THE USE OF ELECTRIC SURVEYING AND PREDICTIVE DECONVOLUTION IN THE SEARCH FOR ANGLO-SAXON GRUBENHÄUSER AT NEW BEWICK, NORTHUMBERLAND, UK

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1. INTRODUCTION

Aerial photographs of the Anglo-Saxon palaces at Milfield, Thirlings and Yeavering in Northern England have shown quasi-rectangular features that have been confirmed by excavation to be *Grubenhäuser* (sunken-floored buildings) (Gates & O'Brien 1988). These buildings are common on mainland Europe and are well documented in settlements of the Anglo-Saxon period in southern Britain (Marshall & Marshall 1993) and northern Europe (Welch 1992). However, at the time of this survey none had been documented north of the Vale of Pickering in North Yorkshire (Cramp 1983) except for some atypical examples at Yeavering, Northumberland (Hope-Taylor 1977). Similar quasi-rectangular features were also present on aerial photographs of a site at New Bewick, Northumberland (NU061206), and assumed also to represent *grubenhäuser*. The goal of this study was to confirm or refute whether the New Bewick contained *grubenhäuser*. Electrical resistivity was chosen as a tool for investigation as it could be used to probe the ground for archaeological remains and natural discontinuities swiftly and relatively easily, and without recourse to laborious, expensive and invasive excavations.

2. THE SURVEY SITE AND METHOD

The site occupies a field one km west of New Bewick farm on the edge of a plateau of glacial sands at an elevation of 94 m and about 30 m above and about 200 m distant from the river Breamish/Till. The closest Anglo-Saxon remains are extremely important. They comprise the Anglian palace settlement of Milfield (Gates & O'Brien 1988), Thirlings (O'Brien & Miket 1991), and the 7th century royal settlement at Yeavering (e.g., Hope-Taylor 1977), all of which are to be found about 16 km to the NW.

Figure 1 shows one view of the crop-marks at the site. The diffuse light-coloured patches are large areas of aeolian deposits which overlie all other crop-marks. There is evidence of recent agriculture in the form of tractor tram-lines, drainage patterns and the traces of an old field boundary. Many of the other light linear crop-marks with a seemingly random distribution are caused by periglacial frost cracking.

The major archaeological features are also shown diagrammatically on Fig. 1. The most prominent is a thick, linear, light-coloured 'L'-shaped feature that has since been excavated to reveal the remains of a boundary ditch (Gates & O'Brien 1988). One of the arms of the 'L'-shaped ditch continues towards the south for approximately 200 m before turning abruptly towards the west for 120 m and then turning towards the NW until it leaves the present day field. It has an intermittent quality and has been attributed to a linear pit alignment. Another linear mark crosses the site towards the north, and there are a number of enclosures. There are a number of solid sub-rectangular marks distributed between the enclosures which have been postulated as *grubenhäuser* by comparison with similar marks at Milfield and Thirlings.

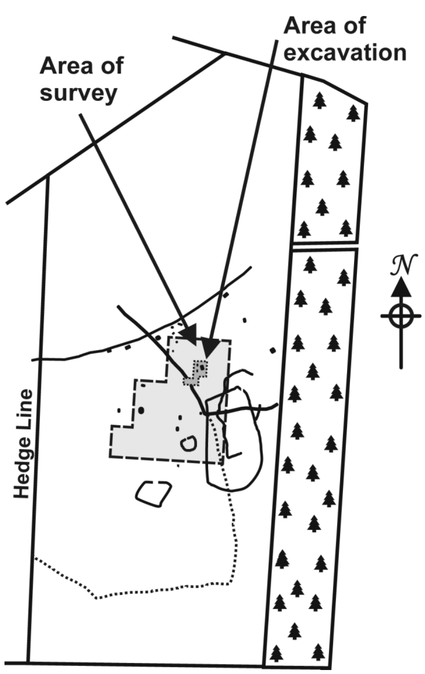

Figure 1. The New Bewick site: Location of the survey, aerial photograph and an interpretation of the main crop-marks. (Aerial photograph from the Museum of Antiquities of the University and the Society of Antiquaries of Newcastle upon Tyne (A/064486/36), © Prof Norman McCord).

