

# **The Battle of the Seelow Heights, April 1945: Conflict Archaeology in the Forests of Eastern Brandenburg, Germany**

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The Berlin Operation constitutes one of the most important strategic offensives in the final stages of World War II, culminating in the capture of the Reich's capital and the unconditional surrender of the Wehrmacht. Between 16 and 19 April, 1945, the most intense fighting of the operation ensued along the Küstrin-Berlin highway in what is now called the Battle of the Seelow Heights, the largest WWII land battle to be fought on German soil. Due to the vast quantities of men and matériel involved in the fighting, an extensive militarised landscape has developed within the forests of East Brandenburg that has to date evaded archaeological scrutiny. A combination of Airborne Laser Scanning data, archival research, and GIS-analysis reveals a striking level of archaeological preservation, consisting of a highly diverse assemblage of military features, including trenches, firing positions, dugouts, logistics facilities, along with other types of war- and conflict-related infrastructure. This unprecedented wealth of well-preserved (earthwork) features distinguishes the Seelow battlefield from other WWII contexts in Europe and provides a unique opportunity to investigate the combat activities and supply infrastructures of two combatting forces, along with other forms of military appropriation of an entire landscape.

Keywords: World War II; Conflict Archaeology; Airborne Laser Scanning; Battle of Seelow Heights; Militarized Landscape; Eastern Front; Military Earthwork

## Introduction

On 16 April, 1945, the Red Army launched the *Berlin Strategic Offensive Operation*, aimed at the encirclement and capture of Germany's capital city. Three entire Soviet *fronts* – with close to 900,000 men, more than 22,000 artillery pieces and some 4,600 tanks committed in the initial attack alone – launched an assault over a 300 km frontline that extended from the Baltic Sea to the Sudeten Mountains (Soviet General Staff 2016). Against this assault stood a worn-out and much reduced Wehrmacht, capable of mustering a mere 126,602 men, 10,400 pieces of artillery, and 754 tanks to the defence (Lakowski 2008).

Despite these overwhelming odds, German Army High Command (*Oberkommando des Heeres* [OKH]) was nonetheless determined to put up a stubborn, last-ditch defence of the Reich's political, administrative, and economic centre. Correctly anticipating the Soviet point of main effort along the Berlin-Küstrin highway, *Heeresgruppe Weichsel* concentrated the majority of its remaining combat forces and reserves under command of *Armeeoberkommando 9* (AOK 9) in an effort to stall the Soviet advance. To that effect, a deeply stratified system of trenches, firing positions, and strong points was established between the Oder River and Berlin, making full use of a complex terrain that generally favoured the defender (Lakowski 2008, 2011; Le Tissier 1996; Stich 2018). With the most intense fighting of the entire operation ensuing in this central sector, the Battle of the Seelow Heights (as it is now widely known) is generally recognized as the largest land battle of World War II to be fought on German territory (Herrmann 2010) (**Fig. 1**).

To some degree, the battle's significance is reflected in the amount of attention it has received from military historians, with the bulk of research directed towards details of

battlefield tactics or issues of depletion and attrition within the Wehrmacht (e.g., Beevor 2002; Citino 2017; Duffy 1991; Foerster 1998; Förster 1998; Frieser 1998; Hastings 2004; Lakowski 1998, 2008; Le Tissier 1996, 1999; Lieb 2020; Ziemke 1968). Cultural heritage scholars, on the other hand, have recently started drawing attention to issues of commemoration and public outreach in connection to the battle and the local memorial site (Brandt 2003; Herrmann 2015a, 2015b; Herrmann and Klar 2017; Klar and Herrmann 2017; Klar, Herrmann, and Laue 2018). This, however, is contrasted by a conspicuous lack of archaeological recognition, considering that the Seelow battlefield has been recognized as one of only three areas within modern Germany that preserve extensive archaeological evidence of WWII combat remains and military structures (Wegener 2014) – along with the battlefield remains of the Reichswald and Hürtgenwald forests along Germany's western border (see Rass and Lohmeier 2011; Stele, Schwickert, and Rass 2021; Wegener 2014).

Indeed, by virtue of the sheer magnitude of military activity – extending over a period of several weeks and entailing the deployment of vast quantities of men and *matériel* – the Seelow battlefield constitutes a prime example of the intense, far-reaching anthropogenic landscape alterations that are now being recognized as a defining feature of modern, industrialized warfare, and that have become a major focal point within the field of modern conflict archaeology (e.g., Brenot et al. 2017; de Matos-Machado et al. 2019; Gheyle et al. 2013; Gheyle et al. 2016; Gheyle et al. 2018; Hesse 2014; Hupy and Koehler 2012; Hupy and Schaetzel 2008; Koch and El-Baz 1998; Note et al. 2018; Passmore and Harrison 2008; Passmore, Harrison, and Capps-Tunwell 2014; Saey et al. 2016; Stichelbaut et al. 2017; Van den Berghe et al. 2019; van der Schriek 2020b; Van Hollebeeke and Stichelbaut 2016).

The availability of extensive Airborne Laser Scanning (ALS) Data,<sup>1</sup> as has been shown in WWII landscapes elsewhere in Europe (e.g., Kobińska 2017; Passmore and Capps-Tunwell 2020; Passmore, Capps-Tunwell, and Harrison 2019; Stichelbaut et al. 2020; Wegener 2014; Zubalík 2019), now offers the opportunity to initiate a detailed and systematic assessment of the archaeological record and its heritage value. To this end, this paper presents the first results of a new research project aimed at a landscape-level investigation of the Seelow battlefield within the context of WWII conflict archaeology.

A combination of desktop mapping using ALS data, archival research and some limited fieldwalking activities have been conducted with the objectives of (i) assessing the level of archaeological preservation in both forested and non-forested areas, (ii) establishing a baseline audit of archaeological survival within the study area and developing a provisional feature typology of both Wehrmacht and Red Army military earthworks as a basis for future research, and (iii) evaluating the interpretative challenges encountered when attempting an analysis of multi-layered, palimpsest modern military landscapes. Here the focus is placed on two distinct and contrasting areas of the battlefield that have been selected for initial analysis (**Fig. 2**). The first centres on the Reitweiner Sporn, a forested promontory overlooking the southern portion of the Oderbruch that was

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1 Both Airborne Laser Scanning (ALS) and Light Detection and Ranging (LiDAR) are often used interchangeably, as they refer to the same basic technique, that is, the collection of (elevation) point data through the use of a pulsed laser beam. However, in contrast to LiDAR, which can also refer to terrestrial laser scanning, ALS is used exclusively in contexts where the scanning device is mounted on a moving, airborne platform. Throughout this study, the term ALS is used, since it more accurately reflects the source of the data employed.

captured by the Red Army during the initial struggle for the bridgeheads and subsequently served as one of the jumping off points for the *Berlin Offensive*. The second area extends over a partially wooded landscape in the vicinity of Petershagen some 15-20 km southwest of the Reitweiner Sporn. Although this area for the most part escaped ground combat during the offensive, it preserves strong evidence for Wehrmacht defensive positions and staging areas.

## **Background to the Study Area**

### ***Topography and Geology***

The landscape of the Battle of the Seelow Heights covers an area of about 6000 km<sup>2</sup> between the Oder in the east and the outskirts of Berlin to the west, and between the city of Eberswalde in the north and the Schwielochsee in the south (**Fig. 1**). In the east lies the Oderbruch, the low-lying floodplain of the Oder River, characterised by highly productive alluvial soils and extensively developed for agricultural purposes, particularly grain cultivation (Bacher 2005; Schlögel 2007; Zawadka 2007). A historically-grown network of watercourses criss-crosses the plain, resulting in a complex, stratified system of dykes, irrigation channels and drainage ditches, turning the Oderbruch into a landscape defined by a long history of artificial landscape development (Bacher 2005; Linde 2007). The few remaining natural watercourses are lined by trees, as are many of the roads that run through the floodplain (often across dams and sleeper dykes) which in turn are flanked by irrigation ditches, slightly elevating them above the otherwise rather featureless terrain.

To the west, the Oderbruch is bordered by a steep escarpment formed by the uplands of the Barnim and the Lebuser Platte and rising up to 100 m above the river valley. Both plateaus present a complex topography of rolling hills, locally incised by steep-sided

stream valleys. The landscape of these uplands is defined by agricultural fields and extensive forested areas, as well as numerous lakes, streams, and other smaller water bodies (Lakowski 2011; LBGR Brandenburg 2010).

The loamy and sandy soils of the area, which stem from glacial outwash and moraine sediments, make this terrain generally favourable to the deployment of armoured forces (Scheit 2007; Soviet General Staff 2016), whereas numerous watercourses, a high groundwater table, and the steep slopes of the escarpment impose significant restrictions on the conduct of mobile offensive operations.

Another defining feature of the area is its network of communication routes. Radiating out from the population and railway hubs of Küstrin and Frankfurt-on-Oder, the major road and railway lines transect the area in an east-westerly direction, while a dense network of subsidiary railway lines and roads facilitates troop movements in the depth of the battlefield (Soviet General Staff 2016).

Although Soviet military planners were fully aware of the specific characteristics and restrictions of the battlefield space, they nonetheless considered the sector between Eberswalde and Frankfurt-on-Oder most favourable to the rapid development of the *Berlin Operation* (Soviet General Staff 2016, 29).

### ***The Military Situation on the Eastern Front, 1944-1945***

Between early June and late August 1944, the Red Army launched a series of five *Strategic Offensive Operations* across almost the entire length of the Eastern Front, most importantly the *Belorussian, L'vov-Peremyshl'*, and the *Lublin-Brest Operations* against *Heeresgruppen Mitte* and *Nordukraine* in Belorussia, Ukraine, and Eastern Poland. Within two months' time, the frontline was pushed several hundred kilometres

to the West, allowing the Red Army to reach the outskirts of Warsaw and the west bank of the Vistula River. In the course of the fighting, *Heeresgruppe Mitte* was all but obliterated, while *Heeresgruppe Nord* was cut off from the German lines and trapped in the Courland Pocket until the end of the war (Glantz 2006; Lakowski 2008; Watt 2008; Zetterling and Frankson 1998).

In reaction to this crushing defeat, OKH shifted towards a strategy centred on fortified places and deeply stratified, static defensive positions in preparation for the defence of the Reich's eastern provinces. Forced by the definitive loss of the strategic initiative, and also accounting for mounting shortages in men and munitions, Wehrmacht defensive strategy on the Eastern Front forewent the modern concepts of mobile warfare and resorted to a behaviour reminiscent of World War I positional warfare on the Western Front (Lakowski 2008, 496-499).

Yet the hurriedly built and unfinished defensive positions, erected between the Vistula and the Oder from September 1944 onwards, proved incapable of repulsing the Soviet Winter Offensive (*Vistula-Oder Operation*), launched on 12 January 1945. Against the resistance of the collapsing *Heeresgruppe A* and the newly-established *Heeresgruppe Weichsel*, Soviet forces of *1 Belorussian Front* quickly advanced 400 km to the west, reaching the Oder by the end of the month (Lakowski 2008; Le Tissier 1996).

Having crossed the Oder on 31 January, the Soviet advance ground to a halt. With their supply lines threatened by a few defiant German fortress cities, and with the flanks of *1 Belorussian Front* exposed, Soviet commanders were forced to divert their attention towards East Pomerania and West Prussia in preparation for the final push towards Berlin. This lull in offensive activity, which lasted until early April, provided Wehrmacht defenders with some much-needed time to prepare defensive positions

along the Oder and replenish their badly mauled and depleted units (Lakowski 2008, 531).

