

WWII Conflict Archaeology in the Forêt Domaniale des Andaines, NW France.

Volume 1 of 1

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Abstract

This thesis integrates archaeological survey, aerial photographs and historical documents to undertake the first analysis of the conflict landscapes and military history of some of the most important German logistics facilities in northern France during the Battle of Normandy in 1944. Post-war survival of features has been remarkably good in this forested setting and this likely constitutes one of the best-preserved and most extensive examples of a non-hardened WWII archaeological landscape yet documented in northwest Europe. Over 900 discrete archaeological earthworks have been mapped and interpreted with the aid of primary source material from both Allied and German archives to characterise munitions, fuel and rations depots in the Forêt Domaniale des Andaines around Bagnoles-de-l'Orne, Orne Département, Basse-Normandie. These landscapes also preserve bomb craters associated with air raids on the facilities by the US Ninth Air Force and these have been mapped and analysed to show that despite 46 separate attacks by over 1000 aircraft, and the dropping in excess of 1100 tons of bombs in the forest during the spring and summer of 1944, the depots continued to function and to support German Army operations until the area was occupied by American forces in August 1944. In some areas of the forest it has been possible to link discrete arrays of bomb craters to individual air raids and even specific flights of aircraft.

This work is yielding new perspectives on the character and operation of fixed depots in the German logistics system in Normandy both before and during the battles of 1944, while also permitting a detailed analysis of the effectiveness of Allied intelligence gathering, targeting and bombing operations against forest-based supply facilities. In doing so it is making a unique contribution to the newly-emerging record of WWII conflict archaeology to be found in the forests of northwest Europe.

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Authors Declaration and Statement.

Unless otherwise stated this PhD by publication is entirely the work of the author. This work is based upon 6 accepted/published papers and an outreach project. The nature and extent of the authors exact contribution to the works is detailed within Chapter 1(Section 5; Paper outlines).

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Chapter 1: Introduction

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1. Introduction

The largest sea-borne military assault in history began on the morning of 6 June 1944, five years after the start of the Second World War (WWII). Operation Overlord, the Allied invasion of mainland Western Europe, was focused on the D-Day beaches along the Normandy coastline west of Caen (Fig.1). The subsequent campaign, commonly known as the Battle of Normandy, succeeded in driving the German Army in retreat over the river Seine and resulted in the capture of Paris on 25 August, and by 31 August the campaign was over. Overlord, and the preceding amphibious (D-Day) assault phase Operation Neptune, were the culmination of a planning and preparation process that had begun in early 1943 and was formalized at the Tehran conference in November 1943 when the Allied leaders of Great Britain (Churchill), America (Roosevelt) and Russia (Stalin) agreed that a new front on the western European mainland would be launched in May 1944. The campaign's success depended not only on overcoming the well-organised German coastal defences and supporting forces, but also the need to support the drive inland. The logistical issues arising from providing such support demanded innovative and sophisticated solutions, including the installation of totally independent, temporary harbour facilities (codenamed Mulberry) in the immediate beach-head invasion area. The surviving Allied documentary record of events catalogues in considerable detail the implementation and conduct of the invasion and its logistics effort and this has greatly informed the historical research and analysis of the Battle of Normandy (e.g. Ruppenthal 1953,1958; Hastings, 1984; Ellis, 1962). Records of the German Army's logistical support in northern France are, by comparison, less readily available and this accounts, at least in part, for the limited number of historical analyses of this aspect of the campaign.

Despite this body of work large gaps remain in our understanding of the ways in which the Battle of Normandy was fought and sustained. One important area is the development of the German Army logistical structure where there is little detailed historical literature and, until recently, none looking at this through the lens of geographical and archaeological research. Logistics are key to an

army's efficient operation since the denial and disruption of supply materials such as fuel, munitions and food severely debilitates its fighting capability (Zetterling, 2000). This aspect of the campaign therefore forms the focus of this research project. Specifically, the work investigates the development of German logistics support in central Normandy, the evidence for this activity in the present landscape and the role played by the American Ninth Airforce (hereafter 9 AF) in attempting to destroy the largest German depot in the battle area. To avoid observation from both French Resistance on the ground and Allied airforces the Germans, wherever possible, made use of the extensive forest cover in many parts of Normandy to help camouflage both fighting units and logistics facilities. One of the largest forested areas that was used by the German Army in Normandy is the Forêt Domaniale des Andaines (hereafter FDA), centered on the spa town of Bagnoles de l'Orne in Lower Normandy, France (Fig. 1). Situated 80-95 km south of the Allied landing beaches, 68 km from the important historical transportation hub of Caen and c.38km west of Alençon, the forest lies on an east to west axis and consists of 55 km² of mixed woodland. Today the FDA is an important recreational and wildlife resource for the Normandie-Maine Regional Natural Park. However, at the start of June 1944 it was the site of the largest grouping of German munitions, fuel and food rations depots in the hinterland of the Allied landing zone.

