	<p><b>Recent Work in Archaeological Geophysics</b></p> <p><b>The Geological Society</b>  <b>Burlington House, Piccadilly, London W1J 0BG</b>  <b>Tuesday 4<sup>th</sup> December 2018</b></p> <p><b>Programme</b></p>
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## Lecture Programme:

- |                  |  |
|------------------|--|
| 0915-0950        | <b>Registration and Coffee</b>   |
| 0950-0955        | <b>Introduction</b>  |
| <b>Session 1</b> | <b><i>Towns: From Uruk to Kathmandu</i></b>  |
| 0955-1010        | <i>Uruk (Iraq) Magnetometry in the First Megacity of Mesopotamia.</i> J W E Fassbinder, S Ostner, M Scheiblecker and M van Ess   |
| 1015-1030        | <i>Vlochos Archaeological Project: Investigating Urban Development Using Non-Invasive Techniques in Thessaly, Greece.</i> D Pitman, R Rönnlund, R Potter, L Shaw, M Vaiopoulou, H Whittaker, F Tsiouka, J Klange and J Hagan |
| 1035-1050        | <i>Geophysical Survey of the Sanctuary and Roman Town of Lucus Feroniae, Italy.</i> S Kay, S Hay, S Keay, C Smith, M Berry and E Maw   |
| 1055-1110        | <i>Seismic Safety in Nepal: Authenticity, Protection and Historic Tradition.</i> A Schmidt, R Coningham, K Prasad Acharya, C Davis and R Bahadur Kunwar  |
| 1115-1145        | <b>Tea/Coffee break</b>  |
| <b>Session 2</b> | <b><i>The Recent past: ceilings to tunnels</i></b>   |
| 1145-1200        | <i>Real-Time GPR Evaluation for Cultural Heritage Preservation.</i> P Barone and C Ferrara   |
| 1205-1220        | <i>Integrative Interpretation of Gravity, Resistivity and GPR Data Over Foundations of Elsecar Gasworks, Barnsley, UK.</i> S Frandsen, A Booth, C Green, T Roberts, J Mound and J Gater                                      |

- 1225-1240 *Sensing Fort St-Pierre: Complementary Geophysical Survey of a 17th Century Fur Trade Post in Atlantic Canada.* J Fowler
- 1245-1300 *"It Had Been a Good Sport" The Discovery of a German PoW Escape Tunnel in Bridgend, South Wales.* L Rees-Hughes, J K Pringle, N Russill, K D Wisniewski and P Doyle
- 1305-1310 **Morning closing remarks**
- 1310-1430 **Lunch (Lower Library) – all delegates**  
**NSGG AGM (Lecture Theatre) – all welcome**
- Session 3** ***Reassessing what we know***
- 1440-1455 *The Fort in the Forest: Re-visiting Buckland Rings hillfort 25 years after its first survey.* L Shaw, J Brown, J Hagan, A Green, B Howard and J Monteith
- 1500-1515 *The Temple or Room? The Interpretation of the Frampton Roman Temple/Villa Site in the Light of Recent Geophysical Survey Results.* P Cheetham, M Russell and D Stewart
- 1520-1535 *Anomalies Don't Grow On Trees. Challenges and Results of Non-Destructive Archaeological Survey in Białowieża Forest.* M Pisz and R Zapłata
- 1540-1555 *Chasing a Drain and Finding Monks: Recent Investigations at Fountains Abbey.* C Gaffney, C Harris, M Langton, H McCreary, M Newman, T Sparrow and R Walker
- 1600-1630 **Tea/Coffee break**
- Session 4** ***Context and community***
- 1630-1645 *Broughton Roman Villa, Oxfordshire: A Wider View.* R Ainslie
- 1650-1705 *Cwmystwyth: Bronze Age Mining Hiding in the Welsh Mountains.* A Roseveare, M Roseveare and S Timberlake
- 1710-1725 *Geophysical Survey and Community Archaeology- Some Successes and Some Failures.* J Lyall
- 1730-1740 **Conclusion**
- 1745-1900 **ISAP AGM (Lecture Theatre)**

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

*Geophysical Investigations of WW2 Air-Raid Shelters in the UK.* J Ainsworth, J K Pringle, P Doyle, M Stringfellow, D Roberts, I Stimpson, K Wisniewski and J Goodwin

*Aerial, Pedestrian and Geophysical Prospection in the Cantabrian Mountains: Early Results from the 'Upland Archaeology Project in NW Iberia'.* K Armstrong and D González-Álvarez

*3D GPR of a Roman Bath House at Castle Hill, Lancaster.* G Blanchy, P McLachan, M Tao, M Tso, M Tabaro, J Ball and A Binley

*Multi-Disciplinary Geophysical Investigations into the 19th-Century Trentham Mausoleum, Stoke-on-Trent UK: Bodily Evidence of a Victorian Scandal?* L G Foster, J K Pringle, I G Stimpson, B Davenward, P Styles, K D Wisniewski and J Goodwin

*Over the Top, Under the Ground: Geophysical Survey at Birr Barracks, Crinkill, Co. Offaly.* A Green

*Discriminating Saxon Shield Boss From Unexploded Ordinance By Advanced Time Domain Electromagnetics: An Evaluation Study.* M Guy, P Linford and D Mortimer

*A Multidisciplinary Investigation to Discern Subsurface Features Evident in and Around Hawthorn Crater with Resulting Implications.* R Hunter, J Wisniewski, K Squires, A Robertshaw, J P Cassella, D Wright, N Lamont, F Graham, P Ottey, J Partridge and J Pringle

*Rediscovery of a Baroque Palace in Bavaria by Multi-Disciplinary Archaeological Prospection.* R Linck and J W E Fassbinder

*Mapping Verulamium.* K Lockyear

*What can we do with Red, Green, and Blue? Interpreting drone data from the West Green at Fountains Abbey.* H McCreary, T Sparrow, C Gaffney, A Wilson and M Newman

*A Possible Inlet Feature at a Roman Port: Using ERT and EMI to Characterise Quay Meadow, Lancaster.* P McLachlan, G Blanchy, M Tao, M Tso, A Binley, M Tabaro and J Ball

*Geophysics with a Lid On.* J Oswin and R Buettner

*A Tale of Two Hilltops.* J Oswin, R Buettner, J Pryke and F Medland

*Cwmystwyth: Bronze Age Mining Hiding in the Welsh Mountains.* A Roseveare, M Roseveare and S Timberlake

*Electromagnetics (EM) as a Reconnaissance Tool in Defining Sites for Conflict Archaeology.* A Ruffell, C Graham, K Lilley, P McCarthy and J McNee

*Pressing Wine In Iron Age Lebanon: Investigating Wine Presses At Tell El-Burak.* M Scheiblecker, A W Schmitt, H Gries and H S Sader

*Medieval Lowland Castles (Niederungsburgen) in Lower Saxony – Augmented Knowledge by Geophysical Prospection.* C Schweitzer

*LoCATE - The Local Community Archaeological Training and Equipment Project.* K Welham, P Cheetham, L Shaw and M Gill

*Geophysical Reassessment of Scheduled Roman Villas.* P Linford, N Linford and A Payne

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

Bartington Instruments Ltd

GuidelineGeo

DW Consulting

Sensors & Software

Geomatrix Ltd

Sensys GmbH (4<sup>th</sup> Dec only)

Geoscan Research Ltd (4<sup>th</sup> Dec only)

## DEDICATION



This booklet is dedicated to Professor Irwin Scollar who celebrated his 90<sup>th</sup> Birthday in November 2018. Over the course of his career Professor Scollar has had profound influence on archaeological geophysics and aerial archaeology contributing many remarkable innovations as well as the renowned book *Archaeological Prospecting and Remote Sensing* first published in 1990 and still in print today.

In honour of his 90<sup>th</sup> birthday members of the International Society of Archaeological Prospection have contributed reminiscences to a dedicated web page: <http://www.archprospection.org/prof-irwin-scollar> and these will also be published in a forthcoming issue of *ISAP News*.

## LECTURE ABSTRACTS

### URUK (IRAQ) MAGNETOMETRY IN THE FIRST MEGACITY OF MESOPOTAMIA

Jörg W.E. Fassbinder<sup>(1)</sup>, Sandra Ostner<sup>(1)</sup>, Marion Scheiblecker<sup>(1)</sup> and Margarete van Ess<sup>(2)</sup>

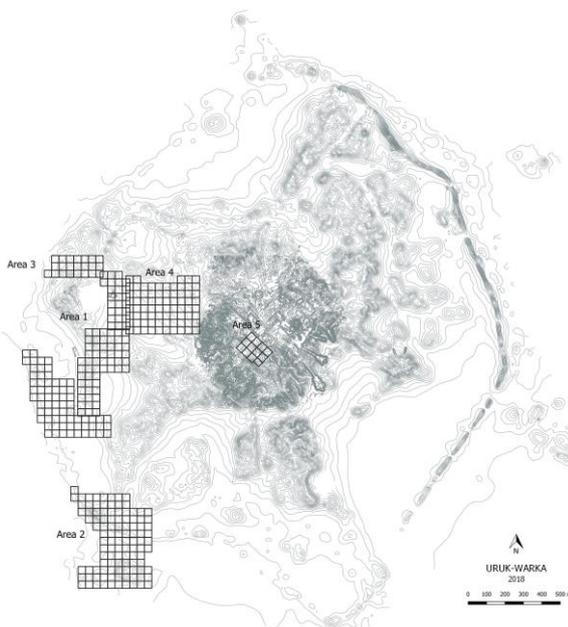
<sup>(1)</sup>Geophysics Department of Earth and Environmental Sciences Ludwig-Maximilians-University Munich, Germany <sup>(2)</sup> Deutsches Archäologisches Institut Orient-Abteilung Berlin, Germany

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Uruk is not only the oldest metropolis but also the scene of action of the oldest epic of humankind, the famous “Epic of Gilgamesh”. About 40,000 residents, on an area of ca. 5 sq. km, inhabited the city already in 3000 B.C. The diameter of the city is 4-5 km, the enclosing city wall has a length of ca. 11 km, but house constructions and temples are found outside the city wall. A network of waterways and canals cross the city from north to south which make the city quarters accessible but also provide water for the irrigation of gardens inside the enclosed city (Figure 1).



Figure 1: Uruk. Panorama view of the city centre with the Ziggurat



Magnetometer prospecting was initiated in 2001 and continued in 2002, resumed in 2016 and carried out for a larger area in 2018 (Figure 2). For the survey, we applied three different types of magnetometers: a caesium Scintrex Smartmag SM4G-special, the caesium Geometrics G-858G magnetometer, both applied as total field magnetometers in a so called duo-sensor configuration and a Foerster Ferex 4.032, fluxgate gradiometer in a so-called “quadro-sensor” configuration. The probes mounted on a frame and carried in zigzag-mode ca 30-40 cm above the ground.

Figure 2: Topographical map with the survey areas 2001-2018 (Margarete van Ess).

Ground conditions are that of a soft and muddy or dusty soil, similar to walking in a marsh in 20 cm deep fresh snow. Such conditions make it utterly impossible to use a wheeled system of any kind.

The magnetometer surveys focuses on the city of Uruk inside and close to the city wall and is supposed to be carried out in all accessible areas of the city. This excludes the central district of Uruk where settlement layers are only 10 to 20 cm high and follow one on top of the other in many levels. The geophysical survey was started in the south-western part of the city and focused on an area north of the Sinkashid Palace, a large canal passing this area in the east, the canal and its branches, a harbour and settlement area in the east of Sinkashid palace and a settlement area southwest of the palace. A second, large part of the city was measured at the southern city wall, bringing to light the structure of the city wall, gardens and fields close to it, technical installations for the large western canal and a huge building complex south of the city wall.

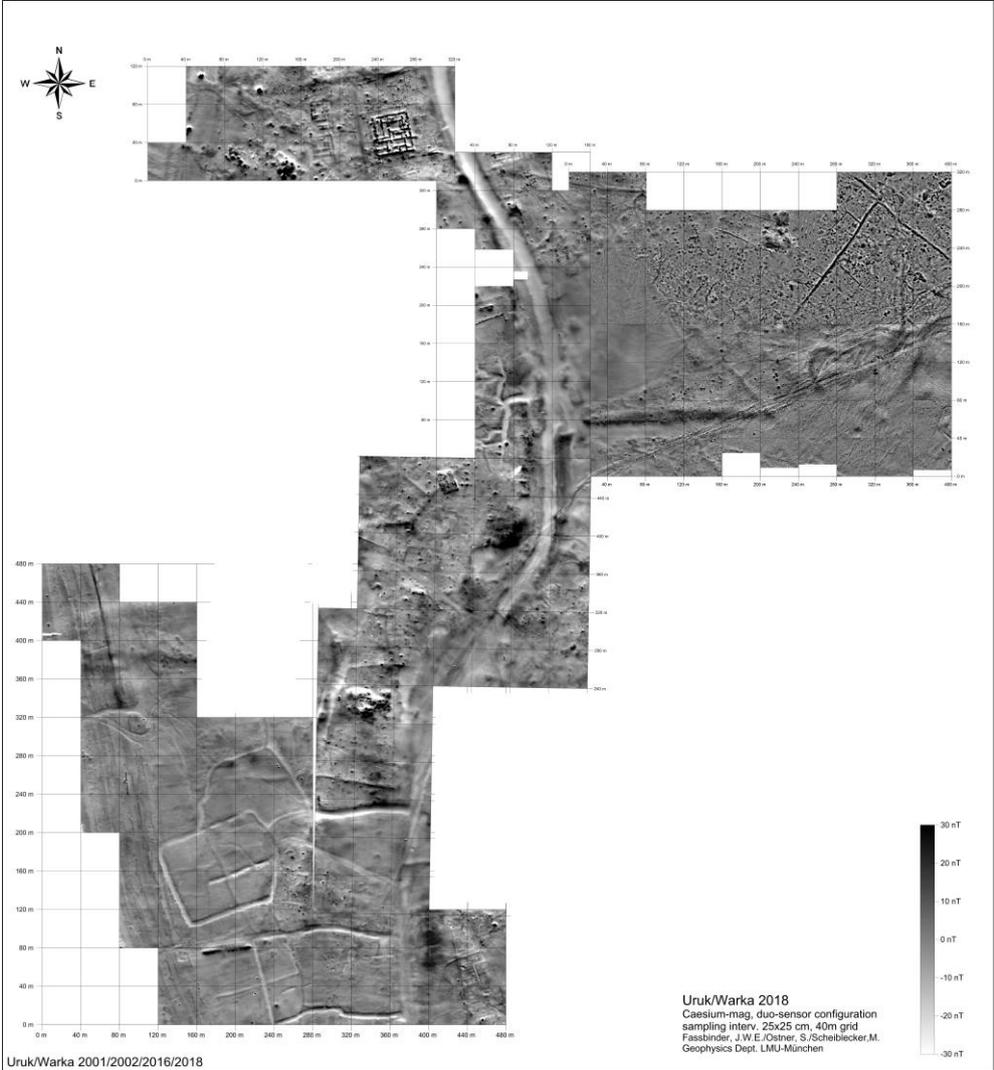


Figure 3: Magnetogram of the survey areas 1, 3 and 4.

In 2016, we investigated an area in the city centre to test the feasibility of magnetometer prospection of this part (Area 5). Here, between the district of the Eanna sanctuary and the Eshgal temple (Irigal) a large, almost square area that had never been studied archaeologically before.

Area 1 (Figure 3), gave insight into settlement areas, gardens and fields close to the city wall as well to the network of canals that obviously served as the main arteries of Uruk. The main canal we traced in the eastern part of the magnetogram throughout a length of 400 m. It is 10 m wide and, at several points, slightly smaller canals branch off to the west. Left and right of the canal are settlement areas, divided by the smaller canals that led to fields and gardens west of the settlement areas. Canals of three or four different widths, the smallest of them belonging to the field irrigation systems characterize the fields.

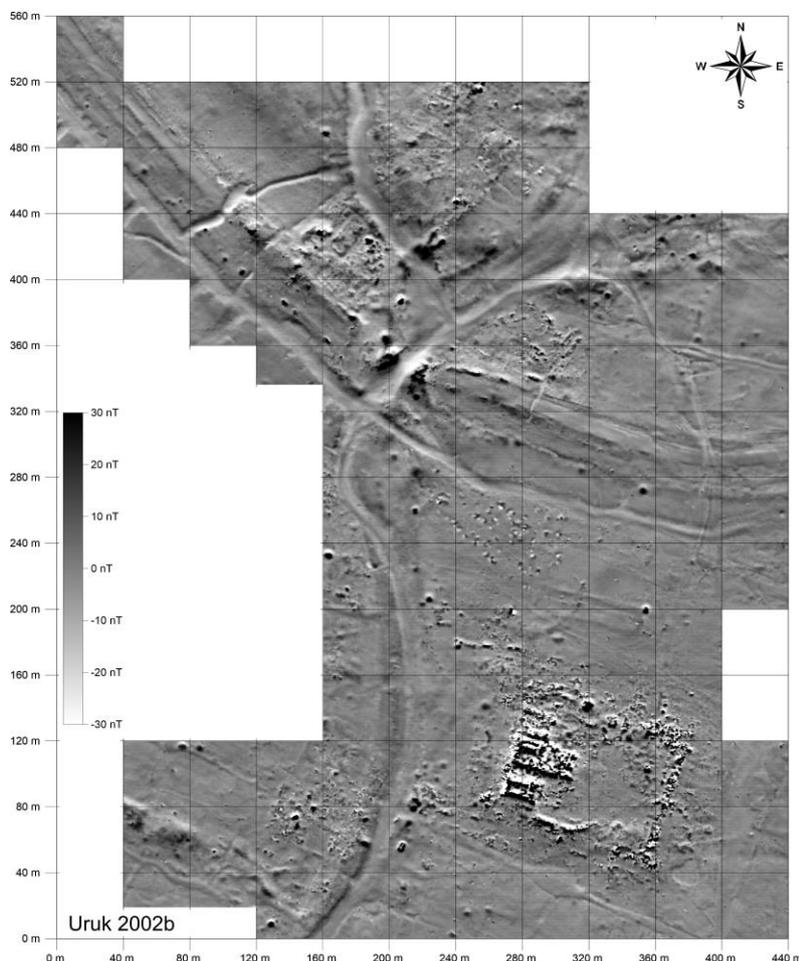


Figure 4: Magnetogram of Survey area 2.

In Area 2 (Figure 4), the city wall and a canal crossing the city wall can be seen. Here, the course of the city wall and at regular intervals its bastions known from previous excavations and documentation elsewhere in the city are clearly visible. The magnetogram moreover reveals that parts of the wall on its inner and outer faces are made of fired bricks, a detail that was not known before. It is also apparent that the wall was made up of more separate lines than were previously known, and that the

canal that circled the city ran just outside it. The entire wall complex was nearly 40 metres wide. The wall itself, with its inner and outer shells of fired bricks, is some 9 metres thick, an observation that corresponds to the excavation findings. Further details about Uruk's structure are provided by the magnetogram of the southwest gate of Area 2, which at nearly 15 metres wide can be interpreted as a floodgate where the inner city's large west and central canals flowed out through the wall. On the outside, the gate was flanked by towers and strengthened with fired brick (Figure 5). In front of the floodgate at a distance of 240 metres, a small side canal branches off to the southeast, expanding roughly midway in front of a large building of fired bricks into a small harbour-like structure.

Area 4 (Figure 3), is characterized by two different major features. In the south a large structure, running east – west seems to accompany canals north and south of it, that lead towards east, i.e. the city centre. Another, shorter and similar structure some metres to the west obviously blocks part of the main canal. None of these structures are visible in the field which is very flat in this part of the city. Without excavation, it will not be possible to determine the nature of these structures. However, they seem to control or guide the water flow and the canals. The area south of it and other areas north of it are characterized by flooded material that has been transported here from the northeast.

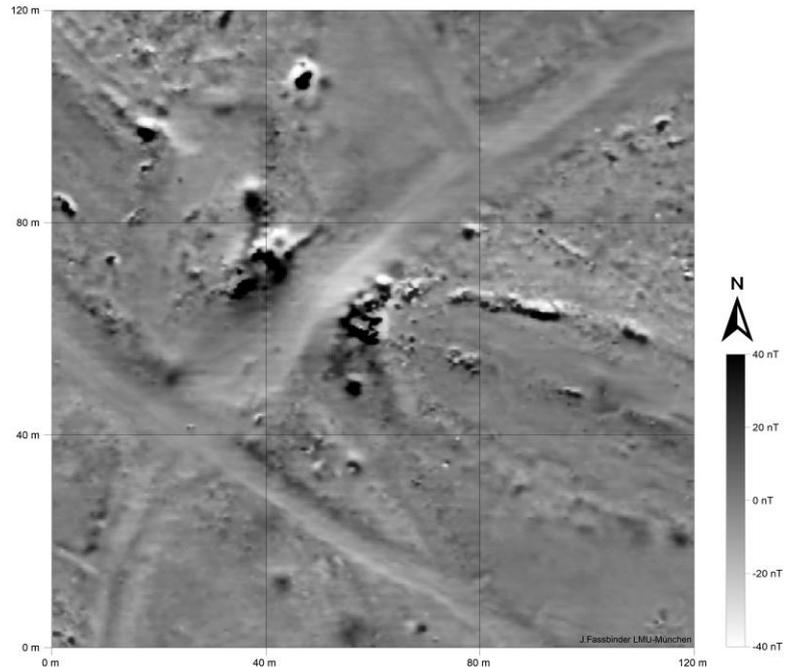


Figure 5: Magnetogram detail of the floodgate.

Detailed analysis of the magnetograms, the topographical information and the archaeological data available will possibly allow for closer insights into the development, the structure and the functions of the city, even without excavation. The magnetometer survey hopefully will be continued and will offer a comprehensive picture of the structure of Uruk through time.

## Bibliography

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Fassbinder, J.W.E., H. Becker, and M. von Ess (2005), Prospections magnétiques à Uruk (Warka). La cité, du roi Gilgamesh (Irak), *Dossiers Archéologie*, 308, 20-25.

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## VLOCHOS ARCHAEOLOGICAL PROJECT: INVESTIGATING URBAN DEVELOPMENT USING NON-INVASIVE TECHNIQUES IN THESSALY, GREECE

Derek Pitman<sup>(1)</sup>, Robin Rönnlund<sup>(2)</sup>, Rich Potter<sup>(2)</sup>, Lawrence Shaw<sup>(3)</sup>, Maria Vaiopoulou<sup>(4)</sup>, Heléne Whittaker<sup>(2)</sup>, Fotini Tsiouka<sup>(4)</sup>, Johan Klange<sup>(5)</sup> and Josephine Hagan<sup>(1)</sup>

<sup>(1)</sup> Bournemouth University, UK; <sup>(2)</sup> University of Gothenburg, Sweden; <sup>(3)</sup> New Forest National Park Authority, UK; <sup>(4)</sup> Ephorate of Antiquities of Karditsa, Greece; <sup>(5)</sup> Arkeologikonsult, Sweden.

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The archaeological site of Vlochós is located on and immediately below the hill of Strongilovoúni (313 masl) just south of the eponymous village in Thessaly, Greece. The Greek-Swedish collaboration ‘The Vlochos Archaeological Project’ (VLAP) was carried out between 2016 and 2018, with participating archaeologists and students from the Ephorate of Antiquities of Karditsa, the University of Gothenburg and Bournemouth University. The project was non-invasive, employing a wide range of methods in surveying the site, including surface survey of standing architectural remains, topographical surveying and geophysical prospection.

During a total of seven weeks of fieldwork, 6 km of fortification walls and terraces were recorded and 13 hectares of ground were surveyed using fluxgate gradiometry. An additional 2.6 hectares of ground were surveyed using ground-penetrating radar (GPR), aiming at providing high-resolution “windows” into the buried remains on site. Most of the site surface was also photographed by a drone, providing the project with high-resolution vertical images of all visible remains. The photographs have been combined into a site-encompassing aerial mosaic, but also into a photogrammetric 3D model.

The work presented here focuses on the gradiometer survey that revealed an extensive urban layout that featured multiple phases of construction (Figure 1). Some of these can be dated confidently on the basis of stylistic elements and surface material, whereas some can only be chronologically positioned in relation to the others.

The extensive gradiometry, executed using a Bartington Grad601-2 gradiometer, covered a low plateau at the base of the fortified hill. The plateau is bounded to the north by the hill and to the south by a river. While some standing remains are visible, the area is largely covered by a layer of sediment and erosion deposits. This survey clearly revealed buried architecture, identified by low magnetic linear features, and areas of magnetic enrichment. In comparing this data with similar, excavated sites it is possible to postulate about the likely character of responses. Clear built structures are visible, some of which corresponding to Ancient Greek forms such as domestic houses, agorai, temples and stoai. Additionally, areas of magnetic enrichment focus on spaces between buildings and likely represent the remains of streets and avenues. Clear phasing can be seen in the differential orientation of street layouts and of some of the defensive structures.



Figure 1: Gradiometric image of the ancient settlement area at Vlochós

The image in Figure 1 can clearly be divided into two phases, one which corresponds to the preserved late Classical and Hellenistic fortifications (mid-4<sup>th</sup> to early 2<sup>nd</sup> century BCE) and another that seemingly occurred later, most likely Late Roman (mid-6<sup>th</sup> century CE). Within the late Classical-Hellenistic phase there is a clear central avenue, running southeast-northwest, with numerous perpendicular streets that demarcate habitation blocks and other civic structures. The later phase of fortification shows hints of truncation of the earlier layout, most notably in the area immediately adjacent to the later wall. In addition, both phases include numerous entrances and towers that can be seen in the interpretations (Figure 2).

A central tenet of the project is the incorporation of multiple non-invasive approaches. When the geophysical evidence is incorporated with the other techniques it becomes possible to propose a preliminary phase schema for the site.

### Summary of Proposed Phases

The earliest phase on the site, identified largely through the survey of standing architecture, consists of a large fortified enceinte, 1.3 km in circumference, encircling an 11 hectare area on the hilltop. The walls of this fortification are preserved to a varying degree, but exceed at places over 2.5 m in height and range between 2.8-3.6 m in width. The wall trace is gently curving along the topography containing no towers, and is constructed in a mix of uncut stones and slightly tooled large blocks. One large tangential gate in the south-west part of the fortification, 11.8 m wide and with an opening of 3.4 m, constitute the only securely identified entrance to the enceinte. A second gate of similar construction was most probably located at the south-east part of the enceinte, but later building activities have nearly obliterated it. In the eastern slope immediately below the fortification wall are the poorly preserved remains of a bastion-like feature, shaped like a semi-hexagon. The function of this feature cannot be identified at present.



Figure 2: Interpretation of gradiometric results.

The second phase at Vlochós can firmly be dated to the late Classical and Hellenistic periods. At this time, an ambitious building programme was initiated, dominated by the construction of a circuit wall, originally ca 3 km in length, supported by towers and jogs at regular intervals. In the area at the base of the hill very little of this phase remains above ground and this was largely the focus of geophysical investigation. A cross-wall of 550 m separated the fortified summit from the area of settlement, running along the slope below the hilltop containing four posterns. Two, possibly three, large gates lead into the settlement at the foot of the hill, one tangential in east, one of the courtyard type in south and possibly one indiscernible in the west.

The third phase of the site's use was identified primarily through the gradiometry survey. It is located within the eastern sector of the flat area south of the hill, but does not respect the outline of the latter, completing a 530 m semi-circular bow from the northeast corner of the Classical-Hellenistic settlement towards southwest. This fortification contained 19 towers, evenly spaced out 20-25 m from one another, with one gate in close to the southwest corner. Several larger structures within the fortification can be identified as belonging to this phase based on their non-alignment with the Classical-Hellenistic street grid, but it appears that this third phase settlement was not densely built up inside the walls.

The fourth and final phase at Vlochós is highly fragmentary. It is mostly discernible as an extensive repair in stone and mortar of the second phase fortification wall on the southeast slope of the hill.

## GEOPHYSICAL SURVEY OF THE SANCTUARY AND ROMAN TOWN OF LUCUS FERONIAE, ITALY

Stephen Kay<sup>(1)</sup>, Sophie Hay<sup>(2)</sup>, Simon Keay<sup>(3)</sup>, Christopher Smith<sup>(4)</sup> Matthew Berry<sup>(1)</sup> and Eleanor Maw<sup>(1)</sup>;

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Since 1997 the British School at Rome, together with several UK partners, has investigated through geophysical techniques a series of Roman towns in the Tiber Valley (central Italy), from Otricoli in the north to Portus at the mouth of the river Tiber. These results have served to improve our understanding of the urban development of these cities which lay close to Rome and were immediately affected by its expansion.

### The site

The town of Lucus Feroniae, brought to light in the late 1950s during the construction of the motorway between Rome and Florence, lies 27km north of Rome, close to the important communications route of the River Tiber and on the Via Tiberina. Initial archaeological research following its discovery principally focused on the public buildings and monuments, including the forum, amphitheatre and sanctuary whereas little is understood of the extent of the town.