Between February and April, heavy fighting erupted for the Soviet bridgeheads, with Red Army units slowly expanding their foothold on the west bank of the Oder against stubborn German resistance and repeated counterattacks (Harrison 2016; Lakowski 2008; Le Tissier 1996). Particularly fierce fighting ensued for the possession of the Reitweiner Sporn, a promontory overlooking the southern portion of the Oderbruch that provided excellent opportunities for both battlefield observation and flanking attacks on the German positions (Busse 1955, 152). Hence, once units of *8 Guards Army* had successfully dislodged the German defenders in this area, an army observation post was established on the promontory and it was from here that Marshall G. Zhukov, commander-in-chief of *1 Belorussian Front*, directed and observed the progress of the offensive.

### ***Issues of Cultural Heritage Management***

To date, only a small fraction of the entire battlefield has been included in the official schedule of monuments, primarily along the escarpment to the north and southeast of Seelow (**Fig. 2**). Most importantly, the Reitweiner Sporn, which is recognised for the remains of a Red Army command and observation post (the so-called ‘Zhukov Bunker’), has been placed under protection as a whole, with small sections of trenches and individual dugouts restored for public access.

Apart from that, and barring the c. 180 military cemeteries, war graves, and memorials scattered across the former battlefield (Herrmann 2015a), the full extent of archaeological remains across the battlefield is still largely unknown. Published archaeological information is limited to a handful of antiquities reports and short notes,

concerned with individual finds, object types, or battlefield contexts (Klar, Herrmann, and Laue 2018; Köpp and Petzel 2014, 2016a, 2016b, 2018, 2019; Petzel 2012; Petzel and Slawinski 2019; Schopper 2001), whereas some preliminary investigations have been conducted by Polish archaeologists across the river (Maliński 2019; Maliński, Radaszewski, and Krajewski 2019; Szalast and Kiarszys 2015).

To mitigate against this lacuna in academic knowledge (and potential for official oversight), local heritage legislation (Land Brandenburg 2004, §10) requires that an official permits is obtained not only for archaeological excavation, but also when purposefully searching for archaeological remains with the help of technological aids. Unfortunately, though, this restrictive legal environment has not been able to successfully stave off the numerous illicit excavators and treasure hunters who frequent the area in search of military paraphernalia and unexploded ordnance (UXO) to sell on the black market (Mitteldeutscher Rundfunk 2020).

## **Materials and Methods**

### ***Airborne Laser Scanning (ALS) Data***

In recent decades, ALS has been recognized as one of the most useful tools for archaeological exploration on a landscape scale, particularly in remote or difficult-to-access regions and especially in woodland environments (Bofinger and Hesse 2011; Bofinger, Kurz, and Schmidt 2007; Crutchley and Crow 2018; Doneus and Briesse 2006a, 2006b, 2011; Doneus et al. 2008; Forlin 2012; Gallagher and Josephs 2008; Hesse 2009, 2010, 2013; Holata et al. 2018; Mlekuž 2013; Risbøl 2010). The ability of ALS to quickly gather elevational information over large swathes of land within a relatively short period of time paired with a high degree of detail makes it an ideal tool for the detection and mapping of both individual archaeological features and entire

landscapes (e.g. Bofinger and Hesse 2011; Bofinger, Kurz, and Schmidt 2007; Doneus and Briese 2006b; Doneus and Kühnleiber 2013; Hesse 2012, 2013; Mlekuž 2013).

Indeed, the increasing availability of ALS data has been central to the rapidly expanding catalogue of documented WWII landscapes across Europe.

### ***Data Acquisition and Limitations***

ALS data for the entire Seelow battlefield was acquired as a Digital Terrain Model (DTM) with a one metre ground resolution from the *Landesvermessung und Geoinformation Brandenburg* (LGB), stemming from four individual scanning projects conducted between February 2009 and April 2011. The available information on data acquisition procedures, system configuration, and processing methodology is summarised in **Table 1**.

As a general-purpose DTM, the data is not specifically designed for archaeological exploration and just barely fulfils (and in one case even falls short of) the minimum requirements for ALS-based archaeological prospection in forested environments (see Crutchley and Crow 2018, 28). Furthermore, the data is provided ‘as is,’ without any control over scanning system type and configuration, or data acquisition and post-processing methodology, which are widely considered crucial elements in archaeological ALS applications (Crutchley and Crow 2018; Doneus and Briese 2006a; Doneus et al. 2008; Doneus, Briese, and Kühnleiber 2008; Doneus, Mandlbürger, and Doneus 2020; Holata et al. 2018; Kokalj, Zakšek, and Oštir 2013; Opitz and Cowley 2013).

It is therefore recognised that the underlying data imposes some restrictions on what is achievable. Given the rather coarse resolution of the data, it might be impossible to discern smaller features of interest or establish their respective planform shape (see de

Matos-Machado et al. 2019; Risbøl 2010; Risbøl et al. 2013). Similarly, it cannot be ruled out that an unequivocal differentiation between anthropogenic and natural features, especially tree throw, might not always be achievable, leading to potential misinterpretations. This is further exacerbated by the fact that many WWII military earthworks, particularly field fortifications, were specifically designed so as to only leave a relatively small footprint on the ground and blend as much as possible into the surrounding terrain. Accordingly, the present audit has not attempted to systematically map features measuring less than c.3m along at least one of their main axes and it is accepted that this will exclude many smaller features that are part of the battlefield landscape.

Nonetheless, general-purpose DTMs have been recognized as an easily accessible and low-cost tool for the initial exploration and identification of archaeological features (Challis 2006; Doneus and Briese 2011; Doneus and Kühteiber 2013; Forlin 2012; Hesse 2013) and have underpinned many baseline audits of WWII remains at both site and landscape scales (e.g., Kobińska 2017; Passmore and Capps-Tunwell 2020; Passmore, Capps-Tunwell, and Harrison 2019; Stichelbaut et al. 2020; van der Schriek and Beex 2018; Wegener 2014). Accepting the limitations of publicly available ALS data, these studies have nonetheless clearly demonstrated their utility within an interpretive framework that not just deliberately excludes smaller features from the analysis, but also relies on contemporary documentation for interpretation.

### ***Data Visualisation***

Following the workflow procedures proposed by Kokalj and Hesse (2017), and acknowledging recent debates about the employment of different data visualisation techniques (Bennett et al. 2011, 2012; Challis, Forlin, and Kinsey 2011; Doneus 2013;

Fernandez-Diaz et al. 2014; Hesse 2010; Kokalj and Somrak 2019; Kokalj, Zakšek, and Oštir 2011, 2013; Štular et al. 2012; Waagen 2019; Zakšek, Oštir, and Kokalj 2011), this project employed three distinct types of data visualisation, namely *Analytical Hillshade*, *Sky-View Factor*, and *Negative Openness* (**Table 2**). The combination of these three techniques has been proven most effective in complex terrain, and are therefore deemed best suited for the present study area with its variegated topography – comprising alluvial plains, steep ridges, gently rolling plateaus, and extensive areas of woodland that characterise the battlefield landscape. Data visualisation was performed using the *Relief Visualization Toolbox* (RVT) software package released by the *Research Centre of the Slovenian Academy of Sciences and Art* (Kokalj and Somrak 2019; Zakšek, Oštir, and Kokalj 2011).

### ***Archival Research***

ALS-based identification and interpretation of potential military earthwork features in this study has been greatly aided by a wide array of contemporary military documents including field manuals and handbooks, army regulations, combat reports, and military maps, issued by both Wehrmacht and Red Army authorities and military formations. These were acquired from a variety of sources: Wehrmacht regulations and field manuals providing information on field fortifications and their tactical employment, the organisation of rear services, and the management of logistics facilities and munitions storage were procured from the *Bundesarchiv-Militärarchiv* (BA-MA) as well as the *Württembergische Landesbibliothek* (Oberkommando des Heeres 1938a, 1938b, 1939, 1941a, 1941b, 1942, 1943, 1944a, 1944b, 1944c, 1945). Relevant maps and documents issued by *Heeresgruppe Weichsel*, on the other hand, were accessed online through a joint German-Russian digitisation project ([www.germandocsinrussia.org](http://www.germandocsinrussia.org)).

Given that access to the *Central Archives of the Russian Ministry of Defence* (TsAMO) remains highly restricted, research on Red Army manuals mostly relied on online databases (militera.lib.ru, nozdr.ru) and collections held by Western institutions, such as the *British Library* or the *Russian Military Studies Centre*. As large numbers of military documents pertaining to the *Berlin Operation* have recently been publicly released by TsAMO ([www.pamyat-naroda.ru](http://www.pamyat-naroda.ru)), these were also accessed online.

A particular effort was made to research and acquire contemporary aerial photographs (AP) of the study area. Although it has not yet been possible to access either German or Russian photographs,<sup>2</sup> some 33 images taken by Allied reconnaissance on 18 March 1945 were acquired through the *National Archives and Records Administration* (NARA). While they provide a high level of detail on ground features in a few select locations, especially in floodplain and urban contexts, their limited availability and coverage means that they are currently insufficient for a landscape-level analysis of the battlefield at large.

### ***Field Survey***

It is widely recognised that desk-based archaeological ALS analysis requires supplemental field survey and ground-truthing to properly establish the characteristics and potential identification of observed features (Bennett et al. 2011; Doneus et al.

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<sup>2</sup> Captured German aerial photographs (the so-called GX Series) of the study area are contained within *Record Group 373 – Records of the Defense Intelligence Agency, 1920-2006* at NARA. As they have not yet been digitised, they were not available for this study. Access to contemporary Soviet photographs is more complicated, as their storage locations and preservation status within TsAMO are currently unknown.

2008; Doneus and Kühleiber 2013; Fernandez-Diaz et al. 2014; Gallagher and Josephs 2008; Georges-Leroy 2011; Hanus 2012). ALS mapping for this study has been supported by a two-day field reconnaissance during which transects along forest tracks in the Reitweiner Sporn and Petershagen study areas were walked. Due to local heritage protection laws, however, work was limited to photographically documenting individual features of interest, and additional work must await the granting of a research permit.

Notwithstanding its brevity, this field survey proved invaluable in confirming a sample of desk-based mapping results, which were identified and interpreted with the help of extensive documentary sources.

### ***GIS Analysis and Feature Mapping***

ALS data, historical maps, aerial photographs as well as field photographs were imported into the ESRI ArcGIS Pro software package for feature mapping and analysis. To organise and structure the data collection process, a regular grid was created for the entirety of the battlefield, which contained information on corresponding ALS tile numbers, study area designator, and process of feature mapping operations. Relevant features were recorded in a polygon shapefile, with the attached data table used to store pertinent metadata, along with observational and interpretational information (see Doneus and Kühleiber 2013).

Detailed feature mapping focused primarily on the two main study areas indicated above. In order to place the results of this detailed mapping into a regional, landscape-level perspective, however, a broad assessment of areas containing evidence for military earthworks and other features related to the militarised landscape was carried out for the entirety of the battlefield area. To achieve this, the ALS data was surveyed in a structured way with the help of the reference grid, with special attention towards

woodlands. Areas interpreted as containing evidence of military activity were digitised as polygons, which depended largely on the recognition of distinct types and patterns of features. Military features identified on APs were digitised in a similar fashion.

