Institution: University of Bradford

Unit of Assessment: C17

Title of case study: Pioneering geophysical prospecting to enhance sustainable approaches to the detection of the buried past

1. Summary of the impact

Bradford's pioneering research into geophysical prospecting has significantly changed the approach to heritage management in the UK and internationally. Our research has influenced the development of commercial survey instruments in this field as well as changing industry guidance/practice. The changes include increased use of more sustainable, non-invasive methods for archaeological investigation and the gathering of richer data about the buried past. Our guidelines for legacy archaeological data have created standards in the archiving of this valuable information resource for public re-use. The group's involvement with Time Team has enhanced public awareness of geophysical prospecting which is demonstrated in the increased use of these techniques by community groups.

2. Underpinning research

For over 40 years Archaeological Sciences at the University of Bradford has developed novel equipment and methodologies that enhance sustainable approaches to detection of the buried past. Research into archaeological geophysics was initially led by Professor Arnold Aspinall (Lecturer 1966-1990, Honorary Lecturer 1990-2013). The research team is now directed by Dr Chris Gaffney (Honorary Lecturer 1993-2007, Lecturer 2007-2013), with significant contributions from Dr Armin Schmidt (Lecturer 1993-2010, Honorary Research Fellow 2010-present), as well as Honorary Research Fellows Dr John Gater (1993-present) and Dr Roger Walker (1990-present). Gaffney, Gater and Walker jointly lead the Bradford Centre for Archaeological Prospection (B-CAP) consortium of industrial and university partners which is a conduit for enabling research impact. Much of the group's work is focussed on the understanding of, and value placed upon, geophysical techniques at both public and professional levels.

We pioneered Twin-Probe (TP) earth resistance measurements for archaeological investigation and this became the worldwide standard array. Theoretical studies carried out at Bradford showed that the TP presented particular interpretational difficulties when features are shallow and smaller than the array separation; clearly a disadvantage when looking for archaeological features (1,2). Aspinall, using an electrolytic tank, investigated non-linear arrays to reduce potential orientation dependence associated with the TP (2). The Square Array's (SA) 2D symmetry reduces this error by interchangeability of current and potential electrodes. Field tests confirmed the enhanced suitability of the SA for shallow prospection and pointed towards integration of TP into the same frame as well as collecting SA via the wheels of a cart. The cart concept was further developed via the B-CAP consortium (3).

Two books authored by Bradford staff, *Revealing the Buried Past: geophysics for archaeologists* (4) and *Magnetometry for Archaeologists* (5) bring together research and practice across a wide spectrum of intensive field and laboratory application. These volumes bridge the gap between the rigorous testing of novel techniques and interpretation in diverse archaeological settings. Reference 5 makes use of the archive of survey data collected during the production of Time Team and serves, not only as a research resource, but also as a conduit to stimulating wider involvement in geophysical survey through illustrations of strategies specifically devised for a non-academic audience. Research also includes a heritage management dimension (6).

Connected with our work on shallow geophysical data, we have also researched and published significant contributions with respect to documentation and archiving of legacy data (7). This includes the first national standards for metadata and archiving of shallow geophysical data allowing greater re-use and an expanded user-base beyond academia. This is significant as

commercial activity forms the largest body of ground-based geophysical data and signifies the embedded relationship that these techniques have within modern archaeology.

3. References to the research

1. Aspinall A, Gaffney CF. (2001) The Schlumberger array - potential and pitfalls in archaeological prospection. *Archaeological Prospection* 8(3): 199-209.
2. Aspinall A, Saunders MK. (2005) Experiments with the square array. *Archaeological Prospection* 12(2): 115-129.
3. Walker R, Gaffney C, Gater JA, Wood E. (2005) Fluxgate gradiometry and square array resistance survey at Drumlanrig Dumfries and Galloway, Scotland. *Archaeological Prospection* 12(2): 131-136.
4. Gaffney CF, Gater JA. (2003) *Revealing the Buried Past: geophysics for archaeologists*. Stroud: Tempus.
5. Aspinall A, Gaffney CF, Schmidt A. (2008) *Magnetometry for Archaeologists*. Lanham: AltaMira Press.
6. Gaffney C, Gaffney V. (2011) Through an imperfect filter: geophysical techniques and the management of archaeological heritage. Cowley D. (ed.) *Remote sensing for archaeological heritage management in the 21st century*. Europae Archaeologiae Consilium. 117-128.
7. Schmidt A. (2002) *Geophysical Data in Archaeology: A Guide to Good Practice*. ADS Series of Guides to Good Practice. Oxford: Oxbow Books.

