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

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Large-scale geophysical surveys were 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 since 2015, in a programme combining archaeological fieldwork with veteran care and recovery (Evans et al., 2019).

Battlefield sites have long been considered challenging for archaeological investigation due to the low-density ephemeral nature of their material evidence and their large spatial extents. Large-scale geophysical survey thus has potential for mapping these landscapes, which are difficult to survey with other more invasive prospection methods. Recognizing the limits of the latter methods, conventional metal detection is now regarded as the primary methodology for examining battlefield sites (Scott & McFeaters, 2011). This has shown to be a highly effective method but limits the potential range of targets that are detectable compared to other geophysical methods.

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 landscapes.

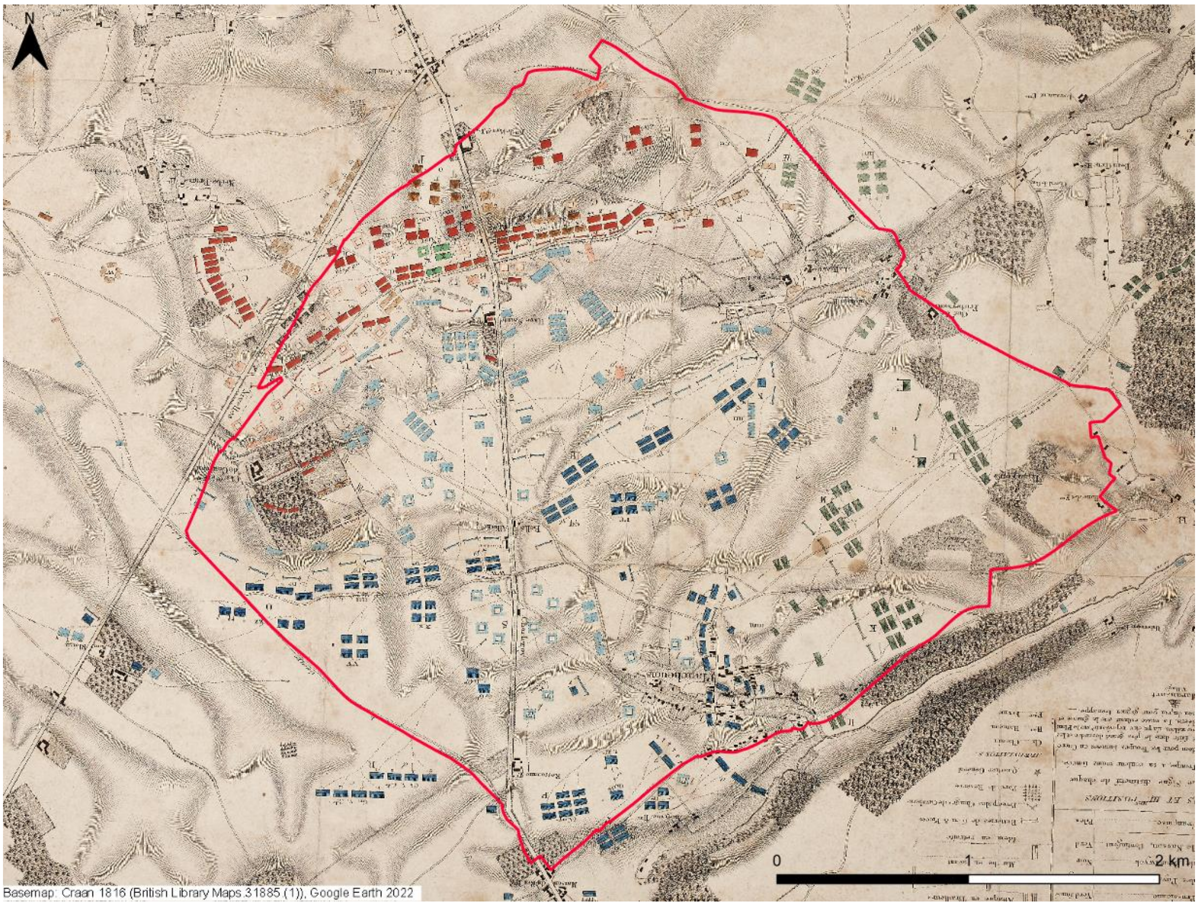

Figure 1 - Map of the battle showing initial troop deployments, produced in 1816, with the protected battlefield area outlined in red. Wellington's Anglo-Allied army (shown in red) deployed along a ridge at the top of the map, with Napoleon's French army in the centre and south (in blue) and Blucher's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

Approximately 100 hectares of the Waterloo battlefield have now been surveyed using fluxgate magnetometry (Sensys MXPDA) and multi-receiver frequency-domain electromagnetic induction (EM) (DualEM 21HS with coil separations 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. Coarser sampling was used for the EM surveys (2 m interline spacing at 8 Hz) to target broader pedological variability and larger archaeological features. 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.

