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The Canterbury Hinterland Project: understanding dynamic rural landscapes through the semi-automated interpretation of geophysical survey results

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The Canterbury Hinterland Project represents a collaboration between researchers at the Universities of Cambridge, Ghent, Oxford, and Nottingham to use non-intrusive techniques in order to understand landscape transformations and changing rural settlement patterns through time. From 2011 to 2015, the project has studied four sites within a 10 km radius of Canterbury, both extensively and intensively. These have ranged from small rural, agricultural settlements to complex multi-period landscapes demonstrating elite power. These sites present a number of interpretative challenges, both in the nature of superimposition of features and in understanding isolated and morphologically ambiguous anomalies.

This paper will focus on technical and methodological developments during the course of this project, particularly through our ground-penetrating radar (GPR) survey, which enable us to develop more robust archaeological interpretations from our data. We will primarily discuss these issues in relation to our work at Bourne Park, the first and most fully investigated site within the project (Wallace *et al.* 2014). One avenue of our research has been to investigate the reliability of automated and semi-automated means of classifying geophysical responses in order to refine possibilities for feature-recognition in complex datasets.

The principal focus for our survey at Bourne Park was identified through a study of aerial photographs of the area and has been subjected to geomagnetic, earth resistance, and inten-

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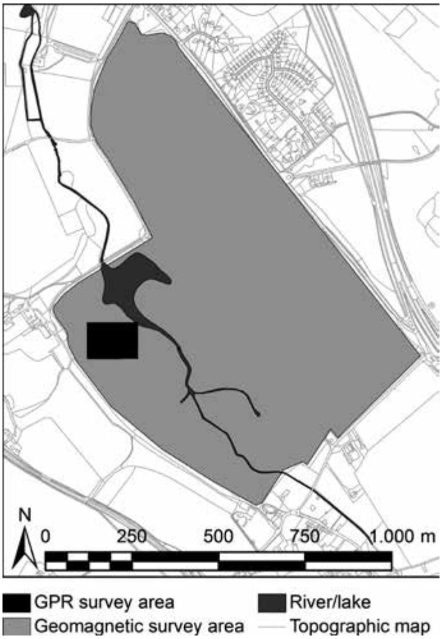

Fig. 1. Location of the surveys at Bourne Park

sive GPR survey as part of the Canterbury Hinterland Project. Geomagnetic survey totalling approximately 50 ha provided the context within which to situate the high-resolution GPR. Approximately 1.6 ha were surveyed (Fig. 1), using a Sensors & Software Spidar GPR network comprising single 500 MHz antennas (Verdonck *et al.* 2013). The inline sample interval was 0.05 m, the transect spacing ~0.125 m. The GPR data were processed using a standard sequence including dewow, time zero alignment, gain, low-pass filtering, background removal, and equalizing of amplitude differences between the channels. Migration velocity analysis resulted in a velocity of ~0.07 m/ns. After 3-D migration and time-to-depth conversion, conventional static corrections were applied since the maximum surface gradient was ~7% (Verdonck *et al.* 2015).

An extraction strategy was designed extraction strategy for Roman wall features employing template matching, which is rarely used in archaeological geophysics but more common in remote sensing for the detection of circular structures (burial mounds or kilns, Schneider *et al.* 2015), or linear shapes such as fallen trees (Nyström *et al.* 2014).

A 2D plot is generated, which synthesizes the GPR reflections at different depths. This can happen for example through the calculation of attributes such as the median frequency (Zhao *et al.* 2013), or by using principal component analysis (Linford 2004). A large time window is used, depending on the occurrence of the archaeological structures. The image in Fig. 2a was generated by calculating the standard deviation of each GPR trace, between 8 and 21 ns. Rectangular templates of different sizes were matched to this image, using 2D normalised cross-correlation (NCC). This resulted in a number of correlation matrices. For each pixel in the GPR image, the maximum NCC was used to create a single correlation image. This process generated a large amount of false positives, indicated in grey in Fig. 2b. Most are small sized, while most true positives abut onto other structures. Therefore, wall detections smaller than half the size of the smallest wall template were removed, and only the detections abutting on at least one other structure were kept (white in Fig. 2b). By fitting rectangular bounding boxes to the areas remaining after this classification, and extruding them, it was possible to select 3D regions for the creation of iso-surfaces. Because the noise caused by non-archaeological soil heterogeneities is removed, visualisation by means of iso-surfaces becomes more effective (Fig. 3).

