

War related impacts (WRI) in archaeological magnetometer data

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Abstract

The relevance of archaeological prospection in conflict landscape research is briefly outlined. Several examples of WRI in magnetometer data are presented and systematized. For a prediction of filled bomb craters in magnetometer data, respective characteristics are worked out.

Keywords

conflict landscapes; geophysical data interpretation; magnetic prospection; war related impacts

Introduction

Intense shelling, bombardment, and trench warfare, key features of modern warfare, leave a sustained material impact on landscapes. The two World Wars of the 20th century have thus created many landscapes, which often figure prominently in historical narratives and cultures of memory. In fact, modern war leaves massively disturbed, polluted soil landscapes and altered geomorphology. Moreover, the wars of the 20th century often left destructive influences on (older) archaeological features across Europe. Furthermore, wars change landscapes in our present that will soon be history. The impact of modern war thus deserves to be studied with appropriate, and often interdisciplinary, methods. Archaeological prospection plays an important role in this process (Stele et al. 2021).

Regarding archaeological prospecting, impacts such as covered and filled explosive weapon impact craters (EWIC) and unexploded ordnance (UXO) are particularly relevant near the former military or war-related infrastructure. Figure 1 shows how they can be detected quite frequently and unexpectedly during geophysical surveys of older archaeological sites.

EWIC and UXO are often accompanied by other WRI and structures, such as aircraft crash sites or massive fortification earthworks (Fig. 2). Based on geophysical data alone, such findings can be quite difficult to attribute. Magnetometer prospecting can provide useful interpretive approaches, but additional data, such as historical aerial photographs, testimonies, and other historical documents, are often necessary for a reliable assessment of WRI anomalies. Therefore, we aim to improve the understanding of WRI anomalies in magnetometer data. For this purpose, we try to work out some characteristic properties of magnetic anomalies caused by such impacts based on several examples.

Approach

Data of handheld carried total field magnetometer Scintrex SM4G-Special, and fluxgate gradiometer Bartington Grad601 are presented in this extended abstract, but data from other magnetometer types are also used for the study. The WRI anomalies were verified using historical

