inner bailey ditch. This quadrant of the bailey is cut off from the south-west quadrant by a bank and ditch **[r72]**, **[r73]** and **[r74]**.

In the south-west quadrant the large structures alongside the defensive wall seem to continue **[r88]**, **[r89]**, and a narrow road seems to make its way through the quadrant **[m99], [m100]**. The remaining results seem to suggest a residential area of buildings radiating out from the edge of the inner bailey ditch **[m93]** – **[m98]**, **[r80]** – **[r90]**. In addition to the walls and deposits, some other responses in the magnetometry may indicate the possibility of industrial features, such a kilns or furnaces, in this sector (for instance close to **[m92]**, **[m93]**) with large dipolar anomalies, some measuring 2-3m across. Indeed the strong positive response from some of the anomalies suggests deposits heavily affected by anthropogenic activity, suggesting dumps of ceramic, ash and other materials. The pattern of settlement, seemingly representing residential occupation, continues around to the western side of the outer bailey. It is just to the south of the western entrance to the bailey that the nature of the features changes, suggesting a completely different series of structures associated with the cathedral. Principally a number of structures are presented in the results that align with the known pattern of structures in this quadrant of the outer bailey (Rahtz and Musty 1960). However a series of anomalies are present in the quadrant that align on a north-east to south-west orientation, that suggest an earlier phase of occupation in the area.

