NSGG
Near-Surface Geophysics Group

Recent Work in Archaeological Geophysics

The Geological Society

Burlington House, London

15th December 2010

Lecture Programme:

0915-1000	**Registration and Coffee**
1000-1005	Introduction
1005-1020	*The Discovery of the Rosnaree Enclosure, County Meath, Ireland: Implications for the Continuing Evaluation of the Archaeological Potential of the Brú Na Bóinne World Heritage Site.* K Barton and C Brady.
1025-1040	*Bronze Age Settlements and New Discovered Ring Ditches of the Maykop Culture in the North-Caucasus (Russia).* J Fassbinder, S Reinhold and A Belinskiy.
1045-1100	*An Empirical Reassessment of the Utility of the Geonics EM38b Together with Suggested Methodologies for its Application in Archaeological Investigations.* P Cheetham.
1105-1120	*New Approaches to Improve Magnetic Prospection: Applications on Archaeological Sites in Provence.* Y Quesnel, A Jrad, H Boukbida, P Rochette, P-E Mathé, J Gattacceca, J-C Parisot, D Hermitte, S Khatib and F Mocci.
1125-1155	**Coffee**
1155-1210	*Longhouses, Field Boundaries and Rocky Outcrops: Modelling of Geophysical Data Sets Affected by Geological Outcrops in the Shetland Island for Past Land Use.* R Legg, J M Bond, C Gaffney and C P Heron.
1215-1230	*Adaptation of Aero-Magnetic Interpretation Techniques for Archaeo-Magnetic Purposes.* S Cheyney, I Hill, N Linford, S Fishwick and C Leech.
1235-1250	*Data Presentation and Interpretation – Using Google Earth as a Delivery Medium.* J Lyall.
1255-1300	Morning closing remarks
1300-1430	**Lunch (available locally)**

1430-1445	*Recent Works in G.P.R. Applied to Cultural Heritage.* P M Barone, E Pettinelli, S E Lauro and E Mattei.
1450-1505	*Reflections from Westminster Abbey.* E Utsi.
1510-1525	*What Shielding? How to Pick Up Signals with a GPR Antenna.* A Schmidt.
1530-1600	**Tea**
1600-1615	*The Ludwig Boltzmann Institute for Archaeological Prospection & Virtual Archaeology - A New Perspective for Landscape Archaeology: Research Programme and First Results From Large-Scale, High-Resolution Archaeological Prospection.* I Trinks, A Hinterleitner, E Nau, T Zitz, K Löcker, M Gabler, W Neubauer, M Doneus, N Doneus, M Kucera, C Briese and D Scherzer.
1620-1635	*Methodological and Archaeological Challenges in the First Season of the Stonehenge Hidden Landscapes Project.* C Gaffney, V Gaffney and W Neubauer.
1640-1655	*Towards Reconstructing an Ancient City: Case Study of Pelusium, Northern Sinai, Egypt.* T Herbich.
1700-1715	*Early Urbanism in Europe? Geophysical Survey at Nebelivka, Ukraine.* Duncan Hale, J Chapman, N Swann, M Videiko and R Villis.
1720-1730	Conclusion
1730-1930	**Wine reception in Lower Library**
1730-1830	Separate event: ISAP AGM

<u>Posters (09:30-19:30 in the Lower Library)</u>:

East Park, Sedgefield, County Durham - Geophysical Survey of a Roman Civilian Settlement. D Hale, N Swann and R Villis.

Mapping Pleistocene Landscape Features Using Archaeological Geophysics. A Butler and J Walford.

Geophysics in Your Back Garden: From Rural Retreats to Royal Palaces 18 Years of 'Geophys' On Time Team. E Wood and J Gater.

'It Never Rains But It Pours' Earth Resistance Seasonality Testing in Bradford. A Parkyn.

The Interface of Geophysical and Geochemical Survey: Towards an Understanding of Geophysical Data Quality in Challenging Archaeological Sites. C Cuenca-Garcia.

Enhancing Magnetic Survey Interpretation of Roman Cities: Geophysical Data Combination and Archaeological Feedback on Ammaia. J Verhegge, A Schmidt, C Gaffney, F Vermeulen and L Verdonck.

Detecting Mass Graves on Historic Battlefields. P Masters and C Enright.

3D GPR-Survey in the Roman Town of Baalbek. R Linck, J Fassbinder and M van Ess.

Neolithic - Early Iron Age Sites at Serteya, North-West Russia: Archaeological Survey, Magnetometry And Susceptibility Prospecting. D Yu Hookk, A N. Mazurkevich and J Fassbinder.

A Ground Penetrating Radar Survey at Thorpe Waterville Castle, Northamptonshire. T Dennis, S Parry, M de Bootman and J Fulcher.

Geophysical Surveys to Assist the Instar Boyne Landscapes Project at the Brú Na Bóinne World Heritage Site, County Meath, Ireland. K Barton, C Brady and Steve Davis.

Identifying The Wessex Culture - A Geophysical Analysis of the Clandon Aggrandised Barrow. P Cheetham and J Gale.

Preliminary Geophysical Survey Results From Songo Mnara, Tanzania. K Welham and H Manley.

Large Scale Geophysical Surveys at the Roman Legionary Fortress of Inchtuthil, Perth & Kinross, Scotland. D J Woolliscroft, B Hoffmann and P Morris.

Archaeomagnetic Prospecting for an Ancient Roman-Byzantine Church Site at Yasilah (Pella) in Northern Jordan. K Fahmi and A Qazaq.

Geophysical Prospection in Peatland Environments: A Toolkit for Archaeological Practice. K Armstrong, T Darvill and P Cheetham.

Beyond Venus; the Geophysical Survey of Links of Notland, Westray, Orkney. A Kattenberg and J Kainz.

Reconstructing the Ring of Brodgar – Using Earth Resistance, ERT and GPR to Locate Further Monoliths. I Wilkins, M Saunders and A Brend.

Recent Geophysical Survey at the Site of Çatalhöyük, Turkey. J Ogden, I Hodder and K Strutt.

Man and Machine: Progress in Geophysical Data Acquisition and Handling. M Roseveare and A Roseveare.

The DART Project: A Major New Investigation Into What Lies Beneath Our Soils. A. Beck, A Cohn, C Gaffney, N Metje, C Neylon, A Schmidt, M Steven, K Wilkinson, D Boddice, R Fry, L Pring and D Stott.

Testing a Multi Method Approach for a Geophysical Investigation of Norwegian Iron Age Settlements – Assessment of Methods and Suggestions for a Sequential Survey Design. A A Stamnes.

Roman Dalswinton in South West Scotland: A Comparison of Single and Sixteen Sensor Magnetic Surveys. R Jones, O O'Grady, R Jones and B Hanson.

Commercial Exhibitors:

3d-Radar

Bartington Instruments Ltd

DW Consulting

Geomatrix Ltd

Geoscan Research Ltd

Utsi Electronics Ltd

LECTURE ABSTRACTS

THE DISCOVERY OF THE ROSNAREE ENCLOSURE, COUNTY MEATH, IRELAND: IMPLICATIONS FOR THE CONTINUING EVALUATION OF THE ARCHAEOLOGICAL POTENTIAL OF THE BRÚ NA BÓINNE WORLD HERITAGE SITE

Kevin Barton[1] and Conor Brady[2]
[1]Landscape & Geophysical Services, Convent Road, Claremorris, County Mayo, Ireland; [2]Department of Humanities, Dundalk Institute of Technology, Dublin Road, Dundalk, County Louth, Ireland.

kevin.barton@lgs.ie

Historically, for site discovery and delimitation aerial photography, and latterly LiDAR, has been used in Brú na Bóinne, an internationally significant archaeological landscape known for its many Neolithic passage tombs and other monuments (Fig 1). The question of where in the landscape the population who constructed and used these monuments was located remains largely unexplored. The present day landscape is mainly composed of the floodplain and terraces of the River Boyne which are farmed in a combination of pasture and tillage crops.

Fieldwalking at Rosnaree in 1999 first identified a large, dense scatter of worked lithics (chipped stone artefacts, primarily flint) in the NE corner of a tillage field (Fig 2A). The lithics suggested intensive activity, possibly involving residential settlement, broadly dating to the Neolithic (c.4,000-2,500 cal BC). Unlike the passage tombs, the Rosnaree site is located on the southern side of the River Boyne, at a highly significant location within the Brú na Bóinne complex. It marks the point at which the river begins to delineate the famous ‘bend’ of Brú na Bóinne and is located directly to the SW and across the River Boyne from the Knowth passage tomb complex. It sits on a hitherto unremarkable low knoll on the first gravel terrace above the river.

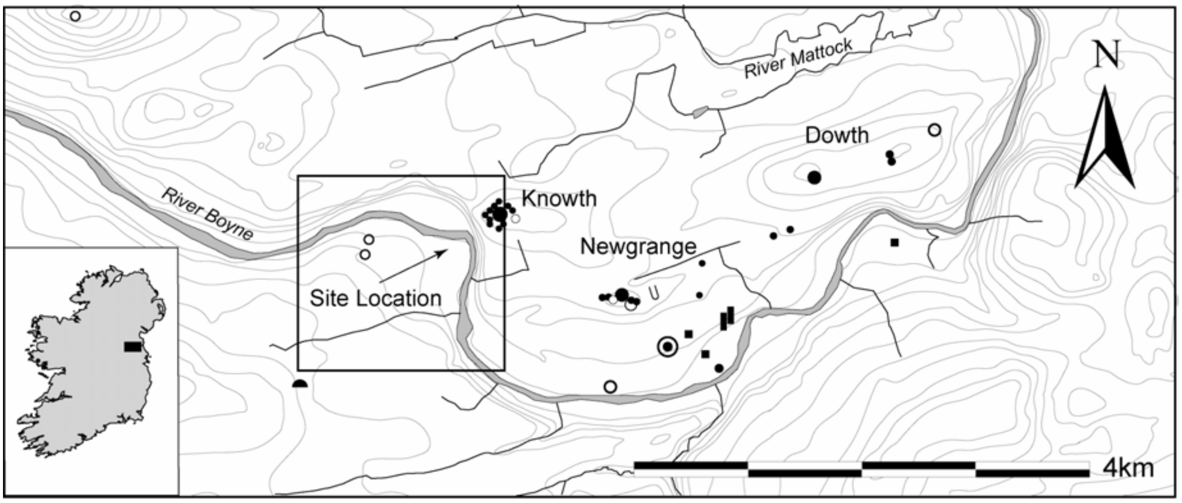


Fig 1: Location of the Rosnaree site within the Brú na Bóinne Complex

Follow-up fieldwalking with combined topographic and reconnaissance topsoil magnetic susceptibility survey on a 10m x 10m grid (Fig 2B & 2C) delineated a zone of susceptibility enhancement coincident with the dense scatter of lithics. The anomalous zone also appeared to be related to a small topographic rise in the NE corner of the field. There was no evidence for the site from legacy aerial photography or in more recent LiDAR data.

In 2008 a magnetic gradiometry survey on a 1m x 0.25m grid (Fig 2D) funded by the Heritage Council revealed the presence of an enclosure which has a complex set of internal features and is likely to be multi-phase. The enclosure is multi-vallate with positive magnetic gradient interpreted as being due to silted ditches. The enclosure measures *c.*110m N-S x *c.*160m E-W. At the time of geophysical discovery a small area of the presumed core of the enclosure was surveyed using earth resistance on a 0.5m x 0.5m grid (Fig 2E). The resistance response differed from the gradiometry response in revealing that one of the ditches lay in a broad zone of low resistance coincident with a channel-like feature seen in the topographic data. Complex features of positive gradient in the core area seen in the gradiometry data were not imaged in the resistance data.

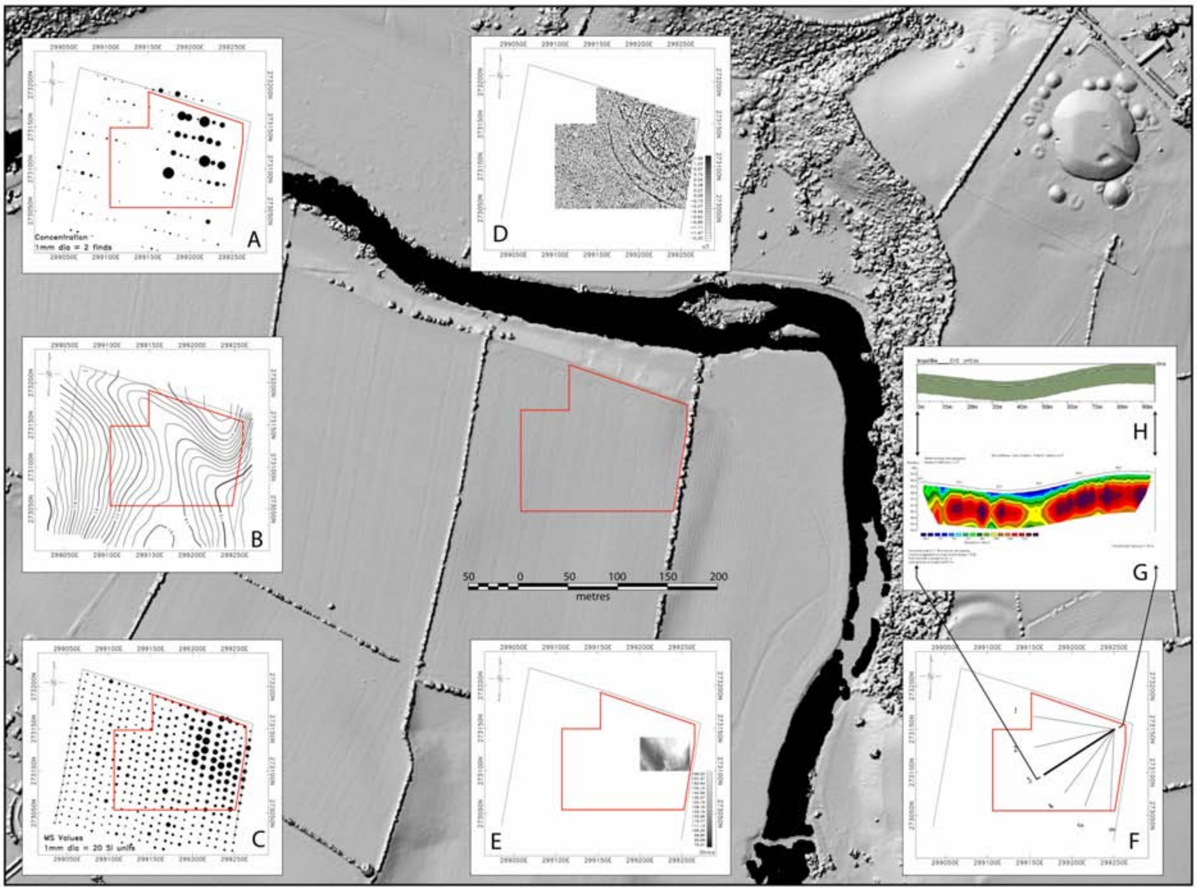


Fig 2: Montage of lithics, topography and geophysical survey results -
***A**: Proportional symbol plot of lithics density recorded during initial fieldwalking survey. **B**: Microtopography (Contours at 0.2m intervals). **C**: Proportional symbol plot of reconnaissance magnetic susceptibility data. **D**: Magnetic gradiometry image. **E**: Earth resistance image. **F**: Location of transect ERT 3 used for radial electrical resistivity tomography and ground penetrating radar profiles. **G**: ERT 3 - Modelled electrical resistivity tomography pseudosection. **H**: Ground penetrating radar section. The background for this image is from a recent LiDAR survey of the Brú na Bóinne World Heritage Site (courtesy of Meath County Council).*

In order to resolve some of the questions arising from the data gathered a series of radial Electrical Resistivity Tomography (ERT) and ground penetrating radar (GPR) transects were planned in 2009 (Fig 2F). ERT 3 (Fig 2G), using a 1m electrode spacing configured in a Wenner array, confirmed the two outer ditches and showed the third ditch to lie in a presumed natural sediment-filled channel. The GPR survey (Fig 2H) used a cart-mounted 400 MHz centre-frequency antenna with a sampling interval of 0.02m. The results were disappointing with a subdued response and little correlation with the ERT results. This may be due to there being a significant silt and clay component in the topsoil and sub-soil.

In order to provide secure dating for the features identified during the geophysical investigations, to explore some of their detail and to test some of the geophysical results, it was decided to conduct a test excavation. The most suitable location lay immediately to the north of the core area where the gradiometry survey had been conducted (Fig 2D), on steeply sloping ground directly overlooking the bank of the River Boyne. From an excavation point of view the selected location had the advantage of being outside the tillage field where the lithic scatter was first identified and thus would not interfere with farming activities. It also appeared that preservation or archaeological stratigraphy was likely to be excellent as there was no evidence of cultivation ever having taken place in this location. An earth resistance survey was done in the area to be excavated as the steep and uneven terrain had prevented gradiometry being carried out. The resistance survey imaged the previously interpreted ditches which are located close to low banks which are not visible in the core area.

In early 2010 in order to further assist the planning of the excavation a 122m ERT transect was carried out to optimise the location of the trenches relative to the ditches. ERT 7 (Fig 3) ran WSW – ESE sub-parallel with the slope and confirmed the location of the ditches seen in the gradiometry and resistance data. In addition the depth and extent of ditches to be excavated were interpreted from the modelled section allowing for appropriate allocation of excavation resources.

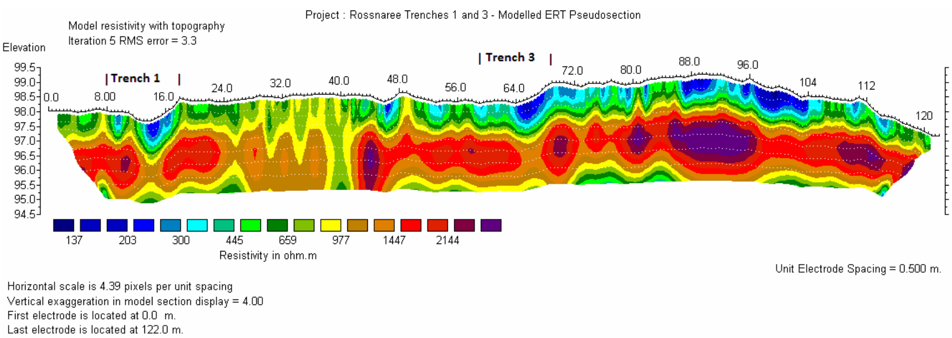
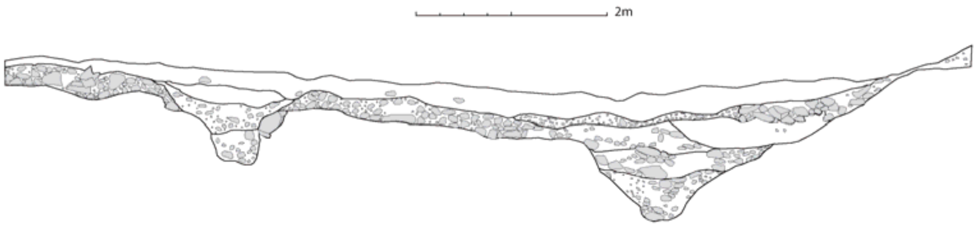


Fig 3: ERT 7 – Modelled electrical resistivity tomography pseudosection (arbitrary height datum) with the location of Trenches 1 & 3 (vertical exaggeration x 4).

The excavation of Trenches 1 and 3 in July 2010 largely confirmed the geophysical interpretation (Fig 4) and recovered artefacts which, pending C14 dating, are believed to be early medieval in date. These excavation results seem to indicate that the ditches are not Neolithic in date and the question of the nature of activity and possible location of the population in Neolithic times at Rosnaree remains unclear. Further detailed geophysical work in summer 2010 will be presented that has identified a 30m x 20m enclosure in the core area which appears to be unrelated to the previously discovered ditches. This will be a possible excavation target for 2011. Investigation of this site addresses some of the key research questions identified in the Brú na Bóinne World Heritage Site Research Framework; developing new and refined methodologies in searching for new sites - in particular those related to settlement, the scale of operation of the monument complex, the changing environment and the significance of the River Boyne itself. What can we learn from lithic scatter, remote sensing and excavation data from this site that can assist us in a larger scale geophysical evaluation of the archaeological potential of the Brú na Bóinne World Heritage Site?

Fig 4: Section drawing from Trench 1 excavated across the outer ditch (vertical exaggeration x 1).



BRONZE AGE SETTLEMENTS AND NEW DISCOVERED RING DITCHES OF THE MAYKOP CULTURE IN THE NORTH-CAUCASUS (RUSSIA)

Jörg W.E. Fassbinder(1), Sabine Reinhold(2) and Andrej Belinskiy(3)
(1)Bavarian State Dept.of Monuments and Sites, Archaeological Prospection, Postfach 100203 D-80076 Munich, Germany; (2)Deutsches Archäologisches Institut Eurasien Abteilung, Im Dol 6. D-14195 Berlin, Germany; (3)Unitary Government Enterprise Naslediye, Stavropol Krai, Stavroplol, Russia.

joerg.fassbinder@blfd.bayern.de

Introduction

On a plateau in the North Caucasian piedmonts, south of the town Kislovodsk, Dmitry Korobov and Sabine Reinhold discovered a new type of Bronze Age settlement. The analysis of satellite and aerial photos revealed more than 55 of these sites. The characteristic of the sites is a symmetric layout of houses around a large central area. By further analysis of satellite images from the lowlands between Stavropol and Pyatigorsk we discovered 16 enclosures that resemble very much in their size and shape those of the well known Neolithic ring-ditches from Slovakia, Austria, Southern Bavaria and from England.

Here we report on the results and the potential of the geophysical prospecting of a selection of different settlements around the Caucasus. Our results show that the combined interpretation of aerial photographs, satellite images, topographical maps and geophysical data reveal detailed information on the archaeological structures and allows already a good understanding of the sites.

Fig. 1: View of the survey site of Kabardinka. In the background the Elbrus massif, with an altitude of 5643m the highest mountain of Europe.

Results

The characteristic trait of the newly discovered settlements in the south of Kislovodsk is a central oval place, surrounded by rows of up to 35 attached buildings. Most of these sites have a symmetrical layout with bear resemblance to the shape of a horseshoe. There are, however, others in the form of large rows of houses. The configuration of the buildings forms small villages, roughly one hectare in size. The architecture is built of stone, that’s why their ruins are still on the surface and on the remote sensing data. They occur in a zone between the foreland and the high mountains of the Elbrus massif around the city of Kislovodsk. So far 55 sites of this type are arranged like an array from the Pokunsyt to Kabardinka mountain ranges and are located on the plateau edges which decline to the north.

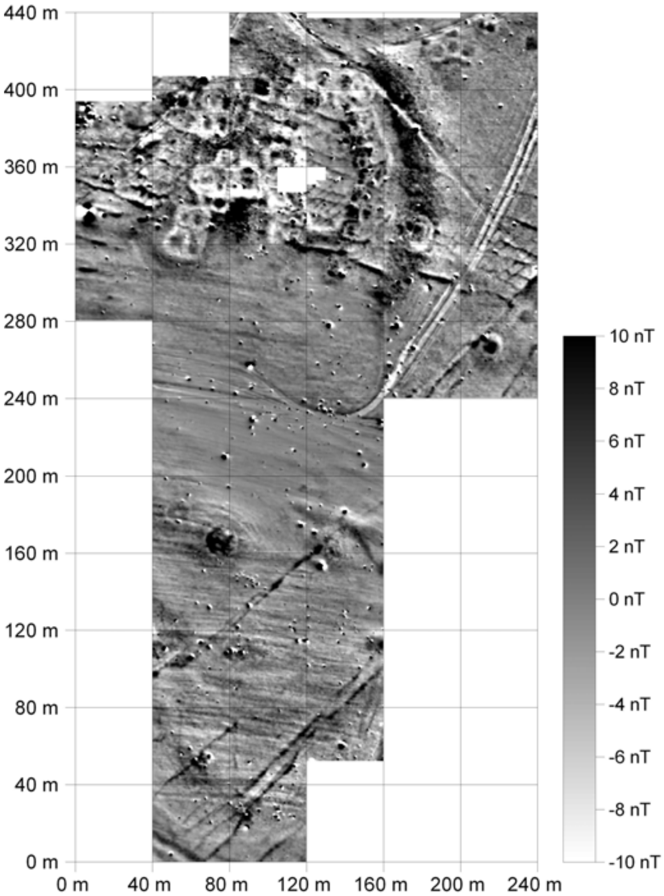


Fig. 2: Magnetogramm of Kabardinka II. Smartmag SM4G special in duo-sensor configuration, total Earth’s magnetic field ca. 49.450 nT, dynamics +/-10,00 nT in 256 grey values from black to white, grid size 40m x 40m, sampling density interpolated to 25cm x 25cm. In the upper part we see the layout of the houses in the shape of a horse shoe in the bottom we found single burials between the upstanding burial mounds.

The sites are at an altitude of 1400 – 2400 meters above sea level and therefore far beyond the zone of agriculture today. Grazing land is used only up to an altitude of 1800m. Therefore we do not talk about a few individual settlements but of a whole cultural landscape with a certain mode of subsistence.

Here the magnetometer data revealed further archaeological details of the inner structure of the houses (fig.2). Inside of some of the houses we detected fireplaces but no traces of pottery kilns. Some other houses were traced by their negative anomaly from the limestone fundaments in the adjacent magnetic topsoil.

The topographically visible structures of the buildings, (nonmagnetic limestone) show up as negative magnetic anomalies in the adjacent soil. These structures are a bit diffuse due to the fact that the stone debris from the walls covers the groundwork of the houses. The interior of these two rows of houses, which face to the inner central area, reveals higher magnetic anomalies than the other rooms of the building. This is due to a higher activity and the use of hearths and fireplaces, and to ceramic or organic material.

The resulting magnetogram images reveal also details on the environment of the settlement. Some of the topographically visible burial mounds have stone chambers and others have not. Moreover some so far unknown burials were clearly detectable. In the south of the biggest burial mound we found the occurrence of further burials.

An additional outcome of the magnetometer survey was the discovery of a ring shaped zone of highly magnetic material outside the settlements. This material consists very probably of highly magnetic midden deposits and is concentrated in a ca 30-meter broad band around the settlement. This zone obviously refers to the arrangement of the settlement. It was crucial for the interpretation that this zone is correlating with an area of a high concentration of pottery findings. If this is due to debris or to the trace of seasonal settlements aligned parallel to the stone houses will be clarified soon by archaeological excavation.

New discovered ring-ditches of the Maykop culture?

The traces of ring ditches similar to the Neolithic ring ditches that were known from Austria, Slavakia, Southern Bavaria and England were found by the analysis of satellite images from as well as during a scheduled Aeroflot airlines flight, during the start from Mineral'nye Vody in May 2010.

Magnetic prospection of two of these sites revealed both a circular ditch with a diameter of ca. 80m (fig.3). Nearly parallel, but outside of the ditch we traced the constructions of a wall, roughly 150m in diameter. No entrance and no other structures inside this monument were clearly detectable by our survey. First archaeological field survey yielded ceramics and pottery findings that could be clearly ascribed to the Maykop culture ca. 3700-2500 BC.

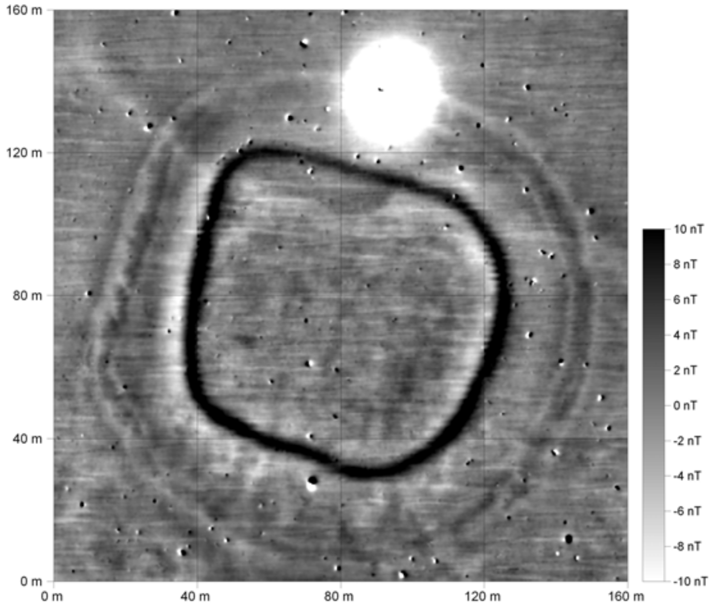


Fig. 3: Magnetogramm of a new discovered ring-ditch near the village Tambukan (North Caucasus). Smartmag SM4G special in duo-sensor configuration, total Earth's magnetic field ca. 49.800 nT, dynamics +/-10,00 nT in 256 grey values from black to white, grid size 40m x 40m, sampling density interpolated to 25cm x 25cm. (The big white spot in the upper part of the magnetogram is caused by a big iron mast of the Russian Topographical Survey).

Conclusion
Without destruction and excavation, but by a combination of magnetometer data with the satellite images, this approach turned out to be a very suitable method, both to find and to discover but moreover to trace previously unseen and unknown structures beneath the large area of these landscapes. An association of these finding with selective archaeological excavation will yield further evidence on the dating but moreover it will also explain the utilization of the settlements and the ring ditches in more detail.

AN EMPIRICAL REASSESSMENT OF THE UTILITY OF THE GEONICS EM38B TOGETHER WITH SUGGESTED METHODOLOGIES FOR ITS APPLICATION IN ARCHAEOLOGICAL INVESTIGATIONS

Paul Cheetham
Archaeology Group, School of Applied Sciences, Bournemouth University, Talbot Campus, Fern Barrow, Poole, Dorset, BH12 5BB, UK.

PCheetham@bournemouth.ac.uk

Electromagnetic induction devices (EMI) of the ‘Slingram’ type were amongst the first geophysical instruments to be investigated for archaeological applications. Despite initially promising results from early work undertaken in the 1960s and 70s, and continued interest in these instruments mainly in France (e.g. Benech & Mamet 1999) and in North America (e.g. Clay 2006; Dalan 2006), the use of these instruments is still the exception rather than the rule, with the number of surveys undertaken being relatively low in comparison to other techniques (Gaffney & Gater 2003: 44).

The Geonics EM38 family of EMI instruments has a long perigee of use in archaeological applications, but it could be argued that they not actually lived up to their potential. Consequentially, their impact, as is true of similar ‘Slingram’ EMI instruments, has been limited. However, the introduction of mechanised multisensor platforms has somewhat reinvigorated the use of these instruments as they can be towed along in conjunction with magnetometry systems. In some such systems the EM38 has been instrument of choice (e.g. English Heritage 2008: fig. 19) and so a reassessment of its use in archaeological evaluation work is timely. There have also been a number of variants of the instrument with the introduction of the EM38DD, which allows measurement in both vertical coplanar (VCP) and horizontal coplanar (HCP) orientations simultaneously, and the EM38B, which allowed both quadrature (apparent conductivity) and in-phase (apparent magnetic susceptibility) to be measured simultaneously, the latter being the most important in the opinion of the author.

Alongside the more general considerations of the value of ‘Slingram’ instruments there have been long-standing technical debates as to the most effective coil configurations, orientations and separations and the use of differing instrument for differing applications (e.g. Benech and Mamet 1999). In respect of the EM38 there are also differing views of even how such instruments should physically be used, with Clay (2006) suggesting holding the EM38 in (VCP) orientation 15cm above the ground for conductivity work while for susceptibility work (e.g. Tatiana & Bevan 2009) it is suggested holding the instrument at a height of 0.6m above the ground to ensure the in-phase response in VCP orientation is always of the same polarity. These two survey methodologies are clearly incompatible if recording in-phase and quadrature responses simultaneously as is possible with the EM38B. Despite debates about the need to consider the orientation of the instrument it is almost invariably employed in the VCP rather than the HCP orientation. However, inspection of the response with depth curves suggests that contrary to this the HCP orientation is far more preferable for general archaeological prospection evaluation work – see figure 1. There is also a dearth of published HCP surveys that consider both in-phase and quadrature responses together, so limiting an assessment of the full potential of this instrument.

