Recent Work in Archaeological Geophysics

The Geological Society
Burlington House, Piccadilly, London W1J 0BG
Tuesday 6th December 2016

Programme

Lecture Programme:

0915-0950	**Registration and Coffee**
0950-0955	**Introduction**
0955-1010	*After the Earthquake: Geophysical Mapping of Underground Cultural Heritage in Nepal.* A Schmidt, R Coningham, C Davis, K Prasad Acharya and R Bahadur Kunwar
1015-1030	*The GPR Investigation of the Shakespeare Family Graves.* E Carrick Utsi and K S Colls
1035-1050	*Determining Geophysical Responses from Graves.* H C Dick, J K Pringle and R van der Putten
1055-1110	*The Impact of Surface Topography on the Performance of Migration Velocity Analysis of GPR Data.* A Harding, A Booth, N Allroggen, V E Turner, C Dyer, J Henderson and J Marsh
1115-1145	**Tea/Coffee break**
1145-1200	*Geochemistry meets Geophysics: in situ XRF surveying in the characterisation of a conflict archaeology site.* A Booth, V Vandeginste, D Pike, R Abbey, R Clark, C Green and N Howland
1205-1220	*Via Belgica; Surveyed, Excavated and Buried.* J Orbons, R Paulussen and B Weekers-Hendrikx
1225-1240	*All Roads Lead to Tibiscum – Preliminary Results of A Polish Landscape Survey Project on a Roman Fort in Romania.* M Pisz and A Hegy
1245-1300	*The Great Dorset Throw Down: The Infra-Site Landscape of a Verwood Country Pottery*. D Carter, P Cheetham and I Hewitt
1305-1310	**Morning closing remarks**

1310-1430	**Lunch (Lower Library)** – all delegates **NSGG AGM (Lecture Theatre)** – open to all Geological Society members
1440-1455	*In Search of the Lower City of Qalat-Idinka: Magnetometer Prospection of Neo-Assyrian Sites in the Peshdar Plain, Iraqi-Kurdistan.* J W E Fassbinder, A Ašandulesei, K Radner, J Kreppner and A Squiteri
1455-1515	*Recent Results from Verulamium.* K Lockyear
1520-1535	*Geophysical Surveying of the Ancient Egyptian Towns: An Overview.* T Herbich
1540-1555	*Experiences Exploring the Use of Archaeological Prospection Data Within Precision Agriculture Systems in the UK.* H Webber
1600-1630	**Tea/Coffee break**
1630-1645	*What On Earth Is This? Non-Archaeological Information in Landscape-Scale Geophysical Prospection Data.* P Schneidhofer, W Neubauer, E Draganits and E Nau
1650-1705	*The Accessibility of Geophysical Surveys in England, or How Easy (or Not) Is It To Find Out Where a Survey Has Been Conducted.* J Lyall
1710-1725	*The Enigmatic Vanishing of the Geophysicist in Archaeological Prospection at the Beginning of the 3rd Millennium.* C Meyer
1730-1740	**Conclusion**
1745-1900	**ISAP AGM (Lecture Theatre)**

Posters (09:30-19:00 in the Lower Library):

Geophysical Prospection at Caisteal Mac Tuathal, Perthshire, Scotland. M Lukas

Reimaging the Black Friary: Recent Approaches to Seeing Beyond Modern Activities at the Dominican Friary, Trim, Co Meath. A Green and P Cheetham

Magnetometer Prospecting of a Major Achaemenid Palatial Structure at Karacamirli, Azerbaidjan. A Persian Paradise in the Caucasus. J Fassbinder, M Scheiblecker, F Becker, K Kaniuth, A Asandulesei and M Gruber

Mining and interpreting archaeo-geophysical data through excavation – a case from prehistoric Knowlton (Dorset, UK). P De Smedt, S Delefortrie, M Gillings, J Pollard and M Green

A comparative approach of EM and magnetic survey for the study of the Neolithic site of Klimonas (Cyprus). C Benech, A Tabbagh and J-D Vigne

Creating Composite Ground Penetrating Radar Datasets from Three Different Antenna Frequencies. J Marsh, A Booth, V Turner, C Dyer, J Henderson, M Guy and A Harding

Beneath the Surface of Roman Republican Cities: Large-Scale GPR Survey of Falerii Novi and Interamna Lirenas (Lazio, Italy). L Verdonck, G Bellini, A Launaro, M Millett and F Vermeulen

Magnetic Modelling Applet Development: An Overview of a Free Web-Based Tool (Commercial Presentation). J Marsh and M Guy

Topographic Correction of Geophysical Data: Comparison of Photogrammetry and GPS Data in the Correction of Poor Accuracy Height Values at Grave Creek Mound, WV, USA. A Corkum, C Batt, J Davis, C Gaffney, and T Sparrow

Cluster Analysis of GPR Profiles Using Image Intensity Distribution and Pattern Descriptor Learning: Applicability for Archaeological GPR Data. L Wei, Q Dou, D Magee, A D Booth and A G Cohn

Recent Geophysical Results from The South Hill at Olynthos, Greece. C Gaffney, T Sparrow, T Horsley, Z Archibald, L Nevett, B Tsigarida, A Corkum and D Stone

On the Trail of the Illyrian Rulers. Achievements and Obstacles During the Multi-Method Geophysical Survey in Shkodër (Albania) and Risan (Montenegro). M Pisz, A Hegy and D Gergely Páll

Geophysical Investigations at the Viking – and Early Medieval Assembly Site of the Frosta Thing. A A Stamnes

Where - the hell - is the western continuation of earthworks Niedersickte? A discovery story in three stages. C Schweitzer

Commercial Exhibitors (09:30-19:00 in the Lower Library):

Allied Associates Geophysical Ltd

Bartington Instruments Ltd

DW Consulting

Geomatrix Earth Science Ltd

Geoscan Research Ltd

Guideline Geo

Sensys Gmbh

LECTURE ABSTRACTS

AFTER THE EARTHQUAKE: GEOPHYSICAL MAPPING OF UNDERGROUND CULTURAL HERITAGE IN NEPAL

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In Nepal the devastating earthquake of 2015 (magnitude 7.8 M_w) killed nearly 9000 people and destroyed many buildings, including a large number of ancient temples and historic structures. During the search for survivors most of the resulting “cultural debris” was removed with heavy machinery (Figure 1) and discarded without recording. Similarly, the subsequent rebuilding efforts often involved unsupervised excavations for extended concrete foundations as bases for new steel super-structures. As a result some of the up to then intact buried archaeological remains were unnecessarily damaged.

Fig. 1: Clearing debris at the Kasthamandap temple, Hanuman Dhoka Durbar Square.

To address this problem a UNESCO-funded project was initiated to record the archaeological remains underneath the three royal squares in the Kathmandu valley (the Durbar squares of Patan, Hanuman Dhoka and Bhaktapur). Small excavation trenches were combined with adjoining GPR surveys (Figure 2) to create archaeological risk maps of these areas. A single-channel Mala 500 MHz GPR system was used with a line spacing of 0.2-0.3 m to record time-slices of the ground. Since the areas had been levelled many times in the past, the fill between buried structural remains created considerable noise in the data. It was nevertheless possible to identify walls and utilities (mostly water pipes) based on comparisons with results found in the excavation trenches.

At the southern edge of Bhaktapur Durbar Square several linear anomalies were aligned in a rectilinear grid pattern and appeared to have the width of walls (approx. 0.3 m), Figure 3. Their shape and overall layout therefore suggested foundations for a building that may have stood in this place, possibly the palace building depicted in a painting from 1858 by Henry Ambrose Oldfield, but not visible today. In addition, several modern utilities cross the square and their mapping provided valuable information for the management of this space. The data from the Durbar squares of Patan and Hanuman Dhoka showed similar results.

Fig. 2: GPR survey on Bhaktapur Durbar Square.

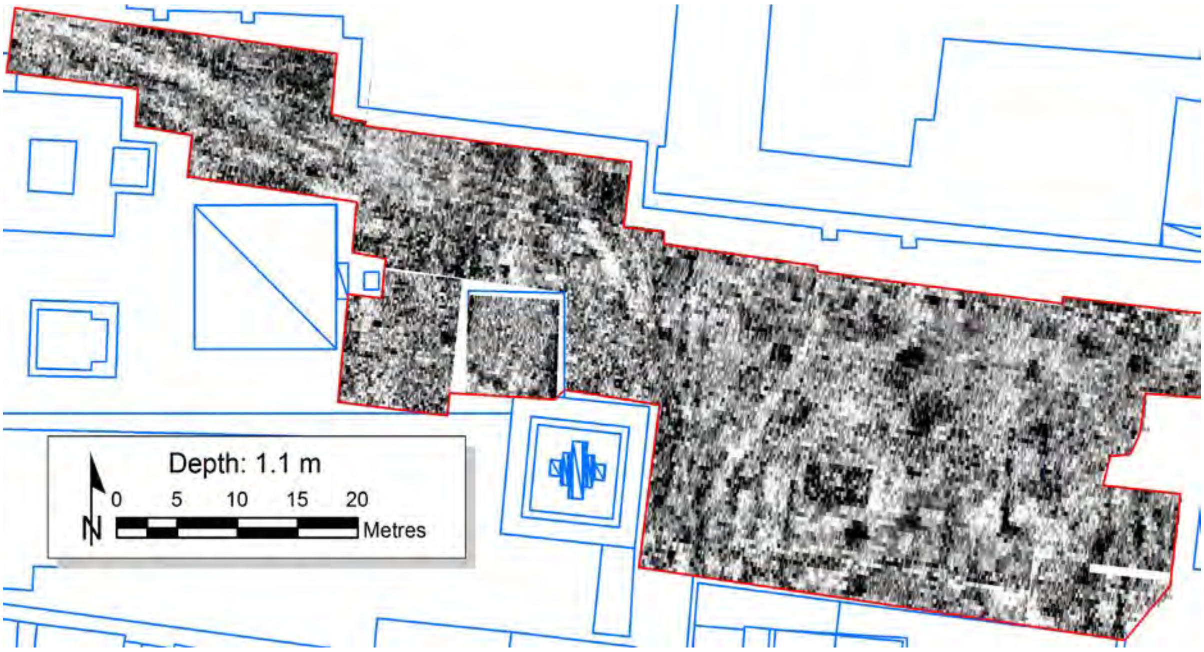

Fig. 3: Time-slice of GPR data from Bhaktapur Durbar Square at approximately 1.1 m depth (strong reflections are black).

THE GPR INVESTIGATION OF THE SHAKESPEARE FAMILY GRAVES

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On 25th April 1616 William Shakespeare was buried in the chancel of his local church, Holy Trinity, Stratford upon Avon, Warwickshire, England. The ledger stone which is thought to mark his grave does not bear his name. Instead it carries a world famous curse threatening anyone who disturbs his bones. In the following years other members of his family were also interred in the same area: his wife Ann in 1623, son in law John in 1635, grandson-in-law Thomas in 1647 and lastly his daughter Susanna in 1649. Each of their graves bears a suitable inscription although it is extremely rare for monumental inscriptions in churches to be directly attributable to the position of the corresponding grave (Rodwell, 2002).

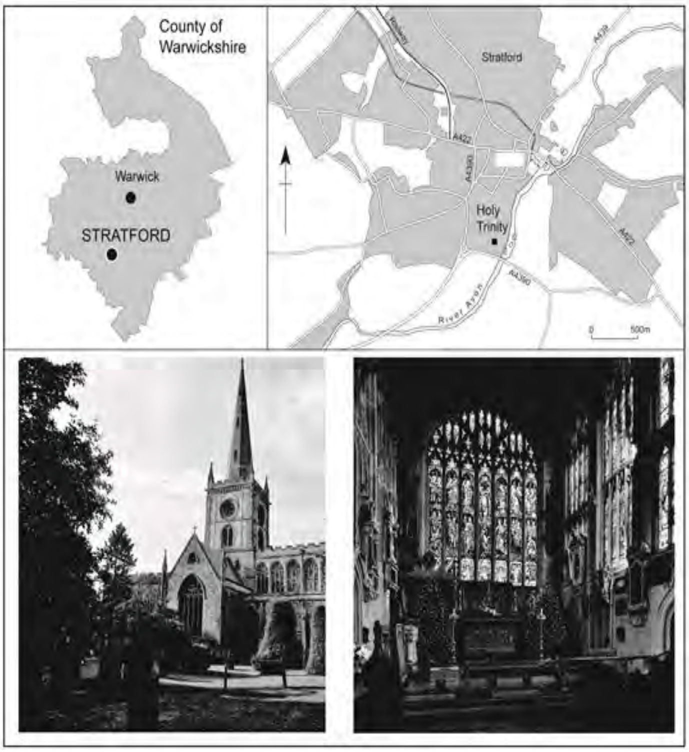

Fig. 1: The Location of Holy Trinity Chancel, the burial site of William Shakespeare.

Little was known for certain about the burial practices for example whether these were individual graves or a family vault. It is unsurprising, given Shakespeare's international fame as both poet and playwright that a large number of myths and legends have grown up around his burial. These range from suggestions of extreme depth of burial to tales of grave robbing.

In recent times the Shakespeare family graves have been protected from invasive investigations. In 2014, as part of a multi-disciplinary programme of archaeological and historical research, permission was granted by Holy Trinity to carry out a GPR survey of the chancel in which lay the ledger stones commemorating the Shakespeare family graves. An initial survey used a 250MHz antenna in order to cope with the presumed depth requirement but this failed to find the graves. The current investigation used a multi-frequency (400MHz, 1.5GHz, 4GHz) approach in order to locate and map the graves. Close line spacing (to conform to the Nyquist requirement) was used to optimise target definition with the aim of determining what material, if any, still remained. The success of this strategy in finding both the Shakespeare family graves and other vaults within the Church shows the importance of using appropriate frequencies and wavelengths in the context of the site conditions including the size of the building above ground, floor composition as well as soils and moisture content, and the depth and definition of the targets (Carrick Utsi & Colls, submitted).

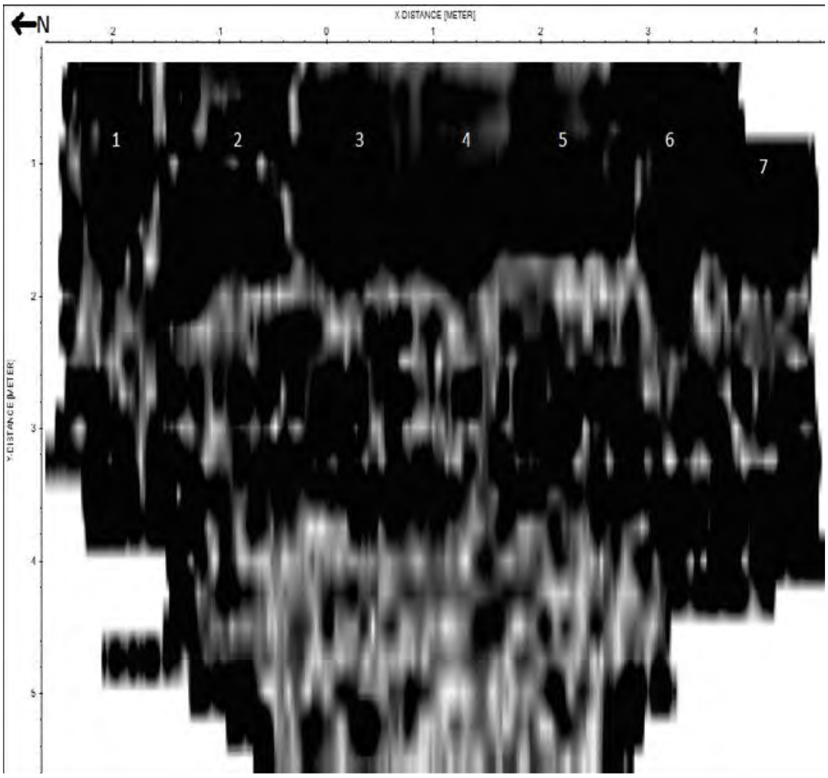

Fig. 2: A 400MHz time slice showing the definition of the graves beneath the Ledger Stones.

The presentation uses GPR data from the Holy Trinity investigation together with comparative data from GPR surveys of Westminster Abbey (another church where detection of graves had previously proved problematic) to illustrate the importance of frequency and wavelength in successfully locating graves in historic churches. The comparisons also demonstrate how it was possible to analyse the data so as to derive information about the structure of the graves and their contents as well as illustrating why one apparently tall tale may actually be true. In spite of the curse and the care of the monuments, William Shakespeare's head may have been removed during the latter part of the 18th century (Carrick Utsi & Colls, submitted).

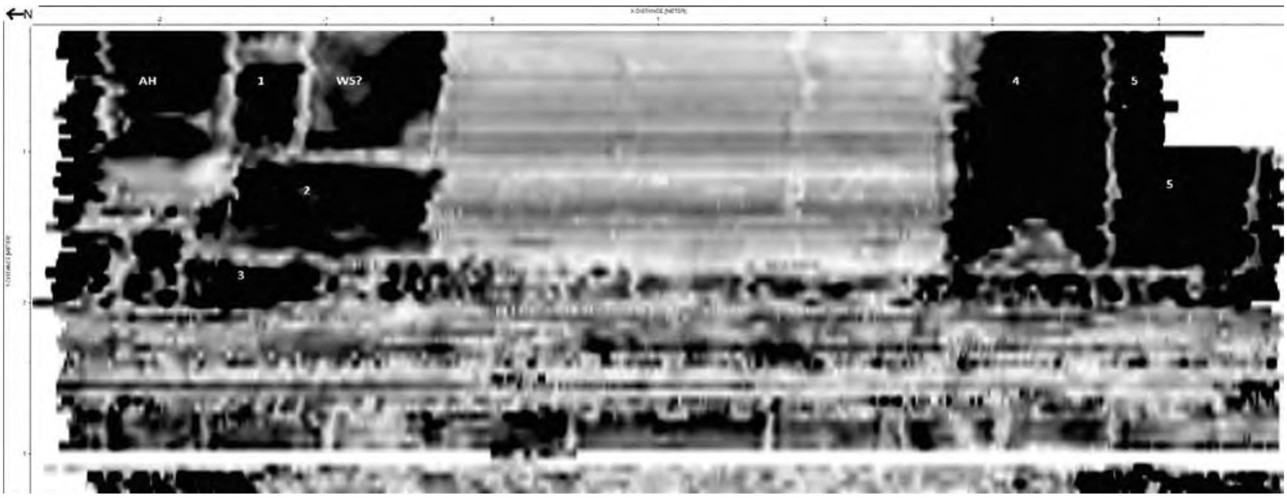

Fig. 3: The outline of a series of graves across the chancel floor with one unusually orientated feature ("2") Time Slice from the 1.5GHz data.

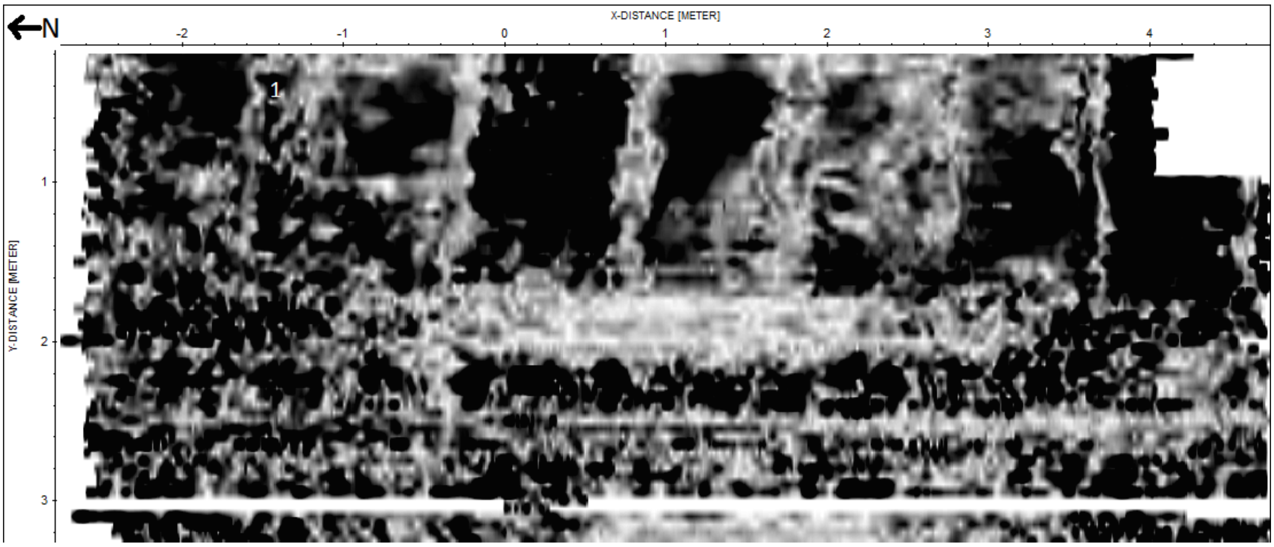

Fig. 4: A time slice from the 1.5GHz data showing the outlines of the graves below the area of the anomalous feature.

Bibliography

Rodwell, W, 2002 The Archaeology of Churches, Amberley Publishing, Stroud.

Carrick Utsi, E & Colls, K, submitted *Archaeological Prospection.*

DETERMINING GEOPHYSICAL RESPONSES FROM GRAVES

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Graveyards and cemeteries around the world are being increasingly designated as full. There is a growing requirement to identify burial spaces or to exhume and then re-inter burials if necessary. Near-surface geophysical methods offer a potentially non-invasive target detection solution; however there has been lack of research to identify optimal detection methods using such geophysical techniques. This study has collected multi- frequency (225 MHz – 900 MHz) ground penetrating radar, electrical resistivity and magnetic susceptibility surface data over known burial sites with different burial ages and in a variety of UK graveyards. Results indicate that progressively older burials are more difficult to detect but successful grave detection is complicated by soil type. Different geophysical techniques were optimal in the three sites surveyed, which therefore suggests a multi- technique approach should be utilised by survey practitioners. Graveyard geophysical targets included the grave soil present above earth-cut graves, the grave contents themselves, brick-lining (if present) and grave soil leachate plumes that are all geophysically detectable from background levels. Grave markers were also identified as not always being located where the burials were positioned. This study clearly demonstrates the value of these techniques in grave detection and informs search teams detecting clandestine burials.

Major result diagrams

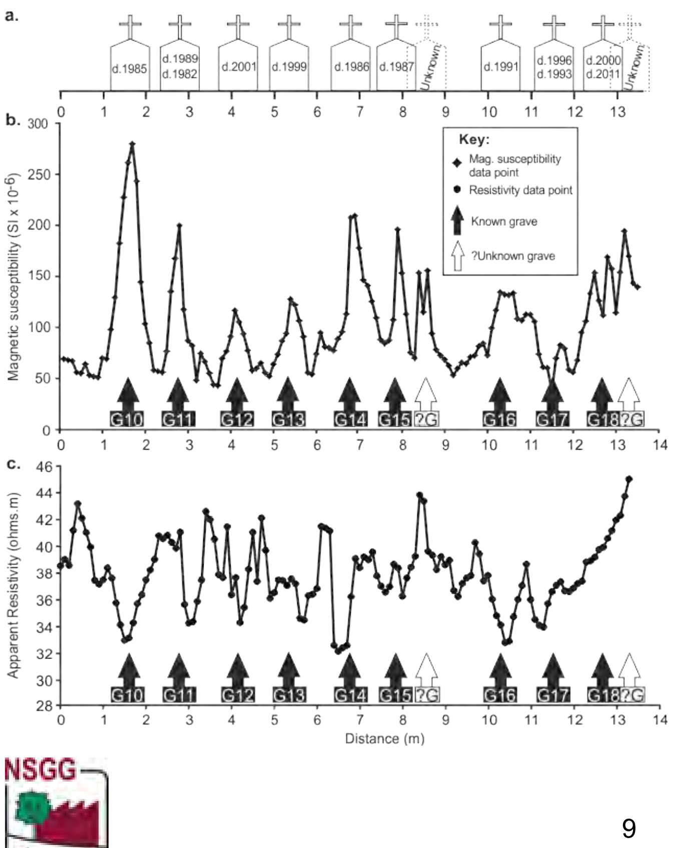

Fig. 1: St. Michael's graveyard survey line 2 (Fig. S1 for location), showing (a) grave locations represented by headstones with year of burial inset, (b) magnetic susceptibility and (c) apparent resistivity profile (with grave positions arrowed) all on common distance scale.

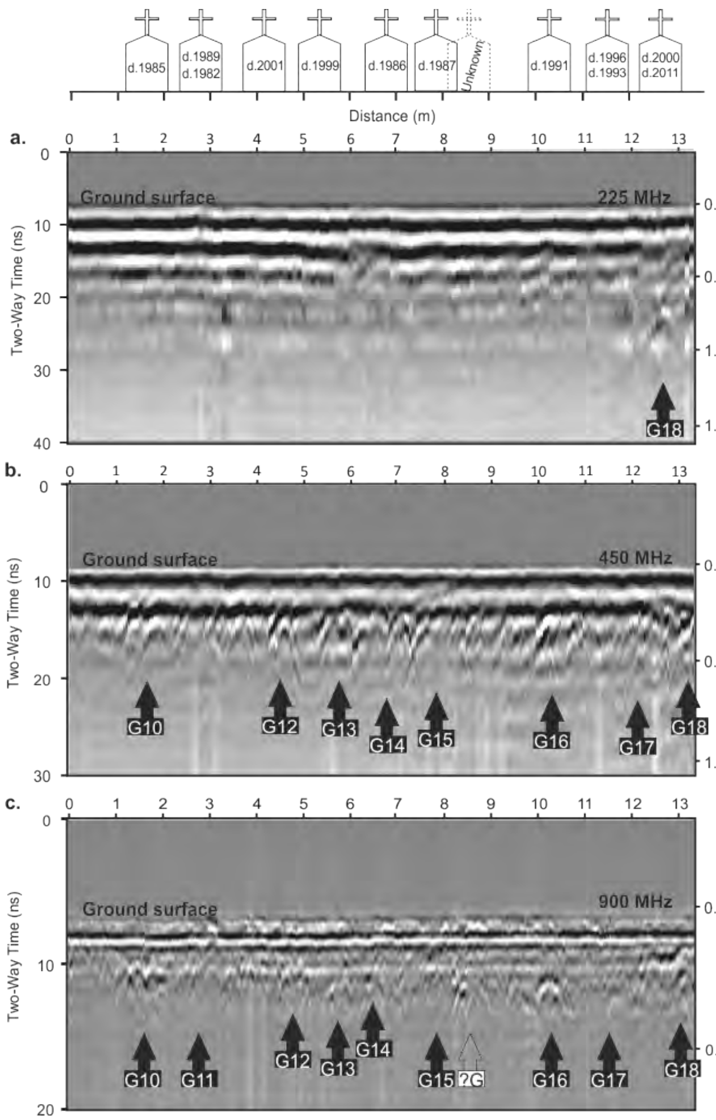

Fig. 2: St. Michael's survey line 2 (Fig. S1 for location), showing (a) grave locations represented by headstones with year of burial (inset) with anomalies (arrowed) all on common distance scale. Where; a, b and c were obtained with 225, 450 and 900 GPR antenna frequencies respectively.

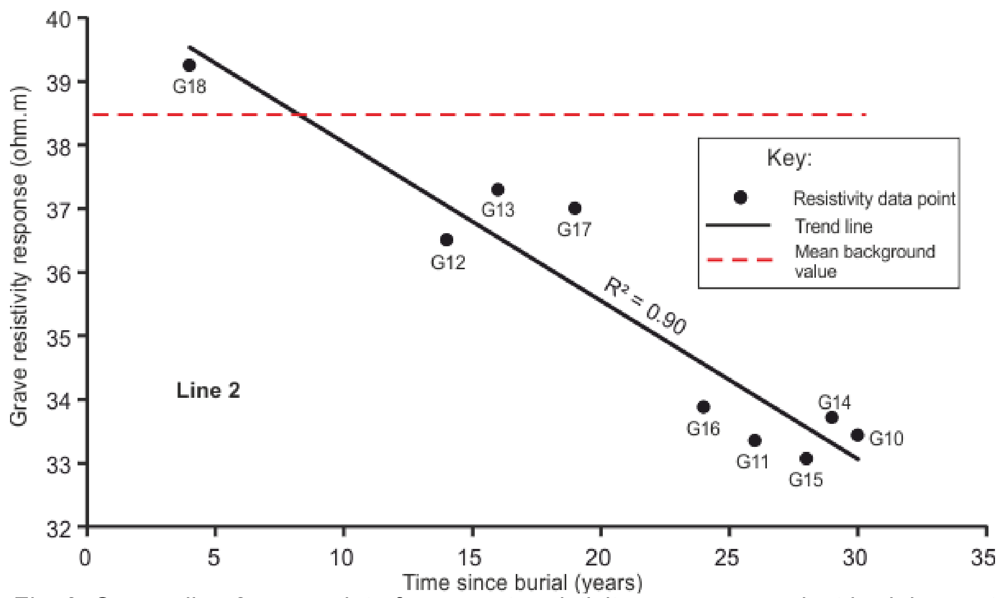

Fig. 3: Survey line 2 cross-plot of apparent resistivity response against burial age at St. Michael of All Angels graveyard, Norfolk, UK.

THE IMPACT OF SURFACE TOPOGRAPHY ON THE PERFORMANCE OF MIGRATION VELOCITY ANALYSIS OF GPR DATA

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Ground penetrating radar (GPR) is a well-established technique for detailed and continuous imaging of the subsurface, particularly for archaeological purposes. Although GPR image quality is often suitable for archaeological interpretation, the accuracy of the implied subsurface structure can be limited. While migration algorithms can improve this, the implementation of migration is often compromised because *i*) velocities are difficult to derive from common offset GPR data, hence migration and depth conversion are based on a single velocity estimate, and *ii*) the effect of topography on the migrated output is often neglected. These compromises can be jointly circumvented using an approach to migration velocity analysis (MVA; Allroggen *et al.*, 2014) that honours topographic variation.

