EARLY RESULTS FROM LARGE-SCALE MULTI-METHOD GEOPHYSICAL SURVEYS AT THE BATTLEFIELD OF WATERLOO, BELGIUM

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This paper examines the initial results of large-scale geophysical surveys recently undertaken at the Battlefield of Waterloo in Belgium (Figure 1), where Napoleon Bonaparte was famously defeated in June of 1815 by a European coalition led by the Duke of Wellington and Prussian Marshal von Blücher. Archaeological research under the auspices of the British charitable organization *Waterloo Uncovered* have been ongoing at the site since 2015. Geophysical surveys were trialled with promising results at the inception of the project and have recently been scaled up to increasingly large areas of the protected battlefield landscape, which comprises a surface area of over 1000 hectares.

Over 100 hectares of this landscape have now been surveyed using fluxgate magnetometry (Sensys MXPDA) and multi-receiver frequency-domain electromagnetic induction (DualEM 21H – coil spacings of 0.5, 1 and 2m) (Figure 2, Figure 3). Magnetometry was undertaken using a five-sensor array with 50 cm sensor spacing and a 100 Hz sampling rate to allow for the identification of relatively small archaeological features (>1 m) and metal scatters (Figure 4). Coarser sampling was used for the EM surveys (2 m interline spacing at 8 Hz) to target broader pedological variability (in particular colluvial deposits based on electrical contrasts related to soil textural differences) (Figure 5) and larger archaeological features. Previous attempts at using ground-penetrating radar at the site have shown that signal attenuation is generally quite high, which is problematic in an environment that has experienced considerable colluvial accumulation resulting in buried archaeological deposits of interest at depths of up to 1m.

These methods were selected for their ability to provide complementary datasets on both magnetic and electric properties at a range of depths and to enable identification of a wide range of potential targets (e.g., hearths and other features related to bivouacs, scatters of metal ordnance, mass graves/cremation pyres, expedient defensive works, and other relevant landscape features such as field boundaries, ditches, structures, and paths).

A range of areas have been sampled, including the main ridge along which the Allied forces were deployed and where they bivouacked the night preceding the battle, areas around several farmhouses which played pivotal roles as expedient fortifications during the battle, and the hinterland of the village of Plancenoit which was the site of a crucial struggle between French and Prussian forces. We present initial results from these surveys, considering the potential advantages and shortcomings of the methods for identifying various targets related to the battle and its aftermath.

While geophysical surveys have been attempted at many battlefields in the past, we believe that this survey represents the largest of its kind ever undertaken at an early

modern battlefield. This has been enabled by mobile survey configurations, now well-established in archaeological prospection, which have shown their value in producing large-scale datasets for understanding vast archaeological landscapes. Battlefield sites have long been considered challenging for archaeological investigation due to the low-density ephemeral nature of the material evidence and their large spatial extent. The primary methodology employed in their investigation has traditionally been systematic survey with conventional metal detectors which, while effective, limits the potential range of targets that are detectable. We consider how large-scale surveys incorporating other geophysical approaches might enhance our understanding of these ephemeral archaeological landscapes.

