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The Application of Geophysical Techniques at Wroxeter Roman City

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Abstract

This paper provides an overview of the geophysical research that has been carried out at the Roman city of Wroxeter (Viroconium) in Shropshire over the past three years, stimulated by the Wroxeter Hinterland Project directed by Birmingham University Field Archaeology Unit (BUFAU). A major part of this geophysical work has been the completion of a fluxgate gradiometer survey over the entire 75 hectare area within the city defences, to build up a complete magnetic map of the remains. The results of this survey are presented and some of the key features identified during initial analysis are discussed. Further investigations, on a smaller scale, have also been undertaken with a range of other geophysical techniques; these are summarised and, where possible, initial results are presented. A strategy for the archaeological interpretation of such a large geophysical dataset is outlined and the research agenda for the geophysics is reviewed and some suggestions made concerning the analytical strength of each technique.

1 The archaeological problem

The initiation of the Wroxeter Hinterland Project (WHP) by the Birmingham University Field Archaeology Unit (BUFAU) in 1995 acted as the stimulus for a major programme of geophysical investigation of the site of the Roman city of Viroconium, at the village of Wroxeter near Shrewsbury in Shropshire. The WHP aims to examine the apparently unusual pattern of cultural transition during the late Iron Age and Roman periods in the region dominated by the Cornovii by focusing on the hinterland surrounding their capital at Viroconium (Gaffney, White and van Leusen 1995). To date surprisingly little evidence of Roman occupation has been found outside Viroconium itself, despite its importance as the fourth largest city in Roman Britain. Although not covered by the Leverhulme funding for the project, a programme of geophysical survey formed a core element of the investigations, spearheaded by a collaborative partnership between GSB Prospection (GSB) and English Heritage's Ancient Monuments Laboratory (AML).

Prior to the present work, understanding of the city was based upon a number of excavations, notably those by Atkinson (1942), Barker (1975), Bushe-Fox (1916), Kenyon (1940), Wright (1872) and Webster (1988). These generally concentrated around the central high status areas surrounding the ruins of the baths basilica, and information about the rest of the city was derived primarily from aerial photographs. This led to Viroconium being viewed as essentially a 'garden city' with large areas of open space inside the defensive ramparts.

2 Survey strategy

The concentration of the geophysical research on the area of the Roman city itself rather than the hinterland appears anomalous within the context of the WHP. However, as outlined below, this arose from a revision of the initial strategy once the first magnetic results had demonstrated, contrary to expectation, the enormous potential of geophysical survey to revise the understanding of the city itself.

Previous geophysical surveys at Wroxeter had had little success in detecting buried Roman structures. For instance Bartlett (1975), when surveying a section of the defensive earthwork for traces of a gatehouse, found that "Although strong magnetic anomalies, suggesting considerable archaeological disturbances, were detected along the town wall line, the definition was not clear enough to say whether a gateway had been present" (Bartlett 1975). Other surveys (for instance David and Payne 1990) had had equally indifferent results suggesting that magnetometry may not respond favourably on the soils of the region. Developer funded work in the locality tended support this conclusion. For instance the magnetometer survey at Whitley Grange (Ovenden 1995) found that only heavily burnt features were detected magnetically, whilst excavation showed that physical remains are still well preserved on the site.

However, the surveys at Wroxeter itself had concentrated almost exclusively on areas either on or just outside the city's defences and had been small in scale and each had been done to attempt to answer a specific localised question with no integration into a wider strategy. With the benefit of hindsight it is clear that these surveys were not situated in the places most likely to contain building remains while the small size of the survey areas provided too little of the background required to understand the often complex geophysical response.

Thus, with relatively modest expectations of the contribution that geophysics could make to the project, an initial strategy was designed involving a pilot survey on some areas of the Roman city where aerial photographs had shown clear evidence of building remains. The suitability of various geophysical techniques could be assessed during this pilot phase and the results would be used to inform the survey strategy for further work in the hinterland, covering sites identified by the Leverhulme funded research. However, initial results using Geoscan Research's FM36 gradiometers and collecting data at a 1.0 x 0.25m sample resolution far exceed expectations, clearly detecting the footings of numerous structures. Of particular interest was the evidence for stone wall footings which were revealed as well defined negative anomalies. This type of response, although not unique, is rare on UK soils and resulting from high magnetic susceptibility in the settlement soils.