We consider the implementation of 'topographic MVA' for GPR data recorded close to the site of Old Scatness broch (Sumburgh, Shetland, UK; Dockrill *et al*., 2010). An Utsi Electronics *TriVue* system was deployed, simultaneously using antennas of 250 MHz, 500 MHz and 1000 MHz centre-frequencies. The site, approximately 70 m x 70 m in area, features considerable topographic variations. Some of these variations are locally comparable with the approximate depth of buried reflective surfaces, a situation that Dujardin and Bano (2013) claim is associated with poor migration output.

Figure 1 shows example *TriVue* data from a representative profile from the acquisition. An extensive reflective surface is observed in the profile, together with two additional horizons that show onlap/offlap relationships. A diffraction hyperbola, corresponding to a modern service through the western end of the site, is also observed. The geometry of each horizon would be modified through migration, but only correctly when appropriate topography and velocity is included. Topographic MVA will be investigated for this profile, and the frequency-sensitivity of the method will be assessed using the multiple components of the *TriVue* record dataset.

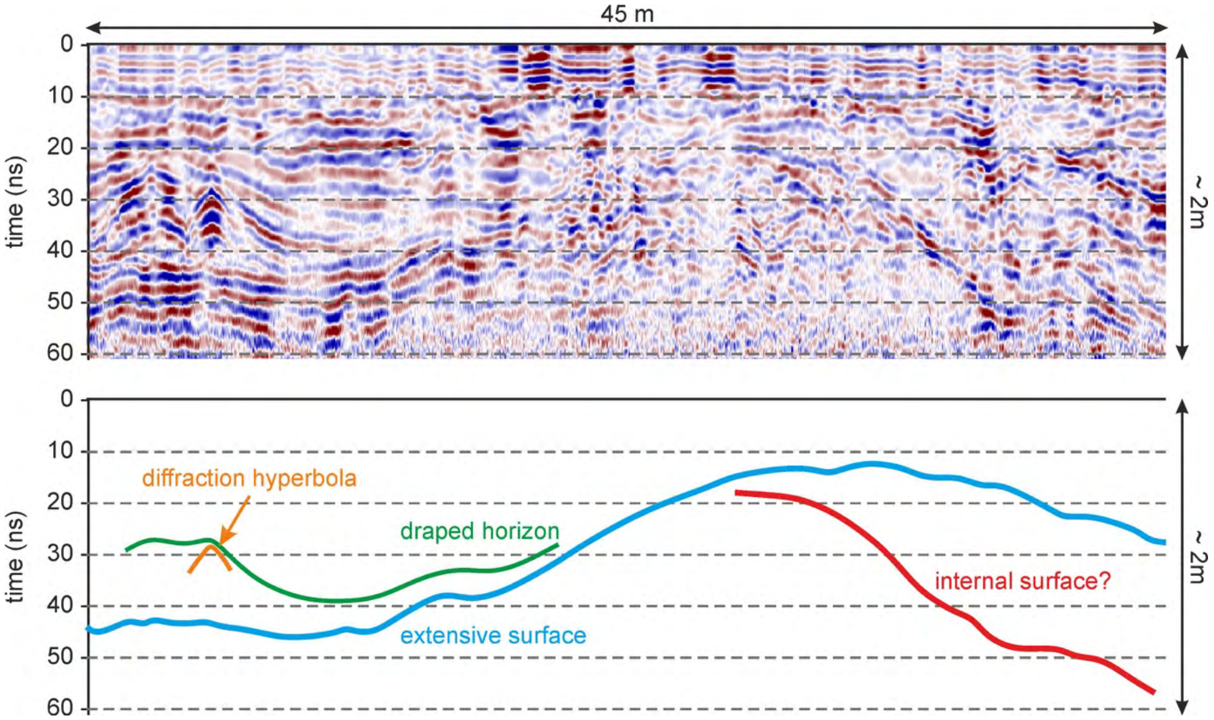

Fig. 1 - Example 250 MHz TriVue data from a representative profile from the acquisition.

References

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GEOCHEMISTRY MEETS GEOPHYSICS: *IN SITU* XRF SURVEYING IN THE CHARACTERISATION OF A CONFLICT ARCHAEOLOGY SITE

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Geophysical techniques are widely applied in archaeological exploration, providing rapid and non-invasive site appraisal. While geochemical analyses contribute significantly in archaeometry, sampling is often destructive, which is somewhat contrary to the recognised benefits of field geophysical survey. However, recent advances in field-portable apparatus facilitate *in situ* and non-destructive geochemical analysis. We investigate the archaeological prospectivity of a site using both conventional geophysical surveys (magnetic gradiometry and electromagnetic – EM – methods) and a handheld X-ray fluorescence (XRF) spectrometer; the use of the handheld XRF instrument facilitates geochemical exploration in the same conservative manner as traditional geophysical surveys.

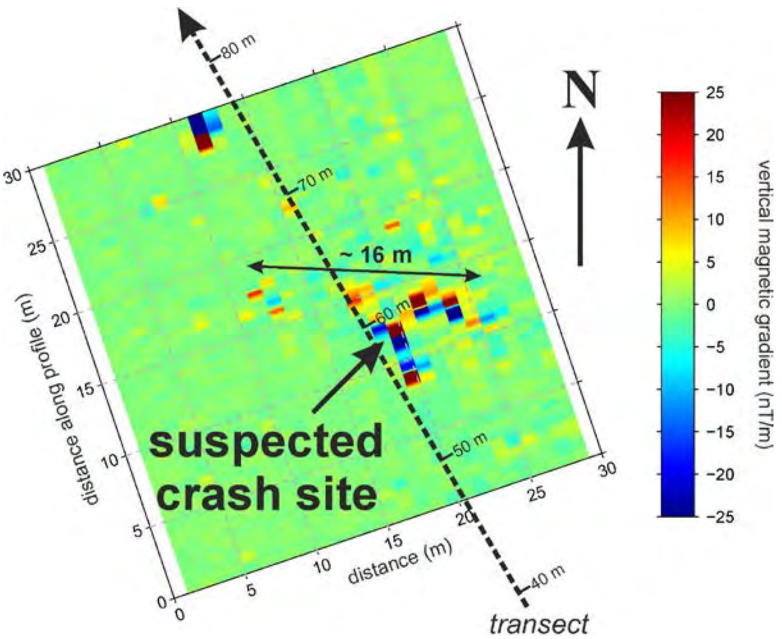

Fig. 1: Magnetic gradiometry data acquired, with a Bartington Grad601 instrument, over the suspected crash site of a Mosquito aircraft.

This novel survey approach is applied to the characterisation of the suggested crash site of a Second World War *Mosquito* aircraft, in the area of Nuthampstead Airfield. The *Mosquito* is an intriguing target since, rare amongst aircraft of the era, it was made chiefly of wood and is therefore less responsive to most geophysical surveys than may initially be anticipated. Nonetheless, a 100 m long transect of EM and magnetic surveys was acquired over the *Mosquito*'s suspected crash site, together with a 900 m^2 grid of gradiometry data (using a Bartington *Grad601* instrument; Figure 1). The transect was also surveyed with a Bruker *Tracer IV* XRF system, with soil samples also taken for subsequent laboratory validation.

Geophysical data show a discrete region of elevated magnetic gradient, with anomalies of ±10 nT/m. This response is attributed to the thermoremanence of a burnt layer at 0.2-0.4 m depth. At the same position, XRF spectrometry reveals local enrichments in copper and zinc ions (400% and 200%, respectively, above background; Figure 2). These metals are present in abundance on board the *Mosquito* as brass alloy, contained both in ammunition cases and in the thousands of screws that held the aircraft together.

Records from the *in situ* XRF sampling compare well with laboratory validated data, including with data from mass spectrometry; however, a bespoke calibration for the local soil type would improve the reliability of absolute geochemical concentrations. Where a target is associated with 'exotic' chemical elements and a source-to-surface transport mechanism is present, we suggest that *in situ* XRF analysis offers an effective and practical complement to conventional geophysical exploration.

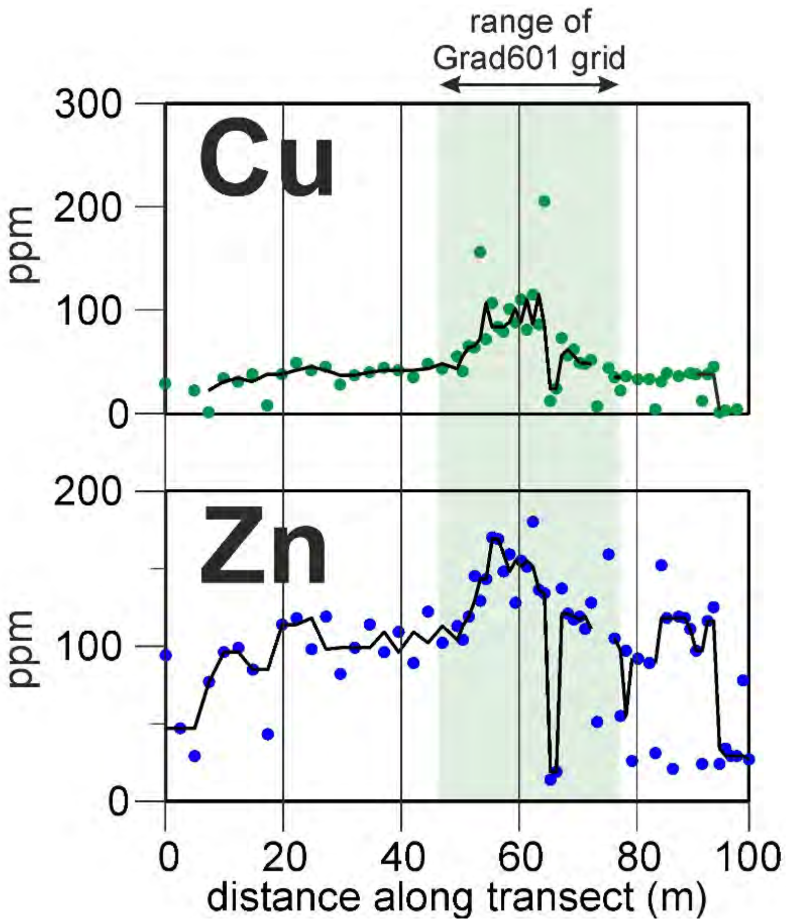

Fig. 2: Records from the in situ XRF survey, showing elevated relative concentrations (in parts per million, ppm) of copper (Cu, upper) and zinc (Zn, lower) ions. The highest concentrations are co-located with the anomaly in the magnetic gradiometry records.

VIA BELGICA; SURVEYED, EXCAVATED AND BURIED

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Via Belgica
The Via Belgica is the Roman road, connecting Boulogne sur Mer at the coast in Northern France, through what is now Belgium to the major Roman city of Cologne in Germany. During the last centuries of the Roman Empire, this road was the northern frontier and is now still visible as the language frontier between the countries with Germanic languages in the North and the countries with Latin languages in the south. This road has been named Via Belgica and is clearly visible on several locations along its entire length.

In 2013 an industrial area was going to be developed near the village of Voerendaal on a confirmed stretch of the Via Belgica. The road has been seen in archaeological trial trenches on both ends of the field that was going to be developed. These prior surveys show that the condition of the Roman road is very different on both ends. On the western side the road is completely intact, a body of gravel in a colluvial löss-matrix. On the eastern side the body of the road has been used as a gravel-quarry and is therefore badly destroyed. Prior to the building activities, an archaeological survey was carried out.

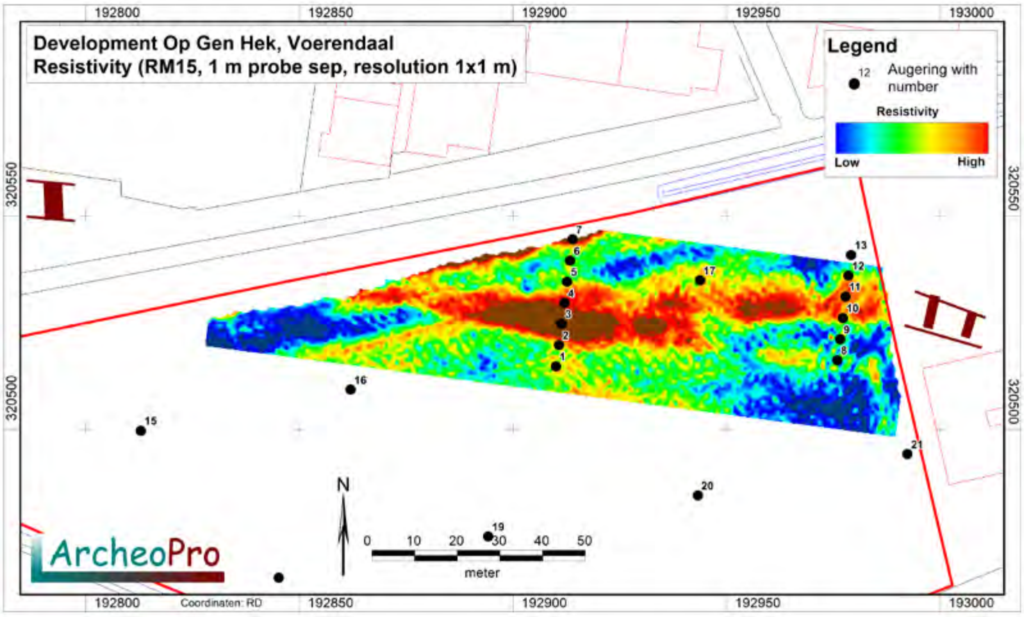
Geophysical surveys
The location was at first part of a research project to test a wide range of geophysical instruments on confirmed and suspected Roman roads. The Geonics EM31 and EM38 were used to check if the road is detectable in fast and large scale geophysical surveys. Secondly the roads were tested with Grad 601 magnetometry and RM15 ERT measurements as well as a 300 MHz GPR.

Both EM measurements did not give good results that could be related to the Roman road. This is mostly because of the high changeability of the soils over a small area due to erosion and colluvial processed in the hilly area. The magnetic measurementsproduced mainly noise from surface materials as the area was in intensive agricultural use for many centuries.

The GPR survey showed some very clear reflections at the expected position of the Roman road. For budget reasons, this GPR survey was not extended over the whole area.

The outcome of these tests resulted in a full survey with the RM15 resistivity with an electrode spacing of 1 metre. A total area of 0.5 hectare was surveyed, covering the expected course of the Roman road. The total area of the industrial development was covered with 24 augerings to determine the exact depth of the archaeological layer.

As the location sits at the bottom of a sloping hill, there is a layer of colluvial löss of 70 centimetres covering the Roman archaeology, rising to more than 150 cm in the higher parts of the survey location.

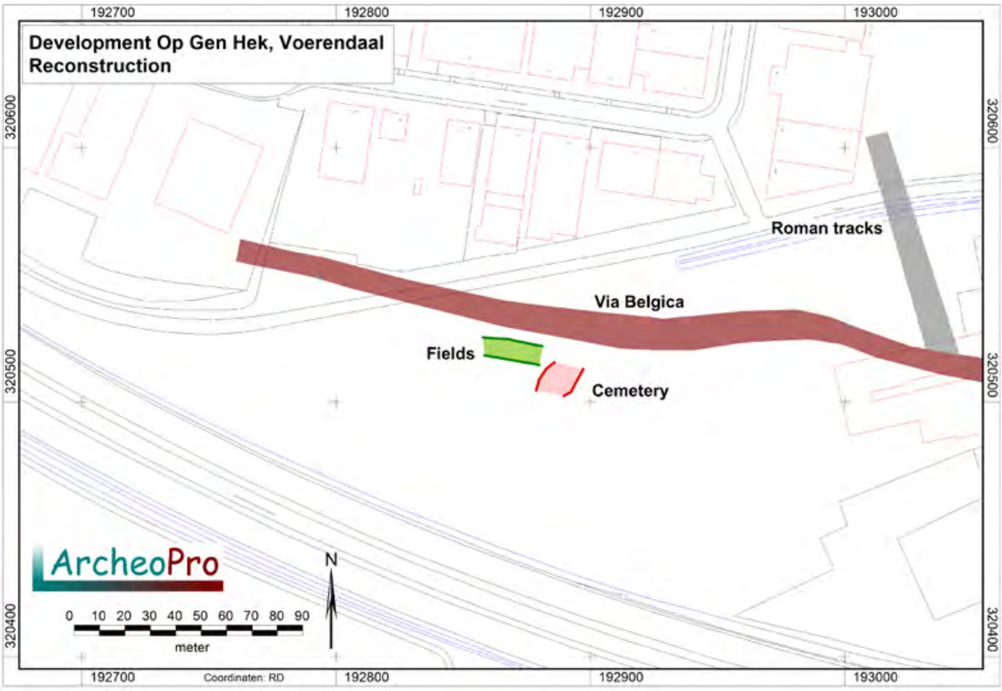


The resistivity showed that the western intact part of the Roman road extended to halfway across the field, then turning into a gravel quarry for the eastern half. The results of the resistivity are confirmed by the augerings. A good evaluation of the preservation quality of the Roman road could be made with the geophysical measurements in combination with the augerings.

Archaeological excavation

The data gathered was used to plan the amount of soil that had to be brought onto the site and the depth and size of the water basins and road, so as to disturb as little archaeology as possible, a process known as "Archaeology-friendly building". Only the deepest parts of the new sewers in the middle of the road would cut into the archaeological level. So for these parts, archaeological excavation trenches were made. The trench proved the Roman road to be badly disturbed at the eastern end, as expected. By the side of the Roman road some structures were found at the same depth as the Roman road. A concentration of cremation burials was found as well as a path with tracks of carts. One zone had a burned layer, probably from agricultural activities. Details analyses of these finds are on its way.

These finds by the side of the Roman road prove that the road is not a singular structure in the field. A wide variety of human activities can be found by the side of the road. So although the excavation was minimal, thanks to the geophysical surveys in combination with the other knowledge of the site, a good reconstruction of the Roman road and the human structures could be made. But thanks to the process of "Archaeology-friendly building", most archaeology of the Roman road is still preserved *in situ*.



Conclusion

This project combined a desktop study with geophysical measurements and augerings to get a good evaluation of the archaeology in the studied area prior to any intrusion in the soil. This information was used to plan the construction work so to create as little disturbance of the archaeology as possible. The small amount of archaeology that had to be disturbed was excavated, creating some new information concerning the Roman road and the human structures that can be found by the side of a Roman road, and yet preserving most archaeology *in situ*.

This project has been labelled by the Dutch Archaeological Authorities as one of the top 14 best archaeological prospection surveys in The Netherlands. It is now used as a “Best Practice” example.

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ALL ROADS LEAD TO *TIBISCUM* – PRELIMINARY RESULTS OF A POLISH LANDSCAPE SURVEY PROJECT ON A ROMAN FORT IN ROMANIA

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The Roman fort *Tibiscum* was a very important spot on the map of the ancient World. Its setting was very significant from a geopolitical point of view – *Tibiscum* was placed on the crossroads of two important imperial roads (see: Benea, Bona 1994). In October 2014 the project of non-destructive archaeological research on Roman fort *Tibiscum* was initiated by Michał Pisz B. A. from the University of Warsaw (UW). The main aim of the project was the recognition of the landscape of the fort and the evaluation of the effectiveness of non-destructive methods for the recognition of the patterning of *Tibiscum* and its neighbourhood. The project was funded by the Polish Ministry of Science and Higher Education and performed in collaboration with the West University of Timişoara (UVT) and the Museum of Caransebeş (MC).

Starting from a scratch

Although the fort itself has been the subject to research since the early XX^th^ century (Ardeţ, Ardeţ 2015), its surroundings were mostly overlooked in the investigations. Regarding the customary methodology, the plan of the survey assumed the use of methods from the most extensive to the most intensive ones. Hence the first task was large-scale extensive field walking survey, undertaken in March 2015. The field walking survey was based on the previous experience of the principal investigator from Poland (AZP programme) and abroad (surveys in Hungary and Bulgaria). However the methodology of the survey was enhanced with modern technologies, e.g. the use of handheld GPS devices and a GIS database (Fig. 1). For presentation and interpretation purposes a few orthophoto maps have been created with the use of a drone. The results of the field walking survey were the basis for planning the next steps of the investigations, since a lot of previously unknown sites and objects have been found.

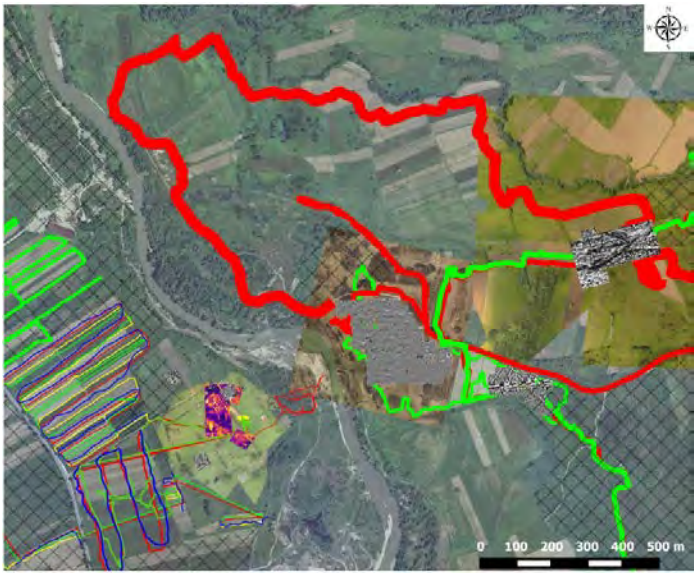

Fig. 1: The field walking survey results – GPS tracks overlayed on the satellite and drone pictures, together with geophysics and aerial thermography results (2015).

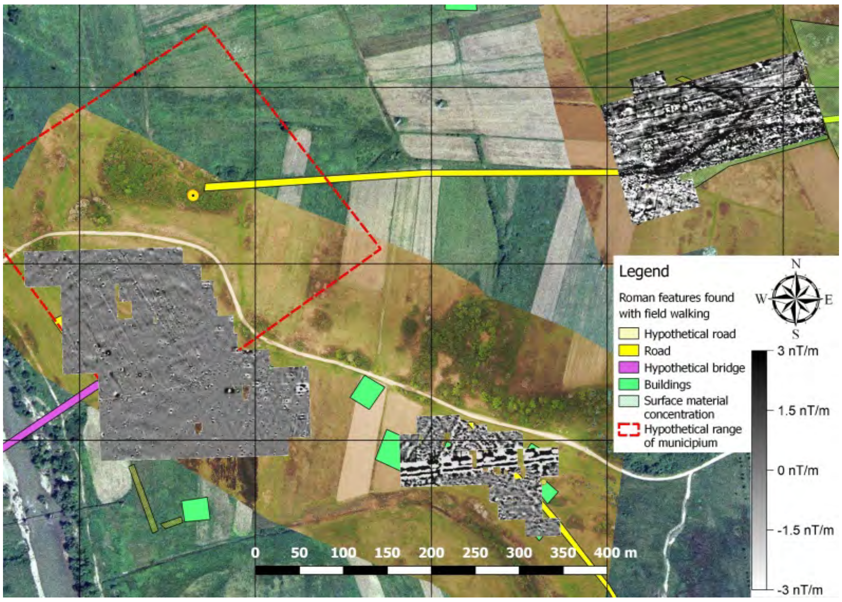

Fig. 2: The field walking survey interpretation and results of magnetic survey from 2015.

A top-down approach

Since almost every non-excavated area was a mystery in *Tibiscum*, the next task after field walking, according to the adopted methodology was a magnetic survey. In April 2015 a total area of *ca* 10 hectares was surveyed with a Bartington Grad 601-2 instrument. Based on the results of field walking, three survey areas were selected to be investigated. The survey results shed a new light on the topography of *Tibiscum* and its closest surroundings. Probably the most interesting results were obtained on an area found in March 2015 (Fig. 2 - Nº 3) – a surface larger than 8 hectares, very rich in archaeological remains (pottery shards, stones, bricks and tiles – all from the Roman age). However only a small part of this whole area was accessible, therefore the magnetic survey area in this part could not be bigger than 3 hectares.

The two remaining areas were very interesting as well and brought a lot of important and surprising results in the context of landscape studies (Fig. 2). The area Nº 1, where presumably the main part of the *municipium* was, brought a set of faint magnetic anomalies, that could be related to activity of the Timiş river. The river is responsible for destroying the southern part of the fort probably at some point in early modern times. The results of the magnetic survey may suggest that it also had a great destructive impact on the eastern bank and therefore preservation of the remains of *municipium*.

A subsequent task, planned for spring 2016 was complementing these results with another geophysical method – earth resistance. The survey was carried out with the Geoscan Research RM85 resistance meter, and the measurements included the area of the *vicus*[1] (directly north beyond the wall of the fort), the western outskirts of the fort, and area Nº 3, in order to acquire additional data about the recently discovered features. The measurements brought very good results, giving additional information about the discovered features and producing a clear image of the remains below the surface.

Thanks to the cooperation between the UW and the UVT, the survey was extended with previously unplanned methods – caesium magnetometry (made with Geometrics G858 magnetometer), earth resistance tomography (GeoTomMK8E1000, both

[1] For the designation of the *vicus* in *Tibiscum* see Benea 1991, 1993

performed by Alexandru Hegyi from UVT) and GPR (GSSI SIR with 270 MHz antenna, performed by David Pall from Geofizika Szeged). The Spring 2016 magnetic survey included the area of the *vicus* and western outskirts of the fort, and some complementary measurements in area Nº 3.

Detailed studies

One of the most promising anomalies was detected in the *vicus*, inside the archaeological reservation of *Tibiscum* (Fig. 3). A very regular, square-shaped, high-resistance anomaly was revealed by the ER measurements, however no specific correlation could be seen on the magnetic map – it was set in a zone of numerous positive magnetic anomalies.

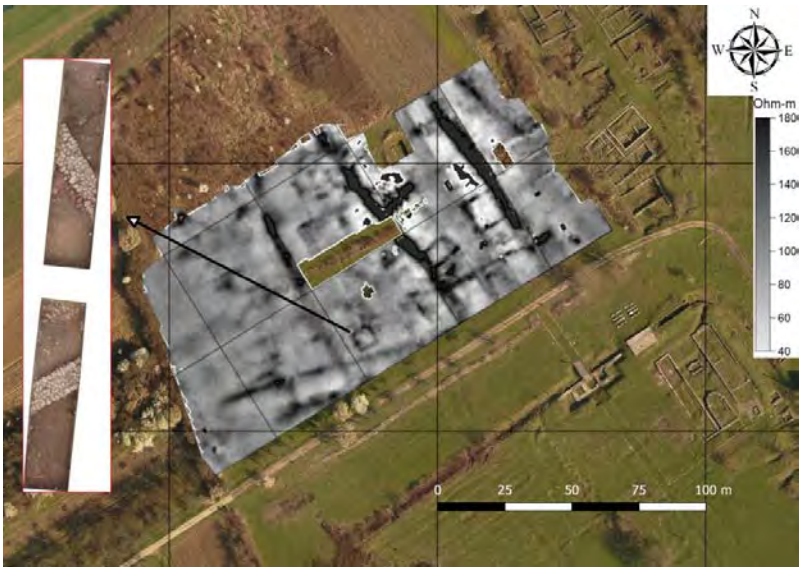

Fig. 3: The results of the ER from vicus and the orthophoto of the test pit, 2016.

The most interesting part of the *vicus* was selected to be surveyed with the GPR in two 40 x 40 m grids in order to bring some more information about the "square anomaly" and its surroundings.

The last step of non-destructive investigation was the ERT measurements. They were performed in two different areas – the square anomaly in the *vicus* (12.5 x 12.5 m, 0.5 m electrode spacing, Fig. 4) and in area Nº 3 (50 x 50 m). The ERT measurements confirmed the previous results and brought some information about the possible thickness of the detected object.

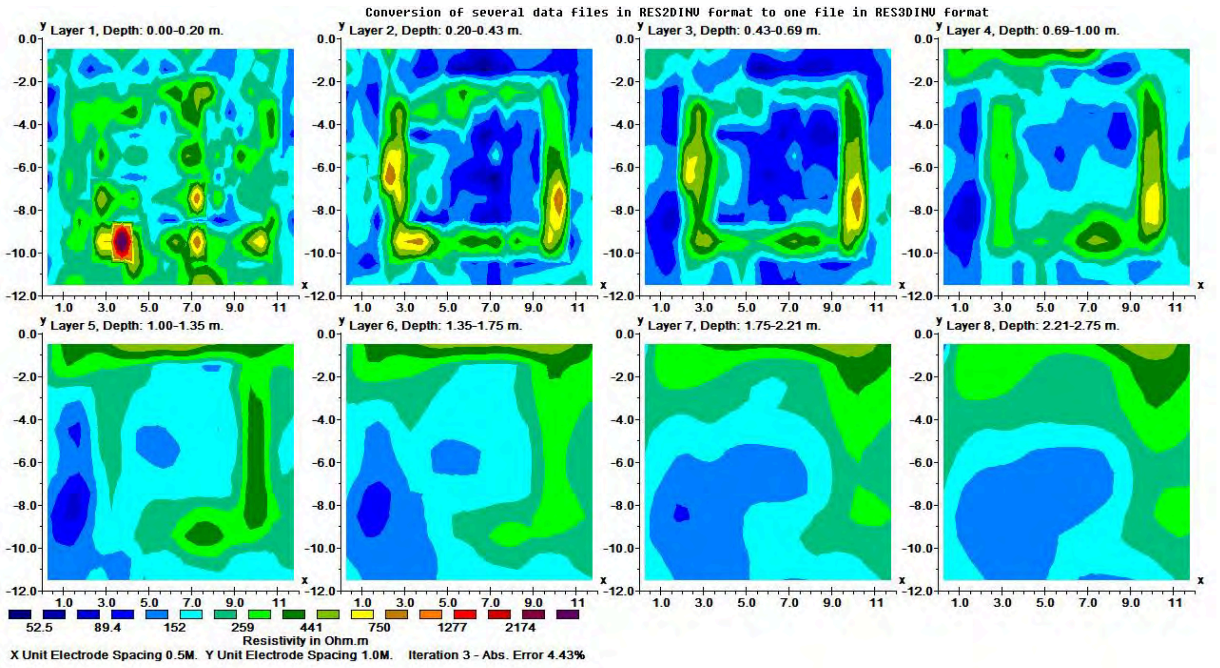

Fig. 4: The results of ERT measurements on the "square structure" in vicus.