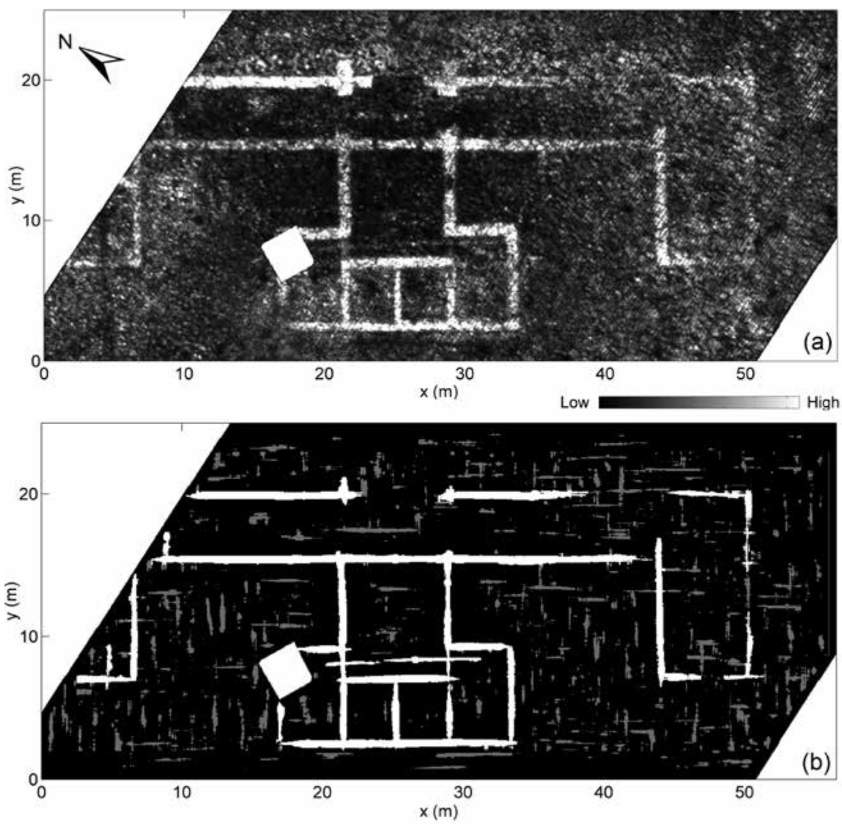

Fig. 2. (a) 2D GPR plot showing part of the area surveyed at Bourne Park, generated by calculating the standard deviation of each GPR trace (between 8 and 21 ns). (b) Image showing areas with a cross-correlation coefficient higher than 0.18 (grey). The areas selected after classification are shown in white

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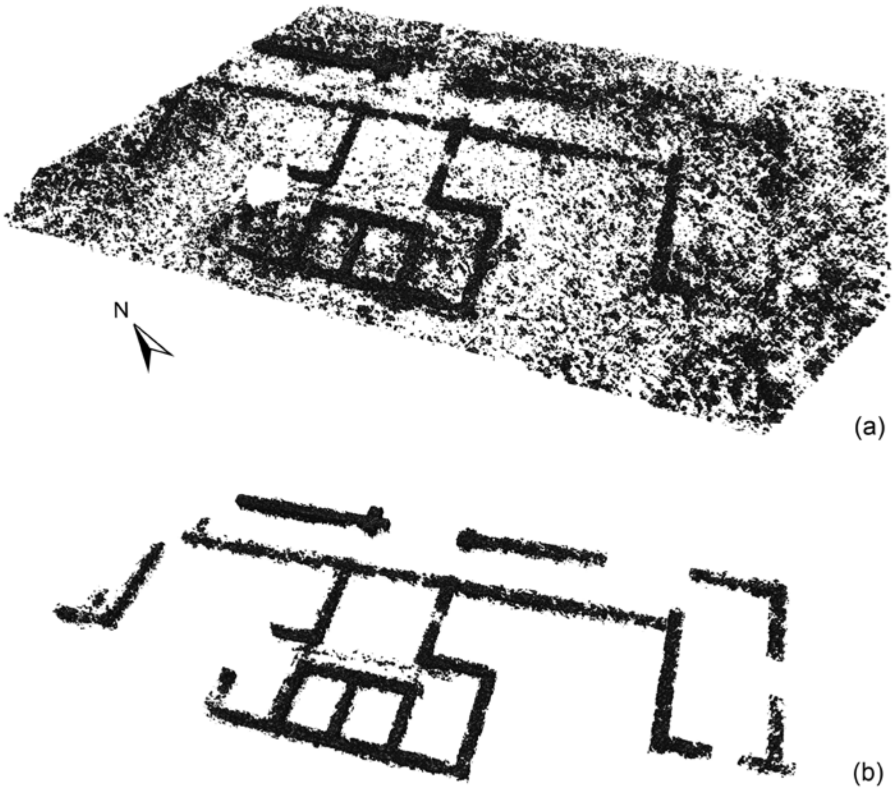

Fig. 3. (a) Iso-surface calculated from the GPR data cube after conventional processing (but before topographic correction). (b) Iso-surface applied to regions selected by means of template matching and classification. The threshold is the same for both iso-surfaces

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