The survey area covered 10,140 m^2. The data was acquired in blocks of 30 m by 30 m, which were pre-surveyed and marked with lines. Each block consisted of 31 lines that were one metre apart and perpendicular to the direction 009°. Each line consisted of 30 measurement points one metre apart by multiplexing 33 electrodes into 4 electrodes using a switch-box and a multi-core cable. Each electrode was planted to a depth of 20 cm with 1 m spacing. Hence, a 1 m spacing Wenner configuration was applied at each grid location. The apparent resistivity measurements were made with an ABEM Mk II Terrameter with a 5-fold stack.

3. INITIAL RESULTS

All the data were analysed in one and two dimensions. Figure 2a shows the variation of the apparent resistivity in the form of a variable colour map. The apparent resistivity varied from a minimum of 240 Ω.m to a maximum apparent resistivity of 1118 Ω.m, representing excellent resistivity contrast. The raw data exhibits a striping perpendicular to the resistivity measurement lines. This is an artefact caused by the use of a Wenner array.

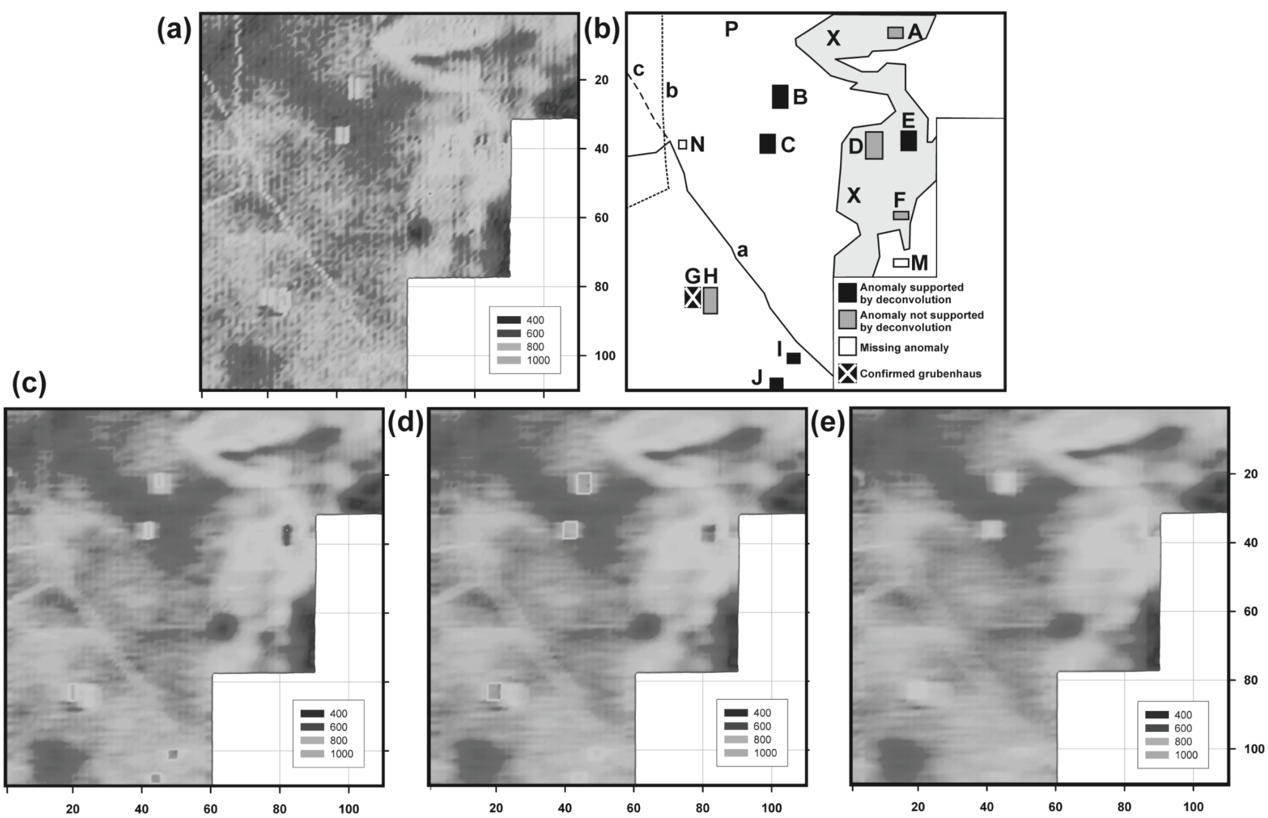

Figure 2. Resistivity maps of the survey area before and after digital filtering. (a) Raw resistivity data. (b) Initial interpretation. (c) Data deconvolved with a source signature of width $w = 3$ m, depth $d = 0.5$ m, and a topsoil cover of $h = 0.3$ m, (d) $w = 4$ m, $d = 0.5$ m and $h = 0.3$ m, (e) $w = 5$ m, $d = 0.5$ m and $h = 0.3$ m.