The project was concluded with the exploration of the test pit, performed together with the partners from MC. The object selected for verification was the square anomaly, as it was considered to be the best surveyed one, and the excavations could bring a lot of information for further interpretations of all the geophysical results. Two trenches measuring 5 x 1 meter were opened, and the remains of stone structures made of pebble were found approximately 20 cm below the ground surface. The interesting results of the excavations and rare finds, including a silver coin, a paved floor, elements of jewellery, and parts of glass pots, encouraged the Romanian archaeologists to continue the excavations in 2017 when the unearthing of the whole structure is planned.

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THE GREAT DORSET THROW DOWN: THE INFRA-SITE LANDSCAPE OF A VERWOOD COUNTRY POTTERY

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Archaeological investigations comprising a topographic survey and geophysical survey, by gradiometer with subsequent targeted earth resistance, was undertaken at one of two 'Verwood' pottery production sites located within the village of Horton, Dorset (Fig.1). 'Verwood' pottery is a form of earthenware that is known to be produced from at least the 17th century on into the mid-20th century. Production centred around several settlements, before the last of the production centres, which were situated in and around Verwood, Dorset, closed in the mid-20th century. Documentary evidence suggests the origins of the industry lie within the late medieval period, possibly emanating from the Alderholt region to the northeast of Horton (Algar et al., 1987). However, currently no physical evidence for medieval production is known.

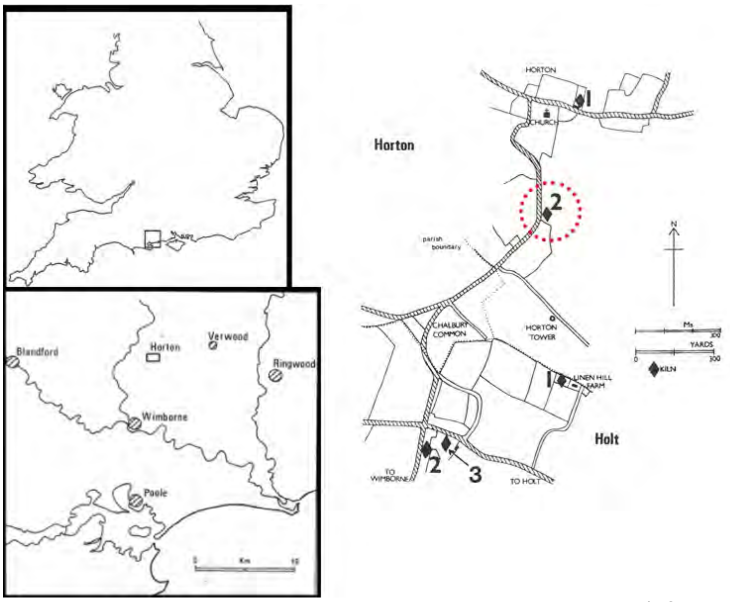

Fig.1: Location plan showing both Horton kiln 1 and 2 (after Algar et al., 1987).

Currently the site at Horton lies under pasture, and is located immediately to the south of the village of Horton, situated on a geological boundary between the Reading and London clay beds. The site lies at the base of a steep north facing slope, where the gradient becomes more gradual changing from 43m above ordnance datum (AOD) in the south, to 40m AOD to the north.
The presence of this site was highlighted by the now defunct Verwood and District Potteries Trust (VDPT) via the examination of historical documentation (Horton Kiln 2 in Algar et al., 1987). This suggested the presence of a brick kiln dating from at least 1596, operated by the Frost family, and a pottery kiln dating from 1701 or earlier. The site at Horton currently forms some of the earliest physical evidence for pottery production within the post-medieval 'Verwood' industry. The brick kiln was revealed during removal of a small area of woodland in 1976; this was listed as 'Brickplace copse' in the tithe map for the area (dated 1844). The discovered brick kiln was then cleaned and photographed by the VDPT, however its discovery was never published and its location was subsequently lost. The pottery kiln was partially visible on the

ground surface at the time of the investigation as a topographic anomaly, and is visible as a ‘mound’ on an estate map dating from 1770 when the site had clearly gone out of use.

The purpose of the study was to examine the layout and survival of associated buildings, including dwellings, drying sheds, and workshops that accompany a pottery. Within the East Dorset or ‘Verwood’ industry, as with most rural pottery industries, these are rather under represented, as the focus of similar investigations has largely focussed on examining the kilns and products of these industries. Few standing examples remain from the Verwood Industry, but those that do show that the associated buildings can range vastly in size and nature, largely dependent on their proposed use. In addition, the building materials that comprise them differ greatly, commonly ranging from brick to cob – the latter a prolific local construction method comprising a mixture of chalk and clay walling. Due to the possibility that the site at Horton had not been developed, and had likely been left as a pasture field since closure, the site was selected as having a high potential for both the study of the pottery kiln itself and its associated buildings. Initially a topographic survey was undertaken to map any topographic anomalies present, such as the kiln mound. Following this, a blanket geophysical survey via gradiometer (Fig. 2) was undertaken to ascertain the nature of any topographic anomalies and additionally to locate the lost brick kiln. This proved successful, highlighting not only the aforementioned features but revealing the presence of what may be an additional, and previously unknown, brick kiln and potential smaller kiln or oven as well as identifying an area of associated building. The locations of these anomalies were subjected to a targeted earth resistance survey (Fig. 3). This yielded further detail and provided an unexpected insight into the nature of the pottery kiln itself. As previously mentioned there are two known pottery production sites in Horton, the first of these was excavated in 1990 (Copland-Griffiths and Butterworth, 1990), and examined a single flue updraft kiln, which had subsequently been altered to include a second flue, with a central division or plinth. This arrangement of the kiln differs somewhat from those seen elsewhere within the industry, where an absence of any central division or plinth is thought to be the norm for post medieval East Dorset kilns. Sadly, however, few examples have been excavated, and of those examined even

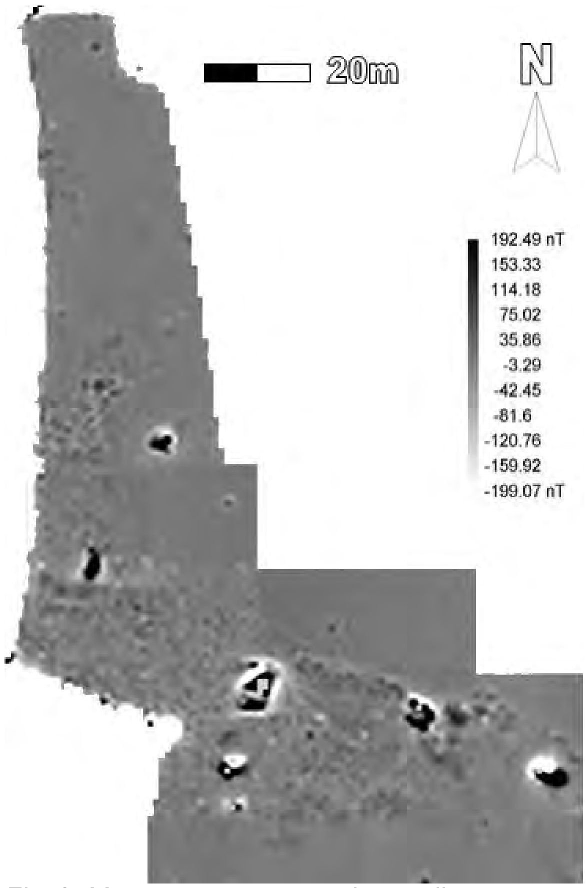

Fig. 2: Magnetometry survey by gradiometer on Horton Kiln 2. Undertaken with Geoscan FM36. Sampling interval 1m x 1m, collected in 20 x 20m grids.

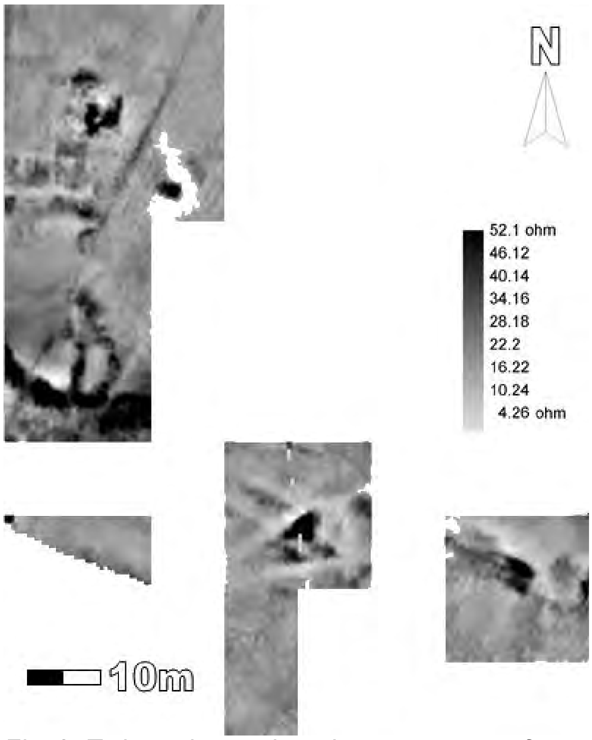

Fig. 3: Twin probe earth resistance survey of Horton Kiln 2. Undertaken using a Geoscan RM15 0.5m mobile probe separation. Data collected at a 0.5m x 0.5m sampling interval in 10 x 10m grids.

less have been published. The earth resistance survey undertaken at the second Horton site suggested the presence of a central division within the kiln.

As a whole, the study of the landscape at the Horton site has shown that the potential location for a pottery production site can be narrowed down, to a certain extent, using historical documentation. Where this exists, and dependent on the detail outlined within, this may shed some light onto a potential date of operation without the need for further archaeological intervention. However, historical documentation is often of a limited nature and can only take a study so far; this site has illustrated that a suite of various geophysical methods can provide further information, and elucidate the nature of a site, ranging from the general site layout to the arrangement of the kiln itself. At Horton, the geophysical survey results were detailed enough to allow for the identification of a central division or plinth within the kiln, which has potentially highlighted a variation within the industry that is specific to this area.

These results are being used to inform a larger study of the transition between medieval and post-medieval pottery industries in the Verwood area.

Acknowledgments
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IN SEARCH OF THE LOWER CITY OF QALAT-IDINKA: MAGNETOMETER PROSPECTION OF NEO-ASSYRIAN SITES IN THE PESHDAR PLAIN, IRAQI-KURDISTAN

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The Peshdar Plain in the Neo-Assyrian period: the Border March of the Palace Herald

Our joint research project[1] in the north-western of Iraqi-Kurdistan sheds new light on a hitherto little known frontier region of the Assyrian Empire in the east, specifically the Border March of the Palace Herald at the border to the kingdoms of Mannea and Ḫubuškia. Gird-i Bazar is the first unequivocally Neo-Assyrian site to be excavated in the region. The occupation layers beginning to be uncovered there offer the rare opportunity, firstly, to explore a decidedly non-elite settlement of the Neo-Assyrian period, secondly, to further our understanding of how the Assyrian Empire organized its frontier zone and, thirdly, to synchronize the Western Iranian pottery cultures (with the key sites Hasanlu, Godin Tepe,Nush-i Jan and Baba Jan) with the Assyrian ceramic material of the 8th and 7th centuries BC. Karen Radner analyzed the textual sources available for the Peshdar Plain in the Neo-Assyrian period, which was found on the site in 2013 and which indicate that as part of the Border March of the Palace Herald it was situated directly at the Assyrian Empire’s frontier with Mannea and Ḫubuškia (fig.1).

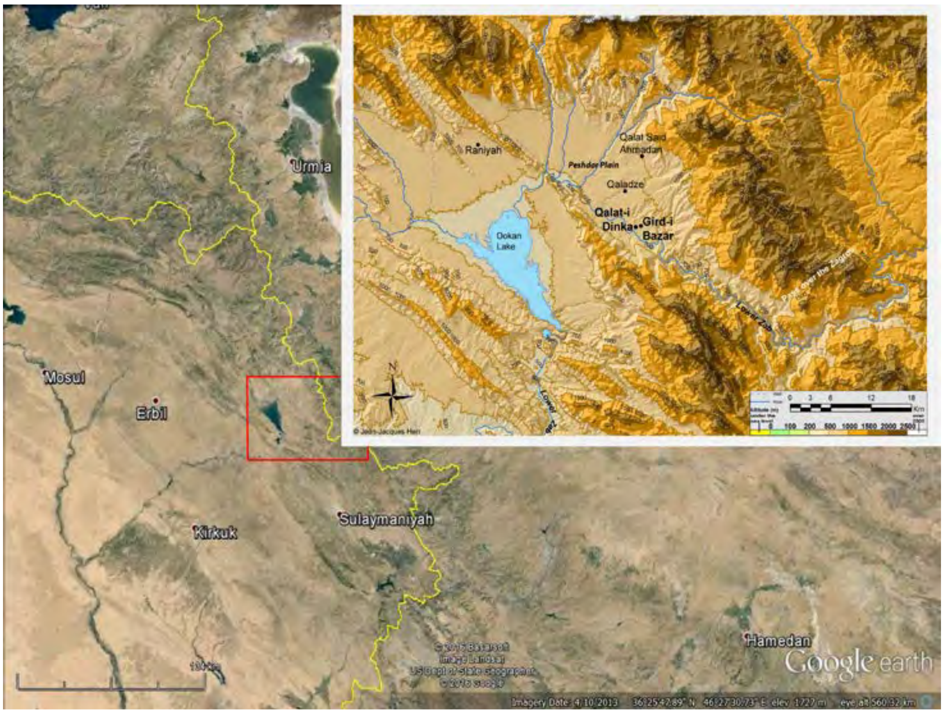

Fig.1: Location of the Peshdar Plain and its key sites (after Andrea Squiteri & Jean-Jacques Herr [1]).

The geo-archaeological survey of Mark Altaweel and Anke Marsh provide a geo-archaeological assessment based on a large survey conducted in August 2015 by Jessica Giraud [2,3]. Both studies strongly suggest that Gird-i Bazar and Qalat-i Dinka were part of one extended Neo-Assyrian settlement that we call the “Dinka settlement complex”. Based on these studies Jörg Fassbinder and Andrei Ašandulesei undertook in 2015 and 2016 the first large scale but high-resolution caesium-magnetometer surveys on selected sites of the Peshdar Plain[4,5].

Results of the magnetometer prospecting

First test measurement with magnetometer were already undertaken in August 2015 on the western slope and on the eastern Plateau of the fortification the Qalat-i Dinka[4]. The assumed small settlement area on a small tell Gird-i Bazar which was already partly destroyed by the construction of a chicken farm and enclosed by a metal fence with an area of only 60x20m, seemed at the first sight not very suitable for magnetometer survey, but never the less revealed a detailed ground plan of a settlement.

The geological background on the slope of the Qalat but also of the whole area is dominated by a para-brown-earth developed on gravels and alluvium of the valley. The survey conditions are manifold, while parts of the area were harvested, others where roughly ploughed ore simply not accessible due to high vegetation with thistles. Parts of the total survey area (in total ca. 1 square km) consists of uneven terrain steep slopes walls or ditches. Therefore we chose a handheld total field caesium-magnetometer for our survey. First tests were made on areas where the ploughing was done already in the previous year. These areas were almost undisturbed and flat so that we could expect the best conditions and almost no disturbances in the topsoil.

Results of the Qalat-i Dinka (western slope)

Qalat-i Dinka is dominating the Peshdar Plain and the lower Zab River. The survey area which was chosen is situated on the south western slope of the mound and enclosed an area of 120x120 m. The survey area is limited by the steep slope to the Zab River and enclosed by a modern field border and fence. In August 2015 the ground of our survey area was harvested but not ploughed and hence only little

Fig. 2: Qalat-i Dinka. Magnetometer measurement of the survey area (ca. 120 × 120 m), on the slope of the fortification. Caesium total field magnetometer Scintrex, SMG-4 special in duo-sensor variometer configuration, total Earth’s magnetic field at the Peshdar Plain 08/2015, 47.500 ±20 Nanotesla, sensitivity ± 10 Picotesla, sampling density 25 × 50 cm, interpolated to 25 × 25 cm, dynamics in 256 grey scales, 40 m grid, high-pass filter overlay.

disturbed by plough furrows. The strong magnetic enhancement of the topsoil and archaeological soils compared to the weak magnetic susceptibility of the bedrock but some strongly magnetized gravels obscure the detection archaeological structures beneath the ground. The resulting picture (fig. 2) is dominated by the archaeological activity and only a few features become clearly visible. These features are concentrated to the upper part of the slope, while in the lower part they were clearly enclosed by the remains of the foundations of a wall. Outside of the limitations we detected only little activity. The magnetometer survey of the eastern plateau of the Qalat revealed a dense activity and many archaeological features. Among these: some foundations, pits and very probably some fortification installations.

Results of the Dinka settlement complex
The starting point for the survey in the plain was the former tell site which was already half occupied by the modern farm house and the chicken farm. On an area of 60 x 20 m we found in 2015 the ground plan of a dense settlement. The adjacent field was not accessible for magnetometer prospection in 2015 but in September 2016 it was harvested and the measurements could therefore be extended by an area of ca. 400 × 400 metres. The magnetometer data revealed structures that were more clear and distinct than was expected from such an area. The magnetogram image revealed very precisely the foundations of a large settlement and as it seems at the moment, very probably an urban district of a large city. Buildings are divided by small streets and the orientation of the complex tends towards the fortification of the Qalat.

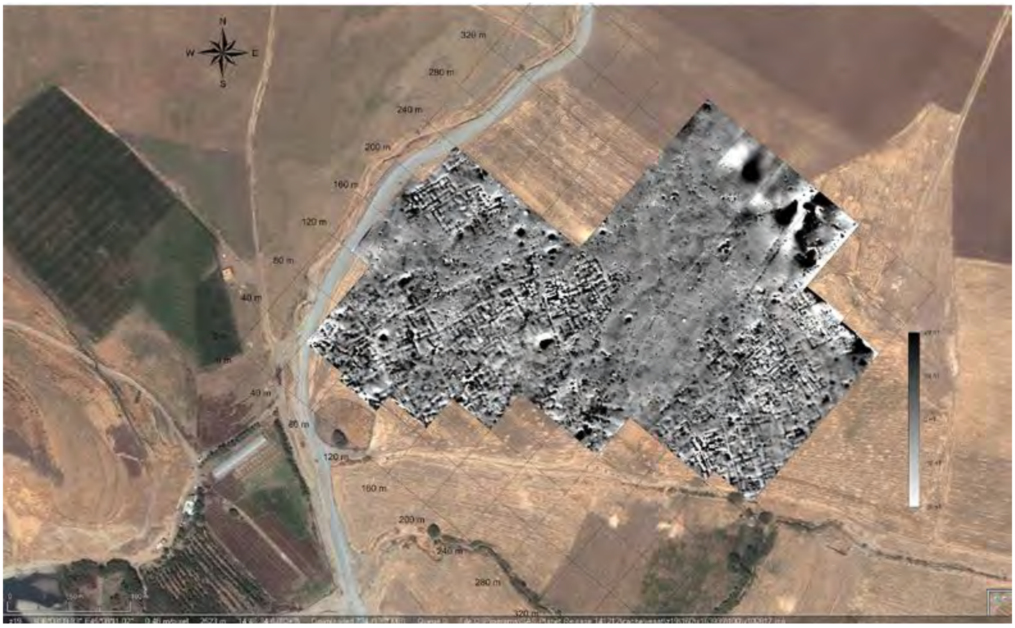

Fig. 3: Dinka plane. Magnetometer measurement of the survey area (ca. 400 × 400 m), adjacent to tell Gird-i Bazar and Gird-i Dinka. Caesium total field magnetometer Scintrex, SMG-4 special in duo-sensor variometer configuration, total Earth's magnetic field at the Peshdar Plain 09/2016, was 47.600 ±30 Nanotesla, sensitivity ± 10 Picotesla, sampling density 25 × 50 cm, interpolated to 25 × 25 cm, dynamics in 256 grey scales, 10x10 high-pass filter, 40 m grid.

Summary

The geophysical results shown above reveal not only several archaeological features but an overall clear ground map of urban district of a city, including living buildings workshops and production sites. The palace and most of the administrative buildings were probably close or at the slope of the Qalat-I Dinka and or will be hopefully detected in the next prospecting campaigns. The shapes, architecture and the layout of buildings which we detected from the Neo-Assyrian period, however, will give the basic information which is probably the groundwork for specific architecture studies, but which has for the moment no parallels in the literature.

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RECENT RESULTS FROM VERULAMIUM

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Introduction

Two years ago at this conference I presented some initial survey results from the *Sensing the Iron Age and Roman Past* project including a survey of that part of the Roman town of Verulamium which now lies under the modern park. That survey is to be published in *Archaeological Prospection* (Lockyear and Shlasko 2016). Since then, the *Community Archaeology Geophysics Group* (CAGG) have undertaken two seasons of survey on the northern side of Verulamium which lies within the Gorhambury Estate. The group have completed a further 35ha of magnetometry survey using the Foerster Ferex system purchased for the group by the AHRC and UCL. In addition, SEAHA have allowed us to use their Mala GPR system and we have completed 8.5ha of GPR survey over the two seasons. This year we were also able to use UCL's RM85 resistance meter and completed 2.5ha of resistance survey (Figure 1).

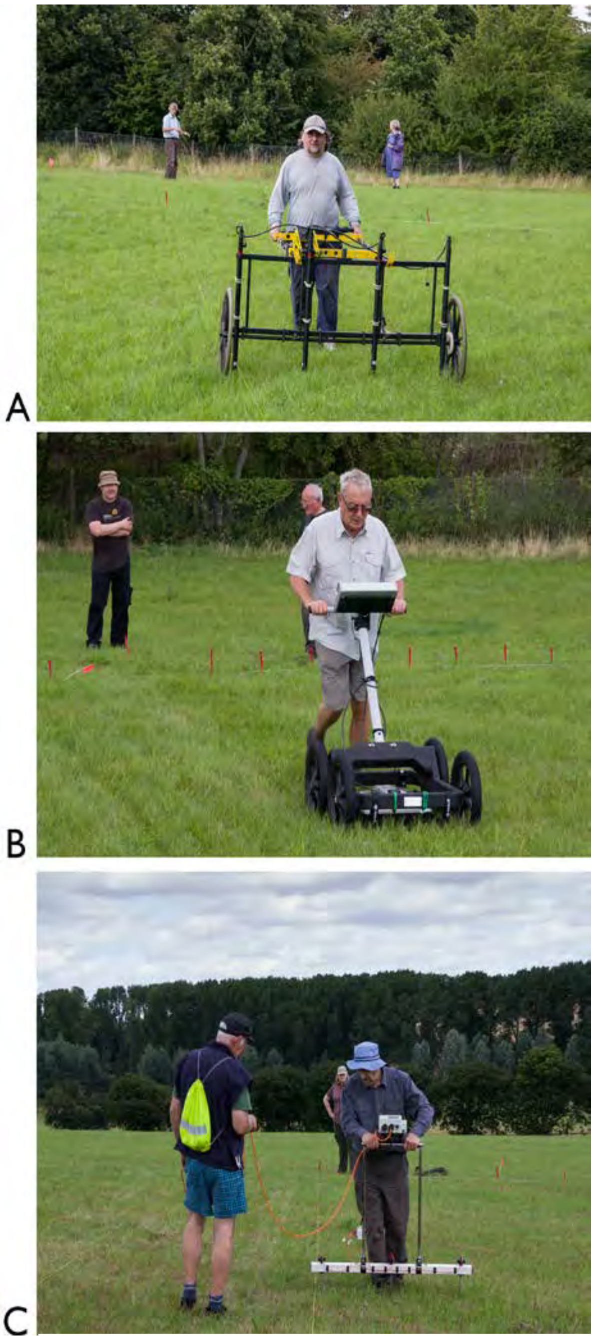

Fig 1: (a) the Foerster Ferex, (b) the Mala GPR and (c) the RM85 in use at Gorhambury by members of CAGG.

The Magnetometry Survey

The survey was undertaken using a Foerster Ferex cart-based system collecting data in transects spaced 50cm apart with 10cm between readings (Fig 1A). The survey was conducted on a 40m grid laid-out using a dGPS. We have now completed the survey of the available area within the town walls of Verulamium. Much less has been excavated on this side of the town, and the majority of what we knew was derived from aerial photography and earlier geophysical surveys.

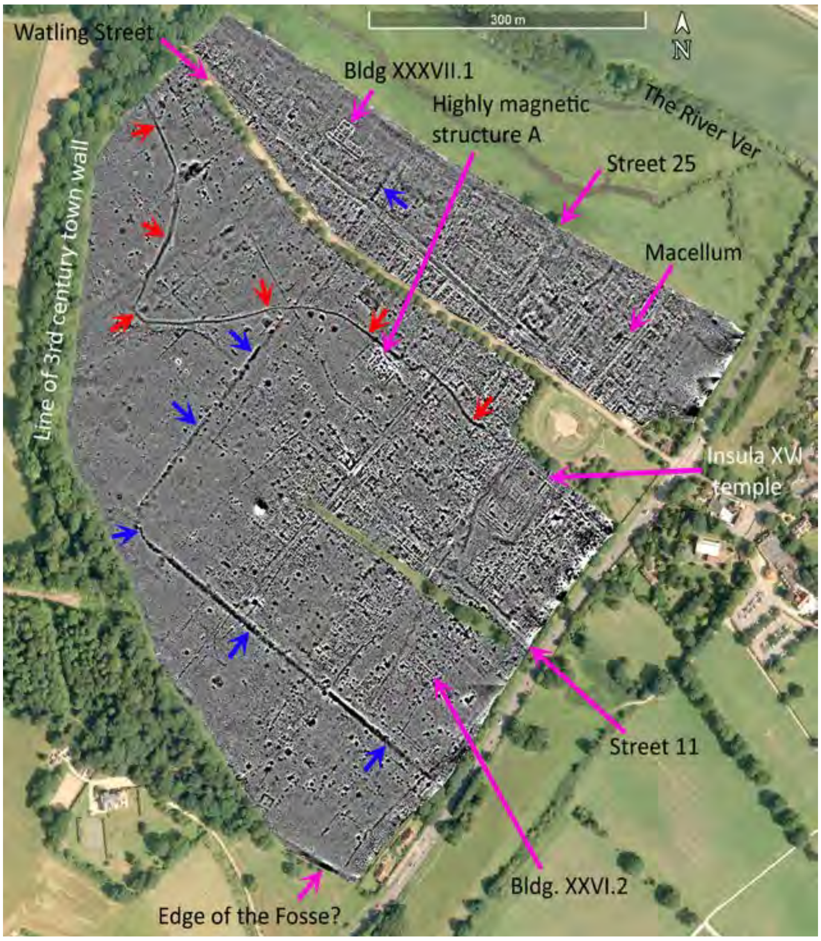

Fig 2: The magnetometry survey of Gorhambury. Image clipped to +/- 7.5nT and black as high readings.

The survey has located a plethora of buildings, mainly within the line of the “1955 ditch”, marked in Figure 2 with blue arrows, which is the late first century boundary of the town. This ditch is the one traced by Martin Aitkin in 1959–60 (Aitkin 1960, 1961). For example, Building XXXVII.1 shows remarkably clearly in the magnetic data (Fig. 3A). (The building and street numbers follow those given by Niblett and Thompson 2005.) Other buildings, such as the Insula XVI temple, show reasonably well despite earlier excavation (Fig. 3B). The macellum, however, has been so extensively excavated over numerous campaigns that, unsurprisingly, it is extremely unclear. Some of the buildings are clearly large town houses of the sort excavated by the Wheelers and Frere, for example Building XXVI.2. There are, however, quite a cluster of smaller buildings along Streets 11 and 25, and especially where those two streets cross (Fig 3D). The line of Watling Street, running NW–SW towards the north of the site, also attracts many buildings. It is only really along the line of that road that there are many structures evident outside the line of the 1955 ditch. In general, the area between the 1955 ditch and the third century town walls is magnetically quite quiet although there are some linear and discrete magnetic anomalies, presumably ditches and pits. There are two areas with remarkably high magnetic responses inconsistent with the common impact of modern ferrous trash (Fig. 2, “highly magnetic structure A, Fig. 3D). These appear to be buildings which have burnt down but not then rebuilt.

The other major linear feature revealed by the survey is indicated by the red arrows in Fig. 2. This feature closely follows the contour line, the major dog-leg to the west being where it crosses a dry valley. This feature is almost certainly the town aqueduct. Outside the wall, Rosalind Niblett has traced a linear feature from aerial photographs which runs up the valley almost to Redbourne which may well be its continuation.

GPR Survey

The GPR survey has mainly been conducted in 40x40m blocks following the magnetometer survey (Fig 1B). Transects at 50cm spacing have been collected using a 450Mhz antenna. Preliminary data processing has been conducted using Jeff Lucius and Larry Conyer's software, with the images created in Surfer. The data will require much more detailed examination in due course.

The GPR survey has concentrated on the area within the 1955 ditch, apart from one block of data collected near the NW (Chester) gate. About two-thirds of the area south of the drive has been completed. The GPR data is very complementary to the magnetic survey data (cf. Figs 3E and F). For example, we are able to differentiate between robbed and unrobbed foundations. Some buildings which show clearly in the GPR data do not show in the magnetic data (e.g. the small apsidal building in Fig. 3C).