The gradiometer survey also detected buildings additional to those identified from the air photograph evidence, suggesting that magnetometry would be a valid technique to assess areas of the city that the photographs indicated were blank and prompting the investigation of a larger area of the city using fluxgate gradiometry. By the end of 1995 some 30 hectares of the 78 hectares within the defences had been covered. These results apparently contradicted the 'Garden City' view of the site and it was decided that a complete magnetic map of Viroconium might not only be possible but also might reveal important new information about the composition of the city. This would allow the WHP to reflect upon the conflicting nature of evidence between the city and its hinterland.

At a practical level this meant that the whole of the available area inside the town's defences had to be surveyed. Despite numerous grant applications funding for this aspect of the project proved unsuccessful. The work could therefore only continue based on the donation of time and equipment from professional groups and the support of volunteers associated with the WHP. It was agreed that continued gradiometer survey would be undertaken by AML and GSB as time permitted, whilst earth resistance survey would be integrated into the volunteer structure of the WHP.

One advantage of working at Wroxeter was that, having demonstrated that the site is clearly responsive to geophysical investigation, it was possible to encourage other geophysicists to use the site as a laboratory to test novel geophysical techniques. In this way the project has benefited from the application of a far wider range of methods than would normally have been the case. Understandably, the scale of surveys contributed on such a basis is necessarily limited, so they have been targeted at areas where they can best help clarify interpretational problems associated with the gradiometry.

3 Fluxgate gradiometer survey

Since the pilot surveys in June 1995, successive campaigns of fieldwork by both GSB and the AML have built up to form a complete magnetic map of the area within Wroxeter's defences. A dataset of over three million magnetic measurements has been amassed covering the entire city (Fig. 1). Examination of the results shows very clear magnetic responses with potential archaeological features visible across the entire area within the city walls. The sheer amount of data makes it difficult to focus on individual anomalies, so it is useful to divide the survey up and compare the results from individual areas. Figure 2 shows a plan of the Wroxeter site and indicates four numbered areas which will be considered in turn below.

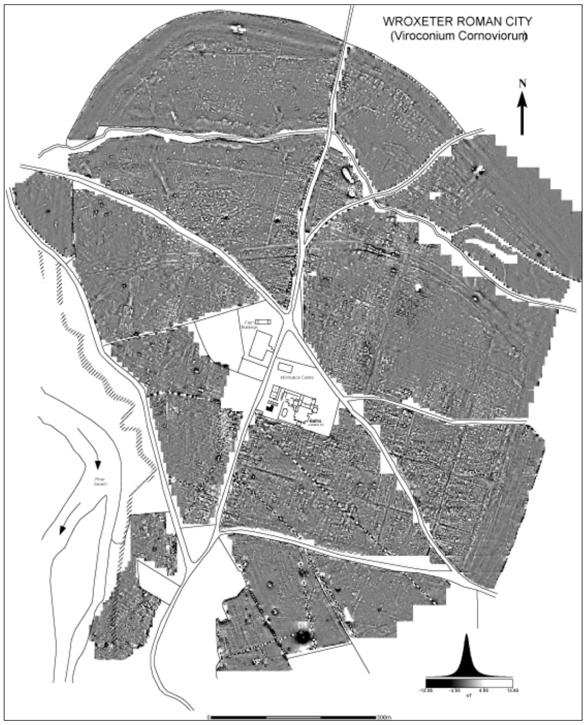

Figure 1.