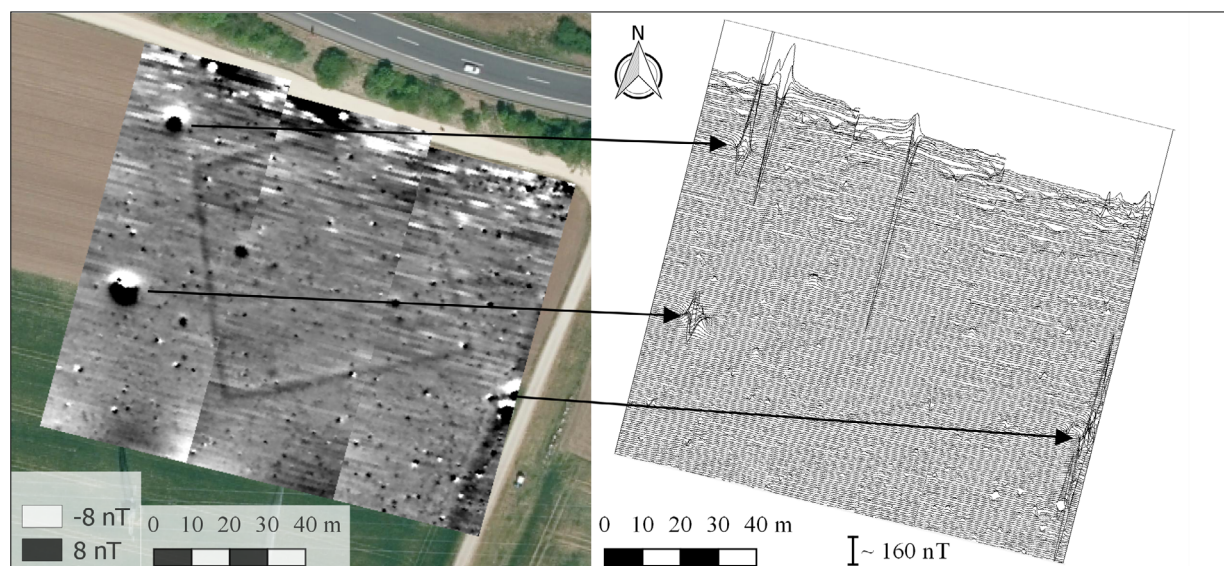


Fig. 1: Feldmoching in the north of Munich (southern Germany). The caesium magnetometer data (left as a shade plot and right as a trace plot) show a Latène square enclosure near the MAN factories, which were bombed by the Allies during the Second World War. Anomalies caused by bomb impacts (WRI-2) are marked with arrows (aerial photograph: ©2022 Bayerische Vermessungsverwaltung).

aerial photographs. This verification and comparing the magnetometer data are carried out using QGIS.

The examples took place in landscapes subject to different intensities of war-related effects during the Second World War. Based on these examples, we first classify the WRI simplistically into three groups:

- WRI-1: Impact craters due to artillery rounds of ~ 50 kg in average;
- WRI-2: Impact craters created by bombs or rounds of ~ 250 kg in average;
- WRI-3: Impact craters/features attributable to heavy bombs/missiles over 1000 kg impact weight.

Results

The anomalies in Figure 2 corresponding to craters from artillery shelling in historical aerial photographs occur mainly as positive anomalies with maximum intensities of ~ 10 - 20 nT/m. Many of these WRI-1 appear to be contaminated with dipolar, ferrous fragments (shrapnel?). Furthermore, the comparison of areas experiencing different intensities of shelling in Figure 2 shows that the magnetograms in intensively shelled areas appear noisier than in moderately shelled areas. In the presented example, the *Wehrmacht* position trenches are expressed as positive anomalies with an intensity of about 15 nT/m.

The WRI-2 anomalies can have a complex and partly different habitus depending on the magnetometer type. They vary widely in size and show very different intensities (range: from ± 30 nT up to $> > \pm 1000$ nT). On the other hand, a repeating scheme can be observed mainly for this group: no matter how intense the anomalies are, they show an exact north-south alignment with the negative part of the anomaly in the north in all our measurements (e.g. Fig. 1).

With regard to the orientation and intensity of the anomalies in the magnetic field, a similar scheme can be observed for some WRI-3 anomalies (Fig. 3). However, the size and structure of the anomalies vary particularly strongly in this group. In the example with V-2 rocket impacts presented in Figure 3, a strong dependence of the WRI-3 anomalies on the lithology and soil texture can be derived.

Discussion

It is important to note that the post-impact backfill can contain remnants of the impact (e.g. UXO) and/or objects that have nothing to do with the impact, such as (post-war) iron debris or settlement waste. We can see an increased WRI-1 influence in the form of irregularly distributed shrapnel and the resulting noise in the magnetograms (Fig. 2). If we look at the individual crater anomalies, they are often hardly distinguishable from features that could also be addressed as older (settlement) pits.