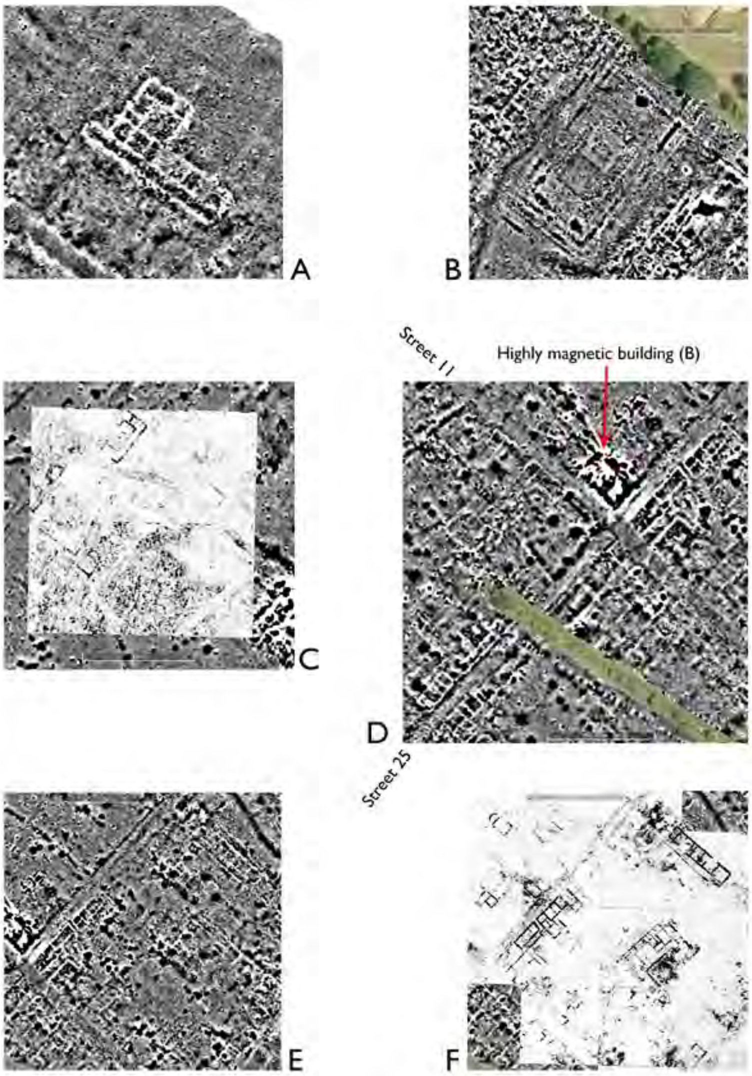

Fig. 3: Extracts from the magnetometry and GPR surveys.

Resistance Survey

This season the group were able to use UCL's RM85 (Fig. 1C). The survey was undertaken at 0.5m transect/reading spacing. Resistance survey has been given the lowest priority by the group at Verulamium partly because of the slow survey speed, and partly because generally, in Hertfordshire, the results are not very enlightening. We also took the opportunity to experiment with using widely spaced remote probes in order to minimise the need for edge matching. As can be seen from Fig. 4, the results were highly successful (cf. Figs 3E and F). We did, towards the end of the survey, have problems with high contact resistance due to the hot weather. The survey covers the western side of Insula XXXI and the Insula XVI temple. The busy complex of buildings at the cross-roads of streets 11 and 25 shows well, as do those to the east of the temple. The large building in the centre is curious as it lies in the middle of the Insula (see also Fig. 3F).

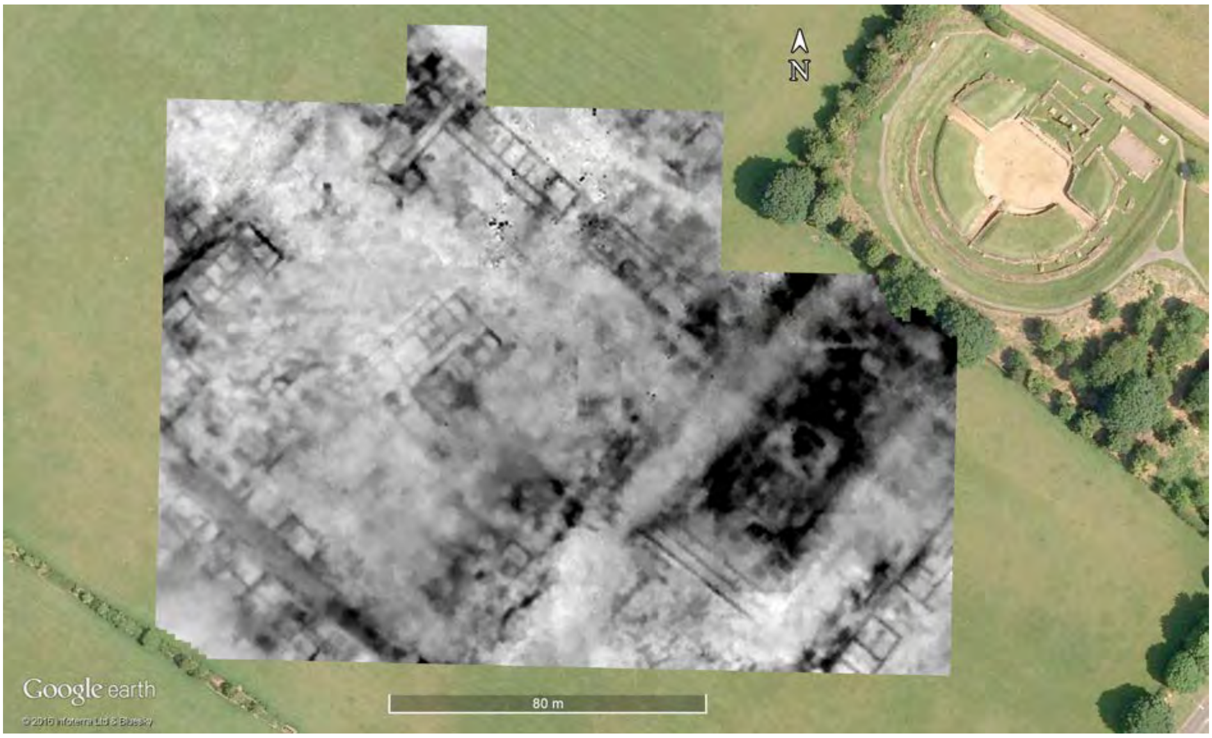

Fig. 4 The resistance survey (black as high resistance).

Conclusions

After two seasons of survey our knowledge of the layout of the western side of the town has increased considerably. The combination of techniques has proved extremely effective. Future seasons will continue the GPR and resistance surveys inside the town walls. We hope to obtain permission to extend the magnetometer survey to areas outside the walls. The work of the group is posted on the project blog <hertsgeosurvey.wordpress.com>.

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GEOPHYSICAL SURVEYING OF THE ANCIENT EGYPTIAN TOWNS: AN OVERVIEW

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Huge progress has been made over the last two decades in research on ancient Egyptian cities, mainly by means of the magnetic method. Town plans have been reconstructed over dozens of hectares, something that could not be achieved by conventional excavation methods. The method is particularly effective in the case of investigations in the valley and delta of the Nile, where the basic building material was sun-dried brick made of Nile mud, a material rich in iron oxides, easily registered using the magnetic method. The first effective application of the method was Helmut Becker's and Joerg Fassbinder's 1996 survey of the Ramesside period capital in Qantir in the Delta. The method then was applied successfully to the survey of other sites in the Delta: the Old Kingdom town in Tell el-Farkha, the Second Intermediate Period and New Kingdom town at Tell el-Dab'a, Late Period towns in Buto, Tell Balamun, Tanis, Sais and Tell Ghaba, Hellenistic-Roman period towns in Kom el-Gir, Kom Dahab, Kom Firin and Pelusium and others. In the Nile valley, surveys were carried out, among others, at the pre-dynastic settlement in el-Amra and the monastic town of Bawit. The method turned out to be effective in surveying sites under cultivation, e.g., Qantir and Tell el-Dab'a, as well as tells (e.g., Buto, Balamun, Tanis).

Surveys carried out in other areas of Egypt, where Nile mud bricks were not used as building material, also turned out to be effective owing to the contrast between architecture built of non-magnetic materials (bricks of local silts, or blocks of limestone, sandstone and gypsum, coral heads) and the surrounding soil characterized by increased values of magnetic susceptibility. The results of prospection in the Hellenistic/Roman period towns in Berenike (Red Sea coast), Plinthine, Marea and Kom Bahig (Mediterranean coast), Ain el-Gazareen and Ain Birbiyeh (Dakhleh Oasis) are good examples.

Precise imaging of the architecture has produced data for identifying and interpreting different parts of the towns (e.g., residential, sacral, industrial, defensive etc.). Under the right circumstances, magnetic surveying can trace subterranean structures with enough precision to date structures on the grounds of characteristics typical of Egyptian architecture of different periods. Surveys of larger areas around towns have supported reconstructions of the paleo-landscape (e.g., recreating canal networks as in Medinat Watfa in Fayum Oasis and Nile branches as in Tell el-Dab'a). Magnetic surveying also seems to be the only method of locating harbors effectively.

Magnetic measurements are taken with two kinds of instruments: fluxgate gradiometers (measuring the vertical component of the magnetic field) and optically pumped (measuring the total value of the magnetic field). A comparison of the results from these two kinds of instruments emphasized the superiority of fluxgate gradiometry in providing more detailed images of the architecture and the higher effectiveness of cesium total field magnetometry in imaging shallow geology, which is in turn highly useful in paleo-landscape studies.

Surveying with the resistivity profiling method has proved effective in examining sites from the Roman period, when fired brick was the basic material in use for building purposes (e.g., Pelusium). The VES (vertical electrical sounding) method also turned out to be effective in paleo-landscape research (e.g., reconstruction of a network of Nile branches and flooded areas in Tell el-Dab'a).

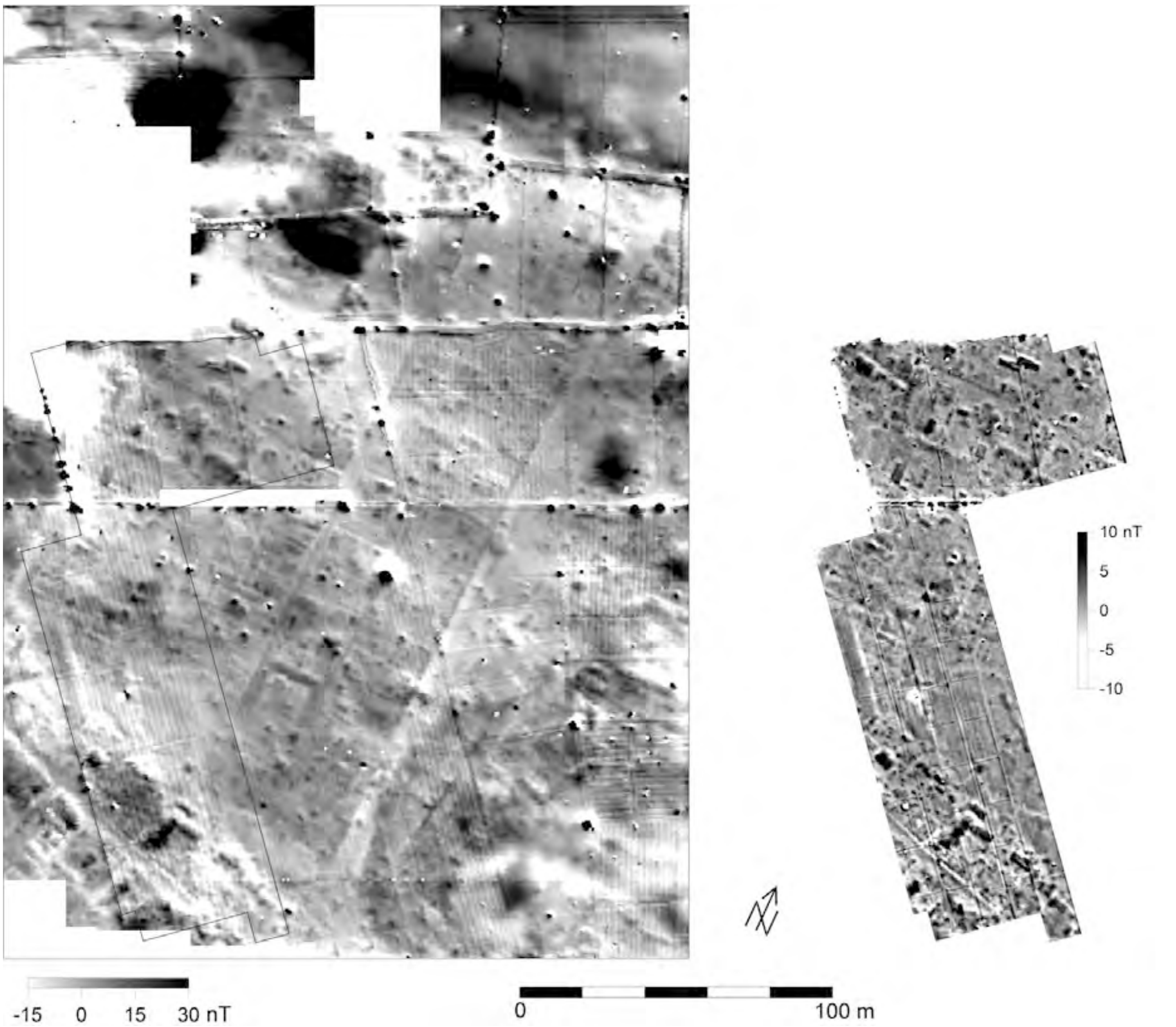

Fig. 1: Tell el-Dab'a. Magnetic maps. Left: measurements of the total value of the magnetic field by a caesium magnetometer (survey by C Schweitzer). Lines mark the area measured by a fluxgate gradiometer. The map shows a regular plan of a town dated to the 1st half of the 1st millennium BC, touching the river from the south. Right: results of the vertical vector of the magnetic field intensity survey.

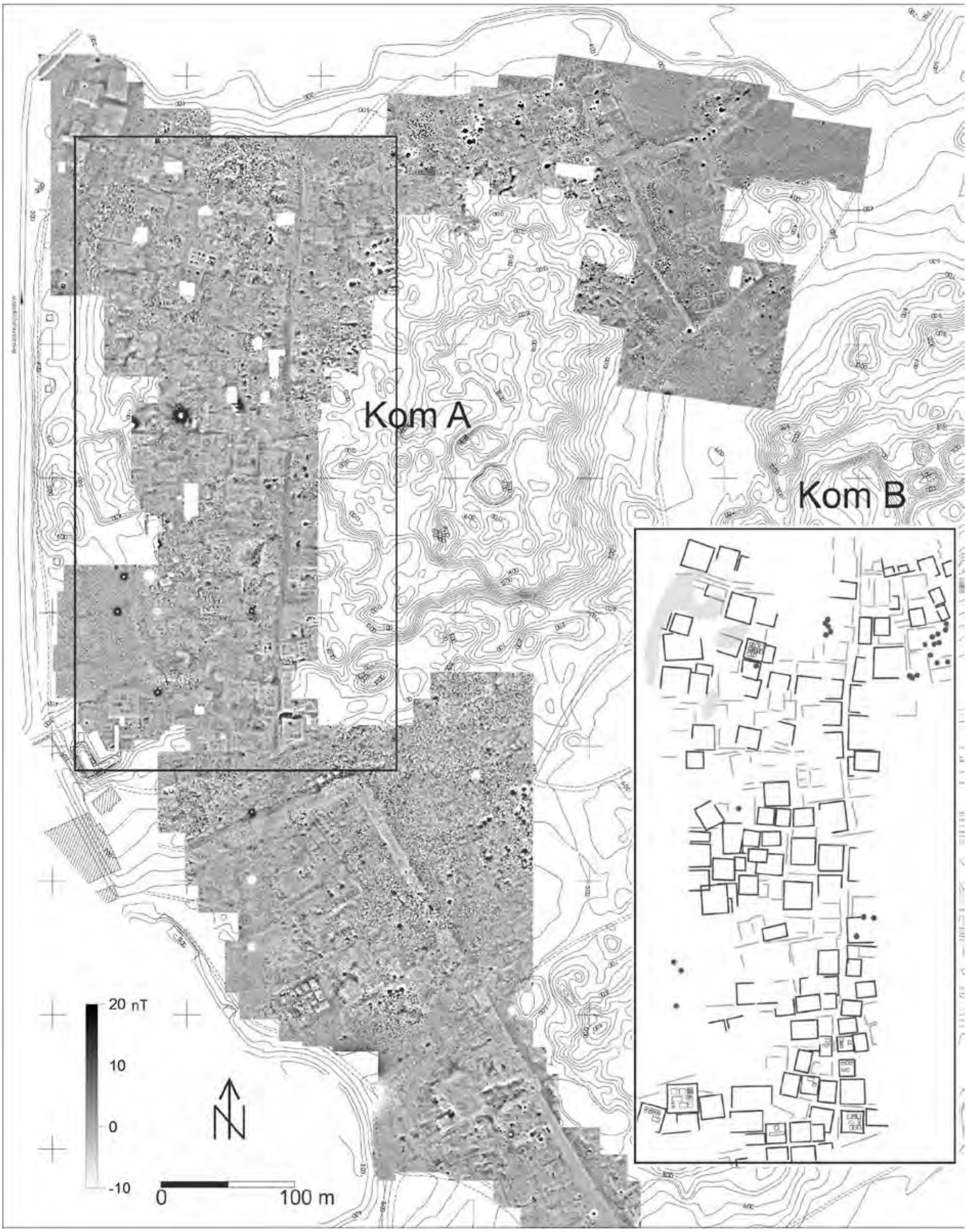

Fig. 2: Buto/Tell el-Farain. Magnetic map. Box on the left marks the part of the map used for the reconstruction of the urban settlement, shown in the box on the right (after Marouard 2010, fig. III-23). Area with anomalies typical for terracotta coffins marked in grey. Black dots correspond to anomalies caused by pottery kilns.

Fig. 3: Berenike. Magnetic map of a Roman town.

The surveys were carried out in cooperation with the Research Centre in Cairo acting on behalf of the Polish Centre of Mediterranean Archaeology of the University of Warsaw, British Museum, Centre d'Etudes Alexandrines, Chicago Oriental Institute, Dakleh Oasis Project, Deutsches Archäologisches Institut, École pratique des hautes études, l'Institut français d'archéologie orientale, Mission française des fouilles de Tanis, Musée du Louvre, Österreichisches Archäologisches Institut, PREDE – CONICET Buenos Aires, Supreme Council of Antiquities of Egypt, Universität Leipzig, Université de Poitiers and others.

For a complete list of the author's publications of his work in Egypt, see:

http://iaepan.vot.pl/en/institute/staff/35-herbich-tomasz#bibliografia

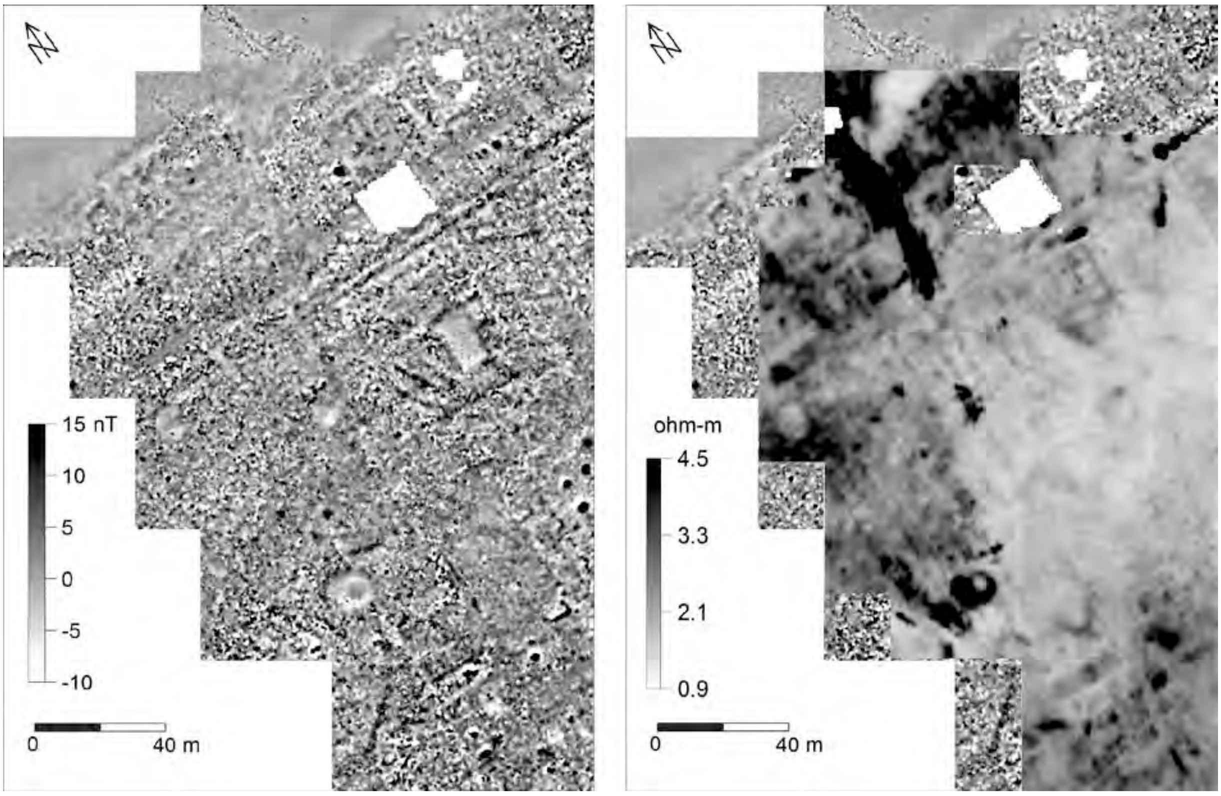

Fig. 4: Pelusium. Left: Magnetic map, right: resistivity map superimposed on the magnetic map.

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EXPERIENCES EXPLORING THE USE OF ARCHAEOLOGICAL PROSPECTION DATA WITHIN PRECISION AGRICULTURE SYSTEMS IN THE UK

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Precision agriculture is an inevitably growing part of the agricultural industry. This is due to the nature of technological development, access to high resolution data and the need to increase production and environmental efficiency. Precision agriculture relies on a wide variety of datasets of varying spatial and temporal resolutions. These also originate from several different sources and are used for many different uses, with the essential underpinning component being soil variation.

In England, 80% of scheduled monuments (those of national importance) lie on agriculturally productive land. A greater number of less important archaeological sites also lie on agricultural land with yet further unknown sites that must be considered. Agriculture is one of the largest threats to this buried heritage so it is essential to connect with and engage agricultural audiences with heritage.

Archaeological prospection, especially geophysics and geochemistry, sits in a unique position between agriculture and archaeology. This research explores some of these connections, with some practical examples, to show how archaeological prospection may be blended with precision agriculture methods to more accurately identify soil variations and their impacts on agriculture.

WHAT ON EARTH IS THIS? NON-ARCHAEOLOGICAL INFORMATION IN LANDSCAPE-SCALE GEOPHYSICAL PROSPECTION DATA

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Today, the use of large-scale, high-resolution motorised archaeological geophysical prospection permits the investigation of enormous areas covering many square-kilometres. Naturally, most of these surveys focus on the detection, mapping and interpretation of archaeological structures. Yet, the amount of discovered archaeological structures can be relatively small compared to the remaining “empty” area in-between, both in terms of actual acreage as well as the size of the data files generated. In some cases, this situation can lead archaeologists, such as paying prospection service customers, heritage agencies and even research funding bodies to question whether the results justify the time, effort and not least the money required for large-scale prospection approaches.

Fig. 1: 3D visualisation of a dune field in Rysensten, Denmark conducted in Voxler 4.

While we are convinced that the results generally justify the endeavour, we would like to stress that high-resolution geophysical prospection data sets do contain more than merely archaeological information. Commonly found types of such non-archaeological structures include palaeoenvironmental features and patterns such as dune systems, former channel systems as well as traces of environmental settings and landscape change throughout time. Even modern anthropogenic structures, for example drainage systems commonly regarded as disturbance, can hold significance and aid in a more comprehensive investigation of archaeological geophysical data.

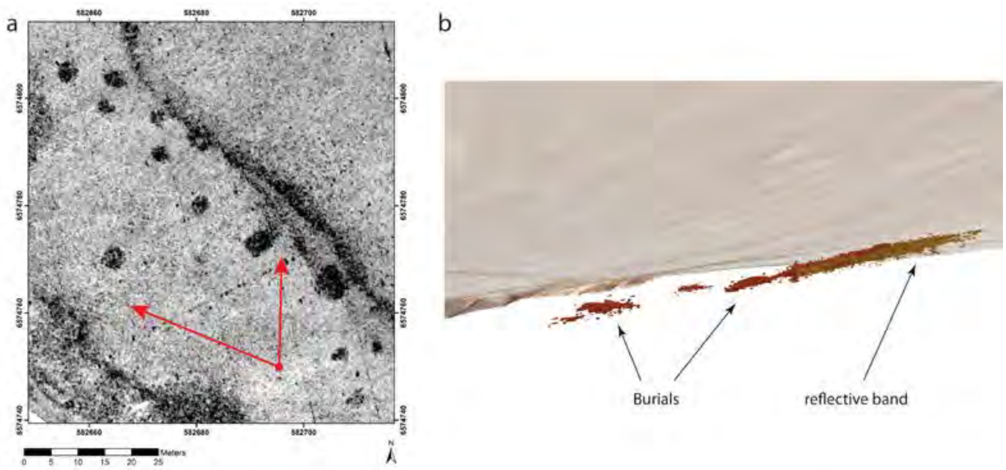

Fig. 2a: GPR depth slice from Båsberg in Norway displaying potential burial mounds next to an unidentified reflective band. 2b Integrated 3D approach to aid in the interpretation.

However, traditional data acquisition, visualisation and interpretation strategies designed for the analysis of archaeological structures are not necessarily suitable for the various types of non-archaeological information. Differences in scale, time range and complexity require an adjusted approach including specific processing steps, 3D visualisation (Fig. 1) and in particular integrated interpretation in a GIS environment (Fig. 2). Besides, the significance of non-archaeological information for the archaeological interpretation of a landscape is often not immediately recognisable and thus necessitates expertise in geophysical prospection, local archaeology as well as geoarchaeology. Ideally, the results of archaeological and non-archaeological information will be incorporated into a virtual landscape reconstruction (Fig. 3).

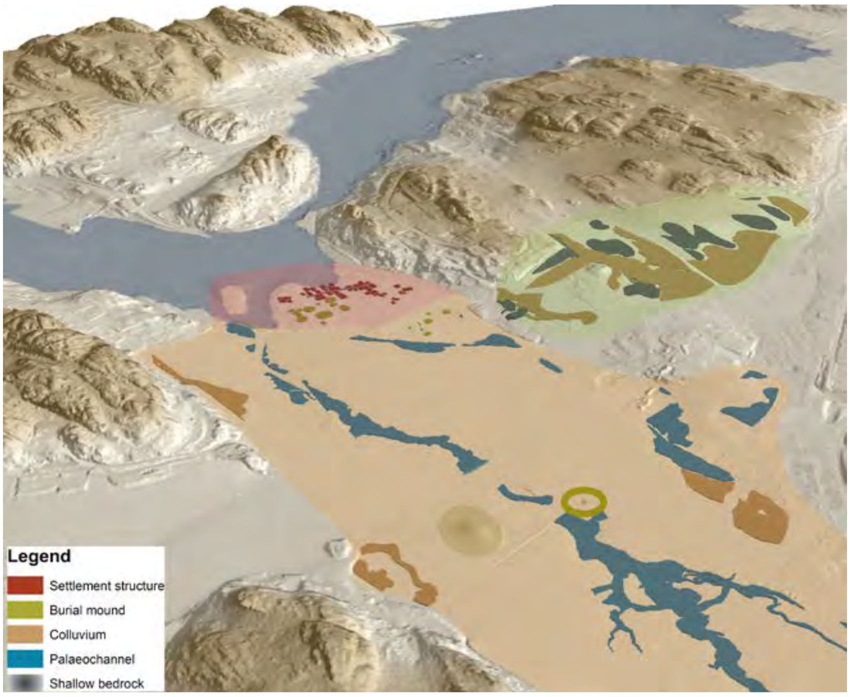

Fig. 3: Virtual landscape reconstruction of Viking Age site Gokstad in Norway using the results of archaeological and non-archaeological interpretation.

In this paper, we will discuss different categories of non-archaeological information contained in large-scale magnetometry and georadar prospection data of various case studies from Norway and Denmark by stressing limitations and illustrating unexpected benefits that can arise from the use of this often disregarded type of data. We will demonstrate how the consideration of non-archaeological information is significant for our understanding of past and present landscapes and why it should be systematically implemented into the landscape archaeological analysis of large-scale studies.

THE ACCESSIBILITY OF GEOPHYSICAL SURVEYS IN ENGLAND, OR HOW EASY (OR NOT) IS IT TO FIND OUT WHERE A SURVEY HAS BEEN CONDUCTED

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For some years (actually decades, now) I have been on a quest to track down all of the geophysical surveys in a given area (in this case, North and East Yorkshire). This paper will present a history of the trials and tribulations I have encountered along the way, and perhaps hint that there might finally be some light at the end of the tunnel.

I will begin by describing the situation which provided the impetus for my obsession, and go on to outline the various methods I adopted over the years in attempts to bring the project to fruition.

Finally, I will present my findings to date, and draw some conclusions about how we could work together to deal with this issue in the future.

THE ENIGMATIC VANISHING OF THE GEOPHYSICIST IN ARCHAEOLOGICAL PROSPECTION AT THE BEGINNING OF THE 3rd MILLENNIUM

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Is the geophysicist a species in danger of extinction within archaeological prospection? During the last decade something interesting has been observed. On one hand, survey equipment like multi-sensor arrays for magnetic prospection and GPR devices have become more and more accessible for both geophysicists and archaeologists. On the other hand, academic archaeological institutes and other institutions have a tendency to invest in hardware rather than in brains. The main and general reason for that is the neoliberal policy of austerity, forced by the governments not only in the southern countries of the European Union. The solution seems simple, instead of creating expensive long-term positions for qualified academics, a one-time investment is placed. The concept is that the apparently simple machinery can easily be operated by precariously paid personnel, i.e. student assistants and interns. But this is a non-voluntary decision, because there is no longer scope for creating and maintaining academic positions.

The question is, how does this policy impact the development of the rather exotic subject of archaeogeophyiscs? Has there already been a swing in the quality of archaeogeophysical works? Does it mean that a skilled geophysicist will not make a living anymore? These questions not only touch on material aspects and changes in ways of gaining knowledge, they concern the identity of archaeogeophysicsts and even of their professional association, the ISAP.

In archaeogeophysics, there are already parallel societies (which is actually nothing to worry about!). Here, at ISAP, there is a more or less sworn community of scholars, entrepreneurs and researchers dedicating a large part of their professional life to archaeogeophysical prospection. But, archaeogeophysics has a second life. Even large and prestigious archaeological research institutions outsource geophysical surveys to semi-skilled and precariously paid freelancers and student workers. The fame of expertise and experience fades. The goals of surveys are downgraded. The most emblematic sentence I have heard in this context, was: We do not need geophysics, we just need the geomagnetic (sic!) image. We will excavate the anomalies anyway.