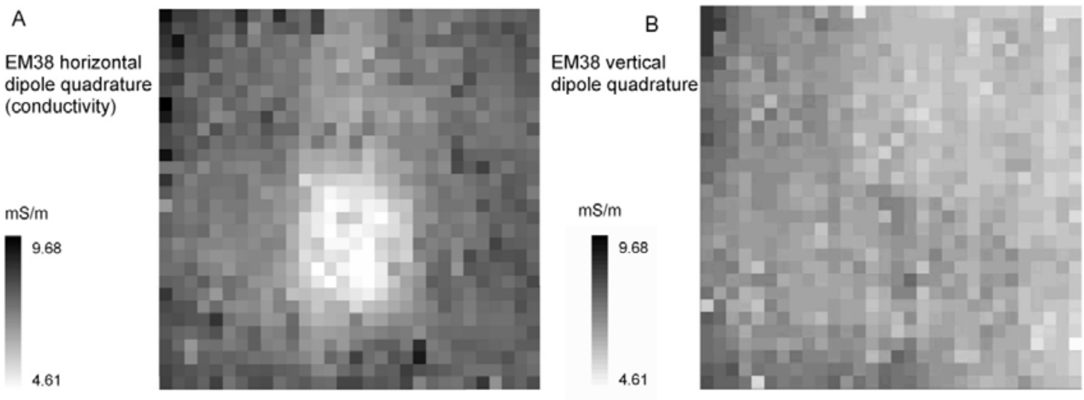


Figure 1: Now you see it now you don't. Geonics EM38B quadrature horizontal coplanar (horizontal dipole) and vertical coplanar (vertical dipole) surveys of the same mound surveyed on the same day plotted over the same range. Such orientation dependency demonstrates the potential strengths of the EM38 – but also dangers inherent in the complexity of the instrument's response characteristics. Data from the Billown Neolithic Landscape Project - Bournemouth University and the Manx National Heritage.

Over a number of years Bournemouth University have been routinely undertaking multi-technique surveys over various monument types. This has resulted in a large database of comparative surveys for the Geonics EM38B and the more usually employed twin-probe, fluxgate gradiometry and topsoil magnetic susceptibility instruments. From this body of work it has been possible to better analyse the strengths and weaknesses of the EM38 and the situations in which it can be most productively deployed. This has demonstrated that its use can significantly enhance the two above mentioned techniques if it is used to its full capacity by using it in both its horizontal and vertical dipole configurations. Further, employing the ability of the EM38B to measure and record both in-phase and quadrature responses simultaneously, has shown that the instrument can produce results that closely mirror those of 0.5m twin earth resistivity, fluxgate gradiometry and topsoil magnetic susceptibility, and that for general evaluation work the horizontal dipole orientation is to be preferred. This paper focuses on a range of practical case studies and will aim to stimulate more interest, and so the more frequent use, of this and similar electromagnetic instruments in archaeological work, both commercial and research.

Bibliography

Benech, C. & Mamet, E. 1999 Optimum Depth of Investigation and Conductivity Response Rejection of the Different Electromagnetic Devices Measuring Apparent Magnetic Susceptibility. *Archaeological Prospection* **6**:31-45.

Clay R.B. 2006 'Conductivity Survey: A Survival Manual' in Johnson, J.K. (ed.) *Remote Sensing in Archaeology: An Explicitly North American Perspective*, Alabama Press: Tuscaloosa, 79-107.

Dalan, R.A. 2006 'Magnetic Susceptibility' in Johnson, J.K. (ed.) *Remote Sensing in Archaeology: An Explicitly North American Perspective*, Alabama Press: Tuscaloosa, 162-203.

English Heritage, 2008. *Geophysical Survey in Archaeological Field Evaluation (2nd Edition)*. English Heritage: Swindon.

Gaffney, C. & Gater, J. 2003 *Revealing the Buried Past*, Tempus: Stroud

Tatiana, S. & Bevan, B. 2009 *A Geophysical Survey at Huseby*. Unpublished survey report for Vest-Agder fylkeskommune, Regionalavdelingen, Kulturminnevernseksjonen, Norway. Available from http://www.vaf.no/Huseby_PKxWo.pdf.file [Date Accessed: 22nd November 2010]

NEW APPROACHES TO IMPROVE MAGNETIC PROSPECTION: APPLICATIONS ON ARCHAEOLOGICAL SITES IN PROVENCE

Y. Quesnel[1], A. Jrad[1, 2], H. Boukbida[1], P. Rochette[1], P.-E. Mathé[1], J. Gattacceca[1], J.-C. Parisot[1], D. Hermitte[1], S. Khatib[3] and F. Mocci[4].
[1]CEREGE, UMR 6635 CNRS/Aix-Marseille University, Aix-en-Provence, France; [2]Tunis-El Manar University, Tunisia; [3]Laboratoire Départemental de Préhistoire du Lazaret, Nice, France; [4]Centre Camille Jullian, UMR 6573 CNRS/Aix-Marseille University, Aix-en-Provence, France.

quesnel@cerege.fr

Several archaeological sites in Provence (France) have been studied by ground magnetic prospection. Our main instrument is a Geometrics G858 magnetometer in a vertical gradient configuration. Different magnetic signals are observed, depending on the site's conditions. The main problem is that recent activities often let many small iron pieces in the sub-surface and surroundings of the target site. Despite our efforts to clean the studied area before prospection, difficulties still occur to obtain a magnetic anomaly map free of noise or unwanted signal. This is enhanced by the generally weak magnetic signal in Provence where limestones compose most of the rocks on archaeological sites. Only remanently magnetized objects/rocks offer significant magnetic field anomalies. Here we present two approaches to improve the identification of true archaeological magnetic sources.

Experimental approach

In the Lazaret prehistoric cave (Nice, France), some hearths were excavated in the clay ground. Archaeologists asked us to perform magnetic prospection to detect other eventual hearths embedded below the actual surface in the cave. However, the magnetic signal of such hearth is hidden by the surroundings like inducely-magnetized iron pieces needed for archaeological investigations. Therefore we tried to reproduce the true magnetic signal of a prehistoric hearth in order to unveil it in the cave. An experimental fireplace using the cave's soil and stones was built in a 1m^2 box (Fig. 1a). Using seaweeds, two consecutive fires of several hours were performed on this analog of soil. Magnetic field over the soil, surface susceptibility and remanent magnetization of the burnt soil, as well as subsurface temperature, were measured before and after fires. The resulting magnetic field anomaly is about 200 nT in amplitude. Among magnetic field anomaly and susceptibility maps, we will also present the results concerning the evolution of the soil magnetic properties during such fires. For example, we discovered that thermoremanent magnetization only affects the subsurface of the soil (Fig. 1b). This simulation will then serve for other archaeological sites where hearths or ovens burnt the soil.

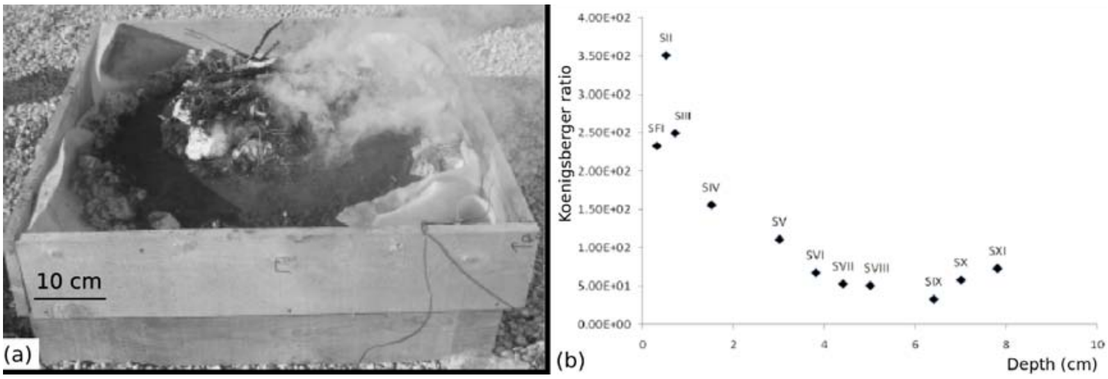


Figure 1: (a) experimental prehistoric hearth using soil of the Lazaret's cave (Nice, France); (b) vertical variation of the Koenigsberger ratio in the burnt soil of the experimental hearth. This diagram shows that remanent magnetization affects magnetic minerals close to the surface up to 1-2cm in depth.

Numerical approach to identify true magnetic sources on archaeological sites, data processing and magnetic modelling can also be performed. Indeed the signal of some recent agricultural iron pieces buried in the soil is often of high amplitude and small wavelength. Then specific data processing like filtering is a suitable method to remove these unwanted anomalies. Application to data acquired on the Roman and Middle Age Richeaume XIII necropolis (Puyloubier, France), where burnt layers of cremation and sepultures covered by Roman tegulae are buried, will be discussed. Additionally, preliminary results of specific forward and inverse modelling to identify archaeological magnetic sources will be introduced. These models are constrained by additional geophysical measurements like Electrical Resistivity Tomography (ERT), which offers a vertical vision of the site. At Richeaume XIII remnants of a limestone building buried in red clays (enriched in iron oxides) were discovered by a magnetic prospection, showing a significant magnetic anomaly with a square shape. The depth of the wall's base was determined by ERT, and excavation has confirmed this depth. Thus only the combination of several approaches, including data processing and modelling, can provide a complete study of an archaeological site. We will try to show how such multi-disciplinary studies are particularly useful in limestone areas and where unwanted magnetic signals are abundant.

LONGHOUSES, FIELD BOUNDARIES AND ROCKY OUTCROPS: MODELLING OF GEOPHYSICAL DATA SETS AFFECTED BY GEOLOGICAL OUTCROPS IN THE SHETLAND ISLAND FOR PAST LAND USE

Robert M. Legg, Julie M. Bond, Chris Gaffney and Carl P. Heron
University of Bradford, UK.

R.M.Legg@Bradford.ac.uk

Land immediately surrounding the remains of three longhouses have been surveyed using earth resistance, fluxgate gradiometer and magnetic susceptibility techniques as part of research into abandoned historic farmsteads on the island of Unst. Two of the structures are located at Hamar overlooking the entrance to a sound on the eastern coast on the island. The first has been fully excavated and dates to cal. AD1020-1220; the second structure has been partially excavated with a covering midden layer dating to cal. AD 1440-1640 (Bond et al. 2008; Outram et al. 2008, table 5.1).

The third structure is located on the eastern shore of Loch Watlee towards the centre of the island and has been provisionally dated as medieval on the basis of it being slightly shorter at 14m (Stumman Hansen 2000, 94). The remains have been incorporated into a later crofting landscape (RCAHMS 2008) with1st edition Ordnance survey maps highlighting a possible area of cultivation just below the structure (National Library of Scotland 2010). The site is part of a wider multi period landscape with a prehistoric cairn c.150m SE of the structure and an 18th century structure indicated by the Statistical Accounts of Scotland (Mouat and Barclay 1791).

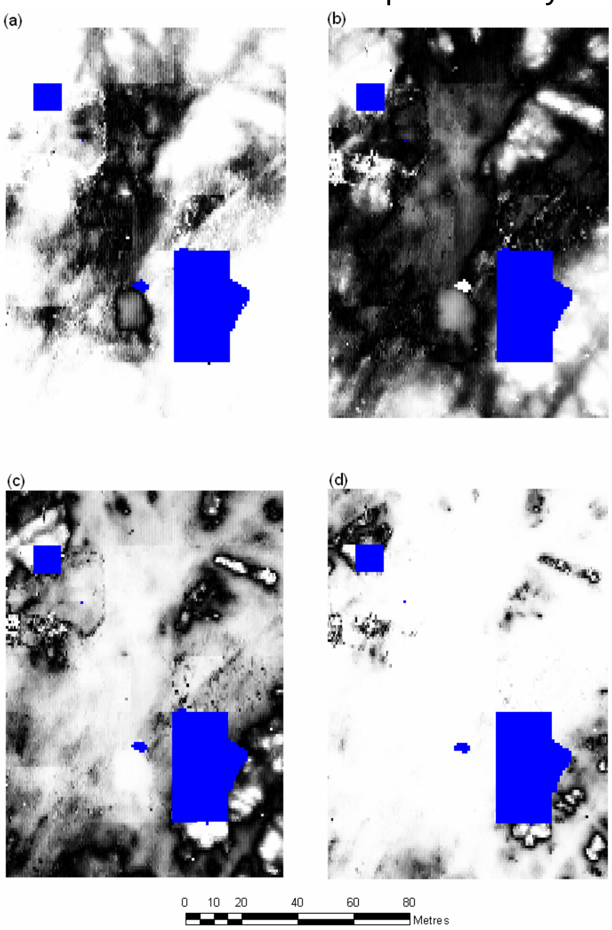


Figure 1: Estimated probability plots from the Hamar earth resistance data set with βk,l =0 for (a) k1=log(R)=1.75, (b) k2=log(R)=1.89, (c) k3=log(R)=1.91 and (d) k4=log(R)=2.15 where white is 0 and black is 1. For (a) please note the three linear features towards the left of the plot and in (c) notice the three anomalies, which would have fitted in between where three previous anomalies would have been.

The principal objective for these surveys were to characterise the past land use as evidenced by field boundaries and changes in soil environment. Remains at both Hamar and Watlee are adjacent to yards and surrounded by field boundaries. Due to the use of local igneous rocks reasonably strong geophysical responses could be expected from archaeological structures at both locations. Identification of these structures though was likely to be complicated by outcrops of metamorphosed igneous rocks at both sites (Mykura 1976, 33-37). Collection of data was also further hindered by steep slopes and small cliffs formed from the larger rocky outcrops.

Results from both surveys highlighted strong magnetic and dielectric responses for the longhouse structures and also adjacent yard areas and structures. Also noticeable were anomalies associable with the soil environment such as palaeo-irrigation channels, water logged soil and areas of increased soil depth. Weak responses were also noticeable for field boundaries and cultivation marks around the longhouse remains. These anomalies noticeably came in multiple orientations at both Hamar and Watlee indicating that there has been more than one phase at both sites. Very strong anomalies are also associated with rocky outcrops and at Hamar a large area of historically scalped topsoil. This along with the strong responses associated with the longhouse remains suppress the weaker responses related to the field boundaries and the soil environment.

This presentation outlines modelling of these different data sets aiming to highlight:

- These weaker anomalies
- Past field and cultivation systems
- Changes to these systems

Modelling of the data sets takes two different forms, the first involving the plotting of quantiles for raster images of the geophysical data sets. The quantiles plot the data within divisions that reflect equal proportions of the cumulative distribution for variable. This was used to try and isolate the geophysical responses to potential field and cultivation systems and the soil environment.

The second is an adaptation of a Bayesian approach outlined by Buck et al (1996, 276-91) known as image segmentation. Within this approach data is modelled for different data levels identified from histograms of the data sets, which are assumed to have a mean and a normal distribution. Buck et al (1996, fig. 10.17) used this analysis to classify each pixel to a specific level. As the anomalies discussed above are very subtle, such an approach is likely to smooth them out. Instead this modelling approach plots estimates for the probability of the cell being a specific level from:

$$P\left(\theta_{i,j} = k \middle| \theta_{-(i,j)}, y\right) \propto e^{-\left(\frac{(y_{i,j}-\mu_k)^2}{2\sigma^2} + \sum_{\substack{l=1 \\ l \neq k}}^{L} \beta_{k,l} u_{i,j}(k,l)\right)}$$

Where $P\left(\theta_{i,j} = k \middle| \theta_{-(i,j)}, y\right)$ is the probability of the true data value equalling level *k* given the true levels of the surrounding cells, $\frac{(y_{i,j}-\mu_k)^2}{2\sigma^2}$ the Normal density function for level *k*, $\beta_{k,l}$ the smoothing factor between levels *k* and *l* and $\sum_{\substack{l=1 \\ l \neq k}}^{L} \beta_{k,l} u_{i,j}(k,l)$ the number of cells assigned to level *l* (Buck *et al.* 1996, 276-91). Use of $\beta_{k,l}$ enables the modelling for different effects of the surrounding cells upon $P(\theta_{i,j} = k | a)$.

Quantile plots appear to more successfully highlight several field systems at both Watlee and Hamar than typical greyscale. At Hamar, the modelling appears to have highlighted anomalies, which are related to a relict field system not initially apparent. Modelling also highlighted further the problem as the anomalies are very slight compared to the strong geological anomalies appearing in the 9^{th} -12^{th} quantiles out of 20. The adapted image segmentation modelling to date has clearly identified a cultivation system between the two structures with a strong fit to the lowest level (see Fig. 1a). The stone clearance anomalies highlighted in the quantile plots appeared to fit within the second highest level (see Fig. 1c).

Bibliography
Bond, J.M., Outram, Z., and Freeth, C.M. (eds) 2008. *Viking Unst Project: excavations at Hamar and the Upper House, Underhoull: field season 2008. Interim Report No.3 (Data Structure Report)*. Bradford Archaeological Sciences Research 20. Bradford: University of Bradford/Shetland Amenity

Buck, C. E., Cavanagh, W. G. and Litton, C. D. 1996. *Bayesian approach to interpreting archaeological data*. Chichester: John Wiley & Sons

Mouat, J. and Barclay, J. 1791. The Island of Unst in Shetland. In Sinclair, J. (ed.) *The statistical account of Scotland 1791-1799: Volume XIX: Orkney and Shetland*. Wakefield: EP publishing (1978 reissue). 495-516

National Library of Scotland. 2010. http://www.nls.uk/maps/counties/index.html#shetland. (last consulted 31/1/2010).

Mykura, W. 1976. *British Regional Geology: Orkney and Shetland*. Edinburgh: Her Majesty's Stationary Office

Outram, Z., Batt, C.M., Swindles,G. T. and Church, M. 2008. Dating at Hamar and The Upper House, Underhoull. In Bond, J.M., Outram, Z., and Freeth, C.M. (eds) 2008

RCAHMS. 2008. HLAMAP http://jura.rcahms.gov.uk/HLA/Map (Last checked 11th March 2010)

ADAPTATION OF AERO-MAGNETIC INTERPRETATION TECHNIQUES FOR ARCHAEO-MAGNETIC PURPOSES

Samuel Cheyney(1), Ian Hill(1), Neil Linford(2), Stewart Fishwick(1), Christopher Leech(3)
(1)Department of Geology, University of Leicester, University Road, Leicester, LE1 7RH, UK; (2)Geophysics Team, English Heritage, Fort Cumberland, Eastney, Portsmouth, PO4 9LD; (3)Geomatrix Earth Science Ltd, 20 Eden Way, Leighton Buzzard, Bedfordshire, LU7 4TZ, UK.

sc112@leicester.ac.uk

Advances in magnetic surveying have meant high-resolution surveys over archaeological sites can now be quickly obtained. However, post-survey processing still generally comprises a sequence of data correction and removal of unwanted artefacts prior to a 2D visual interpretation based on shape and pattern recognition of individual anomalies. Developments in the processing and modelling of aero-magnetic data in the mineral exploration industry have led to the development of several techniques that quickly identify the location and shape of anomalous sources from large spacial surveys. Although not always directly implementable, it is possible that several of these techniques can be adapted for use on archaeo-magnetic datasets.

Several of these techniques, such as the total horizontal gradient (Dole and Jordan, 1978), analytic signal (Nabighian, 1972 and Roest et al, 1992), theta map (Wijns et al, 2005) and tilt angle (Miller and Singh, 1994), are based on the derivatives of the magnetic field, and are primarily used to identify the lateral location of anomalous sources. The process of calculating derivatives results in increasing power of the high-wavenumber features of the dataset. Whilst in aero-magnetic datasets the high-wavenumber component has a low power due to the height of the survey above ground, in archaeo-magnetic surveys the high-wavenumber component generally contains a lot of information, including un-wanted near-surface artefacts and noise. The strong enhancement of this noise component is a major barrier to the direct application of these methods.

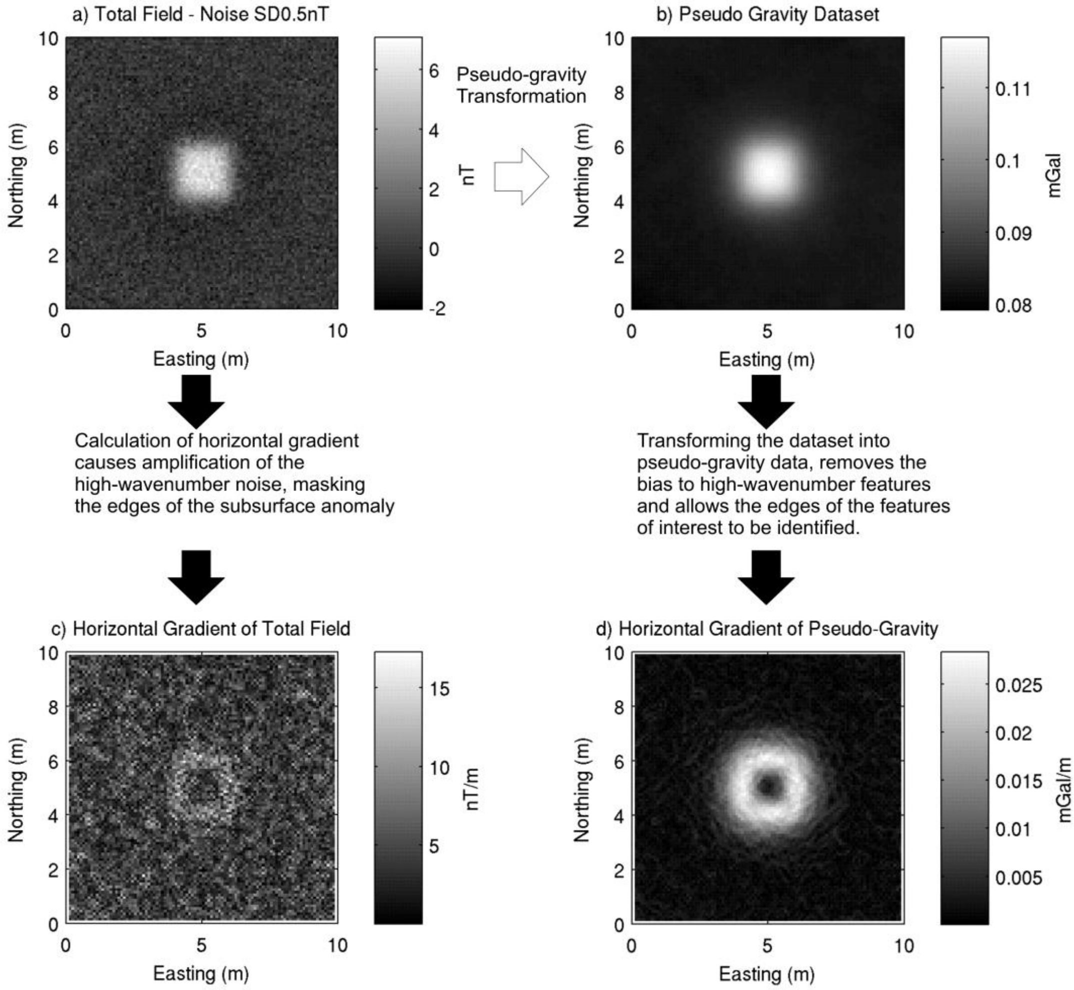


Figure 1: Total Field Data with 0.5nT SD Gaussian noise added; b) Pseudo-gravity dataset of (a); c) Total horizontal gradient of (a;);. d) Total horizontal gradient of (b). Using the peaks in the horizontal gradient to identify the edges of the synthetic prism has been more successful here when applied to the data was been transformed to pseudo-gravity prior to the calculation of the derivative.

One way to overcome this problem is to suppress the high-wavenumber component of the data prior to calculating the derivatives. This can be done by using the pseudo-gravity transformation to generate a pseudo-gravity dataset, which would be observed should the magnetisation be exactly proportional to the density distribution (Baranov, 1957). The resulting dataset is ideal for calculating the derivatives of the field, as the 1st vertical derivative of the pseudo-gravity has an identical power spectra distribution to the original total field dataset. Therefore the power spectra of the calculated derivatives are close to the original ‘observed’ dataset, without bias towards higher-wavenumber features.

Figure 1a shows synthetic total field data generated over a 2x2x0.5m prism buried 0.3m below ground. The body has a magnetic intensity of 0.0375Am-1, and data have been generated at a height of 0.2m above ground. Zero-mean Gaussian noise has been added, with a standard deviation of 0.5nT. Calculation of the total horizontal gradient directly from the reduced to the pole total field data (Figure 1a) results in an amplification of the noise which masks the maxima that should overlie the edges of the buried anomaly (Figure 1c). However, transformation of the total field data into a pseudo-gravity dataset (Figure 1b), suppresses the power of the high-wavenumber features and subsequent calculation of the total horizontal gradient from the pseudo-gravity dataset shows the outline of the anomaly clearly (Figure 1d).

Information regarding depth to features can be obtained by Euler deconvolution (Thompson, 1982 and Reid et al, 1990). A window of specified size is moved across a grid of data, using least-squares inversion to solve Euler's homogeneity equation using a pre-defined structural index. The structural index is related to the attenuation with distance of the potential field, and varies depending on the shape of the source. The processes solves for the lateral and vertical source position, as well as providing an uncertainty of the calculated parameters.

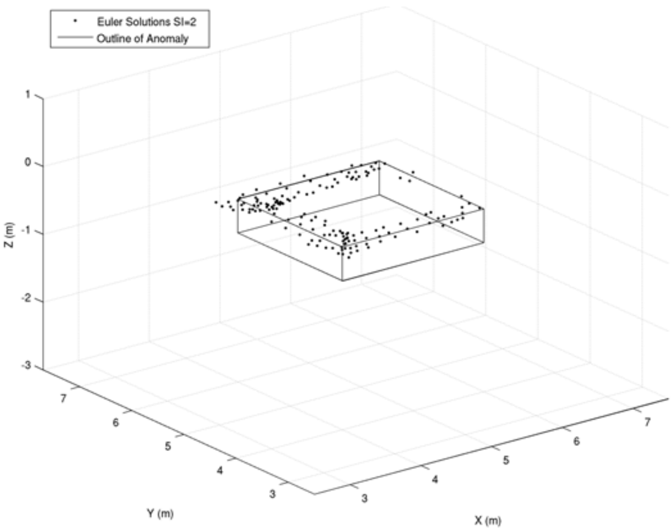


Figure 2: Euler deconvolution solutions for a structural index of 2. The solutions (circles) are clustered around the corners at mid-depth of the synthetic anomaly (solid lines).

Many solutions can be calculated this way, and a selection criterion is often used to judge which solutions to keep. The structural index (N) selected is very important to the output parameters. When an appropriate structural index is chosen, solutions cluster together at the depth of the source. Therefore, position and source type can be estimated by analysing the clustering of various structural indices. Modelling of the synthetic anomaly can be seen in Figure 2. A structural index of 2 has been used, and produced solutions which have clustered towards the upper edges of the anomalous body.

Inverse modelling techniques can been used to generate complete 3D models of the subsurface (Li and Oldenburg, 1996). Typically the subsurface is divided into a serious of cells each assigned a single value of magnetic susceptibility. The susceptibilities are altered iteratively to produce a subsurface model that replicates the observed data when forward modelled. The problem with inverse modelling of magnetic data is the inherent ambiguity due to the nature of the mathematical "inverse problem". Often, although a good fit to the observed values can be obtained, the final model will be non-unique and may be heavily biased by the starting model provided. By using information derived from derivative-based methods and Euler deconvolution, it is possible to produce a rapidly obtained initial model and appropriate depth-weighting parameters for the inversion which will increase speed, and confidence in the final result.

Bibliography

Baranov, V. 1957. A new method for interpretation of aeromagnetic maps; pseudo-gravimetric anomalies. *Geophysics*, **22**, 359-382.

Dole, W.E. and Jordan, N.F. 1978. Slope Mapping. *Aapg Bulletin-American Association of Petroleum Geologists*, **62**, 2427-2440.

Li, Y. and Oldenburg, D.W. 1996. 3-D inversion of magnetic data. *Geophysics*, **61**, 394-408.

Miller, H.G. and Singh, V. 1994. Potential field tilt; a new concept for location of potential field sources. *Journal of Applied Geophysics*, **32**, 213-217.

Nabighian, M.N. 1972. The analytic signal of two-dimensional magnetic bodies with polygonal cross-section; its properties and use for automated anomaly interpretation. *Geophysics*, **37**, 507-517.

Reid, A.B. et al. 1990. Magnetic Interpretation in 3 Dimensions using Euler Deconvolution. *Geophysics*, **55**, 80-91.

Roest, W.R., Verhoef, J. and Pilkington, M. 1992. Magnetic interpretation using the 3-D analytic signal. *Geophysics*, **57**, 116-125.

Thompson, D.T. 1982. Euldph - A New Technique for Making Computer-Assisted Depth Estimates from Magnetic Data. *Geophysics*, **47**, 31-37.

Wijns, C., Perez, C. and Kowalczyk, P. 2005. Theta map; edge detection in magnetic data. *Geophysics*, **70**, L39- L43.

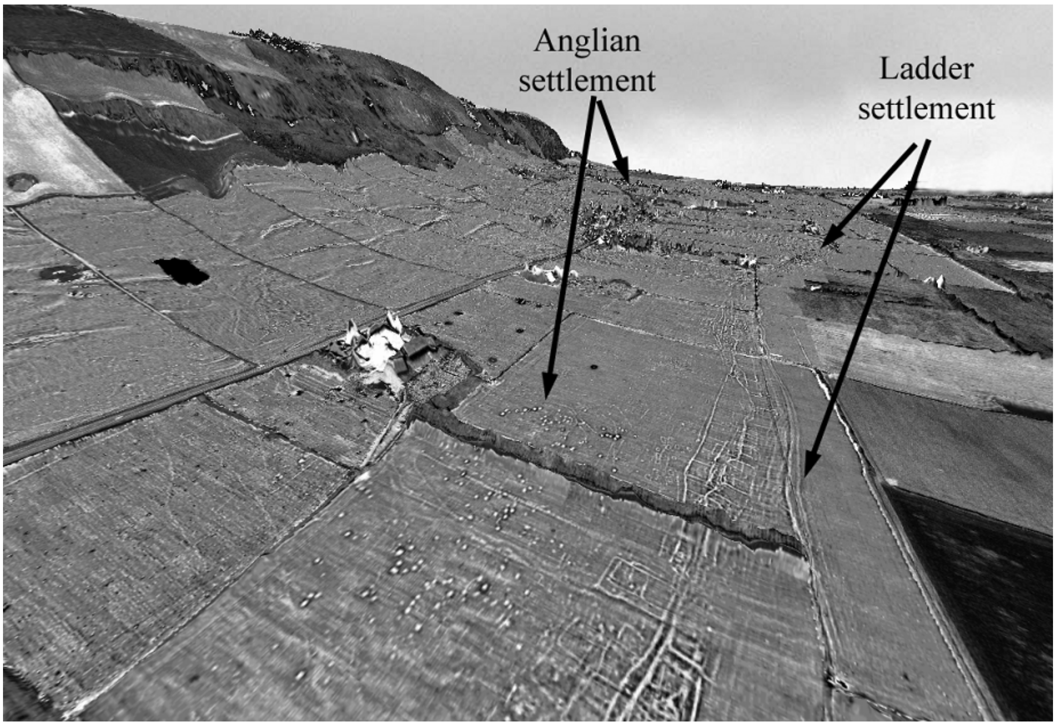
DATA PRESENTATION AND INTERPRETATION – USING GOOGLE EARTH AS A DELIVERY MEDIUM

James Lyall
Landscape Research Centre, UK.

jsl.lrc@btinternet.com

The ability to display geophysical results in freely accessible mapping formats such as Google Earth has been available for some years now, but how many of us have realised the full potential of this resource?

I would like to use this opportunity to demonstrate how we can move away from simply mapping the data to providing a resource which can enhance our knowledge of the underlying archaeology. This process has advantages and pitfalls, both of which I hope to address in this presentation.



Using toolkits, it is now possible to present vector drawings in Google Earth. This has the benefit of allowing us to provide our interpretations of geophysical data in a way which is more readily understood by non-specialist colleagues. In addition, the timeline facility in Google Earth gives an unprecedented opportunity to generate phased vector overlays, allowing anyone with access to the dataset to see the landscape evolving over time.

RECENT WORKS IN G.P.R. APPLIED TO CULTURAL HERITAGE

P.M. Barone, E. Pettinelli, S.E. Lauro and E. Mattei
Dept. of Physics “E. Amaldi” – University of ROMA TRE, Via della Vasca Navale, 84 00146 Rome, Italy.

pmbarone@fis.uniroma3.it

The “Cultural Heritage” phrase encloses a huge world from preventive archaeology to architectonical restorations of ancient buildings. The aim of this work is to show the versatility of Ground Penetrating Radar (GPR) in these different contexts.

To guarantee equality of access to cultural heritage for all - also as a means to strengthen social and historical cohesion - should be considered an utmost priority. An urgent and well focused effort by the national community is needed to rise to this challenge.

Due to this purpose, archaeological prospections could improve the “cultural” knowledge in a new different manner. If the traditional tools applied to Archaeology (i.e. trowels, shovels, bulldozers, etc.) produce, generally, a fast and invasive reconstruction of the ancient past, the geophysical instruments seem to go in the opposite direction giving, rapidly and non-destructively, geo-archaeological information. Moreover, the economic aspect should not underestimate; where the former invest a lot of money in order to carry out an excavation or restoration, the latter spend much less to manage a geophysical survey, locating precisely the targets.