Main contemporary roads and railway lines, as well as the extent of contemporary woodland cover across the battlefield area, were digitised with the help of contemporary German 1:100,000-scale topographic maps. A comparison of these historic maps with modern satellite data indicates a generally high degree of congruence of contemporary and modern woodland cover and also attests to the preservation of (often derelict) historic railway lines within the landscape.

### **Results: The Militarized Landscape of the Seelow Battlefield**

One of the most striking findings of this study so far is the remarkable level of preservation of military-related archaeological features, which are found dispersed throughout the region (**Fig. 2**). To date, coarse mapping based on ALS data has identified features of potentially military origin across c.158 km<sup>2</sup> of the study region, primarily in areas under woodland cover, with a total of 2,515 individual earthwork features mapped and interpreted in detail. These findings not only provide evidence for direct combat activity, such as trench networks, field fortifications, and cratering from artillery fire or aerial attack (**Fig. 3a**), but also contain examples of non-combat activities including storage facilities, vehicle shelters, and staging areas that are also part of the battlefield landscape (**Fig. 3b**). Also included in the data is evidence for military research and production facilities pre-dating the battle, most importantly the remains of the so-called ‘Seewerk Falkenhagen’ munitions factory (see Preuß 2017; Schmaltz 2005) (**Fig. 3c**), and the post-battle remains of field encampments, erected by the Red Army in the final stages of the *Berlin Operation* or shortly thereafter (Kersting

et al. 2018) (**Fig. 3d**).

In contrast, aerial photo analysis currently provides evidence for a total of just c.3 km<sup>2</sup> of military and combat-related features, which in some cases even overlap with the findings from ALS data. Importantly, however, APs provide unequivocal evidence for combat activity within floodplain (**Fig. 3e**) and urban (**Fig. 3f**) contexts, both of which are severely underrepresented within the ALS data as a result of post-war landscape alteration and urban development.

The spatial distribution of these features across the landscape provides important information on the overall level of archaeological preservation within the region. Broadly speaking, the Seelow battlefield can be subdivided into two contrasting landscapes: the Oder floodplain including the Oderbruch on the one hand, and the upland plateaus of the Barnim and Lebusen Platte on the other. Of the contemporary woodland areas, barely two percent are located within the floodplain zone, which accounts for about 16 percent of the battlefield area, with the remainder located on the upland plateaus. Within the floodplain areas, however, only about 37 percent of potential features are located in areas under forest cover, compared to around 77 percent on the plateaus. This finding is rather unusual in the context of WWII conflict archaeology, which has so far provided little evidence for feature survival within floodplain zones.

Still, the vast majority – over 80 percent – of potential military earthworks and other war-related archaeological remains identified in this study are found within the upland region, with only a minority found in open terrain or areas without extensive forest cover. This comes to little surprise, given the well-known limitations of ALS to record archaeological features in certain types of terrain and land cover, especially within

zones of agricultural development (Crutchley and Crow 2018). Given the limited resolution of the data available, it currently remains difficult to assess whether the observed distribution of potential military earthworks should be interpreted as a function of archaeological preservation or rather an artefact of data collection methodology. In any case, the features mapped so far constitute only a small sample of the original military landscape of the Seelow battlefield. Considering that the vast majority of combat activity in the area actually took place during the struggle for the Soviet bridgeheads prior to the offensive proper, and considering that Soviet forces are reported to have dug over 600 km of trenches within their bridgeheads alone (Soviet General Staff 2016, 117), it can be argued that the numbers presented here constitute only a fraction of what survives on the ground and that a significant portion of the battlefield landscape has been lost (or rendered invisible to ALS) due to post-war urbanisation and agricultural development.

Nonetheless, the level of feature preservation within these woodland areas emphasises the anthropogenic character of the landscape, with the forests of the Seelow battlefield constituting an exceptional repository of archaeological features and a prime example of the heavily militarised landscapes associated with 20th century industrialised conflict.

### ***Case Study: Reitweiner Sporn***

One of the most striking examples for the preservation of military structures associated with the Battle of the Seelow Heights is found on the Reitweiner Sporn, where a particularly high density of earthwork features can be observed covering almost the entirety of the spur's wooded NE tip (**Fig. 4**).

### *From Contested Ground to Strong-Point Defensive Position*

Among the most conspicuous features of this area are several lines of trenches, readily identifiable due to their characteristic zig-zag pattern known from contemporary sources (Department of the Army 1954; Oberkommando des Heeres 1944a, 1944c; People's Commissariat of Defense 1942; War Department 1944, 1946; War Office 1943). On the ground, these trenches survive as shallow linear depressions (**Fig. 5**) and comparable examples have by been documented elsewhere (Rottman 2004, 2007; van der Schriek 2016, 2020b; van der Schriek and Beex 2018; Wegener 2014; Zubalík 2019).

The first of these trench lines (**Fig. 6: A**) is oriented approximately in a NE-SW direction in the NE-most section of the promontory, where it hugs the natural contours of a low, west-facing crest, roughly parallel to a forest road. The second trench line (B) is located some 200-400 m further to the west, again generally oriented in a NE-SW direction. A third line (C) can be distinguished running in a NW-SE direction along the base of a SW-facing crest, until linking up with yet another trench line (D) which runs along the crest of a steep, SW-facing ridge.

Each of these lines of firing trenches<sup>3</sup> is distinguished by several rectilinear/sub-circular

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3 Here the term *firing trench* is used to denote trenches connecting individual firing positions (both for infantry weapons and large-calibre guns) and that are used for combat. Conversely, *communication trench* is applied to trenches either used to access firing trenches from the rear or to connect different areas within a larger defensive system. Hence, designations employed in this study are reminiscent of both Wehrmacht and US Army usage, both of which differentiate between trenches used for combat and troop movement respectively (Department of the Army 1954; Oberkommando des Heeres 1944c), whereas Red Army

features arranged along its length, often connected to the main line through a short subsidiary trench. These can be interpreted as either firing positions for infantry weapons – machine guns, anti-tank rifles, and small-calibre mortars – or shelters for the soldiers occupying these trenches.

Additional trenches, usually oriented perpendicularly to the firing trenches, can be interpreted as communication trenches. They often connect frontline firing trenches to rear areas, where additional firing positions, dugouts, and other structures are located, or extend between individual lines of firing trenches, integrating individual positions into a cohesive defensive system.

Located at the NW edge of the promontory, numerous well-defined features can be observed along the slopes of two NW-SE oriented gullies that cut into the escarpment (**Fig. 7**). The larger, southern cluster of features (RS-0001) cuts into the NE-facing slope of the hill, extending some 400 m along the forest track, and consists of c.168 rectangular/sub-circular depressions measuring around 2-6 m in diameter, although some larger features exist as well. The second cluster (RS-0002) is located some 100 m to the NE, with features located on both sides of the valley, again with feature sizes primarily in the size range of 2-6 m (**Fig. 8**).

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documents suggest a differentiation by stage of construction and type of movement (see Rottman 2007). In principle, *firing positions* would be located along the enemy-facing front of a firing trench, with reserve firing positions, dugouts, and shelters located further to the back. Hence, the topology of trenches and their associated features provides important information for the functional differentiation of individual earthwork features, while also enabling the identification of the supposed ‘front’ of the trench.

Dispersed across the ridge, and in some instances integrated via communication trenches, are large numbers of earthwork features that for the most part can be interpreted as evidence for combat positions. For example, a large concentration of c.12-16 feature clusters (RS-0003) can be observed within a small strip of forest on the eastern foot of the ridge consisting of several depressions arranged along short, shallow trenches (**Fig. 9**). Although ALS resolution in many cases precludes a confident differentiation of individual features, most appear as shallow circular/sub-circular depressions, a fact also supported by field survey results (**Fig. 10**).

Similarly dispersed across the area are a number of small, rectilinear features that are usually aligned along forest roads and tracks. Arranged in characteristic herringbone patterns, and measuring c.5-9 m in length and c.2.5-4.5 m in width, they typically feature a road-facing opening in their embankments. Based on these characteristics, they can be interpreted as vehicle shelters, possibly for lorries used either as supply transport or as prime movers for artillery pieces. However, it is interesting to note that the Reitwein vehicle shelters are smaller in size than both Red Army/Wehrmacht shelters for armoured fighting vehicles (AFVs) and archaeologically identified Wehrmacht vehicle shelters from elsewhere in Europe (Capps-Tunwell, Passmore, and Harrison 2015; Passmore, Capps-Tunwell, and Harrison 2013, 2016) (**Fig. 11**). This raises the possibility that these shelters may have been used to conceal horse-drawn carriages rather than motor vehicles, which were heavily used by both the Wehrmacht and the Red Army. Documentary evidence for the practice of concealing horse-drawn vehicles, however, is currently lacking.

Based on the available historical documentation an initial functional and chronological interpretation of the features on the Reitweiner Sporn can be proposed: First, during the period 2 February to 30 March, units of 79 and 88 *Guards Rifle Divisions* fought for the

possession of the Reitweiner Sporn, as indicated by a series of situation maps issued by *1 Belorussian Front*. After initially occupying the eastern slopes between Reitwein and Wuhden until 5 February,<sup>4</sup> *79 Guards Rifle Division* first advanced west across the spur,<sup>5</sup> before frontlines shifted SW where they solidified just NE of Podelzig until the start of the offensive.<sup>6</sup> By early April the NE tip of the spur, along with the floodplain to its east, had been transformed into a heavily fortified strong-point defensive position

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4 Boyok, Lt. General. 'Otchetnaia karta 1 BelF, 61 A, 5 Ud. A, 8 gv., 69, 33 A, 1 i 2 TA s 1.2 po 5.2.45 g. Priolzhenie k delu No 685' [Reporting map 1 Belorussian Front, 61 Army, 5 Shock Army, 8 Guards Army, 69, 33 Armies, 1 & 2 Tank Army from 1 February to 5 February 1945. Annex to folder 685.] 1:100,000. Berlin. 5 February 1945. Fond 233, Opus 2356, Delo 689. TsAMO <https://pamyat-naroda.ru/documents/view/?id=101059579>.

5 Boyok, Lt. General. 'Otchetnaia karta 1 BelF, 61 A, 1 i 2 gv. TA, 5 Ud. A, 8 gv. A, 69, 33 A, 7 gv. kk s 11.2 po 16.2.45 g. 47 A – s 12.2. po 16.2.45 g. 7 sk (3 Ud. A) – s 13.2 po 16.45 g. Priolzhenie No 8. Priolzhenie k delu No 685' [Reporting map 1 Belorussian Front, 61 Army, 1 & 2 Guards Tank Armies, 5 Shock Army, 8 Guards Army, 69, 33 Armies, 7 Guards Cavalry Corps from 11 February to 16 February 1945. 47 Army from 12.2.1945 to 16.2.1945. 7 Rifle Corps (3 Shock Army) from 13.2.1945 to 16.2.1945. Appendix 8 to annex to folder 685.] 1:100,000. Berlin. 16 February 1945. Fond 233, Opus 2356, Delo 689. TsAMO <https://pamyat-naroda.ru/documents/view/?id=101064730>.