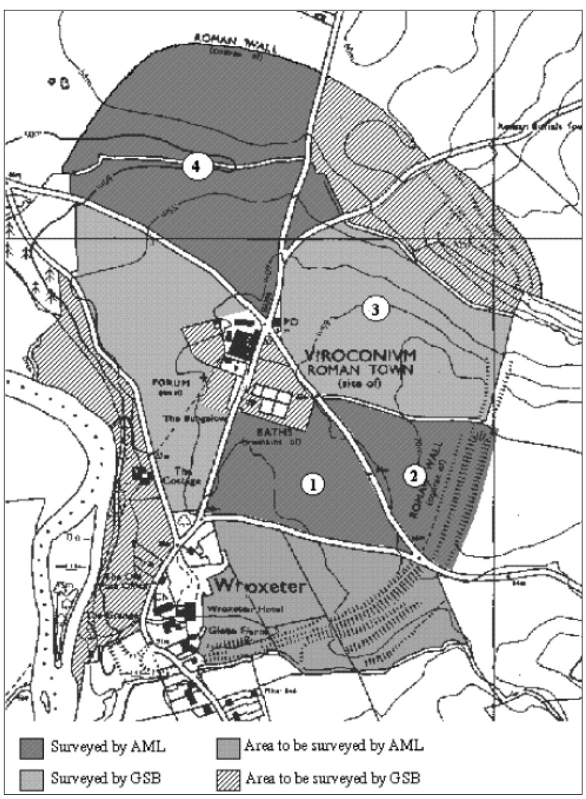

Figure 2.

Areas 1 and 2 (Fig. 3), near the ruins of the baths, show clear evidence of a 'grid-iron' street plan. The ground plans of many high-status stone buildings are also visible, the wall footings being clearly detected as negative magnetic anomalies (darker shades in greyscale plot). In addition to several courtyard villas next to the baths and a linear building with an apse on its northern end, an interesting rectilinear building can be discerned in the centre of the plot. This building, on an east-west alignment, with evidence for an apse at the eastern end, possibly represents an early Christian church. Heightened magnetic gradients inside the wall footings suggest that an intact floor may survive here, near the surface.

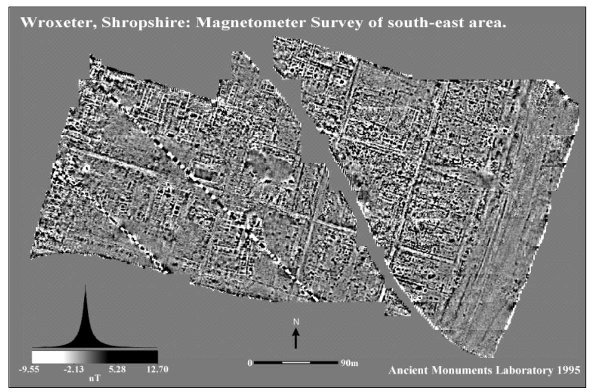

Figure 3.

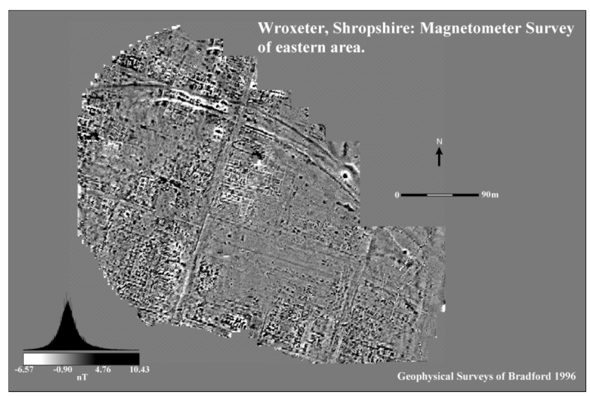

Figure 4.

To the north in area 3 (Fig. 4), the street system and pattern of stone buildings continues although the western part of this field appears to be devoid of magnetic anomalies. A double ditch anomaly can be seen running inside the northern boundary of the field which is thought to represent the original northern boundary defence, the city enclosure later being extended to the north to take in the areas either side of Bell Brook. Closer inspection of some of the building anomalies suggests that in some areas of this field wall footings are more, rather than less magnetic than the background soil. The cause of this reversal in the anomaly polarisation due to buried wall footings may speculatively be attributed to intense heat inducing thermoremanent magnetisation in the stone, perhaps due to a fire in this part of the city.