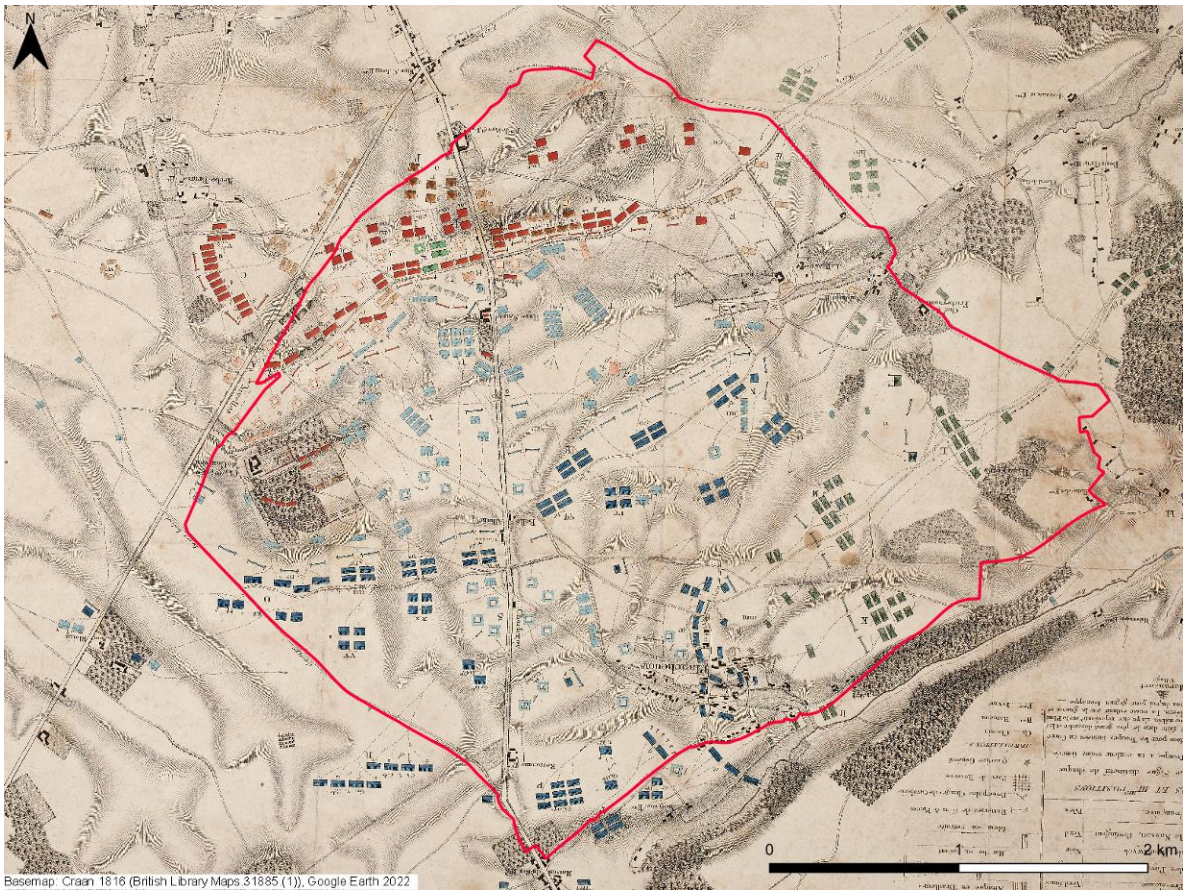

Figure 1 - Map of the battle showing initial troop deployments, produced in 1816, with the protected battlefield area outlined in red. Wellington's Anglo-Allied army (shown in red) deployed along a ridge at the top of the map, with Napoleon's French army in the centre and south (in blue) and Blucher's Prussian forces (in green) approaching the village of Plancenoit in the southeastern corner.f

Figure 2 - Electromagnetic induction survey near the Lion Mound monument, Waterloo.

Figure 3 - Magnetometer survey near Hougoumont Farm, Waterloo.

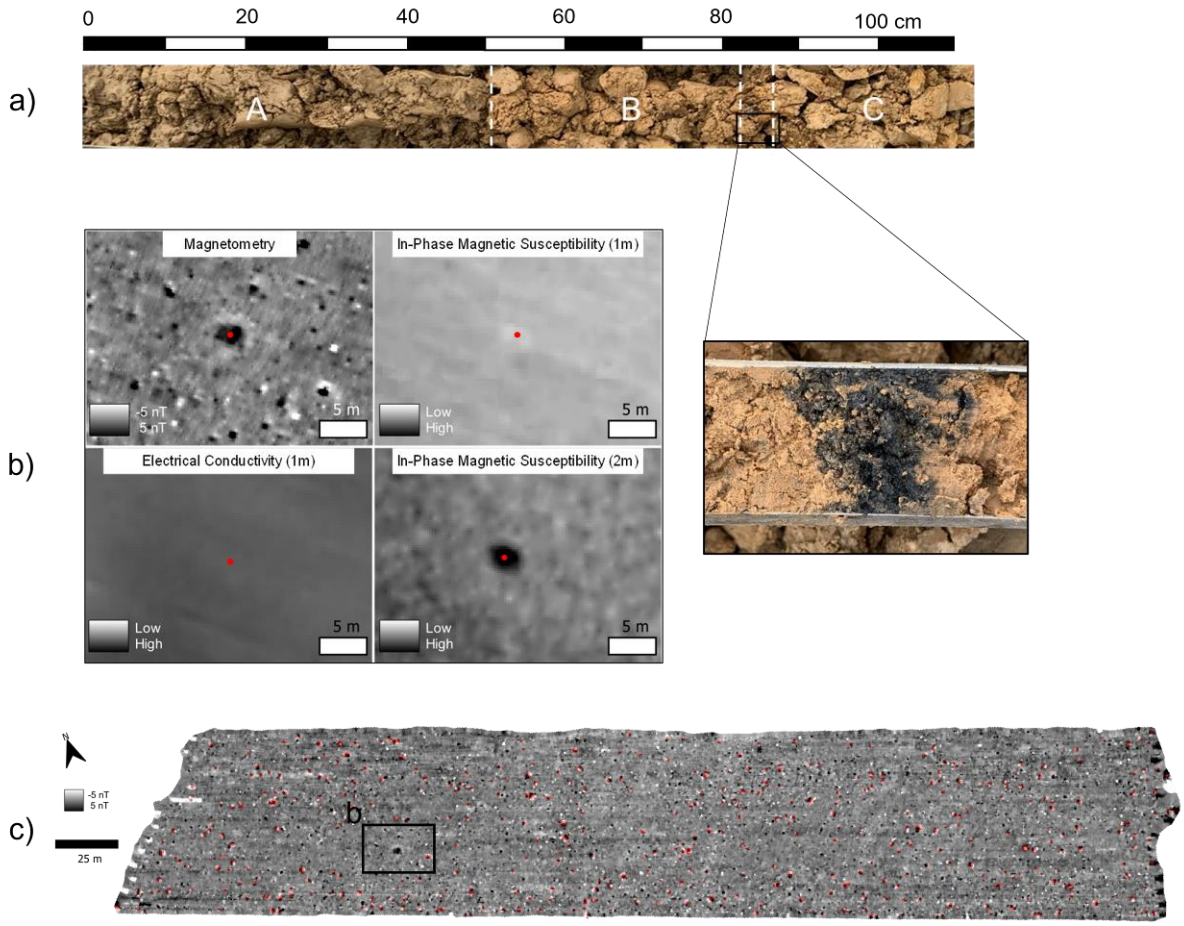

Figure 4 - Example of subtle archaeological feature detected near the ridge that comprised Wellington's main defensive position, consisting of burnt soil lens and associated ferrous metal fragments beneath approximately 80 cm of colluvial overburden. Borehole shown in a); different geophysical contrasts of feature from FDEM and magnetometry surveys in b) along with borehole location indicated by red dot; and larger magnetometry dataset in c) showing inset area and dipole anomalies highlighted in red.

Figure 5 - Overview of apparent electrical conductivity (1m HCP) for entire surveyed area. Note especially the linear resistive zones correlating well with colluvial deposits (outlined in black, from mid-20th century soil surveys). The red outlined area is the protected battlefield zone as shown in full in Figure 1.