Survey information gathered using non-invasive methods contributes to the creation of site strategies, conservation, preservation and, if necessary, accurate location of excavation and restoration units. Therefore, geophysical survey techniques can be used to examine historic buildings and structures and their surrounding properties so that archaeologists and other professionals responsible for heritage preservation are able to assess the integrity of the structures and, where necessary, take action - without destructive testing methods (Conyers 2009; Kvamme 2003; Pettinelli et al. 2010a).

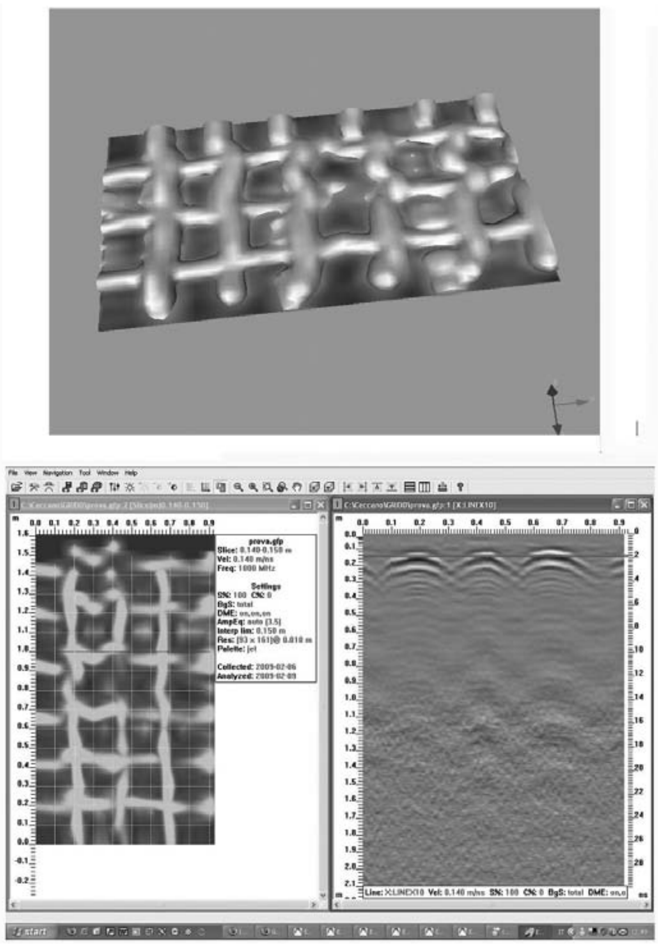


Figure 1: A typical GPR data processing: a 3D contour map, a pseudo-3D time slice and a radargram acquired on a concrete wall with reinforcing bars.

In particular, GPR has, recently, become the most important physical technique in archaeological investigations, allowing the detection of archaeological targets with both very high vertical and horizontal resolution, and has been successfully applied both to archaeological and diagnostic purposes in historical and monumental buildings (Pettinelli et al. 2010b).

During the last five years, the Geophysics Laboratory, in the Department of Physics, at University of Roma TRE, has been heavily involved in applying GPR to solve “cultural heritage problems”.

GPR configuration, antenna frequency and survey modality can be different, depending on the scope of the measurements, the nature of the site or the type of targets. The primary goal of most GPR investigations in cultural heritage is to differentiate subsurface interfaces. Collecting data along a profile, a series of reflection traces produced by buried “targets” (i.e. multi-layers, cracks, lesions, pits, walls, water ingressions, etc.), will produce several anomalies.

GPR has the ability to create pseudo-3D maps and images of buried architecture and other associated cultural and natural features. Usually, the pseudo-3D time slices (or depth slices if the signal velocity is known) give an information on the planar distribution of the buried targets at different depths, whereas the 3D contour maps show the full geometry of the targets (see Fig. 1).

Figure 2: The reconstruction of the GPR anomalies in the archaeological site of Cavallino (Lecce, Italy).

This kind of approach could define physical and chemical changes in the ground that are related to archaeological or architectonical buried materials of importance. When these data and maps are used to test ideas about human adaptation to landscapes or to understand developments of construction techniques or to plan a precise restoration, they offer a powerful and time-efficient way to study ancient human behaviour, social organization, damages during the centuries and other important cultural concepts or fundamental diagnoses. Indeed, maps and images should be generated and integrated with information obtained from other buried or similar artifacts to provide age, structure and context for the surveyed sites.

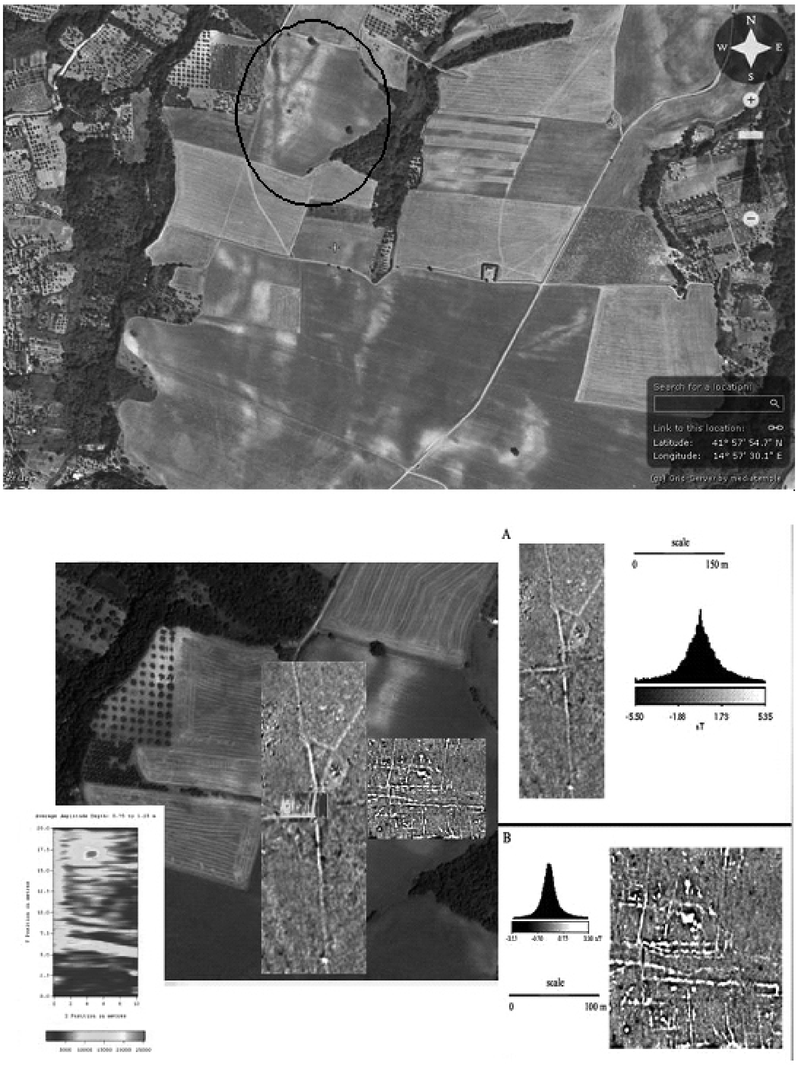


Figure 3: The detection and localisation of the ancient site of Uscosium using aerial, GPR and magnetic data.

We are going to present here several examples of successfully applied radar investigations to different case studies like: i) the reconstruction of the urban development of an ancient city, partially excavated (e.g. the archaeological sites of Ferento, Cavallino, Pompeii and Monte Porzio Catone); ii) the possibility to bring to the light a new archaeological site (e. g. the countryside of San Giacomo degli Schiavoni); iii) the diagnostic investigations before planning the restoration of ancient buildings (e.g. the Domus Aurea, Porticus Octaviae, Domitian Stadium, Saint Paul without Walls Abbey and Zuccari Palace in Rome).

In the first case, the GPR survey collects primary data that can be used to guide the placement of excavations, define sensitive areas containing cultural remains to avoid and place archaeological sites within a broader environmental context and study human interaction with ancient landscapes. For example, in the archaeological area of Cavallino (Lecce, Italy) the GPR data allowed not only to better understand the geometry of the hidden archaeological structures, but also to integrate these data with the archaeological remains partially brought to the light (see Fig. 2).

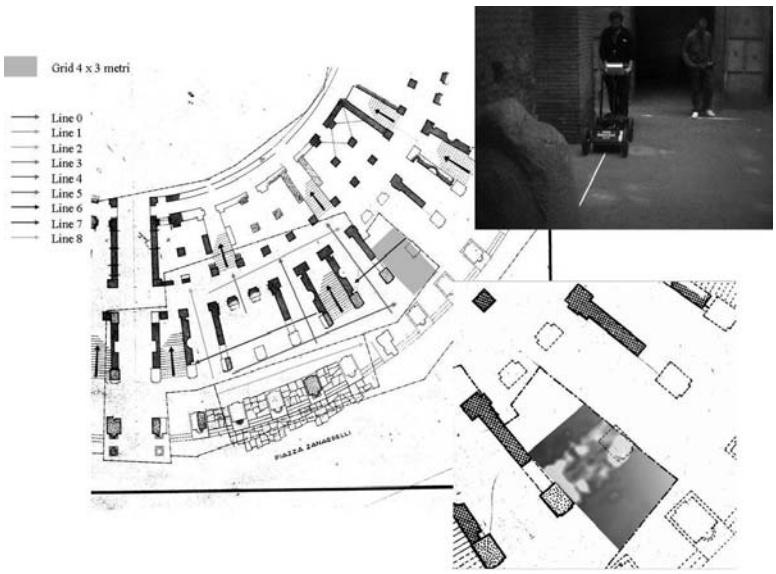


Figure 4: The GPR acquisitions and results inside the Roman Stadium of Domitian.

The second case represents an example of GPR application to detect an archaeological site partially known only by literature or field-walking notes. Who ‘knows’ the landscape with its layers, he knows, for certain, that it is the result of complex dynamics. This gives an opportunity to reflect on the presence of so-called cultural processes beneath the soil: the idea that people lived in landscape and that the distribution of their material remains over broad areas not yet excavated.

The area close to *San Giacomo degli Schiavoni* town (in Molise Region, Italy – see figure 3) is been always subject to particular archaeological investigations in order to localize the ancient settlement of *Uscosium*, the Samnite town first and then the Roman *municipium*. The researches were not a success till now when the geophysical survey has changed the situation, displaying clear anomalies due to a roads crossing and to a built-up rural area in the northern investigated areas. The GPR, helped by a preliminary magnetic survey, allows understanding precisely the geometry and the urban development of the hidden site.

The third example shows how GPR could be employed successfully also in architectonic issues; the processing of the GPR data, collected inside the Domitian stadium, under Navona square (Rome, Italy), highlights not only the presence of Roman sewers and pillars, but also the structural disposition and the geometry of them (see Fig. 4).

In this work it is evident the possibility to generate an image, from which the geometry, dimension and depth of the searched object can be determined; it is very useful not only to identify a “highly valuable” archaeological site and to restrict the excavation to a more “fruitful” area, but also to detect structural problems and diagnostic purposes in historical and monumental buildings, which could not be discovered by any other techniques.

Bibliography

Conyers L.B., 2009, Ground-penetrating radar for landscape archaeology: method and applications. In Campana S. and Piro S. (eds.), *Seeing the Unseen*, Taylor & Francis Group, London: 245-255.

Kvamme K.L., 2003, Geophysical surveys as landscape archaeology. *American Antiquity* **63 (3)**: 435–457.

Pettinelli E., Barone P.M., Mattei E. and Di Matteo A., 2010a, Geophysical Applications: Archaeology and Cultural Heritage. In Turk A.S., Hocaoglu A.K. and Vertiy A.A. (eds.), *Subsurface Systems*, John Wiley & Sons, NJ: in press.

Pettinelli E., Barone P.M., Mattei E. and Lauro S.E., 2010b, Radio waves technique for non-destructive archaeological investigations. *Contemporary Physics*, Taylor & Francis Group, London: in press.

REFLECTIONS FROM WESTMINSTER ABBEY

Erica Utsi
Utsi Electronics Ltd, Sarek, Newton Road, Harston, Cambridge, UK.

erica.utsi@btconnect.com

Continuing Ground Penetrating Radar (GPR) investigations at Westminster Abbey are providing useful information about subsurface structures and also illustrating interesting aspects of using GPR for archaeological investigation. This paper addresses two topics in particular: signal attenuation implications for the selection of antenna frequency and the resulting survey parameter requirements for good imaging.

Antenna Frequency

The relationship between antenna frequency and signal attenuation used to be described as linear i.e. the higher the frequency the greater the rate of attenuation. This is not accurate since this assumption ignores the different relationships between conductive losses and polarisation losses with frequency.

GPR was first applied successfully to Westminster Abbey in 2004 when the Abbey conservation team applied for GPR to be used on the 13th Century Cosmati pavement, in advance of restoration. Trials carried out to demonstrate the capability of the technique included the use of 3 frequencies of antenna: 400MHz, 1GHz and 4GHz. It was apparent that the performance of the 3 antennas, notably their depth penetration, was not directly proportional to their mid-point frequencies. On a practical level, this enabled the selection of antennas for the survey (400MHz and

4GHz) but left unanswered why a higher frequency antenna could effectively out-perform a lower one.

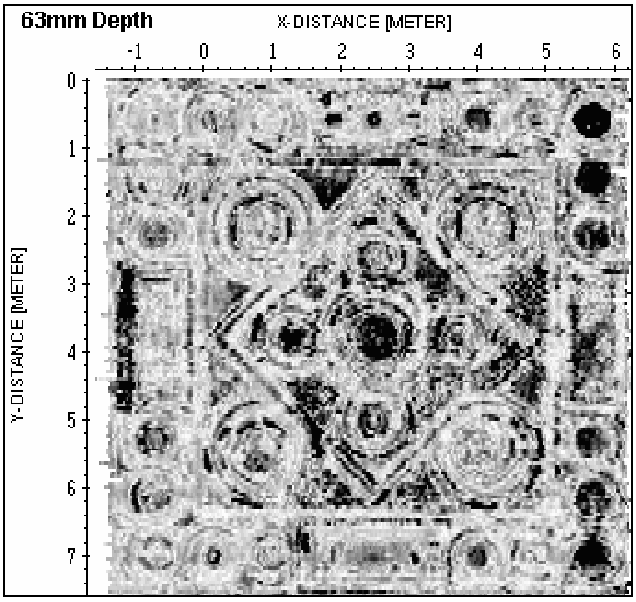


Figure 1: Time Slice from 4GHz GPR Survey of Cosmati Pavement

Recent work on the electromagnetic response of soils now illustrates why the depth penetration and target definition of the 1GHz antenna was a less satisfactory option than expected. Recent research suggests that the different loss components do not behave in a similar manner and that the losses associated with imaginary permittivity cease to have a measurable effect above a given maximum frequency level. For soils, it has been suggested that this maximum frequency may be close to 1GHz. The implication of this research is that it may be preferable to substitute a higher frequency antenna rather than the more traditional lower frequency one. If so, the GPR user accepts a limitation on depth penetration rather than a reduction in target definition which, for archaeological purposes, may be preferable. This was certainly the case for Westminster Abbey where use of a 4GHz antenna made it possible to obtain detailed pictures both of the interior of the mosaic and the underlying burials [Fig. 1, 2]. The degree of detail made it possible to understand the construction of the mosaic, identify repairs, and identify grave goods within the tombs.

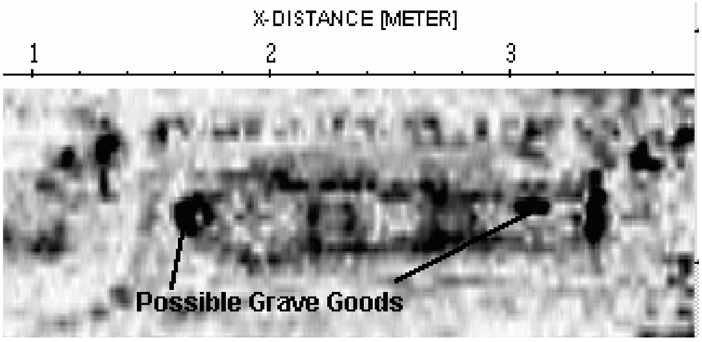


Figure 2: Extract from 4GHz Survey showing possible Grave Goods

Use of this very high frequency antenna is confined to the first 0.5m of subsurface. Although it was extremely efficient at identifying material changes within that depth, it is not a suitable tool for successful identification of the majority of the subsurface features, including the many varied grave structures. The effect is most noticeable when comparing time slices of similar depth.

Previous attempts to map graves using GPR had been unsuccessful. The use of 1GHz antennas with their relatively poor response to the electromagnetic properties of the stone floors may be a factor.

The motivation in using a 1GHz antenna is clear: better target definition. Since it is possible to use a 1GHz antenna on open land outdoors to a depth of c. 1m, it might

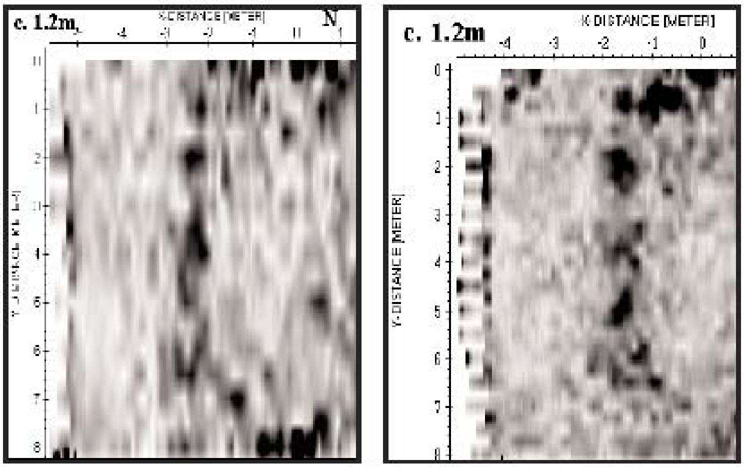


Figure 3: Comparative Time Slices from the Trial (l) and Final Survey (r) using a 400MHz antenna.

have been reasonable to expect better results within the dry sheltered environment of the Abbey. This was not the case.

The current investigations therefore make use of a 400MHz antenna, accepting a compromise between target imaging and depth penetration.

Resulting Survey Parameters for Good Imaging

Even in archaeological applications, GPR is not necessarily used for identical purposes. Some applications are primarily aimed at detection/location in its broadest sense, others are required for detailed definition. The current English Heritage guidelines allow leeway to carry out either type of survey. This is a sensible approach given that funding resources for archaeological geophysics are often limited.

The importance of data density in understanding the GPR images of archaeological features is well understood. One of the ironies of lowering the frequency of investigation is that fewer survey lines are necessary in order to meet the Nyquist requirement for maximum definition, even at shallow depths. In essence this is a recognition that GPRs are blunt imaging tools and the lower the frequency, the poorer the focus. Having selected a lower frequency antenna for the Abbey floor investigations, it is essential to consider what can be done to optimise the data quality.

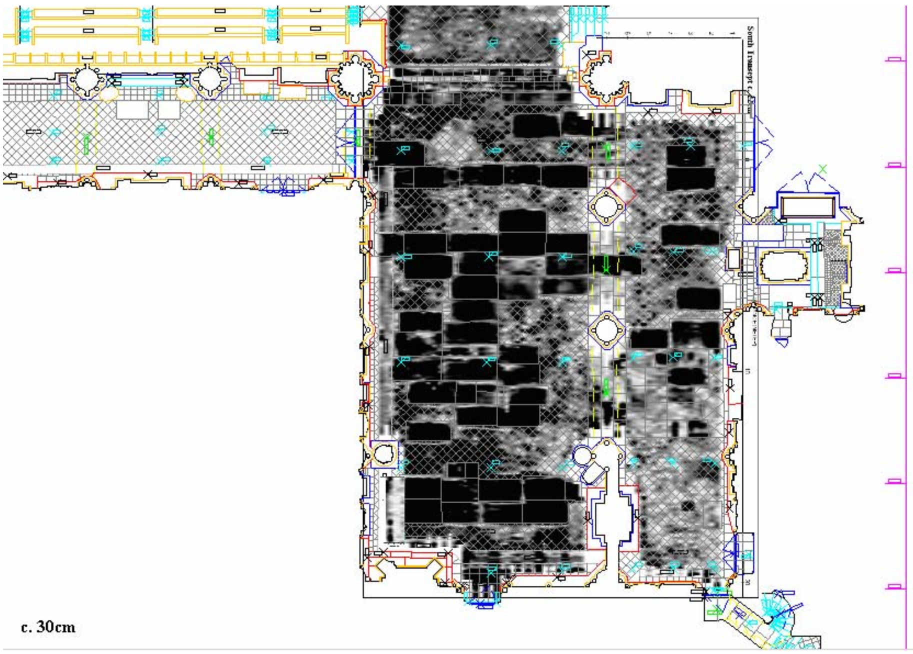


Figure 4: Time Slice from Poets Corner c. 30cm Depth

Comparative 400MHz data from the original trial and the final survey to examine 11thC remains below the 13thC mosaic demonstrate the difference between meeting current EH guidelines & complying with Nyquist imaging requirements [Fig 3]. The trial spatial survey parameters were 5cm sampling interval and 50cm transect spacing, the latter being halved for the final survey. Both images illustrate the existence of large blocks of masonry below the Sanctuary but halving the transect spacing brings the image into focus since the data density now satisfies the Nyquist requirements for this depth. Conforming to Nyquist requirements is one way of countering the image definition loss from using a lower frequency antenna.

Our other approach has been to reduce the sampling interval along the direction of travel of the radar in order to increase the density of data points along this axis. The data obtained to date, from the North & South Transepts confirms that this approach not only reveals the underlying tombs and other structures but also gives a reasonably comprehensible target definition [Fig 4].

It is worth noticing that the 4GHz data which at first sight appears to offer excellent definition is effectively aliased since the Nyquist requirements are not met at shallow depths. There is now a plan to re-examine the more limited areas of the two underlying tomb, reducing the transect spacing and working orthogonally. Integrating the results from the two surveys should provide even better definition.

Conclusions
The choice of antenna frequency is not always straightforward due to the different relationships of the signal attenuation components with frequency. Experimentation may be necessary.

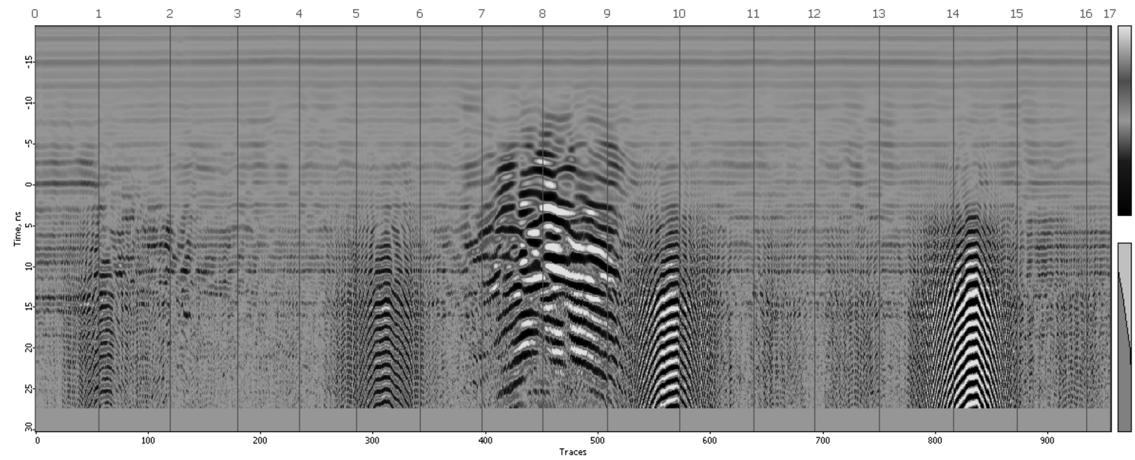
Images from Westminster Abbey illustrate the efficacy of deploying both low and high frequency antennas combined with an appropriate sampling strategy.

WHAT SHIELDING? HOW TO PICK UP SIGNALS WITH A GPR ANTENNA

Armin Schmidt
GeodataWIZ (UK).

A.Schmidt@GeodataWIZ.com

While surveying a Byzantine retreat on a hilltop in Turkey we became excited by the prospect of several additional walls running parallel with the main structure. The signals were regularly spaced and appeared hyperbolic (see Figure). However, it turned out that these signals were periodic burst of external energy detected by the antenna. Similarly, measurements in the vicinity of houses with a satellite dish were impossible as these proved to be extremely strong reflectors. The system used was a Zond 12e with a 900 MHz ‘shielded’ antenna. This presentation illustrates some of the pitfalls encountered with such antenna and the strict data collection and processing regime that is required to minimise the unwanted effects. As a result the imaging of the Byzantine retreat provided clear information about this so-far unknown feature at Pessinus-Balahisar.



THE LUDWIG BOLTZMANN INSTITUTE FOR ARCHAEOLOGICAL PROSPECTION & VIRTUAL ARCHAEOLOGY - A NEW PERSPECTIVE FOR LANDSCAPE ARCHAEOLOGY: RESEARCH PROGRAMME AND FIRST RESULTS FROM LARGE-SCALE, HIGH-RESOLUTION ARCHAEOLOGICAL PROSPECTION

Immo Trinks, Alois Hinterleitner, Erich Nau, Thomas Zitz, Klaus Löcker, Manuel Gabler, Wolfgang Neubauer, Michael Doneus, Nives Doneus, Matthias Kucera, Christian Briese and Daniel Scherzer
Ludwig Boltzmann Institute for Archaeological Prospection & Virtual Archaeology, Hohe Warte 38, A-1190 Wien, Austria.

Immo.Trinks@archpro.lbg.ac.at

In 2010 the *Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology* (LBI) was founded. It is dedicated to the development of new techniques and methodological concepts for landscape archaeology. Based on a pan-European partnership it combines geophysics, computer sciences, geomatics and archaeology to develop efficient and universally applicable methods for the non-invasive detection, documentation, visualisation and integrative interpretation of cultural heritage investigating archaeological landscapes. The LBI together with its European partner organisations is investigating a range of key archaeological landscapes in Austria, England, Germany, Norway and Sweden in order to test and develop novel archaeological prospection hardware, software and methodology. The LBI research programme is focussing on the further development of remote sensing (full wave-form LIDAR, hyper-spectral scanning) and geophysical prospecting as well as GIS-based spatial analysis and archaeological interpretation. An increase in measurement efficiency of geophysical prospection methods is needed in order to render their archaeological application more economical and applicable for landscape archaeology. Novel instrumentation provides new ways to extend conventional aerial archaeology beyond the visible spectrum. New technology concerning the development of motorized multi-channel magnetometer-systems and GPR-arrays and advanced processing methods offer attractive possibilities for large-scale geophysical archaeological surveys. In summer 2010 large-scale archaeological prospection surveys have started at Stonehenge, in Southern Sweden at the site of the Iron Age settlement Uppåkra, in Norway (Vestfold County) and in Austria. We present latest technical and methodological developments in archaeological prospection and first results from the large-scale applications.

http://archpro.lbg.ac.at

METHODOLOGICAL AND ARCHAEOLOGICAL CHALLENGES IN THE FIRST SEASON OF THE STONEHENGE HIDDEN LANDSCAPES PROJECT

Chris Gaffney(1), Vince Gaffney(2) and Wolfgang Neubauer(3)
(1)AGES, University of Bradford, UK; (2)IBM Visual and Spatial Technology Centre, University of Birmingham, UK; (3)Ludwig Boltzmann Institute for Remote Sensing and Virtual Archaeology, University of Vienna, Austria.

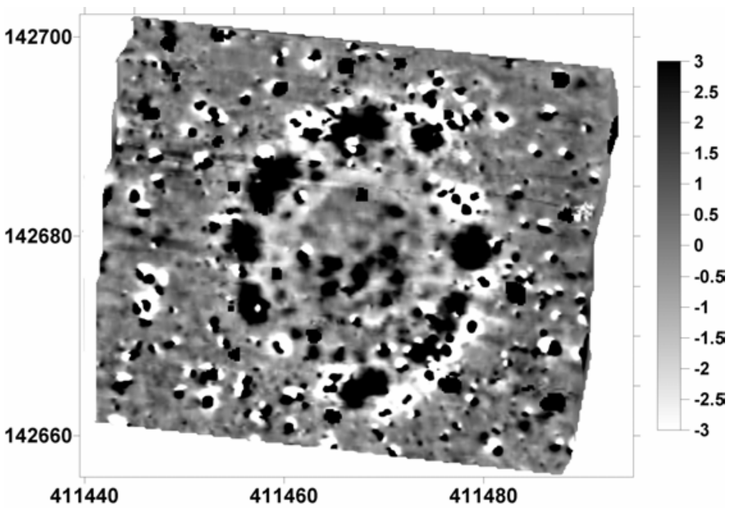
C.Gaffney@Bradford.ac.uk

Stonehenge occupies one of the richest archaeological landscapes in the world, recorded in the course of intensive archaeological and antiquarian research over several hundred years, yet much of this landscape effectively remains terra incognita. This project aims to address current limitations and gaps in our knowledge and understanding of the Stonehenge landscape by conducting a cutting-edge geophysical and remote sensing survey at an unprecedented scale - to encompass a large portion of the World Heritage Site (c.14 square kilometers).

The results of the work will be used to create a highly detailed archaeological map of the ‘invisible’ landscape, providing the basis for a full interpretative synthesis of all existing remote sensing and geophysical data from the study area, as well as comparative evaluation of the results of archaeological excavation data in relation to geophysical results. For the first time it will be possible to create total digital models of the Stonehenge landscape at a true ‘landscape scale’ that will not only transcend the immediate surrounds of individual monuments within the study area, but will also tie them together within a seamless map of sub-surface and surface archaeological features and structures.

Although recent studies have provided an unusually detailed archaeological and digital database for Stonehenge and its immediate environs (notably: RCHME 1979; Richards 1990; Cleal et al. 1995; Exon et al. 2000; Larrson & Parker Pearson (eds) 2008), the historic research emphasis on the monuments has rarely permitted a rigorous analysis of wider landscape structures in relation to the emerging complexity of the archaeological evidence. This is perhaps surprising given the explicit landscape-scale and context of analysis and interpretation embodied in much of this work, including special prominence given to structured ‘symbolic landscapes’, cosmography and architectural order (e.g. Darvill 1997; Parker Pearson & Ramilisonina 1998; cf. Darvill 2006, Lawson 2007). Hitherto, despite the impressive scale and outstanding results of recent fieldwork programmes, especially those undertaken by the Stonehenge Environs and Stonehenge Riverside projects, these have reproduced a fairly traditional monument/site-focused approach to field investigation. The nature, spatial locations and extent of previous geophysical prospection work within the study area are broadly consistent with this wider pattern, being drive either by reactive evaluation strategies determined by the planning process and mitigation of proposed development, or by monument-focused research agenda, resulting in discontinuous, fragmentary, relatively small-scale and often linear rather than spatially-extensive survey areas (Payne 1995; David & Payne 1997; David 2005; Darvill 2005).

The guiding philosophy of the project outlined here is to explore landscape as undivided three-dimensional space and to understand ancient built environments and associated practices at extensive scales within that spatial framework.



Our knowledge of the Stonehenge archaeological landscape will be revolutionized by integrating remote sensing and geophysical prospection with context aware visualization, which combines the existing landscape with prospection and other archaeological data in a seamless fashion. This will result in the creation an unparalleled remote-sensed database, integrating the data in a novel manner in order to inform archaeological research and heritage management for regional and national curators.

The extent of previous geophysical prospection of all kinds within the Stonehenge World Heritage Site up to 2001 has been estimated at 3.1602 square kilometres (David 2005, 14). Since that time, additional geophysical survey in the area, primarily connected with the Stonehenge Riverside Project, probably amounts to less than 800 ha (this is a rough estimate as only a small part of this work is in grey literature; Payne 2006). Overall, therefore, less than 4.0 square kilometres of the landscape have been subject to geophysical survey of diverse types, variable data resolution and uneven and fragmented spatial coverage. In contrast, the project outlined here will consist of a single high-intensity geophysical survey encompassing an estimated 14 square kilometres of the World Heritage Site, providing high-resolution, contiguous extensive mapping of geophysical data in its own right, while also providing a means to tie together and re-evaluate all previous geophysical surveys with reference to a single seamless ‘control’ data set.

The first season of fieldwork which was conducted in July 2010, comprised a three-week period of geophysical and laser survey. The primary data collection included high-resolution magnetic and GPR survey of the Cursus field using motorized and handheld multi-sensor systems and intensive ground-penetrating radar and 3-D laser surveys of the Cursus Barrows. Over 60ha of high resolution data was collected during the first season. The results will identify new and unexpected archaeological results from an area of long-term archaeological interest as well as be used to comment on issues related to the management of the Stonehenge Landscape.

Bibliography

Cleal, R M J, Walker, K, and Montague, R, 1995 *Stonehenge in its Landscape*. London: EH Arch Rep 10

Cleal, R M J with Allen, M J, 1995 The visual envelope. In R M J Cleal, K E Walker and R Montague, *Stonehenge in its Landscape: twentieth century excavations*, 34-40. London: English Heritage.