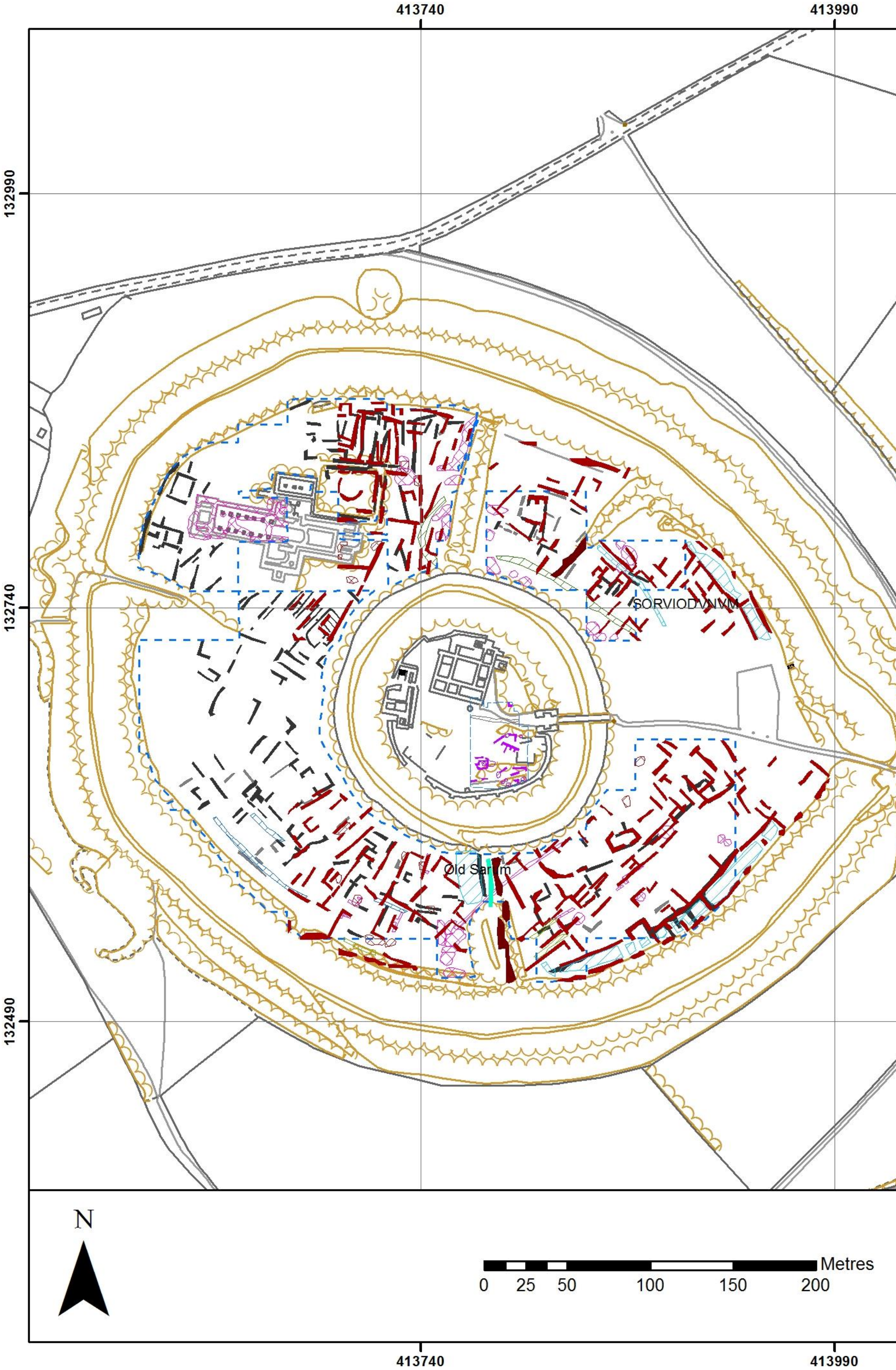

Figure 36 Composite image of the magnetometer, earth resistance and GPR interpretation plots for Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