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

Figure 3 - Magnetometer survey near Hougoumont Farm, Waterloo.

One feature that may relate to the battle was mapped in close proximity to the present-day Lion Monument (which commemorates the spot where the Prince of Orange was wounded). The feature appears as a moderately strong positive anomaly in the magnetometry dataset and is also apparent in the in-phase (IP, magnetic susceptibility) component of the EM data (Figure 4). A sign change occurs in the cumulative IP response between the 1m and 2m EM IP data layers: it presents as a negative magnetic contrast in the shallower coil pair and a posiitive magnetic contrast in the deeper. This is related to the spatial sensitivity of the IP response of this geometry (Tabbagh, 1986), which can serve as a qualitative means to assess the depth positioning of detected features by their ambiguous response in HCP measurements performed with different coil separations. In this case, the responses indicate that the feature is relatively deep (the signal change occurs at approximately 60 cm for this instrument). No appreciable contrast is present in the quadrature-phase (electrical conductivity) EM component. Borehole sampling confirmed that the feature consists of a subtle burnt lens of material with associated ferrous fragments at a depth of approximately 80 cm beneath colluvial overburden. The function of the feature is at present unknown but it may relate to the Allied encampment which was situated in the immediate area (e.g., remains of a hearth or cookpit (cf Drnovský et al., 2021)).