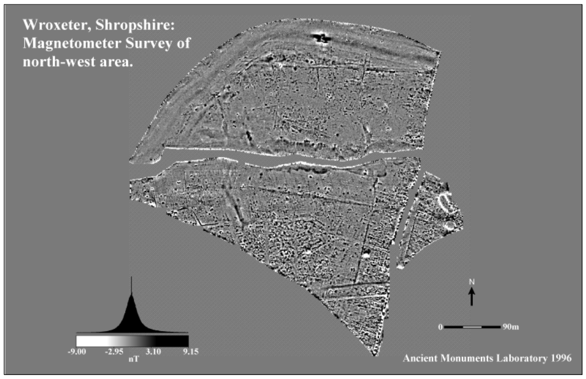

Figure 5.

Finally in the north west of the city at area 4 (Fig. 5), the street plan appears to peter out. However, a large number of small, discrete highly magnetised circular anomalies are visible. Their strong positive magnetic response is suggestive of permanently magnetised features such as hearths or kilns, or concentrations of particularly high magnetic susceptibility, perhaps pits where organic matter has been deposited. Proximity to the water supply from Bell Brook invites the speculation that this area represented an industrial quarter, the economic importance of which merited inclusion within the city's defences.

4 Resistivity survey

Given the slower pace at which resistivity survey can progress, it was apparent that the amount of ground that could be covered with this technique during the life of the WHP would be limited. Hence, work has concentrated on the areas to the south of the baths complex, where the technique's ability to detect buried masonry was most likely to complement the magnetic results. Sterling efforts by volunteers, co-ordinated by John Guite, have produced a 0.5m separation twin-electrode survey covering some 15 hectares, with readings being taken at 1m by 1m resolution. Comparison of this survey with the magnetic results in area 1 (Fig. 6) shows a broad agreement between the two datasets but some new information may be discerned, including evidence for a street immediately to the west of the "church" building and much clearer definition of the rectangular building to the south of it. More detailed analysis of this survey, in conjunction with other results, remains to be completed.

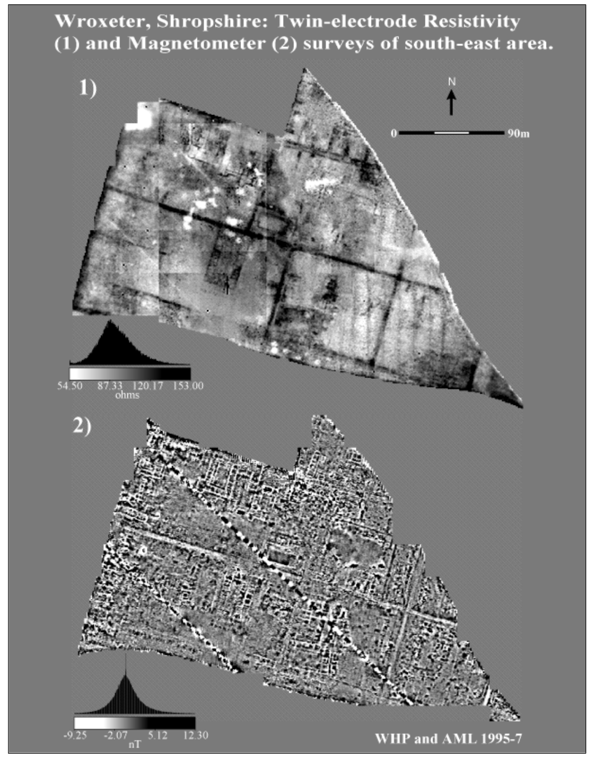

Figure 6.

The project was fortunate to capture the enthusiasm of geophysicists from the CNRS Garchy Institute of Geophysics in France, who tested an experimental towed twin electrode system at Wroxeter in September 1995. This system employed a 1 m probe separation and was thus theoretically able to see slightly deeper than the remains nearest the surface. Despite problems due to contact resistance caused by the very dry summer that year, they were able to survey over five hectares of area 1 at a resolution of 1m by 10cm. An initial analysis of the results (Fig. 7) shows that this survey has also been successful at detecting the stone footings and buildings. It is hoped that a detailed comparison of the similarities and differences between this data and that of the shallower 0.5m survey will yield valuable information about the relative vertical stratigraphy of the surviving wall footings.