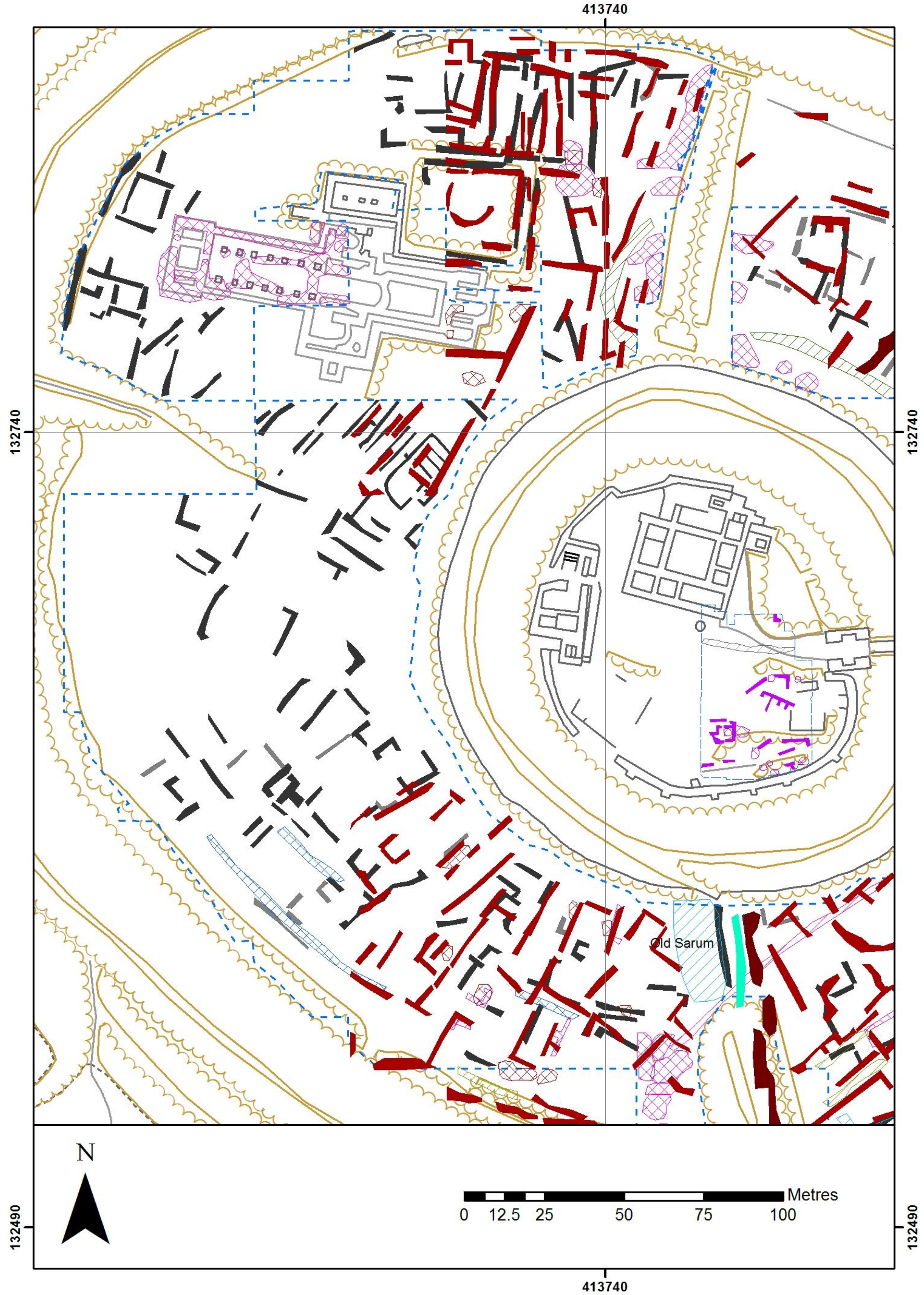

Figure 37 Composite image of the magnetometer, earth resistance and GPR interpretation plots for the western part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