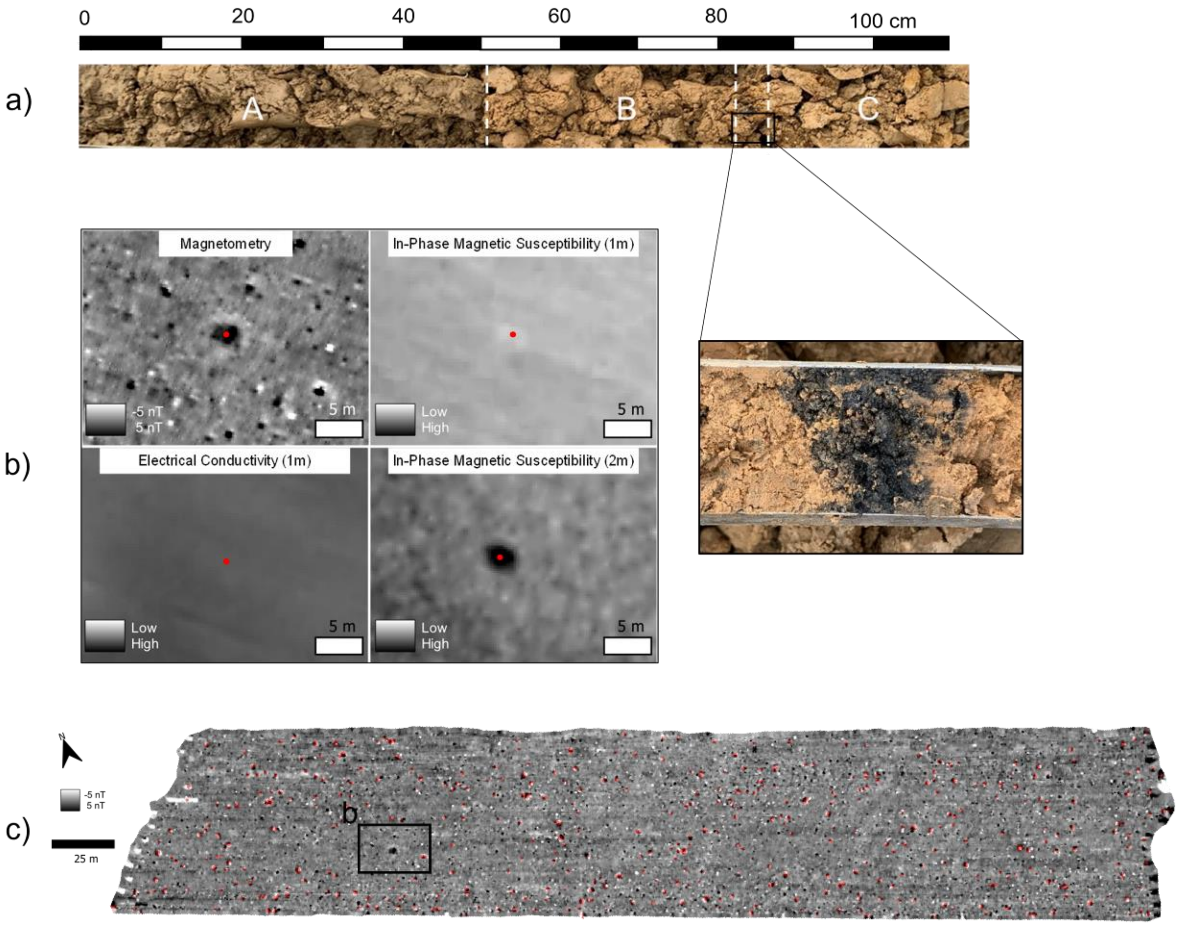

Figure 4 - Example of subtle archaeological feature detected near the ridge that comprised Wellington's main defensive position, consisting of burnt soil lens and associated ferrous metal fragments beneath approximately 80 cm of colluvial overburden. Borehole shown in a); different geophysical contrasts 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.

Colluvial material is known to exist throughout the site and overlies archaeological remains of the battle by a depth of up to 1m in some cases. This is problematic for the use of conventional metal detectors in identifying material that may be deeply buried. Electrical data layers from the EM surveys appear to capture these colluvial deposits as distinct resistive linear features, likely due to the coarser soil textures that characterize them (Figure 5). This allows for a more detailed mapping than the existing mid-20th century soil surveys (Louis, 1958) and may be useful in planning further archaeological work.

Figure 5 - Overview of apparent electrical conductivity (1m horizontal coplanar coil pair) 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.

As previously indicated by other researchers (e.g., Wiewel & De Vore, 2018), magnetometry surveys have the added benefit of rapidly identifying scatters of ferrous material at battlefield sites, some of which may represent ordnance (Figure 4c). Comparison of results with conventional metal detector surveys from the site will seek to address the complementarity of the methods. Of further note, a repeat magnetometry survey of an area of the battlefield indicates significant accumulation of additional ferrous debris over a short period of time. This may be an example of the phenomenon of intrusive green waste, well-documented in British examples (Gerrard et al., 2015) but apparently less well known in the Belgian context.

In sum, large-scale multi-method surveys at the Battlefield of Waterloo have produced intriguing initial results and several further lines of inquiry. In particular, the surveys have shown promise for identifying subtle buried archaeological features and metal scatters possibly relating to the conflict, as well as enabling a more detailed mapping of the dynamic sedimentary environment which may inform further sampling strategies. Geophysical survey thus appears to have good potential for contributing to our understanding of this complex archaeological landscape.

References

Drnovský, P., Hejhal, P., & Průchová, E. (2021). An Early Modern military camp as an archaeological site. The excavation of the field camp in Jaroměř–Semonice (northeast Bohemia). *Archeologické Rozhledy*, *73*(1), 102–141.

Evans, M., Eve, S., Haverkate-Emmerson, V., Pollard, T., Steinberg, E., & Ulke, D. (2019). Waterloo Uncovered: From discoveries in conflict archaeology to militray veteran collaboration and recovery on one of the world's most famous battlefields. In T. Darvill (Ed.), *Historic landscapes and mental well-being*. Archaeopress Publishing Ltd.

Gerrard, J., Caldwell, L., & Kennedy, A. (2015). Green Waste and Archaeological Geophysics. *Archaeological Prospection*, *22*(2), 139–142.

Louis, A. (1958). *Texte explicatif de la planchette de Waterloo 116W* (No. 116W; Carte Des Sols de La Belgique). l'Institut pour l'encouragement de la Recherche Scientifique dans l'Industrie et l'Agriculture.

Scott, D. D., & McFeaters, A. P. (2011). The Archaeology of Historic Battlefields: A History and Theoretical Development in Conflict Archaeology. *Journal of Archaeological Research*, *19*(1), 103–132.

Tabbagh, A. (1986). What Is the Best Coil Orientation in the Slingram Electromagnetic Prospecting Method? *Archaeometry*, *28*(2), 185–196.

Wiewel, A. S., & De Vore, S. L. (2018). A Fluxgate Gradiometer Survey at an American Civil War Battlefield, Pea Ridge National Military Park. *ISAP News*, *53*, 1–5.