6 Boyok, Lt. General. 'Otchetnaia karta 1 BelF, 5 Ud. A, 8 gv., 69, 33 A s 26.3 po 31.3.45 g.' [Reporting map 1 Belorussian Front, 5 Shock Army, 8 Guards Army, 69 & 33 Armies from 26 March 1945 to 31 March 1945.] 1:100,000. Berlin. 31 March 1945. Fond 233, Opus 2356, Delo 708. TsAMO <https://pamyat-naroda.ru/documents/view/?id=100598656>.

supported by high numbers of field guns and large-calibre howitzers (**Fig. 12**).<sup>7</sup>

At the same time, Red Army engineers transformed the area into the primary forward command post for *8 Guards Army*, which encompassed observation posts for both *28* and *29 Guards Rifle Corps* and was used by Marshal Zhukov to direct the offensive (Klar and Herrmann 2017; Schopper 2001) (**Fig. 13**). According to documentary evidence<sup>8</sup> a total of six large rectangular dugouts, six square two-room dugouts, 18 smaller square dugouts, 12 vehicle shelters, five observation posts, 23 shelter trenches, and a total of 266 m of communication trenches was erected between late March and mid-April by *64 Engineer Brigade* alone (see also Klar and Herrmann 2017). As shown in **Fig. 14**, specifications of these types of dugouts correspond to ALS-based measurements for many of the smaller features of clusters RS-0001 and RS-0002, whereas corresponding specifications for the larger features can be found in Wehrmacht documents (Oberkommando des Heeres 1944c) or the archaeological record (Kersting et al. 2018). Therefore, it is possible to interpret these feature clusters as the remains of the dugouts, troop shelters, and bunkers erected by Soviet engineers, which would have made up much of the infrastructure of the command post.

The features of RS-0003 can be interpreted as the firing positions of *243 Mortar Regiment*, which was stationed in this location with its 120 mm heavy mortars by early

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<sup>7</sup> Īakovlev, Major, 'Skhema PTO 28 sk' [PTO (Anti-Tank Defence) Scheme of *28 Guards Rifle Corps*]. 06 April 1945. Fond 886, Opus 1, Delo 467. TsAMO <https://pamyat-naroda.ru/documents/view/?id=114648649>

<sup>8</sup> 64th ISBR. 'Zhurnal boevykh deĭstviĭ 64 ISBR' [Combat Journal of 64 ISBR]. 9 May 1945. Fond 30392, Opus 1, Delo 45. TsAMO <https://pamyat-naroda.ru/documents/view/?id=130750306>.

April.<sup>9</sup> This is consistent with the size-range of Red Army 120 mm mortar emplacements which would typically have consisted of a shallow pit measuring just over 3 m in diameter (Rottman 2007, 37) (**Fig. 15**). Although a detailed functional interpretation of many of these earthworks is precluded by insufficient data resolution, it seems likely that RS-0003 also encompasses as-of-yet unidentified features, including pits for the storage of munitions or supplies.

The apparent correspondence of some of the features recorded on the Reitweiner Sporn with specifications found in Wehrmacht documents raises the possibility that some of these features constitute earlier German positions later occupied and re-used by the Red Army, although this issue cannot be resolved with the evidence and documentation currently at hand. However, the overall orientation and spatial arrangement of these features, located for the most part on E/NE-facing (rear-)slopes, indicates that the vast majority of features should be associated with the Soviet occupation of the spur. The orientation of trench lines A-D as well as their distribution, which corresponds to 79 *Guards Rifle Division*'s line of advance, suggests that at least some of the Reitwein features should be attributed to the phase of intense fighting for the possession of the promontory (**Fig. 16**).

#### *Evidence for Specialised Logistics Facilities?*

Another feature type is more enigmatic, however. Measuring up to 40 m in length and 7 m in width, several exceptionally large, rectilinear features constitute a conspicuous

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<sup>9</sup> Yakovlev, Major. 'Skhema PTO 28 sk' [PTO Scheme of 28 Guards Rifle Corps]. 6 April 1945. Fond 886, Opus 1, Delo 467, Sheet 196. TsAMO <https://pamyat-naroda.ru/documents/view/?id=114648649>.

element of the landscape on the NW base of the Reitweiner Sporn (**Fig. 17**). These features are characterised by well-preserved embankments along the long sides with an opening in (at least) one of the short sides, along with a distinct small recess on one of the long sides, often placed half-way along the length of the feature (**Fig. 18**).

Currently, no documentary evidence has been uncovered that would allow for a conclusive identification of these features. Given their unique typology, however, it can be suggested that they constitute a distinct feature category with a specialized function. This is also suggested by their conspicuous clustering along the edge of the forest in direct proximity to the Küstrin-Frankfurt railway line, which might indicate that they are related to the stockpiling and distribution of railway cargo, such as munitions or supplies. However, differences in both size and arrangement might also indicate functional differentiation. For example, clusters RS-0011 and RS-0012 consist primarily of large, elongated structures dispersed in a rather haphazard fashion, whereas RS-0009 entails both large rectangular and small squarish earthwork features. RS-0010, on the other hand, is arranged in a conspicuous U-shaped pattern with generally smaller feature sizes, potentially optimized for vehicular access (**Fig. 11**). Therefore, RS-0010 might be provisionally interpreted as vehicle shelters, whereas RS-0009, RS-0011, and RS-0012 might have functioned as munitions or fuel depots.

### ***Case Study: Petershagen***

The Petershagen study area, located on the plateau some 15-20 km SW of the Reitweiner Sporn, centres on the villages of Petershagen and Treplin, straddling the Frankfurt-Müncheberg highway (**Fig. 2**). Here the terrain comprises gently rolling agricultural fields interspersed with woodlands flanking narrow steep-sided valleys. Located on the southern shoulder of the main axis of advance, this area escaped combat

during the initial stages of the offensive. Although spatially much more dispersed than on the Reitweiner Sporn, preserved earthwork features clearly attest to a considerable impact from military activity in the area and can be differentiated into two distinct areas, located to the west and east of Petershagen, respectively.

#### *Wehrmacht Defences at the 'Stein Stellung'*

The first area is characterised by some 800 m of well-defined zig-zag trenches forming a discontinuous defensive position along the western crest of a N-S oriented incised valley (**Fig. 19**). This defensive system is best developed immediately west of Petershagen, where two parallel lines of firing trenches, connected via short communication trenches, can be identified (PH-0001). A handful of rectilinear features as well as short, one-/two-pronged trenches are placed along the eastern sides of both trench lines, indicating the locations of firing positions for infantry weapons and two-man rifle positions characteristic of Wehrmacht trenches (Oberkommando des Heeres 1944c).

Several sub-circular earthwork features lie in close proximity to the northern end of this double-trench position and include three large and at least partially embanked features (PH-0002) measuring c.10 m in diameter. Considering that gun pits of this size were used for both light and heavy German artillery (Oberkommando des Heeres 1944c), these may have functioned as artillery firing positions.

Approximately 200 m to the NW of this trench system lies a cluster of 19 rectilinear features and numerous sub-circular earthworks (PH-0003). The rectilinear features, which measure c.4-9 m in length, exhibit a characteristic, albeit crude herringbone pattern alongside a series of forest tracks. Both their dimensions, which are similar to logistics-related examples documented in Normandy (Passmore et al. 2017), as well as

their spatial arrangement suggest these are vehicle shelters. Therefore, PH-0003 can be interpreted as a support facility for the nearby trench complex PH-0001 with provision for vehicle and possibly also logistics storage.

Given the state of development of these positions, as well as their position astride one of the main E-W communication routes, it can be suggested that the fortified positions documented here belong to the so-called 'Stein Stellung' – one of several lines built by AOK 9 in the depth of its defensive sector against penetrations of armoured columns. Although the existence of these ancillary defensive positions has been historically documented, their exact locations and character remain elusive (see Stich 2018).

#### *Panzergranadier Assembly Areas*

Extending over an area of c.4 km<sup>2</sup>, the second group of features presents a larger and more dispersed position that is developed within woodland along the Großer Trepliner Lake and its deeply incised valley (**Fig. 20**). Its most distinctive feature is an array of at least 114 rectilinear features, arranged along a series of forest tracks in the typical herringbone pattern associated with vehicle shelters, along with a large number of earthworks of varying size and planform shape. The vehicle shelters are arranged in about six distinct clusters (PH-0004 – PH-0009), potentially indicating a distribution by differing units. Individual features survive with relatively shallow depths (**Fig. 21**), and with dimensions ranging between 8-24 m they include some unusually large examples by comparison with other features documented at Petershagen or in Normandy (**Fig. 11**). This might indicate that these larger features housed more than one vehicle.

Also present in the area are several small stretches of discontinuous zig-zag trenches that are located respectively on the western crest of the valley astride the Frankfurt-Müncheberg road, and also along the east-facing woodland margin overlooking open

fields and the village of Treplin. This latter cluster of trenches is associated with numerous large and partially-embanked rectilinear/sub-circular features, potentially functioning as gun pits for artillery.

At this early stage of the research, however, the great majority of features in this area cannot be formally classified in terms of their function. These present a wide variety of rectilinear, circular or sub-circular earthworks (many with full or partial embankments) with measurements ranging between 3-13 m. Although a logistics function for at least some of these features cannot be discounted, there is little evidence here for the regular planform configuration or regular spacing of bunkers characteristic of formal, well-planned Wehrmacht army-level or even division-level munitions and fuel depots (Passmore et al. 2017). Numerous relatively large rectilinear and sub-circular features arranged along or behind the trench lines on the eastern tree-line are likely to have functioned as gun positions, and at least three clusters of well-spaced and embanked rectilinear, complex or L-shaped earthworks in the central part of the assemblage can tentatively be interpreted as artillery or flak positions. The remaining, and by far the majority of dugout features identified here are likely to have functioned as shelter for troops, equipment and stores, and other military facilities.

In summary, and with the exception of some clear tactical defensive positions in east-facing localities, the composition and geographical arrangement of earthwork features here presents a marked contrast to that of the 'Stein Stellung,' suggesting a landscape associated with an assembly area for a (partially) motorised Wehrmacht unit.