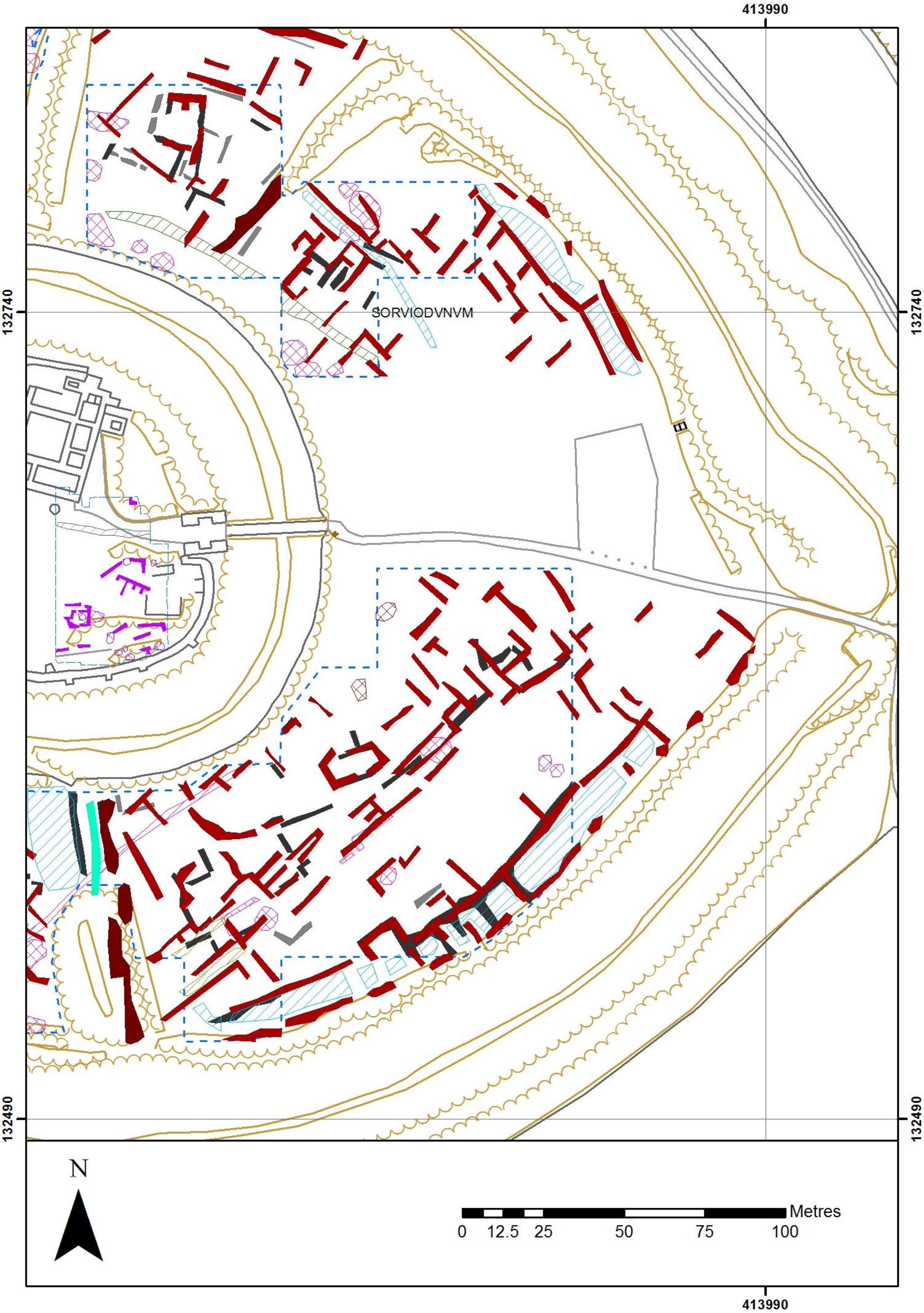

Figure 38 Composite image of the magnetometer, earth resistance and GPR interpretation plots for the eastern part of Old Sarum (© Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service)

These include the linear and rectilinear anomalies **[m119]**, **[m120]**, **[m121]** close to the ditch of the inner bailey, and the more substantial structural remains to the north-west **[m5]**, **[m6]** and **[m7]**. These features may indicate a primary medieval phase of occupation, superseded in a short timeframe by the cathedral and associated buildings that formed the focus of the excavation in the 1910s (Hope 1911; 1914; 1916; 1917). One wall represented in the excavation plan appears to be on a similar alignment. The southern edge of the cutting for the western entrance does, in the geophysics, seem to mark the start of the cathedral close with structures represented on at least two different alignments.

Survey of the north-east quadrant was the least complete, partly due to a lack of time caused by bad weather on the first day, and partly due to the presence of the modern parking area for the English Heritage site. What can be seen from the results of the survey is that the depth of stratigraphy for the area is less than in the other quadrants of the outer bailey, based on the strength of the response from different features. This also seems to be reflected in the results of the ERT survey across the outer bailey (Fig. 35). What does seem to stand out is the continuation of the pattern of settlement witnessed in the south-west quadrant of the outer bailey. A limitation of the 2014 survey is the lack of results for the parking area close to the eastern entrance to the site. This is patently a crucial area of the outer bailey, relating to the entrance to the inner bailey and to the immense structures found in the geophysical survey results in the south east quadrant. It would be beneficial for the survey work in future seasons to be focused in this area if possible.

In addition to the broad pattern of settlement at the site, a number of later potential features also stand out and deserve mention. A large structure in the north-east quadrant **[m41]**, **[m42]**, **[m43]**, **[r32]** indicates a structure superimposed on the medieval settlement pattern. In addition a strong rectilinear anomaly **[m75]**, **[r57]** marks a structure in the south-east quadrant. Finally a large depression in the topography in the southern part of the site is matched by a low resistance area in the **[r75]**, **[r76]** marking possible excavation or mining of chalk in the area. These features suggest some small degree of settlement or at least activity after the 13th and 14th century decline of the settlement.

Work in the inner bailey focused purely on a trial of GPR with the aim of mapping the medieval structures of the bailey and possibly to help locate deeper structures associated with the possible Roman occupation of the site. To this end further processing of the data is necessary. However, the preliminary results do indicate the presence of medieval structures along the southern side of the ring work of the inner bailey **[g7]**, **[g8]**, **[g9]**. It is hoped that, together with the GPR survey of the outer bailey, more extensive work may be conducted in future seasons to ascertain the nature of deposits and structures in both the inner and outer bailey.

5. Conclusions

The geophysical survey at Old Sarum in 2014 highlighted a significant number of archaeological features, and provided an overall plan for the site. It is apparent from the results that the entire outer bailey was heavily built up in the Middle Ages, and the plan of the settlement and the nature of some of the structures can be clearly identified. Among these is the presence of large structures abutting the defensive wall of the site, an open area in front of these structures with an urban residential plan surrounding the ditch to the inner bailey. A change is recogniseable between the outer bailey in general and the area of the cathedral and close. In addition several later structural features are visible, suggesting small scale settlement of the site in the late medieval period or post-medieval period. Clearly there remains much more work to do in terms of non-intrusive survey within Old Sarum itself, and in the surrounding hinterland.