A big part of these groups and actors do not form part of the network, they do not show up at the academic meetings, their results do not enter the interdisciplinary discourse, resulting in a lack of discussions on quality and methodology. Within these circles, archaeological geophysics closely resembles the process of blackboxing in the sense of Bruno Latours' explanation: *When a machine runs efficiently, when a matter of fact is settled, one need focus only on its inputs and outputs and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the more opaque and obscure they become* (Latour, 1999). The concept of the black box not only applies to the measuring devices, it involves the whole cognitive process from the determination of an archaeological site up to the interpretation of geophysical data. There is a competitive tendency on the most “spectacular” image suitable for medial exploitation. Ways and means do not matter. They are just subsumed under the buzzword “technology”. Critical sense and the discourse of the researchers' community get dissolved (Debord, 1970).

How to face this situation? There is no sense in complaining. The solution is to strengthen the interdisciplinary cooperation. That includes focussing on education of both geophysicists and archaeologists. Archaeological geophysics should be a mandatory subject in archaeological careers, the same applies for geophysicists who are about to enter the field of archaeological prospection. Arrogance and belief in miracles are bad concepts, on the contrary, both skilled archaeologists and geophysicists are actors in the archaeogeophysical network and considerably contribute to the planning and execution of geophysical surveys as well as to a more comprehensive interpretation of geophysical data. On the other hand, all actors have to be conscious that they act at a very challenging interface: they are translating physical data into information on past human activity and on the interaction of human societies and landscape. It is about numbers and physical parameters, and it is about language.

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POSTERS

GEOPHYSICAL PROSPECTION AT CAISTEAL MAC TUATHAL, PERTHSHIRE, SCOTLAND

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Topographic, magnetometry, and ground penetrating radar surveys were conducted at the potential Iron Age hillfort of Caisteal Mac Tuathal in Perthshire, Scotland to determine structural extents within, and propose areas of interest for future studies at, the site. This survey concluded the terrace at the base of the southern slope and the area circumscribed by the visible rampart features and cliff faces to be void of potential archaeological anomalies, and no potential structures or entrances were located along the southwestern rampart. However, radar and magnetic anomalies interpreted as a potential structure or *platform*, and an entrance through the rampart, together with a secondary structure were observed along the northwestern rampart. The details of these potential structures are poorly understood because ground-truthing was not conducted during this study. Regardless, this geophysical exploration of Caisteal Mac Tuathal has improved our understanding of the site and structures therein (Fig. 1), and has engendered further questions regarding the site's connection to the nearby crannogs of Loch Tay (Fig. 2).

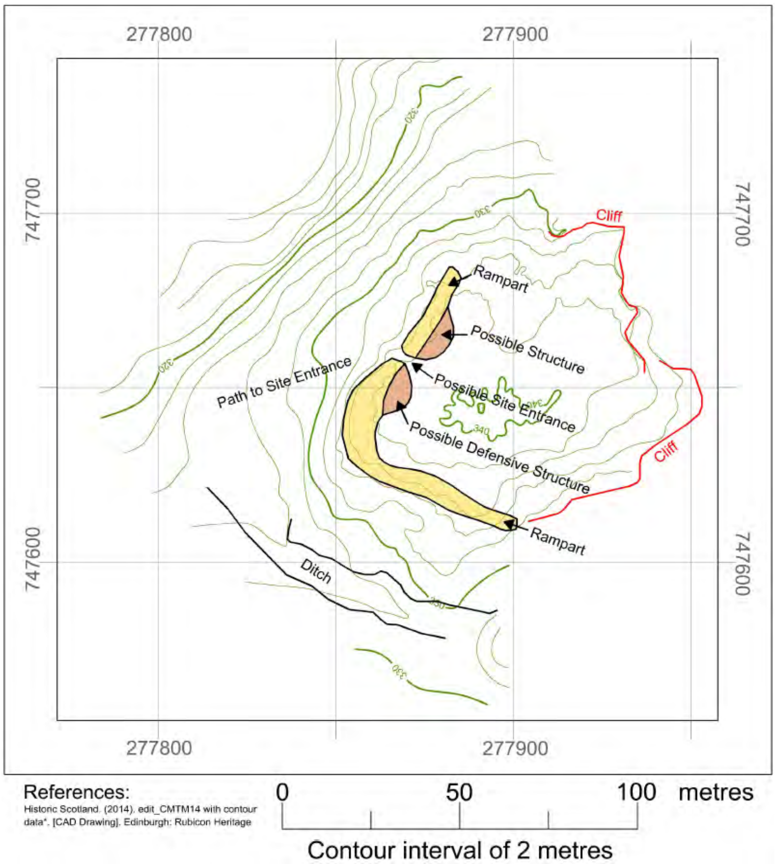

Fig. 1: Map of proposed site features at Caisteal Mac Tuathal.

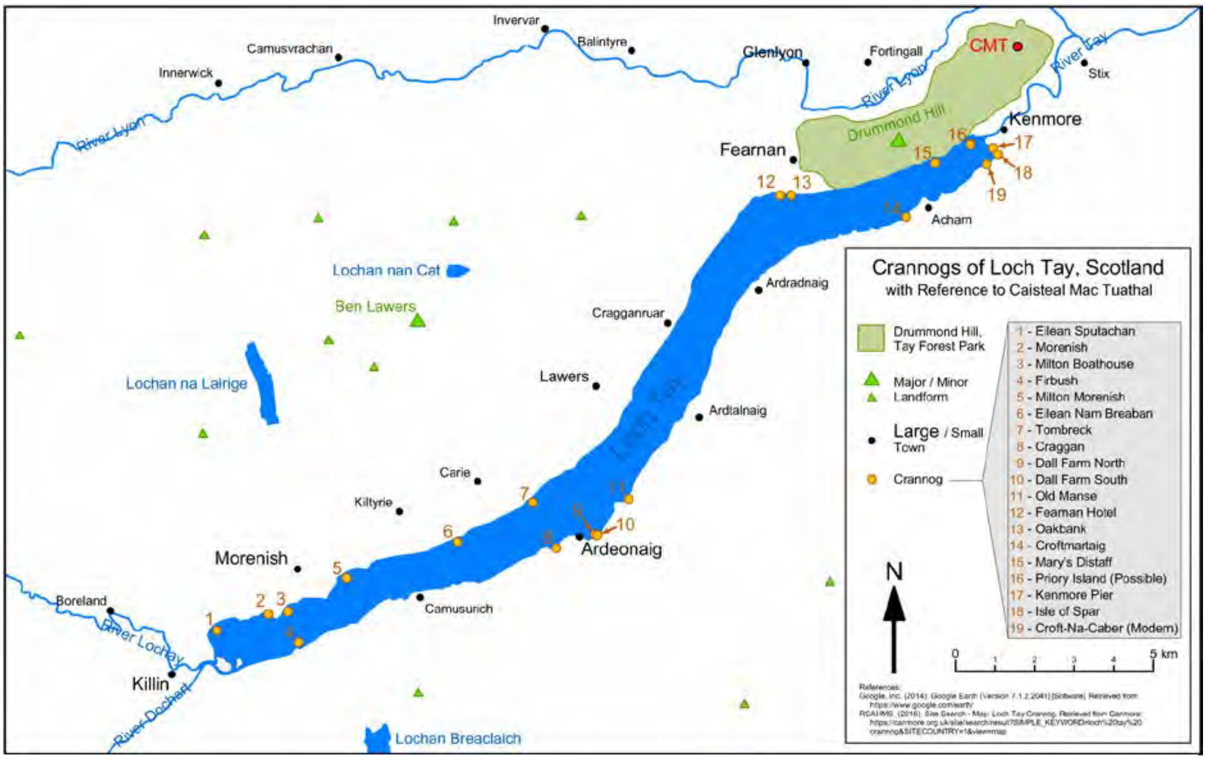

Fig. 2: Caisteal Mac Tuathal (CMT) and the Loch Tay crannogs.

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REIMAGING THE BLACK FRIARY: RECENT APPROACHES TO SEEING BEYOND MODERN ACTIVITIES AT THE DOMINICAN FRIARY, TRIM, CO MEATH

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Archaeological and forensic searches for buried structural and human remains can, in some instances, be hindered by modern rubbish or rubble, often with poor data quality where ferrous objects are present, in clay soils, and/or in waterlogged areas (Ruffell and McKinley 2008). This study was a multi-method geophysical survey (ground-penetrating radar, electromagnetic, and magnetic gradiometry) of unexcavated areas at the Black Friary to delineate areas of anthropogenic activity and refine the standards for ground-penetrating radar survey with the intention of acquiring high resolution data as a method to maximise the potential to positively identify grave-like anomalies.

The Black Friary, a Dominican Friary founded in 1263, was one of several Dominican houses founded after the order arrived in Ireland. After the dissolution of religious orders in the 16th century, the Friary was demolished and quarried. Historic quarrying has produced a thick (*c*. 40-60 cm) rubble layer across most of the site which is overlain by modern dumping. Despite the destruction of the Friary, it continued to hold significance within the community, as evidenced by its continued use as a burial ground throughout the post-medieval period. The Friary is situated in a semi-urban setting outside the northern medieval boundary of Trim town, shown in Figure 1. The surviving ruins of the Friary present as grassy hummocks and exposed stonework.

Fig. 1: Map depicting the location of the Black Friary, Trim, Co Meath. Map data retrieved from ESRI ArcGIS.

Previous surveys have utilized geophysics, topography, and remote sensing. Resistivity, proton magnetometry, and low altitude infrared aerial photography surveys conducted by William Kennedy (1989) identified subsurface features interpreted as foundations of the kitchen, cloister, living quarters, rectory, tower, and chancel. Later topographical, resistivity, and airborne LiDAR surveys confirmed Kennedy's projection of the Friary layout and isolated features possibly indicative of garden structures (see Figure 2; O'Carroll 2014). Recent gradiometry surveys proved inconclusive due to ferrous rubbish, but resistivity surveys delineated large portions of the remaining subsurface structures (O'Carroll 2014).

Fig. 2: Dot density plot of the resistivity surveys conducted by Florida Atlantic University (Kennedy 1989, retrieved from http://iafs.ie/index.php/student-research/).

Surveys in 2015 aimed to establish appropriate parameters for surveying clay variant soils and differentiating target objects from overlying rubble and rubbish (Green 2015), and then expanded to locate the southern cemetery boundary and individual graves within (see Figure 3 for survey locations). GPR surveys were conducted with a MALÅ RAMAC X3M system (250MHz, 500MHz, and 800MHz antennas) employing a 0.02m sampling interval in autostack mode. A 0.1m traverse interval was tested for the cloister garth survey and 0.25m for the town wall and cemetery surveys. A Geonics EM38B was used to conduct electromagnetic surveys at a 1m traverse interval and 0.5m sampling interval. Gradiometer surveys were conducted with a Bartington Grad601-2 at 1m traverse intervals and 0.125m sampling intervals and a Geoscan Research FM256 with 0.5m traverse interval and 0.125m sampling interval.

Anomalies of possible archaeological origin were identified within the cloister garth. An anomaly, located centrally within the cloister *c*. 1m below ground level (bgl), is likely to be of archaeological origin – possibly a well or similar access to groundwater. Three anomalies indicative of possible burials were identified and must be investigated further through excavation. It was anticipated that surveys for the historic town wall would shed light on GPR's ability to detect features below this rubbish layer (Shine *et al*. 2016). Linear anomalies possibly relating to a medieval wall were weakly visible and are currently undergoing ground-truthing. Anomalies corresponding to possible burials within the proposed cemetery boundary were identified using GPR. Test excavations of 'quiet' areas within the garth revealed no modern or archaeological activity, indicating GPR's responsiveness and ability to provide true negatives on this site. As with previous gradiometer surveys, results were hindered by modern rubbish and 'made ground' (Green *forthcoming*). EM proved inconclusive; while there are anomalies possibly associated with the expected burials in the cloister garth, the depth of investigation was considerably less than the GPR.

While there was success from twin probe resistivity in previous surveys, survey parameters and depth of investigation rendered it unable to detect small, low contrast features, thus the need for GPR. By employing a multi-method approach, the Black Friary surveys can inform on appropriate methodologies for locating targets of archaeological and forensic relevance in areas with high clay, rubbish, or rubble content. Based on variable results from GPR surveys, a 0.1m traverse interval and minimum 2m square grid will maximise the potential to locate and recover human interments during the pre-excavation stage of an investigation (Green 2015). However, the additional time required to conduct surveys at a 0.1m traverse interval must be considered. While a 0.1m traverse interval will provide the high resolution data, a traverse interval at least 25% the size of the target object (0.25m for adult human interments) provides enough raw data to isolate apposite anomalies, but may not detect those smaller than the target object, as demonstrated by the decline in data quality shown in Figure 4.

Fig. 3: Location of survey grids with interpretations of data outlined. Map data provided by IAFS.

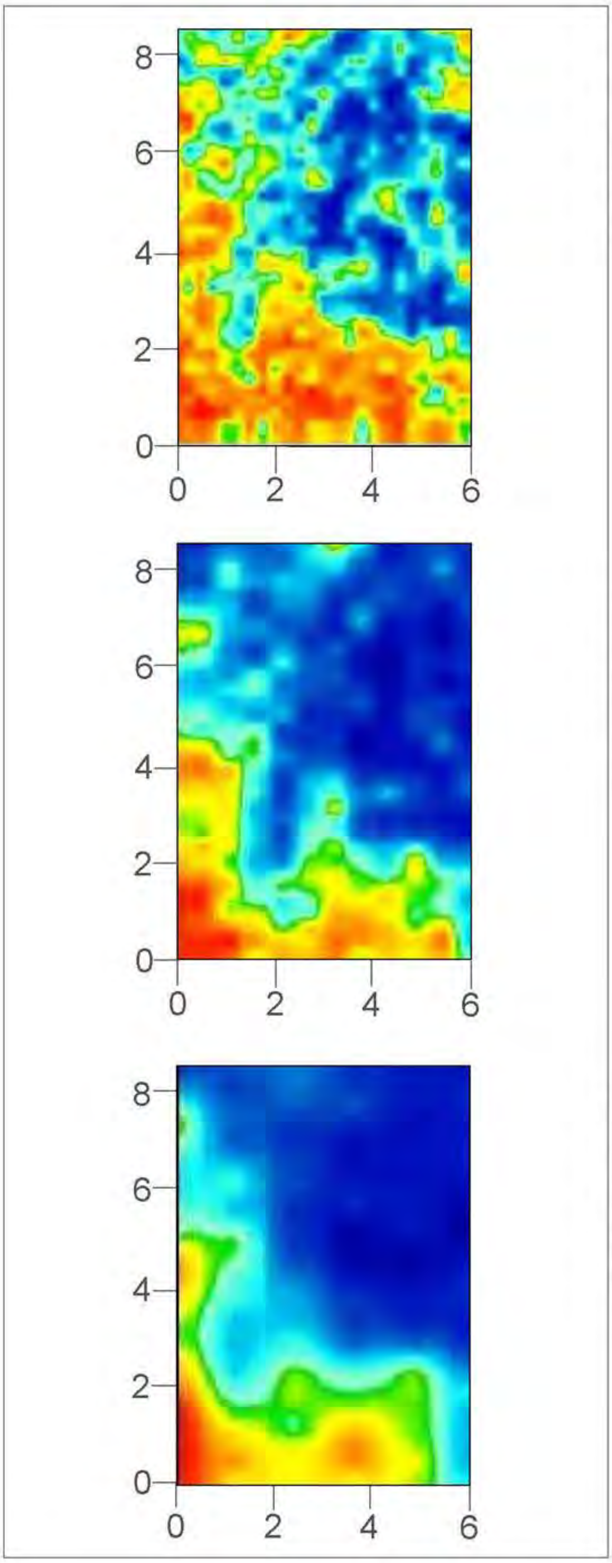

Figure 4a. A representative time-slice (*c.* 45-50cm bgl) from a survey employing a 0.25m traverse interval and 0.02m sampling interval

Figure 4b. The above data (Fig 4a) manipulated to represent a 0.50m traverse interval and 0.02m sampling interval

Figure 4c. The above data (Fig 4a) manipulated to represent a 1m traverse interval and 0.02m sampling interval

Fig. 4: A selection of the comparison data used to determine the effect of traverse interval size on data quality and spatial accuracy.

Acknowledgements
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MAGNETOMETER PROSPECTING OF A MAJOR ACHAEMENID PALATIAL STRUCTURE AT KARACAMIRLI, AZERBAIDJAN. A PERSIAN PARADISE IN THE CAUCASUS

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Karacamirli is the location of a major Achaemenid palatial structure, which has been under excavation since 2006 by Florian Knauss (Staatliche Antikensammlung und Glyptothek, Munich) and Prof. Dr. Ilyas Babaev (Azerbaijan Academy of Sciences) (Babaev *et al.* 2006). The archaeological site covers an area of ca. 2.5 square kilometres (fig.1). The aim of the survey was to further investigate the surrounding landscape through archaeological and geophysical means in order to clarify the integration of this building complex within the micro-region, both structurally and chronologically, and to examine further possibilities for a continued examination of the site as a whole. The site dates approximately to the period spanning from the end of 600 BC through to AD330, with earlier components from the Iron Age period. The primary prospecting areas are located in the north and adjacent to the Palace area. Further prospecting areas were selected simply according to the accessibility and the suitability for high resolution magnetometer prospecting. All areas were scanned using a sampling interval of 25 x 25 cm and meanwhile the area covers more than 0.7 square kilometres. For a better and full understanding of the magnetic survey, we complemented the magnetometer survey with some trench excavations and additional mineral magnetic and susceptibility measurements (fig.3).

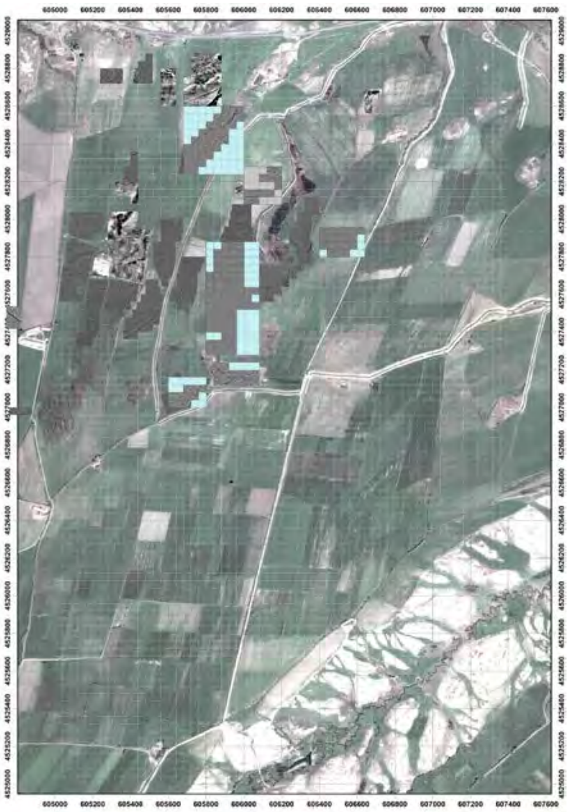

Fig.1: Karacamirli. Satellite overview of the total survey area of 2.5 x 4 km overlaid by the grey shade images of the magnetometer survey areas.

The resulting magnetometer images are at the first sight dominated by ploughing furrows and small but regular irrigation canals. Nevertheless a detailed analysis of the results reveals several pits and remains of pit houses or storage cellars as well as temporary structures of the ancient building site. Besides that the data reveals also numerous natural riverbeds and ancient streamlets but also ancient irrigation canals which belong very probably to the Achaemenid garden site. We traced the enclosing wall of the garden which measures ca. 2 x 500 plus 2 x 400 m, in total ca. 1800 m in length (fig.2). Inside the garden we found a further wall, which divides the garden area and numerous old and some more recent irrigation channels. Outside of the garden enclosure, in the north and in the north-east, we discovered more so far unknown monumental buildings. These buildings are oriented symmetrically with respect to the ground map of the Archaemenid garden and palace structures, indicating that these buildings formed a significant part of this site.

Fig. 2: Karacamirli. The excavated garden palace and the inner enclosure of the Achaemenid garden site. Satellite image, fused with the magnetometer measurements. Caesium total field magnetometer Scintrex, SMG-4 special in duo-sensor variometer configuration and Ferex Förster, four sensor fluxgate magnetometer, sampling density 25 × 50 cm, interpolated to 25 × 25 cm, dynamics +/-8 nT in 256 grey scales, 40 m grid.

Fig. 3: Karacamirli. Excavation trench accross the inner wall of the garden palace.

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MINING AND INTERPRETING ARCHAEO-GEOPHYSICAL DATA THROUGH EXCAVATION – A CASE FROM PREHISTORIC KNOWLTON (DORSET, UK)

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Identified by aerial photography, the presence of a presumed prehistoric long-barrow and ring ditch called for detailed investigation by targeted excavation. Located in Dorset (UK), the features are presumed part of a larger ritual environment of which the 'Knowlton Circles', a complex of Neolithic and Bronze Age monuments, are best known.

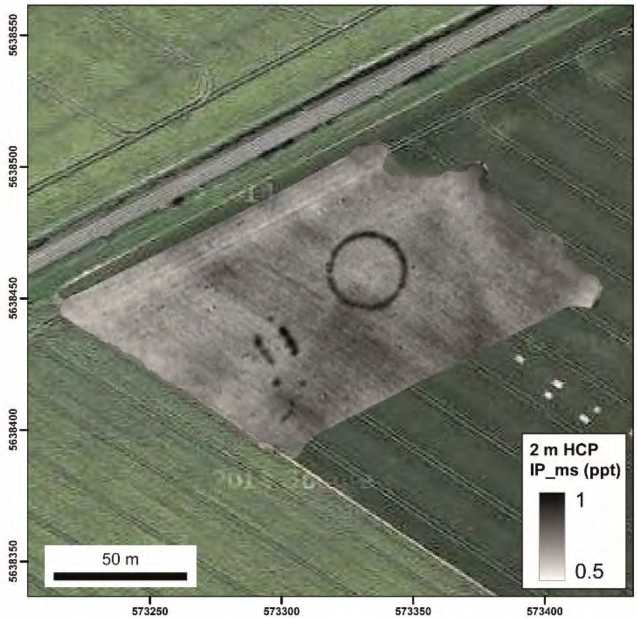

Fig. 1: In-phase magnetic susceptibility data from the Dualem-21HS 2 m HCP coil configuration.

To aid in planning excavations and add to subsequent interpretation, detailed geophysical prospection, in the form of multi-receiver frequency domain electromagnetic induction (FDEM) survey with using a Dualem-21HS sensor, preceded invasive fieldwork. The survey results (Fig. 1) clearly showed the primary features targeted in the excavation and showed varying expression in the multi-receiver EMI dataset. Alongside fine-tuning the excavation layout, the geophysical data were calibrated through recording the soil magnetic susceptibility and electrical conductivity of excavated surfaces and in boreholes, and validated archaeologically by comparison to the excavation results.

Apart from evaluating the survey methodology, the FDEM and excavation data were combined into an iterative interpretation procedure. This entailed joining both datasets on a physical and archaeological level with the aim of creating a reference point which would not only allow improvement of future surveys, but enable better understanding of the 3D morphology of detected features, their level of preservation and geological context prior to excavation. While exemplified through a single case study, this poster presentation aims to address how through considering geophysical prospection data an inherent part of the excavation process, a more robust framework can be constructed for subsequent archaeological interpretation.

A COMPARATIVE APPROACH OF EM AND MAGNETIC SURVEY FOR THE STUDY OF THE NEOLITHIC SITE OF KLIMONAS (CYPRUS)

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The Neolithic site of Klimonas is located near the modern village of Ayios Tychonas, in the Amathous region, at around 10km to the East of Limassol (Cyprus). The settlement spreads on a succession of three natural terraces facing to the south on a total surface that doesn't exceed 1ha (figure 1). The excavations carried out since 2009 by the French archaeological mission "Neolithisation-Klimonas"" and the "Limasol" CNRS project revealed the earliest village of Cyprus dating from almost 9000 B.C (Pre-Pottery Neolithic A, PPNA; Vigne et al., 2012). The site is very eroded, and most of the features are pits or ditches. However, an exceptional communal building of 10m diameter was found, semi-embedded in the substratum. The excavators also found the remains of nearly 25 domestic round buildings of 3 to 6 m in size, which were terraces in the slopes and built out of earth and wooden poles. The excavation revealed a rich archaeological assemblage such as lithics, plant remains and animal bones. Altogether, they reveal that the villagers were hunters-cultivators.

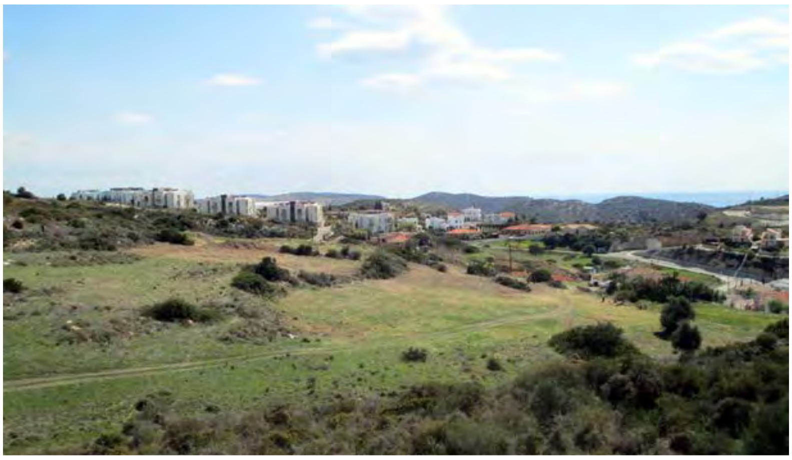

Fig. 1: General view of the Neolithic site of Klimonas (Cyprus).

Magnetic and electromagnetic surveys carried out on the site of Klimonas were aimed at assessing the capabilities of these two methods for the detection and characterization of Neolithic structures similar to those that have already been revealed by excavations. The magnetic survey was conducted using a Cesium gradiometer G-858 (Geometrics) and electromagnetic survey with a "Slingram" device, the CMD Mini Explorer (Gf Instruments, Brno) which allows simultaneous measurement of the magnetic susceptibility and electrical conductivity at 3 different depths (Bonsall et al., 2013). The study area covers a little less than one hectare divided between the 3 terraces and a small meadow below (figure 2). A series of archaeological surveys was carried out on a series of geophysical anomalies: they allowed characterizing the source of the geophysical anomalies and deepening the interpretation of the magnetic and electromagnetic maps. The surveys ultimately revealed more environmental than archaeological information which was particularly helpful to restore the pedological and geological context of the site. The resistivity map clearly differentiates a conductive zone in the western part which was archaeologically sterile, and a more resistive area to the East where the Neolithic settlements are located. The maps of magnetic susceptibility show more complex variations, partly due to soil and geological origin for the lower values, but also of anthropogenic origin for the highest values that are located in areas where most of the archaeological remains were found. Archaeological remains visible on the magnetic map are usually from later periods and the Neolithic structures are generally too small to be individualized. The response of the magnetic signal is dominated by large amplitude anomalies related to the nature of the soil, and the highest anomalies are due to the presence of ultramafic rock boulders. This environmental approach was therefore particularly helpful to recognize the site occupancy arrangements with Neolithic installations in the more resistant areas where Havara plate is close to the surface.

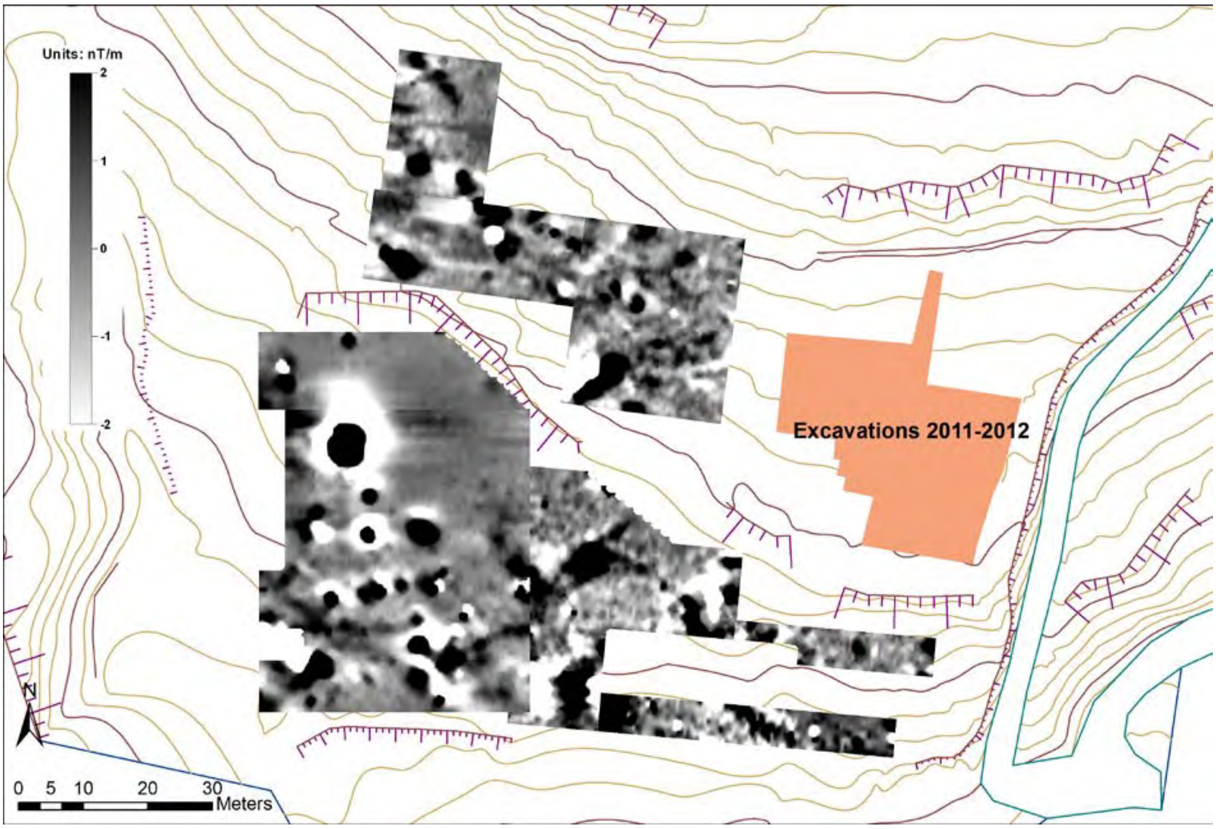

Fig. 2: Magnetic map obtained with the G-858 Cesium gradiometer.