The raw data also shows a number of possible archaeological features. The linear features that were interpreted as ditches or post-hole alignments on the aerial photographs are visible in the electrical resistivity data (labelled (a), (b) and (c) on Fig. 2b respectively). It is fortunate that the features which give rise to these anomalies are sufficiently large or represent a sufficient resistivity contrast. Normally, small ditches and post-hole alignments do not exhibit a sufficiently large anomaly to be detected with a 1-m Wenner array. In particular, linear feature (a) shown on Fig. 2 has been subsequently excavated and shown to represent a ditch 0.9 m deep and 2.3 m wide that was filled with sandy silts that had accumulated gradually (Gates & O'Brien 1988). The qualities of the other linear features indicate that they too are ditches of similar dimensions.

There are 10 small high-resistivity anomalies which are sub-rectangular and have the characteristic 'M'-shaped response from the Wenner array. These anomalies are labelled A to J on Fig. 2b. Each anomaly may represent the remains of buildings; however, the Wenner array signatureconfuses their representation in the raw data. Digital deconvolution has shown anomalies B, C, E, G, I, J to be consistent with the presence of a *grubenhaus* while anomalies A, D, F and H are not, as described subsequently. It should be noted that those anomalies that are not consistent with the presence of a *grubenhaus* may represent the remains of other types of structures. Locations M and N show crop-marks which are similar to those that represent *grubenhäuser* (Fig. 1), but for which there is no evidence in the raw apparent resistivity data.

4. PREDICTIVE DECONVOLUTION

The apparent resistivity measurements are striped perpendicular to each measurement line. This is an artefact of the Wenner method. Traversing a lateral discontinuity of soil resistivity with a Wenner array produces perturbations due to the disturbance of the potential field by the discontinuity. A filled-in pit representing a *grubenhaus* consists of two vertical discontinuities. If the filling material is higher resistivity than the surrounding material, the sum of the two lateral signatures forms a characteristic 'M'- shape. If the filling material is of lower resistivity than the surrounding material, then the sum of the two lateral signatures forms a characteristic 'W'-shape. The shape of the signatures depends upon the difference between the two soil resistivities, the physical dimensions of the in-filled pit and the array spacing. An array spacing of 1 m is sufficient to allow the method to penetrate sufficiently into the soil to recognise the buried pit, which is between 0.3 and 1 m, with a 1-m lateral resolution. Unfortunately, this spacing also produces the 'M'- and 'W'- shaped signatures when crossing buried structures between 3 and 5 m wide, which can obscure the feature in the data. Fortunately, the signature may be removed from the data by using digital filtering if the dimensions of the buried feature are known (Kanesewitch 1975). These artefacts can be removed from the data by the process of predictive deconvolution, where the signature of a feature with given dimensions is calculated and removed from the raw signal. This process improves the accuracy with which the location and the lateral extent of resistivity anomalies can be measured. We have used a modified form of the predictive deconvolution method described by Tsokas *et al*. (1991).

5. FILTERED RESULTS

Figure 2 (c-e) also shows deconvolution of the data in two dimensions using three different anomaly widths. Panel (c) shows the result of a deconvolution with an inverse filter calculated from a postulated feature 3 m wide. The process has sharpened and delineated anomalies B,C, E, G, I, J, but not anomalies A, D, F or H. Anomalies I and J are particularly sharp with this width of filter, and probably represent *grubenhäuser* 3 m wide. Anomalies A, D and F have become part of a large scale diffuse anomaly labelled X in Fig. 2b, while the linear features, which were clear in the raw data have been smeared out by the deconvolution process. Panel (d) shows the results with a deconvolution filter that represents a 4-m wide feature. Anomalies B, C, E, and G are exceptionally well delineated with this filter width and probably represent *grubenhäuser* that are 4 m wide. Anomalies I and J have become less well delineated at this filter width which is consistent with them representing narrower *grubenhäuser*. Anomalies A, D and F have merged further with the background and the linear features are even more diffuse. Panel (e) shows all anomalies as broader and more diffuse than their raw counterparts, indicating that no 5-m wide features are present in the sub-soil. No evidence was found to support the crop-marks labelled N and M in any of the filtered data. Anomaly H appeared in both the raw, 3-m and 4-m results but its interpretation is inconclusive.