6. Recommendations

- The results of the magnetometer and earth resistance survey both successfully indicate the nature and extent of archaeological features at Old Sarum. It is recommended that an integration of different techniques should be applied, including GPR, earth resistance and magnetometry to continue to clearly map such features.
- It was difficult to survey in the north-east quadrant of the site due to the modern parking area. Survey of this area is crucial to our understanding of the site and, as such, it ought to form a priority for survey work in any future season.
- The use of magnetometry and earth resistance should be complemented by extensive GPR survey for the entire outer bailey. This will enable further information to be gained on the nature of the features in this area.
- Based on the results of the 2014 season it is recommended that work in 2015 focus on completion of the survey of the outer bailey, complete survey of the outer bailey with GPR, and commencement of survey in areas outside of the Old Sarum using magnetometry.

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

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Finally, whilst this survey was partly carried out by the authors, its successful completion would have been impossible without the hard work of the survey team. Warm thanks are extended to all of the students, both undergraduate and postgraduate, that attended the survey.

Appendix 1 Details of Survey Strategy

Dates of Survey: 30th March to 11th April 2014

Site: Old Sarum, Wiltshire

Surveyors: The British School at Rome/APSS, University of Southampton

Personnel: Dominic Barker, Scott Chaussee, Elizabeth Richley, Timothy Sly, Kristian Strutt, undergraduates and postgraduates from the Department of Archaeology, University of Southampton.

Geology: Chalk

Survey Type 1: Magnetometer

Approximate area: 4 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: 3 hectares

Grid size: 30m

Traverse Interval: 1m

Reading Interval: 1m

Instrument: Geoscan Research Resistance Meter RM15

Survey Type 3: Ground Penetrating Radar 1

Approximate area: 0.1 hectares

Grid size: 30m

Traverse Interval: 1m

Trace Interval: 0.10m

Instrument: GSSI 200 MHz antenna with SIR-3000

Depth (ns): 120ns

Survey Type 4: Ground Penetrating Radar 2

Approximate area: 0.01 hectares

Grid size: 30m

Traverse Interval: 0.5m

Trace Interval: 0.05m

Instrument: Sensors and Software Noggin Plus Smartcart with 500 MHz antenna

Depth (ns): 60ns

Survey Type 5: Electrical Resistivity Tomography

Number of Profiles: 1

Instrument: Allied Associates Tigre multiprobe resistivity meter

Probe Spacing: 3m

Number of Levels: 12 (overall depth c. 18.7m)

Appendix 2: Archaeological prospection techniques utilised by the British School at Rome (BSR) and the Archaeological Prospection Services of Southampton (APSS)

The following appendix presents a summary of prospection methods, implemented by the BSR and the APSS to determine the extent and nature of sub-surface archaeological structures, remains and features. The methodology usually applied by the BSR and APSS places an emphasis on the integration of geophysical, geochemical and topographic 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. The BSR and APSS 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 (Ω), whereas resistivity, the resistance in a given volume of earth, is measured in ohm-metres (Ω/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 BSR and APSS 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 non-archaeological 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. APSS 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. GPR has been used by APSS at the Domus Aurea in Rome, at Forum Novum, and at Italica in Spain. 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.

APSS operates 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.

Topographic Survey

The modern ground surface or topography often contains important information on the conditions and nature of an archaeological site, and the potential existence of structures buried beneath the soil (Bowden 1999). The changes in topography can also have a great influence on determining the nature of features in a geophysical survey. Therefore it is vital to produce a detailed and complete topographic survey as part of the field survey of any given site. This generally entails the recording of elevations across a grid of certain resolution, for instance 5 or 10m intervals, but also the recording of points on known breaks of slope, to emphasis archaeological features in the landscape.

Survey is usually undertaken by the BSR/APSS using a total station or electronic theodolite, although Global Positioning Satellite systems (GPS) are also utilised, to record the survey points. Computer software is then used to produce Digital Elevation Models of the results. Normally, survey is carried out using a Leica total station (BSR – TC805), with readings taken every 4 metres, and also on the breaks of slope of important topographical features. The resolution can be increased where necessary. Up to 5 hectares per day can be covered.

Integrated Survey Methodology

The survey work carried out by the BSR/APSS 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

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