On present evidence, the most likely formation to have been located here is the *Panzergranadierdivision Kurmark*. After having been deployed in early 1945, the division was hastily thrown into combat in February and March 1945 where it

participated in the fight to contain the Soviet bridgeheads, engaging in several failed attempts to recapture the Reitweiner Sporn. As is clearly documented by a series of situation maps issued by *Heeresgruppe Weichsel* between 27 February and 30 March, *Kurmark* occupied positions on the western shoulder of the Reitweiner Sporn,<sup>10</sup> before being moved into reserve positions at Petershagen around 31 March.<sup>11</sup> On 17 March *Kurmark* had about 30 tanks and 15 tank destroyers at its disposal, along with 13

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10 'Karta polozheniia voisk gruppy armii «Visla», ot 30 marta 1945g., k iskhodu dnia. M 1:300.000.' [Lagekarte der Heeresgruppe "Weichsel", Stand 30. März 1945, abends, M 1:300.000] [Situation map of Army Group Weichsel on 30 March 1945, scale 1:300.000]. Berlin. 30 March 1945. Fond 500, Opus 12467, Delo 47. Rossiisko-Germanskii Proekt Po Otsifrovke Germanskikh Dokumentov v Arkhivakh Rossiiskoï Federatsii [Deutsch-Russisches Projekt zur Digitalisierung Deutscher Dokumente in Archiven der Russischen Föderation] [Russian-German Project for the Digitisation of German Documents in Archives of the Russian Federation.] <https://wwii.germandocsinrussia.org/de/nodes/1792-akte-47-lagekarte-der-heeresgruppe-weichsel-stand-30-m-rz-1945-abends-m-1-300-000#page/1/mode/grid/zoom/1>

11 'Karta polozheniia voisk gruppy armii «Visla», ot 31 marta 1945g., k iskhodu dnia. M 1:300.000.' [Lagekarte der Heeresgruppe "Weichsel", Stand 31. März 1945, abends, M 1:300.000] [Situation map of Army Group Weichsel on 31 March 1945, scale 1:300.000]. Berlin. 31 March 1945. Fond 500, Opus 12467, Delo 49. Rossiisko-Germanskii Proekt Po Otsifrovke Germanskikh Dokumentov v Arkhivakh Rossiiskoï Federatsii [Deutsch-Russisches Projekt zur Digitalisierung Deutscher Dokumente in Archiven der Russischen Föderation] [Russian-German Project for the Digitisation of German Documents in Archives of the Russian Federation.] <https://wwii.germandocsinrussia.org/de/nodes/1794-akte-49-lagekarte-der-heeresgruppe-weichsel-stand-31-m-rz-1945-abends-m-1-300-000#page/1/mode/grid/zoom/1>

motorised 7.5 cm anti-tank guns, both towed and self-propelled.<sup>12</sup> Shortly before the start of the offensive, on 13 April, the division is recorded to dispose of a total of about 63 AFVs (both tanks and assault guns).<sup>13</sup> Although neither self-propelled nor towed

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12 'Dokumenty operativnogo otdela komandovaniia gruppy armii «Visla»: skhema pridannykh podrazdelenii i boevykh grupp gruppy armii «Visla» - po sostoiianiiu na 01.04.1945 g. (boevoi sostav na 17.03.1945 g.)' [Unterlagen der Ia-Abteilung des Oberkommandos der Heeresgruppe Weichsel: Schema der Unterstellungen und Kampfgruppen der Heeresgruppe Weichsel – Stand 1.4.1945 (Kampfstärken vom 17.3.1945)] [Documents of the Ia-Section of Headquarters of Army Group Vistula: Schedule of Units of Army Group Vistula on 1 April 1945 (Combat Strength as of 17 March 1945)]. Berlin. 01 April 1945. Fond. 500, Opus 12467, Delo 7. Rossiisko-Germanskiĭ Proekt Po Otsifrovke Germanskikh Dokumentov v Arkhivakh Rossiiskoĭ Federatsii [Deutsch-Russisches Projekt zur Digitalisierung Deutscher Dokumente in Archiven der Russischen Föderation].

<https://wwii.germandocsinrussia.org/de/nodes/15728-akte-7-unterlagen-der-ia-abteilung-des-oberkommandos-der-heeresgruppe-weichsel-schema-der-unterstellungen-und-kampfgruppen-der-heeresgruppe-weichsel-stand-1-4-1945-kampfst-rken-vom-17-3-1945#page/1/mode/grid/zoom/1>

13 'Donesenie Glavnogo komandovaniia gruppy armii «Visla» o nalichii tankov i shturmovykh orudii na 13.04.1945g.' [Meldung des Oberkommandos der Heeresgruppe Weichsel über den Bestand an Panzern und Sturmgeschützen am 13.04.1945] [Report of Headquarters of Army Group Vistula on Inventory of Tanks and Assault Guns on 13 April 1945]. Berlin. 13 April 1945. Fond 500, Opus 12467, Delo 8. Rossiisko-Germanskiĭ Proekt Po Otsifrovke Germanskikh Dokumentov v Arkhivakh Rossiiskoĭ Federatsii [Deutsch-Russisches Projekt zur Digitalisierung Deutscher Dokumente in Archiven der Russischen Föderation].

<https://wwii.germandocsinrussia.org/de/nodes/1753-akte-8-meldung-des-oberkommandos-der-heeresgruppe-weichsel-ber-den-bestand-an-panzern-und-st#page/1/mode/grid/zoom/1>

artillery is mentioned within the latter schedule, it is conceivable that these continued to be part of the division's combat establishment.

In summary, the evidence available so far strongly suggests that the Petershagen earthwork features are associated with the presence of the *Kurmark* division in this area, which used these sheltered forest positions as a staging and replenishment area between periods of combat action. While the numerous vehicle shelters identified in the area attest to the presence of significant numbers of AFVs, motorised artillery, and supply vehicles, it is also possible that elements of the division were occupying the defensive positions observed within the area. However, the presence of other units cannot be completely discounted at the moment, nor can the possibility be dismissed that the trench lines and firing positions observed belong to a different (potentially earlier) stage of defensive construction in the area.

## **Discussion and Conclusions**

Airborne Laser-Scanning data constitutes an important means through which large stretches of landscape can be archaeologically surveyed at a high speed and low cost. This is particularly true for the archaeological study of 20th century conflict landscapes, given the oftentimes extensive geographical spaces and vast amounts of material remains involved. This can even be achieved through the application of freely-available general-purpose DTMs which, despite their obvious deficiencies in terms of ground resolution and control over data acquisition procedures, provide a valuable source of information on a scale that would be difficult to achieve through other means.

This trend is clearly reflected in the Seelow battlefield. Within an area totalling some 6000 km<sup>2</sup>, at least 158 km<sup>2</sup> provide likely evidence for military or military-related activity, while the 2,515 individual features mapped in detail clearly illustrate the scale

and intensity of combat operations, as well as the degree of preparation and logistics support required by the two combatting forces. In this regard, the combination of ALS data with documentary evidence – especially field manuals, regulations, and maps – has proven a particularly fruitful avenue of inquiry, with historical information proving invaluable in interpreting the spatial patterning of features observed in the data.

Unlike the well-known fixed defensive fortification systems like the West Wall (e.g., Kieser 2010; Wegener 2001, 2006a, 2006b; Wijnands 2011, 2012) and in contrast to many other documented WWII battlefields (Passmore, Harrison, and Capps-Tunwell 2014; Steele, Schwickert, and Rass 2021; van der Schriek 2020a, 2020b) which – owing to the generally mobile character of modern warfare – provide only scant evidence for non-hardened (earthwork) structures, the militarised landscape of the Seelow battlefield is replete with military remains of all types, including fighting positions, command posts, staging areas, and logistics facilities, among others. As such, these remains occupy a unique position within WWII conflict archaeology, arguably constituting the most well-developed and best-preserved instance yet documented within Western Europe of extensive systems of military earthworks – both offensive and defensive in character.

Given the battle's unique historical circumstances, with hundreds of thousands of soldiers and their *matériel* compressed into a relatively small space, the Seelow battlefield provides a unique opportunity to simultaneously study (i) one of the Wehrmacht's largest static, non-hardened defensive systems of the war, (ii) preparations undertaken by the Red Army in the run-up to the actual offensive, (iii) the supply infrastructure of two combatting forces as well as (iv) the non-combat-related military appropriation of the landscape, both as an element of and in relation to the battlefield space as a whole. Moving beyond the purview of traditional battlefield archaeology, the

presence of both combat- and non-combat-related military structures means that the region constitutes a unique study area in which various aspects of a heavily militarised landscape can be documented, analysed, and linked to a wider range of WWII-related remains. Together with the numerous examples of internment and concentration camps documented across Brandenburg (e.g., Andersen and Kersting 2014; Antkowiak 2002, 2003; Antkowiak and Völker 2001; Drieschner and Schulz 2002; Frank and Kersting 2012; Kersting 2020a, 2020b; Kersting and Theune 2020; Sommerfeld, Haubold-Stolle, and Kersting 2020; Trenner 2015) the results presented here significantly contribute to a more complete and complex understanding of an extensive 20th century conflict landscape.

Finally, this study highlights limitations within the currently available data. Although detailed mapping in the two study areas has sought to identify features of military origin within the size limitations defined by ALS resolution, a particular challenge is recognised in differentiating military earthworks within areas potentially impacted by quarrying or similar activities, possibly leading to a misrepresentation of elements of the military landscape. Similarly, it is highly likely that cratering is significantly underrepresented in this study on account of difficulties in differentiating these features from small circular earthworks or natural features, such as tree throw.

Identification and documentation of earthwork features is largely confined to areas where woodland cover has precluded extensive post-war development, preventing the levelling and destruction of archaeological remains. Historical documentation, however, is unambiguous regarding the heavy impact of military activity within the Oder floodplain, suggesting that significant portions of the military landscape remain undetectable through ALS. This is most cogently demonstrated by an analysis of contemporary aerial photographs, which clearly attest to the scale of military activity in

both floodplain and urban contexts, both of which are not amenable to ALS-based research.

This highlights the need for further research. On the one hand, additional archival resources need to be integrated into the analysis, especially contemporary aerial photographs. Taken by the thousands by the Red Army alone (see Soviet General Staff 2016), they will not just aid in the refinement of ALS feature interpretations, but also help to extend mapping operations into non-forested, agricultural areas of the battlefield. In addition, the acquisition of high-resolution ALS data specifically collected for archaeological purposes will mitigate many of the issues observed in the currently available data and help to resolve some of the interpretive issues encountered. Finally, geophysical prospection will provide an avenue to document sub-surface remains and comprehensively assess the level of archaeological preservation across different topographical and geological zones.

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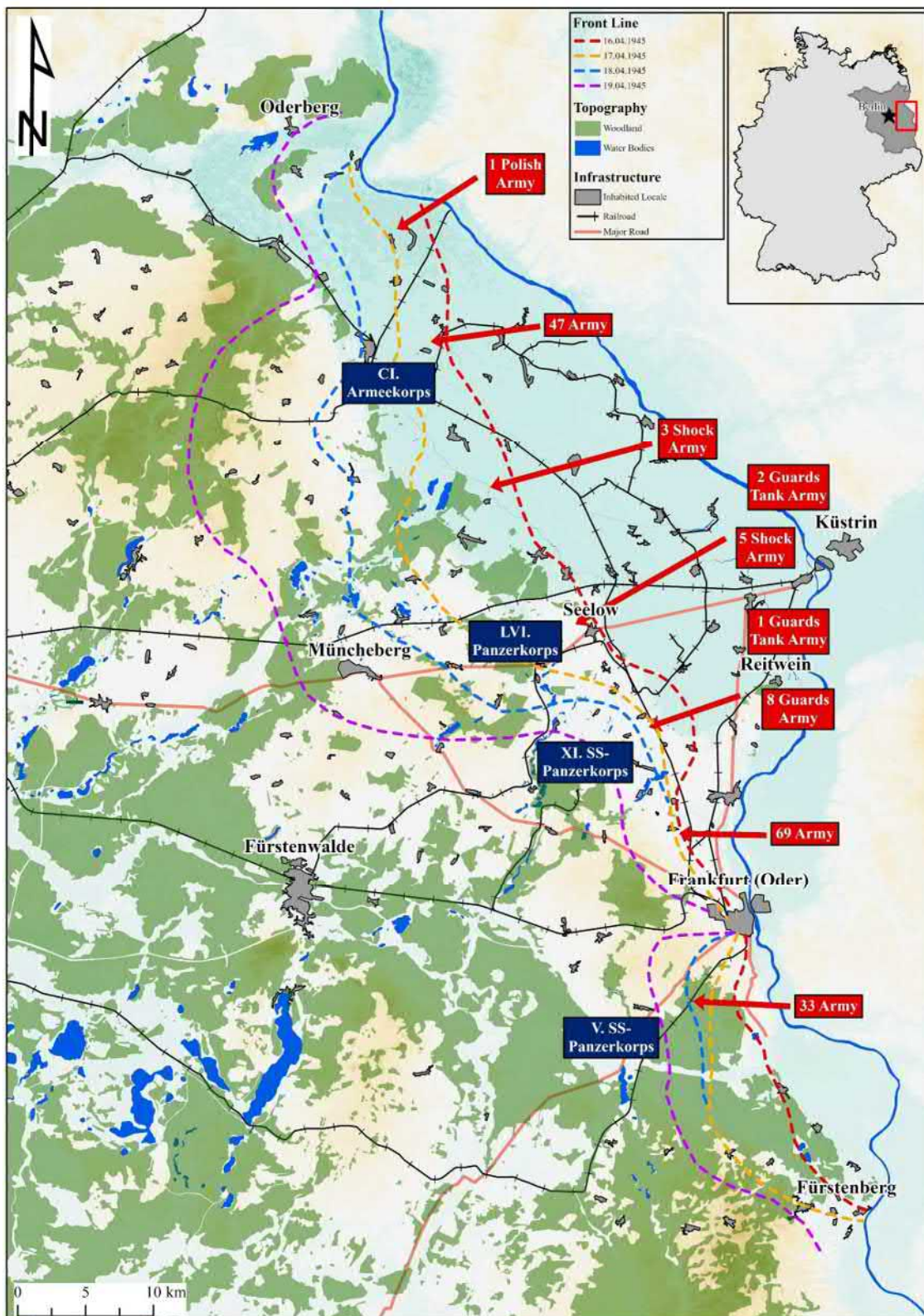


Fig. 1: The Battlefield of the Seelow Heights, Sector of *1 Belorussian Front*.