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CREATING COMPOSITE GROUND PENETRATING RADAR DATASETS FROM THREE DIFFERENT ANTENNA FREQUENCIES

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Ground Penetrating Radar (GPR) is a useful technique for determining subsurface structures in near surface applications. Most GPR systems comprise an antenna pair with a single nominal centre-frequency, but multi-frequency systems allow several different centre-frequencies to be acquired simultaneously. The output of three different frequency-limited radargrams can provide information from the different depth ranges for each antenna frequency, and their simultaneous acquisition minimises acquisition effort. Multi-frequency composite radargrams contain balanced contributions from each frequency band at all depth ranges, allowing the creation of a 'broadband' GPR radargram and a convenient means of interpreting multi-frequency data. However, a simple summation of the radargrams causes the lowest frequency component to dominate the composite, hence a degree of multi-frequency scaling is required to achieve a balanced composite (Booth et al, 2009). This project focuses on strategies to automate this process using a computer algorithm, and understanding the amount of user input required in order to produce a high quality composite radargram.

Data collected from the Shetland Islands, at sites suggested by the Shetland Amenity Trust, are used to develop multi-frequency processing techniques, while also investigating the potential archaeological prospectivity of the subsurface. The sites were located on mainland Shetland, at the Sands of Sound and close to the archaeological excavation at Old Scatness. The multi-frequency GPR system, Trivue by Utsi Electronics, was used and operates with antennas of centre-frequency 250 MHz, 500 MHz and 1000MHz, recording simultaneously as shown in *figure 1*, providing a good penetration depth with the 250MHz antenna while a higher resolution for the shallower features with the 1000MHz data. In addition to GPR, a Geonics EM-31 electrical conductivity meter was deployed, to provide extra information to corroborate the GPR results.

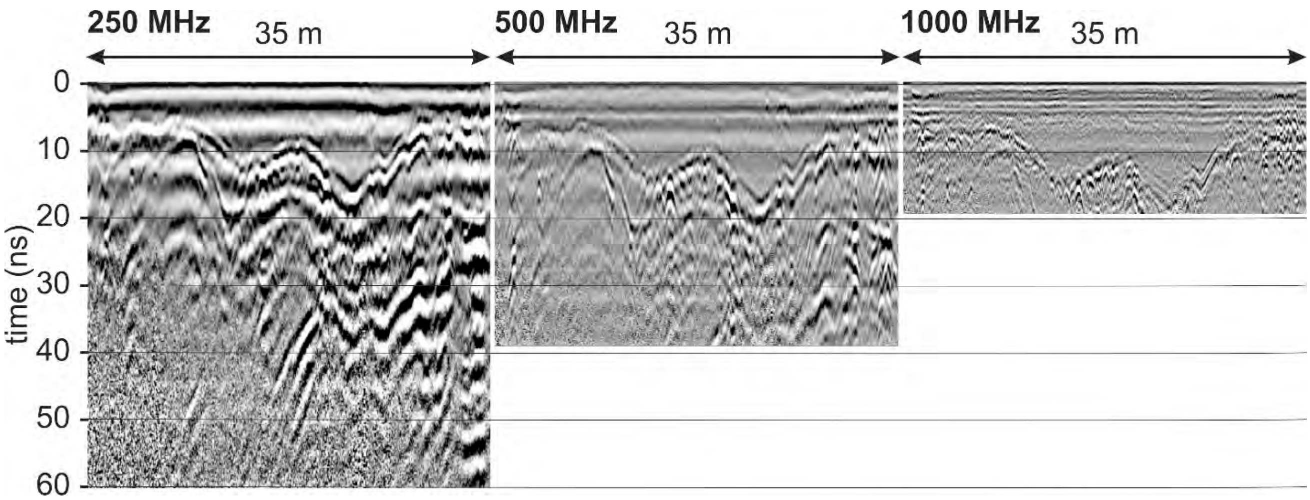

Fig. 1: Radargrams from Sands of Sound site for (left to right) 250MHz, 500MHz and 1000MHz antennas, recorded simultaneously along a 35m line. Data has been initially processed and demonstrates the depth and resolution differences between the centre frequencies, i.e. the 250MHz radargram has the largest depth penetration, however less resolution than the 1000MHz radargram within the first 20ns.

Pre-processing techniques of the frequency limited datasets are independently applied and radargram amplitudes are then scaled using weighting factors. These are calculated according to an idealised amplitude spectrum with both time- and frequency-dependency. Reflections caused by changes in ground surface, i.e. moving over a field to a concrete road, may produce significant ringing in the radargram and limiting the amount of coherent data. To correct this, an automated correction algorithm is investigated to track large differences between traces and adjust weighting factors accordingly depending on different ground surfaces. Such an algorithm would be a useful tool, providing improved image quality and indicating any potential post-processing requirements for interpretation, while also being flexible with different antenna frequencies and ground surface types.

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BENEATH THE SURFACE OF ROMAN REPUBLICAN CITIES: LARGE-SCALE GPR SURVEY OF FALERII NOVI AND INTERAMNA LIRENAS (LAZIO, ITALY)

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Interamna Lirenas and Falerii Novi (Lazio, Italy) were founded in 312 and 241 BC, respectively. Although the fourth–third centuries BC are important in the development of Roman cities as a new urban form, our knowledge of sites remains limited. The study of the early phases of Interamna Lirenas and Falerii Novi should allow us to better understand the scale and character of Roman Republican cities (street grid, public buildings, domestic space). Today, both sites are used as arable land and therefore easily accessible. They have been the focus of investigations by the University of Cambridge and the British School at Rome over several years, including field survey, topographical survey and large-scale magnetometer survey (see e.g. Keay et al. 2000; Bellini et al. 2013).

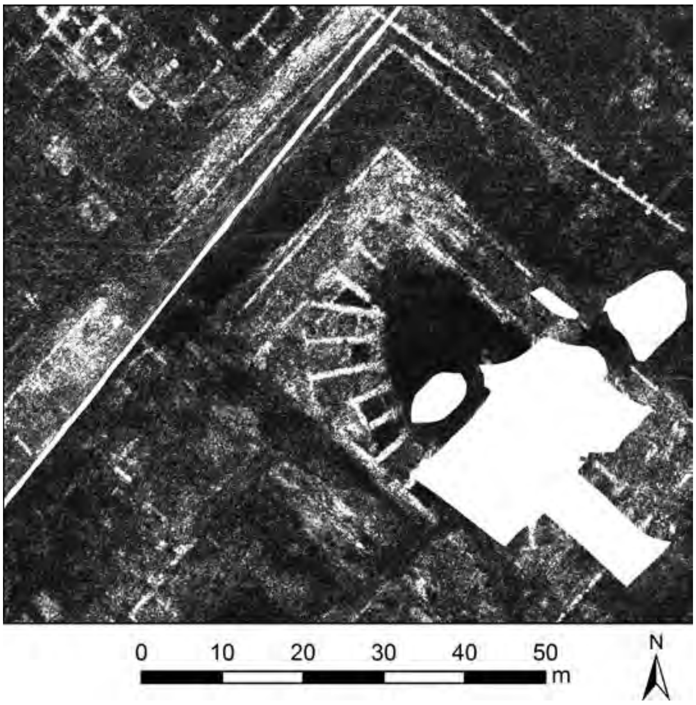

Fig. 1: GPR slice at a depth of ~50–55 cm from Interamna Lirenas, showing the northwestern half of the theatre, not yet excavated at the time of the survey in July 2015.

The current GPR prospection of the two complete towns (each between 25 and 30 ha) takes place within the 'Beneath the surface of Roman Republican cities' project, a collaboration between the University of Cambridge, Ghent University, the British School at Rome and the Soprintendenza Archeologia del Lazio e dell'Etruria Meridionale. Around two thirds of the total area has been covered in the 2015 and 2016 seasons. We use a network comprising thirteen 500 MHz antennas, mounted in parallel onto a wheeled, wooden frame and towed by an all-terrain vehicle. Data are recorded in parallel, slightly overlapping 2 m wide swaths, so that the spacing between the transects is 12.5 cm or 6.25 cm (the latter requires a second pass). Readings are taken every 5 cm along the transects. RTK GNSS positioning information is fed into a navigation system guiding the driver so that the desired trajectory is followed. The geophysical survey data is visualised after completion of each line, to quickly detect possible gaps in the coverage of the survey area and assure data quality.

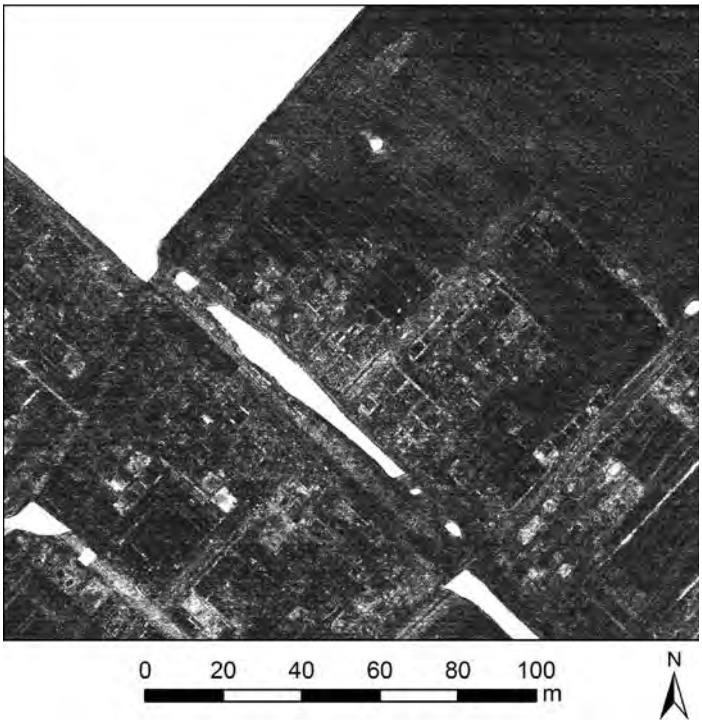

Fig. 2: GPR slice at a depth of ~50–55 cm from Interamna Lirenas, showing the northern part of the site. The topography slopes down in northeastern direction, towards the edge of the town.

Data processing included dewow, time zero alignment, gain, low-pass filtering, background removal and suppression of variations in the amplitudes recorded by the different channels, visible as stripes in the time-slices. To determine the GPR wave velocity and the depth of the archaeological features, migration velocity analysis was performed on selected vertical profiles and horizontal slices. At Interamna Lirenas, also direct observations of the depth were possible in the theatre area, where in 2013 an excavation was started (Bellini et al. 2014; Ballantyne et al. 2015). At the time of the 2015 GPR prospection, only the southeastern half of the theatre had been excavated, while the northwestern half was included in the GPR survey (Figure 1). After the extension of the excavation to the northwestern half in 2016, detailed depth information has become available, allowing accurate calculation of the wave velocity for this area. After time-to-depth conversion and topographical correction, a 3-D interpretation drawing of the GPR anomalies was produced, manually and using automated detection tools (Verdonck 2016).

To make a 3-D comparison between the theatre excavations and the GPR results, a scan of the northwestern half of the theatre was made using a robotic reflectorless total station. Although the scan resulted in a low resolution compared to a survey with a terrestrial laser scanner (approximately 150 points/m²), this sample density was sufficient for the assessment and visualisation of the GPR wave attenuation. The GPR produced high-resolution information on the radial walls supporting the upper part of the *cavea* (seating area) and on the *scaena* wall which forms the background of the *pulpitum* (stage), down to a depth of >1.5 m (Figure 1). However, the lower part of the *cavea* and the wall separating the *pulpitum* from the orchestra (the semi-circular central part of the theatre) are absent in the GPR images, indicating that structures starting at a depth greater than around 80 cm were not detectable by the GPR at the time of the prospection, which took place during a long period of dry weather.

This observation, in combination with the presence of a very large quantity of building material and other Roman artefacts at the surface, seems to indicate that most foundations visible in the time-slices may be equally shallow. Moreover, the question arises whether the absence of features in the GPR data in the lower areas near the edges of the town (Figure 2) is due to a real absence of foundations, or to the presence of colluvium and an insufficient GPR penetration depth. Further investigations (augering, test excavations and measurements of the soil conductivity) are required to clarify this.

Although the archaeological interpretation of the GPR results is still ongoing, they seem complementary to the results of previous work. For example, at Falerii Novi, the GPR provided more information about some public monuments (e.g. temples, theatre, U-shaped building with porticoes), whereas the smaller buildings, often showing as clear magnetic anomalies, are defined less clearly in the GPR data.

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MAGNETIC MODELLING APPLET DEVELOPMENT: AN OVERVIEW OF A FREE WEB-BASED TOOL (COMMERCIAL PRESENTATION)

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In the latter half of 2015 Geomatrix undertook a research and development project to update the magnetic gradient calculator hosted on our website. The program provides a simulation of the magnetic response from a total field gradiometer. The purpose of the program was to provide an easy to access an advanced magnetic modelling platform with simple graphical user interface.

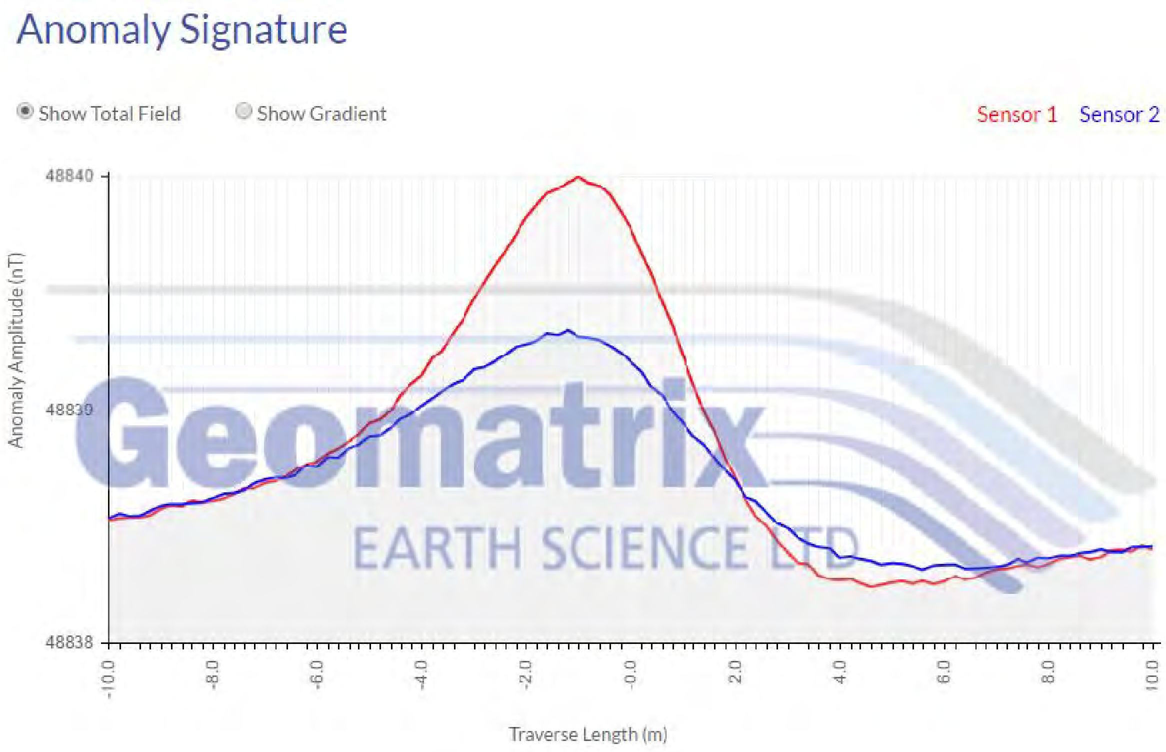

Fig. 1: Total magnetic field recorded by vertically separated magnetometers over a 40kg projectile. Survey and instrument noise has been simulated and imposed onto the magnetic response.

A number of significant improvements were implemented during the development to enhance the functionality of the program. The most important of these were: the population of each model block with an even distribution of magnetic dipoles (Blakley 1995); the ability to locate an object anywhere within a 3D half space; define the traverse heading, and the incorporation of the regional magnetic field based on the International Geomagnetic Reference Field Model (Thebault 2015 et al).

To verify the integrity of the computed magnetic field a database of commonly encountered ferrous and magnetic enhanced targets was created. A shortlist of 8 targets was compiled consisting of commonly encountered marine and terrestrial objects. Each target was selected based upon predefined criteria:

1-	It must be able to measure the targets magnetic susceptibility.
2-	It must be able to record the targets dimensions.
3-	It must be possible to construct the object from rectilinear blocks.
4-	It must be practical to measure the magnetic anomaly of the target using commercially available field equipment.

Many of the objects selected for the validation process exploited the magnetic objects buried in 2013 at the Near Surface Geophysical Group (NSGG) test site, Leicester, for the biennial field exhibition. A 20m^2 area of the NSGG test site was seeded with 16 commonly encountered geophysical targets. 5 of the targets were inert Unexploded Ordinance (UXO) (which were removed after the field exhibition and replaced with objects with equivalent properties). All other targets were chosen to offer a variety of geophysical responses which wouldn't be detected by all of the typical geophysical instruments used for locating UXO (generally Magnetometers/Gradiometers, Transient Electromagnetic and Ground Penetrating Radar) but would be detected by at least one of the techniques (Guy & Leech 2013).

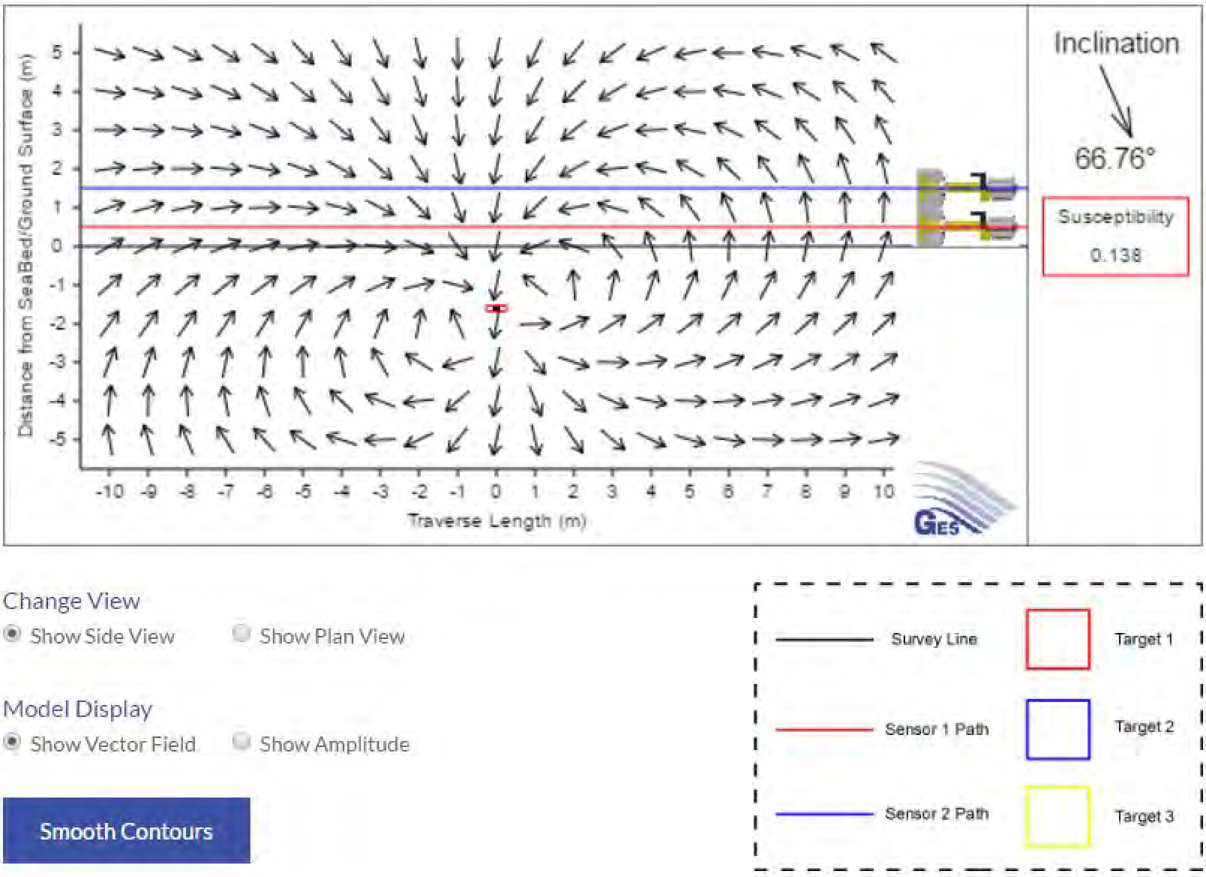

Fig 2: Target geometry and vector field plot.

The targets buried at the NSGG test site are by nature relatively small and can be represented by a single model block in the modelling program. To verify larger targets, constructed from multiple model blocks, the magnetic signature of canal boats were measured as they passed under a foot bridge on the Grand Union canal. Canal boats proved to be a reasonable choice of vessel for the validation process as their shape and construction are reasonably consistent and easy to construct from rectilinear blocks. In order to accurately model the volume of the ferrous material forming the vessel hull it was necessary to incorporate the ability to model hollow blocks. A second model block was used to represent the engine, and third for any super structure on the roof of the vessel.

Although the ability to create multiple model blocks, each with independent properties, goes some way to being able to model complex targets; the necessity to constrain the computation time on a web based application means it is not possible to construct a perfect match between the measured and modelled magnetic field. Having said this, there is good correlation between the anomaly amplitude even if the shape of the anomaly differs. The online magnetic modelling program is therefore a powerful tool and can aid develop an understanding of the likely magnetic anomaly produced by either predefined or user defined models.

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TOPOGRAPHIC CORRECTION OF GEOPHYSICAL DATA: COMPARISON OF PHOTOGRAMMETRY AND GPS DATA IN THE CORRECTION OF POOR ACCURACY HEIGHT VALUES AT GRAVE CREEK MOUND, WV, USA

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Introduction

Grave Creek Mound is located in the town of Moundsville in Marshal County, West Virginia, USA. Built approximately 300-200 B.C. by the Adena culture during the Early Woodland period, this conical-shaped earthen mound measured roughly 21 meters tall and 90 meters in diameter when it was first surveyed in 1838. Grave Creek Mound, once one of numerous in the region now stands alone, as the largest extant mound in the Ohio River Valley.

A ground penetrating radar and earth resistivity tomography survey of Grave Creek Mound was conducted in July 2016 at the invitation of the Delf Norona Museum as part of an on-going effort to better document the mound and its internal structure.

The benefits of a multi-methodological approach are well recorded within archaeological prospection, yet this rarely applies to the topographic survey techniques employed on those surveys. The work presented demonstrates not only the utility of having multiple topographic datasets, but the importance of that data in accurately correcting for topography.

Grave Creek Mound standing at 19 m tall with approximately 30-degree side slope required topographic correction of the ERT and GPR that had been collected. This was achieved through the application of three different topographic techniques. The poster associated with this abstract will chart the process of data collecting through to final corrected data.

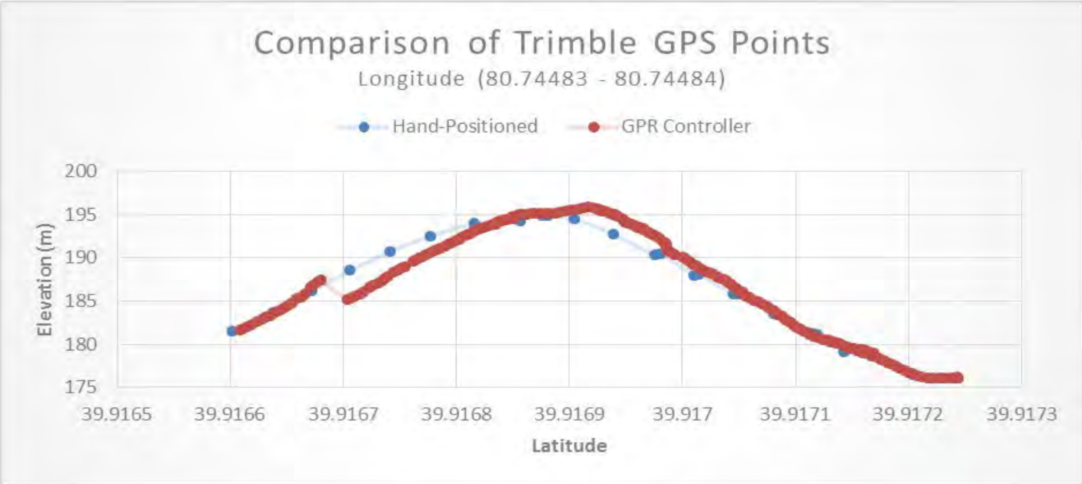
Strategy for Topographic Data Collection

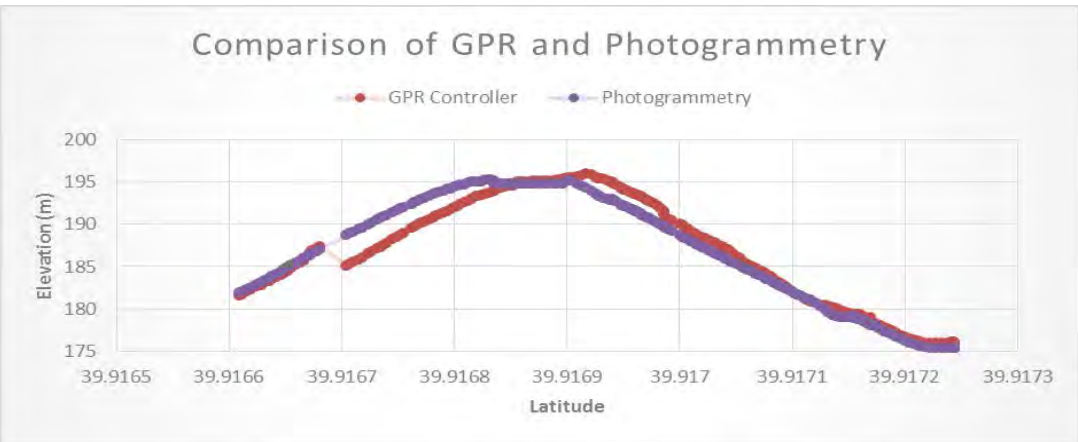
1. A Trimble R10 RTK GPS used in conjunction with the Mala GX160 GPR data controller was used to collect GPS points for topographic correction.
2. A hand-positioned GPS survey was conducted using a Trimble TSC3 controller and the Trimble R10 TRK GPS at a 1.5 m survey interval.
3. A DJI Inspire (FC550) was used to systematically photograph the mound and surrounding landscape with 80% overlap. From this photography a high resolution photogrammetric model of the mound was generated using Agisoft Photoscan with a point spacing of 3cm.
4. As the ERT and GPS data require accurate height information, height values were extracted from a high resolution photogrammetry model and used for the topographic correction.

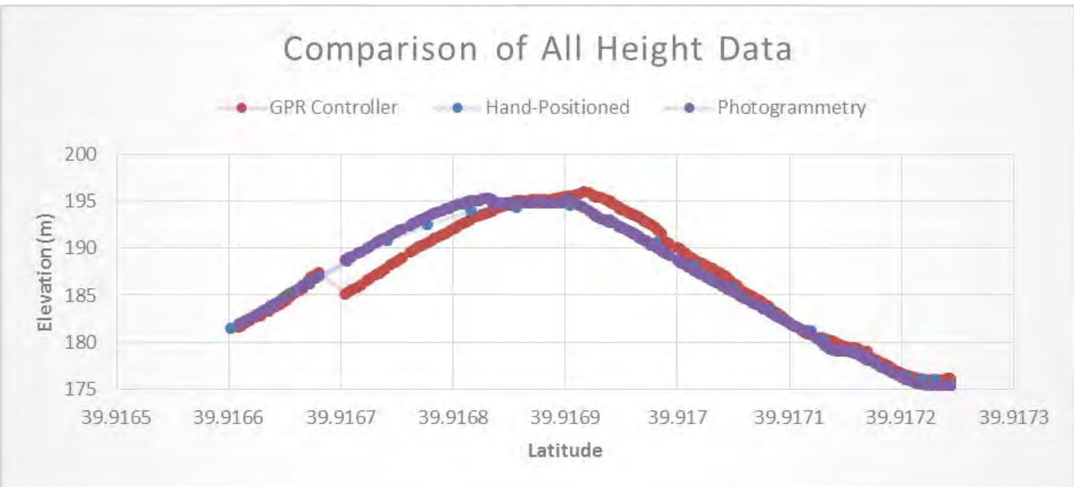
Issues Encountered

The GPS data collected through the Mala GX160 controller was found to be reliable for X and Y position, but wildly inaccurate in the height dimension (Z) regardless of the accuracy being reported by the controller. As the GPR data was collected in timed collection mode, due to the sheer slopes involved rendering the wheeled odometer useless, another source of height information was necessary for the topographic correction of the GPR data.