The site takes its name from a sacred grove dedicated to the goddess Feronia. Whilst there may have been some cult activity on the site from the 8<sup>th</sup> century BC, the monumental phase began in the 4<sup>th</sup> century BC as the sanctuary grew to become an important religious centre, frequented not only by Faliscans, but by Etruscans, Latins and Sabines.

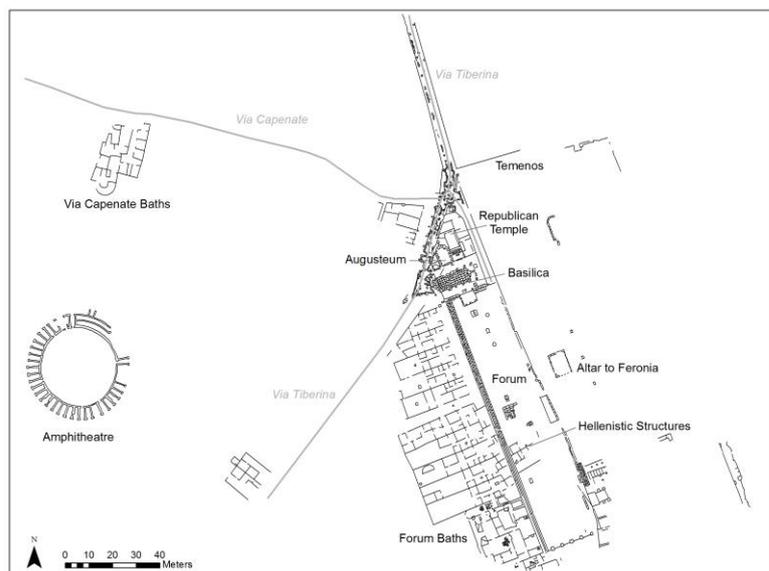


Figure 6: Plan of the known buildings of Lucus Feroniae

The sanctuary was later sacked and almost completely destroyed by Hannibal in 211 BC but was reconstructed between 130 - 110 BC by *Cn. Egnatius* only to be destroyed again in the Sullan age. A new colony was established in the late 1st century BC – the *Colonia Iulia Felix Lucus Feroniae* – and in the age of Augustus the site saw further expansion and construction.

## The geophysical survey

The survey covered an area of approximately 12.5 hectares using Bartington Fluxgate Gradiometers with a traverse interval of 0.5m and data collection at 0.25m. Subsequently, on the basis of the gradiometry results, a Ground-Penetrating Radar (GPR) survey was conducted in 3 areas with the aim of providing further detail to a complex series of features. Using a GSSI 400MHz single antenna, 588 profiles were recorded with a parallel traverse interval of 0.25m, for a total length of 29.6km.

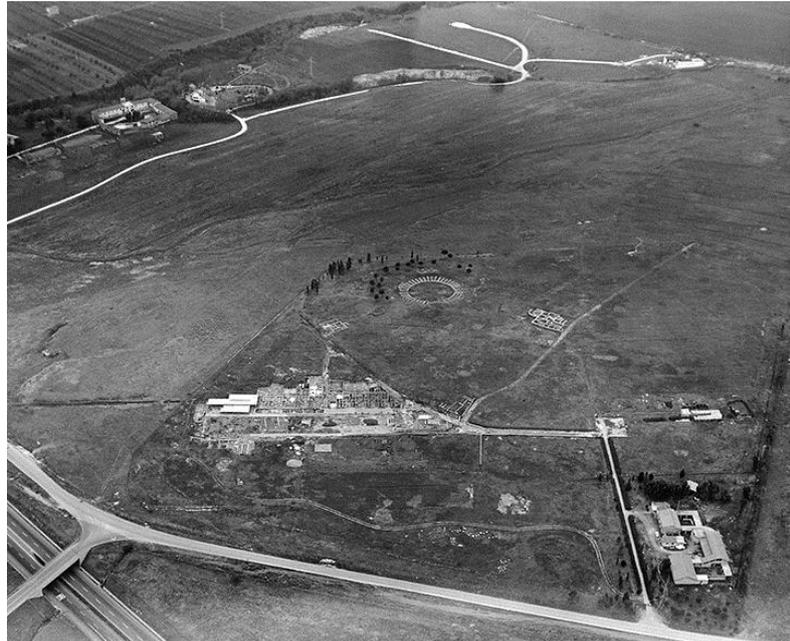


Figure 2: Aerial photograph of Lucus Feroniae

## Results

The geophysical prospection at Lucus Feroniae has provided significant new information about the Roman town and the sanctuary. Starting with a series of isolated structures, the gradiometry survey was successful in mapping a range of buildings and roads which have shown how the town was focused around the forum and the two major thoroughfares, the Via Capenate and the Via Tiberina, rather than a regular spread of insula blocks as seen elsewhere (such as at Falerii Novi, 35km to the northwest).

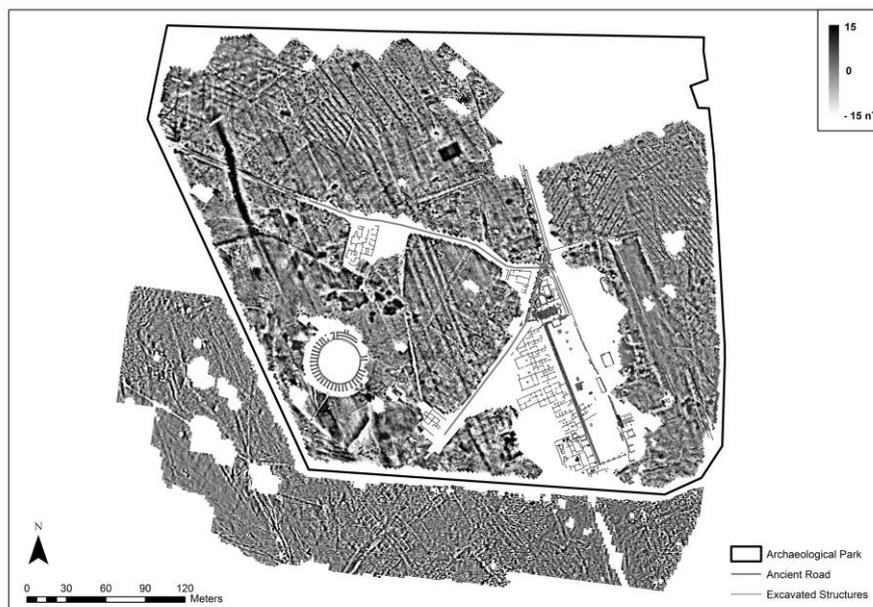


Figure 3: Magnetometer survey results from Lucus Feroniae

East of the forum and altar to Feronia the survey recorded a series of regular parallel anomalies 5 metres apart together with a series of circular features one metre in width and at intervals of 6m. The travertine bedrock is shallow in this area, suggesting that these are a series of features, perhaps for plants, that were cut into the bedrock.

Elsewhere the gradiometry revealed that the small circular amphitheatre, with an estimated capacity of 5,000 spectators, was reasonably isolated with few structures built within the immediate vicinity, whereas the later baths (along the via Capenate) reflected a trend of buildings facing directly on to the principal two roads.

The gradiometry survey immediately outside of the archaeological park to the south had revealed that the settlement continued southwards towards the edge of the plateau where recent excavations had identified a number of tombs cut into the bedrock. The complexity of the results indicated a dense area of occupation that followed the route of the Via Tiberina out of the city.

A central section of the gradiometry survey was subsequently investigated with GPR to clarify the numerous features. A regular grid of data collected over an area of 143m by 60m revealed several buildings along the principal road, behind which were several long parallel anomalies perhaps relating to land division.

### **Summary**

The geophysical survey at Lucus Feroniae forms part of a long-term study led by the BSR into forms of Roman urbanism in central Italy. The results of many surveys have illustrated the close connection between the topographical nature of the location of the sites and the urban form of the towns. The results have also indicated the importance of the role of small centres, rather than towns, that performed an administrative role within the landscape. For further details about the geophysical research programme of the BSR see [www.bsr.ac.uk](http://www.bsr.ac.uk)

### **Acknowledgments**

The authors are grateful for the support of the Soprintendenza Archeologia del Lazio e dell' Etruria Meridionale and in particular Dr. Gianfranco Gazzetti and Dr. Enrico Stanco. The research was funded by the Roger DeHann Foundation.

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Russo, A., Ghini, G. and Caretta, L. 2016 Lucus Feroniae. Il santuario, la città, il territorio. Scienze e lettere, Rome.

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## SEISMIC SAFETY IN NEPAL: AUTHENTICITY, PROTECTION AND HISTORIC TRADITION

Armin Schmidt<sup>(1)</sup>, Robin Coningham<sup>(2)</sup>, Kosh Prasad Acharya<sup>(3)</sup>, Chris Davis<sup>(2)</sup> and Ram Bahadur Kunwar<sup>(4)</sup>

<sup>(1)</sup>*Dr Armin Schmidt – GeodataWIZ, Remagen, Germany;* <sup>(2)</sup>*UNESCO Chair, Durham University, Durham, UK;* <sup>(3)</sup>*Pashupati Area Development Trust, Kathmandu, Nepal;* <sup>(4)</sup>*Department of Archaeology, Government of Nepal, Kathmandu, Nepal.*

[A.Schmidt@GeodataWIZ.com](mailto:A.Schmidt@GeodataWIZ.com)

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In 2015, the Gorkha earthquake in Nepal killed nearly 9000 people and destroyed 500,000 buildings, including 691 historic monuments. The aim of the British Academy funded project ‘Seismic Safety of Kathmandu's Historic Urban Infrastructure’ is to improve the seismic safety and resilience of monuments within Kathmandu's World Heritage sites, while preserving their historic authenticity and traditions. The focus on authenticity not only relates to reconstruction efforts using traditional building methods, but also requires minimising the impact of modern civil engineering interventions on un-documented and still buried historical remains. To record at least some of these, in 2018 GPR surveys were undertaken on some of the areas that were scheduled for rebuilding and reconstruction. For many centuries the Kathmandu valley had experienced cycles of natural disasters and subsequent rebuilding efforts so that the ground contains many layers of historic remains. It is hence necessary to evaluate features detected geophysically in their archaeological and historical context before recommending future preservation strategies.

### **Bhaktapur**

Historical evidence refers to the royal residence in Bhaktapur as the ‘palace of the 99 courtyards’, indicating that it once was considerably larger than what is visible today. Given the layout of surrounding squares and temples the most likely location of the missing quarters is in the western area that is temporarily occupied by a post-disaster prefabricated school complex (Figure 1). As there is the potential for larger intrusive development on the site, the project was invited by the Department of Archaeology (Government of Nepal) and the Bhaktapur Mayor to evaluate the site. The GPR surveys revealed two substantial linear features with rectangular additions. These could either be the remains of foundations carrying a substantial superstructure or massive dividing walls between different sections of the palace (Figure 2). Excavations in the grounds of the school revealed a plethora of features, including an early tank (water reservoir) backfilled and covered by later floors and walls. Protecting these important remains is essential and the geophysical results will be invaluable for the planned construction efforts at the school.

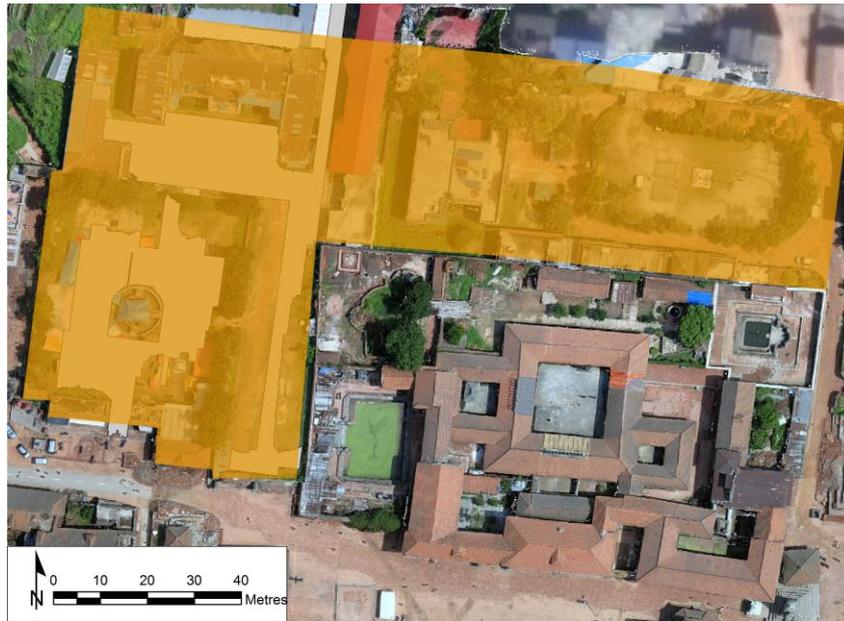


Figure 1: Bhaktapur royal palace and the area of its possible western extension.

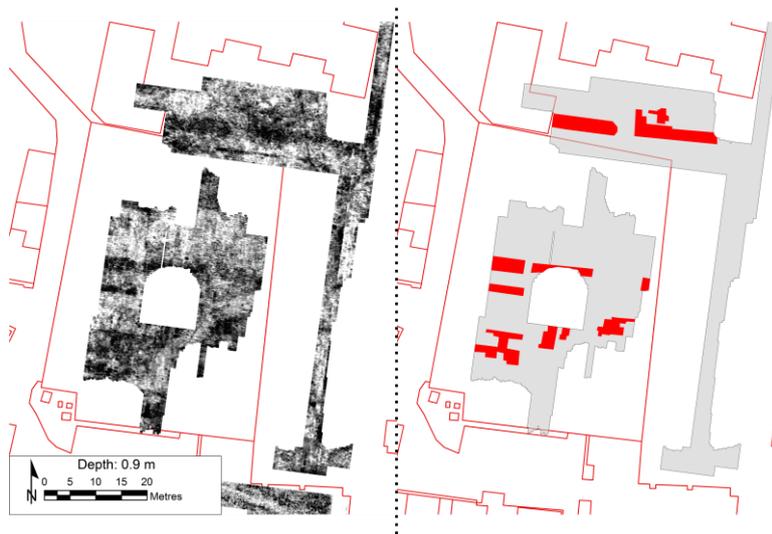


Figure 2: GPR data show substantial linear features in the western area (dark shades indicate strong reflections).

Nearby, the large four-storey Nyatapola Temple suffered hardly any damage during recent earthquakes, withstanding, surprisingly, all ground motions. To gain insights into the historic building methods that may have led to such a resilience, GPR surveys were undertaken over one of the platforms on which the temple was built (Figure 3). The data show clearly that the platforms are composed of individual brick walls, nested like ‘Russian dolls’, and spaces between them were filled with soil and rubble, but lacking any cross-anchoring (Figure 4). The implications of this construction form for seismic safety will be evaluated by the project’s engineering team. The temple adjoins Taumadhi Square and the geophysical surveys there showed no extensions to the temple that would require additional protection. The data from the square mostly revealed modern utilities and their trenches, thereby confirming the narrative that the square had been established in an early building phase of the city and was retained as an open public space ever since. Even though no remains that needed protection were discovered, the resulting map of modern utilities is important to direct future maintenance works.

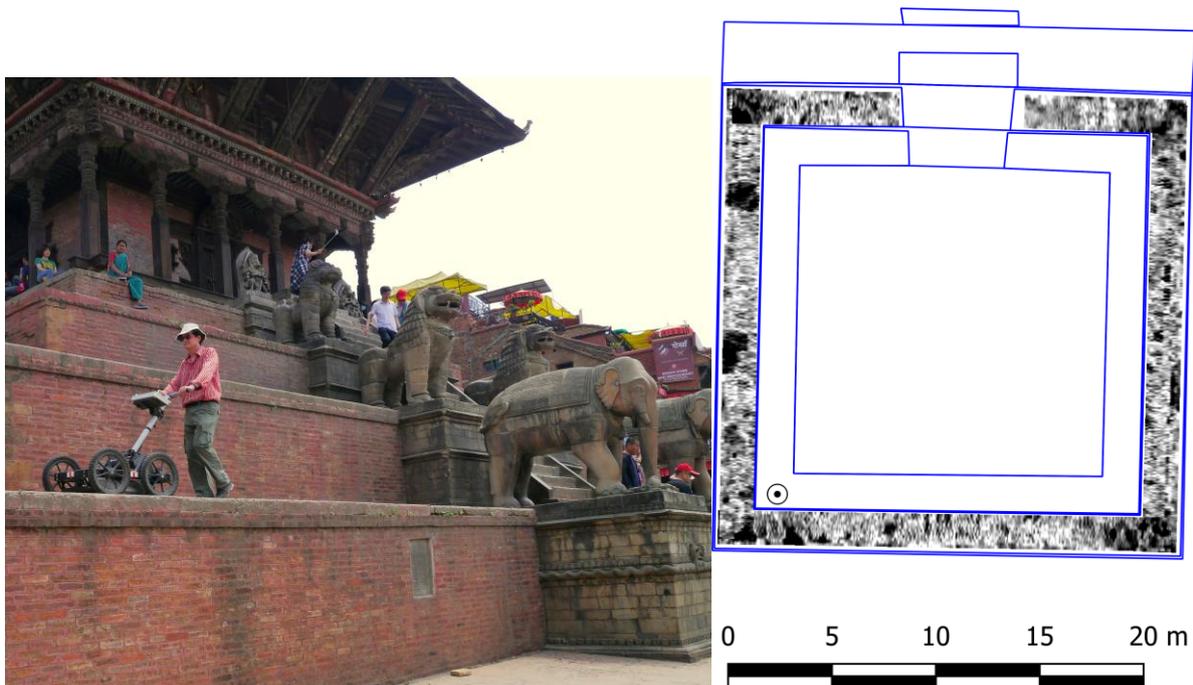


Figure 3 (left): GPR survey on the first platform of the Nyatapola Temple.

Figure 4 (right): GPR data show soil and rubble between the brick walls, but no cross-anchoring (dark shades indicate strong reflections).

### Kathmandu

Rebuilding is already taking place at Hanuman Dhoka royal palace in Kathmandu and extensive steel scaffolding affects even well shielded GPR antennas, limiting considerably the areas that were available for investigation. Nevertheless, various buried structures were recorded during the geophysical surveys confirming that the irregular shape of some of the courtyards was linked to previously different subdivisions, and that some of the earlier shrines had already been removed, leaving only empty trenches behind. The results provide important data for the protection of the buried remains during the ongoing restoration works.

### Changu

After the Gorkha earthquake damage to the standing remains of the Changu Narayan temple has been repaired. GPR surveys were mainly used to record the extent of possible subsurface heritage in advance of reconstruction of the collapsed monuments that formed the courtyard of the main temple. Older structures were visible in the geophysical data and several phases of activity identified in the excavation trench, though none seem to have been affected by recent ground-interventions. As well as identifying earlier phases of activity around Changu Narayan Temple, the data will help with planning future works, including new drainage or the laying of electricity cables.

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## REAL-TIME GPR EVALUATION FOR CULTURAL HERITAGE PRESERVATION

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Moisture damage is the most critical issue regarding the preservation and integrity of cultural heritage sites. The electromagnetic (EM) sensitivity to the presence of moisture, in both soils and structural materials, is quite a well-known phenomenon. Thereby, studying the EM response to the presence of moisture, in order to prevent the damages done to sites of cultural heritage, is a well-established method (Barone 2016). This paper will discuss the ability of a geophysical non-destructive technique (NDT), present in a Ground Penetrating Radar (GPR) system, to investigate a very precious building in Rome that is affected by a moisture problem (the Turkish Room at Villa Medici). This geophysical instrument is able to locate and estimate the extent of water ingress that can aid in the development of restoration plans before permanent damage occurs. The main objective of this paper is to help restorers understand the related hazards, due to the presence of moisture in the wall structures, in truly real-time and to rapidly as well as non-invasively develop strategies for preservation of cultural heritage sites.

Thanks to its high sensitivity to moisture, the GPR investigations were necessary to localize the possible presence of moisture inside the ceiling of the room and to understand the level of structural damage entailing the presence of humidity. This was necessary to plan a proper and focused restoration plan of the Turkish Room vault (Barone & Ferrara 2018).

In Figure 1, the results clearly highlight the presence of a strong anomaly related to the high presence of moisture in a specific part of the internal vault below. The intensity and definition of the anomaly allows us to understand the level of damage and to plan a focused restoration without entirely dismantling the ceiling of this precious room. The potential of such an NDT investigation, using the GPR, allows one not only to detect the presence and the dimensions of a moist layer inside this architectural structure but also (and more importantly) to locate it in depth. The results highlighted in this paper demonstrate the ability of an NDT, such as the GPR, to locate and estimate the extent of water ingress in order to develop restoration plans at the same time of the GPR investigations before permanent damage occurs. Rapidly and non-invasively, the GPR acquisition allows for the restoration managers to immediately develop strategies for the preservation of such a precious cultural heritage site. The restorers, right after the presentation of the GPR results, found the damaged areas behind the frescos and began to re-establish the original condition of the vault by removing the excess moisture in the area as displayed by the GPR investigations.

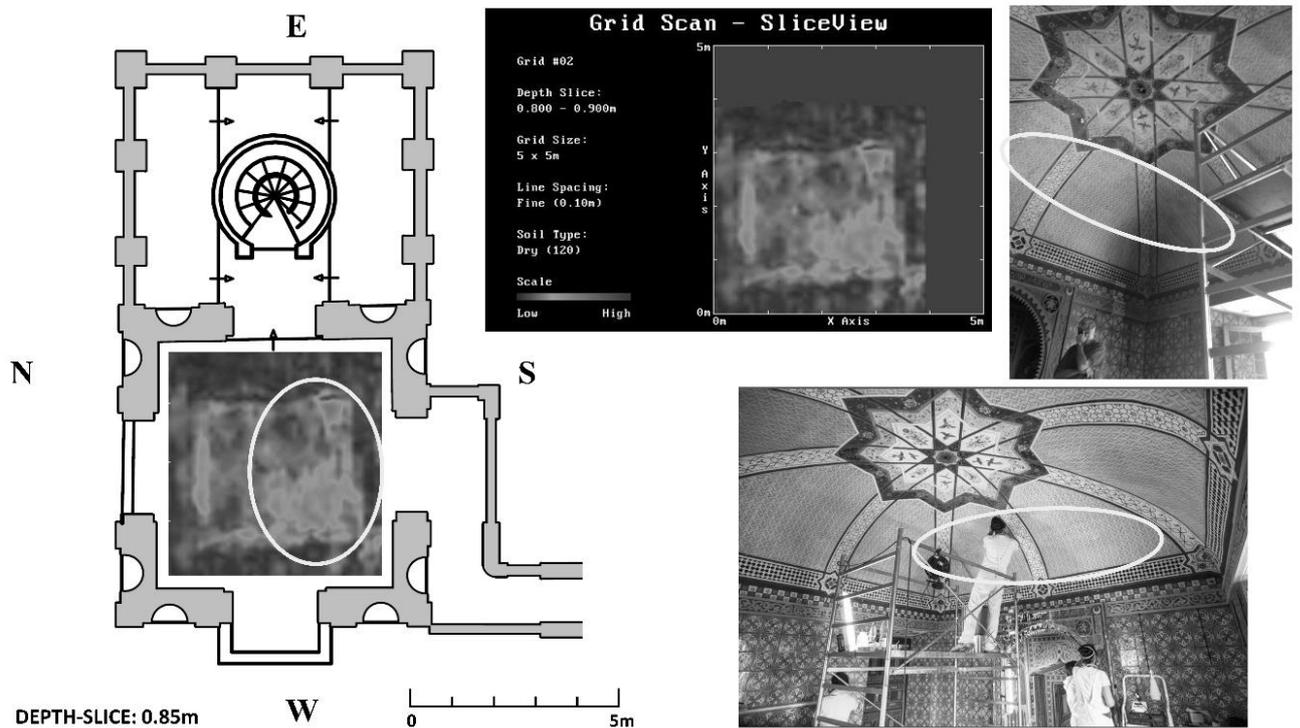


Figure 1: This figure illustrates the depth-slice at 0.85 m circa with the two anomalies caused due to moisture damage (left). The localization of these anomalies, inside the vault, helped the restorers to precisely plan the repair interventions (right).

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# INTEGRATIVE INTERPRETATION OF GRAVITY, RESISTIVITY AND GPR DATA OVER FOUNDATIONS OF ELSECAR GASWORKS, BARNSELEY, UK

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Former industrial sites represent complex problems for geophysical imaging methods, and are seldom adequately characterised by one geophysical survey technique alone. While multi-platform investigations are widespread, the integration of the different datasets is usually done qualitatively, often limited to a visual comparison of geophysical responses. Here, we demonstrate the interpretative potential of quantitatively integrated datasets, both to extract quantitative information about the subsurface target and as a means of exploring the uncertainty that each geophysical method contributes. We demonstrate this approach for a suite of gravity, resistivity and GPR data, acquired over the foundations of a gasometer (Figure 1a) at the former Elsecar Gasworks, near Barnsley, UK.

The Elsecar Gasworks dates from the mid-1850s. Two gasometers were originally present on site (Figure 1b) but both were demolished, likely between 1967 and 1988<sup>1</sup>. There are no records to suggest how complete a set of foundations remain in the ground – i.e., whether the complete tank remains, or whether the whole structure was removed. GPR responses in SUMO acquisitions suggest that its perimeter wall is at least partly intact (Figure 2a), but noisy magnetometer responses precluded further characterisation (Figure 2b). In summer 2018, we therefore extended the SUMO GPR grid, and acquired profiles of microgravity and resistivity data to determine the degree of preservation of the foundations.

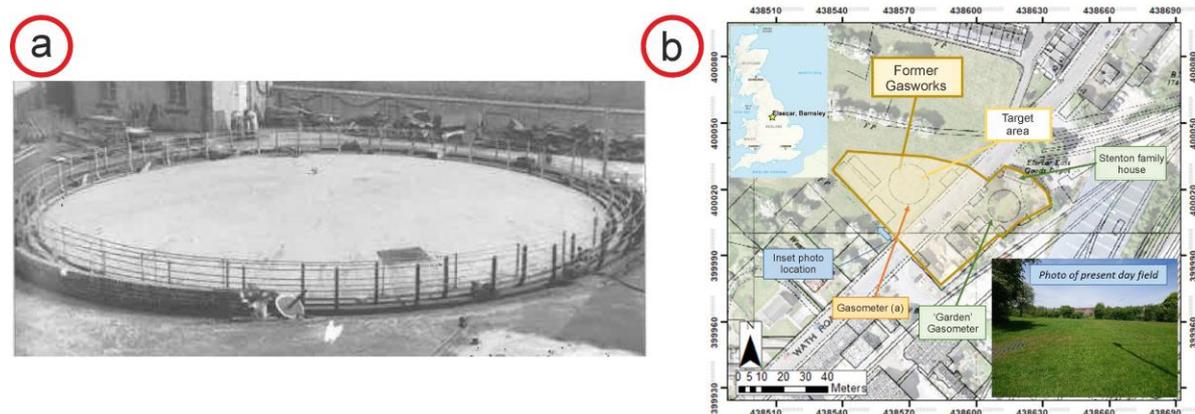


Figure 1. a) Photograph (© Stenton family) of the target gasometer. b) Location map, including 1930s OS mapping and modern overlay. Target gasometer is now located beneath a grassed field (inset, lower), northwest of Wath Road.

Geophysical observations are summarised in Figure 3; GPR data suggest that the perimeter wall of the gasometer is wholly present in the ground, but the gravity Bouguer anomaly of  $-0.035 \pm 0.018$  mGal is too small to suggest its storage tank remains, and the low-resistivity anomaly observed is inconsistent with an air-fill. We

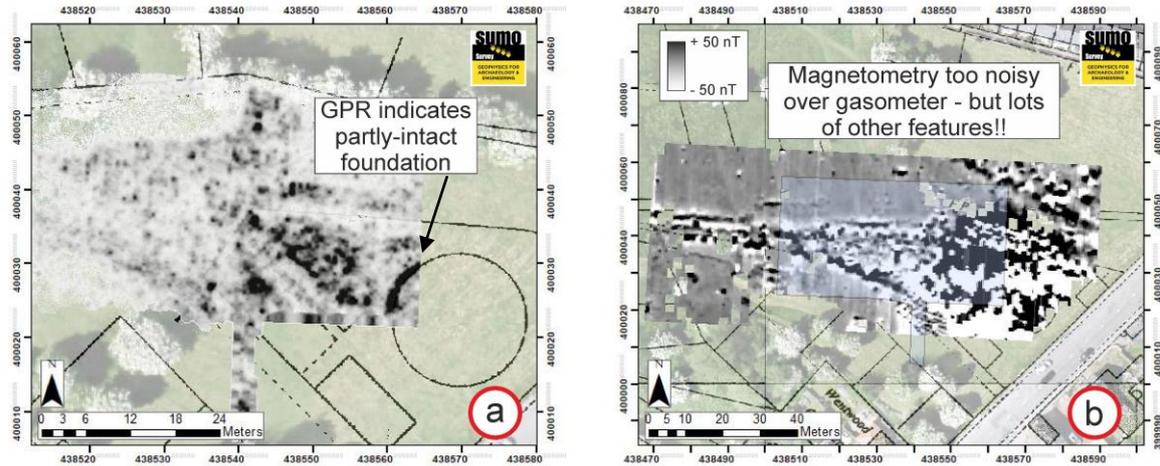


Figure 2. SUMO geophysical data (a – GPR, b – magnetometry) over the target gasometer foundations. GPR indicates some promise of intact structure, but the magnetic data are too noisy.