David, A, 2005 Ground-based geophysical surveys. In T Darvill, *Stonehenge World Heritage Site: an archaeological research framework*, 14-15. London and Bournemouth: English Heritage and Bournemouth University

David, A, and Payne, A, 1997 Geophysical surveys within the Stonehenge Landscape: a review of past endeavour and future potential. In B Cunliffe and C Renfrew (eds), *Science and Stonehenge*, 73-113. Oxford: Proceedings of the British Academy 92

Darvill, T, 1997 Ever increasing circles: the sacred geographies of Stonehenge and its landscape. In B Cunliffe and C Renfrew (eds), *Science and Stonehenge*, 167-202. Oxford: Proceedings of the British Academy 92

Darvill, T, 2005 *Stonehenge World Heritage Site: an archaeological research framework*. London and Bournemouth: English Heritage and Bournemouth University

Darvill, T, 2006 *Stonehenge: the biography of a landscape*. Stroud: Tempus

Exon, S, Gaffney, V, Woodward, A, & Yorston, A, 2000 *Stonehenge Landscapes: journeys through real-and-imagined worlds*. Oxford: Archeopress

Larsson, L, and Parker Pearson, M (eds), 2007 *From Stonehenge to the Baltic: living with cultural diversity in the third millennium BC*. Oxford: British Archaeological Reports, International Series 1692

Lawson, A, 2007 *Chalkland: an archaeology of Stonehenge and its region*. Salisbury: Hobnob Press

Parker Pearson, M, and Ramilisonina, 1998 Stonehenge for the ancestors: the stones pass on the message, *Antiquity* **72**: 308-26

Payne, A, 2006 *Stonehenge Riverside Project, West Amesbury and Greater Cursus, Wiltshire: report on geophysical surveys, July 2006*. London: English Heritage Research Department Report Series no. 41/2007

Richards, J, 1990 The *Stonehenge Environs Project*. London: EH Arch Rep 16

RCHM(E), 1979 *Stonehenge and its Environs: monuments and land use*. Edinburgh: Edinburgh University Press

---

TOWARDS RECONSTRUCTING AN ANCIENT CITY: CASE STUDY OF PELUSIUM, NORTHERN SINAI, EGYPT

Tomasz Herbich
Institute of Archaeology and Ethnology, Polish Academy of Sciences, Al. Solidarnosci 105, 00-140 Warsaw, Poland.

tomasz.herbich@gmail.com

Pelusium (modern Tell el-Farama) in the northwestern part of Sinai was established at the mouth of the now extinct Pelusiac branch of the Nile on the shores of the Mediterranean Sea. The town peaked in development in Ptolemaic and Greco-Roman times, being the most important harbour in Egypt after Alexandria. It was destroyed and abandoned in medieval times. Ruins of a few structures and the walls of the Late Roman fort survived on the ground until the modern age. Excavations in the 20th century uncovered the building of a bath, the foundations of a theatre and a church – altogether no more than 2% of the area of the ancient town. The site was not inhabited again until modern times and is for the most part flat due to erosional processes.

Fig. 1: General view of the site (area north-west of the theatre, seen from south-west).

The ruins are found immediately below the ground surface. Red brick, which is strongly magnetic, was the principal building material. The substrate is alluvial in nature, humid and salty due to the nearness of the sea: it is therefore an excellent conductor. These factors make Pelusium a perfect site for geophysical research, whether by the magnetic or the electrical resistivity methods. The abundance of written sources concerning the town creates an excellent opportunity for confronting the results of geophysical mapping with historical references.

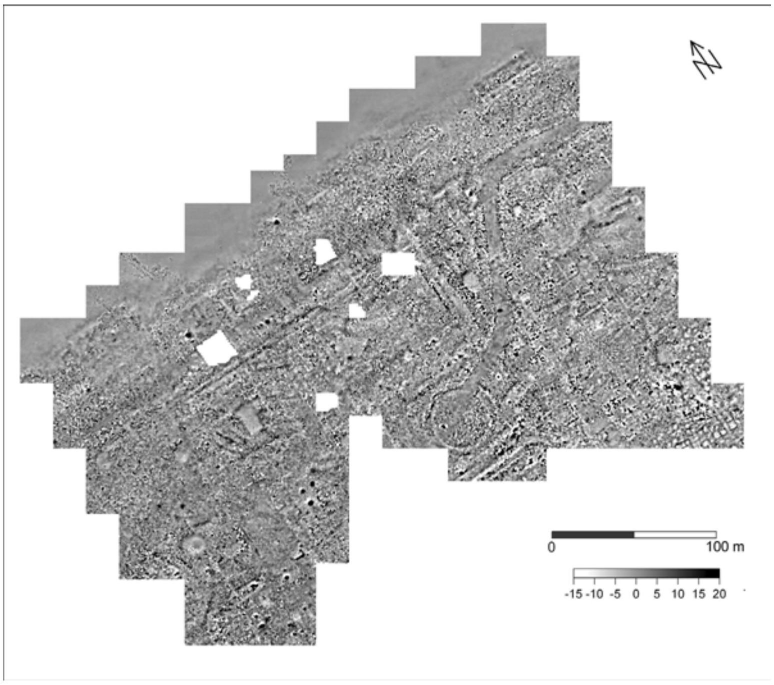


Fig. 2: Magnetic map. Geoscan Research gradiometers FM256. Sampling grid 0.25 by 0.50m, interpolated to 0.25m by 0.25m. Low pass filter. Dynamics – 12/+17 nT (white/black).

Geophysical prospection by the magnetic method was undertaken by an Egyptian team in the 1990s within the fortress walls. The area was not tested archaeologically and the magnetic results were too indistinct for a reconstruction of the inner layout of the fortress (Ibrahim et al 1998).

In 2005, the Polish concession between the northern side of the theatre and the northern town limits became the site of geophysical mapping. It turned out that, assuming proper sampling density in the magnetic survey and appropriate choice of depth range in the electrical resistance measurements, the results of the prospection permitted a reliable reconstruction of large sections of the town plan. The magnetic method made it possible to discover a district of monumental architecture in front of the theatre and to trace its extent, to register a habitational district and the street grid, as well as the extent of individual buildings. The survey also determined the borderline between the city and the lagoon. The most intriguing structure discovered during the magnetic survey is a square building with a round central chamber of a diameter of almost 35m. This building probably functioned as a bouleuterion (Jakubiak 2009: 68).

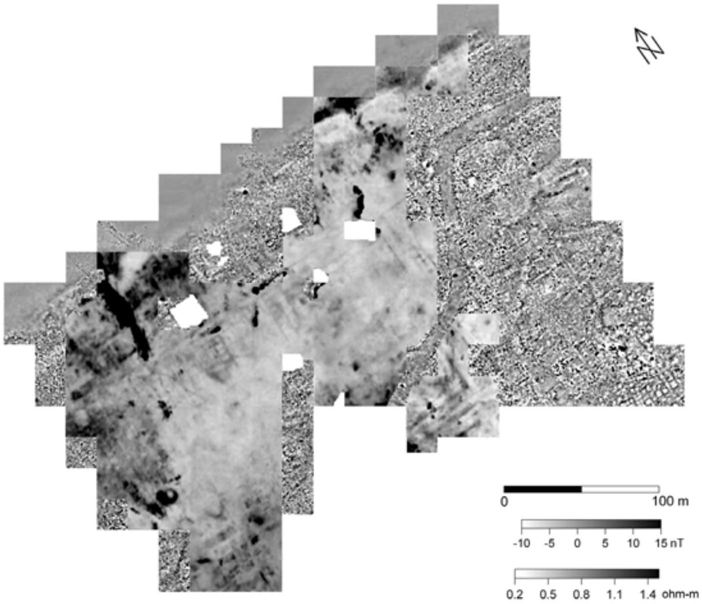


Fig. 3: Resistance map (superimposed on magnetic map). Geoscan Research resitivity meter RM15. Twin probe array, spacing of traversing probes 0.5m, remote probes 3.0m. Sampling grid 0.5 by 1m, interpolated to 0.5 by 0.5m. Low pass filter. Dynamics 0.25/1.5 ohm-m (white/black).

The electrical resistivity survey helped to clarify the plan of a number of structures, whose presence was signalized by the results of the magnetic survey. An integrated approach to the prospection made it possible to identify the building material, whether red brick, mud brick or stone. In a series of cases a possibility of a simultaneous analysis of the magnetic and resistivity image allowed to specify which linear anomalies visible on the magnetic map reflect the constructions and which the spaces between them – so as to correctly establish the location of the structures.

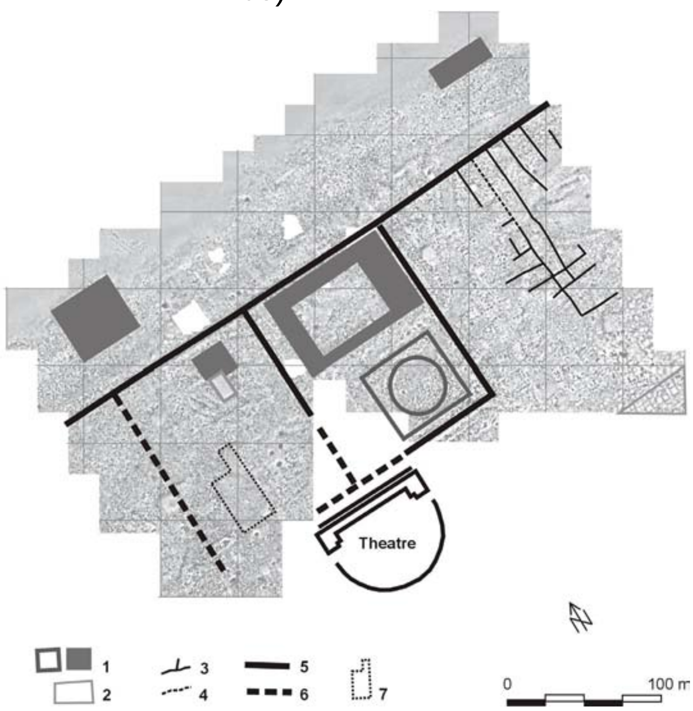


Fig. 4: Archaeological map of the site based on geophysical results. 1 – Red brick buildings; 2 – mud brick buildings and structures; 3 and 4 – narrow streets (reconstructed course of the street in dashed line); 5 and 6 – main streets (reconstructed course of streets in dashed line); 7 – square.

Three brief episodes of geophysical surveying (no more than a few days of fieldwork each time) by the magnetic method (parallel mode, grid 0.25m x 0.50m) covered an area of close to 9 ha. The resistivity method (grid of 0.5m x 1m, twin probe 0.5m) was used on an area of 4.5 ha. It turns out that this is a biggest single area tested by the resistivity method anywhere on an archaeological site in Egypt. The fieldwork will be continued. The research is part of a broader study program aimed at reconstructing urban layouts in the Nile Delta based partly on the results of geophysical prospection.

Bibliography

Ibrahim E.H., Sherief M.R., Al.-Metwally A.A. 1998 Shallow geophysical investigations on Tell el-Farama, Northwest Siani, Egypt, *Archaeologica Prosection* **5**, 91-100.

Jakubiak K. 2009 Tell Farama, Pelusium. City urban planning reconstruction in the light of the last researches, in: Proceedings of the Fifth Central European Conference of Egyptologists. Egypt 2009: perspective of research. Pułtusk 22-24 June 2009, J. Popielska-Grzybowska and J. Iwaszczuk (eds), *Acta Archaeologica Pultuskiensia* **2**, 65-74.

EARLY URBANISM IN EUROPE? – GEOPHYSICAL SURVEY AT NEBELIVKA, UKRAINE

Duncan Hale(1), John Chapman(2), Natalie Swann(1), Mikhail Videiko(3) and Richie Villis(1)

(1)Archaeological Services, Durham University, UK; (2)Department of Archaeology, Durham University, UK; (3)Institute of Archaeology, Kiev.

d.n.hale@durham.ac.uk

In 2009 Archaeological Services undertook a trial geophysical survey for a colleague's research project entitled 'The Climax Neolithic Settlements Project', which is investigating early urbanism in Europe, specifically the contrasting settlement patterns of the Tripolye 'mega-sites' in western Ukraine and the Lengyel rondels in south-west Hungary. This is an international, inter-disciplinary project directed by Drs John Chapman and Mikhail Videiko. The Tripolye mega-sites in the Uman region of western Ukraine are so-called because they range in size from about 220 hectares up to 450 hectares and constitute the largest sites in 4th millennium BC Europe. The best-known group of five such sites comprises Talljanky, Majdanetsko, Dobrovodi, Tomashevka and Nebelivka.

Our trial geomagnetic survey targeted part of the site at Nebelivka, the smallest of the group, covering an estimated 220 hectares based upon aerial photography from the 1980s. The site is surrounded on three sides by gulleys with streams, which form an effective outer limit to the site. Fieldwalking out from the core South East field revealed high surface densities of Tripolye pottery and daub, followed by a gradual reduction in finds density. This distribution matches the aerial photographic interpretation. The crop cover across the seven or eight large fields covered by Nebelivka was variable, leading to the decision to focus on the South East field which had been partially ploughed but on which some stubble cover remained. A trial area of 15 hectares was surveyed.

Previous excavations at mega-sites have all shown that burnt house floors survive at a depth of no more than 1m. It was therefore anticipated that geomagnetic survey would be ideally suited to detecting burnt features overlain by about 1m of loess deposits at Nebelivka. The results of the trial survey by Richie Villis and Natalie Swann, however, surpassed all expectations.

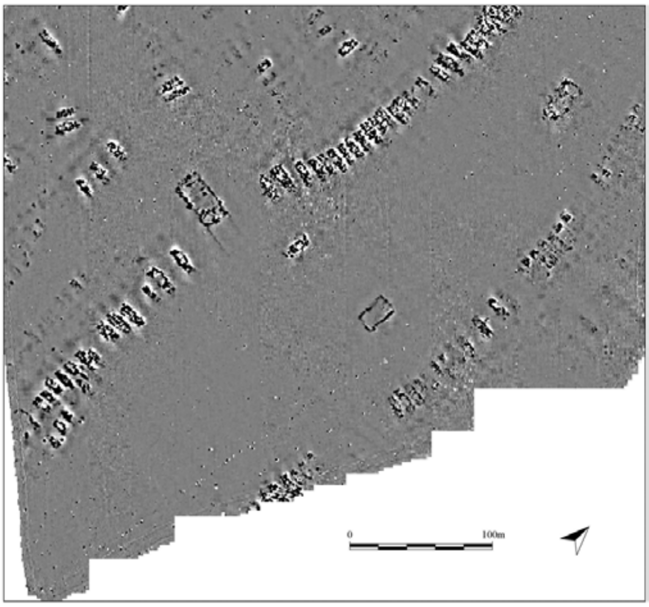


Figure 1: Nebelivka: geomagnetic survey (greyscale range: white - 15nT to black +15nT)

After filtering out the magnetic effects of the local granitic geology rows of houses can be clearly seen, aligned both north-south and east-west, each with probable internal features and an associated backyard or garden area. The more intense rectilinear anomalies correspond to the burnt houses. Since there is little background noise in the data, individual houses can be displayed particularly clearly as profile plots. Rows of similar but weaker anomalies almost certainly reflect unburnt houses and soil-filled features such as ditches and pits. At least five isolated buildings are also evident; these are typically larger than the ones in rows.

One structure, measuring about 40m by 20m, which was detected near the centre of the survey, is the largest structure yet to be found on any Tripolye site. It appears to have an attached enclosure of similar size and is aligned east-west along what appears to be a broad band of near-surface rockhead; this may have been more evident as a ridge before the loess was deposited. Indeed, four of the five isolated building identified so far sit on top of this geological feature.

The geophysical plan provides the clearest example to date of the spatial organisation of a Tripolye mega-site, which is evidently highly structured. The survey has enabled the next phase of preliminary investigation: the targeted coring of house floors in order to recover materials for radiocarbon dating. It is hoped that the geophysical results, together with the suite of radiocarbon dates from some of the building materials, will help to secure significant funding for further research at the site.

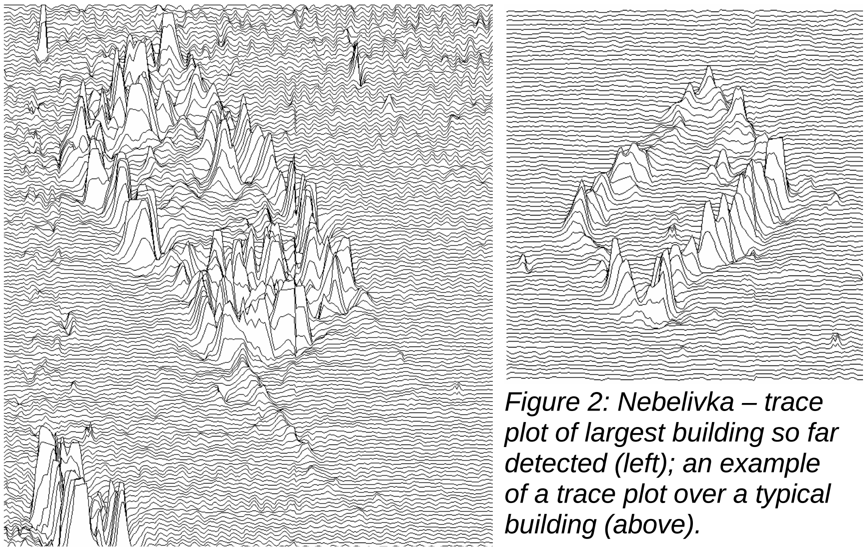


Figure 2: Nebelivka – trace plot of largest building so far detected (left); an example of a trace plot over a typical building (above).

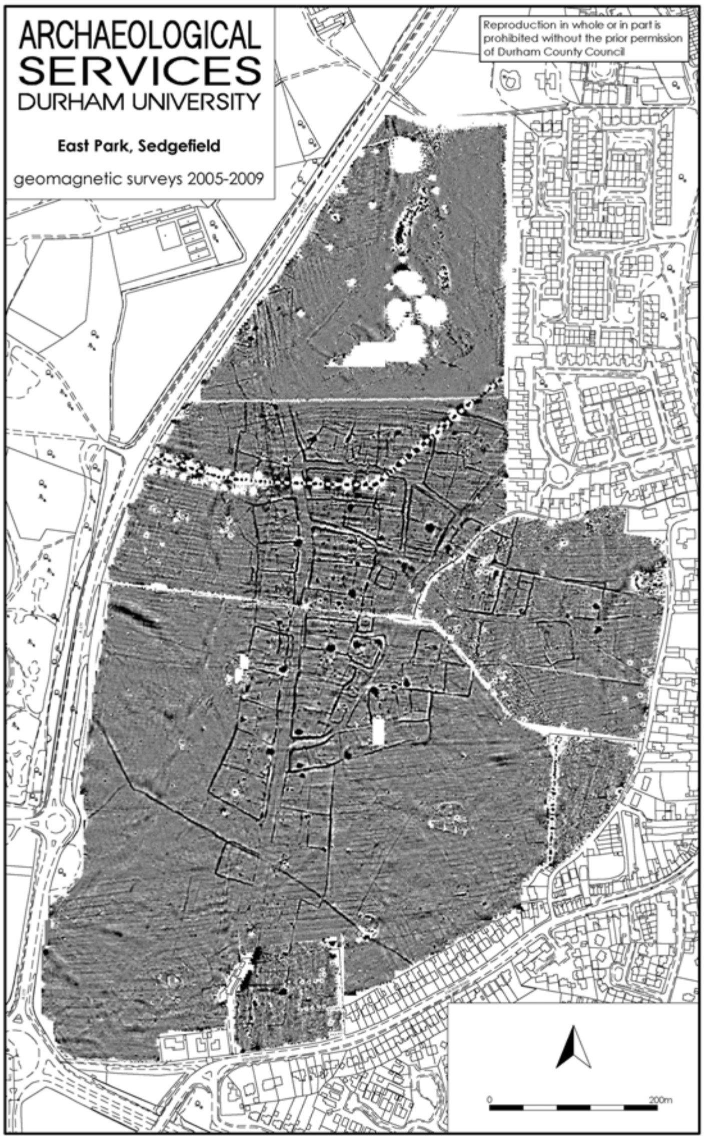
POSTER ABSTRACTS

EAST PARK, SEDGEFIELD, COUNTY DURHAM - GEOPHYSICAL SURVEY OF A ROMAN CIVILIAN SETTLEMENT

Duncan Hale, Natalie Swann and Richie Villis
Archaeological Services, Durham University, UK.

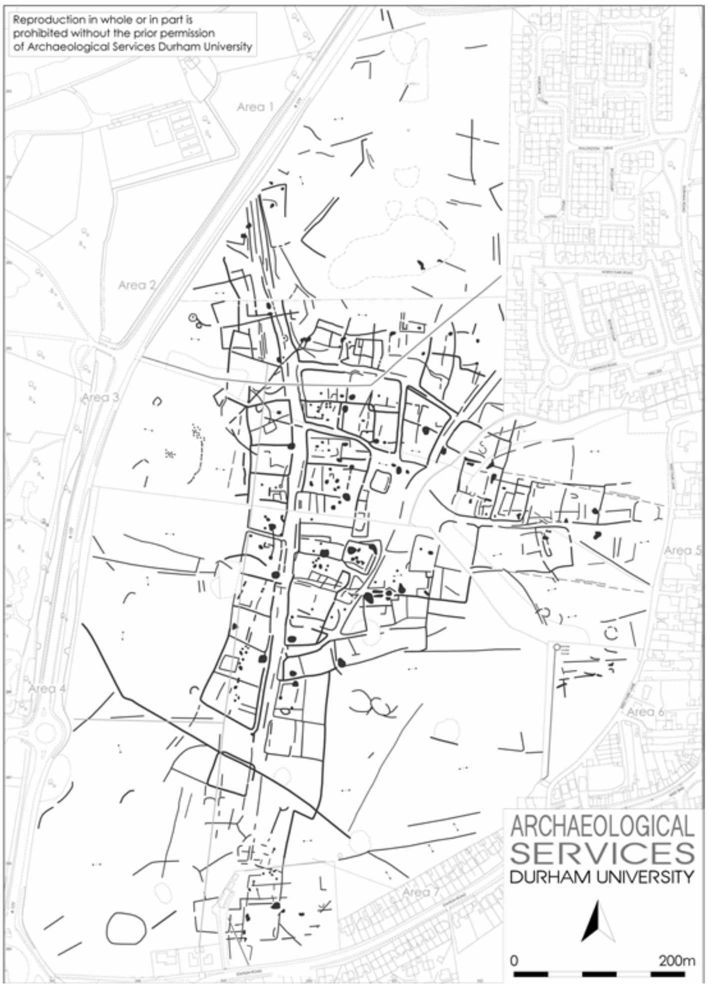
d.n.hale@durham.ac.uk

The settlement at East Park, Sedgefield, was first recognised from the air as cropmarks in the large southern field in the 1990s and the aerial photographs that were taken then, together with the large number of Roman coins found by local detectorists, prompted evaluation of the site as part of a Time Team Channel 4 production in 2002. The evaluation included fieldwalking, metal detecting, geophysical survey of sample areas and trial trenching of selected geophysical anomalies, which confirmed the presence of Roman features and demonstrated the huge potential for further work.



The Sedgefield Community Research Project was subsequently set up as a partnership project led by Archaeological Services Durham University and Durham County Council, to enable student training and community involvement in archaeological research. Between May 2005 and October 2009 approximately 53 hectares were surveyed geomagnetically and four open-area excavations were conducted with students and members of the local community.

The surveys revealed an extensive complex of linear, rectilinear and sub-circular magnetic anomalies, extending over at least 30 hectares. The majority of the anomalies reflect soil-filled ditches, which here define several roads and dozens of enclosures, while others reflect large soil-filled pits and ovens/kilns. A more irregular complex of slightly weaker anomalies in Area 3 appears to underlie the more regular system of enclosures and roads, which is evident over a much larger area. No roads or tracks have been identified in the earlier phase of settlement, which seems to have been in place prior to the construction of Cades Road, and is likely to be pre-Roman.



The principal axis of this Roman ‘small town’ is aligned roughly north-south along Cades Road, a Roman road which is believed to start at Brough-on-Humber and which heads north via York and Chester-le-Street to Newcastle upon Tyne. The majority of the settlement is located on the east side of this road, although a continuous row of enclosures does flank the western side of the road for over 800m, throughout the surveyed area. Indeed, the ditched enclosures on both sides of the road appear to continue beyond both the north-western and southern limits of the study area. The enclosures typically measure 40-50m square, though both larger and smaller ones are also present. Many of the enclosures have large subcircular positive magnetic anomalies associated with them, almost certainly pits, often at or near their corners. Up to 30 of these features have been detected by the surveys. Excavation of one such anomaly in 2005 confirmed that it was a large pit, measuring several metres across and at least 3m deep. These pits may originally have been excavated to provide sand or gravel, or, where it occurs, clay, possibly for a local pottery industry. One geophysical anomaly investigated by Time Team in Area 3 was proven to be a pottery kiln, believed to have been built with clay from a local source. Subsequent use of these large pits may have been for water storage for small-scale industries in this part of the town, as also evidenced by metal-working slag and several clay and stone ovens recorded in another part of the 2005 excavation. The pits could also have served as watering holes for stock, however, many of the enclosures appear to have internal features indicative of domestic or industrial activities rather than simply livestock management. The internal anomalies almost certainly reflect a variety of features, including postholes, beamslots, gullies, pits, ovens, hearths and kilns.

Although evidence for timber buildings was recorded inside both the enclosures excavated in 2005 and 2006, neither appears to represent purely domestic occupation: the one to the west of Cades Road was associated with a number of small clay ovens while that to the east of Cades Road was sited in an otherwise open space near the centre of the known settlement and may have had a public function.

Further post-holes identified in the eastern part of the 2007 excavation may have been associated with one or more timber buildings there. Whilst some structures in the surveyed areas may have been occupied, it seems that any higher status houses may have been on the higher ground to the east, beneath the present town. The geophysical survey of the Show Field (Area 5) did not detect evidence for stone-founded buildings, but the regular pattern of enclosures does continue eastwards across this area, to both north and south of another road, and beneath the modern town. The internal divisions and other features within some of these eastern enclosures are particularly clear. At the western end of this main east-west road, the road opens out onto the large central space around the unusual small enclosure mentioned above.

Taken as a whole, the site is a substantial Roman civilian settlement, all the more significant in this region for its lack of evidence for any military presence.

Later features detected at the site include medieval ridge and furrow cultivation remains, post-medieval land boundaries and more recent land drains and services.

MAPPING PLEISTOCENE LANDSCAPE FEATURES USING ARCHAEOLOGICAL GEOPHYSICS

Adrian Butler and John Walford
Northamptonshire Archaeology, UK.

abutler@northamptonshire.gov.uk

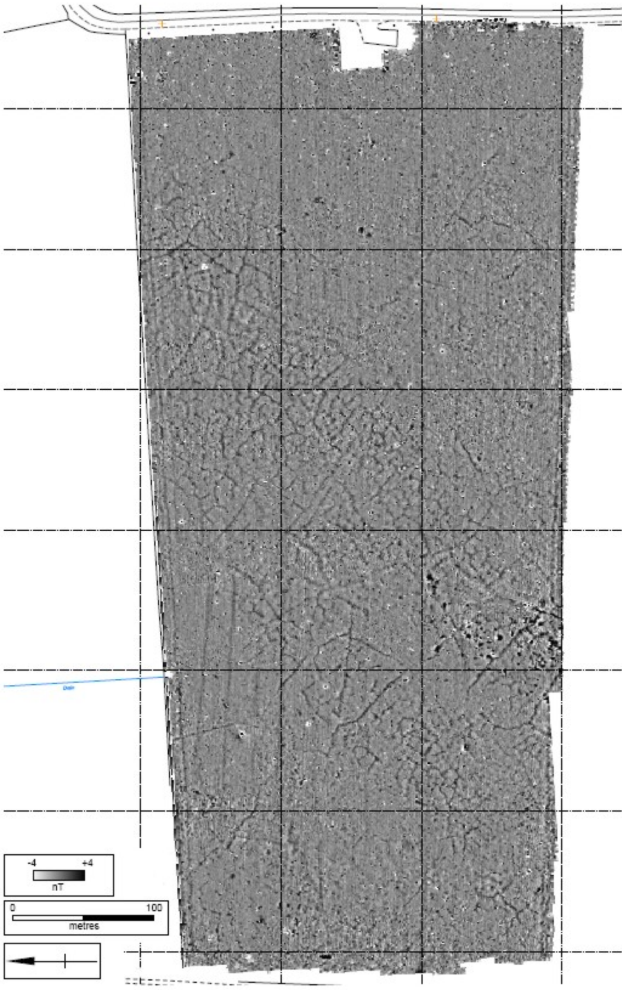
Commercial archaeo-geophysical surveys detect a wide range of anomalies, some of which are not of direct archaeological interest. Magnetic surveys often map Pleistocene periglacial geological features, such as patterned ground, ice wedges, solution pipes and palaeochannels. These are not always identified correctly and may be confused with archaeological features, such as pits and enclosures, or even discounted out of hand.

Such data are rarely given the attention they deserve. Should efforts be made to publicise the potential of this information to a wider audience of relevant geological specialists, quaternary scientists and geotechnical engineers? This poster outlines exploratory research into the advantages of dialogue between archaeologists and geologists.

Several case studies from the Northamptonshire Archaeology survey archive are presented, supplemented, where possible, by excavation results. They are offered on a strictly qualitative basis as research is at an early stage and empirical study is yet to be carried out.

Patterned ground, which manifests as non-sorted networks and stripes, are well known from chalk geologies of the UK. We have encountered examples of magnetic response to this effect at several sites in Norfolk, where we have also had the opportunity to take some measurements following excavation. Survey on the solid limestone and ironstone geologies of Northamptonshire, Leicestershire and

Cambridgeshire are well known for their ice polygon networks. These features are detected in magnetic surveys and, as is demonstrated in the results, can easily mask or be mistaken for archaeological sites.



Geophysical research by geologists into Pleistocene near-surface features could improve understanding of the totality of the geophysical response. This in turn would feed back into interpretation of anomalies which currently present challenges to the archaeological geophysicist. Benefits to near surface geology could include the provision of:

- High resolution geophysical data
- Large datasets, widespread through the UK
- Precise locations of features (i.e. more accurate than aerial photography)
- Information on possible geotechnical hazards

This poster seeks to demonstrate how a hitherto underused resource can be of advantage to both geologists and archaeological geophysicists.

GEOPHYSICS IN YOUR BACK GARDEN: FROM RURAL RETREATS TO ROYAL PALACES, 18 YEARS OF 'GEOPHYS' ON TIME TEAM

Emma Wood and John Gater

GSB Prospection Ltd, Cowburn Farm, 21 Market Street, Thornton, West Yorkshire BD13 3HW, UK.

gsb@gsbprospection.com

Back in 1993 the first series of Time Team was recorded for Channel 4 television. 18 years and 200 projects later, the programme is still going strong and is now viewed in over 34 countries worldwide. Geophysics (colloquially referred to as 'Geophys') has played a prominent role in the entire series: from the first shoot at Athelney, where viewers saw a near complete abbey plan emerging out of a printer in the back of a vehicle, to the latest challenge where we will be seen surveying the bottom of a reservoir in Devon.

During the past 18 years a variety of techniques has been employed to meet a series of challenges – both televisual and technical. From pixellated images to high resolution 3D models and from recording spot readings to employing motorised vehicles, viewers have seen the development of software and instruments over the years.

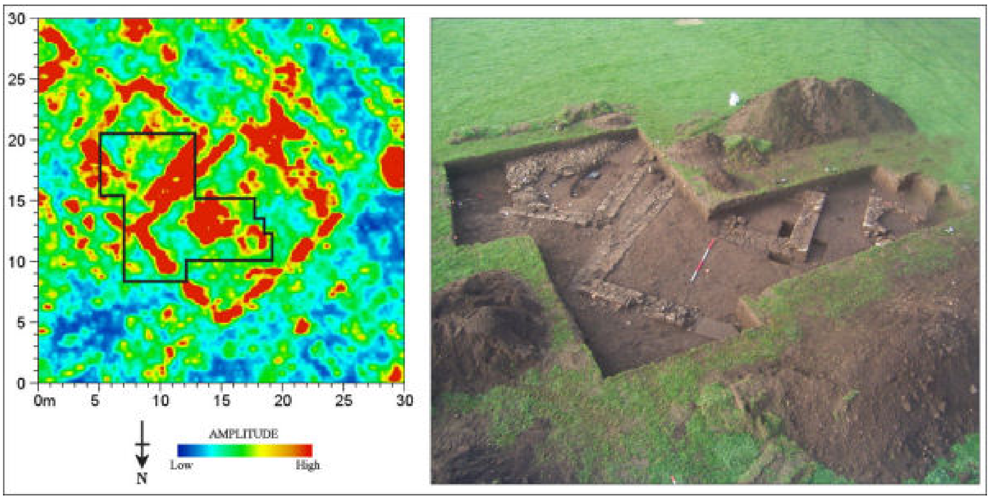


Figure 1: Binchester Mausoleums – Radar results showing outline in black of excavation trench (photo).