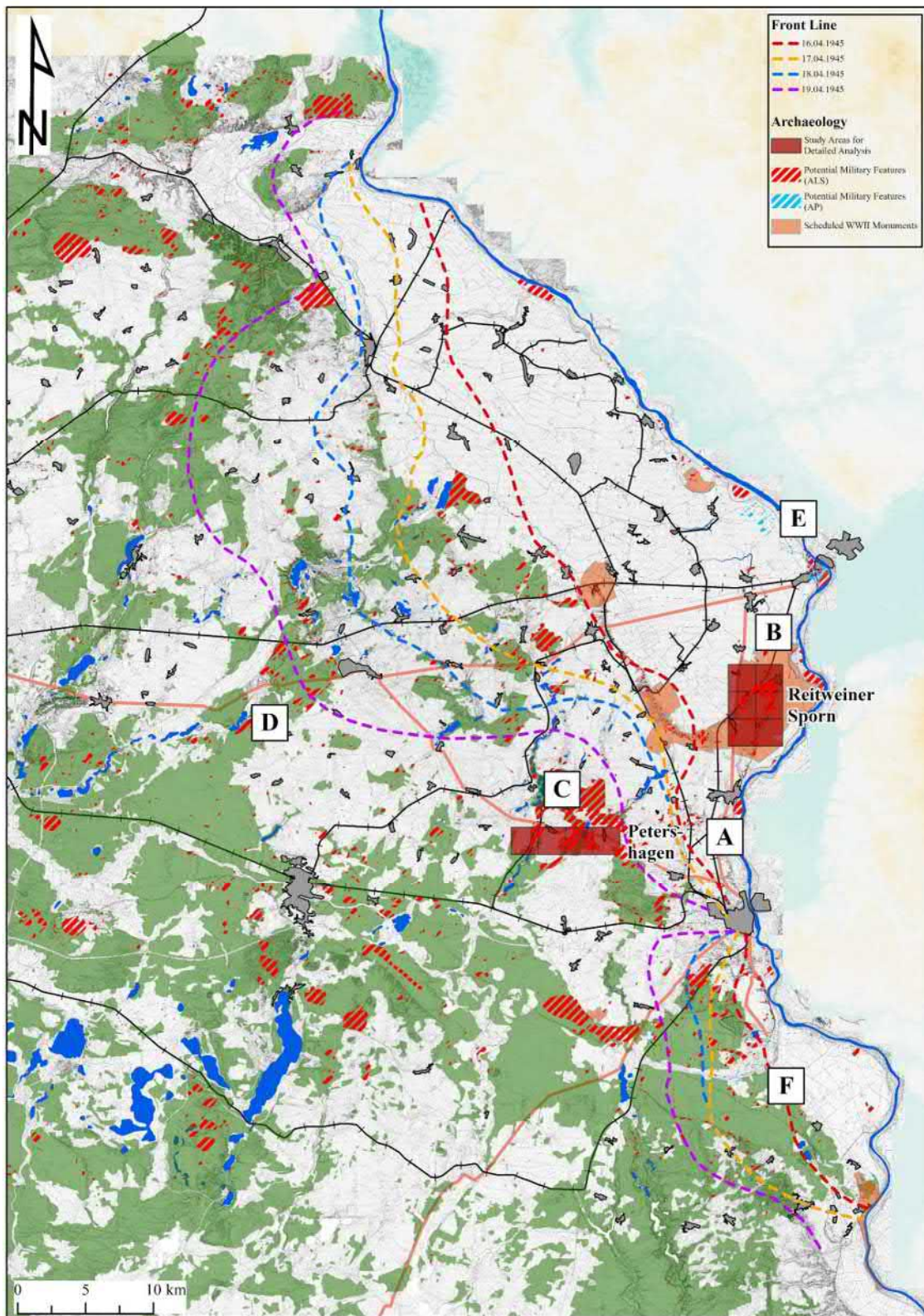


Fig. 2: Available ALS data and documented areas of feature survival on the Seelow battlefield. Locations of Fig. 3 close-ups indicated. Base Data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.

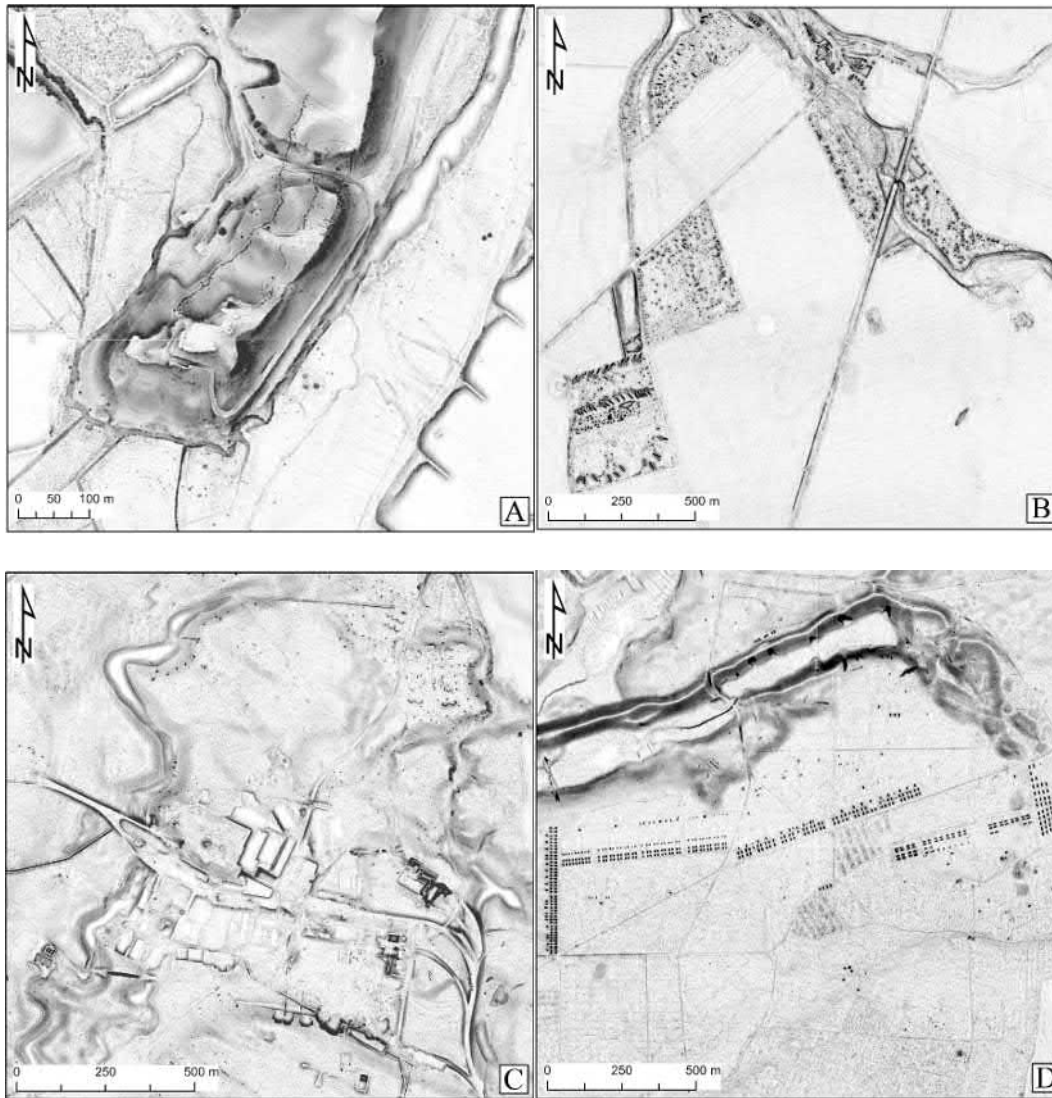


Fig. 3a: Trenches, field fortifications and shell cratering near Wüste Kunersdorf. Base Data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.

Fig. 3b: Potential logistics facilities in the Oderbruch near Neu-Manschnow. Base Data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.

Fig. 3c: Falkenhagen “Seewerk” chemical weapons research and production facility. Base Data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.

Fig. 3d: Red Army forest encampments near Müncheberg. Base data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.



Fig. 3e: Trenches and combat positions in the Oderbruch floodplain near Bleyen-Genschmar. Base Data: NARA RG 373, Spot Number D9920, Sortie US7-57D, Exposure 3107.

Fig. 3f: Trenches and combat positions in an urban environment at Wiesenau. Base Data: NARA RG 373, Spot Number D9920, Sortie US7-57D, Exposure 3077.

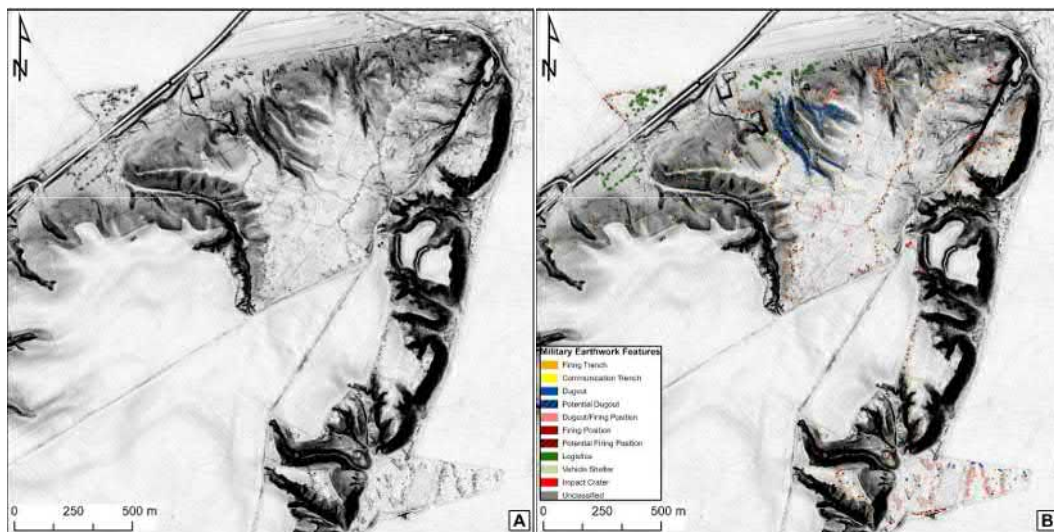


Fig. 4: Earthwork features on the Reitweiner Sporn. (a) uninterpreted ALS image; (b) proposed functional interpretation. Base data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.