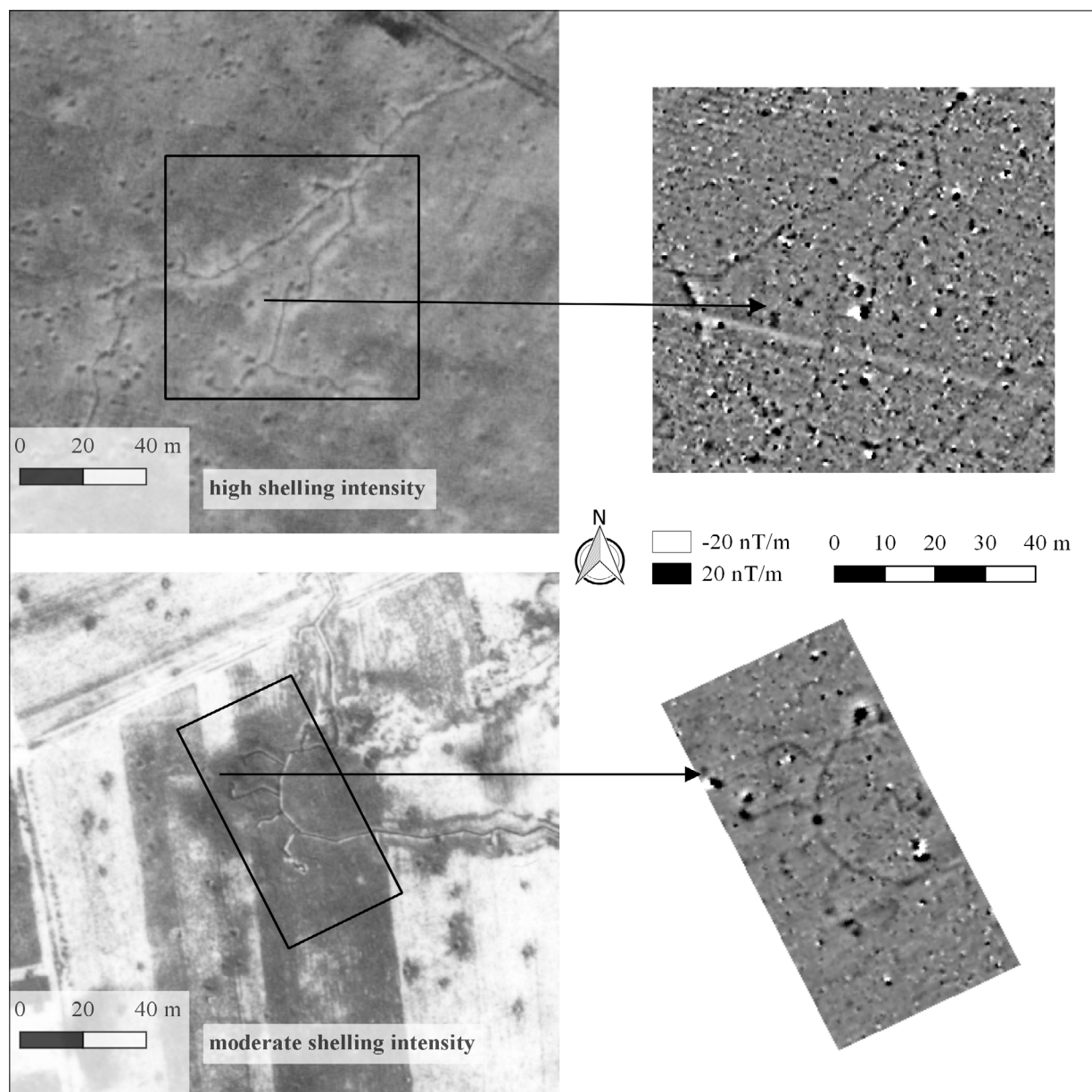


Fig. 2: Areas with artillery shelling of varying intensity in the Hürtgenwald (western Germany) on the left (National Collection of Aerial Photography (NCAP), Scotland). The gradiometer data on the right were acquired for investigating the state of preservation of the *Wehrmacht* position trenches.

For bombs and some rocket impacts, characteristics can be worked out that allow a reliable assumption as a WRI-2 or 3 impact. Anomalies of such impacts are aligned precisely north-south, with a negative part in the north. The intensity of the anomalies depends primarily on what remains in the crater after the explosion. Several scenarios are possible: if only the heated soil material remains, we see thermoremanent behavior that rarely goes above anomaly intensities of ± 50 nT; if we observe anomaly inten-

sities above ± 150 nT and more, we must expect shock-remanent munition remnants; at anomaly intensities well above ± 1000 nT, the presence of UXO is very likely (Stele et al. 2022). However, this repeating scheme does not seem to apply to all WRI-3 impacts (see e.g. Yalding in Fig. 3).