This poster will highlight some of the facts and figures about the survey work and present the results from a number of different locations which we have had the good fortune to investigate.

‘IT NEVER RAINS BUT IT POURS’ EARTH RESISTANCE SEASONALITY TESTING IN BRADFORD

Andrew Parkyn
Division of Archaeological, Geographical and Environmental Sciences, University of Bradford, Bradford, West Yorkshire, BD71DP, UK.

a.k.parkyn@bradford.ac.uk

Introduction

Earth resistance measurements are directly affected by variations in moisture content as the water within the soil contains electrolytes that are capable of holding a charge and therefore allow an electrical current to flow. Variations in the moisture and electrolyte content of soil will directly affect the results of earth resistance surveys as measurements are dependent upon the displacement of ions in the interstitial water in the soil Scollar (1990).

Subtle changes in earth resistance values can be recorded on a diurnal basis but variations are more pronounced on a weekly or monthly basis. David et al. (2008) states that weather, vegetation cover, soil types and feature type can also affect Earth resistance measurements. To overcome these variations, English Heritage guidelines (David et al. 2008) suggest earth resistance surveys should be conducted at the time of year when moisture contrasts are more pronounced or to resurvey a site at different times of year.

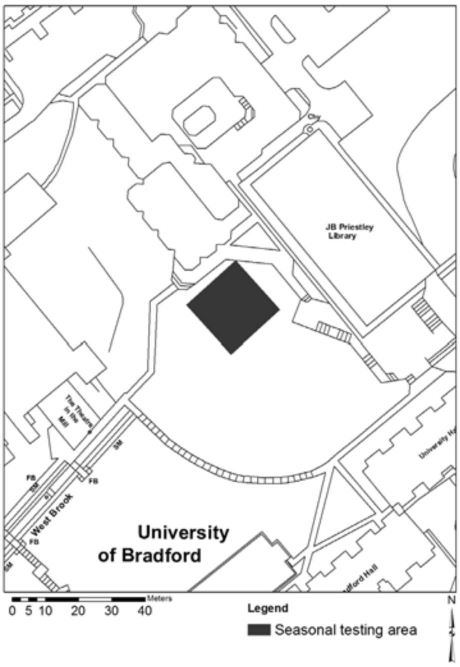


Figure 1. Showing the location of the seasonality testing area at the University of Bradford. (© Crown copyright / data base right 2009. An Ordnance Survey/Edina supplied service.)

As part of the ongoing research and development of the Geoscan Research MSP40 it was considered important to study the effects of seasonal variations on the equipment which has not been fully considered in direct comparison with the other earth resistance array types over a 20m x 20m survey area (Figure 1).

Methodology

The seasonality data was collected over 16 consecutive months on a 20m x 20m grid on the University of Bradford amphitheatre. Monthly testing was considered sufficient to identify seasonal variation on site. Surveys were carried out during the middle of the month where possible to allow a consistent gap between measurements. Multiple array configurations were used to provide comparative array measurements (Table 1).

A miniature Earth resistance frame was also built using stainless steel screws as electrodes; the probe separation was 0.05m and measurements were configured as a Wenner array. The frame was built to study the moisture changes of the very near surface soil horizon.

Survey parameters & sampling strategy (Table 1)

Equipment & probe separation	*Measurement Configuration*	*Sampling Interval*	*Traverse Interval*	*Method of collection*
MSP40 (0.75m)	Alpha & Beta	0.5m	1m	Zig Zag (encoder wheel)
Manual square (0.75m)	Alpha, Beta, Gamma & 0.5m Twin probe	0.5m	1m	Zig Zag
Twin probe (0.75m)	Single measurement	0.5m	1m	Zig Zag
Near surface moisture test (0.05m)	Wenner	1m	1m	Zig Zag

Results

The research project considered the mean apparent resistivity values alongside single high and low resistivity data points and an analysis of the changing calculated areas of six separate anomalies for each month. The data sets were converted to apparent resistivity values to allow comparisons between data sets without the geometry and dimensions of the array influencing the comparisons.

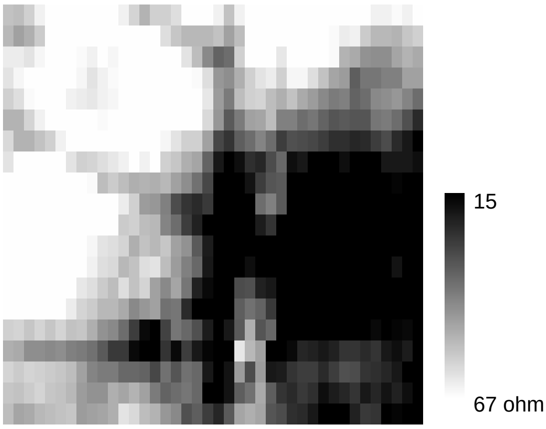


Figure 2: Showing a typical earth resistance data display of the seasonality test area from the 0.75m manual square array, values converted to apparent resistivity rho_A (17.09.2009).

Local Met Office weather station data was accessed to allow analysis between the net moisture change (including precipitation and evapotranspiration rates) and monthly apparent resistivity values (Figure 3). Results showed a short lag time between increases in soil moisture and decreasing apparent resistivity values.

Discussion & conclusions

The results indicate a significant difference between the apparent resistivity values of the different arrays. Converting the resistance values to apparent resistivity subtracts any effects the type and dimensions of an array may have on the data. Closer correlations between values would be expected. The differences in values may be due to the depth of detection of the square and twin probe arrays. The square array has a reduced optimal depth of detection (depth of greatest current density) when compared to a twin probe array with an identical probe separation (Roy & Apparao 1971). This may explain the increased resistance values of the square arrays if the topsoil is heavily compacted.

However the manual square array and MSP40 shows smaller percentage change (between the minimum and maximum monthly values) in resistivity than the twin probe array. This may indicate that a square array is less prone to seasonal variations than the twin probe array. The 0.5m twin probe and manual square array data sets were collected sequentially on the same frame. As a result the centre of the array is always in the same location for both configurations.

The monthly measurements show a reverse trend to what would be expected as all arrays show higher apparent resistivity values during the winter and spring than the summer months due to an unusually wet summer and dry winter. The study highlights the difficulties in choosing an optimal time for earth resistance survey as it is directly affected by the recent weather patterns in the months immediately preceding a survey.

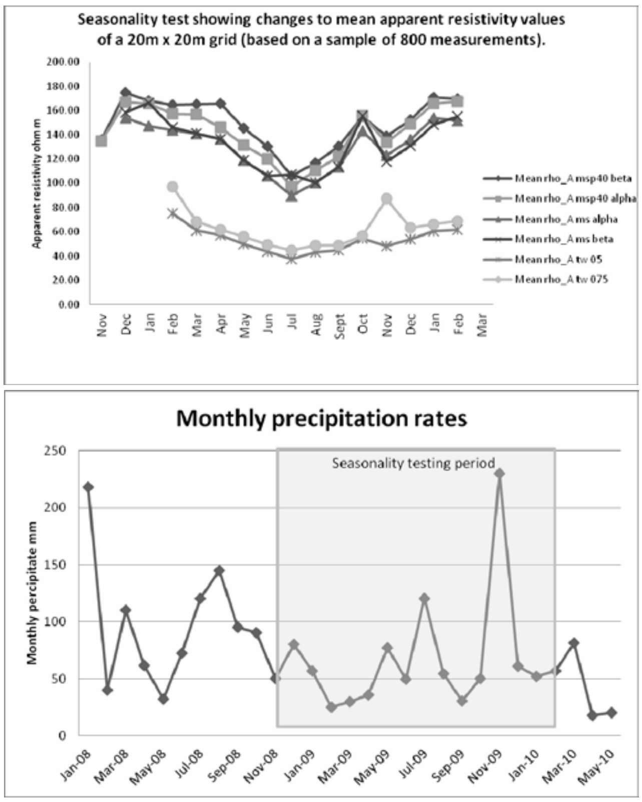


Figure 3: Showing the changing monthly apparent resistivity values of the 0.75m MSP40, 0.75m manual square, 0.5m and 0.75m twin probe arrays and the precipitation rate information from the local Met Office weather station.

Bibliography
David, A., N. Linford, P. Linford, L. Martin & A. Payne 2008. *Geophysical Survey in Archaeological Field Evaluation*. Swindon: English Heritage.

Roy, A. & A. Apparao 1971. Depth of Investigation in Direct Current methods. *Geophysics* **36(5)**: 943- 959.

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

THE INTERFACE OF GEOPHYSICAL AND GEOCHEMICAL SURVEY: TOWARDS AN UNDERSTANDING OF GEOPHYSICAL DATA QUALITY IN CHALLENGING ARCHAEOLOGICAL SITES.

Carmen Cuenca-Garcia
Department of Archaeology, University of Glasgow, UK.

c.cuenca-garcia.1@research.gla.ac.uk

Geophysical and geochemical techniques have been widely applied to detect and investigate archaeological sites. Integrated geophysical survey plays a major role in the discovery and exploration of archaeological sites. Geochemical survey also provides valuable information on the location of sites, but it also has the potential of determining source and spatial extent of past human activities and in investigating the use of space in archaeological sites.

Both approaches have tended to operate independently of each other but their interface can be of great help in order to understand the capacities and limits in detection of different near-surface geophysical techniques for archaeological prospection.

This poster will introduce an on-going NERC PhD research project which explores this interface by characterising the geophysical response of common archaeological features in terms of chemical signatures and soil properties to comprehend why that geophysical response varies in quality. This should allow a more confident prediction of the most appropriate survey strategy to be used at archaeological sites lying in challenging soil environments.

The research is focussed on archaeological sites in Scotland which lie in contrasting drift soils and have existing data records (geophysical and/or geochemical surveys, aerial photography, excavation records). Integrated geophysical surveys and geochemical sampling are currently being undertaken. The different geophysical responses will be determined with respect to soil moisture content, texture, conductivity and geochemical composition to evaluate the performance of the different geophysical techniques used.

ENHANCING MAGNETIC SURVEY INTERPRETATION OF ROMAN CITIES: GEOPHYSICAL DATA COMBINATION AND ARCHAEOLOGICAL FEEDBACK ON *AMMAIA*.

Jeroen Verhegge[1,2], Armin Schmidt[2], Chris Gaffney[2], Frank Vermeulen[1] and Lieven Verdonck[1]
[1] *Dept. of Archaeology, Ghent University, Sint-Pietersnieuwstraat 35, 9000 Gent, Belgium;* [2] *Div. of Archaeological, Geographical & Environmental Sciences, University of Bradford, Bradford, West Yorkshire, DB7 1DP, UK.*

jeroen.verhegge@ugent.be

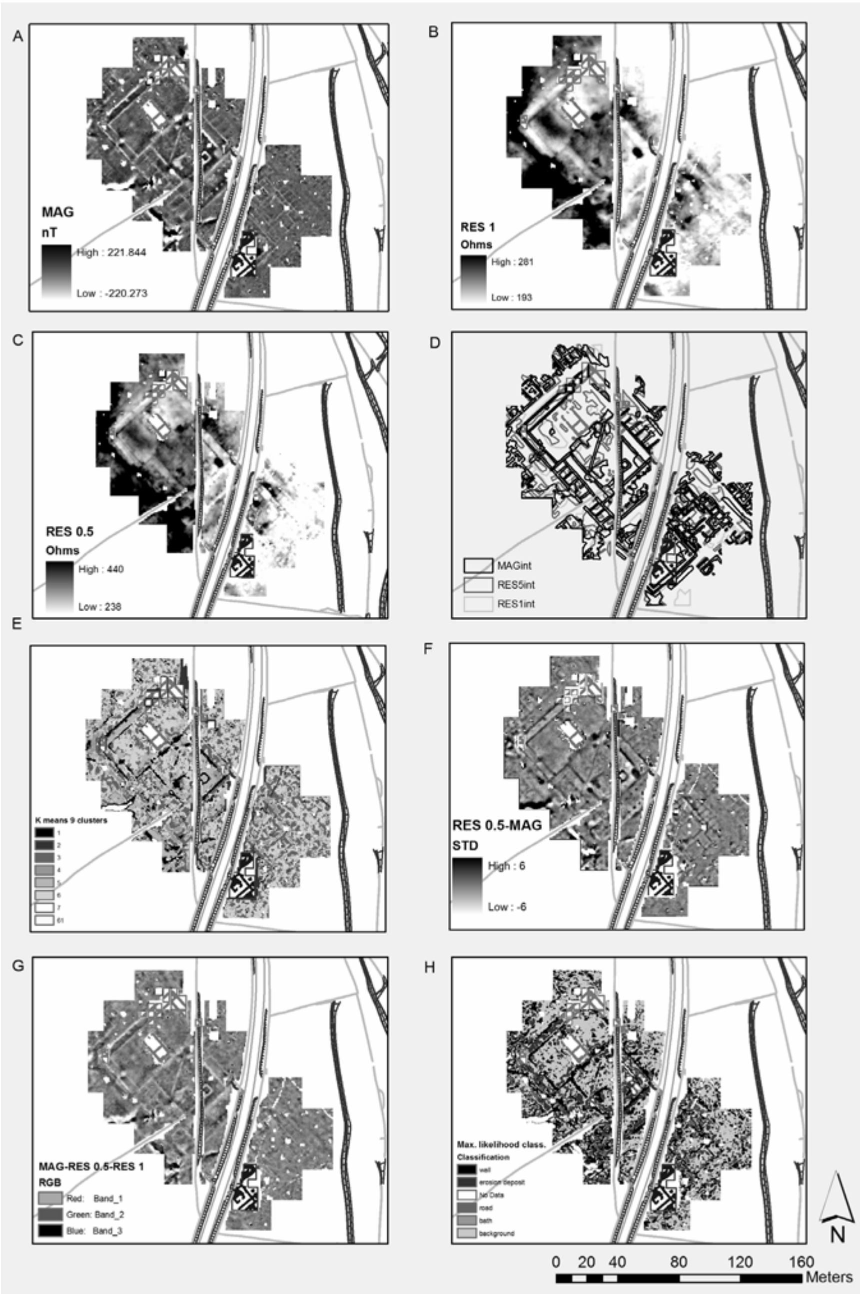
The Roman town of *Ammaia*, situated just south of São Salvador da Aramenha (Marvão, Portugal), was most likely founded ex nihilo as capital of the Civitas Ammaiensis in the early 1st century AD, a period of restoration and homogenization in the Iberian Peninsula. Due to its favourable location and natural resources, *Ammaia* prospered until the 5th century AD, when gradual abandonment started. By the 8th century, it was replaced by the Arabic hilltop settlement of Marvão (Corsi & Vermeulen 2007). In spite of its rediscovery in the 1930s, scientific research only started in 1994 by the 'City of *Ammaia*-foundation' with excavations of mural and intra mural structures at the southern gate, parts of the portico surrounding the forum and the partially destroyed baths south of it (Pereira 2009). From 2001 onwards geo-archaeological research gave insights into the town wall circuit, water supply, natural resources and geomorphologic history of the site (Vermeulen et al. 2005). In 2008, ground-penetrating radar (GPR) survey partially revealed the forum layout (Verdonck et al. 2008).

The research presented here is aimed at revealing the rest of the forum and an adjacent insula to further complete the known picture of the monumental town centre, using magnetic and earth resistance survey and feeding back archaeological excavation data. Since several geophysical datasets have been and will be collected to develop the intra and extra mural town layout, a site specific data integration strategy for combined data visualisation, classification and interpretation could well enhance the overall archaeological interpretation (Kvamme 2006; 2007).

For this project, fluxgate gradiometer data were collected using a Geoscan Research FM256 magnetometer along 0.5m separated traverses in parallel (fig. A). Earth resistance data were gathered using a multiplexed Geoscan Research RM15, with mobile probes separations of 1m (fig. B) and 0.5m (fig. C), collecting data every 0.5m along 1m separated traverses.

Data processing includes grid matching, zero mean traversing, de-spiking, targeted median filtering, low pass filtering and high pass filtering, wherever necessary. Data normalisation and standardization is necessary for operations on continuous datasets but also useful for other data combination methods. This was done using high pass filtering for resistance data, all data were standardised until $\mu=0$ and $\sigma=1$. Finally all datasets were resampled equal and georeferenced.

The results confirm and complete the known layout of the forum, occupying the area of about 2 insulae and fitting well within the rectangular street pattern of the city. It seems to consist of a temple, possibly surrounded by a temenos and a filled in portico, at the north-western end. This part is separated from the south-eastern end by a wall and a series of monuments in front of the temple. The forum square shows various possible monumental remains, a drain at an angle and is surrounded by 2 porticos and a clearly visible basilica at the southern end. Both the basilica and forum square are in their turn flanked by a series of tabernae. The insula south of the forum contains a part of a peristyle house and the baths seem to be built to include the footpath next to the road, indicating that they were a later addition. This is confirmed by recent excavation results (Vermeulen et al. 2009).



The integration of 'manually traced' anomalies (fig. D) is the simplest method but does not add new information. Simple graphical data combinations, if used on a limited number of non-normalised datasets, can reveal new insights, but rely heavily on the chosen cut-off values. They can combine 3 different visual classes: contour lines, 3-d models and colour scales including shadow plots (Schmidt 2002). These are easily made but mentally hard to interpret. Varying colour scales can be combined in their turn, in this case RGB-composites or partially transparent overlays are created. These plots still require manual tracing and interpretation though, but show correlations between the datasets.

The results of Boolean operations depend largely on the preferably normalised data reclassification into anomalies and a trendless background. On *Ammaia*, it was found useful to create a binary dataset for positive resistance and GPR and negative magnetic anomalies. This way, the detection of wall features by all instruments could be assessed using Boolean union. However, the loss of information through this reclassification was not compensated by the additional interpretational value of the Boolean operations. Unsupervised K-means cluster analysis (fig. E) reclassifies the data automatically into a number of predefined classes, also causing a loss of feature definition. When used with a limited number of preferably, but not necessarily normalized datasets, this method does define useful anomaly classes depending on the number of output clusters. Operations on continuous data do require standardized datasets with a normal distribution. Due to an abundance of negative magnetic wall anomalies, the resistance and magnetic data sum and product (Doneus & Neubauer 1998; Piro et al. 2000) mainly obscures features, while the difference (fig. F) reinforces them, mainly around the baths area. A normalised differential index only accentuates the edges of the anomalies. Minimum and maximum overlays do not produce significant results due to the complexity of the archaeological data. Principal component analysis (fig. G) shows most of the variance in the first component, while the second component shows mainly where resistance and magnetic data differ. The variance in the third component is mainly due to anomalies in all datasets. Maximum likelihood (supervised) classification (fig. H) is able to roughly classify some types of anomalies. The quality of classification largely depends however on the uniqueness of the assigned signature. Since too few datasets were available, this classification could not be done with acceptable results. To this end, further research into the geophysical signatures of the buried remains of *Ammaia* is needed.

In the next few years, more geophysical and other remotely sensed datasets will be collected on *Ammaia*, requiring further research and study of appropriate data combination techniques and integrated interpretations strategies.

Bibliography

Corsi, C. & F. Vermeulen 2007. Elementi per la ricostruzione del paesaggio urbano e suburbano della città romana di Ammaia. *Archeologia Aerea* **3**: 13-30.

Doneus, M. & W. Neubauer 1998. 2D combination of prospection data. *Archaeological Prospection* **5(1)**: 29-56.

Kvamme, K. L. 2006. Integrating multidimensional geophysical data. *Archaeological Prospection* **13(1)**: 57-72.

Kvamme, K. L. 2007. Integrating Multiple Geophysical Datasets. In J. Wiseman and F. El-Baz (eds) *Remote Sensing in Archaeology*: 345-37411. new york: springer science+Business Media, LLC.

Pereira, S. 2009. *A Cidade Romana de Ammaia. Escavações Arqueológicas 2000-2006* Ibn Maruán, Nr. Especial (II). Marvão: Edições Colobri.

Piro, S., P. Mauriello & F. Cammarano 2000. Quantitative integration of geophysical methods for archaeological prospection. *Archaeological Prospection* **7(4)**: 203-213.

Schmidt, A. 2002. *Visualisation of multi-source archaeological geophysics data*. In M. Cucarzi and P. Conti (eds).

Verdonck, L., D. Taelman & F. Vermeulen 2008. *Ground-penetrating radar survey at the Roman town of Ammaia (Portugal)*. Recent work in archaeological geophysics: 35-36.

Vermeulen, F., M. De Dapper, C. Corsi & S. Deprez 2005. Geoarchaeological Observations on the Roman Town of Ammaia. *Internet Archaeology* (**19**)

Vermeulen, F., D. Van Limbergen & S. Dralans 2009. *Excavations in the Bath House complex near the Forum of Ammaia*. CIDEHUS.

Acknowledgements
This research, part of a MSc dissertation project, was made possible thanks to practical support by Div. of Archaeological, Geographical & Environmental Sciences at the University of Bradford, the Dept. of Archaeology at Ghent University and the People-Marie Curie-funded project 'Radio-Past'.

DETECTING MASS GRAVES ON HISTORIC BATTLEFIELDS

Charlie Enright and Peter Masters
Centre for Archaeological and Forensic Analysis, Department of Engineering and Applied Science, Cranfield University, Shrivenham, Wiltshire, SN6 8LA, UK.

p.masters@cranfield.ac.uk

Throughout history many battles have been fought across Britain and the rest of Europe. Despite this blood drenched history, mass graves containing human remains associated with a battle have rarely been discovered pre-dating the two world wars. The most famous discovery of a mass grave in Europe, where a direct link to a battle can be established, is that of the Battle of Wisby (1361), fought between Sweden and Denmark. The skeletal remains of 1185 victims, many found wearing their armour and buried with their weapons, were discovered interred in pits (Thordeman 2001). Other notable discoveries include the commingled remains of 400 individuals from the Battle of Aljubarrota (1385) (Kjellstrom 2005) and most recently, the discovery of 43 individuals found beneath the Towton Hall, relating to the Battle of Towton (1461) (Boylston et al 2010). The accidental discovery of the Towton mass grave during construction work sparked the first attempt in the United Kingdom to locate further mass graves from an historic battle using geophysical techniques (Sutherland 2003).

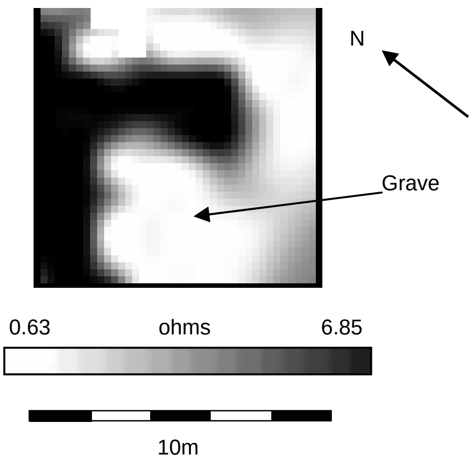


Figure 1: Resistance survey showing greyscale image of enhanced data. Simulated grave shown as low resistance anomaly.

This poster presents the results obtained from a series of integrated geophysical surveys conducted on known historic battlefields in order to locate mass graves. This research project was undertaken as part of an MSc in Forensic Archaeology and Anthropology.

Four most commonly used techniques were employed; GPR, earth resistance, magnetometry and EM38.

The objectives of this study were to adapt and expand on the strategy and methodologies employed at the Battle of Towton mass burial site, to demonstrate the importance of utilising an integrated array of geophysical survey techniques to enhance the interpretability when locating such remains and to gain a greater understanding of the physical properties exhibited by mass graves to increase confidence levels in the interpretation of geophysical results.

A grave pit was excavated, filled with plastic skeletons, backfilled and left for just over 2 months to simulate a mass grave on the Shrivenham campus, Cranfield University, Swindon. This was used as a control site in order to record the types of responses expected from each of the techniques used. All techniques produced unambiguous anomalies associated with the location of the mass grave. The earth resistance results produced a typical response of a mass pit (Figure 1).

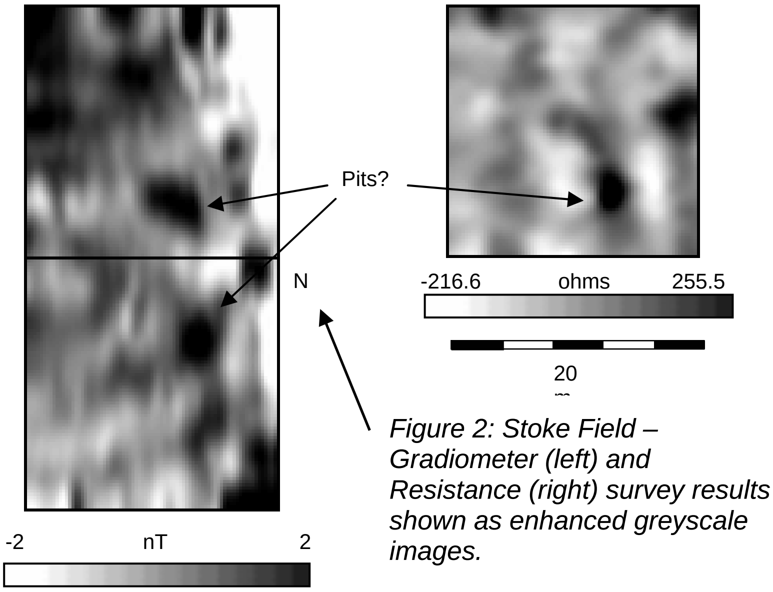
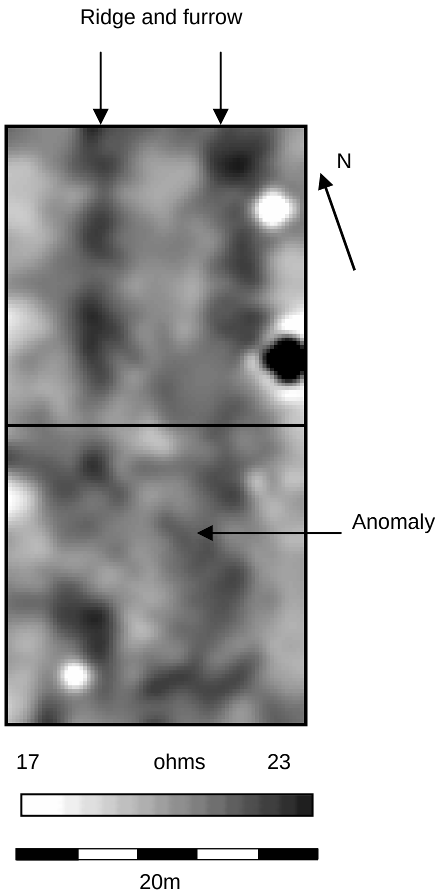


Figure 2: Stoke Field – Gradiometer (left) and Resistance (right) survey results shown as enhanced greyscale images.

Each of the techniques was applied to historic battlefields - Battles of Bosworth (1485) and Stoke Field (1487) from the War of the Roses (1450 – 1487) and Edgehill (1642) and Naseby (1645) from the English Civil war (1638 – 1660).

It was demonstrated that there are no comparable similarities between the historical sites possibly due to the variation in soils and geologies.

Stoke Field in Nottinghamshire was chosen as a result of previous archaeological evidence, and because it was known, it produced the best results from all four techniques as the soils and geology of the area seem to be conducive to the detection of such features (Figure 2) (Nottinghamshire HER L1679). The least known battlefield location was that at Bosworth. The geophysical survey was based on diagnostic finds found from the recent metal detecting surveys. The results showed a possible interruption in the ridge and furrow and could indicate the presence of a probable pit-like feature (Figure 3). However, this area was not to all techniques worked perfectly is this area due to the underlying geology, which is comprised of clay deposits.



This initial research has shown that using a combination of various techniques increases the detection of anomalies associated with grave type features considerably. However, this work is part of an ongoing research study and with future possibilities of incorporating a multidisciplinary approach by using other techniques such as geochemistry will aid in the detection of such remains.

Bibliography

Boylston, A., Coughlan, J., Holst, M., Knusel, C., Novak, S., Sutherland, T., 2010 The Towton Mass Grave Project. Available from http://www.brad.ac.uk/acad/archsci/depart/resgrp/towton/

Kjellstrom, J., 2005 A Sixteenth Century Warrior Grave from Uppsala, Sweden: The Battle of Good Friday. *International Journal of Osteoarchaeology*. 15, 23-50.

Sutherland, T. L., 2003 Towton, 1461: An integrated Approach to Battlefield Archaeology. *Landscapes*. **4 (2)**, 15-25.

Thordeman, B., 2001 *Armour from the Battle of Wisby 1361*. US: Chivalry Bookshelves

3D GPR-SURVEY IN THE ROMAN TOWN OF BAALBEK

Roland Linck(1), Jörg Faßbinder(1) and Margarete van Ess(2)
(1)Bavarian State Dept. of Monuments and Sites, Archaeological Prospection, Postfach 100203, D-80076 Munich, Germany; (2)German Archaeological Institute "Orient Abteilung", Podbielskiallee 69-71, D-14195 Berlin, Germany.

roland.linck@blfd.bayern.de

The Roman city centre of Baalbek in Lebanon (Fig. 1) was declared as UNESCO World Heritage site in 1984. Due to its location, the fertile Beqaa plain was colonized nearly continuously since the 8th millennium BC. In Roman times Baalbek became an important provincial town of the colony *Colonia Julia Augusta Felix Berytus*. The huge sanctuary of Baalbek also named as Heliopolis was constructed in the 3rd century AD. The centre is dominated by the Jupiter temple that is surrounded by several courts. Today the ruins of Baalbek are famous for its still upstanding monuments and its large sanctuary. The Jupiter Temple covers a ground area of 270 x 120m and its columns are 88m in height. So it is considered as one of the biggest temples ever built. Some of the building blocks have a size of up to 21.3 x 4.3 x 4.6m and a weight of 1200 to 2000 tons and are the largest building blocks that were ever used for the construction of architecture.

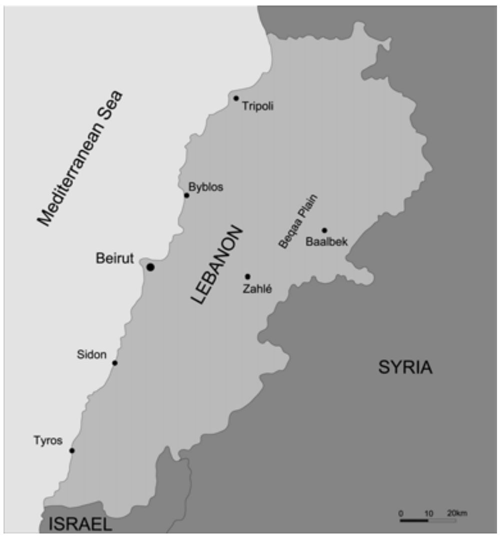


Fig. 1: Schematic map of the Lebanon. Baalbek is located in the Beqaa plain in the eastern part of Lebanon.

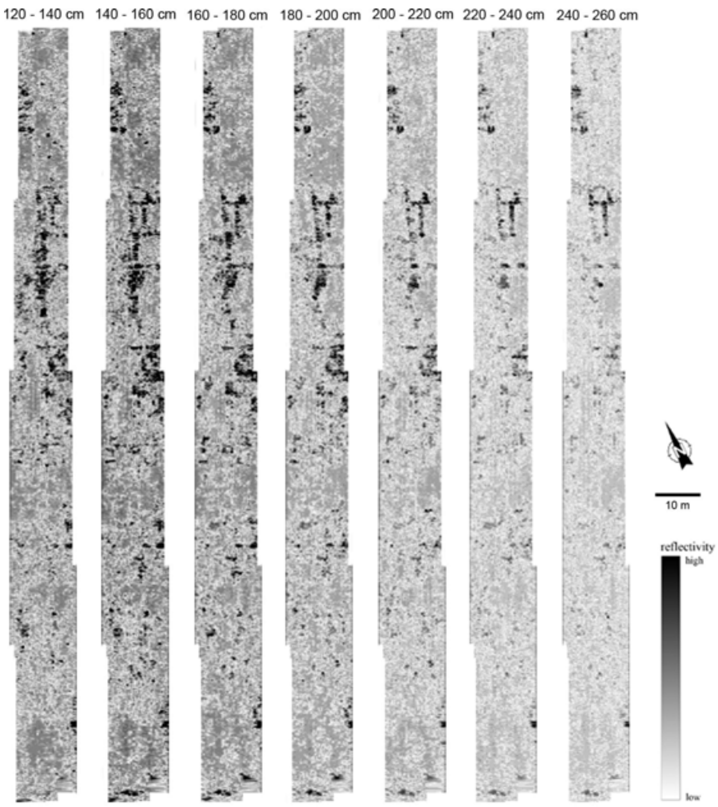


Fig. 2: Selection of depth slices with 20 cm thickness of Area 1 in Bustan el Khan. Grid size: 180 x 15m.