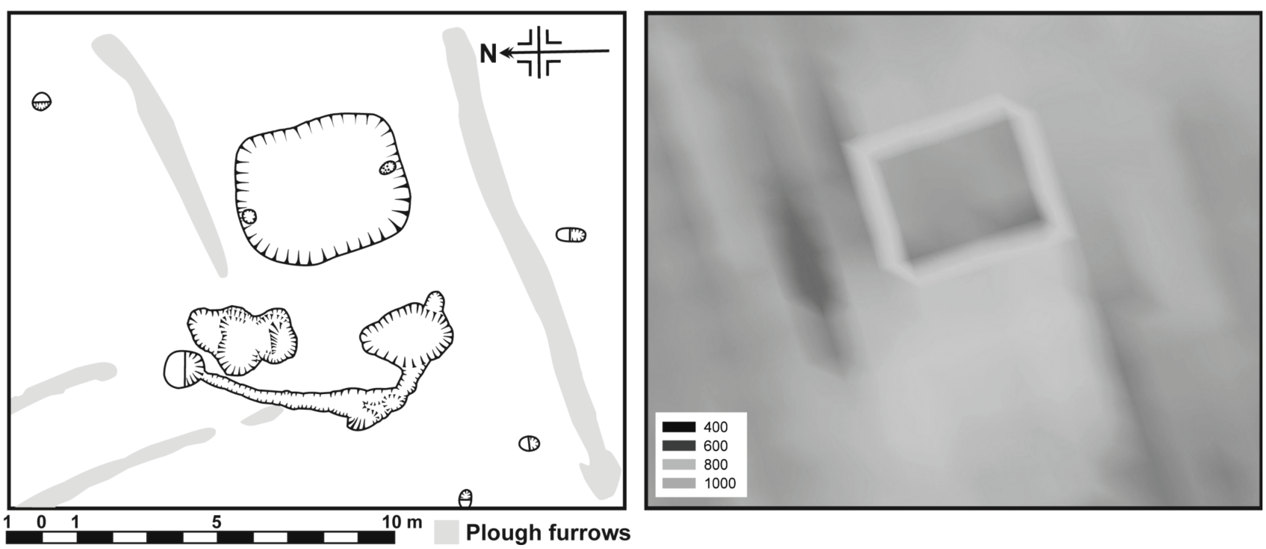

Figure 3. Comparison of the results of the excavation of anomaly G with the results of the deconvolved apparent resistivity data with $w = 4$ m, $d = 0.5$ m and $h = 0.3$ m.

6. EXCAVATION AND DISCUSSION

A trial excavation was subsequently carried out at the site (Gates & O'Brien 1988), which has demonstrated beyond doubt that one of the sub-rectangular crop-marks that correlates with anomaly G represents the remains of a sunken-floored building. Figure 3 shows the excavation plan next to the results of the electrical survey. The high-resistivity areas correspond almost exactly to the location and extent of the excavated *grubenhaus*. The deconvolved resistivity anomaly is 5 m by 4 m with a pit depth of 0.6 m below 0.3 m of topsoil, which compares well with the dimensions of the excavated *grubenhaus* (4.7 m by 3.9 m with a pit depth of 0.5 m below the base 0.3 m of topsoil). The corners of the electrical data are artificially sharper than they should be due to the effects of the colour interpolation implemented by commercial imaging software. The resistivity data shows no record of any of the post holes that were found during the excavation, however, the deconvolved data may be reproducing some of the plough furrows. Anomaly H, which lies just below the *grubenhaus* in the figure, was too complex to be interpreted from the filtered data. However, the excavation shows it to result from a complex group of pits in the cultural layer, to which no purpose has been ascribed.

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