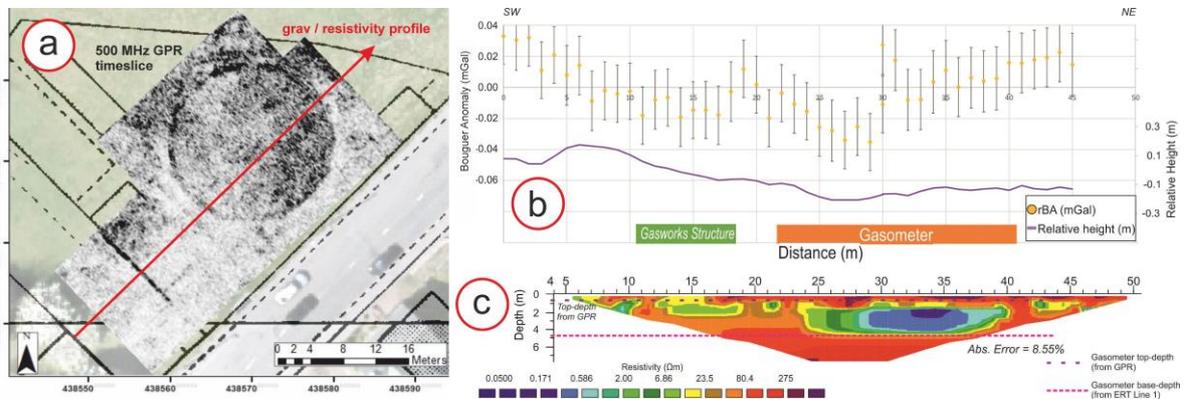


Figure 3. Geophysical data acquired in summer 2018. a) 500 MHz GPR timeslice, showing the full perimeter of foundations. b) Bouguer anomaly, showing a small negative gravity anomaly over the gasometer foundations. c) Inverted resistivity section, showing a large low-resistivity anomaly localised within the perimeter in (a).

therefore suggest that the gasometer foundations were backfilled with rubble and have since become saturated with pooled water.

To add quantitative support to this interpretation, we combined numerical inferences from each platform into an analytic expression for the gravity response to a vertically-orientated cylinder<sup>2</sup>. This would allow us to compare the density of the gasometer fill with that of the host clay soil at the site. The expression requires parameterisation of:

- i) the cylinder radius, estimated from GPR data as  $9.4 \pm 0.35$  m,
- ii) the depth to its upper surface, also estimated from GPR as  $0.58 \pm 0.15$  m (although this quantity combines the errors from GPR velocity and travel-time),
- iii) the depth to its lower surface, estimated from resistivity as  $4.4 \pm 0.5$  m, and
- iv) the gravity anomaly, estimated as reported above.

Uncertainties were propagated by means of a Monte Carlo simulation<sup>3</sup>, with each of the above parameters assigned a likelihood distribution. The results of this analysis are shown in Figure 4a: the probability density function suggests that the density of the material inside the foundations is only  $291 \pm 74$   $\text{kgm}^{-3}$  lower than its host soil, hence inconsistent with an internal air-fill. To complete this uncertainty analysis, Figure 4b shows the relative contribution of each individual parameter to the total

uncertainty range. The definition of the Bouguer anomaly clearly contributes the greatest uncertainty, in part due to the small anomaly size versus the inherent survey noise, and ambiguity in removing a regional background. The GPR-derived quantities contribute very little uncertainty (representing, at most, 3% of the contribution from the Bouguer anomaly), however that of the resistivity-derived depth estimate (~ 25% of the contribution from the Bouguer anomaly) could be reduced with the use of an inversion algorithm that favours sharp layer boundaries.

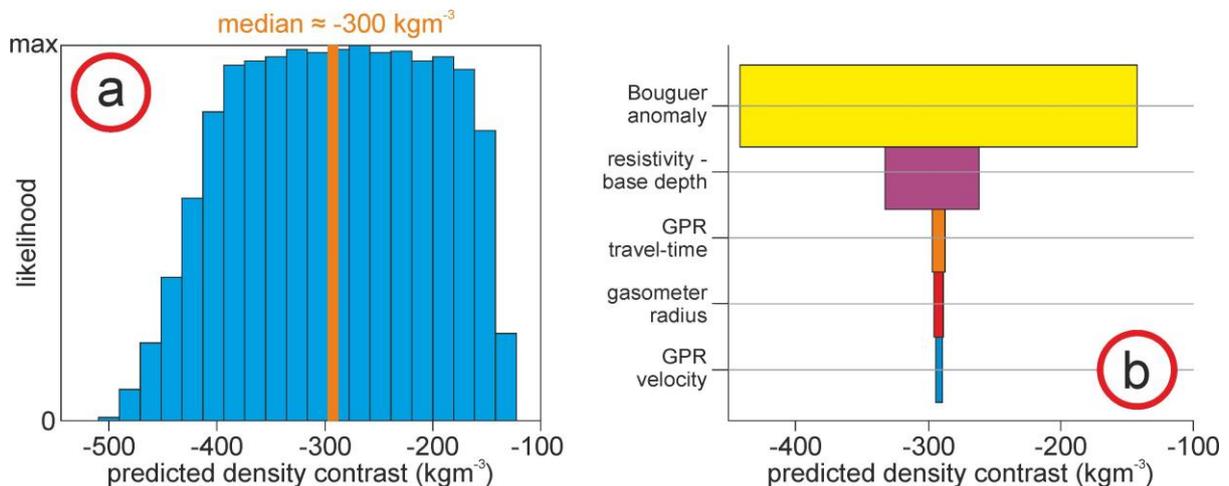


Figure 4. Monte Carlo propagation of uncertainties in establishing the  $\sim 300 \text{ kgm}^{-3}$  density contrast between the gasometer and its host mudstone. a) Likelihood of a range of densities based on the uncertainties in the quantities in (b). b) Ranked uncertainty contribution of individual components to the calculation of density contrast. GPR travel-time and velocity are combined to give the depth estimate.

Our final interpretation of the density contrast could be confirmed by sampling the material on site although, consistent with many archaeological and/or industrial brownfield sites, this is not immediately possible. We have therefore demonstrated a robust, quantitative means of integrating geophysical observations across multiple platforms, and appraising the shortcomings in each. This approach could be replicated for any target where an analytic expression for some geophysical property of interest exists.

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## SENSING FORT ST-PIERRE: COMPLEMENTARY GEOPHYSICAL SURVEY OF A 17<sup>th</sup> CENTURY FUR TRADE POST IN ATLANTIC CANADA

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Merchant-adventurer Nicolas Denys' 17<sup>th</sup> century career in Atlantic Canada is a story of buccaneer capitalism, intercultural negotiation, and ultimately financial ruin. He seems to have had very bad luck. Today he is remembered less for his business acumen than for the book he authored in forced retirement, *Description géographique et historique des costes de l'Amérique septentrionale*, which provides a vivid account of life among migratory labourers, Indigenous people, and a nascent colonial establishment (Ganong 1908).

Political risk made Denys' world a challenging place for merchants, and defence – from foreigners and countrymen alike – was an essential preoccupation of frontier traders (MacDonald 1983). Denys' fortified trading posts were staffed not only with clerks and labourers but with armed men. His principal fort on the Atlantic Coast was located at St-Pierre on Cape Breton Island, a long-established rendezvous between Europeans and Indigenous people. Unfortunately for Denys, Fort St-Pierre mysteriously caught fire in the winter of 1669 and, as he laments, “everything I had in the place was consumed” (Ganong 1908: 105). His finances were also beyond recovery (MacBeath 1966).

Such events, though catastrophic in their day, create important opportunities for archaeologists by producing sites that have not been picked clean by the usual abandonment processes (Schiffer 1987). Test excavations by Parks Canada archaeologists in the mid-1980s confirmed the richness of Fort St-Pierre, the remains of which were located through historical documents (Wallace 1999). But the site has been ignored by archaeologists since then.



Figure 1: Aerial view of the site facing the Atlantic Ocean to the south.

The present research employed LiDAR, EMI, and GPR in an effort to record and interpret surface and sub-surface features at Fort St-Pierre. The LiDAR data was acquired through the Province of Nova Scotia's open data initiative, while the terrestrial geophysical data was captured during the summer of 2018 with an EM38B by Geonics and a Noggin 500 GPR by Sensors & Software. Our high-resolution surveys mapped the interior of Denys' fort to reveal an interesting array of archaeological features. Survey grids were geospatially anchored to sub-centimetre accuracy with a Leica GS14.

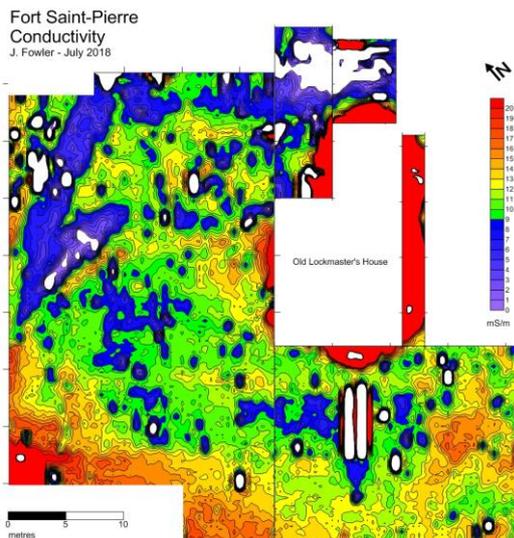


Figure 2: Conductivity contour plot of the site.

Modern intrusions, unsurprisingly, constitute the most visible and extensive geophysical anomalies, the most significant of which is a 19<sup>th</sup> century house. Denys had cleverly established his post at the Atlantic end of a popular portage route linking the ocean to a large interior lake, thereby ensuring convenient access for the Indigenous paddlers who supplied him with furs. Victorian industrialists carved a canal through this passage and built the lock master's house within the trace of Denys' long-abandoned fort. Since then, several additional infrastructure upgrades have been introduced at the site.

Beyond these geophysical nuisances, however, significant elements of Denys' post are evident in the data. By comparing the geophysics to Parks Canada's excavation records it is possible to 'reverse ground-truth' our results and expand upon earlier interpretations based on excavations alone. In this sense, the project is a kind of geophysically-enabled archival archaeology. In addition to supporting new inferences, this project also highlights once again the value of complementarity in archaeological geophysics. Interpretations based on the interplay of LiDAR, ground conductivity, magnetic susceptibility, and GPR far exceed what any of these methods can achieve singly. The GPR, for instance, not only has a greater depth of penetration, but sees through modern features that effectively saturate the EM response. For its part, the magnetic susceptibility channel offers interesting metrics on a site we know to have been burned.

This paper briefly outlines Denys' career, summarizes the project's preliminary results, and suggests ways in which the methodology may be profitably applied elsewhere in 17<sup>th</sup> century New France.

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## “IT HAD BEEN A GOOD SPORT” THE DISCOVERY OF A GERMAN POW ESCAPE TUNNEL IN BRIDGEND, SOUTH WALES

Luis Rees-Hughes<sup>(1)</sup>, Jamie K. Pringle<sup>(1)</sup>, Nick Russill<sup>(2)</sup>, Kris D. Wisniewski<sup>(1)</sup> and Peter Doyle<sup>(3)</sup>

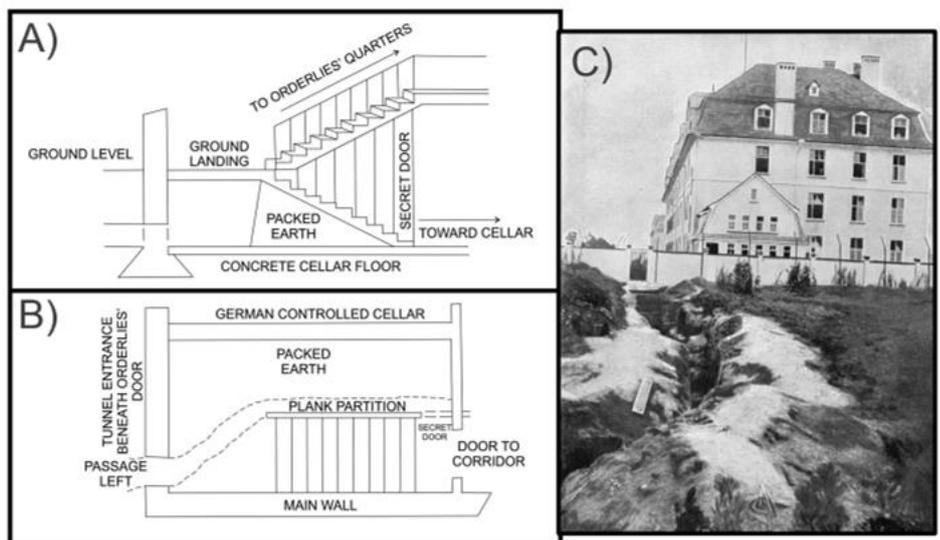
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A developing area of interest in conflict archaeology has been the location and characterising of P.O.W. camp escape tunnels, as part of a wider interest in the study of P.O.W. camps (Mytum and Carr, 2013). Underground tunnelling has been a popular method for prisoners to escape confinement for centuries, and particularly so during the two world wars, both of which saw mass internment on a scale not seen before (Schneck, 1998; Moore, 2006; Doyle 2008, 2011) (Figure 1). The diversion of military resources and the general obstruction to the Military Command was the primary objective of the capture military personnel. This was most commonly achieved by organising coordinated mass escapes. The diverted resources and manpower needed to search and recapture the escaped PoWs could take weeks and result in serious disruption to planned military activity. The most popular way of escaping captivity was through tunnelling.

There were generally two types of escape tunnels: (1) relatively short tunnels, excavated quickly to enable small numbers of prisoners to go under camp perimeter fences and escape, and which entailed

relatively little work, but which were generally poorly concealed (see Doyle, 2011); and, (2) relatively long tunnels that were meticulously planned, engineered and operated by highly organised and expertly-trained personnel, for example, the well-known WW2 allied 1944 ‘Great Escape’ (see Brickhill, 1952; Burgess 1990; Doyle et al. 2013; Pringle et al. 2007) and the escape from Colditz Castle (Reid, 1952, 1953; Doyle, 2011). Such camp escape attempts, whilst mostly unsuccessful (WW2 P.O.W. documented tunnel escapes are summarised in Table 1), were high profile and of great interest to the general public with a large number of accounts published both during and after conflict (Williams 1951; Hargest 1946; Reid 1952; Burt and Leasor



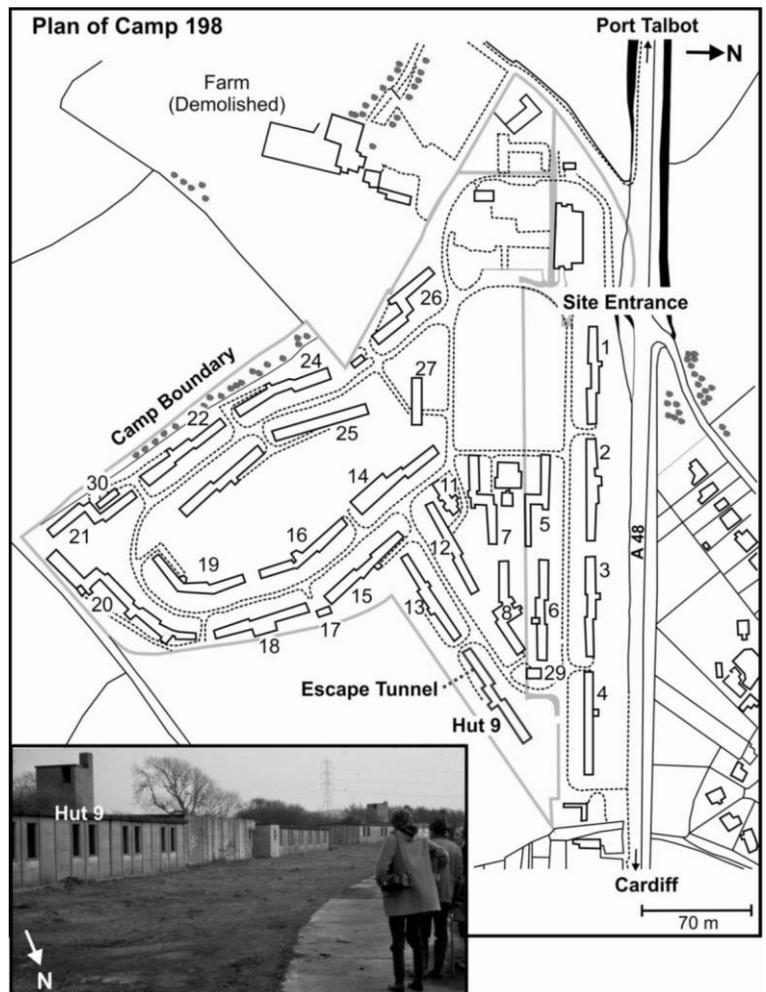
**Figure 1:** PoW escape tunnel constructed at Holzminden PoW Camp, Saxony during WW1.

1956; Rogers 1986) with, arguably the so-called 'Great Escape' of Allied P.O.W. airforce officers in 1944 being the most famous (Brickhill, 1952).

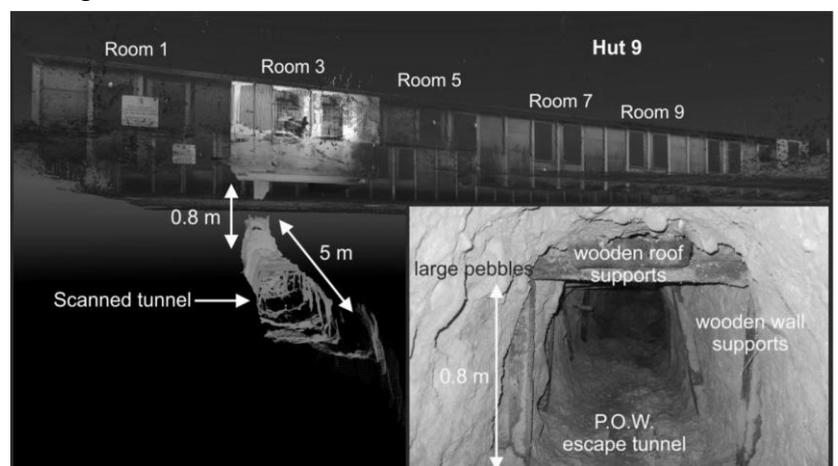
The high profile and well known PoW escape attempts from Stalag Luft III and Oflag VI-C (Colditz Castle) were attempted by Allied PoWs and a substantial amount of work has been conducted on the tunnels and the methods used to create them. One area that has been widely ignored is the attempts of Axis PoWs to escape from Allied PoW camps. The largest escape of German PoWs in WW2 was in March 1945 from Camp 198, situated in Bridgend, South Wales, UK. The escape consisted of a 13m tunnel driven from Hut 9 and was thought to have ended just outside the camp's perimeter fence (Fig. 2). Since camp closure the site has become derelict and has not been scientifically investigated.

This presentation reports on the search to locate the PoW escape tunnel that was dug from Hut 9. This hut remains in remarkable condition, with numerous pieces of PoW graffiti still present. Also preserved is a prisoner-constructed false wall in a shower room behind which excavated material was hidden, though the tunnel entrance itself has been concreted over. Near-surface geophysics and ground-based LiDAR were used to locate the tunnel (Fig. 3) (Rees-Hughes et al. 2017). Archaeological excavations discovered the intact tunnel and bed-board shoring.

With Allied PoW escape camp attempts well documented, this investigation provides a valuable insight into the previously ignored German escape efforts and also attempts to explain why German escape attempts were less successful than Allied attempts.



**Figure 2:** Site Map of Camp 198 circa 1945. Highlighted is the location of Hut 9 and the escape tunnel.



**Figure 3:** LiDAR and Photographic Imagery of the Hut 9 Escape Tunnel, displaying the intact first 6m of the tunnel.

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## THE FORT IN THE FOREST: RE-VISITING BUCKLAND RINGS HILLFORT 25 YEARS AFTER ITS FIRST SURVEY

Lawrence Shaw<sup>(1)</sup>, James Brown<sup>(1)</sup>, Josephine Hagan<sup>(2)</sup>, Ashley Green<sup>(2)</sup>, Brett Howard<sup>(3)</sup> and Jonathan Monteith<sup>(2)</sup>

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### Background

Located on the southern edge of the New Forest National Park, Buckland Rings is a multivallate Iron Age hillfort. The site lies on a flat-topped upstanding knoll, 27 meters above sea-level, situated on a gravelly ridge that extends from Burley, south eastwards to the Lymington River. Consisting of three ramparts with ditches, the fort is sub-rectangular in shape and covers an area of 6 hectares (Figure 1). Other than the extant bank earthworks, there is little to no evidence of archaeological remains within the interior of the hillfort. This is largely due to the impact of intensive ploughing which took place within the fort until the middle of the 20<sup>th</sup> century.

Excavations by Hawkes in 1934 saw several investigatory trenches across the defensive earth works as well as within the fort interior (Hawkes, 1936). His work identified that the entrance was in-turned, as well as revealing large postholes, indicating the Hillfort was once gated. Hawkes also identified an “occupation-hollow near the entrance which contained habitation material. Reassessment of Hawkes’ original plans by Joanna Close-Brooks identified inconsistencies in the original interpretation which established a new hypothesis that the hollow feature may represent evidence of a circular house platform which were not recognised at the time of the excavation. Other than this evidence no other evidence of occupation has been identified within Buckland Rings. Recent observations during modern infrastructure works close to the site have identified large quantities of medieval remains, thought to be associated with the improving of the land for agricultural purposes, but no prehistoric evidence was discovered (Green, 2018).

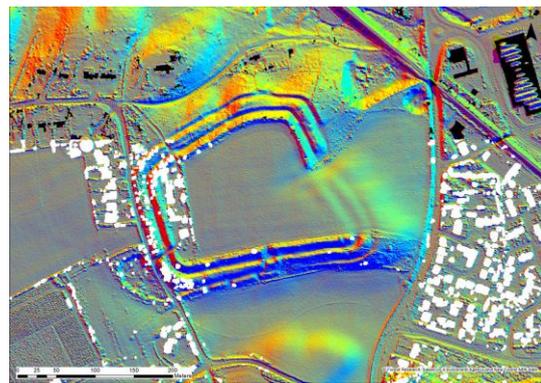


Figure 7: Lidar image of Buckland Rings Iron Age hillfort.

In April 1993, the Historic Buildings and Monuments Commission for England carried out a geophysical survey of Buckland Rings. A magnetometer survey using a Geoscan FM36 fluxgate gradiometer and a magnetic susceptibility using a Bartington MS2-D with a MS2 susceptibility meter were conducted to inform future management strategies for the site. The survey was conducted to inform the management strategies for the site. The results, however, were unable to provide conclusive evidence about the utilisation and occupation of the interior of the hillfort (Payne 1993). The methods used were magnetometry using a Geoscan FM36 fluxgate



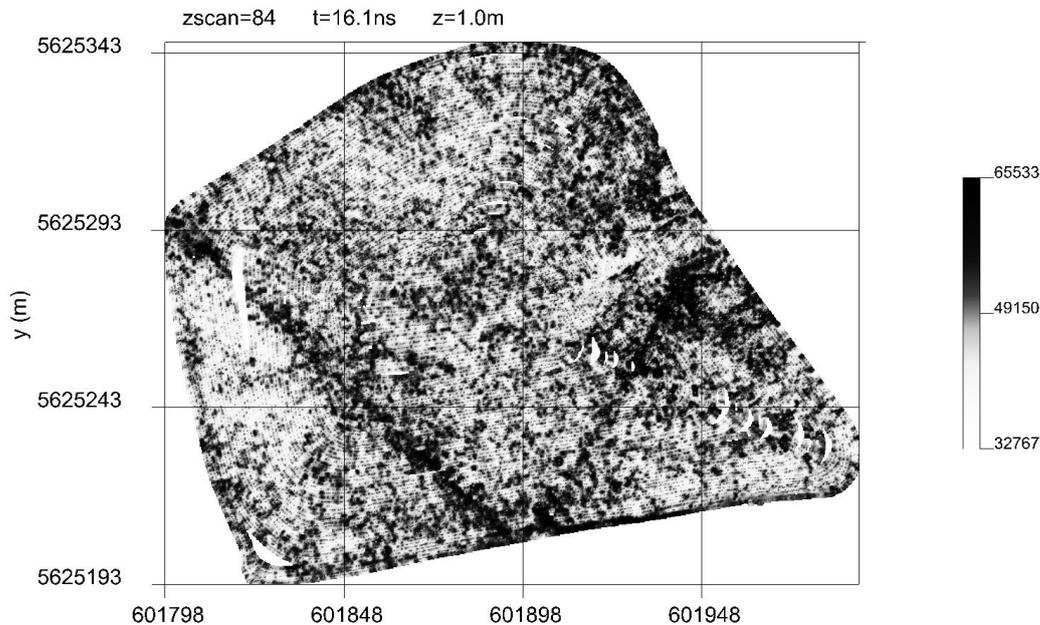


Figure4: GPR time slice of Buckland Rings Iron Age Hillfort showing modern footpaths as well as circular ditch features and rectangular enclosures within the centre of the fort.

Based on the results seen in the magnetometry, both the CMD-MiniExplorer (Howard, 2018, Bournemouth University 2018) and GPR surveys focused on the interior of the hillfort. These surveys confirmed the presence of multiple circular features as well as evidence of internal divisions, ancient trackways and pits visible throughout the interior of the hillfort.

This paper will review the responses identified in each dataset as well as examining how each technique performed within the sands and gravels of the New Forest and how the evidence might shape future guidance and research strategies.

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## THE TEMPLE OR ROOM? THE INTERPRETATION OF THE FRAMPTON ROMAN TEMPLE/VILLA SITE IN THE LIGHT OF RECENT GEOPHYSICAL SURVEY RESULTS

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The Roman site of Frampton (Dorset) is something of an archaeological enigma. Discovered and first excavated in the 1790s (fig. 2), four rooms, all connected by corridors were found to contain high quality figurative Roman mosaics, one famously bearing the rare Christian Chi-Ro monogram and an even rarer inscription (fig. 1), These floors have been considered by some scholars to be part of a temple complex situated on a raised platform amid the water meadows of the river Frome. A scheduled ancient monument, the site is listed “Frampton Roman villa” (Historic England 2018), however, its position, right on the valley floor, made no apparent sense as a domestic structure, and the early plans suggested a series of isolated structures, convincing some archaeologists that it had a religious function. At the time of the excavations, the mosaics were considered to be some of the finest found in Britain, with King George III visiting on two occasions. The site was further investigated in 1903, but nothing was discovered to help understand the structure any better, and so the temple or villa question has remained unresolved.



Figure 8: Detail from the Frampton mosaics (Lysons 1807)

### Recent work

The site is now in the care of Dorset Wildlife Trust who wished to understand more about the building in order that it could be managed more effectively, and this gave Bournemouth University a chance to conduct a geophysical examination. Whilst magnetometry and earth resistance surveys provided some useful general information, the structure had been covered with flints sometime in the past to protect the mosaics, and extensive water meadow engineering had also affected the site, so like the 1903 investigation, these surveys failed to resolve the issues of interpretation.



Figure 9: The military (note their tents) excavating the site in 1796/7 (Detail of Plate 1 - Lysons 1813)

### Recent work

Despite the extremely wet situation and silty/clay geology it was decided to try ground penetrating radar (GPR). Against expectations, GPR did produce results which enabled the site plan to be more confidently resolved (fig. 3). Even so, the low-lying wetland position of the site is still an issue for some with regard to interpretation and so this paper will also aim to address this issue through the use of geophysics to analyse landscape change in the Stour river valley.

### Acknowledgements

Thanks to Dorset Wildlife Trust for allowing access to the land and to Harry Manley, Geoinformatics Demonstrator at Bournemouth University (BU) for geoinformatics support. Ashely Green, PhD student at BU, helped process the GPR data.