Since 1898 the site was excavated by the "Orient Abteilung" of the German Archaeological Institute (DAI) Berlin. In a close cooperation with the Institute of Geophysics, the Bavarian State Department of Monuments and Sites carried out two campaigns of radar prospection all over the historical city centre. The aim was to receive further information on the ancient re-mains. The survey sites are located in an urban area and some of them are covered with asphalt, a 3D GPR-survey was therefore most promising for these conditions. Furthermore Ground-Penetrating-Radar provides us with depth information of the structures which can help the archaeologists in planning their campaigns. The measurement was done with an impulse modulated GSSI SIR-3000 and a 400 MHz antenna which supplies the best compromise between resolution and skin depth. As a result of the good ground conditions with dry and sandy soil and therefore a big contrast to the stone walls, the archaeological structures until 3m depth could be resolved.

One of the survey grids is located in the so called district of *Bustan el Khan*, where Roman houses near a road leading to the ancient centre were expected. The depth slices show three late Roman houses in the depth of 120 – 320 cm (Fig. 2). In case of the building in the north-east, several rooms and a semicircular apse can be seen, whereas only some walls remained of the other two.

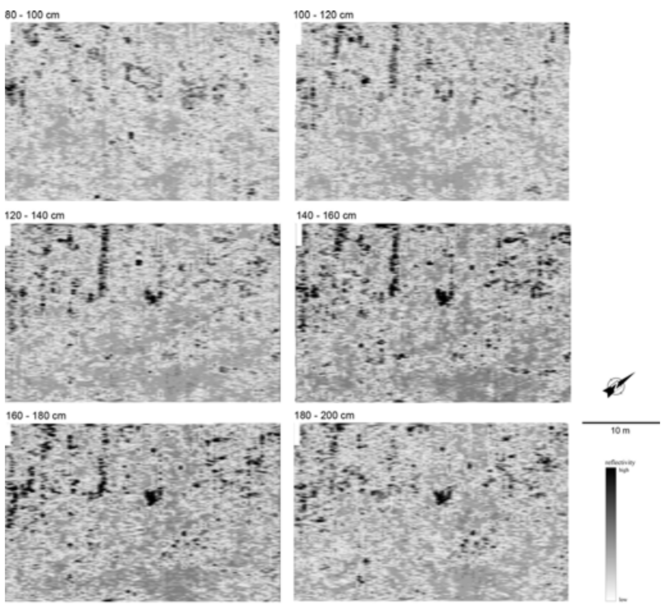


Fig. 3: Selection of depth slices with 20 cm thickness of Area 2 in Bustan el Khan. Grid size: 40 x 26m.

In a nearby second grid, further Roman houses can be seen in the same depth (Fig. 3). Here a division in two distinct houses is reasonable. The open space between them belongs eventually to the ancient road towards the Roman theatre.

Another area is located in the sanctuary, nowadays called *Qalaa*. The survey should reveal whether there remained still some fundaments of the Byzantine basilica, built in the altar court, although the visible walls were removed by an excavation in the 1920s. The depth slices between 120cm and 420 cm show two massive wall constructions as high reflective blocks (Fig. 4). The outer one is persistent; the inner one can be divided in two huge columns. A comparison with the plan of the basilica reveals that they correspond with the southern exterior wall and one of the column rows in the interior. So even after breaking down the visible Byzantine structures to reveal the Roman remains, the basilica's foundations can be seen in the depth slices.

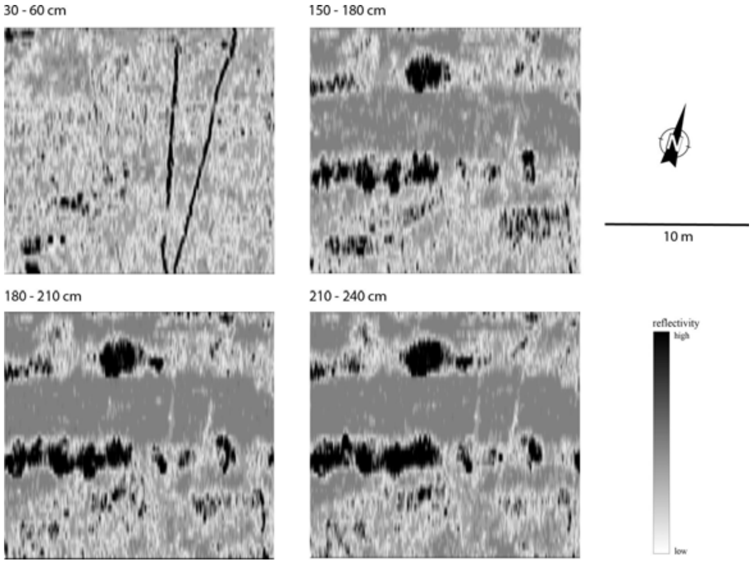


Fig. 4: Selection of depth slices with 20 cm thickness of the grid in the Qalaa. Grid size: 24 x 22m.

Bibliography

Michel M. Alouf 1999 *History of Baalbek* (24. Aufl.). The Book Tree, San Diego. ISBN 978-1585090631

Roland Linck 2009 *Adaption und Optimierung eines Bodenradargerätes für die geophysikalische Prospektion in der Archäologie*. Diploma Thesis at the Institute of Geophysics of the Ludwig-Maximilians-Universität Munich

Margarete van Ess 2001 Heliopolis – Baalbek 1898–1998 – Forschen in Ruinen. Ausstellung in Baalbek-Libanon zur Erinnerung an den Besuch Kaiser Wilhelms II. am 11. November 1898. DAI – Orientabt., Direction Générale des Antiquités du Liban. Das Arabische Buch, Berlin 2001. ISBN 3-86093-309-4

Theodor Wiegand: Baalbek. *Ergebnisse der Ausgrabungen und Untersuchungen in den Jahren 1898 bis 1905*. 3 Bd. de Gruyter, Berlin 1921ff.

NEOLITHIC – EARLY IRON AGE SITES AT SERTEYA, NORTH-WEST RUSSIA: ARCHAEOLOGICAL SURVEY, MAGNETOMETRY AND SUSCEPTIBILITY PROSPECTING

Daria Yu. Hookk(1) , Andrei N. Mazurkevich(1) and Jorg W.E. Fassbinder(2)
(1)*The State Hermitage Museum, 34, Dvortsovaya emb., 190000 Saint-Petersburg, Russia;* (2)*Bavarian State Dept. of Monuments and Sites, Hofgraben 4, 80539 Munchen, Germany.*

hookk@hermitage.ru

Introduction

The Neolithic – Early Iron Age sites of Serteya were discovered in 1972 during farm labor at the small river Serteya, ca. 10 km east of the town of Velizh and about 80 km north of Smolensk. The traces of two cultural layers with archaeological material became visible and gave evidence for the North Belorussian culture, the first stage of the Zhizhitsian culture and the final stage of the Usvyatian culture (Dolukhanov, P. et al.2004). A trench excavation in the river and in the sediments revealed multiple dwells, planks and other constructions. The archaeological survey of 1973 proved that in particular the underwater excavations have to be considered as the most effective investigations on these sites (Hookk & Mazurkevich, 2007). Further sites in the landscape around the river, were discovered only by archaeological field survey and by small test excavations. Due to the fact that the landscape is abundantly covered with vegetation a large scale geophysical prospecting is impractically and out of question. Here we report on magnetometer prospecting that was applied on a selection of small areas of the landscape such as to detect further archaeological structures on the adjacent sand, at riverbanks and on Neolithic hunter places in the forest. Since 2008 the survey was extended by susceptibility prospecting on archaeological excavated areas.

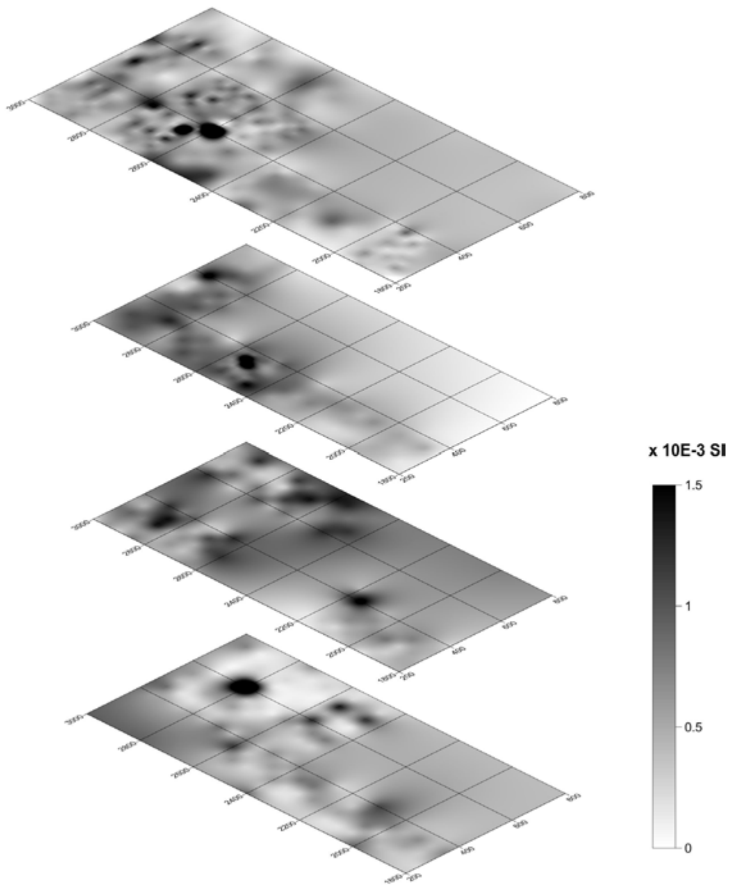


Fig. 1: Susceptibility prospection at the archaeological site Serteya α on three different layers (25 cm, 35cm, 45 cm, 65 cm from top to bottom) of the excavation. Magnetic susceptibility meter SM-30 (ZHinstruments, Czech Republic, sensitivity ± 10E-7 SI units, operating frequency 8 kHz), sampling interval 20 x 20 cm.

Geophysical prospection methods

The magnetic susceptibly prospection was carried out by the magnetic susceptibility meter SM-30 (ZH-Instruments, Czech Republic). For magnetometer prospection we used the Scintrex Smartmag SM 4G-special system in a duo-sensor configuration in a total field mode (Fassbinder, 2007). The diurnal variations of the Earth's magnetic field are reduced to the mean value of the calculated data of the 40 x 40m square. This configuration is very sensitive to artificial and technical disturbances and rapid variations of the Earth's magnetic field. However, all the locations of the archaeological sites of Serteya are far from any modern civilization and technical disturbances, moreover the sunspot activity was rather small in the years 2007-2010.

Susceptibility prospection on excavated layers

During the excavation the magnetic susceptibility of selected layers was measured by the handheld Kappa meter SM30 (ZHinstruments) in a sampling density of 20 x 20 cm. For a better understanding and for the comparison of the results with the magnetic prospection, the susceptibility values were visualized in grey shade pictures (fig. 1). By these measurements we were able to distinguish the different constructions of the cultural layers on the different levels. This correlates perfectly with the independent periods of inhabitation in early Iron Age–Bronze Age. The relicts of the early Iron Age construction were detected in the layers of 20 cm , 35 cm, 45 cm and 65cm. The remains of the Bronze Age construction were detected in the layer of 65 cm (see fig.1 from top to bottom). On this level we finally found traces of constructions that were destroyed by fire.

Conclusion

The magnetic prospection of some areas has shown only one big spot anomaly as a summary of all the constructions of the cultural layer in this place. Additional measurement of the magnetic susceptibility enables us to recognize and to discriminate the traces and structure of houses fireplaces and midden deposits. In this paper the authors will illustrate the sensitivity and the potential of magnetic methods in general and highlight, that magnetic susceptibility measurement can help to visualize archaeological structures that might be overseen during the archaeological excavation.

Bibliography

Dolukhanov P., A. Shukurov, K. Arslanov, A.N. Mazurkevich, L.A. Savel'eva, E.N. Dzinoridze, M.A. Kulkova, G. I. Zaitseva (2004). The Holocene Environment and Transition to Agriculture in Boreal Russia (Serteya Valley Case Study). *Internet Archaeology* **17** (http://intarch.ac.uk/journal/issue17).

Fassbinder, J.W.E. (2007). Unter Acker und Wadi: Magnetometerprospektion in der Archäologie. In: Wagner, G.A. (ed) *Einführung in die Archäometrie*. Springer, Berlin, Heidelberg, New York, pp.53-73.

Hookk, D.Yu., Mazurkevich, A.N. (2007) Fuzzy logic and Neolithic wood In: Small Samples big Objects, M. Mach (ed). *Proceedings EU-Artech Seminar*, pp. 40-50, Munich.

A GROUND PENETRATING RADAR SURVEY AT THORPE WATERVILLE CASTLE, NORTHAMPTONSHIRE

Tim Dennis[1], Michael de Bootman, Steve Parry[2] and John Fulcher
[1]School of Computer Science and Electronic Engineering, University of Essex, Colchester, CO4 3SQ; [2]Northamptonshire Archaeology, 2 Bolton House, Wootton Hall Park, Northampton, NN4 8BE Address, Essex, UK.

tim@essex.ac.uk

Introduction

Thorpe Waterville lies about 4 km northeast of Thrapston on a former Roman road, now the A605 to Peterborough. The location of a Norman castle was uncertain until confirmed in 2009 when a ground resistance survey on an assumed moat was carried out by Northamptonshire Archaeology on behalf of the present owners, Sir Roger Martin and Grace Martin, and reported in detail in Walford (2009).

Figure 1: Northamptonshire Archaeology 2009 ground resistance survey result [1], highpass filtered. White represents resistance higher than the local mean (shown as grey), black lower.

Fig. 1 is a reprocessing of the Northamptonshire Archaeology dataset which reveals a building outline with toroidal foundations on its three accessible corners. The interior shows considerable detail, including a possible set of foundations (A) on a different orientation.

GPR Survey

In summer 2010, the area within the moat was resurveyed using an Utsi Electronics GV3 with time window of 40 ns. Traverses were taken at 0.5 m intervals, with a sample density scaled to 10 samples/m for display. Additional areas were surveyed on a ridge immediately north of the moat, and within the 'courtyard' of a mediaeval domestic building.

Results

Fig. 2 shows a representative timeslice of the areas surveyed, at approximate depth below the local surface of 1.5 m. The pattern of responses strongly resembles the ground resistance image. The dimensions between probable curtain wall lines are approximately 51 m north-south and 54 m east-west. Diffuse external returns (B) adjacent to these may indicate rubble from a collapse. The two western towers have maximum outer diameters of 18 m. The northeastern tower is slightly ovoid, exterior major axis 12 m. The internal diameters of the three visible corner towers range between 5.5 and 6 m.

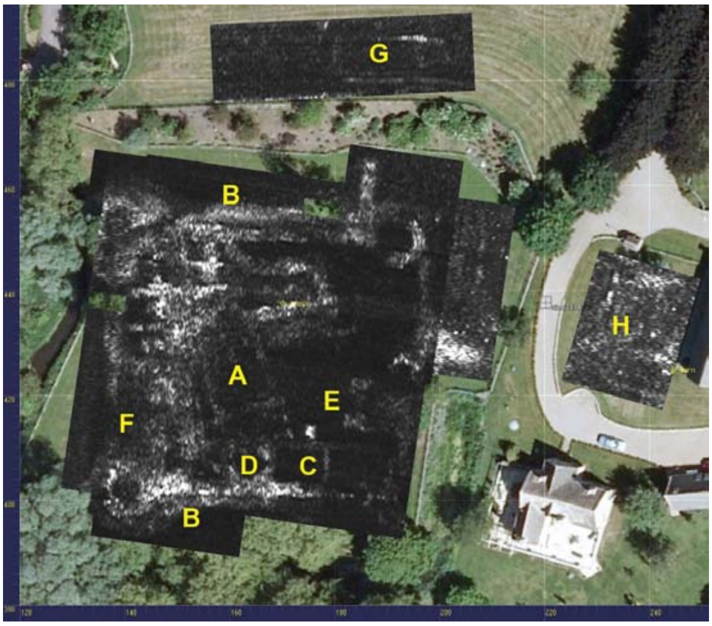


Figure 2: GPR survey, timeslice 187

At least two rooms (C) adjoin the interior of the south wall; nearby is another possible tower foundation (D). The east wall may not be straight - two 2.8 m square foundations (E) lie approximately 10 m from the presumed line of its southern section. They may indicate part of an entrance gateway but not at the position suggested by topography.

The second set of foundations (A) is repeated; later timeslices show more detail but it is difficult to interpret. Only visible at maximum time delay are three circular features to the right of (F) about 2 m diameter and lying within a recess backed by wall foundations; these may represent the central pillars of an undercroft to a substantial building.

Outside the moat area, the frontage of the barn showed foundation lines (H) corresponding to former agricultural buildings, extant in 1964. The block to the north of the moat detects a previously-unknown structure (G), 23 x 7 m overall. There is some evidence of a curved eastern end, suggesting an apse, so a chapel is a possibility.

Conclusions

Detailed archaeological interpretation of the results of both resistance and GPR surveys has yet to be done. Given that strong responses are present at the maximum time range used, repeat GPR survey on some areas of the site with extended range may be beneficial.

Bibliography

Walford J 2009 'Archaeological geophysical survey of Thorpe Waterville Castle, Northamptonshire', *Northamptonshire Archaeology Report* **09/179**.

GEOPHYSICAL SURVEYS TO ASSIST THE INSTAR BOYNE LANDSCAPES PROJECT AT THE BRÚ NA BÓINNE WORLD HERITAGE SITE, COUNTY MEATH, IRELAND

Kevin Barton[1], Conor Brady[2] and Steve Davis[3]

[1]Landscape & Geophysical Services, Convent Road, Claremorris, County Mayo, Ireland; [2]Department of Humanities, Dundalk Institute of Technology, Dublin Road, Dundalk, County Louth, Ireland; [3]School of Archaeology, University College Dublin, Dublin, Ireland.

kevin.barton@lgs.ie

Historically aerial photography, and latterly LiDAR, have been used to identify and map new sites in the Brú na Bóinne World Heritage Site (WHS), an internationally significant archaeological landscape known for its Neolithic passage tombs, other monuments and megalithic art (Fig 1). The landscape is largely composed of the floodplain and terraces of the River Boyne which are farmed in a combination of pasture and tillage crops.

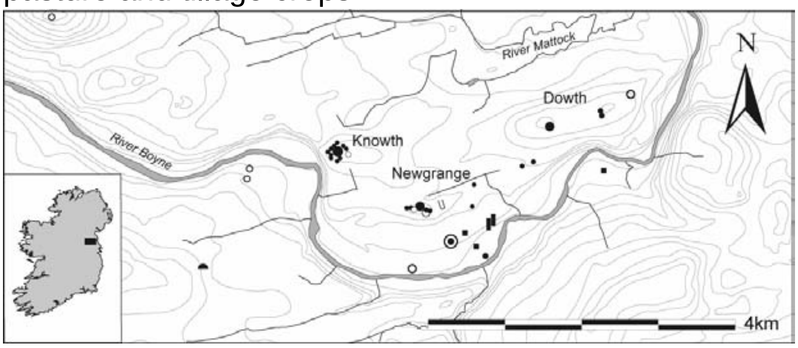


Fig 1: Location of the Brú na Bóinne WHS and its Principal Visible Monuments

The INSTAR (Irish National Strategic Archaeological Research) Boyne Landscapes Project is a response to some of the key issues to be addressed in the research strategy published in the Brú na Bóinne WHS Research Framework (Smyth, 2009).

Key issues to be addressed where geophysical survey can be of assistance include:

- Reconstruction and modelling the palaeoenvironment and landscape development
- Establishing the nature and extent of later prehistoric activity
- Understanding the structural sequence and phasing of the passage tombs
- Investigating the sequence of monuments between Newgrange Passage Tomb and the River Boyne
- Integrating monuments and landscapes
- Understanding land-use change
- Investigating the archaeology of the River Boyne

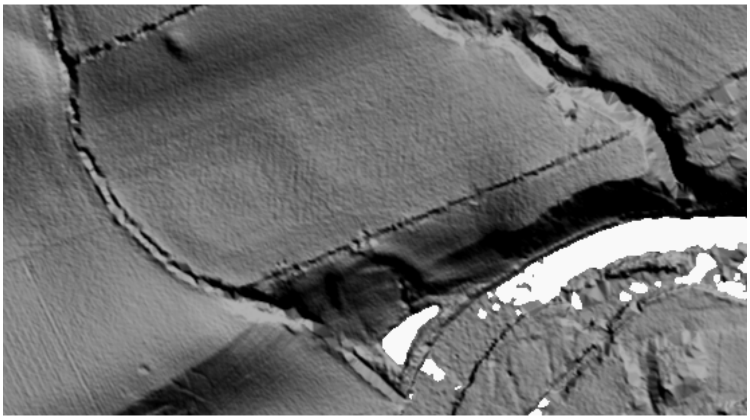


Fig 2: Low Topographic Profile Site LP1 identified from LiDAR

The project is developing an integrated and comprehensive landscape archaeological model for the Boyne Valley, with a focus on linking changing land use and environment to the known landscape of ancient monuments and settlement. The project has aimed to collate all available landscape and environmental data into a GIS database for modelling purposes, and to use this database to identify zones of likely change in the natural and cultural landscapes. Ground-truthing of specific zones of the river system against the model developed from the GIS database is being carried out, and then integrated into the GIS, providing a comprehensive dataset for and model of landscape and river history in the Boyne Valley.

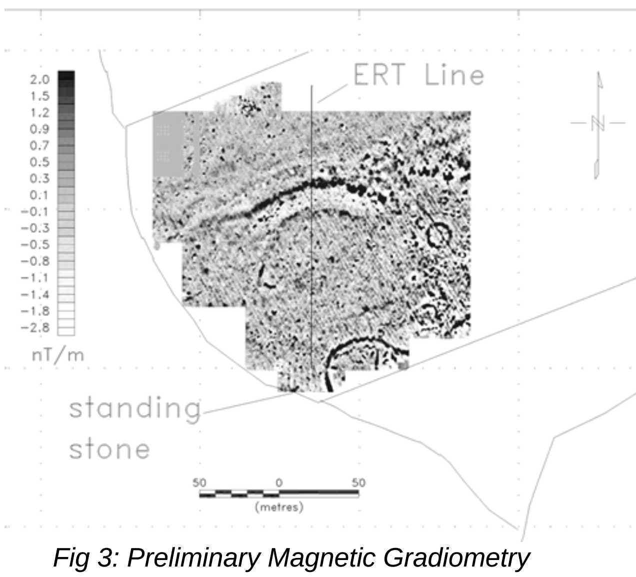


Fig 3: Preliminary Magnetic Gradiometry Results with Location of the Electrical Resistivity Tomography (ERT) Line

Ground-truthing involves a combination geophysical survey and coring to obtain material for sedimentological and geochemical analysis and for radiocarbon dating. Surveyed zones include previously identified sites as well as areas with high archaeological potential based on landscape analysis using LiDAR. The preliminary results from low topographic profile site LP1 identified during the current project using LiDAR

(Fig 2) are presented here.

LP1 is located on the north bank of the River Boyne on the first terrace above the floodplain. The feature has a diameter of approximately 100m and lies close to a standing stone (Site D). The site was initially investigated by magnetic gradiometry on a 1m x 0.25m grid (Fig 3).

The gradiometry results partially map the northern part of LP1 where there appear to be two parallel curving ditches with the southerly ditch forming part of LP1. The remaining part of the topographic anomaly does not have a strong magnetic expression. This may be due to the nature of the sediments on the lower part of the sloping terrace and/or agricultural activity. There are two previously unrecognised features at the south and at the east of the survey area. The southern feature is presently interpreted as a sinuous ditch. The eastern feature is a circular ditch some 15m in diameter possibly enclosed by a ring of pits giving an overall diameter of some 30m.

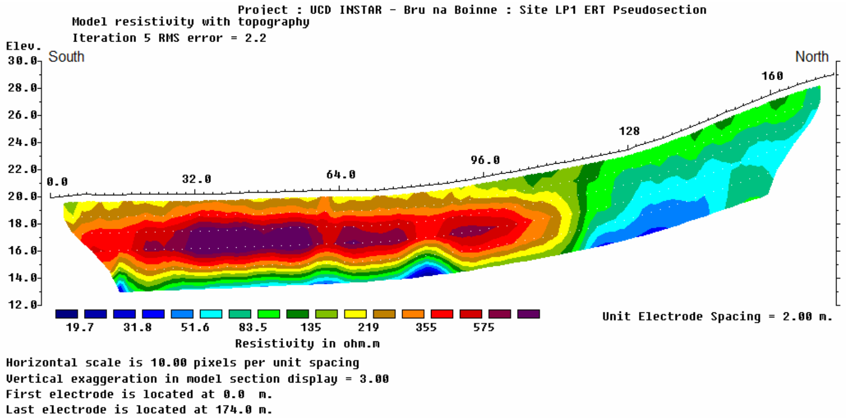


Fig 4: Modelled ERT Pseudosection with topography (x3 vertical exaggeration)

In order to investigate the sediments and the sub-surface structure of LP1 an N-S ERT transect was carried out using a Wenner array with 2m electrode or ‘a’ spacing. The modelled pseudosection is given in Fig 4.

There is an approx. 10m height variation between the lower ground in the south and the higher ground in the north of the pseudosection. There are two main features seen in the pseudosection with a higher resistivity ‘lens’ lying in the lower ground and low resistivity material forming the higher ground.. There is an intermittent, thin lower resistivity veneer of variable thickness lying on the ‘lens’. The ‘lens’ could be comprised of sands and gravels which have been laid down by the river in a bowl or hollow which itself has been exploited to form an enclosure. The features in the ERT section provide targets to be investigated by coring in order to investigate the relationship between LP1 and the riverine landscape.

The poster will present results from a series of sites currently being investigated in the Brú na Bóinne World Heritage Site.

Bibliography

Smyth, J. (2009). *Brú na Bóinne World Heritage Site Research Framework*. The Heritage Council : Kilkenny.

IDENTIFYING THE WESSEX CULTURE - A GEOPHYSICAL ANALYSIS OF THE CLANDON AGGRANDISED BARROW

Paul Cheetham and John Gale
School of Applied Sciences, Bournemouth University, Talbot Campus, Fern Barrow, Poole, Dorset BH12 5BB, UK.

PCheetham@bournemouth.ac.uk

In a recent paper the cultural package that is defined as the 'Wessex Culture' has been brought into question (Needham & Woodward, 2008) through a re-examination of the artefacts from one of the archetypal barrows associated with the culture: the Clandon Barrow in Dorset and with reference and re-appraisal of other comparative material.

One of the problems highlighted in this paper was the contextual association of the deposit, it having been recovered from an excavation undertaken by antiquarian Edward Cunnington in 1882, and not formally published until 1936 (Drew & Piggott 1936). Cunnington's records whilst limited by today's standards were nonetheless sufficiently detailed to suggest that the objects were found amidst a barrow that had a definable series of layers and features which in hindsight hinted at a structure that was multi-phased and relatively complex. Furthermore, the deposit (s) that constituted the group of artefacts could be interpreted as not being related to the primary build of the burial mound but could possible be of a second or later phase, which may not be funerary in origin.

The burial mound located a few miles to the south west of the county town of Dorchester, survives as a large upstanding barrow on the periphery of the main collection of barrows located slighter further to the south on the main body of the South Dorset Ridgeway. The size of the barrow has led to its possible identification as an 'aggrandised' barrow associated with other similarly large mounds in Wessex (Lanceborough, 1km to the east of Clandon and Conquer barrow at Mount Pleasant just 4km further east still are similarly 'aggrandised'). The aggrandisement of Clandon is further advanced by the form of the monument itself which upon inspection has the appearance of a 'ledge' approximately halfway up its slope, more noticeable on its western flank. This ledge could be interpreted as evidence of a restructuring of the original mound possibly even as much as indicating a second mound on top of the original. It is possible therefore that one interpretation of the artefacts recovered by Cunnington in 1882 is that they were from this later mound, if that could be proven.

Figure 1: The Clandon 'aggrandised' Bronze Age 'Wessex Culture' barrow. Note the step on the right hand side of the mound - this step runs around a more than half of the circuit of the mound.

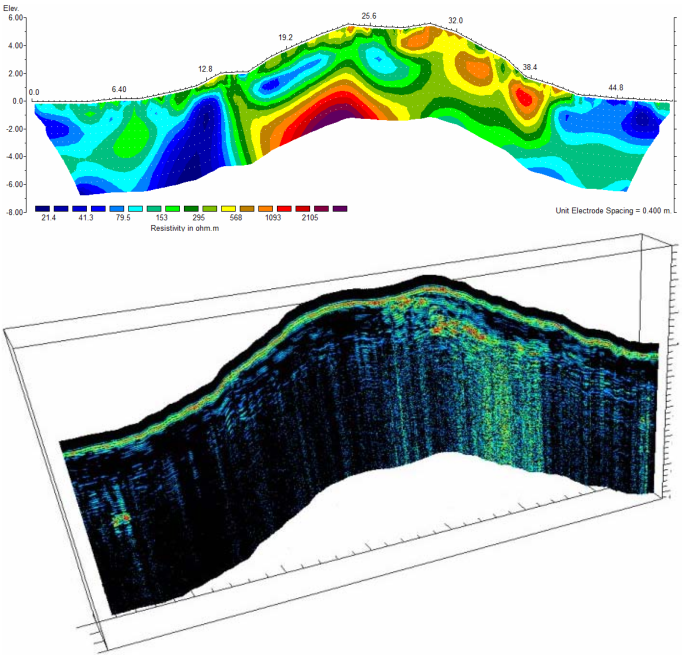


Figure 2: Preliminary Pole-pole electrical image (top) and 500MHz GPR (bottom) images revealing distinct inhomogeneity in the upper mound material. Electrical image created by a Tigre 64 and Res2Dinv. GPR image created by a Mala RAMAC X3M and GPR-Slice.

Short of re-excavating the barrow the only viable approach to a better understanding of the surviving monument, and therefore the original observations made by Cunnington, is through geophysical means.

The core of the mound and its immediate surroundings, have subsequently been the focus for an geophysical investigation involving GPR (250 & 500MHz), electrical imaging (Wenner, pole-pole and double-dipole) on the mound itself and more conventional earth resistance and fluxgate gradiometry area surveys around the mound.

The early results would seem to indicate that the mound does indeed appear to have been of a two phase construction with one superimposed on an earlier mound which was almost certainly left untouched by Cunnington and therefore the fine objects recovered are unrelated to the original burial monument. The surveys also reveal distinct inhomogeneity in the superimposed mound which could have complicated Cunnington's interpretation

Bibliography

Drew, C.D. and Piggott, S. 1936 Two Bronze Age barrows excavated by Mr Edward Cunnigton. *Proceedings of the Dorset Natural History & Archaeological Society*, **58**, 18-25.

Needham,S. and Woodward, A. 2008 Clandon barrow Finery: Synopsis of Success in an EBA World. *Proceedings of the Prehistoric Society*, **74**. 1-52.

PRELIMINARY GEOPHYSICAL SURVEY RESULTS FROM SONGO MNARA, TANZANIA

Kate Welham and Harry Manley
School of Applied Sciences, Bournemouth University, Talbot Campus, Fern Barrow, Poole, Dorset BH12 5BB, UK.

KWelham@bournemouth.ac.uk

This poster presents the results of geophysical survey conducted at the UNESCO World Heritage Site of Songo Mnara, Tanzania. Located on an island in the Kilwa archipelago, Songo Mnara is a Swahili stonebuilt town that has been largely undisturbed by modern occupation. It contains a well preserved network of coral buildings which are gathered around a number of open areas (Figure 1).

Figure 1: A view of the remains of the coral buildings at Songo Mnara that surround the open areas within the site.

Geophysical survey was conducted at Songo Mnara to explore the use of space, and the boundaries of anthropogenic activities within and outside of the town. A combined geophysical approach was taken using both fluxgate magnetometer and electro-magnetic survey. The results identified specific regions of activity including town boundaries, and areas of iron working. However, the most striking feature of the results was the reoccurring presence of circular anomalies seen within the open spaces between buildings (Figure 2). Field investigation coupled with geoarchaeological and environmental evidence has found a direct correlation between these areas and patches of red soil present on the site. It is thought likely that these are linked to anthropogenic activity, and a possible indication that open spaces were being specifically used and managed.