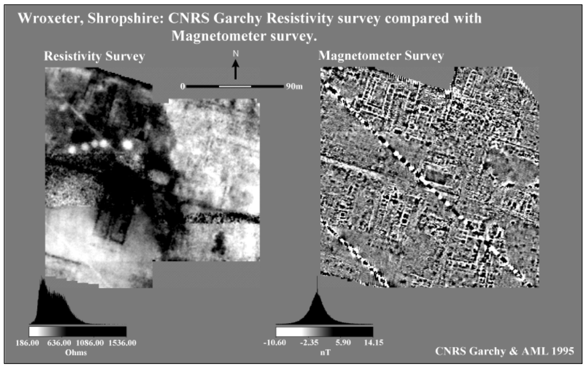

Figure 7.

In March 1997, English Heritage and BUFAU held two open days at Wroxeter as part of Science, Engineering and Technology week (SET97). In addition to demonstrating a variety of geophysical techniques to the public, some useful new data was gathered for the WHP. Paul Cheetham, of Bradford University, tested a novel method for collecting resistivity pseudo-sections and a modified twin-probe array (Cheetham 1997). Cheetham's results (Fig. 8) seem to show evidence of previously undetected wall footings on the eastern side of the apsidal building east of the baths complex.

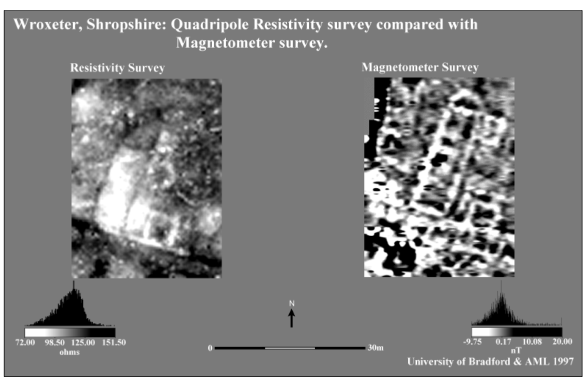

Figure 8.

5 The third dimension

Geophysical effort has been directed not only at planning the near surface remains but also to obtain depth information from targeted features, to get some idea of burial depths and vertical stratigraphy. Much of this work has involved novel equipment and techniques and has been carried out by practitioners keen to test their methods at Wroxeter. As much of this was experimental in nature and contributed on a voluntary basis, the analysis of the results will understandably take some time, so for the most part, results will not be presented here.

5.1 Resistivity pseudo sections

Initial tests using resistivity pseudo-sections were conducted by GSB during the summer of 1995. Unfortunately, very dry climatic conditions hampered electric current penetration and response was dominated by near surface effects. However, more recently, further work has been undertaken by Dr. Roger Walker of Geoscan Research using the new MPX15 multiplexing system (Walker 1996) in the field for the first time. With this system, twin-electrode readings can be taken at six different electrode separations, ranging from 0.25 to 1.5m, simultaneously over the same spot. The results, over a limited 60 by 40m area, highlight the stratified nature of the site, with the array resolving features of a stone building at different depths. It is hoped that the results of this survey will inform the combined interpretation of the 0.5m and 1.0m resistivity surveys described above, allowing the insights gleaned from this dataset to be extended over the wider area they covered.

5.2 Ground penetrating radar

During September 1995, Wroxeter also played host to a collaborative team from Miami University and the NARA Institute, Japan. These researchers measured a large number of radar profiles, gathered over a five hectare area, by repeating parallel traverses one metre apart. Using specially developed software (Goodman *et al.* 1995), the vertical radar profiles were stacked together and horizontal slices were taken through them to produce a sequence of "time slices" showing the subsurface at increasing depth. As with Walker's resistivity profiles, it has been possible to resolve different features at different depths and it appears that the radar may be able to detect an earlier phase of building beneath the near surface remains mapped by the magnetic survey.