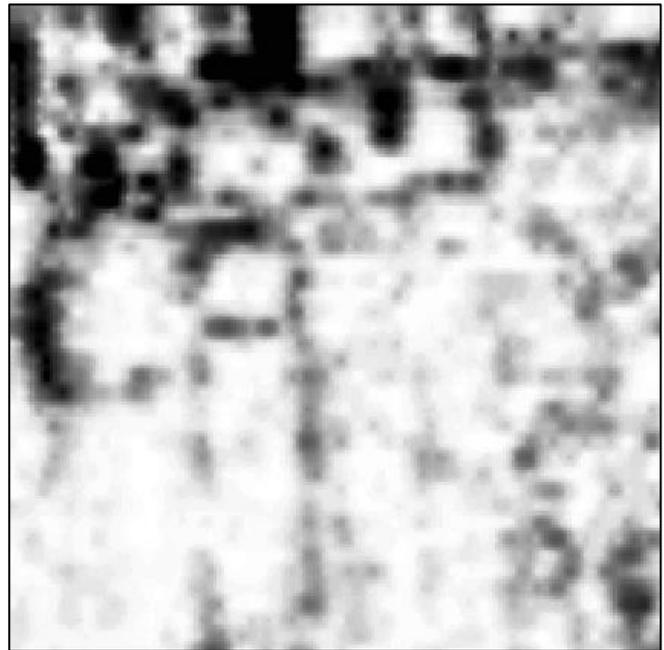


Figure 10: 500MHz GPR time slice results

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## ANOMALIES DON'T GROW ON TREES. CHALLENGES AND RESULTS OF NON-DESTRUCTIVE ARCHAEOLOGICAL SURVEY IN BIAŁOWIEŻA FOREST.

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The Białowieża Forest is the last and the largest old-growth forest of Europe. In the late 1970's it became a UNESCO World Heritage Site, mostly because of its unique natural values. Yet in 15<sup>th</sup> century some part of it became the property of a Polish king, and a century later the first forms of protection of its natural environment were introduced.

The heritage of the Białowieża forest is not limited just to the natural environment. Archaeological research has proven the existence of several archaeological sites, however, it was extremely challenging to detect any traces of human activity in the virgin environment of the forest with traditional methods like field walking survey within Polish national survey programme (AZP).

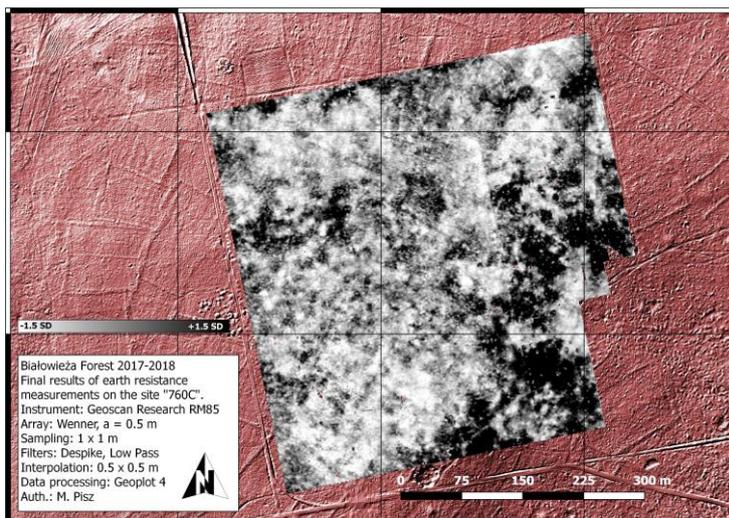


Figure 11 – The results of earth resistance survey in Ladzka forest.

The total area of 21.5 ha have been surveyed with this method on this site.

### “Cultural Heritage of Białowieża Forest” project

“Inventorying cultural heritage” – activities, which are carried out within the assignment commissioned by the State Treasury – the State Forests National Forest Holding - General Forest Management. The aforementioned initiatives, realised since 2016, constitute yet another example of the research on cultural resources in forested areas in Poland as well as the first example, in the history of Polish archaeology, of the area manager initiating and supporting the protection of historic heritage in the form of interdisciplinary, systematic research (Stereńczak et al. 2017; Zapłata and Stereńczak 2018 / in print). Research financed by the General Forest Management – research realized by consortia, commissioned by the State Treasury – the State Forests National Forest Holding, the General Forest Management.

## **Geophysical research in the woods**

One of the group of methods implemented in the workflow of the research in the Białowieża Forest was archaeological geophysics. The aim was to gather any further information about possible archaeological sites and objects which have been distinguished based on LiDAR data. As the survey might be considered as a “Level I prospection” (Gaffney, Gater 2008: 88-91) it was rather aimed at recognizing of a large surfaces than a high resolution sampling of particular objects.

Three basic groups of geophysical methods have been applied in the research. Magnetic measurements have been taken with both caesium and fluxgate instruments, shallow earth resistance has been supplemented with magnetic susceptibility, and conductivity measurements have been taken as well. It was an assumption to apply at least two various, complementary methods at each site.

## **The specifics of the research in Białowieża Forest**

The application of geophysical methods in sites of the Białowieża Forest has to face two basic challenges. First of all, the workflow of field measurement in woodland requires consideration of a number of aspects which determine the field methodology. The second serious impediment is both the nature of the archaeological objects (mostly pit objects) and the fact that they are deposited in an old glacial landscape. These conditions make it difficult to properly interpret the geophysical data, particularly as there are still not many known and unearthed archaeological objects, and the sandy-clayey subsoil tends to produce natural soil disturbances (like ice wedges) which may produce deceptive anomalies of natural origin.

The presentation is expected to be a contribution to the discussion about the workflow of geophysical measurements in the woodlands, both considering the field works as well as the interpretation of the obtained data.

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## CHASING A DRAIN AND FINDING MONKS: RECENT INVESTIGATIONS AT FOUNTAINS ABBEY

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### The Context

We struggle with the same issues of site management today that our forebears did and often we need to revisit ‘improvements’ that require updating or changing as a result of subsequent events. In 1856 the site of Fountains Abbey ruins required new site drainage; when the drain was cut a number of unexpected, stone-lined, graves were discovered and reported in the local newspapers. Scroll on 150 years and it is climate change that necessitates new drainage on the site. Obviously, that’s a challenge in a place like Fountains Abbey, unless you can trace and reuse the Victorian insertion cuts. Given the success of geophysical techniques on the West Green and reported at a previous NSGG meeting (Gaffney et al, 2014) it was appropriate that we considered the use of similar techniques to identify the location of the drain.

### What Did We Do?

The investigations at the East Green of Fountains Abbey used a battery of techniques; geophysical and more remote in nature. The mainstays of the work include: GPR, various earth resistance arrays, magnetometry of differing types as well as EM survey. In order to understand the context of the work, we undertook significant drone, laser and photogrammetry at the site. Ultimately a small excavation was carried out to help us enhance the detail of our interpretation.



Figure 12: GPR timeslice indicating position of burials and the drain that cuts the burials on the East Green, Fountains Abbey

### What Did We Find?

None of us were expecting what we found, though – a graphic representation of what appeared to be graves described in the newspaper account. Several seasons of work later and something over 1000 graves have been identified, many suspected of multiple occupancy. *Archaeologically*, it came as no surprise that the monks' cemetery was here – although that had surprised the Victorian excavator John Richard Walbran. He had thought he was digging the abbot's garden in 1852, when the half dozen surviving gravestones were encountered. Walbran, like all of his twentieth century successors, didn't investigate the extent or character of the graveyard, though. Both moral reservations about needlessly disturbing the dead and a supposition that the physical archaeology of cemeteries probably has little to tell us have made burial places amongst the least explored parts of monastic sites. At Fountains this inhibition has, if anything, been amplified by a generalised feeling that the site had been completely explored and understood by 1900. Nothing new to learn here. Move on.

### What Does This Mean?

This project shatters those illusions and promises to help kick-start long-stalled exploration, certainly of Fountains Abbey and perhaps of other monastic monuments too. It is a revelation in terms of the detail of the archaeology present that a battery of geophysical techniques can seemingly detect, particularly where the specifics of the soils, geology and archaeology are suitable as they so obviously are here. With such preconditions it is clearly possible to undertake a 3D spatial investigation of a burial ground incorporating excavation, which can then be offered an archaeological – and ultimately historical - interpretation.



Figure 2: Location of excavation superimposed on GPR image and with point cloud derived from drone data

In the case of Fountains, there appear to be a number (provisionally eight) of zones within cemetery where the detected anomalies share a set of characteristics at variance with those in neighbouring areas. The causes/meanings of these variations will require considerable further thought and research, but the obvious drivers would be chronological development, changes in liturgical requirements over time, zoning of the graveyard for different populations and changes in burial fashion over time. If we can understand these changes then we are not only adding new paragraphs to our understanding of the history of the abbey, but also obtaining invaluable new data for the vexed question of the demography of the abbey through its lifespan. Beyond purely archaeological considerations, modern understanding of heritage value includes a focus on social/communal value – human interaction with heritage.

### **What Is The Outcome?**

Even for those who have been long involved with looking after Fountains, it has perhaps been too easy to “overlook” the monks and lay brothers for whom this was home. We know their part in the story, but they seem lost and past. One of the greatest outcomes of the results, is the vividness with which the individuals are – rightly – so powerfully placed back into the archaeology of the site. They are not gone; they never went away but have been here at rest, some of them for nearing 900 years. The more one comes to understand medieval ideas about death, and the way in which the deceased formed a link between the living community and the place they occupied, the more powerful this revelation becomes and stands to revitalise/radicalise how today’s visitors connect the heritage at Fountains Abbey.

On a more prosaic level, we still need to think about drains and other aspects of site management too. The geophysical investigation of the East Green is telling us completely unexpected things about the history of the area and how it might be vulnerable – all of which will assist the National Trust’s ability to conserve it into the future.

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## BROUGHTON ROMAN VILLA, OXFORDSHIRE: A WIDER VIEW

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In August 2018 there was a degree of interest in the UK and wider press about the discovery of a large Roman villa near Banbury in Oxfordshire. This presentation will seek to put the remains and their publicity into some sort of context.

The villa may be associated with other remains in the vicinity of Madmarston camp, an Iron Age hillfort which is being ploughed to bits despite being a Scheduled Ancient Monument. There are records, going back to the 18<sup>th</sup> century, of dense remains in the area and I will be looking at whether the records on the Historic England Pastscape system are reliable.

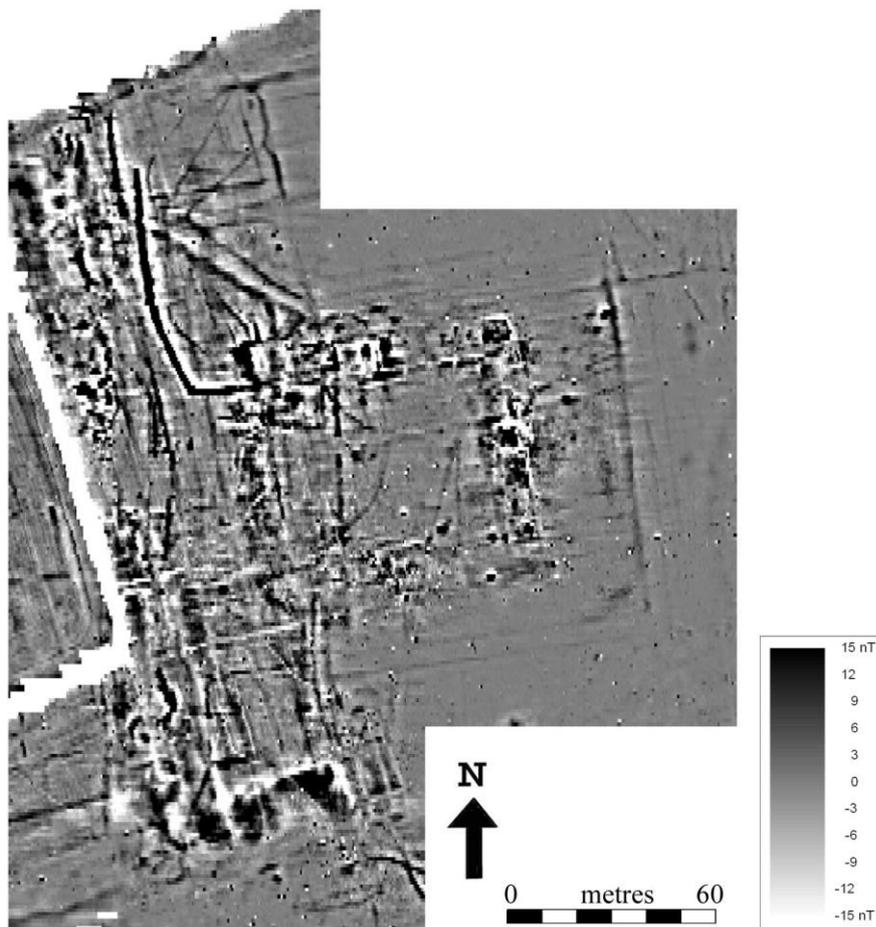


Figure 13: Magnetometer survey of Broughton Roman villa

Whilst the magnetometry results for the Roman villa (Figure 1) were covered in the Association for Roman Archaeology newsletter for March 2018, the press coverage of the subsequent excavation largely ignored the role of geophysics in locating the site. I will look at the press coverage and its background with a view to seeing what went right and wrong with a view to making suggestions on how things could be improved.

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## CWMYSTWYTH: BRONZE AGE MINING HIDING IN THE WELSH MOUNTAINS

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### Introduction

Cwmystwyth, in the Cambrian Mountains in mid-Wales, has been increasingly heavily mined for lead from the medieval period through to the 19<sup>th</sup> century but there are also important Bronze Age copper mining remains. We have been working alongside the Early Mines Research Group (EMRG) over the last few years, undertaking geophysical investigations to complement and expand their understanding of the (complicated) landscape. We have been using geophysics as a broad prospecting tool as well as to investigate known features. This paper is about the geophysical aspects only and work is ongoing (both EMRG and TG) so plenty of new questions are arising.

### What answers were we seeking with geophysics?



Figure 1: ERT profile down the Comet Lode openwork

The Comet Lode openwork was previously partly excavated and was found to contain well-preserved antler picks and wooden items as well as many hammer stones within the several metres of fill. We used ERT (Iris SyscalPro) to try to determine the depth and shape of the Bronze Age mining, with some success. This challenge was both physical and geophysical, as the terrain is steep and uneven and there were difficulties with high contact resistance in places!

Around the openwork we also covered an area with EMI survey (GF Instruments CMD Explorer) and spot magnetic susceptibility readings (Bartington MS2) in an

attempt to identify potential zones of activity, whether industrial or domestic. Parts of the hillside escaped the 18<sup>th</sup> and 19<sup>th</sup> century large scale mining but there are also medieval features in the mix. Along the skyline is a scatter of Bronze Age cairns. The prominent Pant Morcell cairn is sited on a spur and 'looks' straight into the Comet Lode openwork. We carried out caesium magnetometer (Geometrics G858) and twin-probe electrical resistance (Geoscan Research RM15) surveys around the cairn to provide potential context.

One of the low-altitude challenges has been to locate Bronze Age settlement: the mining activity was intensive and large but where were they living? The hillside near the mining area is quite exposed. We carried out caesium magnetometer surveys on fields near the valley bottom and identified some potential areas of interest. (This followed some of our earlier work identifying smelting hearths using a Geonics EM38.) There are some curious features, including some shallow hollows and a strongly magnetic 10m diameter circular feature with surrounding ovoid ditch that is being investigated with test pits.



*Figure 2: Caesium magnetometer survey in the valley bottom*

A spatial control network has now been established (lots of leg work!) and further investigation is planned nearby at a newly discovered location that may be a 'sister' site to the Comet Lode openwork.

## **Conclusions**

Cwmystwyth is a fantastic place to survey and the quality of archaeological remains is worth the significant effort needed to investigate them. The EMRG are a pleasure to work with and devising solutions to the research questions is a welcome challenge in multiple ways. Some combinations of method and circumstance are particularly unusual, even experimental, and our results so far are encouraging. Our staff also benefit from involvement in this unusual project.

EMRG webpage <http://www.earlyminesresearchgroup.co.uk//cwmystwyth.html>

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## GEOPHYSICAL SURVEY AND COMMUNITY ARCHAEOLOGY- SOME SUCCESSES AND SOME FAILURES

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This paper will look back at 25 years of teaching local archaeology societies and community groups how to conduct geophysical surveys, and take a critical look at whether these could be deemed “successful”, or rather how we might define what a successful outcome might be.

While it is both necessary and worthwhile to be positive about promoting amateur involvement in our discipline, I have encountered a number of failures over the years. I intend to analyse why these failures occurred, and then attempt to establish protocols which might mitigate against these happening again in the future.

# POSTERS

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## GEOPHYSICAL INVESTIGATIONS OF WW2 AIR-RAID SHELTERS IN THE UK

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In the prelude to the Second World War, the British government prepared for an aerial onslaught that, it was predicted, would raze cities to the ground and cause mass casualties. By 1938, the Air Raid Precautions Act ensured that Britain would be ready for aerial attack, and formally adopted a principle that the protection of the population from bombing would be through dispersal of the population. This meant evacuation, and protection on a local scale, rather than the construction of deep shelters intended to protect the population en-masse. As a result, such air raid shelters that were produced were the responsibility of the local authority, and all too often this meant that that responsibility devolved to the householder, who was expected to create bomb- and gas-proof rooms. It also means that the archaeological record of air raid shelters is relatively rare, with the distinct possibility that such features are under threat.

As such, this study reports the results of non-invasive geophysical surveys over three different air-raid shelter sites, located in Stoke-on-Trent and London. Multi-technique geophysical surveys were required to locate, identify and characterise the shelters, as well as to determine optimal geophysical detection method(s) and equipment configuration(s).

Study results found that the three intact, Stanton-type pre-fabricated shelters in Stoke-on-Trent could be successfully located by ground penetrating radar, electrical resistivity, magnetometry, gravity and electromagnetic methods. The partially demolished shelters in Central London provided a geophysical response (from EM and GPR) but could not be further characterised. Finally, the intact, mass public-type shelter in South London was detected by EM and GPR methods. Subsequent intrusive investigations confirmed London site interpretations.

This study shows that these important, but hitherto-neglected, wartime shelters can still be in good condition and near-surface geophysical surveys can detect and characterise their location, size, burial depth and even their construction materials. The outcomes suggest that geophysical surveys can be used to help assess the integrity of such buried structures and help to bring WWII British history into the wider scientific community and the public domain.

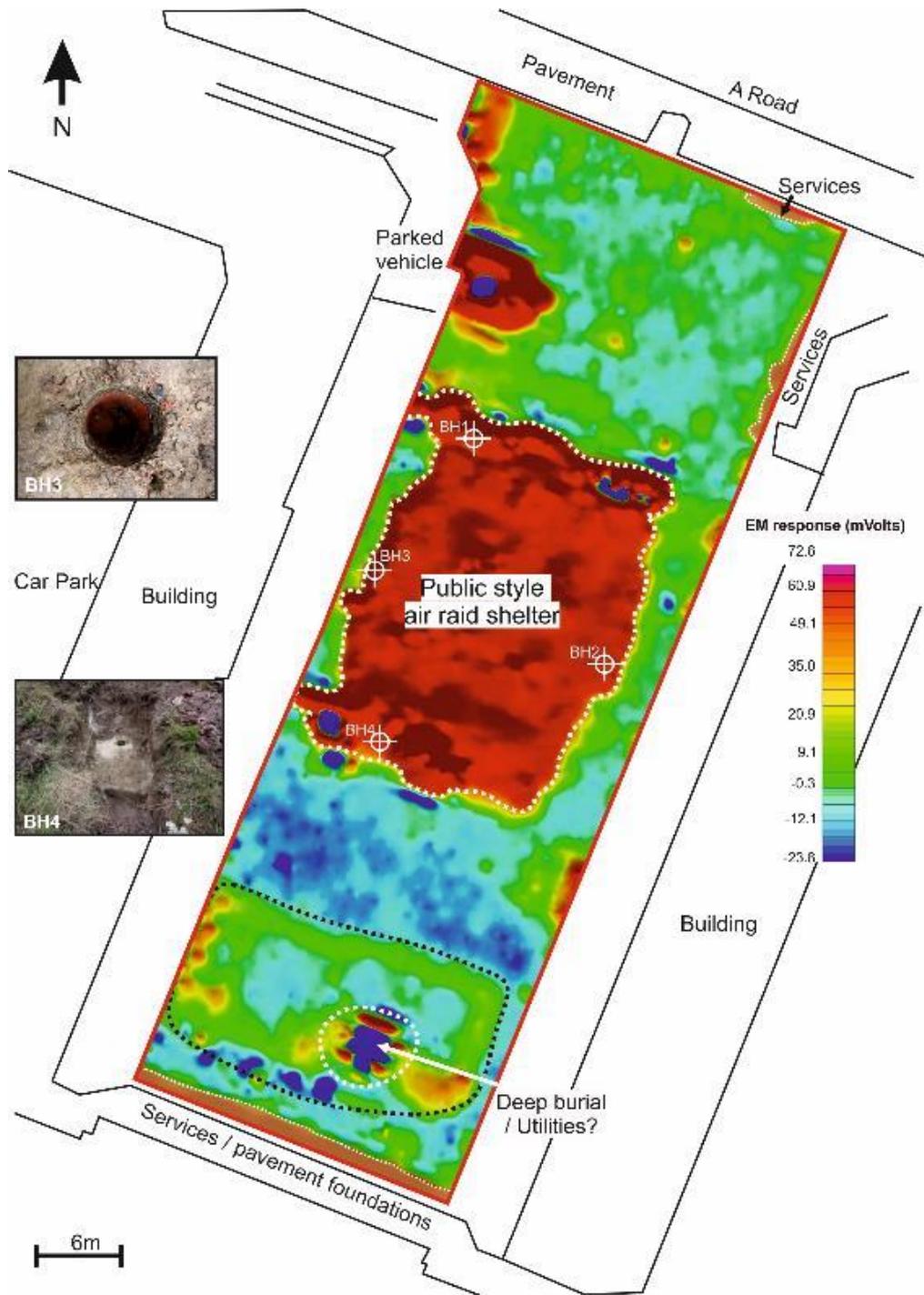


Figure 14: Electromagnetic EM61 dataset with pertinent features, including the below-ground public air-raid shelter remains, subsequent borehole positions and photographs of Boreholes 3 and 4 also shown

## AERIAL, PEDESTRIAN AND GEOPHYSICAL PROSPECTION IN THE CANTABRIAN MOUNTAINS: EARLY RESULTS FROM THE 'UPLAND ARCHAEOLOGY PROJECT IN NW IBERIA'

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This poster presents the results of two pilot phases of prospection in the Babia region of the Cantabrian Mountains, in Northern Spain (figure 1).

Upland areas in the Cantabrian Mountains constitute a void in the regional archaeological knowledge of North-Western Iberia. Interpretations about the long-term anthropization of these mountains rely mainly upon palaeoenvironmental datasets. These demonstrate an earliest anthropogenic impact during the Late Neolithic (ca. 4000 BC) in the form of forest clearance; this pressure both increased and decreased during subsequent periods – a warning against evolutionary readings on the diachronic shaping of cultural landscapes in this area (González Álvarez forthcoming, 2019). Mobile herding strategies are assumed to be the main human inputs in the anthropisation process, with human communities taking advantage of the verticality in the local geography to exploit the different biotopes that can be found over short distances. The lack of archaeological datasets prevents us from building detailed narratives about the social and productive forms used by pastoralists over the course of time. Traditional herding activities from 19<sup>th</sup> and 20<sup>th</sup> centuries described by travellers and ethnographers constitute our main reference to understand the preindustrial exploitation of the uplands. Therefore, historical/archaeological interpretations of the cultural biographies of the Cantabrian Mountains are quite static and ahistorical (González Álvarez *et al.* 2016).

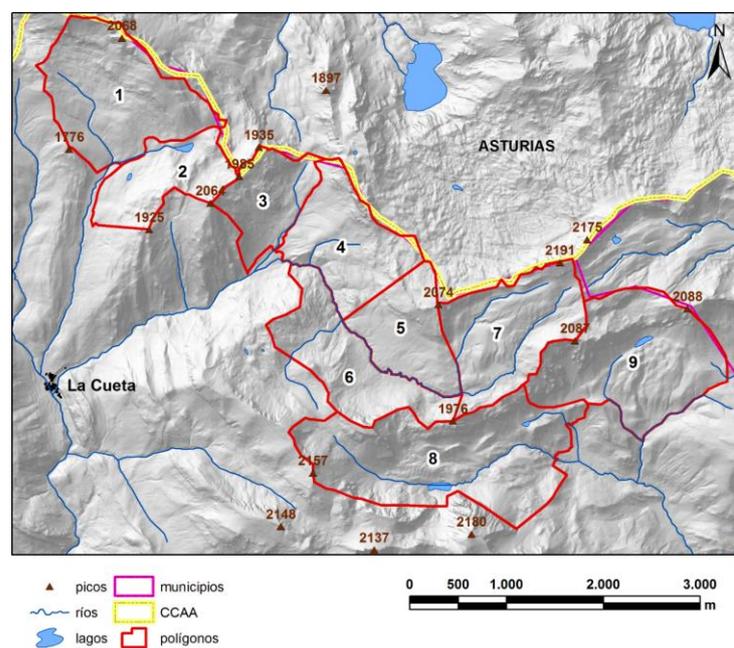


Figure 15: Location of the study areas

Aiming to recover archaeological information from the uplands and draw a more complex archaeological interpretation of long-term anthropization, we have designed a pilot project in the uplands of Babia (North of León) in order to identify ancient sites and thus to address a better understanding of prehistoric herding activities in the

uplands. Along with remote-sensing prospection, pedestrian field-walking, the excavations of test-pits and ethnoarchaeological investigations, geophysics is one of the key strategies to conduct our field-project. The results from our 2017 and 2018 campaigns are quite promising so far, having identified more than 100 sites related with herding activities between 1600 and 2000 m asl, ranging from the Early Bronze Age to the present day.

### Phase 1: aerial prospection

An initial assessment was made of the survey polygons using aerial imagery and LiDAR DEMs datasets available at the *Centro Nacional de Información Geográfica* (website: <https://www.cnig.es/>). Potential anthropogenic features were searched for by visual inspection, and then digitised into the project GIS along with preliminary classifications and observations. There were no archaeological inventories from the study area prior to our work, having identified so far more than 100 potential structures of archaeological interest

### Phase 2: Pedestrian survey

Field walking teams, equipped with RTK GPS and printed GIS extracts visited all of the identified 'features' discovered in phase one, and completed recording for each of them. The RTK GPS was used to record additional features not seen in the aerial images, or correct mistakes in the interpretation using more closely observed points on the ground. Additional features in the landscape of archaeological interest, but not seen in phase one, were also recorded. Some fieldwalking was also conducted where visibility allowed it, particularly at locations where erosion processes exposed the surface, to establish potential dating and functions for the structures observed.