Raw Data Outcome

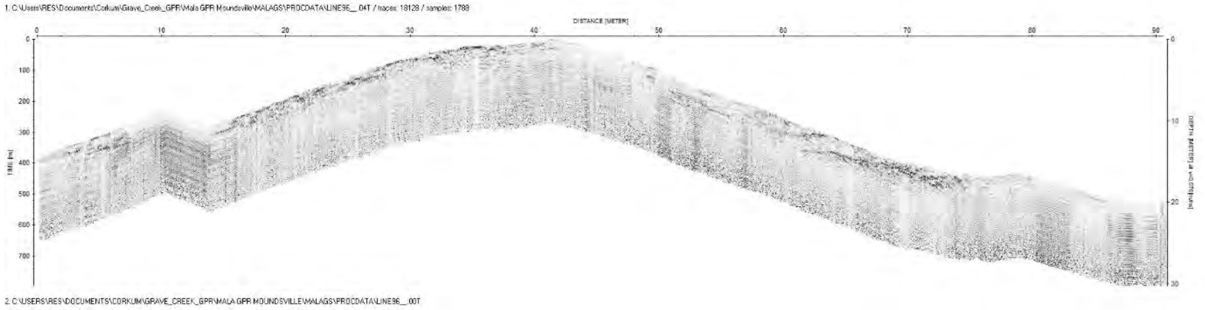




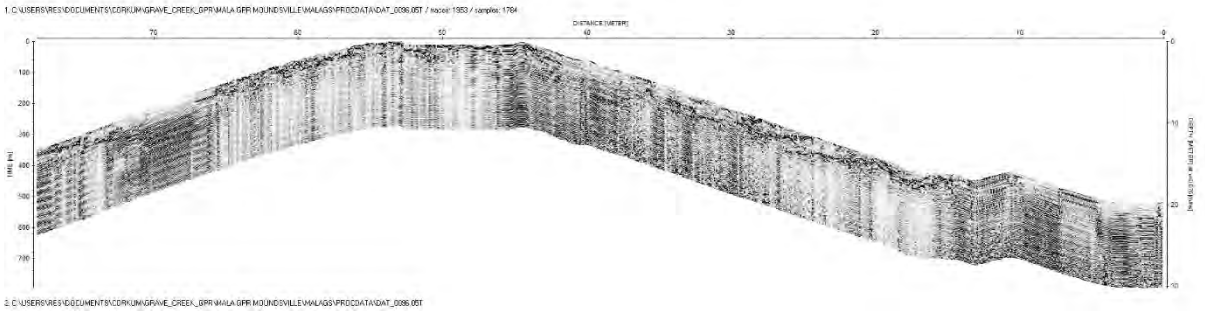


Topographic Correction of data
The hand-positioned GPS data while useful in providing baseline for the other topographic data sources, ground control points for the photogrammetry, and providing the topographic correction for the ERT survey, was not of sufficient resolution to provide the topographic correction for the GPR data. This necessitated a replacement of the height values within the GPR data with those from the photogrammetry model. This was done through the use of a custom python script and QGIS.

1. Use of GPR Controller GPS Height values



2. Use of Photogrammetry Height Values



Summary
Grave Creek Mound is an extreme example of the topography likely to be encountered through survey. The issues encountered during survey, while exaggerated due to the sheer size of the topographic variation present, can occur even under ideal conditions. Through the collection of multiple sources of topographic data an accurate model of the mound is possible, with each providing a necessary function in the resulting topographic correction. The importance of redundant topographic survey techniques, particularly when dealing with large topographic variation, cannot be understated. The multi-technique approach builds resilience directly into the survey strategy, which is indispensable if accuracy issues within one of the data sets occur.

CLUSTER ANALYSIS OF GPR PROFILES USING IMAGE INTENSITY DISTRIBUTION AND PATTERN DESCRIPTOR LEARNING: APPLICABILITY FOR ARCHAEOLOGICAL GPR DATA

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Cluster analysis is a means of partitioning a dataset into a number of clusters, each consisting of similarly classified data and distinct from other clusters. Increasingly, ground penetrating radar (GPR) systems include real-time displays of data that are both georeferenced (Francese *et al.*, 2016) and pre-processed (e.g., Chambers *et al.*, 2013). Cluster analysis offers a potential means of automating the initial appraisal of a GPR dataset, in almost real-time as successive profiles are recorded and analysed. However, GPR responses are often complicated and their interpretation benefits from the eye of an experienced user. Nevertheless, cluster analyses have been considered as a useful aid to the non-specialist (Ayala-Cabrera, 2014), and we consider the value they add to initial data appraisal for two example GPR datasets.

The simpler of these two datasets was acquired around an industrial site in northern Germany, and features metallic pipes at various depths, in a homogeneous sandy overburden; these data are considered simple because diffraction hyperbolae from the pipes are typically free from interference, and signal-to-noise ratio is high (Figure 1a). The second dataset was acquired over the foundations of Grosmont Priory, North Yorkshire; the structural complexity of the target gives rise to a variety of GPR responses, including overlapping diffraction hyperbolae and specular reflections (Figure 2). Both datasets were acquired with a Sensors&Software pulseEKKO PRO system, with antennas of 500 MHz centre-frequency.

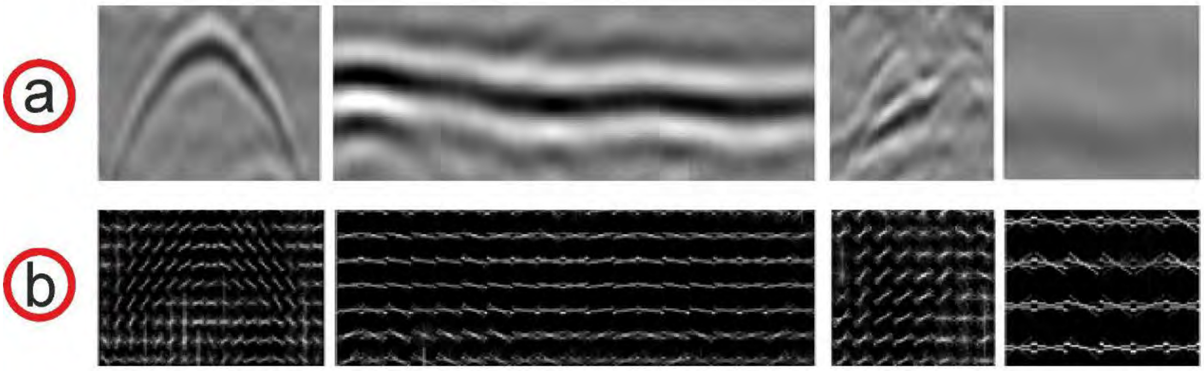

Fig. 1: Examples of a) GPR responses in the simple 'industrial' dataset, and b) samples of their characterisation into different cluster types. From left to right: diffraction hyperbola; specular reflections; chaotic responses; quiet zone.

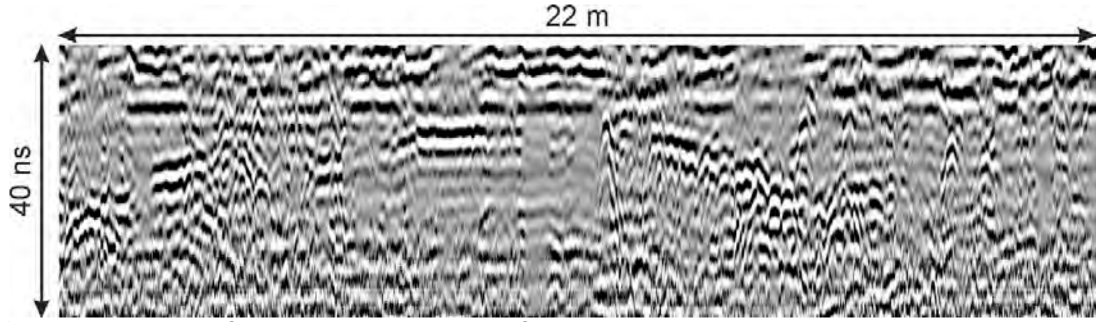

Fig. 2: Archaeological GPR data acquired over Grosmont Priory, North Yorkshire. The data includes a variety of overlapping responses and are thus more complex than the dataset in Fig. 1.

Cluster analysis was trialled for both datasets, with the aim of distinguishing *i*) diffraction hyperbolae, *ii*) regions of specular reflectivity, *iii*) chaotic responses and *iv*) 'quiet zones' containing little identifiable radar response. Examples are shown in Figure 1b, for the test data from the industrial site. After initial screening to distinguish 'quiet' and 'intense' zones of GPR responses, the latter are further classified using a variety of pattern descriptors. Among these descriptors is the histogram of oriented gradients (Dalal et al., 2005), from which shapes are recognised in the data; these algorithms are used extensively in automated object recognition software.

Following the definition of a group of training samples for each cluster, image descriptors are supplied to a variety of machine learning techniques. This optimises the classifier by which different patterns are distinguished. Thereafter, given a new GPR profile, the algorithm can automatically cluster the image into different areas with a possible classification (e.g., Dou et al., 2017). We show initial results from these trials of cluster analysis, and consider the applicability of clustering in the automated appraisal of GPR data.

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RECENT GEOPHYSICAL RESULTS FROM THE SOUTH HILL AT OLYNTHOS, GREECE

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The Olynthos Project is a multi-disciplinary collaboration between the Greek Archaeological Service and the British School at Athens, centred on an investigation of the Classical city of Olynthos, Chalkidiki. The aim of the Project is to explore the history of urbanisation at Olynthos and to understand the construction of identity by the community's inhabitants at the household, neighbourhood, community and regional scales. These questions are being addressed using geophysical and field survey techniques together with targeted excavation. The project is now in its third year. While the first two years were primarily focused on the North Hill, this year work began on the South Hill and this poster will comment on the recent work.

There are four components to the geophysical investigation undertaken on the South Hill at Olynthos: Magnetometry, Earth Resistance, Electromagnetic Induction (EMI) and GPS.

Magnetometry was found to be successful by team members in previous years when working on the North Hill at Olynthos. In 2016 it was proposed that a Bartington Grad601-2 dual fluxgate gradiometer be used on a non-magnetic & non-conducting cart using a GPS guidance system as a base level of information on the South Hill.

EMI is a technique that is currently receiving renewed interest for archaeological investigations and we used a CMD mini-Explorer to capture both magnetic and electrical responses from the ground. The latter is equivalent to Earth Resistance (ER) but does not require physical contact needed by commonly used ER systems, and therefore can be used in a greater variety of environmental conditions. This was thought to be important due to the variable ground conditions on the South Hill. The instrument also mapped at three different depths thereby potentially allowing some phasing of the data. The EMI data was also collected on a non-magnetic and non-conducting cart, using a GPS guidance system. The integrated GPS was used on the cart to provide precise locational information on each data point. This has the benefit of reducing user 'gait' and eliminating the need to correct for irregular pace with is endemic complications in all handheld devices.

Geoscan Research earth resistance meters were used to collect Twin-Probe data over the South Hill using a standard gridded methodology. All the data was incorporated into the project's GIS and interpreted using classifications that are suitable for this site.

In particular geophysical survey using earth resistance and EMI has for the first time revealed the layout of the streets and building blocks over the central and southern part of the South Hill. Supporting the geophysical interpretation is surface collection which was conducted over the whole of the South Hill. This has provided a range of material including local ceramics suggesting that the first millennium settlement here originated in the Early Iron Age to Archaic periods, as defined by the local ceramic chronology. Trial trenches located within the area of the geophysical survey are beginning to provide stratified evidence for the history and character of that occupation. It is evident that the archaeology mapped by the geophysical techniques is providing the backdrop to new interpretations at the site of Olynthos.

ON THE TRAIL OF THE ILLYRIAN RULERS. ACHIEVEMENTS AND OBSTACLES DURING THE MULTI-METHOD GEOPHYSICAL SURVEY IN SHKODËR (ALBANIA) AND RISAN (MONTENEGRO)

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Since 2001, the Antiquity of South-Eastern Europe Research Centre of the University of Warsaw has been studying the history of ancient Illyria. For the last 15 years, an interdisciplinary research project, including archaeological excavations, has been carried out in Risan (Montenegro) – the ancient town of Rhizon (Dyczek 2014). Since 2011, the ancient city of Scodra (Shkodër in Albania) has also become the subject of archaeological research (Dyczek, Shpuza 2014).

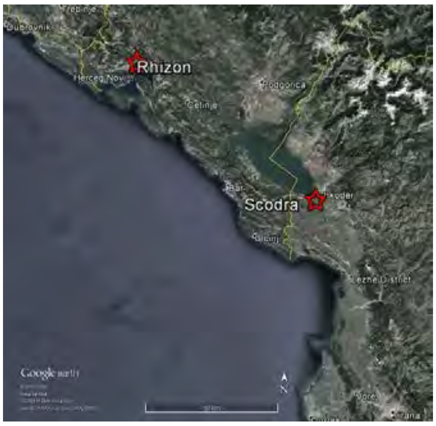

Fig. 1: The location of Risan and Shkodra.

The sites and their limitations

Although the eastern shore of the Adriatic sea is a very rich region in respect of e archaeological heritage, the natural geology and patterning in the coastal part of Balkans is very unfavourable for geophysical survey. The topography (mostly hills or river valleys) imposes limitations on the size of the surveyed areas. The local geology had a strong influence on the choice of the building material in the past (walls are mostly made of non-magnetic limestone).

The capital of King Genthios and the capital of Queen Teuta

The first attempt with the use of non-destructive methods in Polish research in the Balkans was made by Tomasz Herbich in 2008 in Risan. The earth resistance survey results were considered by the principal investigator as hard to interpret because of the multi-layered character of the site and the modern usage (Herbich 2009, p. 95). The next attempt was undertaken by Christoph Rummel in 2011, when both sites – in Risan and Shkodër – were surveyed with the use of the magnetic method. Although the results were judged as difficult to interpret, they contributed some new information to understanding the structure of both sites (Rummel 2013, p. 7).

Fig. 2: A bird's-eye view over a stronghold of Rozafa.

Multi-method approach

The magnetic measurements of Rozafa castle were undertaken using a cesium vapor total field magnetometer G-858G from Geometrics. Due to the sloping and rugged land form inside the stronghold, a differential GPS was used to obtain high accuracy positioning of each measured point. The reading dynamics was very high because of the depth variations and the diversity of archaeological features. The surveyed area has been transformed in the past several times, thus it is strongly iron-contaminated as well, diminishing the role of magnetic measurements in the process of prospection.

Fig. 3: A bird's-eye view over Risan.

The situation was similar or worse in the ancient city of Rhizon, located on the shore of Kotor bay. Nevertheless, two grids for magnetic measurements were set. The first one near the ongoing excavation trench where presumably the remains of the palace of Illyrian king Ballaios were found. The other was a small grid inside the walls of the ancient town – it was the only clear and large enough area.

The results of magnetic survey have brought some anomalies that could be evidence of archaeological structures inside Rozafa castle. Most of them could be interpreted as building walls. Unfortunately, in Risan we have been able to see only the walls of the non-excavated part of the building on the other side of the mentioned trench. Therefore the implication of the GPR and the earth resistance methods seemed to be a more reasonable direction of the prospection campaign.

The earth resistance measurements were performed with a Geoscan Research RM85 instrument with various probe arrays (from a=0.5 metre Wenner array up to Twin probe with a 2 metre remote electrodes spacing).

While in Albania the ground itself was quite accessible, the problem was the sloped areas. On the other hand, in Risan the area was quite flat but the soil in many places too dry and packed to place the electrodes. However the natural conditions in Kotor bay exclude the possibility to perform the survey in another time of the year, because the groundwater level rises almost to the topsoil.

Regarding the mentioned obstacles, the results of the earth resistance measurements may be considered as satisfying. In Albania, numerous linear anomalies have been detected. They probably stem from the architectural structures, however it is impossible to define their chronology – the stronghold was inhabited since Illyrian times until modern times, with the strongest dynamic in the Venetian and Ottoman periods (Dyczek, Shpuza 2014, p. 395-396). In Risan, some interesting linear anomalies have been registered as well. Regarding their pattern, they could be interpreted as remains of the buildings, which would fit to the city plan.

The Ground Penetrating Radar survey was performed together with geophysicists from the University of Szeged (Hungary). The measurements were taken with the GSSI SIR 3000 system. Due to the specifics and the complex stratigraphy of the sites, GPR was considered to be the best shallow geophysical technique to be applied.

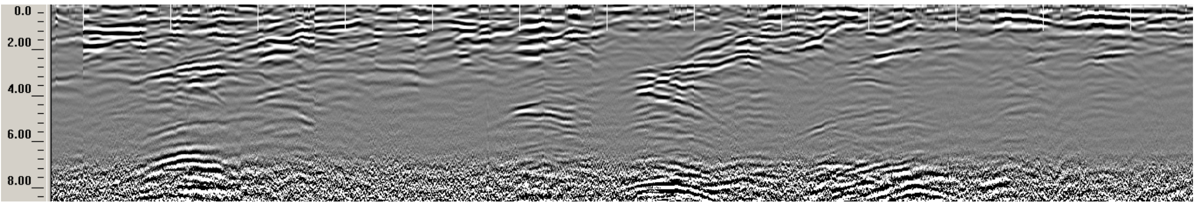

Fig. 4: One of the GPR profiles from Rozafa (estimated depth in meters) – the anomalies on various depths show the complexity of Rozafa's stratigraphy.

In Albania there were two major survey areas: one was placed inside the walls of the stronghold and the other one in the lower city, at the foot of the Rozafa hill. The aim of the measurements in the lower city was to find remains of the big wall enclosing the ancient town. Two grids on the floodplain and one long profile (*ca* 1500 m) along the modern asphalt road were measured. In Rozafa castle, a total number of 11 grids was set, covering an area of approximately 6000 m2. The 200, 270 and 400 MHz antennas were used for the measurements.

In Montenegro, the accessible area was also divided into 11 grids. The difficult survey conditions in Risan gave a big advantage to the GPR over the magnetic or ER method. Since the stratigraphy of the site was much shallower than in Shkodra, only 270 and 400 MHz antennas were used.

In both cases the measurements brought some good results, revealing the anomalies that could correspond to the ancient walls. The most interesting results were obtained at Rozafa, where on a depth of *ca* 6-8 metres, anomalies that could correspond to thick illyrian walls were registered.

All the results were complementary, which shows how important a multi-method approach is, especially when considering surveying in difficult conditions, like in Montenegro and Albania.

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GEOPHYSICAL INVESTIGATIONS AT THE VIKING – AND EARLY MEDIEVAL ASSEMBLY SITE OF THE FROSTA THING

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The peninsula of Frosta has in late Viking Ages and in the Scandinavian Middle Ages been the arena for the assembly site of Frosta Thing. The Frosta Thing-site was probably an *allthing* - a Thing where all free men had the right to participate, until the early 10th century. Later, the Frosta Thing became a supra-regional gathering of representatives from a larger part of what is Mid-Norway today (also known as a representational Thing), where 458 representatives sent from the local regions within the Law-district gathered somewhere at the peninsula over several days in mid-July. We do not know when this activity started at the peninsula, but the final Assemblies were in mid-16th century. By this time, the Frosta Thing as a representative Thing had lost its place to the Ørating in Trondheim.

While we have some information on the Thing-assembly from medieval historical sources from sagas, legal documents and place names, the archaeology of the Thing-site at Frosta has remained largely unknown. Little is known of how exactly the representatives organised themselves in the landscape, where and how they dwelled during their stay, and if such an Assembly also involved an element of trading and other social- and financial activities. Although a wide range of monuments are known in the area, such as Iron-Age and Viking-Age burial mounds and traces of medieval settlement sites present as blackened earth and fire cracked rocks, this has not been drawn into a larger cultural historical analysis of the landscape.

To achieve a better insight into the organisation of the Frosta Thing-Assembly, a large scale archaeological and historical study was initiated in combination with geophysical surveys. Available Lidardata, oblique aerial photos, historical maps and other sources were allocated and drawn into the study of the landscape. The geophysical surveys included large-scale magnetic susceptibility mapping, fluxgate gradiometer-surveys and high-resolution ground penetrating radar-surveys.

Results

The large-scale topsoil magnetic susceptibility (figure 1) revealed several clearly delineated areas of human activity, interpreted as early medieval rural farmsteads. They are very closely placed in the landscape, with no more than 300 meters between each settlement.

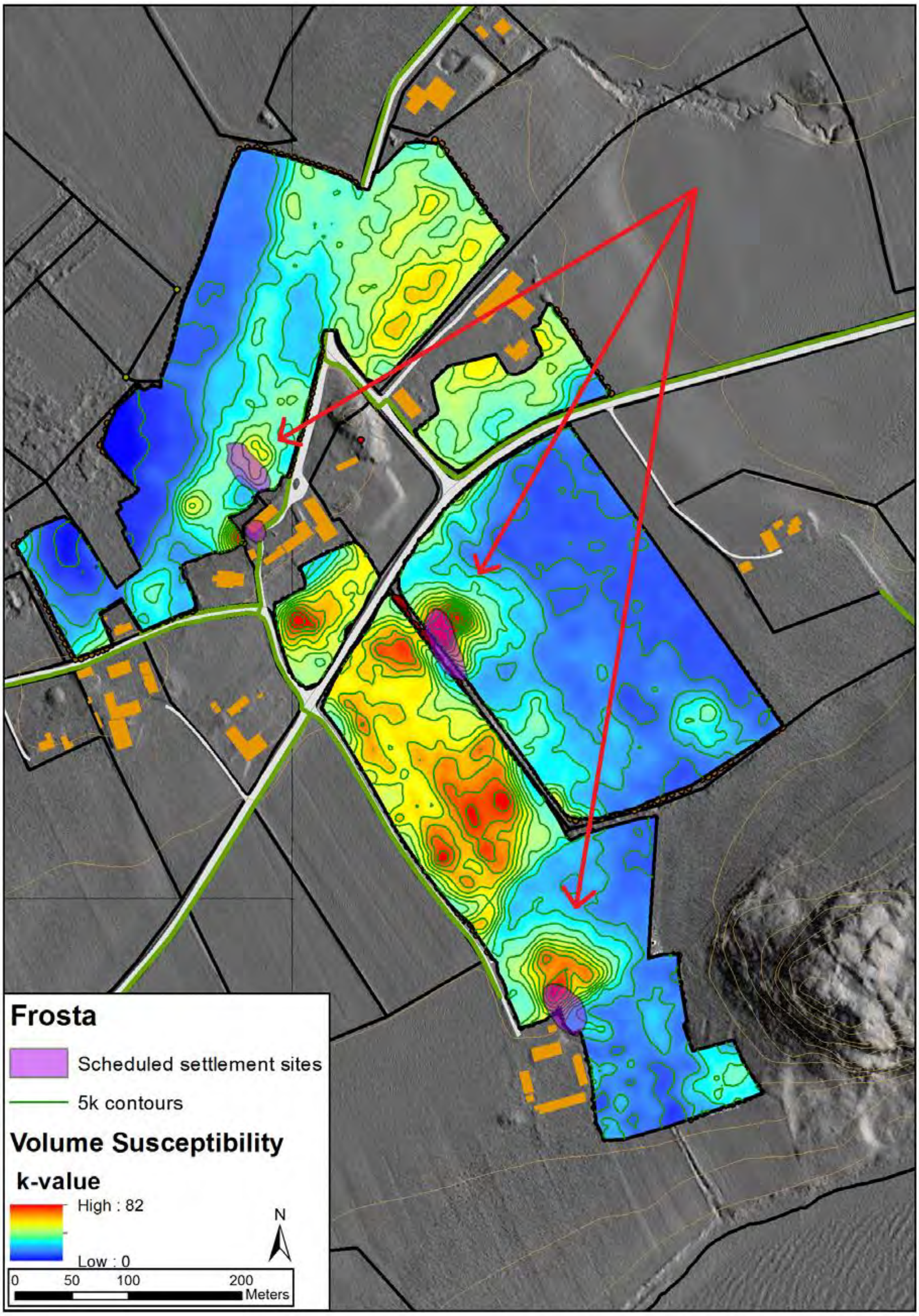

Fig. 1: Large Scale topsoil magnetic susceptibility around the farms of Logtun and Logstein.

Fig. 2: High-resolution GPR conducted with a 3d-radar Mark IV GPR-system with a ground coupled antenna array.

The high-resolution GPR was conducted at a ridge at the farm Rygg (which literally can be translated to the English word “Ridge”). This is where the antiquarians Gerardh Schønning (1778) and Lorentz Didrich Klüwer (1823) both placed a series of mounds, stone settings and the location of the Thing itself. This is some 800 meters west of the farm Logtun (which can be translated to “courtyard of the law”), and is set so it is visible from the fjord from both sides of the peninsula.

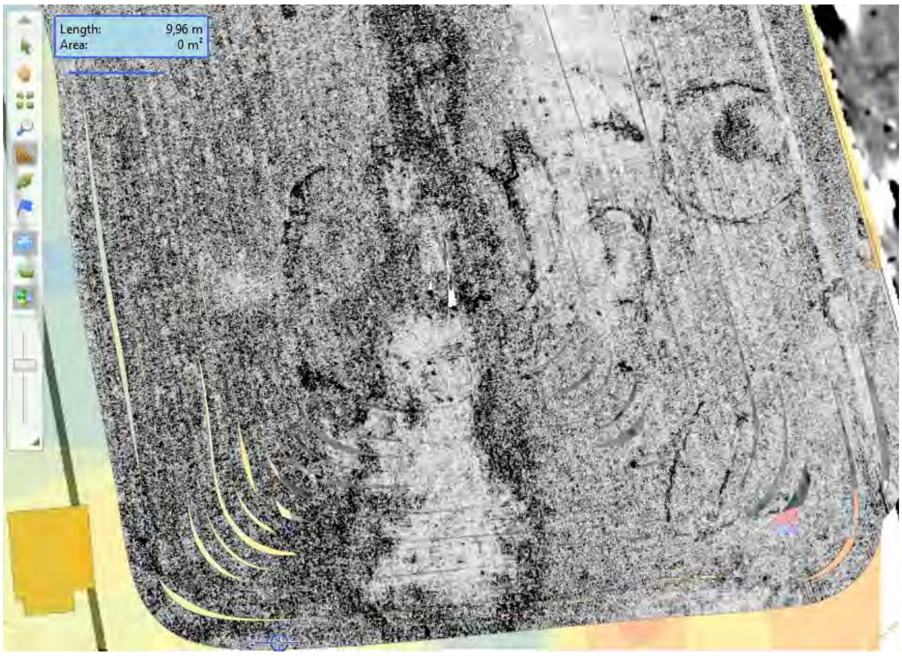

Fig. 3: Results from High-Resolution GPR-survey, showing the presence of three burial mounds and one potential house-foundation. Black is high relative reflectivity.

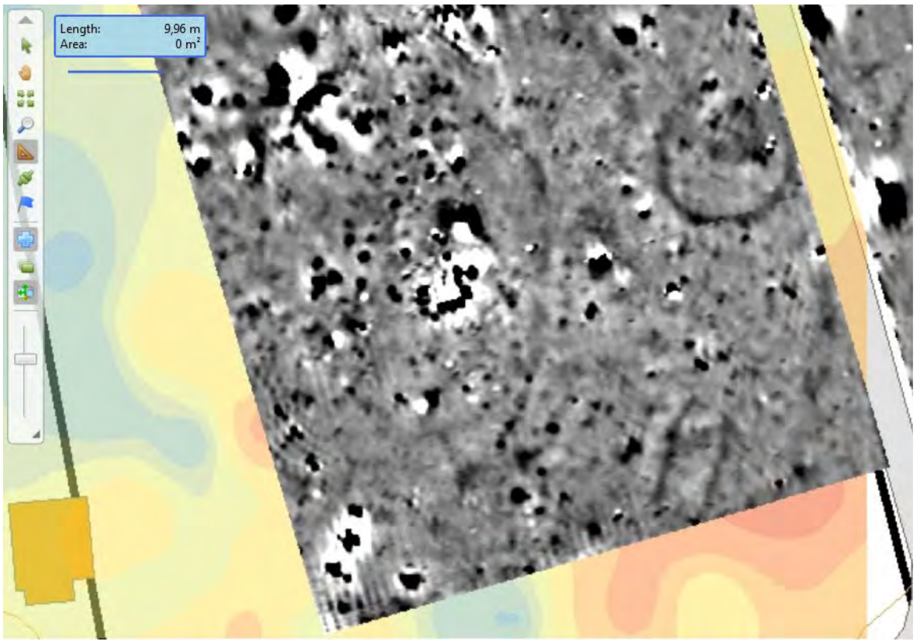

Fig. 4: Fluxgate gradiometer-survey from the same area as figure 4. Note the building foundation, and the presence of strong reflectors in figure 3 where there are anomalies in the fluxgate gradiometer-data. Black 6 nT, White – 6 nT.

Preliminary Conclusions

While the final analysis and interpretation of these results are still under investigation, it is highly interesting to be able to identify additional burial mounds in one of the areas assumed to be a central part of this landscape. The presence of a mound of 25-28 meters in diameter (see figure 3) must have been a focal and important point in this landscape. Also, the presence of an oblong anomaly in both the southern part of figure 3 and 4, is highly interesting, as this can very well be the archaeological remains of a house foundation – although house (or boat)-shaped burial mounds are known in the region. If this anomaly really is a building construction, this could be the first Thing-booth found in this region. The geophysical results also show the presence of closely situated farmsteads in this region, as well as a series of pits identified in the GPR data which has strong magnetic contrast in the fluxgate gradiometer data. This can be interpreted as the remains of either fires or cooking-pits associated with the Assembly of lawmen at Frosta.

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WHERE - THE HELL - IS THE WESTERN CONTINUATION OF EARTHWORKS NIEDERSICKTE? A DISCOVERY STORY IN THREE STAGES.

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In the area east and south of Brunswick (Braunschweiger Land), Lower Saxony, Northern Germany, there is a concentration of Neolithic monumental earthworks with one, two and three ditches. They were mainly discovered by aerial prospection and partly investigated by excavation (GESCHWINDE ET AL. 2009)[2]. One of the most important cluster of earthworks is currently affected by planned construction measures east of the village Niedersickte in a triangle shaped area (Fig. 1). In order to being part of the planning process the archaeologist had to proof the existence of two earthworks with one and two ditches crossing the construction area. And there was the problem. None of the many aerial pictures had shown there any signs of the earthworks in this specific area although the crop has changed from wheat to rye and sugar beet, whereas in the eastern neighborhood the earthworks were nicely visible in the crop marks.

That was the reason to perform a geophysical investigation with the twofold aim: to proof the existence of the earthworks in the planned construction area and to document their conservation status before destruction. Prospecting for the earthworks resembled a detective story divided into three stages: first, a magnetic test measurement without results; secondly, a combined resistance measurement and magnetics west adjacent to the farmstead at Wolfskamp 1 with the discovery of a double trench, later identified as old field boundaries; thirdly, a combined study of elevation models built from LIDAR-data, aerial photographs and resistivity measurement which finally could proof the existence of the two earthworks within the construction area.