Fig. 5: Remains of trenches on the Reitweiner Sporn. (a) communication trench running uphill from the valley floor in 2021; (b) heavily eroded trenches of strong point position in 2021. © The authors.

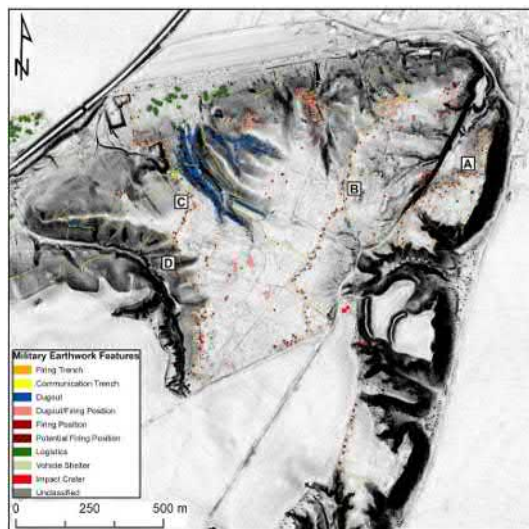


Fig. 6: Earthwork features on the Reitweiner Sporn. Successive trench lines indicated. Base data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.

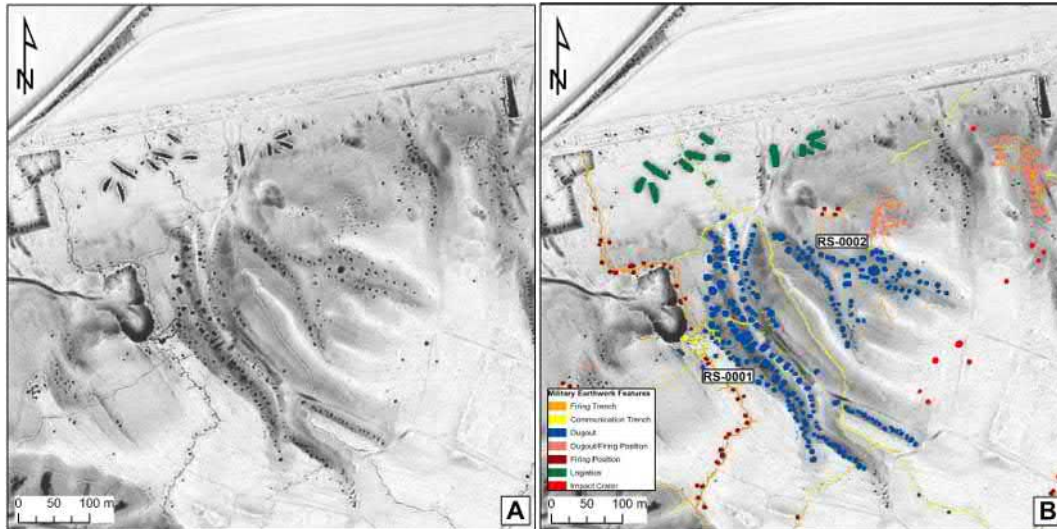


Fig. 7: Red Army dugouts on southwestern edge of Reitweiner Sporn. (a) uninterpreted ALS image; (b) proposed functional interpretation. Base data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.



Fig. 8: Remains of Red Army dugouts on Reitweiner Sporn. (a) view of the area in 1993, © Gedenkstätte Seelower Höhen; (b) single dugout in 2021, © The authors.

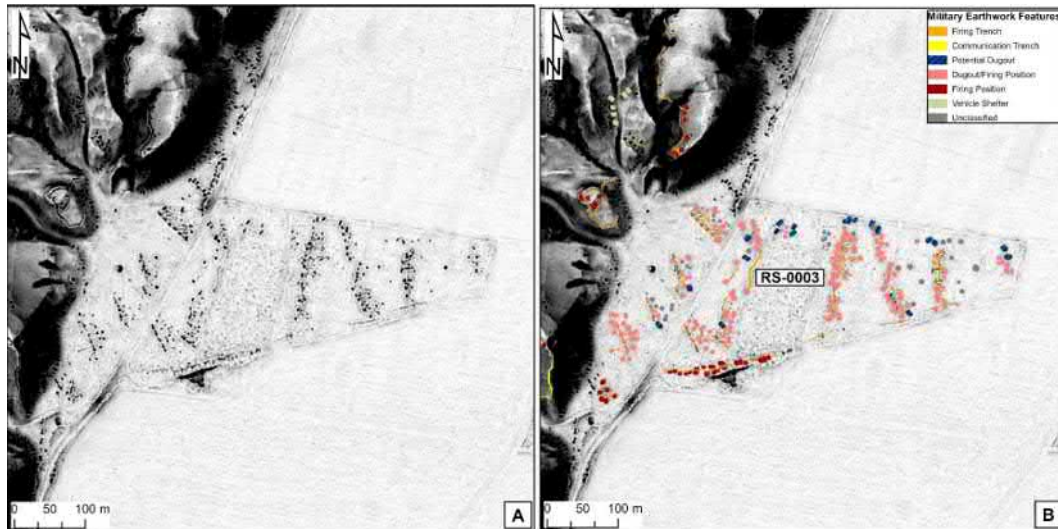


Fig. 9: Red Army mortar positions on E foot of Reitweiner Sporn. (a) uninterpreted ALS image; (b) proposed functional interpretation. Base data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.



Fig. 10: Remains of likely Red Army mortar positions in 2021, © The authors.

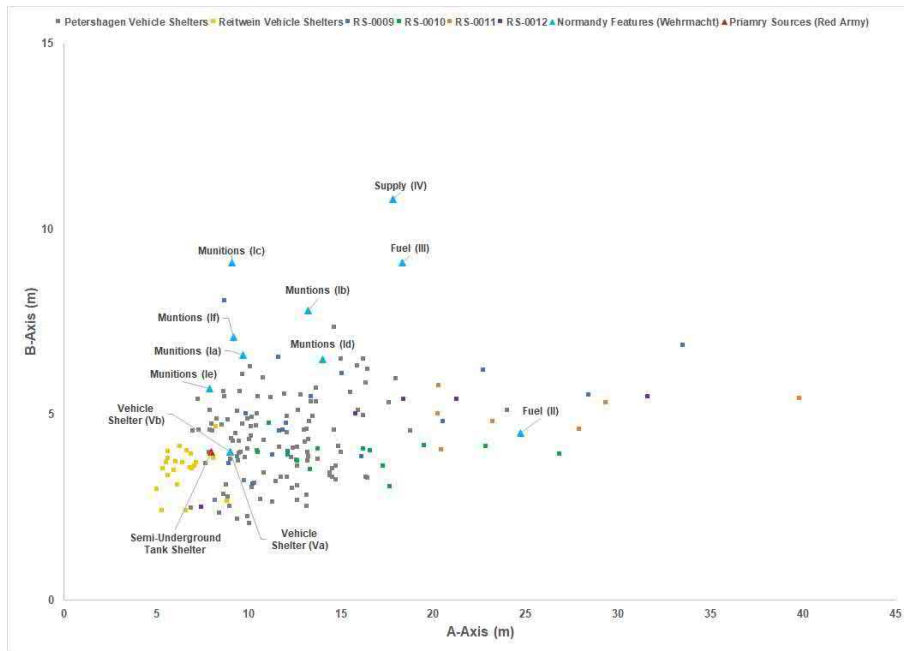


Fig. 11: Plot of A/B-axis measurements for vehicle shelters and potential logistics facilities.

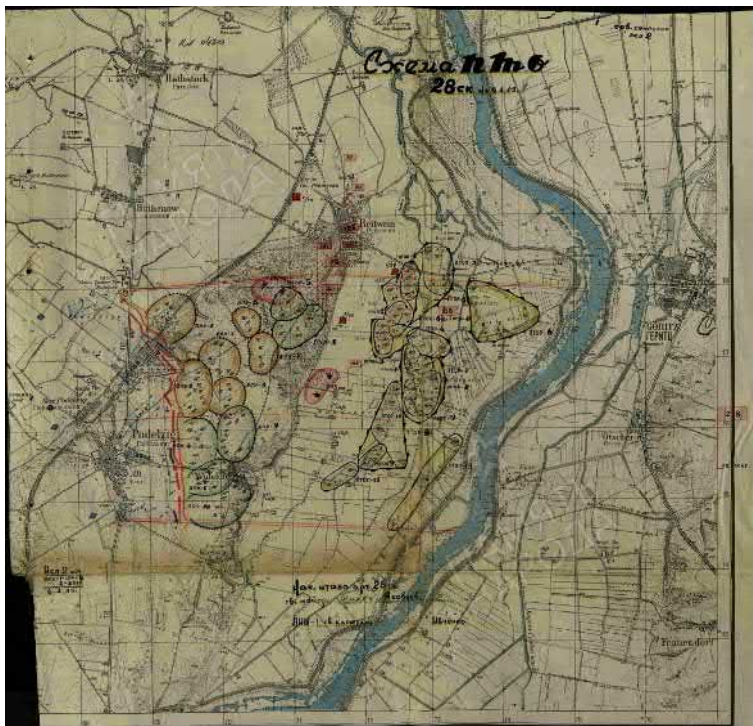


Fig. 12: Map of PTO (Anti-Tank Defence) Scheme of 28 *Guards Rifle Corps*, 6 April 1945. Base data © Ministry of Defence of the Russian Federation (Министерство обороны Российской Федерации).



Fig. 13: Remains of 8 *Guards Army* observation post on Reitweiner Sporn. (a) view of the observation post in 1993, © Gedenkstätte Seelower Höhen; (b) same area in 2021, © The authors.

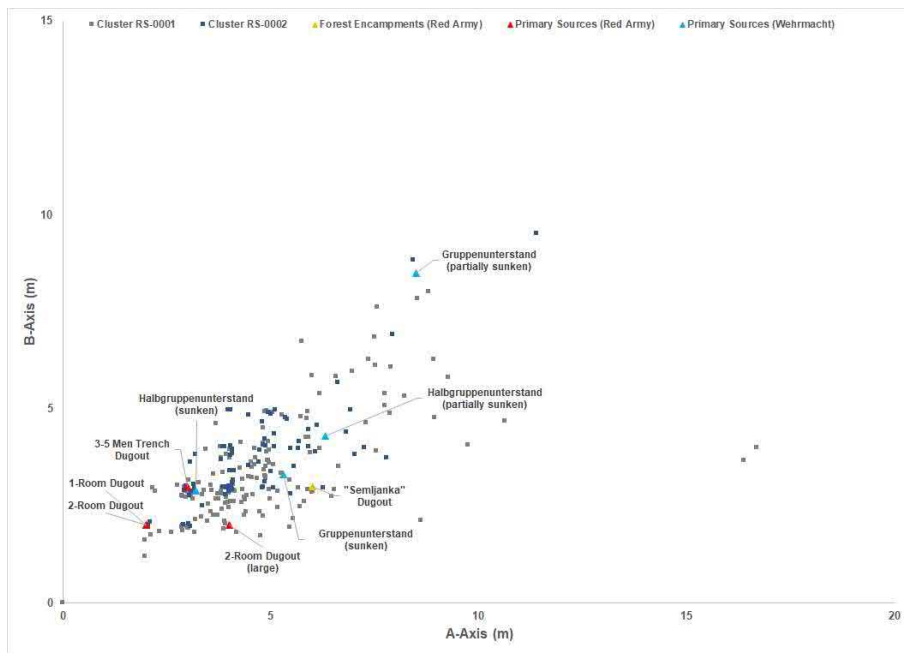


Fig. 14: Plot of A/B-axis measurements for dugouts.