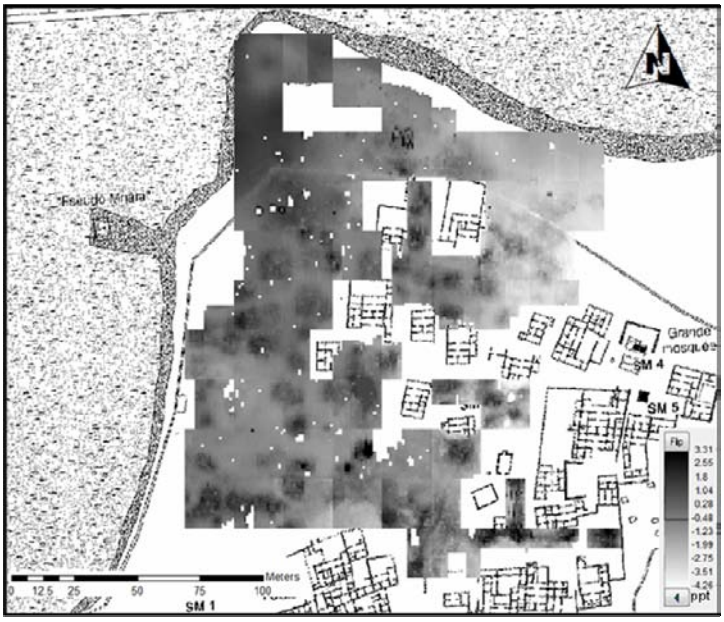


Figure 2: Magnetic susceptibility results from the electro-magnetic survey (EM38B) at Songo Mnara (after Pradines 2005).

Bibliography

Pradines, S. (2005) Archéologie et préservation du patrimonie: le project franco-tanzanien de Kilwa, 2002-2005, *Nyame Akuma* **63**: 20-6.

LARGE SCALE GEOPHYSICAL SURVEYS AT THE ROMAN LEGIONARY FORTRESS OF INCHTUTHIL, PERTH & KINROSS, SCOTLAND

D J Woolliscroft[1], B Hoffmann[1] and P Morris[2]
[1]Roman Gask Project, School of Archaeology, Classics and Egyptology, University of Liverpool, 14 Abercromby Square, Liverpool , L69 7WZ; [2]Blairgowrie Geoscience, 7 Lochy Terrace, Blairgowrie, PH10 6HY, UK.

morris_p@btinternet.com

The Roman Gask project was set up in 1995 to study Roman sites in central Scotland, in particular the network of first century military installations north of the Clyde-Forth line (Fig 1). An extensive series of aerial photography flights, geophysical surveys and excavations have been carried out under its auspices (1). In the last two years interest has focused on the great legionary fortress of Inchtuthil, built as the central base for the Highland boundary operations.

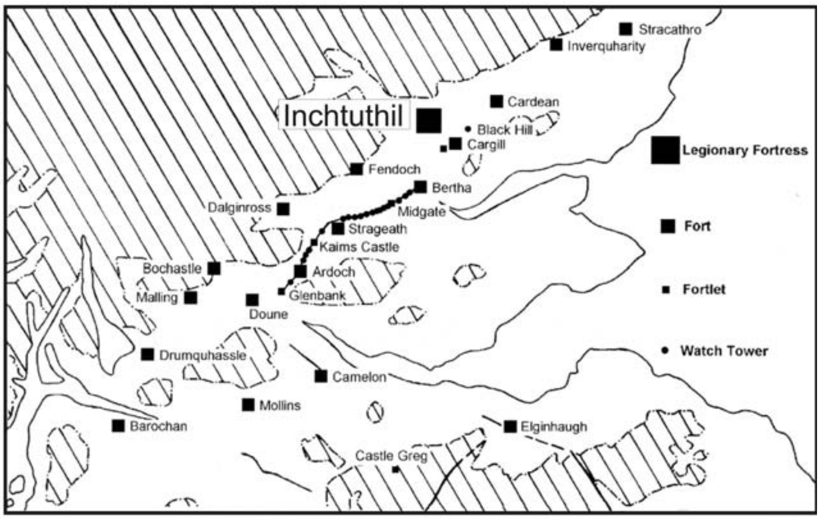


Fig 1: Late 1st century Roman military installations in central Scotland

The fort stands on a large steep sided plateau beside the River Tay; a strong defensive position. A detailed plan was worked out by I.A.Richmond and J.K. St Joseph from a campaign of large scale trenching carried out between 1952 and 1965 together with aerial photography of crop marks and an understanding as to how a typical Roman fort should be arranged (2). Given the size of the fort, which was designed to house some 5000 men and covers an area of 25 Ha, more complete excavation was out of the question. Doubts remained as to the validity of this reconstruction so the Gask project initiated magnetic and more limited resistivity surveys to map as much of the plateau as possible including the fort and some adjacent temporary camps.

The total magnetic survey will be about 65Ha of which about two thirds of this has been recorded to date. The remainder will be completed when agricultural and sporting activities permit. This poster presents the data acquired in 2009 covering the fort and its immediate environs (Fig 2). The results agree very well with most aspects of Richmond's proposed plan thus confirming its reliability.

Fig 2: Magnetic gradiometer survey – Inchtuthil Roman legionary fortress.

One of the highlights of the original excavation was the discovery of about 10 tons of Iron in the form of about a million nails, most of which were perfectly preserved, which had been buried when the fort was abandoned. Had these still been in place the resulting magnetic anomaly would have been spectacular; even now with the iron excavated an anomaly still exists over the site where the nails were hidden.

In addition to the Roman remains the plateau provides evidence of long occupation and a variety of non-Roman features have been imaged by the geophysics including a Neolithic mortuary enclosure, Iron Age burial mounds, 18th century park boundaries and the bunkers of a 20th century golf course.

Bibliography

1 www.theromangaskproject.org.uk
2 Pitts,L.,F. and St Joseph,J.,K. (1985) Inchtuthil, the Roman legionary fortress, Britannia Monograph Series, No. 6, London

---

ARCHAEOMAGNETIC PROSPECTING FOR AN ANCIENT ROMAN-BYZANTINE CHURCH SITE AT YASILAH (PELLA) IN NORTHERN JORDAN

Khalid J. Fahmi and Ahmad Qazaq
SeisEng International, Toronto, Canada.

kjfahmi@hotmail.com

Yasilah or better known to both local and international archaeologists as the ancient Roman-Byzantine (29 BC – 1453 AD) community of PELLA, is one of the eight Decapolis cities in the present-day Hashemite Kingdom of Jordan where ancient Greek, Roman & Byzantine archaeology is entrenched and very much apparent. At about 8 km from the northern city of Irbid (Arabella in Roman) on the Irbid-Ramtha highway, the Yasilah archaeological site is located about 1 km south of the highway at the confluence of Wadi Sawwa & Wadi Warran (Fig. 1).

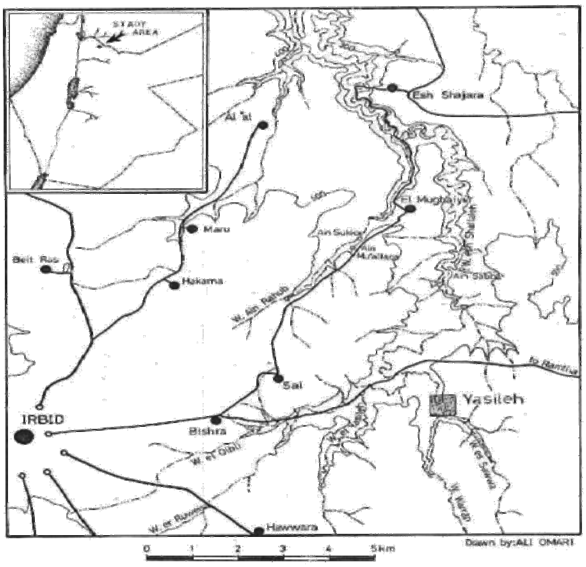
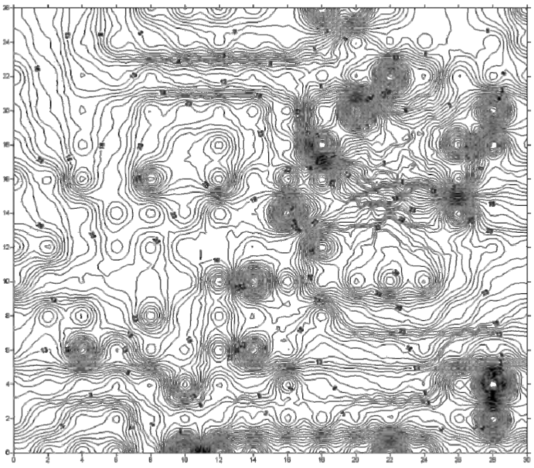


Fig 1: Location map showing the Yasilah archaeological site east of the northern city of Irbid, Jordan.

Most of the archaeological work done on this site was performed by Professor Zaydoun Mohaisen and his team of the Archaeology & Antiquity Institute at Yarmouk University (Irbid) in the late 80's and early 90's. He was able to unearth some important components of a unique site for a Roman/Byzantine church with many artefacts, building components and materials such as carved rock and fired clay brick and mosaic tiling. In order to preserve the site the whole area was backfilled to an average thickness of ~ 150 cm (and surface machine packed) with local soil, topsoil, gravel and rock fragments (made up mainly of carbonate sediments) of Upper Cretaceous to Eocene age.

The earth's total magnetic field for the investigated site and the diurnal magnetic variations were measured using two identical Geometrics Precession Proton Magnetometers. Archaeological artefacts and soil samples were collected and the magnetic susceptibility was measured using a Micro Kappameter. With a 2m station spacing grid, 28 N-S profiles at 50m length and 24 E-W profiles at 38m length were executed. The results of this survey were presented as a magnetic anomaly contour map (Fig. 2). Qualitative and quantitative interpretations were made for these maps. In addition, using the relevant geometric contour shapes and equations the depth, width and magnetic susceptibility of the causative bodies were estimated.



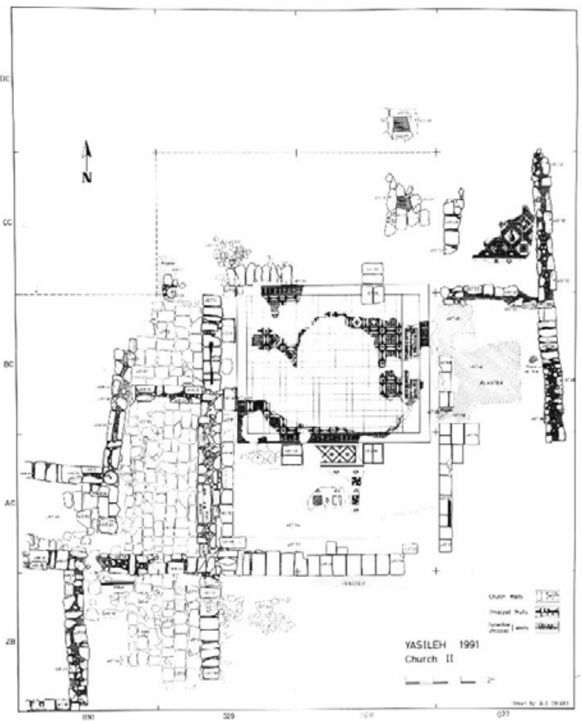


Fig. 2 (above): Geomagnetic anomaly contour map of the total magnetic intensity field at the Yasilah archaological site, northeastern Jordan.

Fig 3 (right): Site plan of the excavated Byzantine church showing the "box-like" boarders of this ancient structure which matches the "box-like" magnetic anomaly shown in Fig 2.

Based on the aforementioned, the following conclusions are made:

1) The total magnetic intensity values recorded range between a maximum of +34 ɣ and -40 ɣ. This variation is typical of shallow buried archaeological sites. The burial depth range is therefore placed at 100-150 cm from existing ground elevation.
2) Fig. 2 reveals the following results:
   - The closed concentric almost circular "reverse" magnetic contours with the cross-sectional anomaly shape almost symmetrical that are concentrated in the upper eastern part of the map indicate a series of NE-SW trending "pits" or "ditches". This area is yet to be excavated.
   - The open longitudinal parallel magnetic contours in the upper western part and the lower eastern part of the map (with a very limited variation of magnetic intensity) reflect the possible existence of walls, roads, promenades and/or paths which have yet to be excavated.
   - The "box"- like contours in the western central part of the map coincide almost exactly with the layout of the previously excavated Byzantine

church site sketched in Fig. 3. This is a clear and undisputable indication that the geomagnetic method of prospecting for buried archaeological sites is an accurate and successful technique which is fast, efficient, non-invasive and non-destructive.

GEOPHYSICAL PROSPECTION IN PEATLAND ENVIRONMENTS: A TOOLKIT FOR ARCHAEOLOGICAL PRACTICE

Kayt Armstrong, Tim Darvill and Paul Cheetham
School of Applied Sciences, Bournemouth University, Talbot Campus, Fern Barrow, Poole, Dorset BH12 5BB, UK.

karmstrong@bournemouth.ac.uk

Waterlogged sites in peat often preserve organic material, both in the form of artefacts and palaeoenvironmental evidence as a result of the prevailing anaerobic environment. After three decades of excavation and large scale study projects in the UK, the sub-discipline of wetland archaeology is rethinking theoretical approaches to these environments. Wetland sites are generally discovered while they are being damaged or destroyed by human activity. The survival in situ of these important sites is also threatened by drainage, agriculture, erosion and climate change as the deposits cease to be anaerobic. Sites are lost without ever being discovered as the nature of the substrate changes. As conventional prospection methods such as aerial photography, field walking and remote sensing are not able to detect sites under the protective over burden, a prospection tool is badly needed to address these wetland areas.

Figure 1: Case Study Locations. Map from Van de Noort et al (2002, 7).

Geophysical survey has become a major means of site investigation in the UK over the last 20 years, but has only rarely and inconsistently been applied to peatland environments. The inherent assumption has been that these environments are too wet and homogenous for archaeologically meaningful anomalies to be detected. This

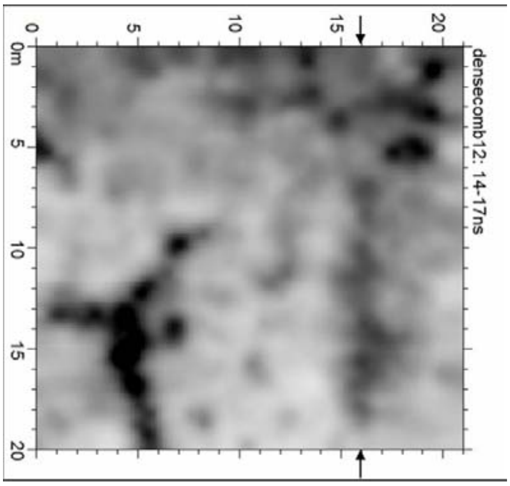


Figure 2: GPR Timeslice (14-17 nS) from 250 MHz survey at Shapwick Heath, Somerset Levels. Marked anomaly corresponds to the known location of the Sweet Track, the dendritic anomaly is thought to be a bog oak. Darker colours represent higher amplitudes, scales are in metres.

poster presents a ‘toolkit’ for archaeological geophysical prospection in these difficult environments. It was developed following a period of research undertaken between 2007 and 2010 at Bournemouth University that sought to challenge these underlying assumptions. The project demonstrated the potential of conventional geophysical survey methods (resistivity, gradiometry, ground penetrating radar and frequency domain electromagnetic) as site prospection and landscape investigation tools in peatland environments.

Eight case-study sites were surveyed using a combination of conventional techniques, chosen to represent different combinations of peat sequences and archaeological site types. A balance of upland and lowland sites were selected, on Dartmoor and the Preselli Hills, and in the East Anglian Fens and the Somerset Levels (figure 1). At three of the sites ground truthing work in the form of excavations, bulk sampling and coring was undertaken to validate the survey interpretations. This was followed up by laboratory analysis of the physical and chemical properties of the peat and mineral soils encountered.

The key conclusion of the case study work undertaken is that conventional geophysical prospection tools are capable of detecting archaeological features in peatland environments, but that the nature of the deposits encountered creates challenges in interpretation. Too few previous surveys have been adequately ground truthed to allow inferences and cross comparisons. The upland case studies demonstrated that geophysical survey on shallow types of upland peat using conventional techniques yields useful information about prehistoric landscapes. The situation in the lowlands is more complex. In shallow peat without minerogenic layers, timber detection is possible (figure 2). There are indications that in saturated peat the chemistry of the peat and pore water causes responses in the geophysical surveys, which could be developed as a proxy means to detect or monitor archaeological remains. On sites where the

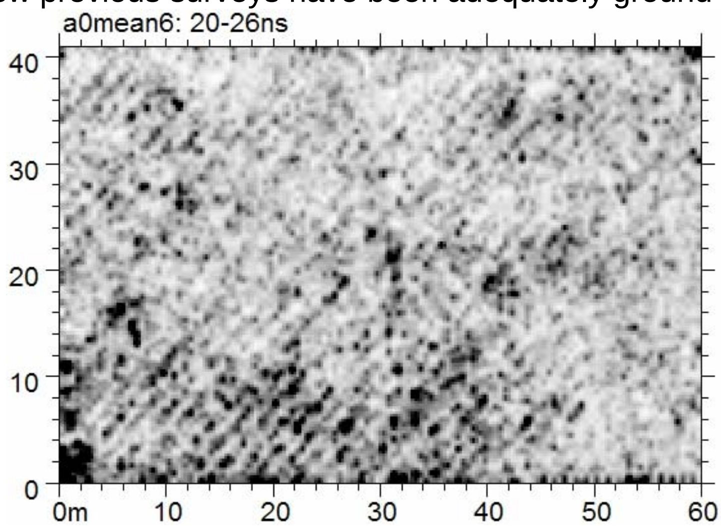


Figure 3: GPR Timeslice (20-26nS) from 250MHz survey at Flag Fen showing previous land use (either cultivation or peat workings) not visible from the surface features and on a different alignment to the recorded field system. Darker colours represent higher amplitudes, scales are in metres.

sediments are more complex or affected by desiccation, timbers were not detected with the methods attempted. However, important landscape features were (figure 3) and there are indications that geophysical surveys could be used as part of management and conservation strategies.

Geophysical prospection can contribute to theoretically informed wetland archaeology as a tool for site detection, landscape interpretation, and conservation, and it is possible to maximise the amount of archaeologically useful information recovered by informed selection of geophysical techniques and strategies.

The most important output of the project, apart from the surveys themselves, was the ‘toolkit’ (figure 4) to aid in commissioning, planning and executing future surveys in these environments. Future research should aim to further our understanding of the relationship between geophysical response and peatland geochemistry, alongside a more extensive programme of surveys and ground-truthing work to improve survey methodologies and archaeological interpretations, using the toolkit as a starting point.

Implications for the way geophysicists work with curators and commissioners of surveys were also identified. It is necessary for the geophysicist to be involved with the ground truthing work on peatland sites, to create positive feedback loops that allow us to build a body of knowledge and so improve on interpretations and understanding. Where the surveyor is not doing the follow-up excavations, such as in development/ planning situations, the need for communication between the excavator and surveyor is high, to allow combined interpretations to be formed, and to allow the geophysicist to explore any problems with the interpretation. Local curators have a vital role to play in this process.

Planning

Conduct auger surveys prior to geophysical work to identify major sediment sequences and anomalous areas

Select techniques based on results of auger surveys; choice of radar antenna will depend on both the size and depth of the archaeological target, and on the sediment characteristics

Be prepared to move away from ‘standard’ practice where the situation warrants it such as smaller resistivity arrays in shallow upland peat soils

Upland	Lowland
In order of preference:	In order of preference:
Resistivity (adjusting array dimensions to match soil depths)	Techniques that resolve anomalies that vary with depth such as ERT or GPR, ideally in 3D or pseudo 3D
GPR (high frequency & high density)	
Magnetometry (only on sites expected to show magnetic contrasts, and where igneous geology is not a problem	Magnetic surveys essential to provide context and cross checks. EM or Gradiometer as appropriate to site/sediment

Both: Avoid using techniques in isolation: EM is useful cross-check

Analysis and Laboratory

Data processing and interpretation needs to mitigate very low signal:noise ratios, and to be conducted with a good understanding of the sediment sequence on the site, achieved through laboratory analysis. As a minimum: soil/sediment analysis to identify peat types, soil types, particle size distribution, % organic and moisture content.Where chemical effects are suspected, ICP-OES or similar should be employed to look for meaningful variation. This should form a coherent part of the overall project, not be an add-on.

Publication: All surveys should be reported to EH and the AIP as a minimum. Publication in journals or via institutional repositories is better

Figure 4: The Toolkit: An outline of suggested future practice for archaeological geophysical prospection in peatland environments.

The results of the surveys, ground truthing and follow up work must be disseminated. Publication is the preferred route, but where this is not possible, report summaries (at least) should be lodged with English Heritage for inclusion in the survey database, and with the Archaeological Investigations Project so that other researchers can access and build on the conclusions. It is also useful for archaeogeophysicists to take these results to non-geophysical conferences, to engage with the wider discipline, and to gain feedback and insight from other specialisations such as geoarchaeology.

Acknowledgements
This research project has been supervised by Prof. Darvill and Paul Cheetham, many thanks to them for their support and expert guidance. It has been funded by a Bournemouth University PhD Studentship which has funded fieldwork, equipment and software. English Heritage funded the ground truthing work on Dartmoor and have also provided support and guidance and assisted with permissions for fieldwork, as have Natural England the Dartmoor National Park Authority, the Fenland Archaeological Trust, and the many landowners and local archaeologists that have been involved.

BEYOND VENUS; THE GEOPHYSICAL SURVEY OF LINKS OF NOTLAND, WESTRAY, ORKNEY

Alette Kattenberg and Jakob Kainz
ORCA Geophysics, Orkney College, East Road, Kirkwall, Orkney, UK.

Alette.Kattenberg@orkney.uhi.ac.uk

The discovery of the Orkney Venus in the summer of 2009 brought the site of the Links of Notland to the attention of the media. But beyond Venus there are many more interesting aspects to the site.

Located in a complex archaeological landscape, on the coast of Westray, it lies within a deflating dune system; wind erosion causes archaeological remains to be exposed and buried by shifting sands, making it a challenge for archaeological geophysics. A combined magnetometer and EM38 survey was conducted in order to determine the nature and fuller extent of surviving archaeological remains in this rapidly eroding, fragile and changing landscape.

In recent years, rescue excavations have been carried out in parts of the site where the archaeology is exposed and rapidly blown away by the wind. Geophysical surveys have been conducted to gather information about the non-excavated parts. The site comprises of extensive late Neolithic and Early Bronze Age structures, field systems and midden deposits. In close proximity to the site is the Iron Age broch site of Queen o' Howe. Of a later date, and partly visible on the surface are structures associated with kelp-working, mainly pits and buildings.

This poster shows the results of the combined geophysical survey in a landscape with a considerable time depth that is rapidly disappearing.

RECONSTRUCTING THE RING OF BRODGAR – USING EARTH RESISTANCE, ERT AND GPR TO LOCATE FURTHER MONOLITHS.

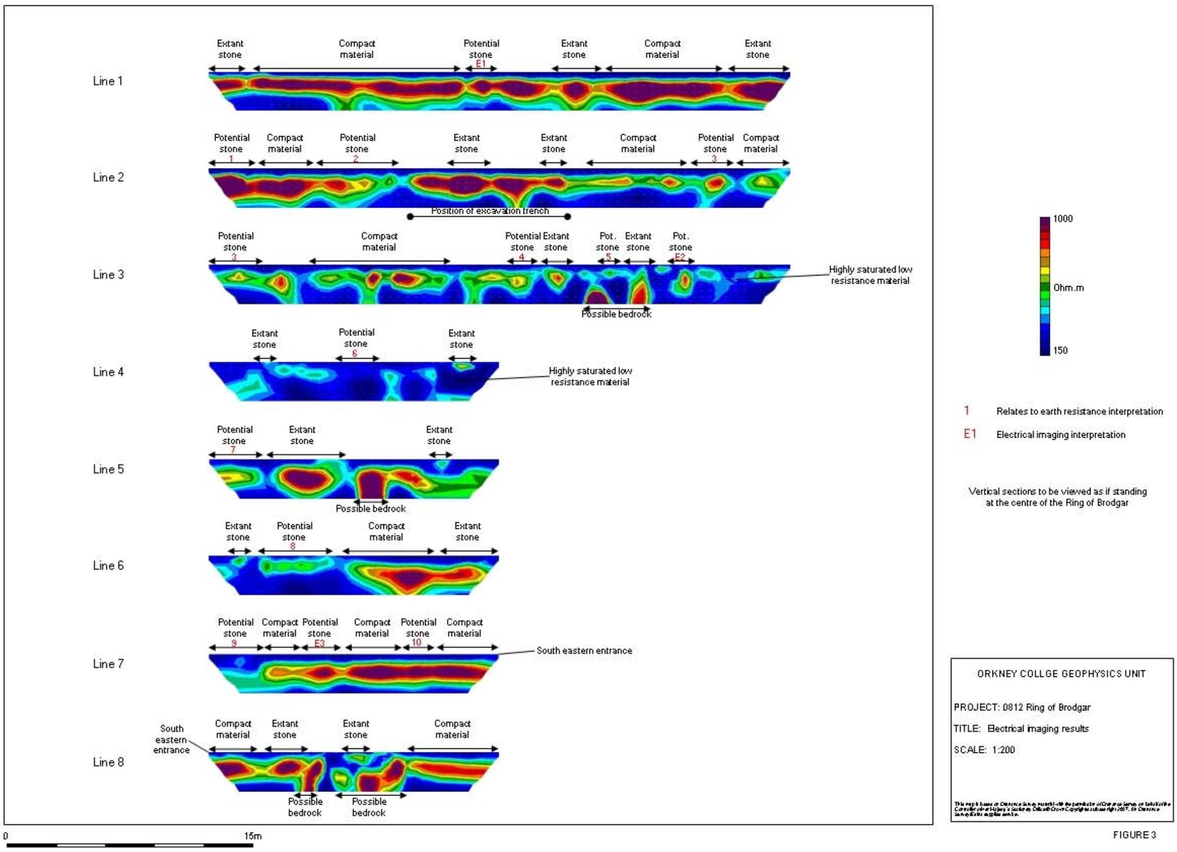
Mary Saunders, Ian Wilkins, Amanda Brend
ORCA Geophysics, Orkney College, East Road, Kirkwall, Orkney, UK.

Ian.Wilkins@orkney.uhi.ac.uk

In 2008 and 2009 a geophysical survey was undertaken at the Ring of Brodgar in conjunction with the excavations carried out by Colin Richards from the University of Manchester and Dr Jane Downes from Orkney College UHI.

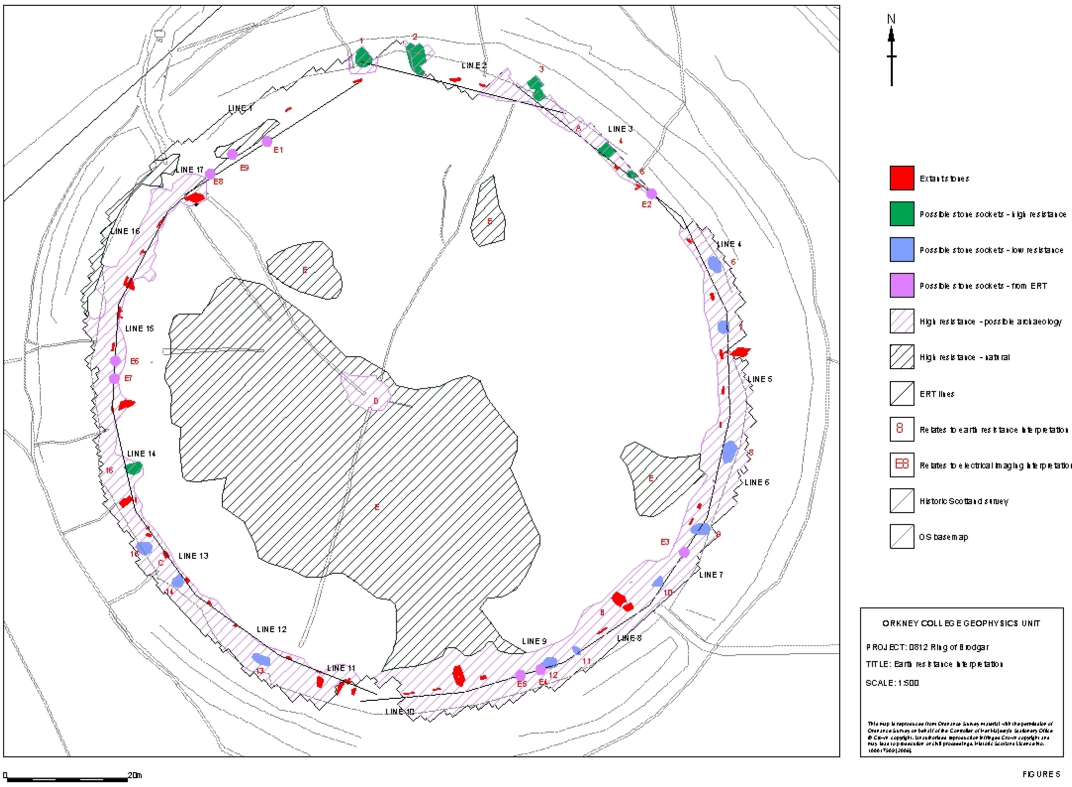
A high resolution earth resistance survey was undertaken across the interior of the monument, within the confines of the ditch, in an attempt to define the locations of any stone sockets or buried stones.

Around the circumference of the monument, close to the stones, an ERT survey was undertaken to define potential stone sockets in section.



In 2010, a GPR survey, using a 900MHz antenna, was conducted around some of the potential stone sockets identified by the earth resistance and ERT surveys.

The use of a suite of non destructive techniques has helped identify some potential stone sockets, thus aiding in the interpretation of the monument.



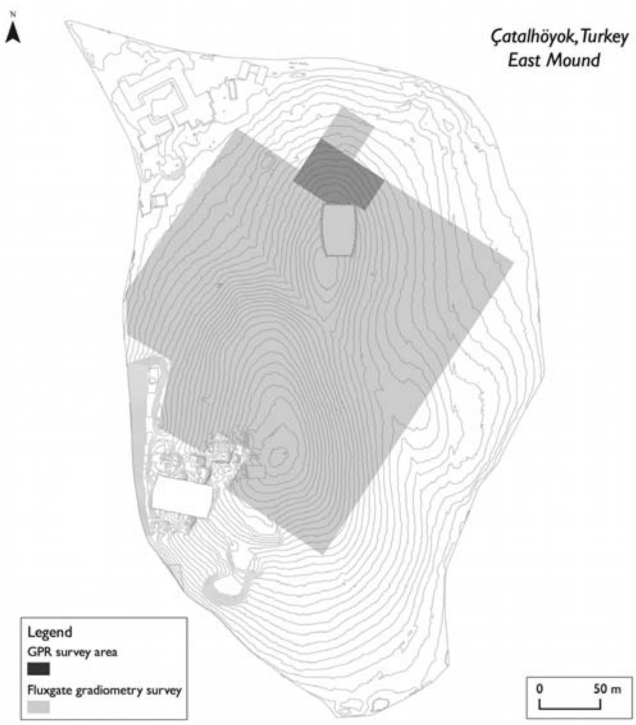
RECENT GEOPHYSICAL SURVEY AT THE SITE OF ÇATALHÖYÜK, TURKEY

Jessica Ogden[(1)], Kristian Strutt[(2)], Graeme Earl[(3)] and Ian Hodder[(4)]
[(1)]L – P: Archaeology, Ltd, UK; [(2)]Archaeological Prospection Services of Southampton, University of Southampton, UK; [(3)]Archaeological Computing Research Group, University of Southampton, UK; [(4)]Çatalhöyük Research Project, Stanford University, USA.

j.ogden@lparchaeology.com

As part of the ongoing research being currently conducted at the Neolithic site of Çatalhöyük, Turkey, L – P: Archaeology and the Archaeological Prospection Services of Southampton (APSS), in a joint collaboration between the University of Southampton and the Çatalhöyük Research Project, were invited to conduct a pilot geophysical study on the East Mound. Though previous magnetic, resistivity, and GPR surveys were conducted in 1995 (Clark 1996) and 2000 (Dobbs and Johnson 2000), it was determined that given recent technological advancements in geophysical survey in archaeology, the site might potentially provide an opportunity for not only geophysical research but also for the advancement of the overall understanding of unexcavated structures within the tell.