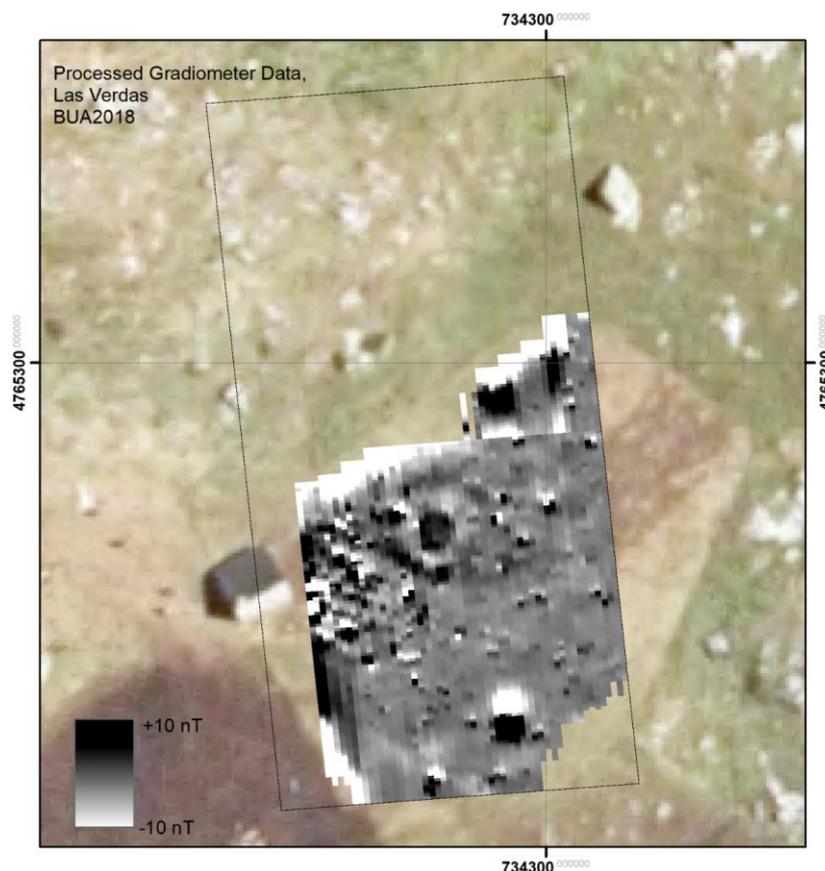
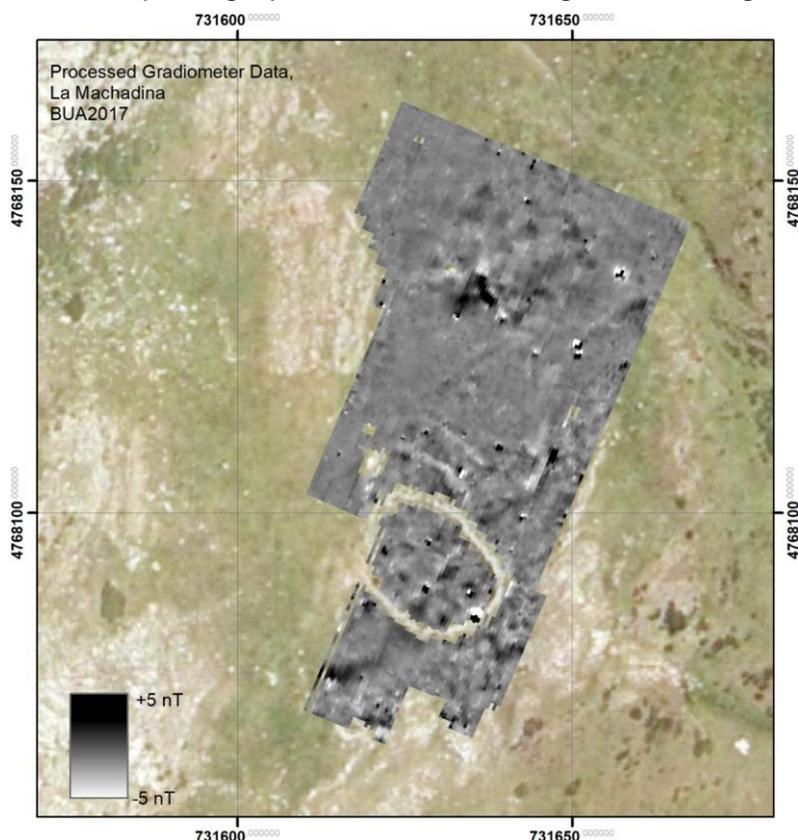


Figure 16: Processed Gradiometer Data from a current summer farm at Las Verdas

**Phase 3: Gradiometer and Magnetic Susceptibility survey** Areas adjacent to and including upstanding features logged in phase 2 were targeted for small-scale gradiometer surveys. We were necessarily restricted to hand-held instruments on gridded surveys due to the practicalities of getting equipment up to the survey sites, which were reached by 4x4 and then by further hiking. Nevertheless, results in previous fieldwork in a similar landscape in Northern Calabria by one of the authors (see de Neef *et al.* 2017) suggested that magnetic contrasts sufficient for detection do exist on upland archaeological sites in limestone landscapes. This proved correct in Babia as well, with the detection of buried limestone structures showing as negative anomalies against magnetically enhanced soils. This was not the case on every site, with results proving challenging to interpret in around half of the surveys. This is in part thanks to the low contrast environment, the ephemeral nature of the occupation of some of the sites, and the small and fragmented surveyable areas encountered in the uplands. The sites where buried (we assume) limestone structures were identified all showed signs of being long term foci of occupation, with upstanding features from a variety of periods present and all showing signs of re-occupation and re-use. Identifications include a pastoralists' hut (Figure 2) just meters from a modern hut and an early phase of an enclosure system with multiple revisions (Figure 3), now disused. We tested large scale magnetic susceptibility survey at Lagüezo (North of La Cueta) with a group of five readings taken in a c. 1m spot zone, roughly every 5m. This worked was conducted with a Bartington MS2 with D field loop. The averaged measurements are plotted in Figure 4. This was a continuation of testing begun by van Leusen and colleagues in Italy (2014), to examine the possibility of MS survey as an adjunct to fieldwalking for the identification of small rural archaeological sites. In this case, the results are complicated by the co-presence of archaeological sites and currently used summer farms, which produce thick layers of animal dung over large areas. This can be seen in the aerial photograph used as the background for Figure 3.



*Figure 3: Processed Gradiometer data from an enclosure at La Machadina*

#### Phase 4: Test pitting

Archaeological excavations constituted the last phase in our pilot project aiming to assess the chronology and function for a sample of the sites explored. We have excavated 15 small test-pits and trenches so far, including huts, enclosures for animals, caves and small shelters at different locations. These works have resulted in the identification of seasonal pastoralist sites from different chronologies, ranging from Early Bronze Age to Contemporary period. Further investigations will hopefully reveal a chronological patterning in the sites location or typologies. Future research will include open area excavations at selected sites and extending palaeoenvironmental and radiocarbon sampling at archaeological layers.

#### Funding

The fieldwork has been conducted with the support of the Institute of Heritage Sciences (Incipit), CSIC [2017-2018]; the Department of Archaeology, Durham University [2017-2018]; the Prehistoric Society (2017 Small Grant) [2017]; the Instituto Leonés de Cultura de la Diputación de León and the Cabrillanes City Council [2018]; and the Rosemary Crump Fund [2018].

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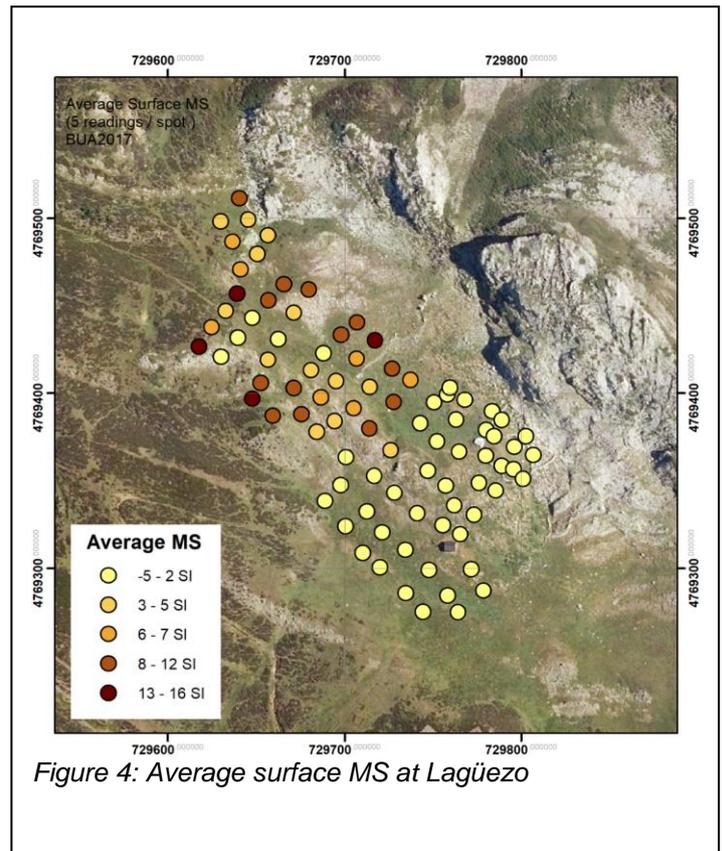


Figure 4: Average surface MS at Lagüezo

## 3D GPR OF A ROMAN BATH HOUSE AT CASTLE HILL, LANCASTER

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Lancaster Castle Hill and the surrounding area is the site of a series of several Roman fortifications and became an important military base in the 3<sup>rd</sup> and 4<sup>th</sup> Centuries. It is part of a network of Roman settlements in North West England. The site has been investigated in a number of archaeological campaigns and most recently in 2015 with the Beyond the Castle Project. These surveys have revealed a number of interesting features including Roman walls, roads and building foundations. Outside of this work we conducted several geophysical surveys at Quay Meadow and Vicarage Field to identify other potential regions of interest.

In this work we present 500 MHz GPR data from surveys conducted in Vicarage Field East, the site of a Roman bath-house (Figure 1). There has been relatively little work conducted at this site, it was excavated in the 1950s and then surveyed in 2015 using magnetometry as part of Beyond the Castle project. The GPR surveys we conducted were carried out in transects with 40 cm spacing and, once corrected for topography, successfully revealed several linear features (Figure 2), most likely rooms, and horizontal reflectors which could be the remains of Roman flooring. As the ruins are relatively shallow (< 1.5 m) GPR performed well at this site and provides key information for future excavations. It is anticipated that guided future excavations will enable the a fuller understanding of Roman activity in Lancaster.



Figure 18: Aerial view of the site.

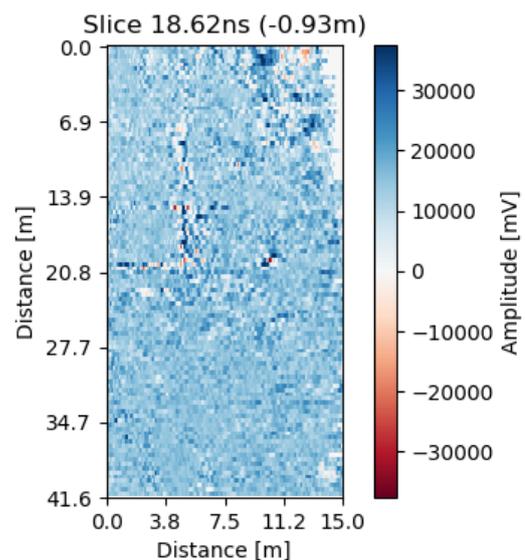


Figure 17: GPR slices showing straight anomalies probably related to remains of walls.

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## MULTI-DISCIPLINARY GEOPHYSICAL INVESTIGATIONS INTO THE 19TH-CENTURY TRENTHAM MAUSOLEUM, STOKE-ON-TRENT UK: BODILY EVIDENCE OF A VICTORIAN SCANDAL?

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Trentham Mausoleum was built in 1808 for George Grenville Leveson-Gower, 2nd Marquis of Stafford and later the 1<sup>st</sup> Duke of Sutherland. Although he was not buried within the mausoleum, nine of the 1<sup>st</sup> Duke's descendants were interred within the building between 1832-1893. Seven of these burials were initially interred within one of two intra-mural stone vaults, but were reburied under the mausoleum floor in 1904. Their memorial stones were re-set into the floor, alongside the grave slabs of the 3<sup>rd</sup> Duke and his son, both of whom had originally opted for burial beneath the chamber floor.

An additional burial, that of Mary, Dowager Duchess of Sutherland, took place in 1912. Mary was a scandalous figure in late Victorian society, first achieving notoriety in 1883 with the suspicious death of her first husband and a well-publicised affair with the 3<sup>rd</sup> Duke of Sutherland. She and the Duke married in 1889, just four months after the death of his first wife, Anne. The Duke died in 1892 and his will, which had been altered heavily in favour of Mary, was contested by his children. A settlement was eventually reached, but not before Mary had served a short prison sentence for destroying legal documents. Mary died in 1912 and, despite remarrying in 1896, her will directed that her remains be buried alongside those of the 3<sup>rd</sup> Duke inside Trentham Mausoleum. Although her wishes were carried out, her details were not added to the 3<sup>rd</sup> Duke's grave slab.

Despite the presence of memorial slabs within the mausoleum, rumours persist that some or all of the remains were removed in the early 20<sup>th</sup> century. Similarly, the lack of a discrete memorial has created confusion over whether the Dowager Duchess was ever interred within the building. To shed light on these



Figure 1. Part of the ground-based LiDAR survey of Trentham Mausoleum, Stoke-on-Trent, UK.

questions, a 500 MHz GPR grid was collected within the mausoleum. Subsequent analysis suggests that at least two open voids are present beneath the mausoleum floor, each with brick sides and a raised plinth.

A detailed micro-gravity survey was also collected over the same area, to determine whether voids (which may be associated with graves) are present or not. This was difficult to undertake due to the above-ground mass of the mausoleum itself.

A detailed ground-based LiDAR survey was undertaken, both inside and outside the building, in order to generate an accurate 3D model. This was subsequently used for numerical modelling (from first principles using the VBA function in Microsoft Excel) to remove the mausoleum’s effects from the microgravity dataset. Processing of the microgravity survey data revealed three detectable anomalies that could be correlated to three tombs but not the central grave of the 3<sup>rd</sup> Duke.

Invasive archaeological investigation would no doubt ground-truth these findings, but would be logistically difficult and constrained by the grade I listed status of the building. . The implications of the investigation are that high resolution, multi-geophysical investigations can be utilised within buildings.

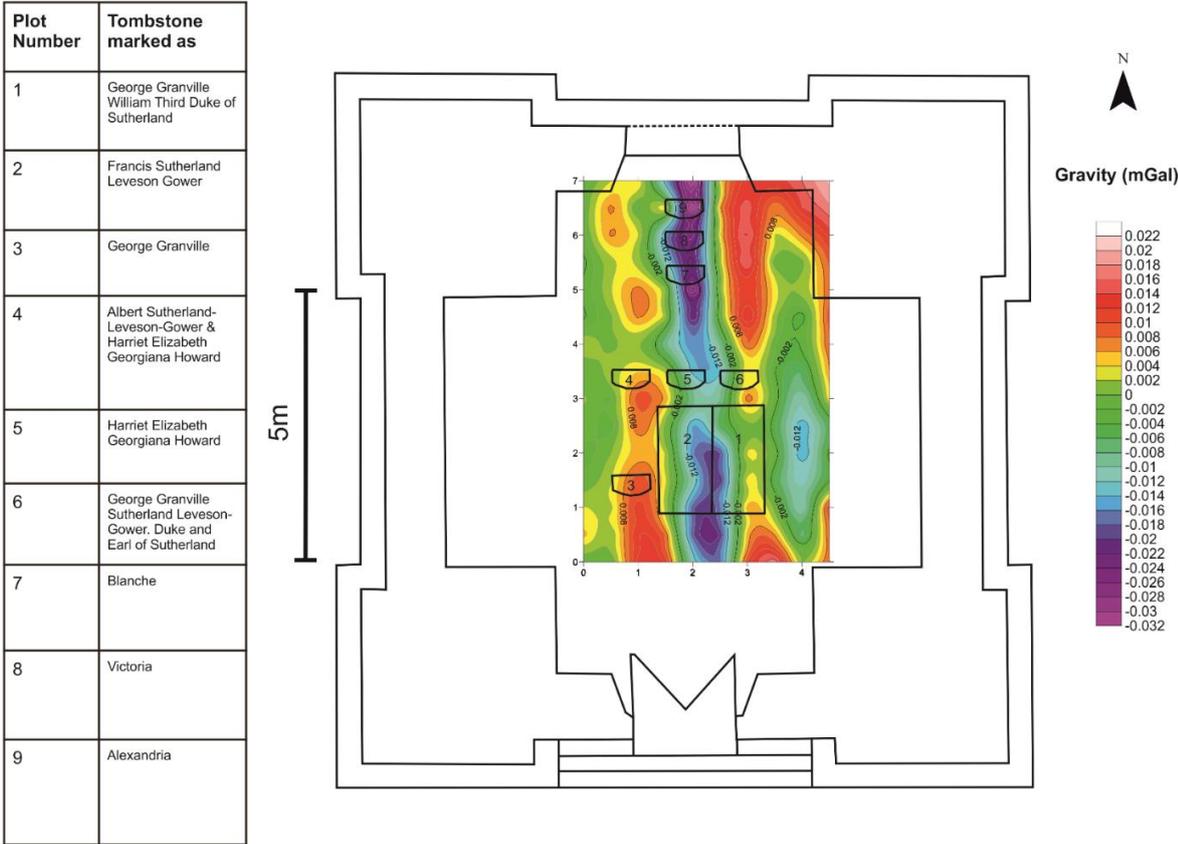


Figure 2. Processed microgravity dataset collected within Trentham Mausoleum, together with the identified surface tombstone details.

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## OVER THE TOP, UNDER THE GROUND: GEOPHYSICAL SURVEY AT BIRR BARRACKS, CRINKILL, CO OFFALY

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### Background

Birr Barracks, locally known as Crinkle Barracks, was built between 1809 and 1812 by Bernard Mullins. Initially the barracks accommodated up to 1100 men; however, following the introduction of sanitation regulations the barracks was limited to a maximum of 600 men. During World War I, recruitment increased substantially which likely prompted the construction of training trenches west of the barracks' perimeter wall.

The barracks' original purpose was to provide additional troops to assist in defending the Shannon, particularly the crossing point at Banagher and Portumna (National Inventory of Architectural Heritage 2018). From 1873, it served as the depot for the 100<sup>th</sup> Regiment of Foot and 109<sup>th</sup> Regiment of Foot, which were later merged to form the Prince of Wales' Leinster Regiment in 1881. Following this, the barracks acted as various regimental depots until February 1922. During WWI the barracks were used as a training ground to prepare soldiers to fight on the Western Front.

The Irish Republican Army took control of the barracks in February 1922, but with the outbreak of the Irish Civil War the barracks were burned and destroyed on 14 July 1922 to stop the National Army from reoccupying it. The burnt ruins were subsequently demolished, with remaining rubble removed in the 1950s and the training trenches backfilled.

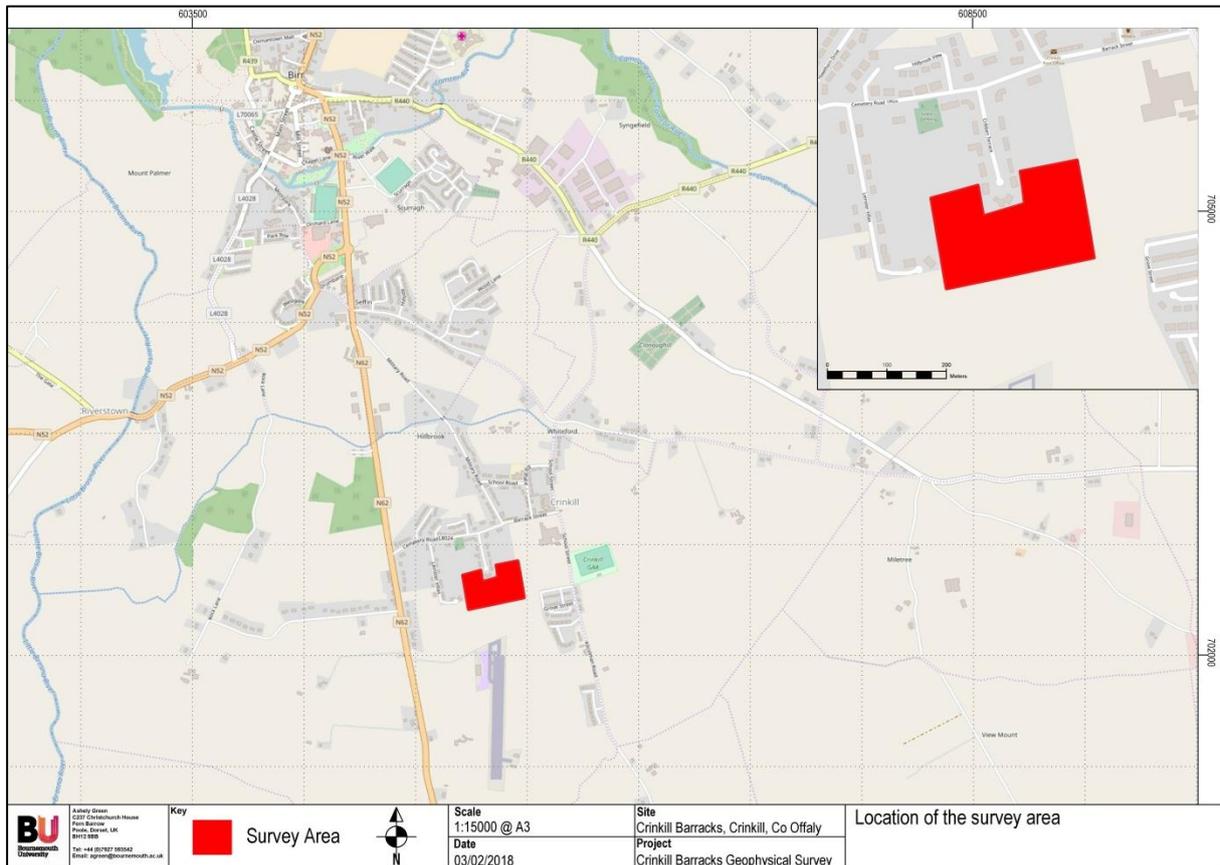


**Figure 1: View of the barracks' surviving perimeter wall and survey area**

The perimeter walls with gated entrances protected by bastion shaped outer works with gun loops to north and west sides are the only extant remains of the barracks (National Inventory of Architectural Heritage 2018). The site of the barracks is now occupied by a factory and handball club, while the site of the training grounds is in use as pasture and was accessible for geophysical survey.

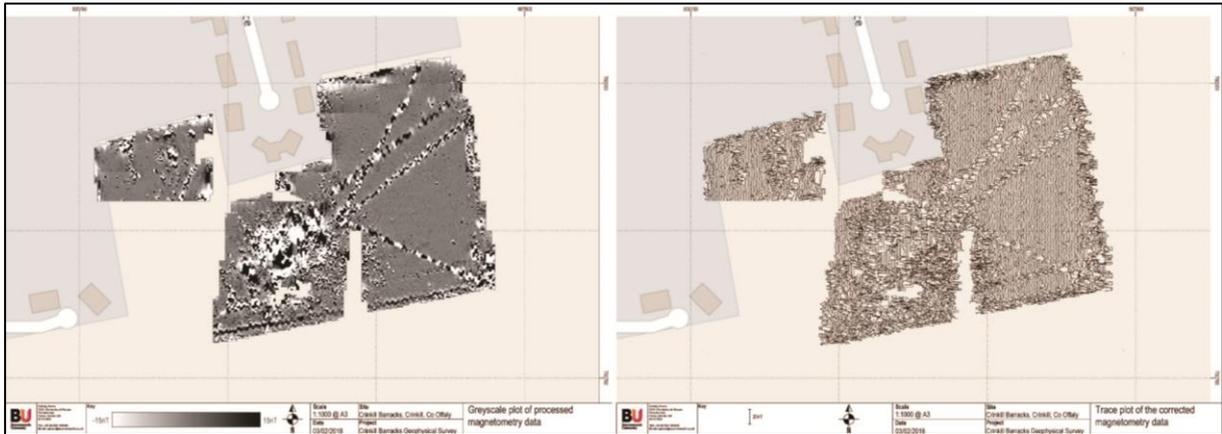
## Geophysical Survey

A geophysical survey was carried out in December 2017 (Licence No. 17R0238), along the western extent of the barracks. The survey area comprised approximately 2.5 hectares of pasture bounded by Birr Airfield to the south and a housing estate to the north, shown in Figure 2. The survey area was chosen to target the training ground and original pump house associated with Birr Barracks.



**Figure 2: Location of the survey area**

An initial survey to determine the suitability of the site for future high resolution geophysical survey was conducted with a Bartington Grad-601 gradiometer using a 1m traverse interval and 0.125m sampling interval. Despite the noise in the dataset caused by from modern activity on the site, responses of archaeological potential were identified throughout the survey area. From the data presented in Figure 3, the original gas works linking the pump house to the barracks can be relocated. Further to the gas works, three sections of potential training trenches, and potential 19<sup>th</sup> century features of the barracks were identified. These responses were targeted for excavation.



**Figure 3: Greyscale plot of processed magnetometry data (Left) and trace plot of corrected magnetometry data (Right)**

**Excavation**

In August 2018, the Irish Archaeology Field School (IAFS) led a community excavation on the site – the first excavation of WWI training trenches in the Republic of Ireland (BBC News 2018; Offaly Independent 2018; IAFS 2018). Dr Denis Shine and Stephen Callaghan managed the excavation which aimed to clarify the location, morphology, and construction of the training trenches. Evaluation trenches were positioned to target the potential archaeological features identified in the magnetometry data and highlighted in Figure 4.



**Figure 4: Interpretation of the magnetometry data**

The excavation located multiple sections of the training trenches and the gas works. The training trenches are a classic zig-zag shape and shallower at the southern extent of the training grounds but reached approximately 1.2m deep towards the northern extent of the training grounds (IAFS 2018). The *in situ* gas pipes were also recovered, extending east from the disused pump house to the barracks.

## Conclusion

Responses identified as potential archaeological features in the magnetometry data were confirmed to result from the gas works and zig-zag style training trenches through excavation. While the extent of the barracks is outlined on historic mapping, prior to the survey and excavation there was no record of the location and characteristics of the training trenches. Even with the 'noisiness' of the survey area, initial geophysical survey proved successful in highlighting the training trenches and features associated with the barracks, and informing excavation strategies.

## Future Research

Both the initial geophysical survey and excavation proved successful in locating features of interest relating to occupation of the barracks. Based on the success of the landscape magnetometry survey, additional ground-penetrating radar (GPR) and multi-depth electromagnetic induction (EMI) surveys are proposed for future phases of the project in order to map the remaining extent of the training trenches and military graveyard.

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# DISCRIMINATING SAXON SHIELD BOSS FROM UNEXPLODED ORDNANCE BY ADVANCED TIME DOMAIN ELECTROMAGNETICS: AN EVALUATION STUDY

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## Introduction

A systematic metal detection survey, undertaken in an arable field in the South East of England, led to the discovery of a mid-6th century burial containing a variety of grave goods; including a Saxon shield boss, spear, knife and tweezers. Following the discovery, aerial mapping (review of aerial photography and airborne laser scanning) and geophysical survey (Magnetics, GPR and Earth Resistance) were conducted by Historic England to determine the extent of the Saxon activity on the site and assess historic land use from the 1940s to present.

The results of the magnetic gradiometer survey indicated significant numbers of strong ferrous dipole anomalies in the vicinity of the grave. Historic records supported by aerial photography indicated a strong probability some of these anomalies were remnants of WWII ordnance. To further characterise the dipolar ferrous anomalies an advanced Time Domain Electromagnetic (TDEM) metal detector survey was undertaken using the Geometrics MetalMapper2x2.

## Methodology

The MetalMapper2x2 consists of four 35 cm by 35 cm transmitter coils and four 10 cm by 10cm three-component receiver coils. The instrument illuminates the ground with each transmitter coil sequentially and measures the induced transient magnetic field on all receiver channels, producing a total of 48 decay curves per measurement station during a static measurement sequence. Inverting the recorded x, y and z decay curves leads to the local (X,Y,Z) position of the target beneath the array, the orientation of its principal axes, and the principal axis polarizability. The amplitude of the primary polarizability, and the ratios of the second and third polarizabilities to the first are then used as matching criteria to compare the field measurements to a reference library of responses from known buried ferrous objects (ESTCP 2012). These comparisons are numerically scored on a scale from 0 to 1, with 0 representing an extremely poor match and 1 a perfect match.



Figure 1: MetalMapper2x2 advanced Time Domain Electromagnetic Metal detector

A 30 m by 30 m area was systematically surveyed with the MetalMapper2x2 over the area containing the burial, with the objective of providing a simple visual anomaly comparison with the magnetic gradiometer results.

In addition the dynamic survey assisted with locating a control station free from metallic material. The control station was visited on an hourly interval and used to correct the inherent Electromagnetic Induction (EMI) response of the system components and ground properties. The Standard Function Test (SFT) was also performed at the control station using a known calibration sample to verify the MetalMapper2x2 performance.

Forty eight static measurements were recorded with the MetalMapper2x2 over significant dipolar anomalies identified from the magnetic gradiometer survey. One of the measurements was a known Saxon shield boss buried at a depth of 27.5cm below ground level (bgl).

## Results

Results from the dynamic data acquisition are depicted in Figure 2 and show good correlation with dipolar anomalies in the magnetic survey but, with the exception of target known shield boss, no further boss-like anomalies have been detected in the area covered.