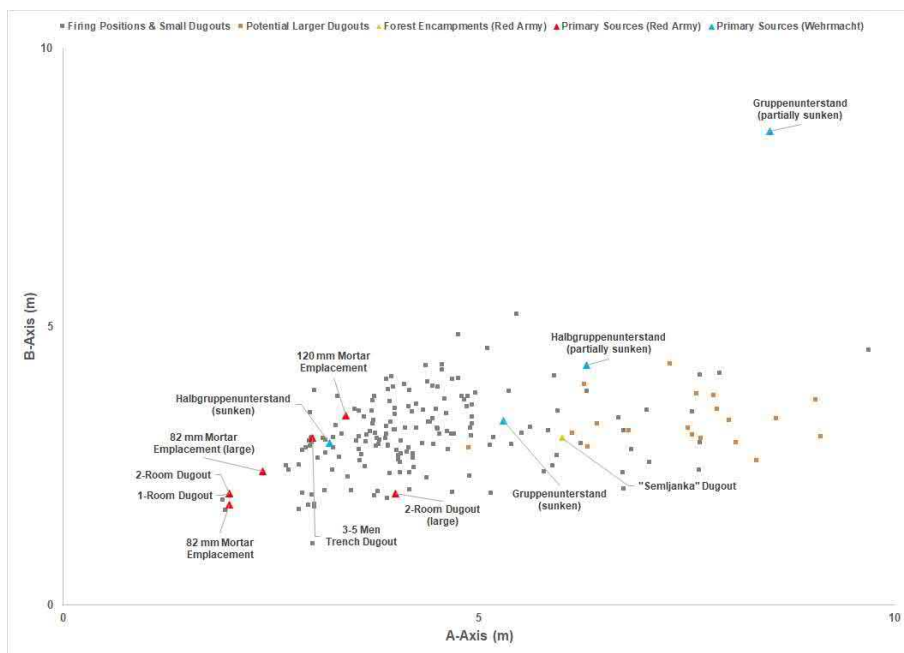


Fig. 15: Plot of A/B-axis measurements for firing positions/dugouts.

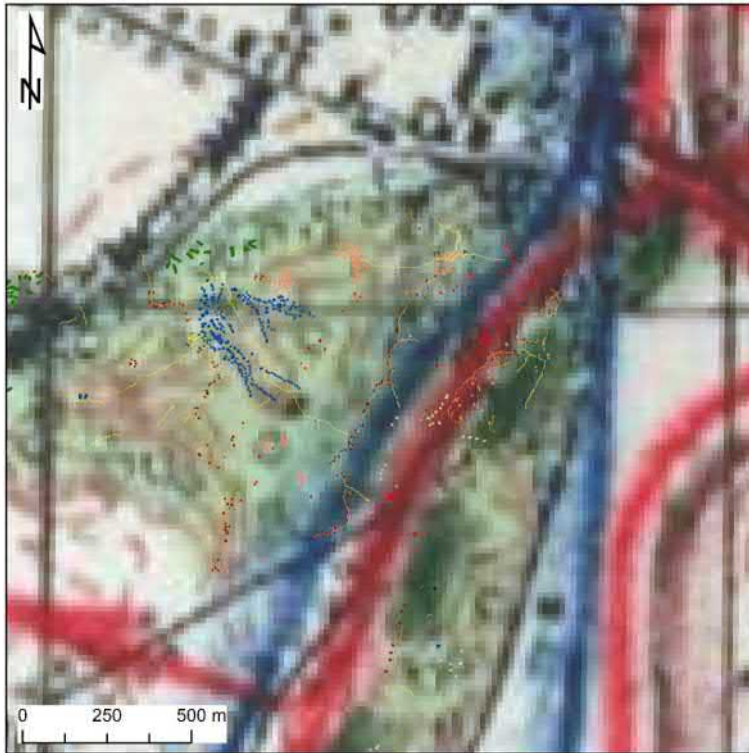


Fig. 16: Digitised military earthwork features on the Reitweiner Sporn overlaid over Red Army situation map of *1 Belorussian Front*, 5 February 1945. Base data © Ministry of Defence of the Russian Federation (Министерство обороны Российской Федерации).

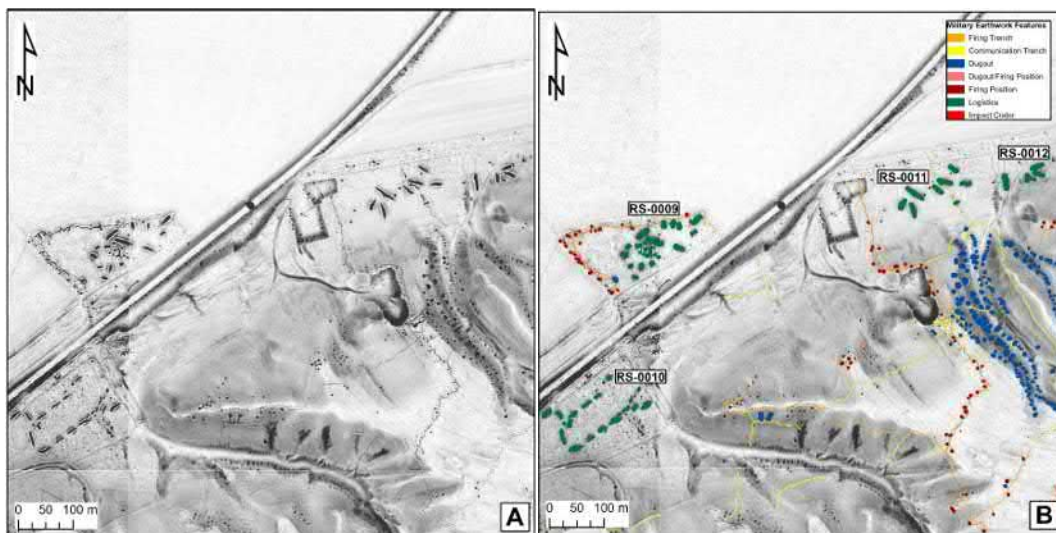


Fig. 17: Red Army logistics facilities at northwestern foot of Reitweiner Sporn. (a) uninterpreted ALS image; (b) proposed functional interpretation. Base data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.



Fig. 18: Remains of Red Army logistics facilities. (a) view of area in 1993, © Gedenkstätte Seelower Höhen; (b) view of area in 2021, © The authors; (c) view of feature from top of embankment in 2021, © The authors, (d) close-up of recess on side of same feature, © The authors.

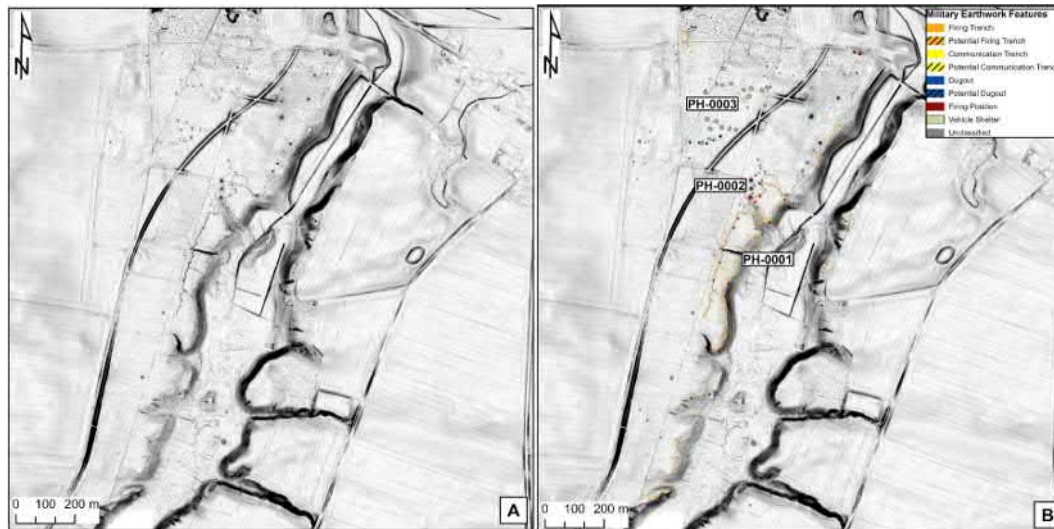


Fig. 19: Wehrmacht field fortifications west of Petershagen. (a) uninterpreted ALS image; (b) proposed functional interpretation. Base data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.

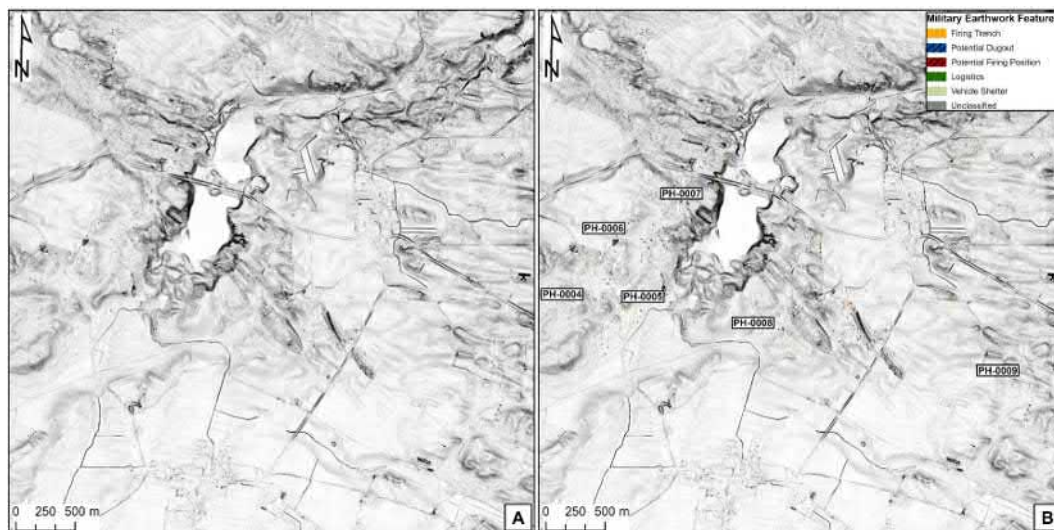


Fig. 20: Wehrmacht vehicle shelters and field fortifications east of Petershagen. (a) uninterpreted ALS image; (b) proposed functional interpretation. Base data © “GeoBasis-DE/LGB, dl-de/by-2-0, (modified)”, SVF visualisation.



Fig. 21: Remains of Wehrmacht vehicle shelters in Petershagen area in 2021, © The authors.