Evidence of Quality: Articles (1,2,3) are in the discipline's leading research journal for near surface heritage investigation. References (1,2,3,6) were peer reviewed. The books (4,5,7) have Google Scholar citations of 54, 173 and 24 respectively.

4. Details of the impact

A significant contribution of our research can be charted through the change in professional use of earth resistance surveying away from the dominance of the Twin-Probe to the Square Array. Bradford research highlighted the value of the Square Array configuration to reduce orientation problems and issues related to reversal of signal. The significance of this can be seen by the commercialisation of the Square Array (SA) by Geoscan Research. Geoscan used the published research to collect SA data via a cart system, as suggested by Aspinall. In addition, via small grants and a Case PhD with Geoscan Research, the Bradford group has developed this into a low footprint multi-sensor device with improved service delivery incorporating GPS positioning. When investigating archaeology buried beneath vulnerable surface deposits measurements of many parameters in one sweep is key to sustainable actions. This is a major concern within heritage management. The SA incorporating the cart system is now used widely for heritage management for archaeological purposes as well as speculative prospection for planning purposes. Geoscan Research has sold this system throughout the EU and exported to both New Zealand and the USA (a). In some areas, such as Eire, it is the dominant collecting tool for earth resistance: data from the National Roads Authority Archaeological Geophysical Survey Database suggest that prior to 2008, 4% of resistance surveys used the SA with 33% thereafter. One Irish group report 41 SA surveys since 2008 (76% of all resistance surveys) as opposed to only six SA surveys prior to that period. The reasons for the popularity of the Bradford-inspired SA include quality of data, increased speed of survey and richer datasets (b).

Policy and Guidance

Bradford research into archive digital data format and associated metadata for archaeological geophysics led to the first guidance for data longevity (7). The reach of the impact is demonstrated in that the metadata schema proposed by Schmidt was incorporated into the OASIS system (Online Access to the Index of Archaeological Investigations) in 2007. Subsequently contractors and researchers undertaking geophysical survey have included metadata and survey documentation in OASIS submissions; many have also included grey literature reports (c). Schmidt's work demonstrates international reach with an updated version of reference 7 including good guidance for geophysical survey in the USA (d). The Bradford work significantly influenced the Institute for Archaeologists' Geophysical Special Interest Group (GeoSIG) and, within their inaugural meeting, archiving of geophysical data was identified as one of the major issues for commercial groups. The Bradford contribution forms part of the IfA's Draft Standard and Guidance, which has become a professional standard (e).

The value and impact of Bradford's research is clearly demonstrated in the English Heritage (EH) guidance on geophysical survey (f). Worldwide these guidelines are recognised as the benchmark for commercially-focussed evaluation and the authors draw heavily on Bradford's contribution. There are 15 references in the document to the Bradford geophysical group. Ten are post-1993 and include references 2, 4 and 7. According to EH figures the document has been downloaded *c*. 9000 times since 2008 while 2500 hard copies have been distributed (g). These figures far outnumber professional geophysicists working in archaeology, demonstrating a wider reach to consumers of geophysical surveys including planners, developers and community archaeologists. Unique downloads indicate that 15% are international and the reach can be demonstrated as the guidelines have been incorporated into many other guidance documents including the Dutch Quality Standard (KNA), Bavarian State, National Roads Authority (Ireland), the EuroGPR Guidelines for Archaeology, the Californian Transportation Cultural Handbook, and the European Association of Archaeologists guidelines (g). In addition, the international value of reference 4 for guiding new geophysical users is demonstrated by the 22 citations within the archaeological geophysics for Department of Defence guidance document funded by the American government's Environmental Security Technology Certification Program (h and i).

Interpretation and Public Engagement/Awareness

Public engagement with geophysical prospection has increased significantly throughout the last decade. The understanding and use of prospection techniques by the public is strongly linked to the work of the geophysical group at Bradford. The work of Gaffney and Gater has impacted on public perception by introducing new techniques and methods on successful TV programmes. Their long-term contribution to C4's Time Team is an obvious example of this and is underpinned by reference 4. However, the impact of this research is much deeper than the 2-3 million regular viewers and 15-20 million who watch occasionally. Community groups have, as a result of the visible demonstration of the techniques pioneered by the Bradford group, undertaken surveys of their own. Much of this activity is Heritage Lottery-funded. Since 2008 HLF has funded over £1 million on 34 projects that incorporated geophysics into their bids, and this is a shift away from watching to doing archaeology by a greater number of the public (j).