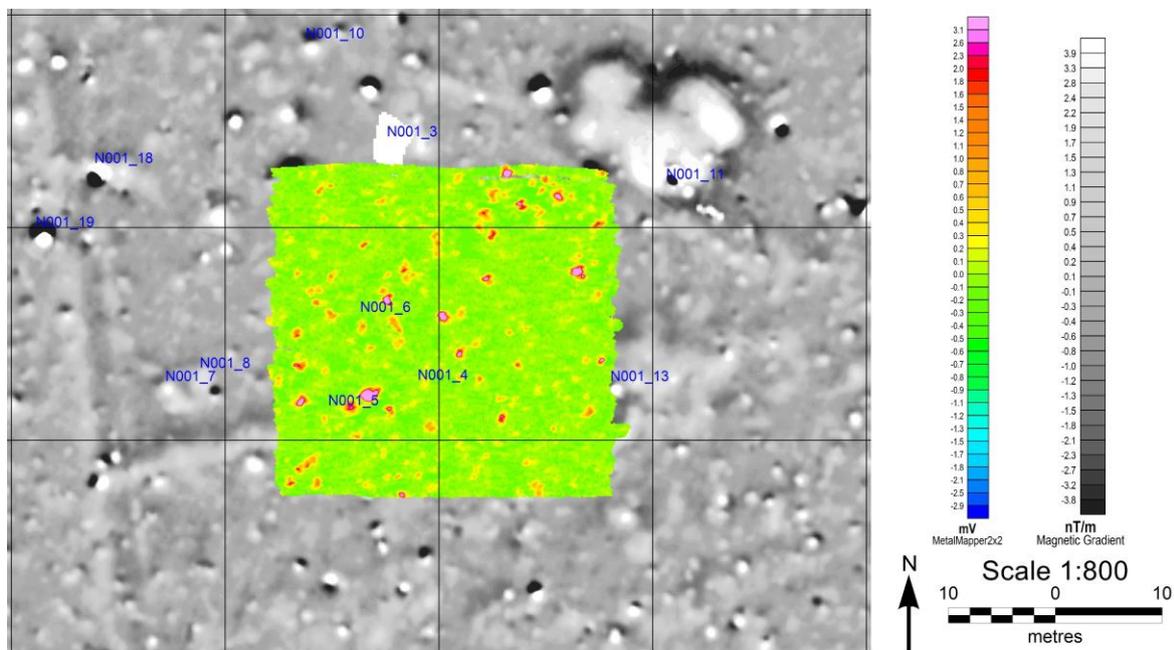


Figure 2: Caesium Gradiometer results with MetalMapper2x2 dynamic results overlaid.

Interpretations for the Static measurement were derived by matching the measured polarizabilities against the existing object library. The present object library does not include a measurement for a Saxon shield boss and therefore a proxy was identified by recording a measurement over the known *in situ* shield boss (measurement N001-5). The closest proxy was found to be a 60 mm Mortar M49A4, measured at Blossom Point. A shield boss is a fairly complex shape consisting of a dome and circular flat plate, unlike a mortar which is a constant cylinder tapering at both ends. The symmetrical shape of the shield boss produces two polarizabilities with the same amplitude and decay profile, and one polarizability with differing amplitude and decay profile; similar, but not identical to, a cylinder. The differences in shape between the shield boss and mortar result in a match coefficient no greater than 92%. When characterising unexploded ordnance (UXO) a match of greater than 98% is required

to confidently identify the target, suggesting the Mortar is a reasonable proxy, albeit not an exact match. Analyses of the polarization decay with time for the measurements at N001-5 are shown in Figure 3.

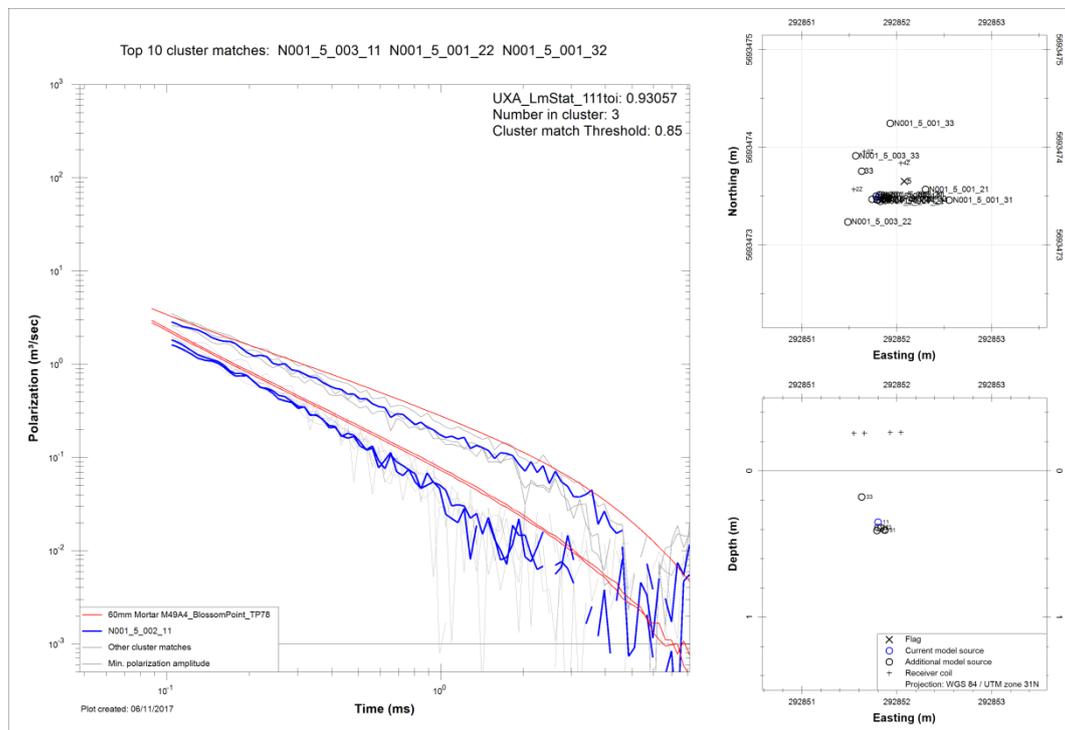


Figure 3: Inverted polarizability curves and best fit modal for N001-5, known Saxon shield boss buried at a depth of 27.5m bgl.

## Conclusions

The result from the MetalMapper2x2 survey complimented the other geophysical survey and aerial mapping interpretations. Unfortunately at this time the instrument was unable to clearly discriminate between the Saxon shield boss from unexploded ordnance present on the site using a proxy from the current object library. The results of the dynamic and static survey have the potential to be re-analysed once a model has been added into the MetalMapper2x2 object library following further research into the metallurgy of the artefact.

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## A Multidisciplinary Investigation to Discern Subsurface Features Evident In and Around Hawthorn Crater with Resulting Implications

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The war of attrition that plagued the Western Front during WW1 resulted in the development of new strategies to overcome the opposing enemy defences. Hawthorn Ridge was one such location, chosen to protect the town of Beaumont Hamel, France. Renowned as the site of the largest cumulative explosion (70,600lb's) of the war, the area exists today as Hawthorn Crater. Due to neglect, the remnants of war were left to gradually degrade and collapse, regardless of their historical and academic value or the threat they pose. However, these now is a focus within the sub-discipline of conflict archaeology, driving the first ever detailed investigation into this crater.

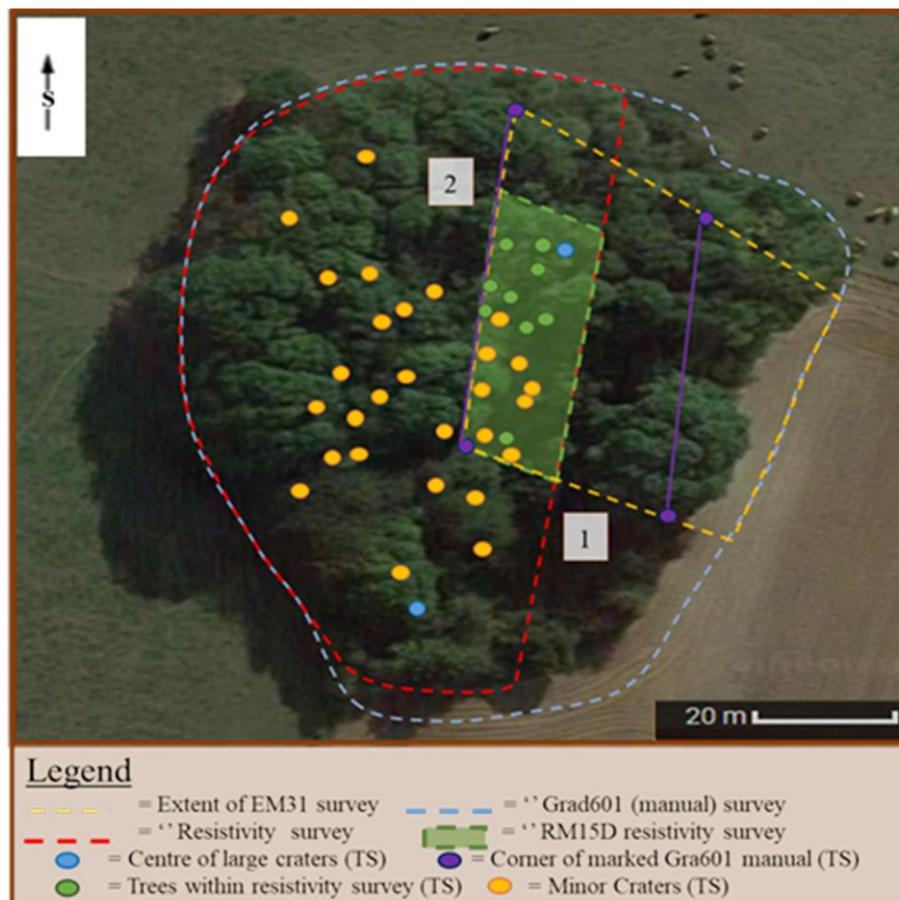


Figure 1. Modern aerial photograph displaying the placement and extent of the total survey and all geophysical techniques utilized during the investigation. Letters correspond to contoured surfaces below (Google, 2017).

The aim of this investigation was to evaluate the evolutionary and morphological aspects of Hawthorn Crater and discern subsurface WW1 remnants through the application of various remote sensing techniques. Due to the complexity of the investigation it was necessary to conform to a multidisciplinary approach. This comprised of a desk study (photographs, video footage, plans and terrestrial LIDAR) and a fieldwork expedition (TS, EM, resistivity and magnetometry) conducted from the 17th to 19th June 2018. Data collected was processed, analysed and integrated to develop a stronger analytical picture of the test site.

Results identify the location and scale of various WW1 remnants within the designated 1.2Ha area around the crater, including various shallow surface debris, a network of trenches, dugouts and potential preserved remains of the H3 mine. This survey validates the effectiveness of applying remote sensing techniques within a multifaceted investigation.

Academically this research has advanced the knowledge of Hawthorn Crater, WW1 tactics and conflict archaeology as a whole. It has categorized areas of susceptibility to subsidence based on corresponding subsurface voids, along with potential UXO's requiring hazard reduction through clearance. From a socio-economic standpoint the research will strengthen the region both on a local and international scale through increased global interest. The report will reinforce the base knowledge for the ongoing five-year HCPP, working in collaboration with several prominent academics.

## REDISCOVERY OF A BAROQUE PALACE IN BAVARIA BY MULTI-DISCIPLINARY ARCHAEOLOGICAL PROSPECTION

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### Case study

The Baroque summer residence “Tiergarten” was built at the end of the 17th century by the prince of Oettingen-Oettingen in the area of the Ries-Crater in western Bavaria. For the construction, a natural hill was artificially levelled and hence a plateau was created that is flat towards the north and steep towards the other sides. After some decades, the palace was re-used to manufacture faience. But by the middle of the 18th century the whole building complex was ruinous and all buildings were completely removed. So nowadays only the flat plateau gives a hint to the former size of the site.

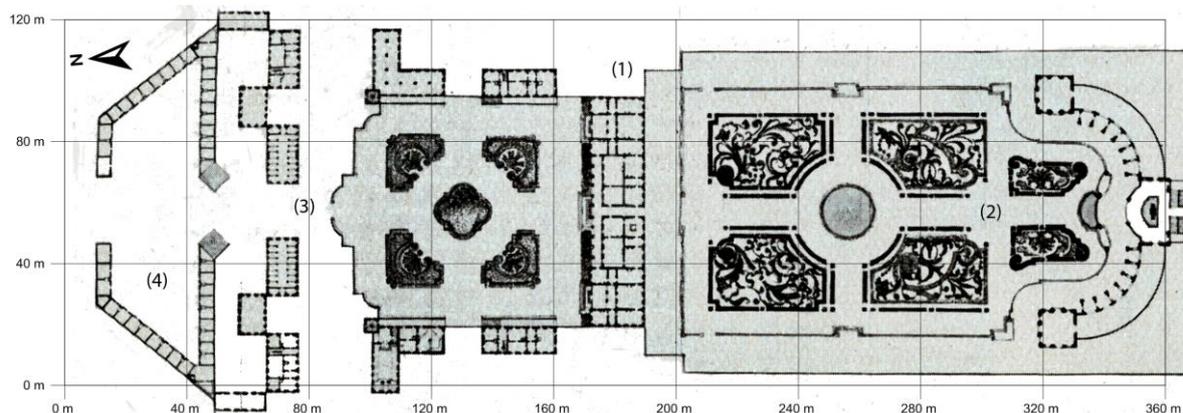


Figure 19: Plan of the Baroque summer residence drawn by Johann Paul Thomas Edel around 1730. 1 = Main buildings, 2 = Flower garden with Belvedere, 3 = Subsidiary buildings, 4 = Enclosure walls with barracks.

### Layout of the palace

The former layout of the summer residence is known from a Baroque plan of around 1730 by Johann Paul Thomas Edel (Figure 1). It shows the main building as an elongated single-storey building. North of it monumental staircases had been erected that led to a huge courtyard that was flanked by several subsidiary buildings. The northern closure of the courtyard had been a trapezoidal enclosure wall with attached barracks for the palace guards. South of the main building a garden was installed with a semi-circular belvedere and a fountain.

### Results of multidisciplinary prospection

Over the last 250 years the palace was buried in oblivion, until it was rediscovered in 1979 by the Bavarian aerial archaeologist Otto Braasch and partly documented by aerial images in the last decades (Figure 2). Most of the structures in the northern

part of the palace could be identified, as this area is used for agriculture and crop marks can occur. But in some areas the detailed layout still was unclear and especially nothing was known about the southern part that is used as grassland. Therefore geophysical prospection of the whole palace area was conducted with magnetometry (Fluxgate and Caesium magnetometers) as well as ground-penetrating radar (GPR). While the magnetic survey could be done on the whole plateau, the radar survey had to be concentrated to an area of 80 x 80 m in the north-eastern part due to the advanced vegetation.



*Figure 20: Northern part of the Baroque palace in the aerial photograph; view from southeast. Bavarian State Department for Monuments and Sites - Aerial Archaeology, Date of photography: 02.07.2006 by Klaus Leidorf, Archive Nr. 7128/081\_8963-21*

Comparing the magnetogram with the old Baroque plan of Edel reveals that there are many consistencies. So the non-scaled plan could be scaled for the first time with the help of our results. The magnetogram (Figure 3) shows that the main building with the staircase and the entrance in the north was constructed as the plan shows. Only the floor plan of the distinct room cannot be resolved anymore.

Also the detailed layout of the garden coincides with the plan. Furthermore an old water pipeline could be mapped that runs diagonally through the garden near to the central fountain. This detail had not previously been known.

In contrast the size and location of the subsidiary buildings does not fit well to the plan of Edel. But this could be due to the many documented renovation and repair works that have been done there. The only building that could not be documented in our magnetic survey is the bastion in the northernmost part, as it was destroyed by the construction of a modern water pipeline.

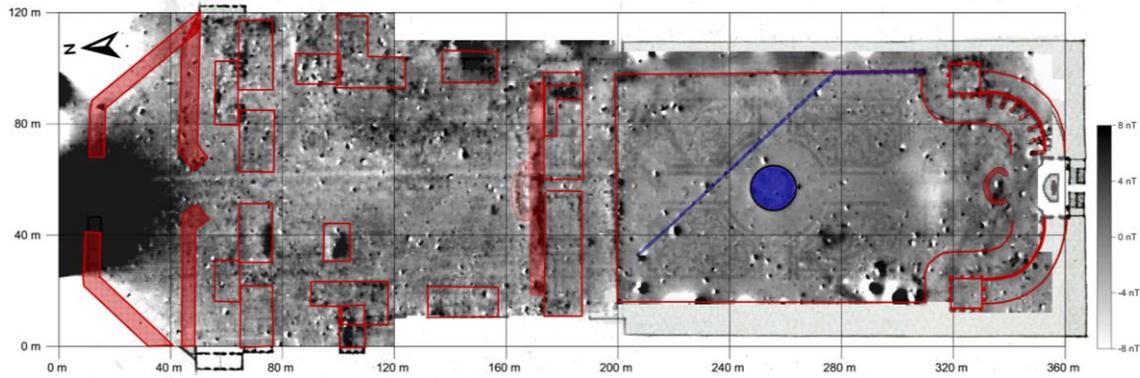


Figure 21: Magnetogram of Baroque palace overlain with plan of Edel and digital interpretation (red = walls, blue = fountain & water pipeline). SM 4G-Special Caesium Magnetometer, duo-sensor configuration, sensitivity:  $\pm 10$  pT, dynamics:  $\pm 8$  nT, point density: 0.

Our geophysical measurements furthermore revealed bricolage created during the erecting of the enclosure walls. Whereas the north-eastern wing fits to the symmetric axis of the palace and corresponds to the Baroque plan, the north-western one deviates partly by 5 m.

The faience factory could be associated to the eastern subsidiary buildings, as our magnetic survey shows areas strongly affected by fire there. Another building or cellar that is fire-affected and not mapped in the old plan can be detected in front of the western subsidiary buildings.

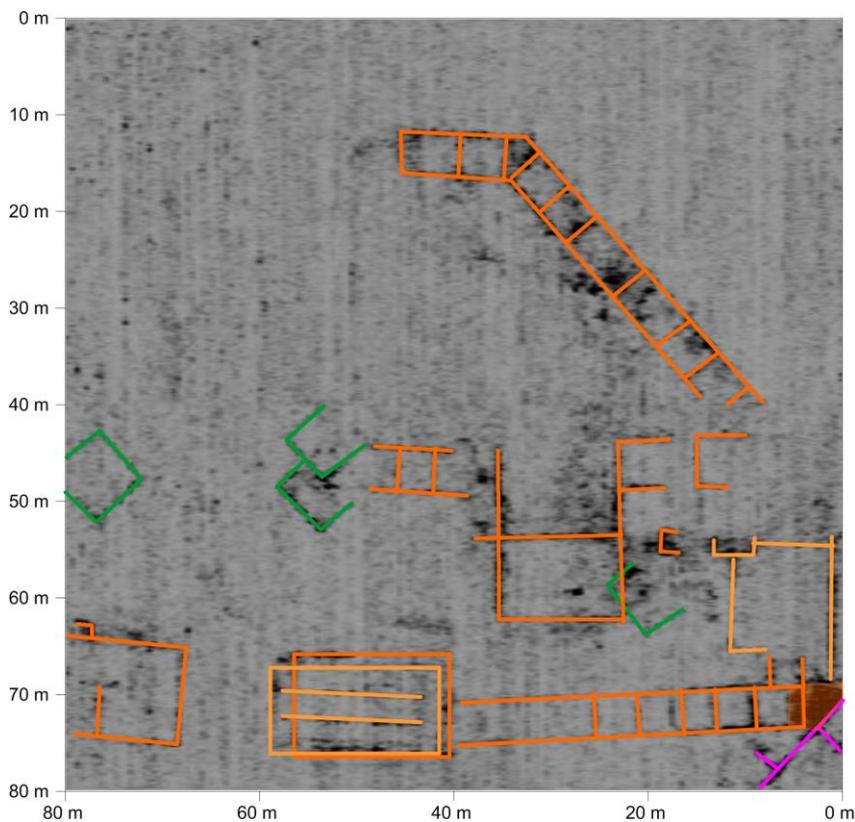


Figure 22: Depth slice of 60-80 cm overlain with digital plan of structures. GSSI SIR-3000 with 400 MHz antenna, sample interval:  $0.02 \times 0.5$  m. Archive-Nr. 7128/081. Size of area: 80x 80 m. Building phases: orange = main phase, light orange & green = possible renovation and repair phases, magenta = sewage system.

The GPR survey reveals that the Baroque remains are merely covered by a thin soil layer. The walls can be captured between 20 and 120 cm depth below the modern surface. The walls are only preserved to a depth of 1 m beneath the surface, as only the last remains of the foundations were left in the ground during deconstruction of the palace. In the north, the radar depth slices show the eastern part of the barracks as an elongated building bent by 135° (Figure 4). The soldiers' rooms have a standardized size of 2.5 m. After 35 m length, the structure bends towards the west and ends in an approximately square entrance gate which has a counterpart on the other side of the access road. In the southern part of the radar images, another similar structure running east-west can be identified that has never been documented before. This structure ends in a 16 x 10 m building in the west that had been previously mapped by Edel. At the same place another slightly shifted building of 17x 9 m size with two parallel walls is preserved. This could be interpreted as remains of renovation work. In-between several further walls can be identified and reconstructed to further buildings of 12 x 8 m and 7 x 12 m size. The linear structures in the south-eastern corner of the depth slices can be interpreted as parts of a former sewage system. At the same location the remains of a Baroque pavement is preserved.

The multimethod geophysical prospection hence provides a comprehensive overview of the preserved remains of this Baroque summer residence. Furthermore the accuracy of the old plan of Edel can be tested. The survey furthermore shows that it is always advisable to do a survey with all possible geophysical methods, as each shows different details and only the combination leads to a complete plan of an archaeological site.

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## MAPPING VERULAMIUM

Kris Lockyear on behalf of the *Community Archaeology Geophysics Group*  
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In 2013 the *Community Archaeology Geophysics Group* completed a magnetometer survey of Verulamium Park which covers approximately half of the Roman city of Verulamium (Lockyear and Shlasko 2017). Since 2015, the group has undertaken four month-long seasons of work on the northern half of the town which lies within the Gorhambury Estate. The work from the first two seasons was presented at the 2016 conference (Lockyear 2016). Since then, the group has expanded the magnetometer survey outside the walls to encompass the area surrounded by an earthwork known as The Fosse, as well as expanding the GPR and earth resistance surveys within the town walls. Additional surveys have also been completed in the grounds of Darrowfield House, and the GPR and earth resistance surveys within Verulamium Park have been expanded. This poster presents highlights from our results.

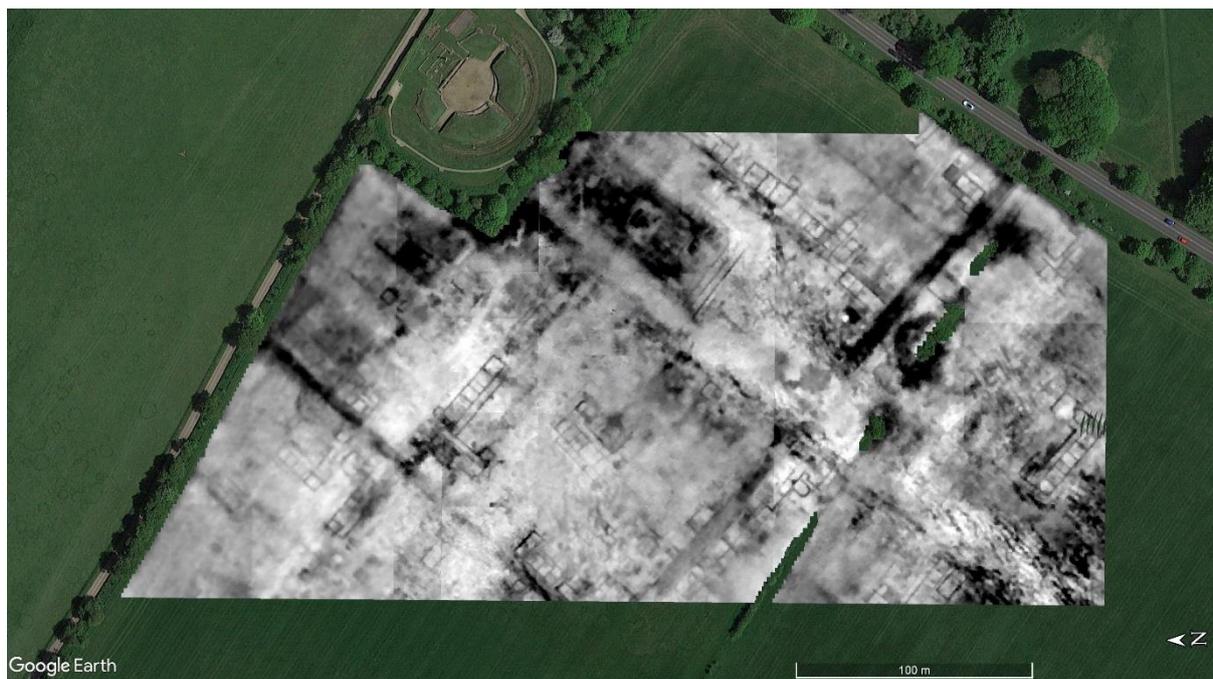


Figure 1: The Earth Resistance survey at Verulamium / Gorhambury as of 29/8/2018.

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## WHAT CAN WE DO WITH RED, GREEN, AND BLUE? INTERPRETING DRONE DATA FROM THE WEST GREEN AT FOUNTAINS ABBEY

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Two drone surveys were carried out at Fountains Abbey in North Yorkshire during the summer of 2018. One occurred in July, recording unprecedented parch marks in the grass at the site – yet another fantastic archaeological discovery resulting from the nationwide drought (Grady 2018). The second survey took place in September, after several weeks of normal English weather (i.e. rain). Both surveys were carried out by personnel from University of Bradford's Visualising Heritage research group.



This poster will focus on the West Green, where recent geophysical surveys have revealed a large, previously unknown guesthouse (Gaffney et al. 2014). This discovery is helping to expand our understanding of England's largest Cistercian monastery (Newman 2015).

For both surveys, a DJI Mavic Pro was used to collect a series of RGB photographs. Reference targets were recorded using a total station. Orthophotos were subsequently created using PrecisionMapper, a cloud-based photogrammetry software package. The application of Vegetation Indices is a common method of detecting archaeological features in multispectral imagery (Bennett et al. 2012). However, similar algorithms can also be applied to RGB imagery. A Green Leaf

## Fountains Abbey - Green Leaf Index of September 2018 drone imagery



Index was calculated for both the July and September orthophotos, drawing out subtleties in the parch marks that are not obvious in the unprocessed data.

The RGB orthophotos were separated into red, green, and blue bands in QGIS. The following GLI formula was then applied to create a new raster layer for both the July and September datasets:

$$\text{Green Leaf Index (GLI)} = (2 * G - R - B) / (2 * G + R + B)$$

(PrecisionMapper 2018)

Initial examination of the two contrasting datasets (shown below) suggests that both are valuable sources of archaeological information. In July, the parch marks clearly revealed the large stone guesthouse to the west of the main Abbey complex. However, the September imagery shows Victorian tramway tracks cutting across this guesthouse – a feature that is all but invisible in the July imagery. This is likely due to an accumulation of moisture along the trackway, allowing for healthier grass to grow above it (see September figure).

Further analysis must be carried out to link spectral responses with geophysical anomalies found in previous surveys of the West Green. The GLI is only one of many Vegetation Indices that will be applied to this data to pull out further subtleties. More drone surveys will also be carried out, using multispectral sensors to record infrared bands. This will allow a direct comparison between RGB data collected under ‘ideal’ conditions (ie. July 2018), and multispectral data collected under ‘non-ideal’ conditions.

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## A POSSIBLE INLET FEATURE AT A ROMAN PORT: USING ERT AND EMI TO CHARACTERISE QUAY MEADOW, LANCASTER

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Lancaster Castle Hill and the surrounding area is the site of a series of several Roman fortifications and became an important military base in the 3<sup>rd</sup> and 4<sup>th</sup> Centuries. It is part of a network of Roman settlements in North West England. The site has been investigated in a number of archaeological campaigns and most recently in 2015 with the Beyond the Castle Project. These surveys have revealed a number of interesting features including Roman walls, roads and building foundations. Outside of this work we conducted several geophysical surveys at Quay Meadow and Vicarage Field to identify other potential regions of interest (Figure 1).



Figure 1: Aerial view of the site.

Quay Meadow is the site of an old Roman Port. The land immediately to the north east was reclaimed in the 18<sup>th</sup> century, changing the course of the River Lune. Archaeological work at the site has revealed a Roman road leading towards the Castle and several building foundations. We conducted some initial GPR and EMI surveys of the site. The GPR was successful in locating the Roman road, but the EMI did not show many features related to Roman buildings. The EMI did however reveal a conductive feature east of the meadow (Figure 2). This feature is around 20 m wide and runs perpendicular to the original river course. Additional electrical resistivity surveys reveal the structure of this feature and better understand its origin.

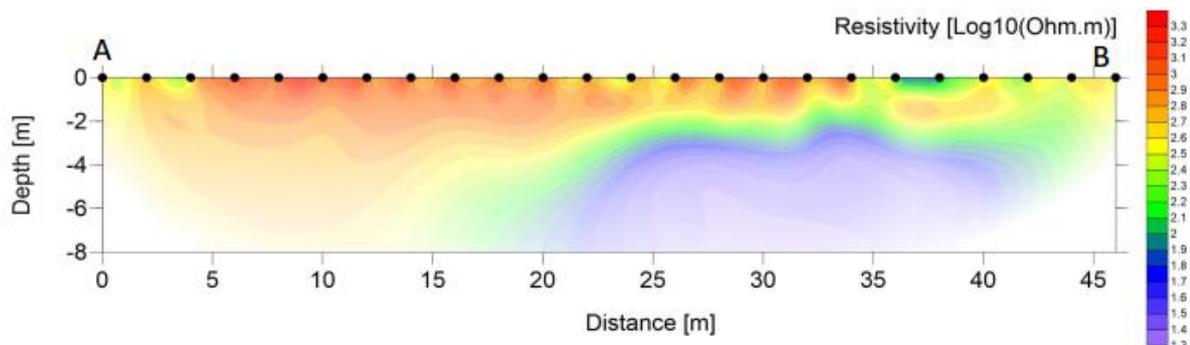


Figure 2: Inverted ERT section of the inlet feature.