Stage 1: Magnetometer prospection

The prospection started on March 2016 with a cesium magnetometry and a total field measurement (Scintrex Smartmag SM4/4G). Surprisingly the magnetic survey remained unsuccessful. None of the archaeological relics such as trenches and pits were visible in the area (Fig. 1). The negative result was explained by the acid, sandy and wet soil environment in an often flooded depression near the brook Wabe. The disappointed geophysicist wanted to stop immediately all investigation activities in order to save additional expenditures for the sake of the archaeologist's small budget. But the archaeologist pleaded for a continuation and the geophysicist proposed to change to resistivity measurements.

[2] The earthworks of Niedersickte are part of the research project EWBSL Michael Geschwinde and Dirk Fabian Raetzel in which they investigated earthworks in the Braunschweiger Land. With Google aerial photography, aerial surveys and some geophysical surveys they could document a landscape with a previously unexpected high number of Neolithic earthworks with one-, two- and three ditches (Geschwinde 2009).

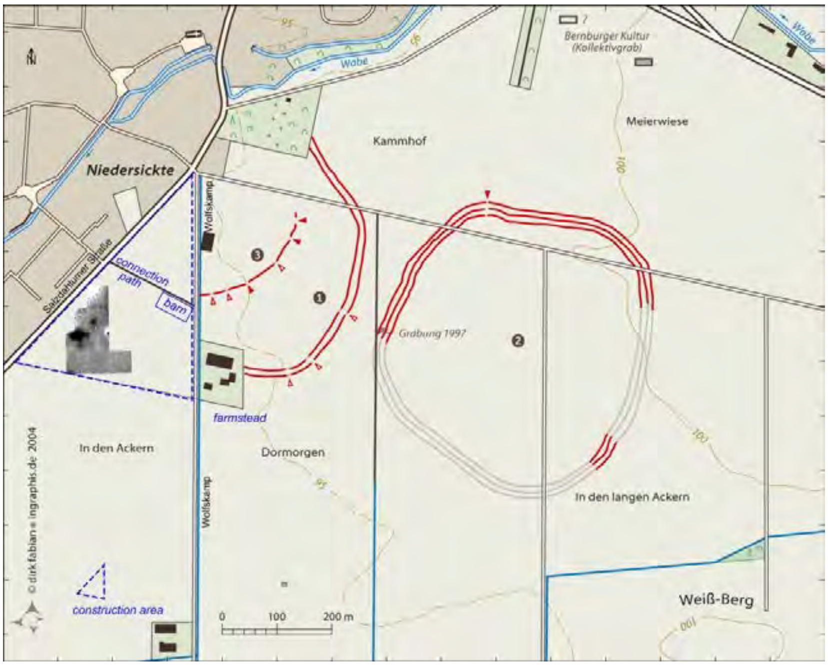

Fig.1: Situation map of Niedersickte (after stage 1): the double earthwork 1 disappears underneath the farmstead. For earthwork 1 and 3 there has never been seen a westerly continuation on aerial pictures into the construction area. No archaeological findings were detected by the magnetometer survey.

Stage 2: Prospecting west of the farmstead

The next prospection trial took place in April 2016 with a combined resistivity measurement (RM15 Geoscan Research) and magnetics west and adjacent to the farmstead at Wolfskamp 1 (Fig. 2). The selected test location on the construction area was closest to the double earthwork and only 100m away from the place where it has been last seen disappearing underneath the eastern side of the farmstead. Magnetics was tested again.

Fig.2: Situation map of Niedersickte (after stage 2 and 3): the two low impedance lineaments of the resistivity map belong to a system of early modern field boundaries marked by trenches (T). The resistivity map of stage 3 confirms the presence of the double earthwork (1 with gate G) and 3 in the construction area.

The onsite processing of the resistivity data revealed indeed a double ditch feature and the nice result could be immediately presented shouting a loud 'Heureka' to the happy archaeologist attending this exercise. The magnetic recording again remained without findings. However, the subsequent analysis of the detected double trench showed that we were dealing with long parallel trenches from early modern field boundaries with a separation of 16 to 19m instead of ca.12m as expected for the earthwork. After this failure we were at a loss. The search for the earthwork recalled the earlier more often played, Battleships'. Where should we continue the prospection? In addition, various options were discussed. Should the earthwork just stop underneath the farmstead? However, none of the Neolithic earthworks in the Braunschweiger Land had shown a sudden end but all consisted of enclosure structures. On the other hand the resistivity method had shown to be successful to detect ditches in the soil environment of Niedersickte due to its increased porosity. A piece of the puzzle for the solution was the crossing of the bridge over the brook Wabe which reminded the geophysicist that the investigation area was close to a wet depression area. Perhaps the Neolithic paleogeography was similar to the present one. This thought was leading to stage 3.

Stage 3: Analysis of elevation model, aerial photographs and resistivity measurement

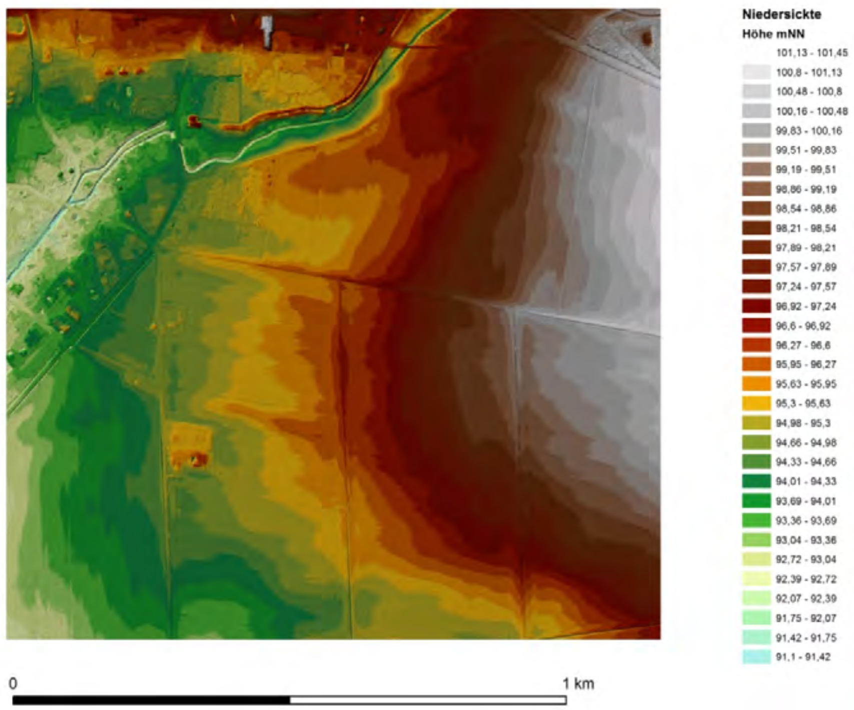

Fig.3: The elevation model of Niedersickte (after stage 2) has been built from LIDAR-Data by A. Niemuth (NLD). The terrain is westerly dipping towards the wet depression of the brook Wabe (starting with dark green).

The next step was a request to Andreas Niemuth, NLD Hannover, for a digital terrain model from LiDAR data derived from airborne laser scanning for the study area. The high-resolution terrain model revealed a slightly dipping terrain towards the brook Wabe that is barely noticeable when viewed in the investigation area (Fig. 3) The double earthwork of Niedersickte follows from the east at first the slope and meets at the farmstead on the contour line of 94,5mNN which probably was the level where the wet area of the brook Wabe started. When the earthwork was built the wet terrain might have been avoided by a sharp bend to the North following a course which is now covered by the road Wolfskamp. When reaching the concrete foundation of a demolished barn the contour lines turn left and follow the connection path. If the course of the earthwork followed the contour line we had to search along the connection path. Studying the aerial pictures we discovered south of the path two slightly curved ditches. We performed a resistivity measurement which could confirm the existence of the double earthwork in that area (Fig.4). We even discovered a gate for the outer ditch. North of the connection path a small section of the earthwork 3 had been revealed.

Fig.4: The final reconstruction for the earthworks 1 and 3 of Niedersickte (solid line: proven; dotted line: reconstructed).

As we could proof the existence of the earthworks within the construction area the archaeologist remained part of the planning and construction process which he had otherwise lost.

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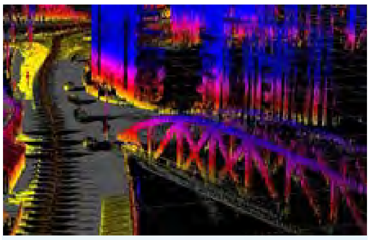


UAS Solutions Ltd provide Airborne LIDAR and Photogrammetry Services using Unmanned Aerial Vehicles. The LIDAR product we offer has the ability to provide much enhanced resolution when compared to conventional airborne systems. The Routescene LIDAR Pod collects data at a rate of 700,000 points per second which can provide up to 400 data points per square metre.

A typical mission using our Vulcan X8 Raven combined with the Routescene LIDAR Pod and the Velodyne HDL 32 sensor, has the ability to map an area up to half a square kilometre per mission. UAS Solutions holds CAA Permission for Aerial Work using professional pilots drawn from the commercial aviation community.

BARTINGTON INSTRUMENTS LTD

5, 8, 10, 11 & 12 Thorney Leys Business Park,
Witney, Oxfordshire, OX28 4GE

www.bartington.com sales@bartington.com

Bartington Instruments is a world leader in the design and manufacture of magnetic field measuring instruments, commonly used for archaeo-geophysics site survey investigations, forensics applications and location of UXO (unexploded ordnance).

Gradiometers

The innovative features of Bartington's new **Grad-13** digital, three-axis gradiometer provide a real leap forward in these applications.
The **Grad-13** gives:

- Enhanced data gathering, with the user now able to collect three vector gradients and the ability to calculate field gradient;
- Increased sensitivity, allowing for enhanced data interpretation of the underlying archaeology or buried features;
- The ability to be cart-mounted as a multi-sensor array. Multiplexing units providing power are also available;
- Optional third-party software allowing for data collection and processing of GPS based surveys;
- Land version rated to IP67. Submersible version available for use in downhole applications.

Grad601

The **Grad601** handheld gradiometer system, now the industry standard in the UK for commercial archaeological investigations, is still available alongside the **Grad-13.** Existing users can, with minimum updates required, easily use the **Grad601** with the **Non-Magnetic Cart** for multi-sensor, **GPS** based surveys.

Gradiometer Systems

Bartington also supplies **Non-Magnetic Carts** for mounting either the **Grad-13** or **Grad-01-1000L** (sometimes referred as Grad601 sensors) to provide a complete system for fast, accurate, large area surveying.
The **Non-Magnetic Cart** can accommodate up to 12 **Grad-13** or **Grad-01** sensors. The cart is constructed from a set of carbon fibre tubes and comes equipped with self-damping suspension. At 4 metres long and weighing just 20kg, it can be manually pushed or towed by a single operator. The cart is easily disassembled using one single tool for ease of transportation.
For very large area surveys, or where speed is of the essence, an additional 4 metre long, 9kg towing attachment allows the cart to be towed behind a small vehicle.

Magnetic Susceptibility Instrumentation

Bartington produces versatile instrumentation for measuring the magnetic susceptibility of many types of material including soils, rocks, core samples, powders and liquids. Magnetic susceptibility measurements quickly provide information about the level of magnetic enhancement of samples, thus enabling, for example, areas of likely archaeological content to be discerned.

The **MS3** meter enables data to be directly acquired and displayed on a laptop or a field computer. It operates with all **MS2** sensors, including **MS2B** for individual samples and **MS2D** loop for field mapping.
Bartington also manufacture the **BSS-02B Borehole Magnetic Susceptibility Sonde,** high precision, low noise **Fluxgate Magnetometers, Magnetic Shields** and **Helmholz Coil** systems.

Some of the equipment is displayed during this event.
Many examples of the practical applications of Bartington products can be found at http://www.bartington.com/market-sector-applications.html.
For further information about the equipment, please feel free to discuss your requirements with us, or contact us at sales@bartington.com.

DW CONSULTING

Boekweitakker 28, 3773 BX Barneveld, The Netherlands

www.dwconsulting.nl dwilbourn@dwconsulting.nl

DW Consulting is well known throughout the geophysical prospection community for our data processing software. We have 2 main products:

- **TerraSurveyor** software for processing 'flat' or 2D data such as that produced by magnetometers or resistivity meters
- **TerraSurveyor3D** software for processing 3 dimensional data with a specific emphasis on data from downhole cores.

This year sees the introduction of a new, hardware based product:
TerraLogger

This provides a complete kit to add field datalogging capabilities to any Bartington MS-2 & MS-3 magnetic susceptibility meter.

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 properties. We offer one of the largest short term Geophysical Instrumentation rental pools in Europe and pride ourselves on our commitment to unbeatable service for our customers.

Rental pool Items for Archaeological Prospection:

Caesium Vapour and Fluxgate Gradiometer systems; including 6 Geometrics G-858 Cs vapour and 2 Bartington 601-2 Fluxgate gradiometers.

Resistance and Resistivity instruments; Geoscan Research RM85 Advanced; the system offers an internal multiplexer and integrated GPS logging function. The RM85 is accompanied by the PA20 (supplied with a 0.5m, 1m and 1.5m beam) or with shallow sounding accessories. Multiple ERT systems are also available with RES2DINV inversion software.

Ground Penetrating Radar systems; Offering two 8 channel GPR controllers with a variety of antenna (from 250MHz- 4 GHz), and the newly released multi frequency Trivue system!

EM Conductivity instruments; featuring two Geonics EM38MK2, two EM31MK2 & a GF Instruments CMD. These instruments are suitable for electrical conductivity mapping and the identification of buried metallic objects

On show at this event- The KT20 with new 3F-32 field coil.

The KT-20 is a flexible handheld tool for soil science. With a variety of interchangeable multi frequency coils the KT-20 is capable of measuring Magnetic Susceptibility, Conductivity/ Resistivity, Induced Polarisation and Geospatial Positions.

Contact sales@geomatrix.co.uk for further information.

NSGG Near-Surface Geophysics Group

Historic England

GEOSCAN RESEARCH Celebrating 30 Years 1984 - 2014

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 professional and amateur archaeological use. Our products are also used in environmental, forensics, geological, civil engineering and peace-time military applications.

The product range comprises earth resistance meters, fluxgate gradiometers, mobile sensor platforms and associated Geoplot 4.0 computer software. Our products are low cost, user-friendly, light-weight and have proven reliability.

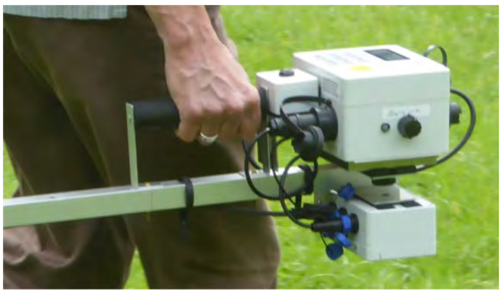
Coming soon - RM85 / FAB1 Gradiometer Data Logging System

The versatile RM85 resistance meter system has proved to be popular over the last few years, giving users the choice of probe array (PA20) or cart based (MSP25) measurements.

That versatility is soon to be expanded further by letting users convert their resistance meter into a handheld fluxgate gradiometer with the addition of a FAB1 (Fluxgate Adapter Box 1), carrying frame and SENSYS FGM650 fluxgate sensor. In addition, a FAB1 and FGM650 can also be mounted on an MSP25 cart to add gradiometer logging to the resistance measurements. GPS data can also be simultaneously logged if required.

The RM85 then becomes a 3-in-1 instrument reducing ownership costs and offering extra flexibility: resistance - probe mode data logging (Twin, Wenener etc.), resistance - wheel mode data logging (Square array for rapid area coverage) and gradiometer data logging.

The FAB1 acts as an interface for the output of a SENSYS FGM650 fluxgate gradiometer to the RM85. The FAB1 is powered by a user supplied power bank fitted inside. It can be programmed via an RM85 menu for gradiometer operation (averaging for noise reduction, resolution, GPS baud rates etc). Measurements can be made with a handheld system or MSP25 cart system.



Handheld Gradiometer Mode

For use as a handheld gradiometer, a BASIC or ADVANCED RM85 is mounted on an aluminium CF51 carrying frame with the FAB1 positioned underneath the meter and a SENSYS FGM650 held vertically at the opposite end of the frame. The CF51 has an integral Start/Stop switch mounted next to the carrying handle which initiates data collection; data collection rate is controlled by an internal timer. The switch can also be operated using the thumb of the carrying hand. On more challenging terrains, the switch unit can be removed and can be used as a separate hand-log trigger by adding an optional extension lead. In handheld gradiometer mode RM85 battery life is extended by about 5 hours to 12 hours total since circuitry for resistance measurements can be powered down.

Gradiometer Measurements with the MSP25 Cart

In this mode an ADVANCED RM85 / EPIB1 / MSP25 collects high resolution square array resistance data as usual from the wheeled system but, with the addition of an FAB1, the RM85 can also collect gradiometer data. The FAB1 is mounted on the MSP25 main platform and a gradiometer mounting frame is fitted to support the SENSYS FGM650 sensor tube which is cushioned against vibration. (The configuration shown here also has an FM256 collecting data independently from the RM85).

GPS

GPS data can be logged simultaneously with the gradiometer and resistance data. The GPS unit connects to a FAB1 RS232 port when gradiometer data is being collected. The GPS unit should have an update rate of 10-20 Hz for optimum data sampling. GPS logging is only available with an RM85 that has the GPS logging option fitted. The GPS unit should have a small magnetic signature when used with the handheld system but is not so critical for MSP25 systems.

Twitter

Keep up to date with developments by following us on Twitter: @GeoscanResearch

Although the name Guideline Geo may not be familiar to you, hopefully the brands it has brought together will be. MALÅ and ABEM have been producing high quality innovative geophysical equipment since the first half of the 20th century and now, under the Guideline banner, they can operate as one company, able to offer reliable solutions for a wide range of applications from high resolution investigation of an individual feature to the mapping of entire landscapes.

MALÅ

MALÅ grew out of the Swedish Geological Unit, who introduced the first electromagnetic loop system for ore detection. MALÅ has come a long way since then and now the range of products runs from 25MHz unshielded antennas for landscape-scale studies, through versatile single and multi-channel shielded systems up to high frequency (up to 2.3GHz) handheld antennas for investigation of buildings and individual features.

Fig. 1: MALÅ MIRA multichannel 3D GPR array (16channel, 450MHz version) with total station mast.

MALÅ has supported a number of high profile archaeological institutions including the Ludwig Boltzmann Institute, the University of Bradford, Channel 4's Time Team and is also a trusted partner to numerous commercial operators.

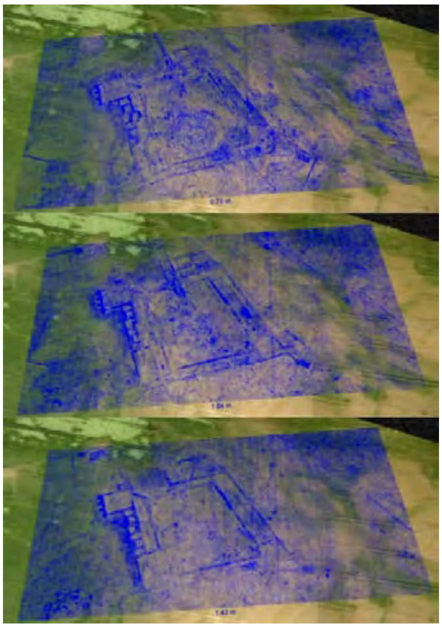


Fig. 2: MALÅ GPR data from over a Gladiator training camp (courtesy of Ludwig Boltzmann Institute).

The introduction of HDR (High Dynamic Range) antennas in early 2014 delivered significant improvements in both penetration and resolution over their forerunners. In fact, the improvement in performance is such that, in side-by-side comparisons, the HDR antennas challenge the output of more expensive dual frequency systems. This improvement in resolution and penetration means that the MALÅ EasyLocator Pro HDR (450MHz) is now not simply a tool for utility mapping but an attractive and capable entry-level instrument for many archaeological groups.

ABEM

Formed in 1923, ABEM has an unparalleled history of geophysical equipment manufacture. The product range comprises electrical resistivity, seismic and time-domain electromagnetic instruments. All systems are stand-alone units with large daylight visible colour screens and no requirement for an external PC. Impressive ingress protection ratings, even during data collection, intuitive user-interfaces, on-board GPS and market-leading specifications make the range ideal for commercial, research and teaching purposes.

Fig. 3: ABEM Terraloc Pro seismograph mapping upland peat deposits.

The latest incarnation of the Terrameter LS resistivity meter, released in autumn 2016, has added an innovative licensing system to what was already a powerful yet compact survey tool. This offers customers the option to buy a cost-effective entry-level instrument which can be upgraded to a full-functioning sophisticated system (or any stage between) through a simple product code update, either online or via USB. Upgrades can be permanent or time-limited if the extra capabilities are required only for a specific project. Early next year will see the implementation of 3G connectivity and an innovative 100% duty cycle method of Induced Polarisation survey (there is no ‘current off’ time in the measurement cycle) thereby greatly increasing the speed at which IP data can be collected.

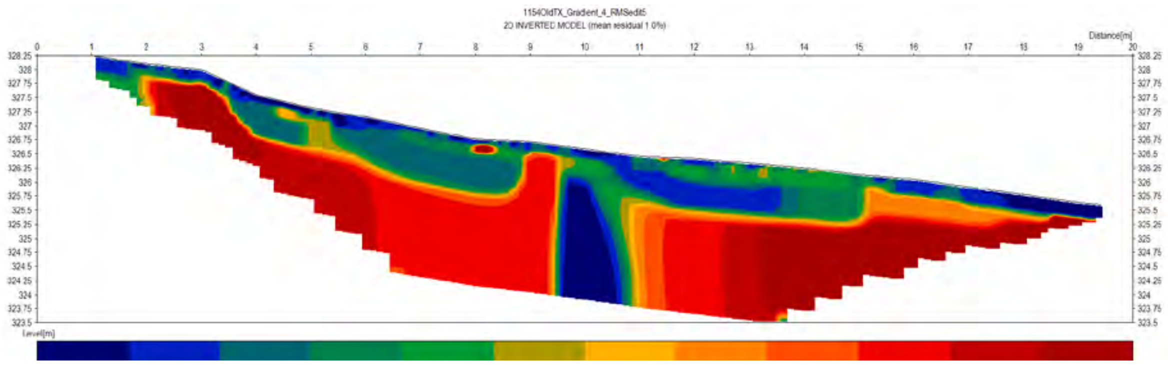


Fig. 4: ABEM Terrameter LS resistivity survey over the site of historical mining works.

Come and see us in the Library if you wish to learn more about any of our products or discuss potential solutions for your upcoming projects.

SENSYS SENSORIK & SYSTEMTECHNOLOGIE GMBH

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T: +49 (33631) 59650, F: +49 (33631) 59652

www.sensysmagnetometer.com info@sensys.de

Magnetic and electromagnetic systems for large area surveys

The demand for a faster non-invasive evaluation of large areas before excavation is constantly growing. Thus SENSYS tailored its geomagnetic push cart and vehicle towed survey systems to archaeological requirements, supporting the decision making process for any excavation planning.

These systems have been used amongst others to survey 284 ha around Stonehenge, UK (see Figure 1). A multitude of archaeological settlements have been revealed by using SENSYS systems for example the Bronze Age Settlements in Vrable, Slovakia (see Figure 2).

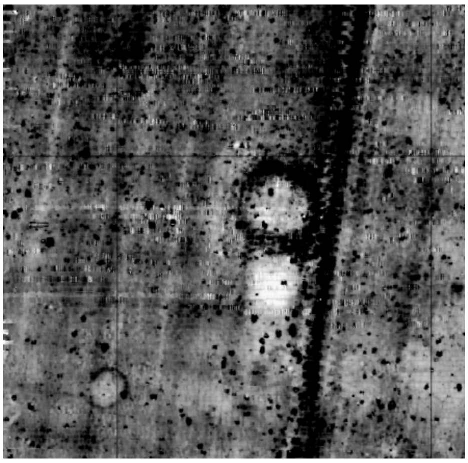

Fig. 1: Various barrows near Stonehenge, UK located with the electromagnetic system AMOS.

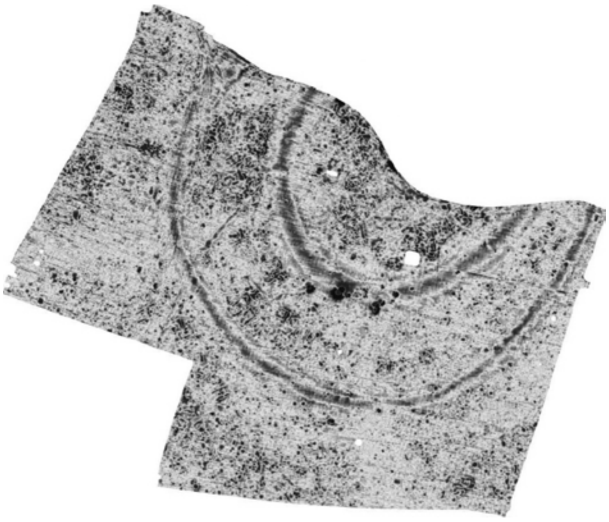

Fig. 2: Bronze Age Settlement in Vrable, Slovakia located with the vehicle towed system MAGNETO®

Improving archaeological measurement for more than 25 years

Since 1990, SENSYS has been developing and producing Fluxgate magnetometers and TDEM measurement systems at its German premises close to Berlin. SENSYS products range from hand held devices, push cart multi channel systems (called MXPDA) and vehicle towed multi-channel systems (MX V3), as well as underwater and offshore racks (SEARACK) or UAV based ultra light weight survey solutions (MagDrone II).

SENSYS focuses on being in charge of all components – frames, probes, data loggers, cabling and software. The growing group of clients includes the DAI (Deutsches Archäologisches Institut), IMS Forth, National Institutes in Hungary, Denmark, many German Universities as well as commercial customers across Europe. SENSYS systems are already used around the globe and just recently in Greece, the United States, Israel, Mongolia, etc.

THE BRITISH ISLES CONTINUOUS GNSS FACILITY

http://www.bigf.ac.uk

BIGF: since 1998, the national archive for GNSS data continuously recorded by currently around 150 permanent reference stations, sited throughout mainland Britain, Northern Ireland and Ireland

If you use DGPS or RTK GPS in the field, then you should know that BIGF is a resource for you.

GEEP geophysics platform, equipped with GPS and four caesium magnetometers, working at a gravel quarry.

GPR acquisition (Image credit NERC GEF).

Stonehenge Riverside Project.

BIGF supports a wide range of archaeological research e.g.:

A multi-dimensional geophysical approach to the study of buried ecclesiastical remains.

Archaeological assessment of Dartmoor peat.

Archaeological landscape appraisal using geophysics, of Windwick Bay, South Ronaldsway.

Archaeological research and training excavation of a Neolithic site.

Archaeological survey around a known Romano-British site.

Cirencester Abbey test GPR survey.

Estuary development during the mid-late Holocene response to relative sea level and climate change, in the Taw Estuary.

Geomorphological history of Studland, Dorset.

Geo-referencing GPR and gradiometry surveys of the Knowe of Swandro, Orkney Islands.

Stonehenge Riverside Project.

BIGF is funded by the Natural Environment Research Council, and operated by the The University of Nottingham. GNSS data are supplied free of charge to BIGF by these collaborators: Environment Agency; Land and Property Services Northern Ireland; Leica Geosystems Ltd; Met Office; NERC British Geological Survey; NERC National Oceanography Centre (Liverpool); NERC Space Geodesy Facility; Newcastle University; Ordnance Survey of Great Britain; Ordnance Survey Ireland; University of Hertfordshire and The University of Nottingham.

NSGG Field Equipment Exhibition
May 11th 2017
10 am – 4 pm

The NSGG field exhibition is a biennial event which gives geoscientist the opportunity to get hands on with geophysical equipment in the environment they were intended to be used.

It is a great opportunity to get hands on with the latest instrumentation, provide feedback and ask questions.

Held at the NSGG Geophysical Test Site in Leicester, SK 629 016, the venue consists of various near surface geophysical targets for delegates to survey with the equipment on show.

Pervious exhibitors:

allied Associates Geophysical Limited	Bartington Instruments	FOERSTER	Geomatrix Earth Science Ltd	GEOSOFT
DW Consulting	GEOSCAN RESEARCH	GuidelineGeo ABEM MALÅ	SENSYS Sensorik & Systemtechnologie GmbH	Utsi Electronics

For further information contact Matt Guy
Tel: 01525 383438 ; Email: matt@geomatrix.co.uk
http://www.nsgg.org.uk/meetings/

FORTHCOMING NSGG EVENTS IN 2017

Geophysics Field Exhibition & Demonstration: NSGG Test site, University of Leicester, 11/05/2017 – see flier on preceding page.

Research in Progress meeting: to be confirmed but possibly attached to the above event.

Please check the NSGG website meetings page for further details as these develop: http://www.nsgg.org.uk/meetings/

OTHER CONFERENCES OF INTEREST IN 2017

The 12th International Conference on Archaeological Prospection will be hosted by the School of Archaeological Sciences at the University of Bradford, UK, between the 12th and 16th September 2017.
http://www.ap2017.brad-vis.com/

ACKNOWLEDGEMENTS

I am grateful to Abigail Marsh of the Historic England (HE) Research Group Business Coordination Team for help with the organisation, especially editing this abstracts booklet; NSGG Treasurer, Tim Grossey, for his sterling efforts sorting out and running the online registration system; Jamie Pringle and Sam Toon for updating the meeting web pages on the NSGG and Geological Society websites; my colleagues Andy Payne and Neil Linford in the HE Geophysics Team for their assistance; and to HE itself for funding the production of the abstracts booklet and for allowing us time to organise the meeting. Thanks are also due to Louise Dyer and staff at the Geological Society for help facilitating proceedings; and to Chris Leech and the NSGG committee for advice as plans have taken shape. I and the NSGG committee also thank the International Society for Archaeological Prospection for their collaboration in the event including funding for a poster prize and student bursaries.

Finally thanks to all our presenters and commercial exhibitors for their contributions which made the meeting possible as well as to everyone who has attended and participated in an extremely successful event.