5. Sources to corroborate the impact (indicative maximum of 10 references)

a. Geoscan Research. Square Array Testimonial document

b. Letter: Earthsound Geophysics. Describes increased commercial use of Square Array.
"… *we purchased a Square Array and we now use it for the majority of our earth resistance work. This has changed the way we carry out geophysical surveys…We chose to purchase the instrument following reviews of the square array and initial results of the instrument (Aspinall and Saunders 2005, Walker et al. 2005). We have found that the research carried out by the University of Bradford has been enormously helpful for the development and practice of archaeological geophysics and we closely follow their research outputs to determine what future impacts we can use in our commercial work*."

c. Email: Deputy Director, Archaeology Data Service
"*Most notably the metadata schema he proposed was incorporated into the OASIS system…this has enabled the more routine recording of surveys and their results by local Historic Environment Records and at a national level by English Heritage and the RCAHMS*."

d. Schmidt A, Ernenwein E, 2011, Guide to Good Practice: Geophysical Data in Archaeology http://guides.archaeologydataservice.ac.uk/g2gp/Geophysics_Toc

e. http://www.archaeologists.net/groups/geophysics IFA, 2010, Draft Standard and guidance for archaeological geophysical survey http://www.archaeologists.net/sites/default/files/node-files/geophysicsSG.pdf

f. English Heritage Guidelines (David A, Linford N, Linford P. 2008: Geophysical survey in

archaeological field evaluation. English Heritage, Swindon.) http://www.english-heritage.org.uk/publications/geophysical-survey-in-archaeological-field-evaluation/

g. Email from Geophysics Manager, English Heritage
"… *the guidelines attempt to synthesise the results of relevant research and tests published by leading researchers in the discipline and draw from these recommendations for best practice. As such I note that we have cited 15 works that draw upon the research of present and past staff and honorary lecturers at Bradford University and, in particular, I'd draw attention to three of these publications:*
Schmidt A. 2002. We did not consider it necessary to attempt to define standards for the digital archiving of archaeological geophysical data within the guidelines because we thought the work that Armin Schmidt did for the Archaeological Data Service comprehensively covers the considerations and so we referred the reader to his publication.
Aspinall A and Saunders MK. 2005. In our discussion of earth resistance methodologies we drew upon Aspinall and Sanders's work as one of the few recent publications re-evaluating the square array, their examination of the directional sensitivity of the alpha, beta and gamma configurations was especially useful.
Gaffney CF and Gater JA. 2003. We drew upon this book extensively and I see that we cited it on no less than 10 separate occasions. It provides clear and concise explanations of many of the practicalities involved in geophysical data collection and processing ... we referred the reader to these explanations in many of our discussions of best practice. We also leant heavily on this work for discussion of the different levels of geophysical survey employed for evaluation archaeology. It provides a good overview of the considerations and workflows that apply in applications of archaeological geophysics beyond the academic sector."

h. Ernenwein E and Hargraves M.L. 2009 Archaeological Geophysics for DoD Field Use: a Guide for New and Novice Users http://serdp-estcp.org/Tools-and-Training/Resource-Conservation-and-Climate-Change/Cultural-Resources-Management/Archaeological-Geophysics-for-DoD-Field-Use-A-Guide-for-New-and-Novice-Users

i. Letter: Project manager, US Army Corps of Engineers Army Engineer Research and Development Center
"*In the US, we frequently look to the UK as a model for the successful integration of geophysics into compliance, community, and academic archaeology, and we attribute much of that success to the University of Bradford research community…When writing our guidance document, we naturally took a very close look at the existing volumes of similar character...we found Gaffney and Gater's 2003 volume to be extremely useful. They appeared to have found just the right mix of fundamental concepts, technical details, discussion of field issues that confront the novice, and detailed examples that illustrate geophysics' potential…Many American geophysical practitioners recognize the University of Bradford program and the greater Bradford geophysical community as a historic and current leader in geophysical applications*."

j. Head of the Historic Environment (Heritage Lottery Fund)
"…*we are now seeing increasing numbers of applications for projects that involve geophysical survey… I am convinced that the popularity of the Time Team programme…has raised the profile of geophysical survey and encouraged greater public interest and involvement … and the numbers of applications for community archaeology projects (including a geophysical component) have increased as a result*."