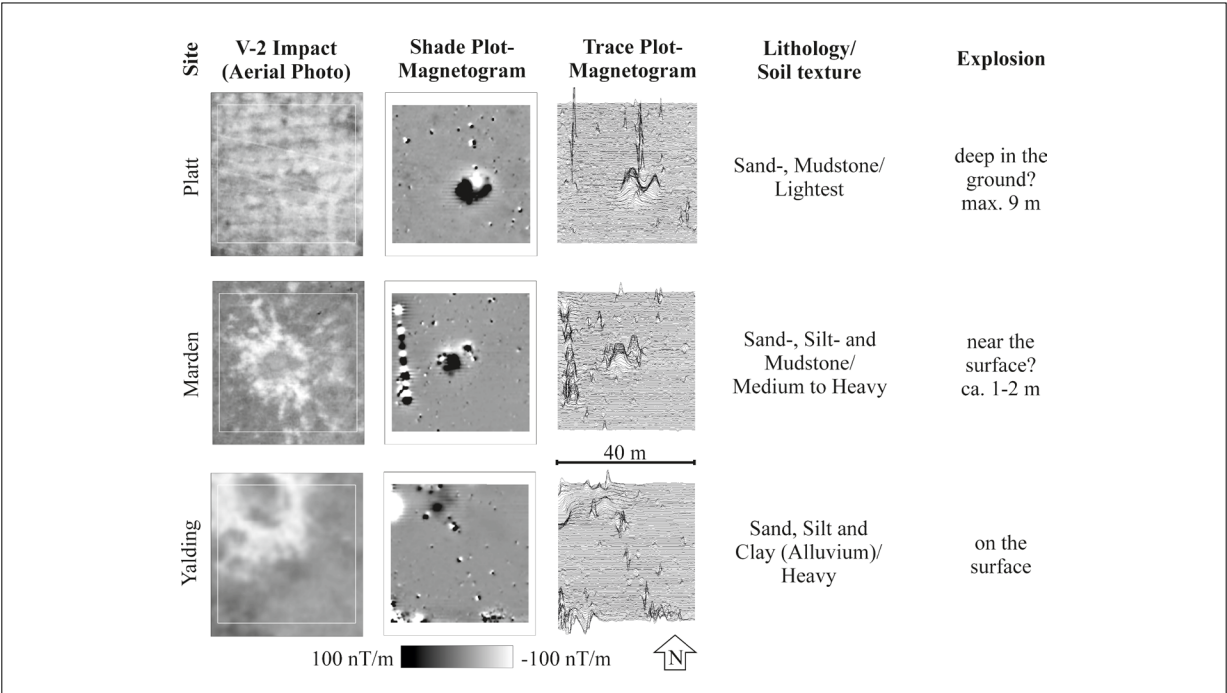


Fig. 3: Three sites with V-2 rocket impacts in the Medway catchment area (Kent, GB). In addition to the dependence on the soil texture, the depth of the explosion can also be deduced from the shape of the crater and the WRI-3 magnetic anomaly (sources: Google, ©2023 Kent County Council (historical aerial photographs); United Kingdom Soil Observatory).

Conclusion

To research WRI-cases, it is always advisable to use historical aerial photographs to interpret geophysical measurements. Multitemporal aerial reconnaissance images are often available for bombarded infrastructure objects. If no historical aerial photographs are available, it is possible to explore the suspected areas for patterns of impact craters using the historical imagery of Google Earth Pro.

Due to their typical north-south orientation with the negative part of the magnetic anomaly in the north, craters of the WRI-2 group are relatively easy to recognize in the magnetograms. More difficult to determine are influences of the WRI-1 and 3 groups. However, there are often different historical sources available for areas with such impacts.

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