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## GEOPHYSICS WITH A LID ON

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As part of its major education and expansion plan The Archway Project, the Roman Baths in Bath were required to carry out limited archaeological work in the vaults under the road to the south of the baths, immediately next to the Great Bath, in areas previously used for storage. These areas have been subject to sporadic investigation over many decades, but there had been no coherent reporting of this work.

The Archway Project will enhance the visitor experience at the Roman Baths by creating public access to *in-situ* Roman remains that are currently not open to visitors. It will dramatically improve the site's learning offer by converting listed buildings into a learning centre for the Roman Baths and by creating an archaeological 'investigation zone' where schoolchildren and learning groups can participate in hands-on archaeological activities. The Project will also enable local people and visitors to Bath to explore and learn about the Roman, Georgian and Victorian heritage of Bath in exciting new ways by creating a World Heritage Centre for the City of Bath.



*Surveying in the vaults under the street: advantage: it is under cover;  
disadvantage: it is a very constricted space.*

The Bath and Counties Archaeological Society (then the Bath and Camerton Archaeological Society) were contracted to the project, working in liaison with Cotswold Archaeology, to undertake geophysical survey over those areas of earth flooring relinquished to see if there were any previously unknown deeper features before Cotswold Archaeology could undertake shallow remedial excavations.

Working under the vaults in January was an attractive proposition, although the space was not entirely watertight. There were also a number of disadvantages: the area was heavily encumbered with iron joists and trunking, so magnetic techniques were not useable; much of the floor area was disrupted by previous excavation pits, wooden decking, rubber matting, concrete scree and courses of ancient walls so maintaining any grid for logging geophysics data was not trivial. As an insurance against major problems in location, all resistance data were also hand written on to paper. This proved invaluable when there was some corruption of the data on the download at the end of the first day.

Most geophysical techniques rely on producing a plan of sub-surface signal returns, which in turn requires a sufficient area and a good density of readings within that area to produce a pattern which can be interpreted. Even techniques which produce an elevation plot by probing varying depths along a line require a continuous line of sufficient length to produce interpretable results.

The measurement grid was set to take readings at half-metre intervals in either direction in order to give a good number of measurement points within the confines of this space.

Techniques tried included twin-probe resistance, resistivity profiles (ERT), thermal and radar. Each showed varying degrees of success. Resistivity profiles proved the most useful, especially when combined to produce depth slices. Twin probe resistance using one metre mobile probe separation could look deeper, but the long bar was so unwieldy in the constrained space that it was only possible to survey one part of the area using it.

There was a further constraint in that we were not allowed to penetrate into the floor: our resistance probes had to make good electrical contact while only touching gently against the surface.

The area surveyed was to the south of the Great Bath, under the modern York Street. It was divided into two rooms by a modern wall. The western room was wider, over 10 m, but the available floor so constrained by rubber matting and hardboard walkways that only lines of probes for profiling could be deployed.

The eastern space was about 30 m long, subdivided midway by a slight step. The upper (eastern) end had an earthen floor and could be surveyed in almost normal ways. However, it was only some 6 m wide, and there were interruptions, including test pits, modern pillars and Roman walling which limited the clear area to about 15 m by 3.5 m, with a leak in the vaulting rendering the far eastern end very wet. The lower (western) part had very little uninterrupted floor.

There was further space to the south of the eastern area, never excavated and so containing unknown Roman archaeology. A limited attempt was made to probe this space with radar, with some success, but a full investigation would require very elaborate planning and execution.

The techniques, the constraints in their use and the results obtained for each instrument will be discussed in this paper.

*We are grateful to the Archway Project staff of the Roman Baths, Bath, for allowing us to publish this paper, to all the volunteers and coordinators who gave their time for this project, to Cotswold Archaeology, and to all the sponsors of this project. The principal sponsors are shown below.*



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## A TALE OF TWO HILLTOPS

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Two hilltop sites near Bath are discussed and compared in terms of location, techniques used, problems encountered with those techniques in extreme opposite conditions, and the results obtained. One site, to the north of Bath, had been excavated over 100 years ago, was scheduled and was surveyed during wintery weather. The other site, to the west was previously unrecorded and was surveyed at the height of this hot, dry summer. Both sites were under grass but were limited by farming calendars. Snow drifts helped to delineate earthworks on one, parch marks on the other. Both sites had LiDAR coverage, but of limited quality. Both sites used gradiometry, magnetic susceptibility, twin-probe resistance and resistivity profiles.



Setting the grid in snow

Settlement Field is a promontory on the far north-eastern corner of the Lansdown plateau, about 230 m OD, with precipitous drops of 5 m on north and south sides (before falling away less steeply), meeting at an eastern point like a ship's prow, while the level approach to the west was protected only by a more recent stone wall. The northern edge commanded views across to the Severn estuary, and to the southern Cotswolds while the southern view was down the Swainswick Valley with the north of Salisbury Plain in the far distance. The site had been trenched in 1905-8 by Gray and on the basis of a find, has since been described as a Roman pewter manufactory. Earthworks are prominent in the central portion of the site, but time and resource limitations precluded a full earthwork survey. The site is scheduled and required licence to survey. It is also protected as part of a scheduled battlefield (Battle of Lansdown, 1643). The survey started with snow on the ground (but the ground was not frozen) and ended in pouring rain. There was some concord between survey, earthworks and excavations but there were also major discrepancies.

The hilltop just to the west of Temple Cloud, 10 km south of Bristol, had remained open land in the midst of Paul's Wood through maps from 1720 onwards. Its panoramic views west and south to the Mendip ridge, east to Clutton Hill and beyond as far as the Marlborough Downs and north to Dundry Hill is only interrupted by modern hedges. The steep hillside undergoes two breaks of slope to become a plateau some 160 m OD. Only the west side of the site was available initially, separated from cattle only by a wire fence, which was downed in a cattle invasion which created a hiatus in the survey. This turned out to be an advantage as rain in the intervening period softened the ground enough to reduce resistance survey to normality: initially, the ground was so hard that each grid had taken 90 minutes to complete.



Electrical resistance meets physical resistance

Magnetic techniques demonstrated that the lower break of slope was natural, but the upper delineated a settlement area, probably prehistoric and Roman, with a later beacon. However, the settlement appeared from resistance survey and parch marks to be contained by a wall, notwithstanding the ditch-like signature of the magnetometry. The eastern part of the settlement only became available for survey in October 2018. The site was previously unrecorded and only came to light by the astute observation of a member of our amateur archaeological society.

*Many thanks are due to Tom Bravin, owner and farmer of the Lansdown site, and to Tom Rees-Mogg, owner and Kevin Curtis, tenant farmer, of the Temple Cloud site, for allowing us access to their land. The Lansdown survey was undertaken under Section 42 licence, issued by Historic England.*

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## ELECTROMAGNETICS (EM) AS A RECONNAISSANCE TOOL IN DEFINING SITES FOR CONFLICT ARCHAEOLOGY

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Case-study examples are given that show EM as a quick and effective tool in defining battlefield sites and military installations. This work shows that EM provides an effective 'bridge' between the Desktop Study of geology, soils, past-land-use, local intelligence/archives and the full implementation of a multi-proxy geophysical survey and possible excavation. As well as the desktop study, some simple pre-requisites are needed, such as some idea of the size and depth of metalliferous/ferrous/non-ferrous items, the background environment, and availability of GNSS recording. Filtering of spatially-referenced EM data, based on the above, can provide clusters, patterns or lines of anomalies that discount the inevitable outliers in the first iteration of survey. The method is not fool-proof however, and examples are given where confusion or failure was the result.

The cases to be discussed are:

1. The location of Spitfire P8074, crashed into a hill-top bog in County Donegal, Ireland, buried to a depth of 6-8m.
2. The footprint of a Bailey Bridge, built by the US Corps of Army Engineers over the River Lagan (County Antrim), Northern Ireland.
3. Definition of Wehrmacht Howitzer trenches at Brecourt (Normandy, France): the location of the famous 101st Airborne Division 'Band of Brothers' assault.
4. Location of a crashed P38 Lightning in County Monaghan.
5. The area occupied by an R101 'Blimp' Airship Station in WW1 at Whitehead (County Antrim, N.Ireland).
6. Definition of a WW2 aircraft breaking yard at Dalgety Bay, Firth of Forth, Scotland.
7. Attempted location of a Spitfire crash-site at the City of Derry Airport.

Each case has a full desktop and reconnaissance ahead of it, with a range of targeted geophysical techniques (magnetics, GPR, radiometrics) that followed, some of which will be reviewed.

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## PRESSING WINE IN IRON AGE LEBANON: INVESTIGATING WINE PRESSES AT TELL EL-BURAK

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The archaeological site of Tell el-Burak, Lebanon (Figure 1), is located on the Mediterranean coast, 9 km south of Sidon. Excavations started in 2001 in a joint project of the American University of Beirut, the Eberhard-Karl University of T ubingen and the German Archaeological Institute (DAI), and since 2013 also of the Johannes Gutenberg-University Mainz (Kamlah et al. 2016, 79-80). Magnetic measurements began in 2002 under the direction of Christian H ubner. Recently, a wine press was excavated and this raises the question of whether there are more wine presses and their organization at Tell el-Burak. Therefore, geophysical investigations were carried out in March 2018.

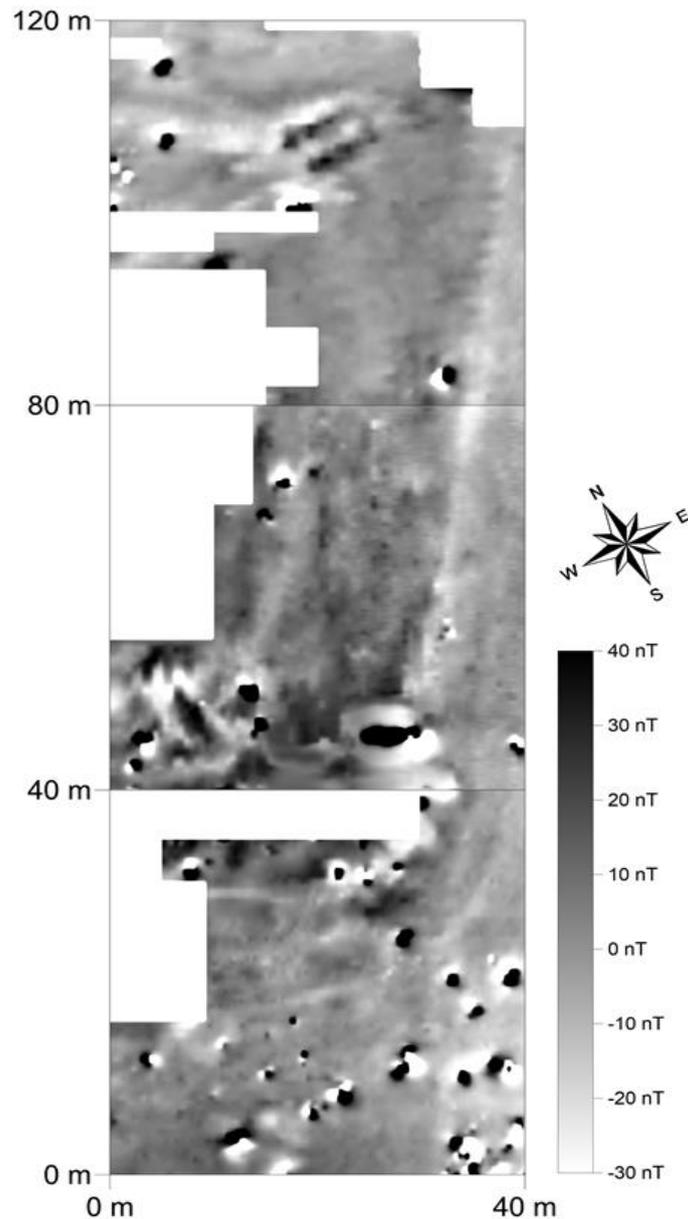


Figure 1: The southern part of the magnetic survey area looking from north-west to south-east showing the trenches at different levels and the area, where the topsoil was removed for geophysics (Photo: M. Scheiblecker).

Firstly, magnetometry was chosen to get an idea of the enlargement and arrangement of the settlement (Fassbinder 2017, 499). Total field measurements

with the Geometrics G-858 in a so-called duo-sensor configuration (Fassbinder 2017, 500) covered especially the eastern and southern slope (Figure 1) as well as parts of the western slope of the Tell. Magnetic susceptibility measurements (Kappameter Zh Instruments SM 30) accompanied these investigations. Secondly, at selected spots, Electrical Resistivity Tomography profiles (ERT, 4point light 10 W, Lippmann Instruments) complemented the magnetic measurements in order to distinguish archaeological materials and to get depth information (Tabbagh 2017, 214). Two chains of 20 electrodes were used with a spacing of 50 cm to get profile lengths of 20 m.

Figure 2: Tell el-Burak, eastern slope. Magnetometer survey of the area in the eastern part of the site. Caesium total field magnetometer Geometrics G-858 in duo-sensor configuration, total Earth's magnetic field at Tell el-Burak 03/2018,  $45.460 \pm 40$  nanotesla, sensitivity  $\pm 10$  picotesla, sampling density  $25 \times 50$  cm, interpolated to  $12.5 \times 12.5$  cm, dynamics in 256 grey scales, 40 m grid.



Magnetometry Tell el-Burak, 03/2018

© Institute of Near Eastern Archaeology and Geophysics  
 Department of Earth and Environmental Sciences,  
 Ludwig-Maximilians-University Munich, M. Scheiblecker  
 Geometrics G-858G, sample intervall  $50 \times 12.5$  cm,  
 interpolated to  $12.5 \times 12.5$  cm, 256 grey scales

The eastern part of the mound (ca. 120 x 40 m; Figure 2) revealed negative magnetic anomalies parallel to the slope, partly three next to each other. Diamagnetic stone like limestone (magnetic susceptibility of limestone on the surface at Tell el-Burak:  $0,0021 \cdot 10^{-3}$  [SI]; Fassbinder 2017, 503) was used to erect walls for either terracing or for fortification- it is not yet clear. In the northern part, a rectangular positive anomaly is visible, probably a building. In the southernmost area, the magnetogram revealed several bright shadows, negative magnetic anomalies. Given the example of an already excavated wine press, these anomalies might indicate further instances, consisting of two different levels of limestone. ERT (Figure 3) was used exactly where these negative anomalies appeared to check if there are more wine presses and characterize their form.



Figure 3: Tell el-Burak, southern slope, view to the south. The ERT in use with 40 electrodes, spacing 50 cm (Photo: M. Scheiblecker).

Different configurations have been applied to investigate the sub-surface in 20 m profiles. The Dipole-Dipole measurement of Profile 3 at the southern part of the mound (Figure 4) revealed between 4 m and 8.5 m two sections with very high

resistivity at two different levels below the surface and indicating that it is situated between 0.5 and 2 m depth. High resistivity values can be ascribed to stone features (Tabbagh 2017, 212-213) leading to the expectation of more wine presses still unexcavated, one of them was made visible by ERT measurements.

ERT (Electrical Resistivity Tomography) Tell el-Burak, 03/2018  
Profile 3 SW3 DD

© Institute of Near Eastern Archaeology and Geophysics Department of Earth and Environmental Sciences, Ludwig-Maximilians-University Munich, M. Scheiblecker  
4point light 10W (Lippmann), electrode distance 50 cm, 40 electrodes, Dipole-Dipole configuration

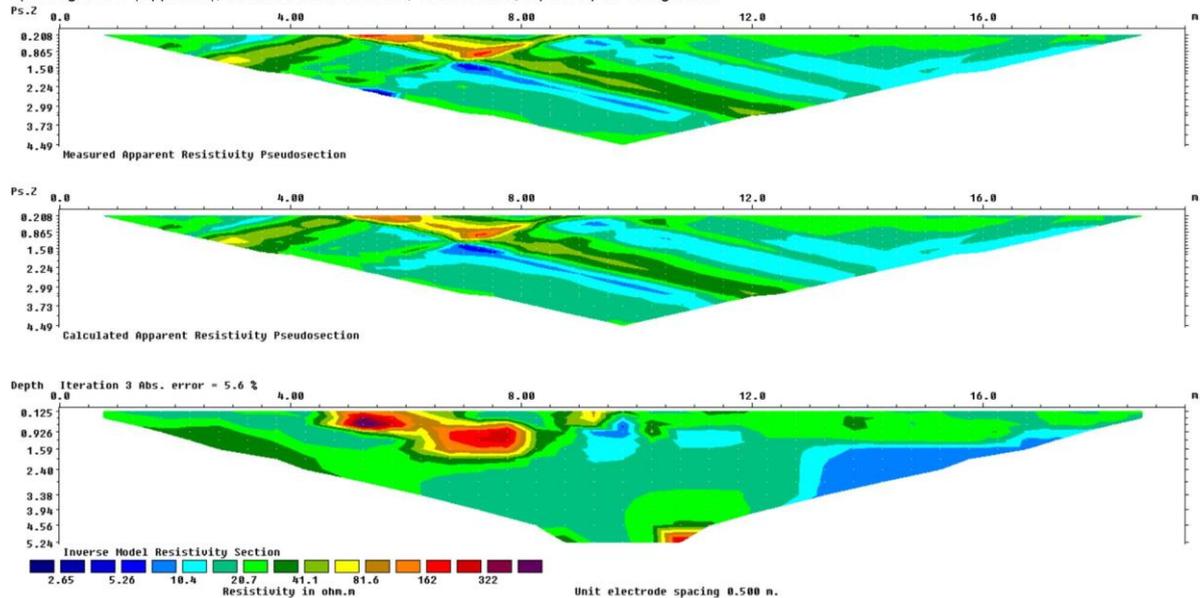


Figure 4: ERT Tell el-Burak, southern slope, Profile 3 SW3 Dipole-Dipole configuration.

Combining two geophysical methods revealed more details about the organization of the tell as well as more wine presses in the southern area of the mound.

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## MEDIEVAL LOWLAND CASTLES (NIEDERUNGSBURGEN) IN LOWER SAXONY – AUGMENTED KNOWLEDGE BY GEOPHYSICAL PROSPECTION

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Castles are very popular in Germany. Researching their history has a long tradition going back to the 19<sup>th</sup> century with early regional attempts to catalogue all known castles (e.g. Schuchhardt 1931, Grimm 1958). Recently the European Castle Institute<sup>1</sup> EBI has started to establish a record of every single castle in the country, information which it is uploading into a public database called EBIDAT ([www.ebidat.de](http://www.ebidat.de)). At first the well-known castles in Rhineland-Palatinate, North Rhine-Westphalia and the Saarland were completely recorded. In August 2018 Lower Saxony followed to gather the information of 1397 castles, royal palaces and fortresses.

Only a few medieval castles from Lower Saxony entered into EBIDAT are still standing. Most castles on the database have long since disappeared with only scarce indications in the terrain proving that they once existed. Some of the castles are mentioned in literature and other sources. Many medieval castles have been studied by archaeologists with small excavations. But only a restricted number of sites were studied by geophysical means (probably less than 25 to 30).

In the northern part of Lower Saxony the lowland castles are of special interest for the research of medieval castles in order to augment and validate knowledge about medieval history. Due to the lack of hills they were mainly built in the lowlands protected by the flood plains of the rivers and marshes (Figure 1). The castles were mostly built on artificial earth mounds and fortified by water-filled ditches or dry moats and/or ramparts, palisades and curtain walls.

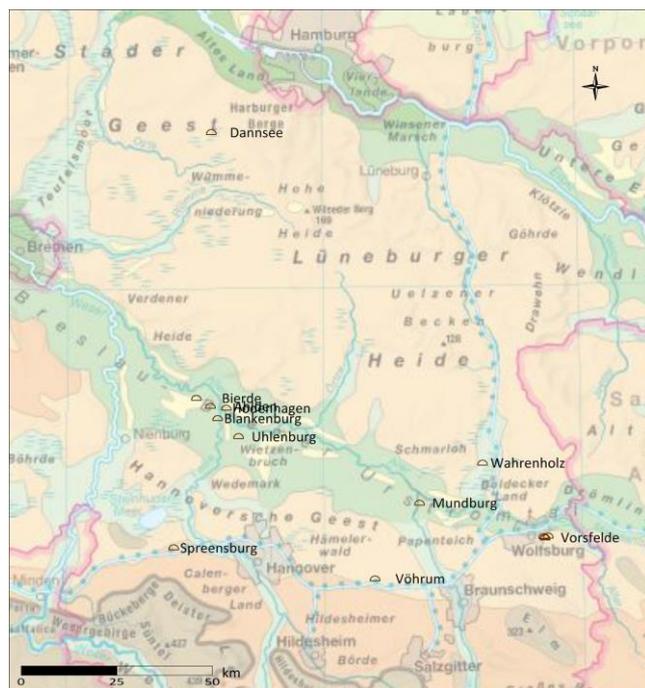


Figure 23: Geographic map of Lower Saxony

During his past 17 years of geophysical prospection activity the author had the opportunity to study a dozen lowland castles in Lower-Saxony in close cooperation with district and county archaeologists<sup>2</sup>. Project financing often came from communities, local societies, environmental protection parties and tourist guides. The later were increasingly interested in early local history and were willing to sponsor state-of-the-art investigations.

The applied geophysical methods were cesium magnetometry using a high sensitive Scintrex- SMARTMAG SM4G-special magnetometer and the earth resistance method using the RM-15 instrument from Geoscan Research, England. No GPR has been applied due to the prevailing wet environment. For each of the sites aerial photos had been taken mainly in summer and winter time (low sun with hard shadow and coverage by snow to detect tiny findings). In recent years LiDAR data has been used taking advantage of the relative height resolution of an incredible 1 to 2cm. The interpretation of the geophysical maps resulted often in a construction plan of the castle which was later checked by targeted excavation trenches accompanied by intense study of written sources, documents and historical maps.

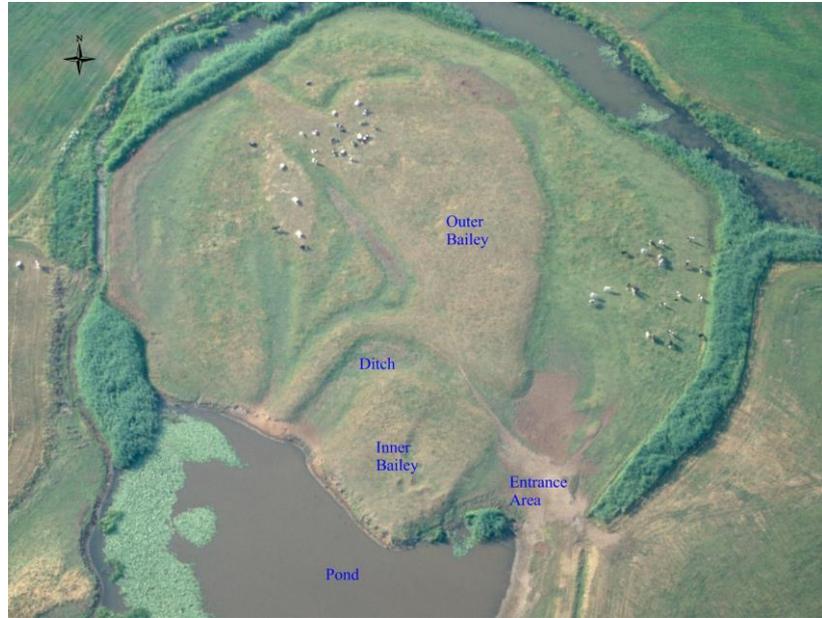


Figure 2: Aerial photo of the motte-and-bailey castle Uhlenburg 14th century (photo by Herbert Hoinkis 2003).

The poster will show results from 10 lowland castles (Figure 1) which will include 5 castles from a special study about the lowland castles in the Aller-Leine-valley (Heine et al.2005, example Uhlenburg, Figure 2). Each of the investigated castles highlights a special episode of medieval history.

Two castles Wahrenholz and Vorsfelde will be shortly presented which showed especially interesting results.

### Wahrenholz

The early medieval lowland castle Wahrenholz was built 995 AC by the bishop of Hildesheim Bernward in order to defend the eastern border of his diocese against Slavic tribes. This was his second castle after the Mundburg which he built before some 20 km southwest at the confluence of the rivers Aller and Oker.

Initiated by H-W.Heine a geophysical survey was performed in 2012. The resistivity measurement revealed the construction map with bailey, wall, inner and outer ditch of the oval shaped lowland castle which was once built in the meandering stream of the river Ise (Fig. 3). The site was already investigated in 1919 by some excavation trenches made by C. Schuchhardt which appear as low impedant white stripes in the resistivity map. An excavation followed the geophysical study (Biermann and Frey 2015) which confirmed the interpretation. Stimulated by the good result for Wahrenholz the search for the location of the Mundburg has restarted. Its location is

difficult to find due to the ever changing course of the Aller and Oker in the glacial valley Aller during the last 1000 years.

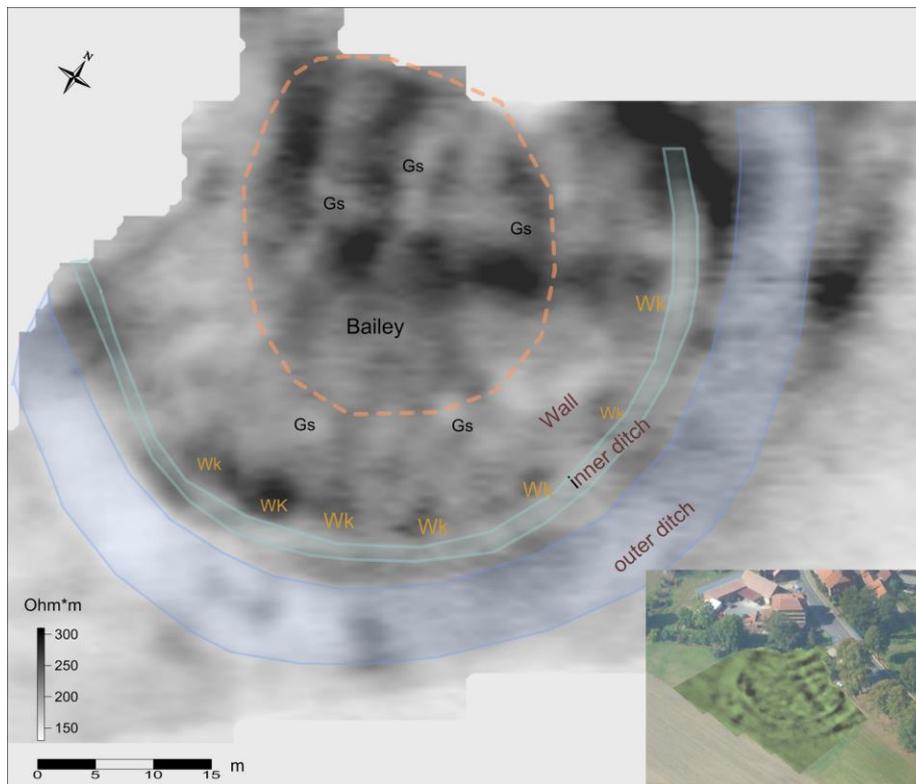


Figure 3: Lowland Castle Wahrenholz – resistivity map. Light stripes (Gs) probably excavation trenches by C. Schuchhardt (1920). Dark spots (Wk) mark fortified foundation areas of the wall. Inlet: aerial photo of the site with overlain resistivity map.

## Vorsfelde

The history of Vorsfelde begins around 1130 AC as a planned city foundation at the river Aller with two parallel roads probably initiated by Lothar III. At this point, the kilometer-wide Aller-Urstromtal was narrowed to about 1,500 meters. A shallow ford allowed since the Middle Age, the trade route from Brunswick to the exclave Calvörde. The area around Vorsfelde was fought over between the dukes of Brunswick and the margraves of Brandenburg. From written medieval sources at least three defending castles or strongholds are known which so far cannot undoubtedly assigned to the three known archaeological sites Motte, Fester Platz and Altes Haus. In August 2018 a new site close to the former shallow ford was investigated by caesium-magnetometry and resistivity measurement. In the old flood plain of the river Aller we discovered a large motte-and-bailey castle complex with inner and outer bailey (Figure 4). The resistivity map shows the high impedant locations of former buildings. The foundation of main building and keen was constructed using highly magnetized stones (granite, gabbro) marked in dark (from overlain magnetogram). The new find of the largest castle around Vorsfelde will initiate a new interpretation of historical sources.