The radar coverage was extended during the SET97 demonstrations when Peter Fenning and colleagues from Earth Science Systems Ltd. covered a 30 by 30m area over the Forum in a similar manner. The 230 Mb of data collected are still being processed but initial results are promising showing strong reflectors and deep vertical stratigraphy (Fig. 9).

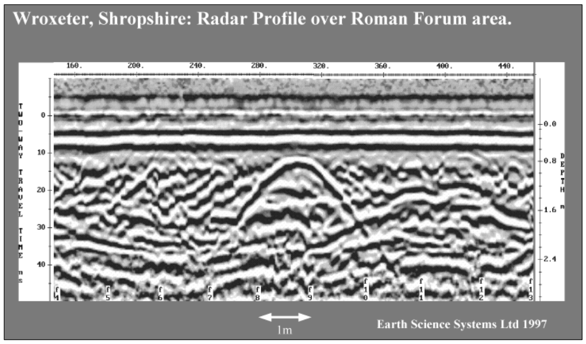

Figure 9.

6 The site as a geophysics laboratory

The well preserved remains at Wroxeter have made it an obvious test-bed for the application of novel prospecting techniques to archaeology and some examples have already been mentioned. Further measurements have also been collected with both Scintrex and Geometrics Caesium vapour magnetometers, to evaluate the improvement in resolution that they give over more conventional fluxgate gradiometer surveys. This study has recently been extended in collaboration with Jorg Faßbinder of the Bayerisches Landesamt für Denkmalpflege in Bavaria, Germany. During May 1997 he tested a system based on highly sensitive caesium vapour sensors designed for aerial magnetic survey (Becker 1995). Measurements made with this instrument will be compared with those from a detailed 0.5 by 0.25m fluxgate gradiometer survey undertaken at the same time, over a one hectare grid in the field labelled area 2.

7 Detailed interpretation

Owing to the tight timescale of the WHP, geophysical interpretation for the initial Leverhulme report will be based primarily on the fluxgate gradiometer results with integration of the resistivity work and other surveys being reserved for a later, more comprehensive, report. Nevertheless, the sheer size of the complete magnetic survey and the amount of archaeological features detected within it makes detailed interpretation a challenging task. Thus, the strategy adopted has been to divide the data up by fields and examine each individually; this task has been shared between members of the participating survey groups at the AML and GSB. Each area is interpreted using pre-agreed conventions and layers, and several test areas will be exchanged between the two groups for re-interpretation to ensure consistency. Digitisation of the interpretations is being done using either AutoCAD outputting in DXF format or directly into the GRASS GIS system. Finally all the interpretation layers will be collated into the WHP GIS system at BUFAU. Area 1, immediately south of the baths complex, will be of key importance to the final interpretation as it benefits from the evidence of complementary techniques as well as excavation. It is hoped that evidence for the burial depth and state of preservation of features can be inferred from the wealth of data available here and that this information can be applied to inform conjecture in other parts of the wider magnetometer survey.

8 Future geophysics at Wroxeter

Although a complete magnetic map of the Wroxeter has now been amassed using fluxgate gradiometers, coverage with other techniques has necessarily had to be restricted to relatively small areas. On a smaller site the work to-date might be considered only the first stage of a full geophysical evaluation as, although the gradiometer survey has detected a great deal of previously unknown Roman activity, it is likely that other methods will be able to reveal additional complementary information. Specifically, the gradiometer, measuring the first derivative of the vertical gradient of the local magnetic field is particularly sensitive to near surface features. Hence, the gradiometers have generally tended to detect the structures that were standing in Wroxeter during its heyday in the third century AD. However, it is known from excavation that the remains of earlier structures also survive buried more deeply. It is clearly a priority to extend coverage with methods able to detect more deeply buried remains and provide depth information. Their potential to add significant information has already been demonstrated on the test areas surveyed so far.

Such detailed coverage with a range of techniques over the entire Roman city will be a significant challenge given the area involved. However, the benefits are enormous. Such survey will allow for better management at the site, an assessment of the pre-stone built city and an enhancement of the model based on the magnetic response.

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