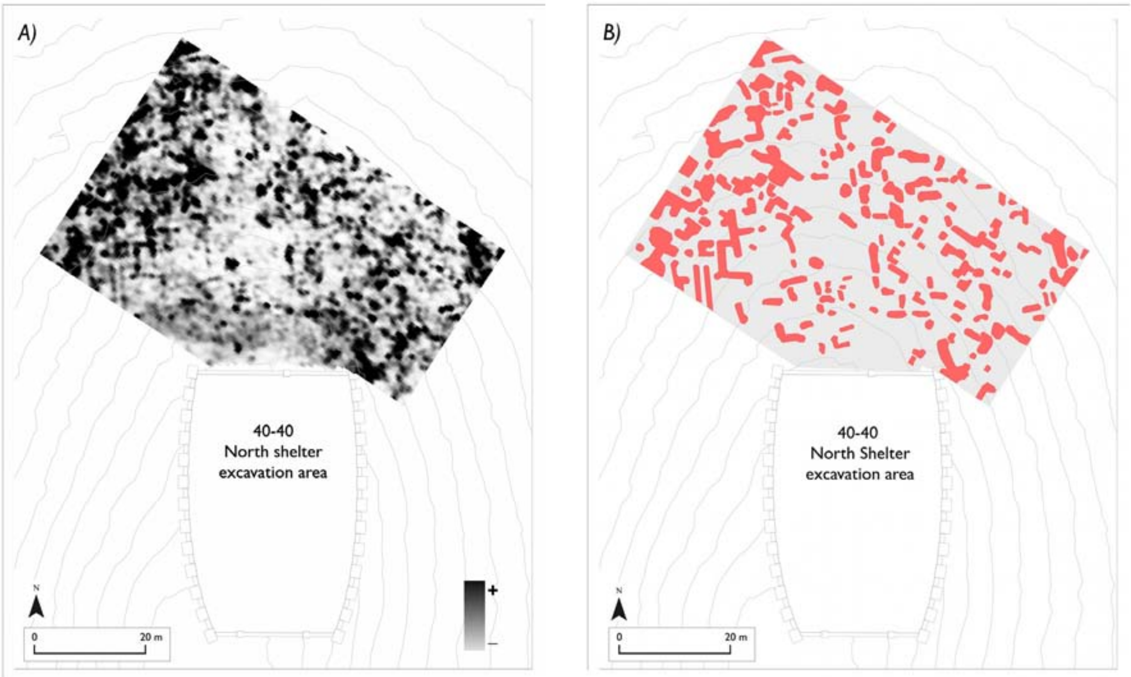
The geophysical survey was initiated with the aim of locating and mapping the remains of sub-surface archaeological deposits across the East Mound. The site produced a number of challenges to geophysical survey. First it was determined that the general nature of the archaeological deposits at Çatalhöyük is such that an integrated approach to geophysical survey was necessary for a successful outcome. As the mud brick houses and living surfaces were made from the local sediments, it



was feared that this lack of compositional variation between the surrounding subsoil and the structural remains might prevent the detection of archaeological deposits within the geophysical results. Additionally, the different levels of overburden between the highest and lowest slopes of the tell in turn varied the depth and resolution for which archaeological deposits could potentially be detected. With all of these factors in mind, GPR and fluxgate gradiometry were chosen with the hope that with the combination of excavation evidence, magnetic signatures, and the benefits of detecting features at depth, the pilot survey would prove successful in advancing knowledge about buried remains at Çatalhöyük.

To date, the gradiometer survey has covered ca. 5ha of the East Mound at a 0.1nT resolution, and 0.5m x 0.25m survey interval using a Bartington Grad601-2 dual-sensor fluxgate gradiometer. The gradiometer survey was overseen by Kristian Strutt, and has thus far been very successful in detecting evidence for burnt structures at the highest point of the East mound, as well as identifying additional linear features near the excavation areas. However, site conditions such as extensive rodent burrows, and metallic debris and structures protecting the excavated remains have potentially masked subtle changes in the magnetic gradient in these areas.

In addition to the magnetic survey, a small overlapping 60m x 40m area, was surveyed using a Sensors and Software Noggin Plus GPR with a 500MHz antenna and Smartcart frame, at a 0.25m line spacing. The GPR survey, overseen by Jessica Ogden, was located along the north side of the “4040” shelter on the northern side of the East Mound. As one of the aims of the survey was to determine the applicability of GPR in resolving features at depth at Çatalhöyük, a test area was chosen which overlapped with previously excavated structural remains and living spaces. This survey area then provided depth calibration data for known features within the results, as well as additional identifiers which assisted in feature classification and interpretation. Preliminary results have proven successful in corroborating previously excavated near surface walls and interior rooms, as well as identifying additional linear alignments extending to the north along this side of the tell. These results have shown a series of structures, typical in size and organization to those fully excavated structures on the East Mound. In addition, they support the prevailing assumption that the organization of this community of living spaces extends in a ‘radial’ pattern around this edge of the mound.



Results (A) and interpretations (B) of 500 MHz Ground-penetrating radar survey at Çatalhöyük in June 2010. Preliminary velocity analysis estimated this time slice at approximately 85cm below ground surface.

With the success of this 2010 pilot season, it is our hope to extend the GPR survey to cover the entirety of the East and West Mounds, and the magnetic survey to include parts of the surrounding landscape. With a greater surface area surveyed, the geophysical survey combined with excavation evidence could potentially contribute to questions about the spatial organization and social hierarchy of buildings and spaces within the site, as well as address questions concerning the situation of Çatalhöyük within the landscape as a whole.

Project Acknowledgements

The geophysical survey conducted at Çatalhöyük in June 2010 was funded by Stanford University via the Çatalhöyük Research Project and by the University of Southampton via the Archaeological Prospection Services of Southampton and the Çatalhöyük Visualisation Project (directed by Stephanie Moser). The field survey would also not have been possible without the dedication and assistance of survey team members Grant Cox and Eleonora Gandolfi.

Bibliography

Dobbs, C. A. and D. Johnson. 2000. “Field report on geophysical investigations.” Çatalhöyük 2000 Archive Report. http://www.catalhoyuk.com/archive_reports/2000/ar00_06.html

Shell, C. 1996. “Magnetometric survey at Çatalhöyük East.” In I. Hodder (ed) *On the surface: Çatalhöyük 1993-95*. Cambridge: McDonald Institute for Archaeological Research and the British Institute of Archaeology at Ankara.

MAN AND MACHINE: PROGRESS IN GEOPHYSICAL DATA ACQUISITION AND HANDLING

Anne Roseveare and Martin Roseveare
Archaeophysica, Ltd, Kitchener's, Home Farm, Harewood End, Hereford, UK

a.roseveare@archaeophysica.co.uk

The natural progression in the practical application of geophysics to archaeology is from personal to automated data collection and handling, much as many other areas where technology is developing. We can compare some of the processes to those experienced during the agricultural revolution: imagine the impact of Andrew Meikle's threshing machine of 1786 or John Fowler's use of steam engines for ploughing in the mid 1800s. Will we see the work change beyond recognition and will there be a reorganisation of field labour? On our journey we have already travelled some distance: how many newer practitioners have experience of the swinging needle on an analogue display or written numbers on squared paper?

Change and how we manage it are the big questions facing us now, the difference being that technological advances are enabling faster and more dramatic changes than might have been foreseen even a few years ago. Developments in GNSS receivers, improved computing facilities and communications already affect how we design and undertake geophysical surveys, as well as how we use the information afterwards. We can appreciate the benefits so far but there are complexities, too. It's our responsibility to handle these well so the end users understand the effects of the changes.

Geophysical expertise will be needed to exploit the possibilities as it will become more important to understand the limitations and apply technology effectively. Crucially, a lack of expertise could result in the misapplication of technology. Some likely consequent problems may be familiar already, such as inappropriate sampling intervals and under-qualified analysis and interpretation. Mechanisation in the wrong hands could too easily lead to degradation of survey quality, ultimately to the detriment of the profession.

In addition to the questions of data quality, there are some practical problems to solve. Data processing and storage have faster and larger needs: mainstream hardware can be reasonably expected to fulfil these and there will be changes in the software needed to provide the necessary data capture, processing and quality audit tools. However, multi-instrument platforms do not necessarily equate to greater speed or precision of measurement.

But what about the human aspect? Motorised instrument platforms can remove much legwork and operator fatigue, much to the relief of those of us who have spent years trudging round fields. Some skills will become redundant and new ones will become necessary to survive, just as some equipment will be superseded. It might not be a comfortable ride, as the profession discards preconceptions, familiar field techniques and people.

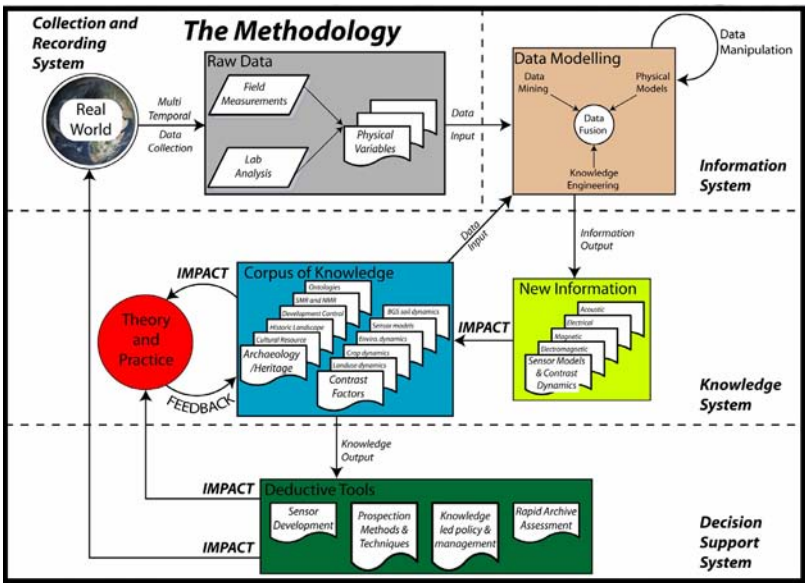
How do the customers know what to ask for and what to expect? There is already an increased need for transparency about the capabilities and limitations of the techniques, methods and practitioners. For example, we can all see that off-grid GNSS-tracked systems can produce uneven data density: how we design, carry out and document our coverage must demonstrate to the non-specialist how well the survey fulfils its purpose. Aspects that may be more complicated are the documentation of high-volume data handling, or the demonstration of relevant competence by the project geophysicist. Companies that are expected to deliver services in a commercial environment will find the competition gains new dimensions and the guiding authorities will find it harder to stay a step ahead.

In summary, this paper draws our attention to the metamorphosis of this industry sector. Whilst we all thrive on discovery and analysis it is important to step back, look at ourselves and recognise the fresh challenges that are arriving. Otherwise (to expand upon a comment made by Irwin Scollar in Vienna) we'll be collecting stamps faster than ever but won't know their worth.

THE DART PROJECT: A MAJOR NEW INVESTIGATION INTO WHAT LIES BENEATH OUR SOILS

A Beck[(1)], A Cohn, C Gaffney, N Metje, C Neylon, A Schmidt, M Steven, K Wilkinson, D Boddice, R Fry, L Pring and D Stott
[(1)]*DART Project, School of Computing, University of Leeds, UK.*

A.R.Beck@leeds.ac.uk



Detection of Archaeological Residues using remote sensing Techniques (DART) is a three-year 'Science and Heritage' initiative funded jointly by the *Arts and Humanities Research Council* (AHRC) and the *Engineering and Physical Sciences Research Council* (EPSRC).

The main aim is to understand the relationship between the external drivers of climate and weather, responding soil parameters (especially moisture) and vegetation indices, and the results obtained from geophysical and aerial detection approaches, including hyperspectral imaging. To examine the complex problem of heritage detection DART has assembled a consortium consisting of 25 key heritage and industry organisations, academic consultants and researchers from the areas of computer vision, geophysics, remote sensing, knowledge engineering and soil science.

TESTING A MULTI METHOD APPROACH FOR A GEOPHYSICAL INVESTIGATION OF NORWEGIAN IRON AGE SETTLEMENTS – ASSESSMENT OF METHODS AND SUGGESTIONS FOR A SEQUENTIAL SURVEY DESIGN

Arne Anderson Stamnes
Arkeolog, Norway.

arne.stamnes@gmail.com

The site of Gustad, Ekne in Nord-Trøndelag County in Norway is a site with over 200 years of research history, with old antiquarian maps and written sources mentioning as many as 18 burial mounds or cairns and at least two houses and some finds dating to the 10th century being handed in to the regional archaeological museum in Trondheim. The site has never been targeted for an archaeological investigation, but was aerial photographed in 2007 to some extent confirming the information from the old maps.

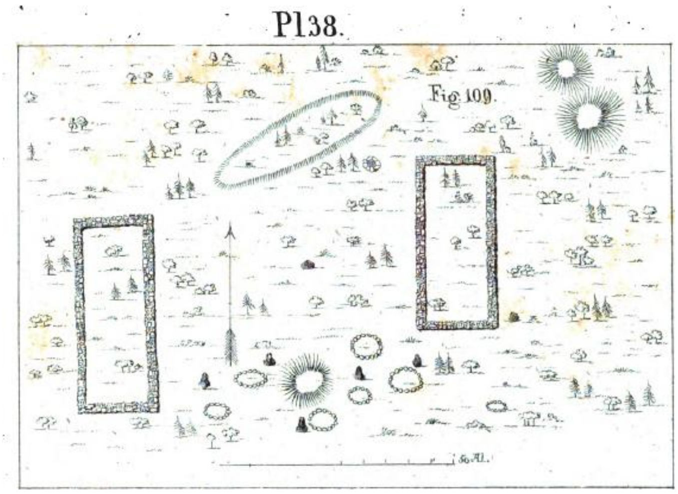


Figure 1: L.D.Klüwers map from 1822 over the site.


Figure 2: Aerial Photo by Lars Forseth, Nord-Trøndelag County Council 2007.

The summer of 2010 a multi method geophysical investigation was conducted as part of a research project, resulting in a MSc thesis at the University of Bradford, in collaboration with the Norwegian University of Science and Technology (NTNU) in Trondheim and Nord-Trøndelag County Council. 3d-radar has also been involved at a later stage. The usage of geophysical methods within Norwegian Cultural Heritage Management is a field that is still in its early stages, with no more than about 60 geophysical surveys being conducted the last 20 years. As approximately half of these are done within the last 5 years, an increased interest has been noticed. A lack of targeted research within the field of archaeological geophysics can still said to be noticeable.

Topsoil Magnetic Susceptibility measurements, Fluxgate Gradiometer, Earth Resistance and a Ground Penetrating Radar survey was conducted at Gustad. By comparing and analysing the results from the geophysical survey with the known archaeology, the applicability of each method was evaluated by investigating and discussing issues concerning the geophysical response of the known archaeology. The necessary resolution to delimit the site and identify its archaeological components was analysed, and a suggestion of optimal methods, resolution and sequence for investigating similar sites was made. This survey is considered an important addition to the current knowledge of archaeological geophysics in Norway, and can serve as a good reference for future work.

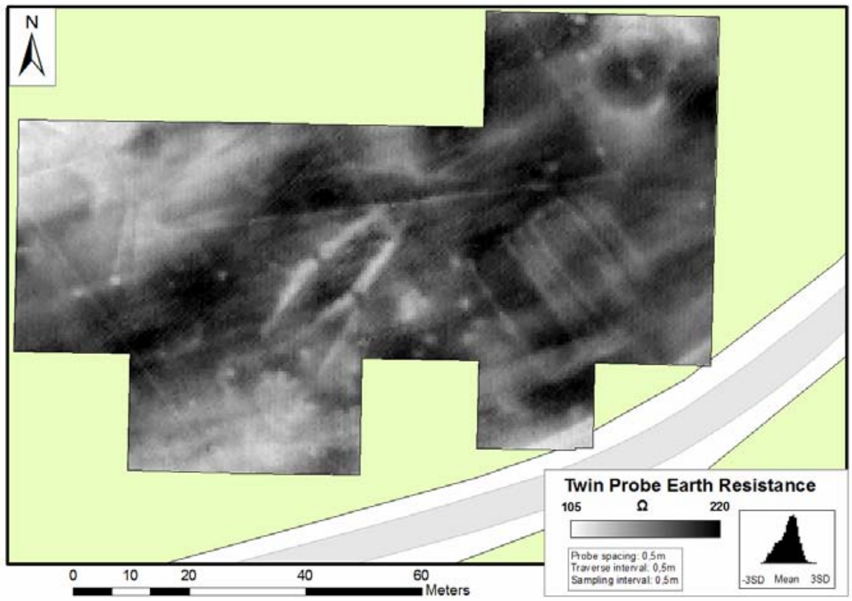


Figure 3: Twin probe Earth Resistance Survey from the summer of 2010 conducted by Arne Anderson Stamnes.

ROMAN DALSWINTON IN SOUTH WEST SCOTLAND: A COMPARISON OF SINGLE AND SIXTEEN SENSOR MAGNETIC SURVEYS

Richard Jones[(1)], Oliver O'Grady[(2)], Rebecca Jones[(2)] and Bill Hanson[(1)]
[(1)]*Archaeology, University of Glasgow, UK;* [(2)]*Royal Commission on the Ancient & Historical Monuments of Scotland, Edinburgh, UK.*

r.jones@archaeology.arts.gla.ac.uk

A complex of Roman forts and camps at Dalswinton in Dumfriesshire in SW Scotland has been successfully explored by aerial photography since the site's discovery in 1947. Some very limited excavation took place in 1954 by Richmond and St Joseph. In 2009, two investigations of Roman military presence in that region of Scotland targeted Dalswinton for large-scale magnetic survey: one employed two Bartington single sensor fluxgate Grad 601 gradiometers, the other was Sensys Sensorik und Systemtechnologie GmbH's MAGNETO®-MX-16-Kanal-System consisting of a sixteen-sensor array placed on a cart with a GPS-defined location system and attached to a vehicle.

This presentation has two aims, one is to set out the logistics and results of the two magnetic surveys and their correlation with the aerial data. There is particular emphasis on the results obtained in a 1.85 ha area encompassing the ramparts and interior of the northern part of the later fort. Comparison in this area was

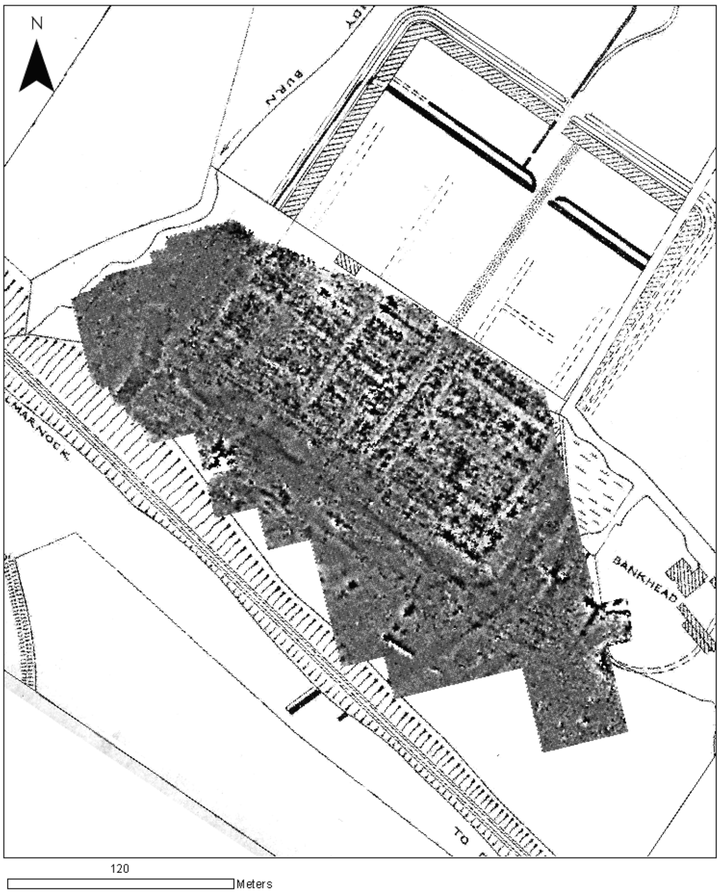


Fig 1: Grey-scale graphic of the (Bartington) magnetic survey of the southern part of the fort at Dalswinton superimposed over the fort's plan. Black shows positive values.

encouragingly close, although both surveys were affected, but to different extents, by background noise arising from the ferruginous sandstone.

The other aim is to correlate the geophysical data obtained especially for the southern half of the fort (Fig. 1) with the archaeological view that there were two phases of this fort's occupation and that the orientation of the second phase was arranged at right angles to the first.

COMMERCIAL EXHIBITORS

3D-RADAR AS

Klæbuveien 196B, 7037 Trondheim, Norway

http://www.3d-radar.com *sales@3d-radar.com*

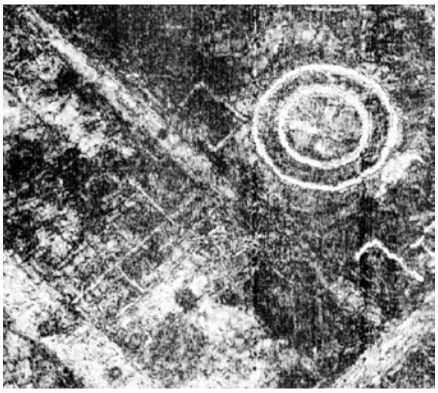
3D-RADAR
a Curtiss-Wright Company

3d-Radar (Trondheim, Norway) develops and manufactures 3D Ground Penetrating Radar (GPR) for high resolution sub-surface imaging and continues to deliver increased performance to fulfil the most demanding requirements from the GPR community.

The GeoScope 3D GPR combines the step-frequency radar technology with an ultra-wideband antenna array which makes it possible to provide focused sub-surface images of buried objects with high resolution and high image quality.

Typically 3D GPR have been used for pavement evaluation (road, highway), bridge deck, railway ballast and airport runway/taxiway inspection, utility mapping and archaeology.

Survey in progress at Stonehenge.



English Heritage data-set over a Romano-Celtic temple at Silchester Roman Town.

The GeoScope™ 3d GPR imaging system is designed to cover wide areas more efficiently and thus allowing less time to be spent at each site for field work.

English Heritage acquired the 3d-Radar GPR system in 2008 and has conducted numerous successful archaeological surveys including the Roman Town at Silchester and more recently at Stonehenge.

BARTINGTON INSTRUMENTS LTD

5, 10 & 11 Thorney Leys Business Park, Witney, Oxon, OX28 4GE, UK

www.bartington.com *sales@bartington.com*

Bartington Instruments Ltd. is a world leader in the design and manufacture of high precision fluxgate magnetometers and magnetic susceptibility instruments.
Our equipment is used around the globe for archaeological exploration, UXO detection, geophysical investigations and many other applications that involve detection of buried magnetic anomalies.

The Grad601 Gradiometer is an ideal instrument for magnetometry surveys in archaeology and for pipe and cable location. Since its introduction in 2004, it has rapidly gained an enviable reputation for its ease of use, automatic set-up and excellent stability. With a 1m vertical sensor separation, and a 0.03nT resolution, recorded data is of a very high quality, whilst fluxgate technology ensures the Grad601 is one of the lightest instruments available.

The MS2 Magnetic Susceptibility system has become an instrument of choice for the susceptibility measurement of soils and other geological samples.
Our new MS3 Meter remains compatible with almost all MS2 sensors and probes and it can be used for both laboratory and field work. The instrument has a very wide variety of applications including archaeological prospecting, mineral identification and nanoparticle analysis. When linked to a portable computer, the MS3 Meter offers enhanced data collection capabilities. Such a system provides a compact and portable way to acquire, display and save data in the field, ideal for tasks such as initial survey work.

Bartington Instruments also designs and manufactures products for users involved in physics, medical physics, geosciences, industry and defence. We can provide a range of single and three-axis fluxgate magnetometers and gradiometers, along with associated data acquisition systems.

DW CONSULTING

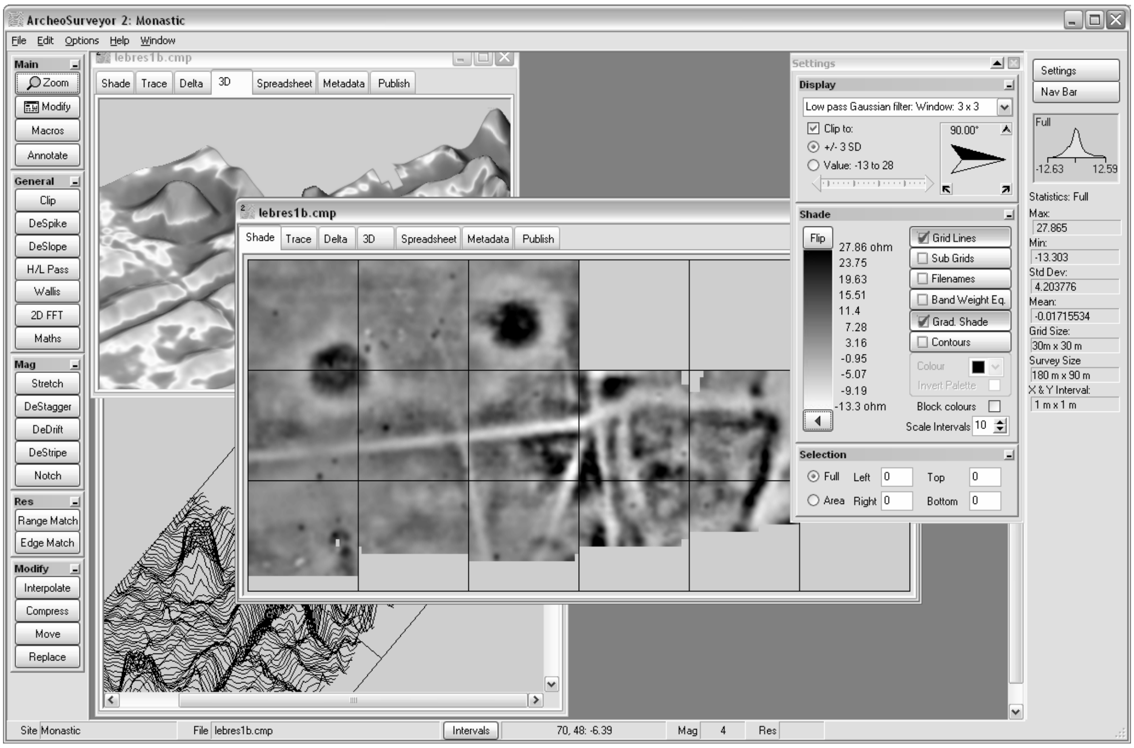
Boekweitakker 28, 3773 BX Barneveld, The Netherlands

www.dwconsulting.nl *dwilbourn@dwconsulting.nl*

DW Consulting produces software for acquiring, assembling, processing, visualizing and publishing Geophysical data. The programs have been specifically designed to meet the needs of archaeologists and continue to be developed in close co-operation with many instrument manufacturers and users.
The two main programs are:

ArcheoSurveyor
This targets 2 dimensional data such as that created by Magnetometers & Resistivity meters.

ArcheoSurveyor3D
This was developed to display volumetric data from Magnetic Susceptibility down-hole probes. However it can also handle other 3D datasets such as pre-processed GPR data.



ArcheoSurveyor Software

GEOMATRIX EARTH SCIENCE LTD

20 Eden Way, Pages Industrial Park, Leighton Buzzard, Beds, LU7 4TZ, UK

www.geomatrix.co.uk *sales@geomatrix.co.uk*

Geomatrix Earth Science is a dedicated instrument supply company specialising in Geophysical instrumentation for the investigation of near surface ground conditions for many applications including Archaeological Prospection and Forensic investigations.

Our portfolio includes:
The Pro-Ex and X3M range of Ground probing Radar from Mala Geoscience. The Pro-Ex range includes the ability to use a variety of antenna frequencies to enable you to tailor your system to the task at hand, be it detection of man-made or natural voids, buried artefacts and man made built or excavated structures metallic and non-metallic services and culverts, depth to bed rock studies. The Pro-Ex stores data digitally, so it can be downloaded to PC and digitally enhanced. Mapped or grid surveys can be performed so areas can be viewed in plan form, with depth slices at operator selected depths enabling complex structures to be resolved.

EM conductivity instruments, which are suitable for metallic object location and electrical conductivity mapping of large areas

Caesium Vapour and Fluxgate magnetometers and gradiometer systems, which can map man-made features, obstructions and buried ferrous objects.

Electrical Resistivity Tomography and Seismic systems, which are ideally suited to depth to bedrock determination and Geo-archaeology studies.

Unique to Geomatrix is the GEEP system, which allows multiple instruments to be mounted on a single platform which is then towed over the ground using a small tractor at speeds of 2-3m/sec depending on terrain. Positional accuracy is ensured by use of a differential or RTK GPS system depending on the desired accuracy of the finished survey. The GEEP allows large areas to be surveyed in great detail and at high speeds whilst ensuring high data quality.

All instruments are available on a sale or rental basis.

GEOSCAN RESEARCH

Heather Brae, Chrisharben Park, Clayton, Bradford, BD14 6AE, UK

www.geoscan-research.co.uk *info@geoscan-research.co.uk*

Geoscan Research designs and manufactures geophysical instrumentation for both professional and amateur use. Although primarily for archaeological use, our products are also used increasingly in other areas including environmental, forensics, geological, civil engineering and peace-time military applications.

The product range at present comprises earth resistance meters, fluxgate gradiometers, mobile sensor platforms and associated computer software, with new measurement techniques currently under development. Our products are low cost, user-friendly, lightweight and have proven reliability. Our equipment has appeared frequently on archaeological and historical television programmes.

UTSI ELECTRONICS LTD

Sarek, Newton Road, Harston, Cambridge, CB22 7NZ, UK

www.utsielectronics.co.uk *enquiries@utsielectronics.co.uk*

Utsi Electronics Ltd is an innovative UK based manufacturer and designer of the Groundvue Ground Penetrating Radars (GPRs).

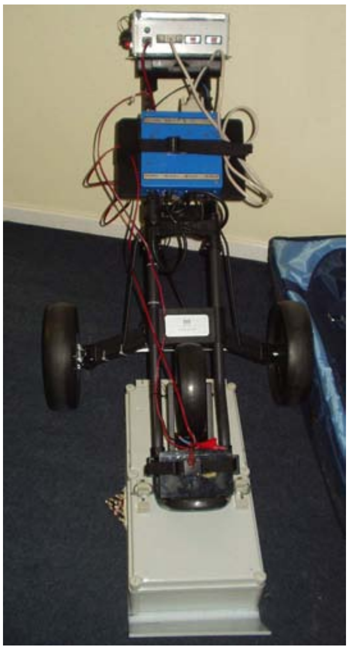
The Groundvue GPRs use twin arrayed antennas to reduce noise. They use very broad band frequency spectrum to produce a high signal to noise ratio, resulting in better depth penetration for the same frequency of antenna & good signal clarity.

Due to our extensive research collaborations, we can supply the widest range of antenna frequencies – anything from 6GHz down to 15MHz. The systems most commonly used for archaeological and forensic investigations are:

- Groundvue 3 either as a single or a multi-channel radar, typically with one or more 400MHz, 250MHz & 1GHz antennas;
- Groundvue 5 (4GHz) for detailed target definition; &

- Groundvue 2 (50MHz) for wetland investigations

The lower frequency systems (Groundvues 2, 6) are used worldwide for geological applications.



Our multi-channel Groundvue 3 is the fastest available, having simultaneously triggered antennas without cross channel interference. Data collection speeds in multi-channel mode or when using GPS/Total station are equivalent to 1000scans/sec with all channels operational. Simultaneous triggering also allows automatic depth calibration during survey. Groundvue GPRs comply fully with current European legislation.

GPRs are available for purchase or hire and we can field experienced survey teams or recommend a reliable survey provider from our clients. The company provides training in GPR techniques, both for beginners and for more experienced users.

Specialist design and research work is carried out in collaboration with European University and other Research Organisation partners. Technical enquiries for new GPR designs and developments are welcome.

FURTHER CONFERENCES OF INTEREST IN 2011

There will be a session on archaeological prospection at the CAA 2011 conference in Beijing, China between the 12th and 16th April:
http://jrogden.wordpress.com/2010/10/03/caa-2011-archaeological-geophysics-session/

The EAGE Near Surface Geophysics meeting will be held in Leicester, UK between the 12th and 14th September:
http://www.eage.org/events/index.php?evp=3993&ActiveMenu=14&Opendivs=s3,s14

The 9th International Conference on Archaeological Prospection will be held in Izmir, Turkey in September between 19th and 24th September:
http://www.archprospection.org/conferences.php

ACKNOWLEDGEMENTS

We are grateful to English Heritage for funding the production of this abstracts booklet and for allowing us time to organise the conference. Thanks are due to Louise Dyer and the staff at the Geological Society for help in facilitating the day and Oliver Kuras, the NSGG committee as well as Alistair Ruffell and Duncan Pirrie for helpful discussions as plans have taken shape. We also thank Sara Anders and Jamie Pringle for mounting digital versions of the conference documents on the Geological Society and NSGG WWW sites respectively and the ISAP committee for offering a prize for the best poster.

We are also grateful to our commercial exhibitors: 3d-Radar AS, Bartington Instruments Ltd, Beta Analytic, DW Consulting, Geomatrix Earth Science Ltd, Geoscan Research Ltd and Utsi Electronics Ltd as well as the NSGG and FGG who have contributed funds to make the wine reception possible.