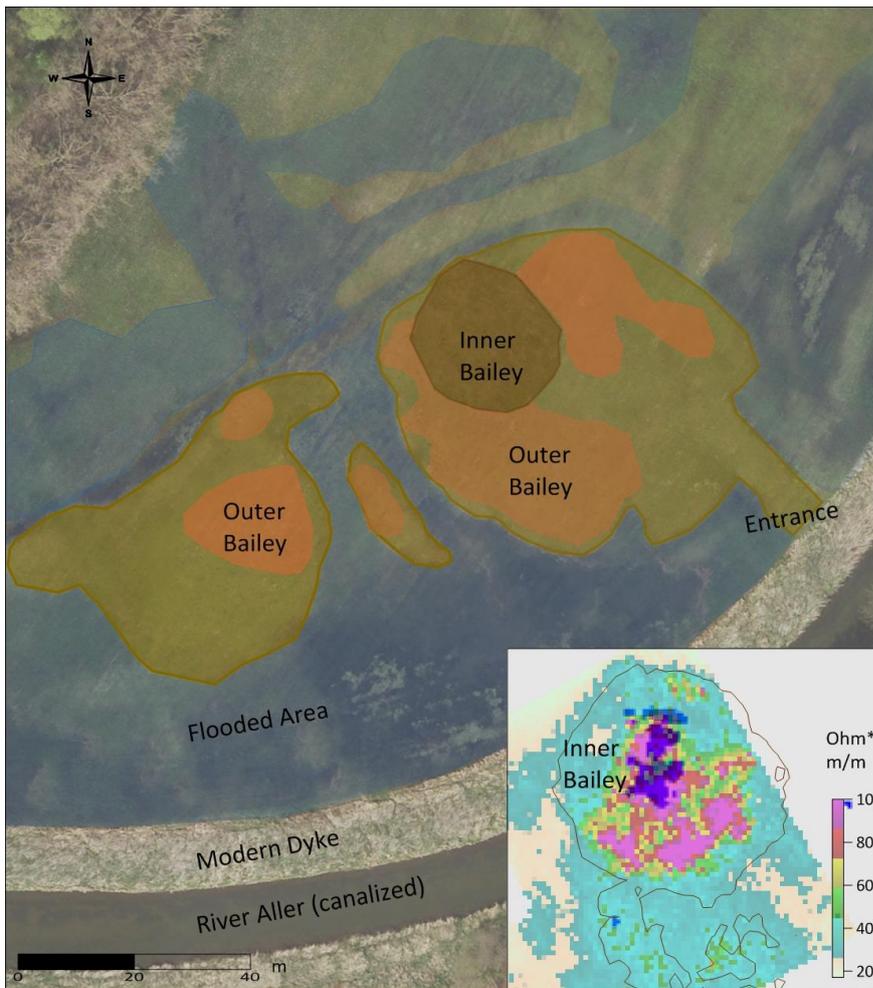


Figure4: Motte-and-bailey castle Vorsfelde - Paleographic model of the flood plain of the river Aller. Inlet: resistivity map.

Verlagsgesellschaft Athenaion, Potsdam

### Notes

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<sup>2</sup>Cooperation esp. with Hans-Wilhelm Heine (†2012), archaeologist and ‘Burgenforscher’, Lower Saxony State Service for Cultural Heritage (NLD) (Heine et. al, 2005)

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## LoCATE - THE LOCAL COMMUNITY ARCHAEOLOGICAL TRAINING AND EQUIPMENT PROJECT

Kate Welham<sup>(1)</sup>, Paul Cheetham<sup>(1)</sup>, Lawrence Shaw<sup>(2)</sup> and Michael Gill<sup>(3)</sup>  
*(<sup>1</sup>)Department of Archaeology, Anthropology & Forensic Science, Bournemouth University; (<sup>2</sup>)New Forest National Park Authority; (<sup>3</sup>)Avon Valley Archaeological Society*

[kwelham@bournemouth.ac.uk](mailto:kwelham@bournemouth.ac.uk)

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LoCATE (Local Community Archaeological Training and Equipment) is a partnership between archaeologists at BU and the New Forest National Park Authority (NFNPA). Working with archaeological societies and community groups from across Dorset and Hampshire, the project provides access, training, and support for the use of advanced survey equipment that would otherwise be hard to get access to. LoCATE aims to support the research that local groups already do by extending the range of techniques and skills they can use. Our goal is to work enable an even greater contribution to the understanding of the rich archaeological heritage of our region.

The initial training day was held in the New Forest in December 2015 with 7 different groups represented.

- Avon Valley Archaeological Society (AVAS)
- The Christchurch Antiquarians
- Dorset Diggers Community Archaeology Group
- East Dorset Antiquarian Society (EDAS)
- Local History Broadmayne
- New Forest History and Archaeology Group
- New Forest National Park Authority Volunteers.

Since then further training days have been organised with these and other societies and groups.

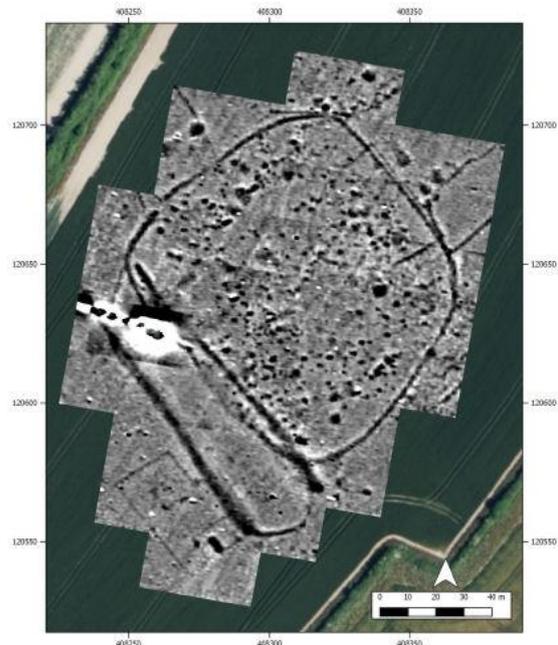
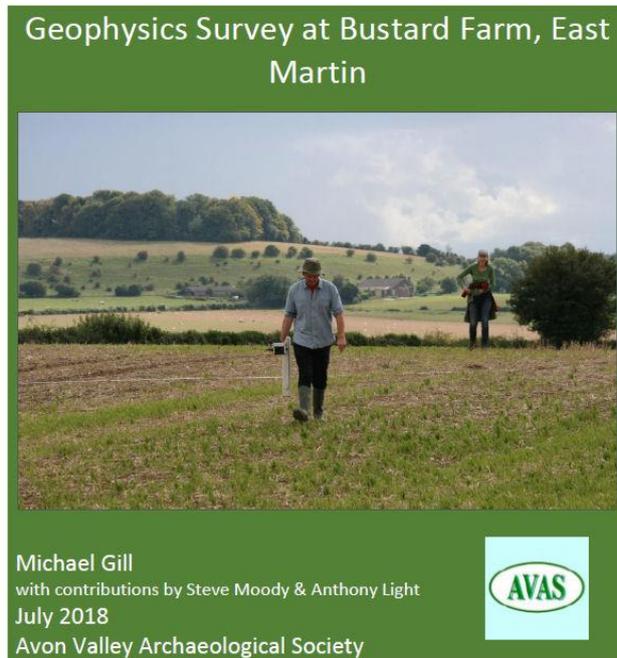


Figure 24: LoCATE training day (Photo: L Shaw)

LoCATE is organised by a BU staff, Prof. Kate Welham and Paul Cheetham, and affiliate researcher Lawrence Shaw of the NFNPA. The first instrument made available was a Geoscan Research FM36 followed a year later by a Geoscan Research RM15, both redundant BU instruments. Most recently a total station has been added to the equipment pool, funded through the Heritage Lottery Funding (Our Past and Our Future, Landscape Partnership Scheme) and the Hampshire Field Club and Archaeological Society. Access to the equipment is managed through the New Forest's volunteer equipment loan system.

## Case Study: Avon Valley Archaeological Society (AVAS)

To date the Avon Valley Archaeological Society has been the most frequent user of the LoCATE geophysical equipment and has produced some stunning results under the guidance of member Michael Gill. The Society uses Dave Staveley's Snuffler freeware geophysics software to process their geophysical data (Staveley 2018).



Figures 2 and 3: Report cover & FM36 gradiometry results from Bustard Farm, East Martin (Hampshire)

In September 2017, AVAS undertook a gradiometer survey of a long mound, and adjacent enclosures, to the north east of Bustard Farm, East Martin. The Royal Commission on the Historical Monuments of England (Bowden 1990) had previously visited the site and plotted cropmarks from aerial photographs. At that time, the long mound was said to be 'of uncertain origins'. The current survey aimed to investigate further the long mound and establish its relationship to the adjacent Romano-British enclosure. The results of the gradiometer survey suggest the long mound is a possible earthen long barrow. The results have also clearly defined the large Romano-British enclosure to the north east of the long mound, as well as revealing a previously unrecognised rectilinear enclosure to the south west of the mound. The poster presented at the conference includes further examples of AVAS survey successes.

### Sources

Bowen, H 1990 *The Archaeology of Bokerley Dyke*. London: HMSO

Staveley, D 2018 *Snuffler - Freeware Geophysics Software*. Available from: <http://www.sussexarch.org.uk/geophys/snuffler.html>

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## GEOPHYSICAL REASSESSMENT OF SCHEDULED ROMAN VILLAS

Neil Linford, Paul Linford and Andy Payne  
*Historic England Geophysics Team, Fort Cumberland, Hampshire*

[Paul.Linford@HistoricEngland.org.uk](mailto:Paul.Linford@HistoricEngland.org.uk)

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Since 1913 significant archaeological sites in the United Kingdom have been protected as Scheduled Monuments, a designation system intended to protect and manage a representative sample of the most important types of archaeological remains. However, sites scheduled in the early- to mid-twentieth century, often relied on scant evidence such as surface finds or poorly documented antiquarian excavations to determine what archaeological remains might be present. These are referred to as “old county number” (OCN) records after the original monument numbering system used before the modern universal designation numbers were introduced. Recent surveys of three OCN monuments, all designated as Roman villas, demonstrate the potential for modern geophysics to improve understanding of what has been scheduled, in some cases changing the interpretation of the monument.

### Low Ham, Somerset

Excavations in the 1940s uncovered the south-western range of buildings, now partially colonised by a badger sett. However, geophysical survey (Figure 1) reveals potentially four ranges of buildings arranged around a rectangular central courtyard with a roadway running northeast towards the nearby river and surrounded by an extensive field system. Intriguingly, one building uncovered by an extension to the original excavation proved to be post-medieval suggesting some of the remains may relate to a later C17th mansion known to have been built somewhere in the vicinity but until now thought to be beneath the modern farm buildings. It is hoped further small-scale excavations this autumn will help unravel the mystery.

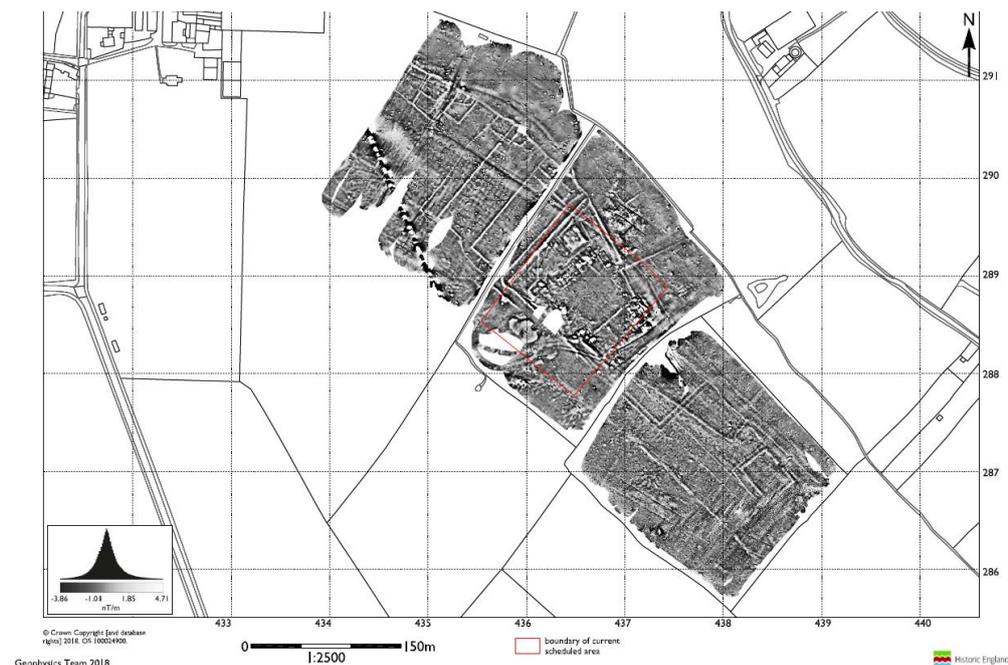


Figure 1: Caesium magnetometer survey of Low Ham Roman villa, indicating the scheduled area

## Nuthills Roman villa, Wiltshire

The Nuthills villa is known from some Roman finds and crop mark remains of a fragmented coaxial ditch-defined field system mapped by aerial photography with a rectangular double-ditched enclosure nearby. However, magnetometer survey (Figure 2) reveals the ditch system to be an elaboration of two Iron Age banjo enclosures while GPR reveals the wall footings of six buildings on different alignments (Linford *et al* 2018). The site plan is suggestive of a Roman temple or shrine complex like those at Uley and Lydney in Gloucestershire, rather than a Roman villa.

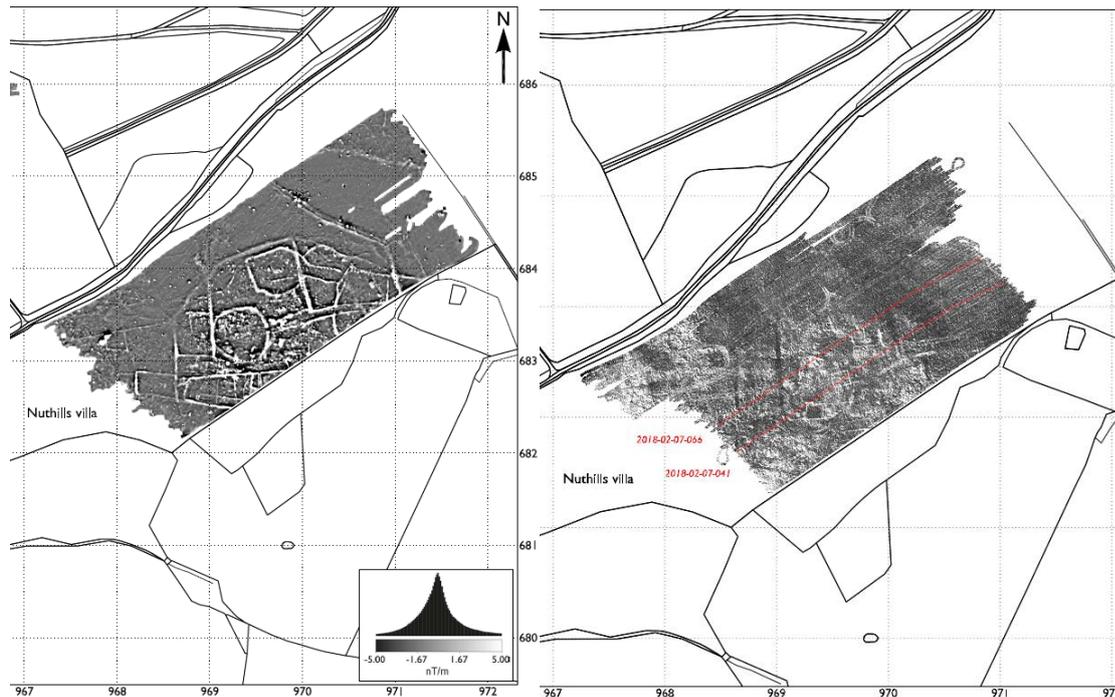


Figure 2: Caesium magnetometer survey (left) and GPR survey (right) of Nuthills Roman villa.

## Bradford Abbas, Dorset

Roman remains were discovered at Bradford Abbas by a local professor of geology in the 19<sup>th</sup> century and further limited excavations were carried out by amateur archaeologist Charles Bean in the 1950s, uncovering the footings of a Roman building assumed to be part of a villa. After interpretation of new aerial photographic evidence in 2013 revealed a Roman marching camp on the other side of the same farm this interpretation was called into question (Winton and Grady, 2013) and it was decided to re-evaluate the existing scheduled remains. Preliminary geophysical survey results (Figure 3) reveal a complex picture more suggestive manufacturing settlement than a villa.

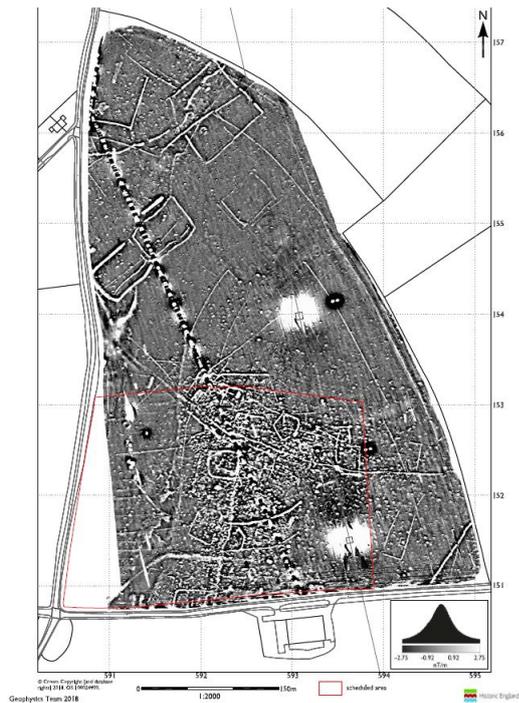


Figure 3: Caesium magnetometer survey of Bradford Abbas Roman villa, indicating the scheduled area

## Bibliography

N Linford, P Linford and A Payne 2018 [Verlucio and Environs Project, Bowood Estate, Calne Without, Wiltshire: Report on Geophysical Surveys, February 2018](#). *Historic England Research Report 41/2018*.

H Winton and D Grady 2013 [A Roman Camp at Bradford Abbas, Dorset](#). *Historic England Research Report 37/2013*.

## COMMERCIAL EXHIBITORS

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### BARTINGTON INSTRUMENTS LTD

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**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](mailto:sales@bartington.com).

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Guideline Geo manufactures solutions for non-destructive mapping of the subsurface. Through our world leading brands, ABEM and MALÅ, we offer sensors, software, services and support necessary to map and visualise the subsurface.

### **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.



Figure 1: MALÅ MIRA multichannel 3D GPR array (16channel, 400MHz version).

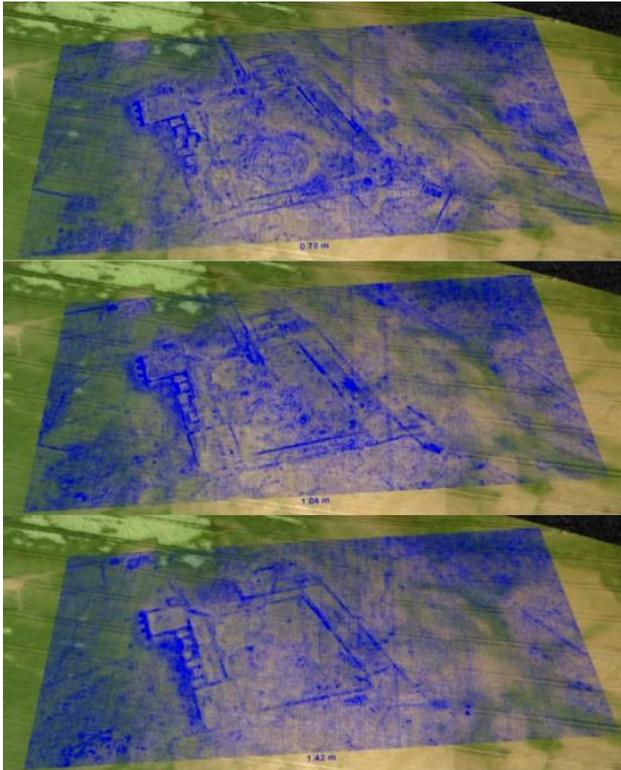


Figure 2: MALÅ GPR data from over a Gladiator training camp (courtesy of Ludwig Boltzmann Institute).

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.

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.

**ABEM** This improvement in resolution and penetration means that the MALÅ Easy Locator Pro HDR (450Mhz) is now not simply a tool for utility mapping but an attractive and capable entry-level instrument for many archaeological groups

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.



Figure 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.

**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.**

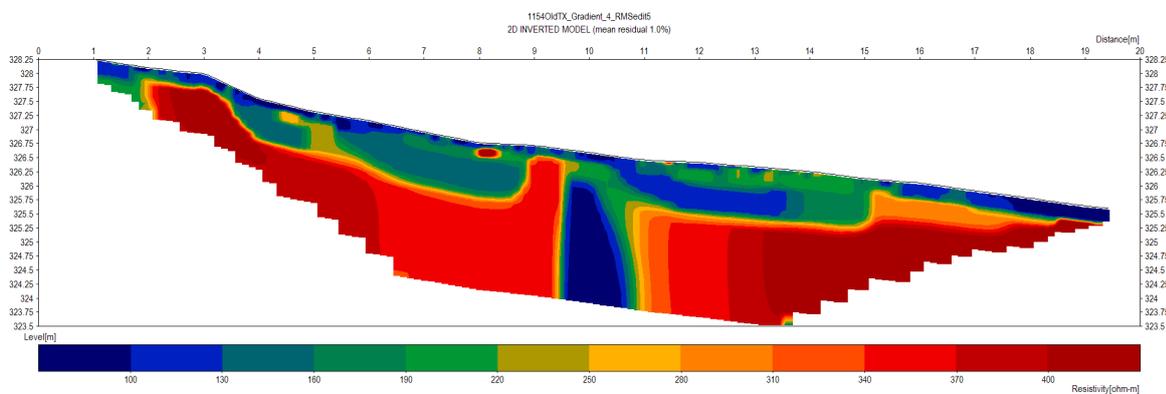


Figure 4: ABEM Terrameter LS resistivity survey over the site of historical mining works.

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## DW CONSULTING

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DW Consulting is well known throughout the geophysical prospecting 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. TerraSurveyor can download directly from many common instruments such as the Bartington Grad 601 and GeoScan RM & FM range. It can also import data created by a wide range of instruments and many other formats. Processes are designed around the needs of geophysical prospecting and so can correct all the problems inherent to the physical operation of the instruments used. Data can be visualised in a number of different ways and saved as georeferenced images or in other file formats. All data is stored as XML source data plus processes, this means that the source is never lost and all processes can be modified at any stage.
- **TerraSurveyor3D** software for processing 3 dimensional data with a specific emphasis on data from downhole cores. TerraSurveyor3D is an easy to use, 3D visualisation program for cored and multi-layered data. As with

TerraSurveyor, the data is stored as XML source data plus processes. Limited processing is included (clipping, high/low pass filter) but the emphasis is on display of IsoSurfaces, Fences (cross-sections), Curtains (multi-faceted cross-sections joining cores) and their relationship to surface features.



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Sensors & Software manufactures instrumentation, including ground penetrating radar (GPR) systems, to deliver subsurface imaging solutions to customers worldwide. Understanding what lies beneath the surface of materials like soil, rock, rubble, pavement, concrete, water, ice, and snow open endless possibilities. Our subsurface imaging solutions empower informed decision-making.

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## Introducing the G-864

The G-864 is the latest generation portable gradiometer from Geometrics, a fully integrated system with wireless data transfer to a rugged portable tablet. Survey lines can either be imported from a KML file or computed from a baseline established at the start of the survey. The operator is guided along the active traverse by three navigation views. With its ability to support multiple G-862 magnetometers, and variety of deployment strategies, users can create multi sensor arrays for high performance large area surveys.

Geomatrix have just added two G-864 Cs vapour gradiometers with NavMag software into their rental pool. For further information and rental prices please contact [sales@geomatrix.co.uk](mailto:sales@geomatrix.co.uk).



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### 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.

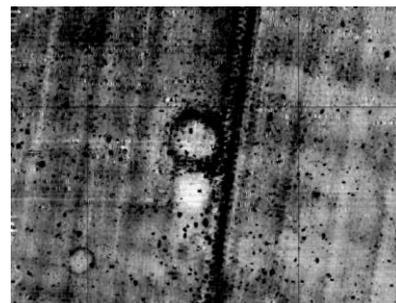


Figure 1: Various barrows near Stonehenge, UK located with the electromagnetic system AMOS

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

### Improving archaeological measurements since 1990

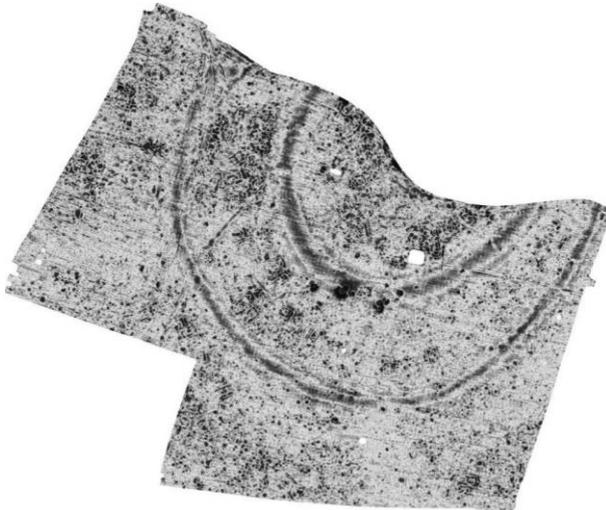


Figure 2: Bronze Age Settlement in Vrable, Slovakia located with a vehicle towed multi-channel system

SENSYS is developing and producing Fluxgate gradiometers and TDEM measurement systems. The company premises are located in Berlin since the company premises closed to Berlin since the products range from hand held devices, portable multi-channel systems (MXPDA) and towed multi-channel systems (MX V3), to ground systems (MX3D UW) and airborne systems (MagDrone R3).

SENSYS focuses on being in charge of all components – frames, probes, data loggers, and software. The growing group of clients includes the DAI (Deutsches Archäologisches Institut), the IMS Forth, National Institutes in Hungary, Norway, United States and many other Universities as well as commercial customers round the globe.

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## GEOSCAN RESEARCH

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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.

## 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 now 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.

## MSP25 Cart Non-Uniform Operation and Towing Kit

The MSP25 cart system can now collect data on a non-uniform basis, using GPS for position information, as well as gridded data collection. A towing kit is also available.

## Twitter



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

## FORTHCOMING NSGG EVENTS IN 2019

### **Geophysics Field Exhibition & Demonstration:**

**Date:** 16<sup>th</sup> May 2019.

**Location:** NSGG Test site, University of Leicester Recreation Ground, Stoughton Road. Oadby.

The NSGG field Exhibition is a biennial event which showcases the latest Geophysical instruments on the market. Held at the NSGG test site the event provides users to get hands on with the equipment and collect data in an environment seeded with various geophysical anomalies.

### **Postgraduate Research Symposium:**

**Date:** 17<sup>th</sup> May 2019.

**Location:** NSGG Test site, University of Leicester Recreation Ground, Stoughton Road. Oadby.

The postgraduate symposia offer students of near-surface geophysics the opportunity to present their research to their peer group, plus a network of academic and industrial practitioners, in a relaxed and supportive environment.

A call for papers will be issued in January 2019

### **New Advances in Geophysics Conference:**

**Date:** November/December 2019

**Location:** To be determined

The NSGG and British Geophysical Association (BGS) are co-organising a conference at the end of 2019 focused on bridging the gap between geophysical measurement and physical subsurface quantities- past, present and future.

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

## OTHER CONFERENCES OF INTEREST IN 2019

The Chartered Institute for Archaeologists Geophysics Special Interest Group (ClfA GeoSIG) will be hosting a session devoted to reviewing ClfA standards and guidance for archaeological geophysics during the annual ClfA conference on the 24<sup>th</sup> – 26<sup>th</sup> April 2019. See: <https://www.archaeologists.net/conference/2019>

The 13th International Conference on Archaeological Prospection will be hosted by The School of Science, the Institute of Technology, Sligo, Ireland, between the 28<sup>th</sup> August and 1<sup>st</sup> September 2019. See: <https://www.ap2019sligo.com/>

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**17-21 MARCH 2019**

**Facts**

- SUNDAY MARCH 17 – THURSDAY MARCH 21, 2019
- PORTLAND MARIOTT DOWNTOWN WATERFRONT HOTEL, PORTLAND, OREGON
- 400 ATTENDEES
- 40 EXHIBITORS

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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.