Figure 1: The Overlord area



This thesis reports the first attempt to combine archaeological survey and historical documentation in order to explore aspects of the German logistics system in the FDA and wider Normandy region, and also the efforts of Allied airforces to destroy them. The main aims of the study are as follows:

1. To evaluate the extent and character of archaeological preservation in the FDA and interpret it in the context of records of German logistics operations and Allied air attacks;
2. To locate logistics landscapes in the FDA in the context of the wider German logistics network and operations in Normandy;
3. To evaluate the effectiveness of Allied intelligence, targeting and bombing tactics employed against German logistics depots in the FDA;.
4. To provide a template for similar projects in other parts of the European Theatre of Operations during WW2.

In the remainder of this chapter I describe the origins and development of the research (Section 2), provide a brief synthesis of the historical literature specific to the Normandy Campaign (with a particular focus on logistics) and the broader disciplinary context of conflict archaeology (Section 3), and review the methods and archival sources used (Section 4). There follows a summary of the six academic papers that constitute the published academic output, together with an account of how this work has prompted and informed the development of a heritage trail in the FDA (Section 5). Finally, Section 6 provides a brief overview of the work to date and outlines a number of emerging research agendas.

2. Origins and development of the research

At a height of over 2.5 meters, horseback provides a good vantage point for observing archaeological features in the landscape. During a hack in the FDA in the winter of 2004 I was interested to see craters in the forest floor (Fig. 2).

Later, again from horseback, it became clear that the area had been attacked



Figure 2. Multiple bomb craters in the Forêt Domaniale des Andaines (Photo: Author, 29 March 2014)

in a number of other locations and that some parts of the forest featured well-preserved earthworks. Having a military engineering background I have an appreciation of military operations in the field and the presence of military artifacts, including the partial remains of 200 litre fuel drums (identifiable as German by lettering and date markings) indicating that the forest had been used to store German fuel supplies. Clusters of earthworks elsewhere in the forest were associated with ruptured shell casings, shrapnel fragments and burst shells. I was surprised that there was such a level of evidence surviving considering the temporary nature of earthworks that were created 70 years ago (Fig. 3). In conversations with neighbours I was told that the FDA had been repeatedly attacked by air during the summer of 1944. During 2006, using the website of the Institute Geographic National (IGN), I inspected aerial photographs from 1949 that confirmed my initial research and identified a number of other locations in the forest where military-type earthworks and

crater sites were found to survive. On horseback and on foot it was possible to determine an approximate scale of the depots. Bunkers constructed of earth are visible along forest tracks and roads for a total of c.19km.



Figure 3: Earthwork associated with fuel storage in the Forêt Domaniale des Andaines (Photo: Author, 29 March 2014)

Yet, and despite Bagnoles de l'Orne being a major tourism centre with a dedicated visitor centre, there is currently no available information on the military features in the forest or local guides. Further afield, English language battlefield guides on Normandy (e.g. Holt and Holt, 2014) tend to focus upon the landing beaches of D-Day. There are significantly fewer guides available on the inland battlefields, including for example Sutton Publishing's series edited by Trew (2004) and Joyce (1999), but these do not mention the presence of bomb craters or German supply related features.

Rather more information on the FDA in WWII is available in the regional French

popular media and historical literature, although the former tend to focus on post-war munitions recovery within the forest. However, local historian Alain Hairie has published a number of booklets documenting eye-witness statements of the German occupation in the locality (e.g. Hairie, 2007), and these provide anecdotal insights into the local perception of events after 60 years and make specific mention of a number of logistics depot sites within the forest. Hairie (2007) also draws on the wartime activities of Rougeyron, a member of an Escape and Evasion network and whose Resistance work was located in the area around the forest. Elsewhere in Normandy André Laroze (2004) has written about the Forest of St Sever du Calvados in WWII which was the site of a German munitions depot (codenamed Lager Michel). This site benefits from the provision of several tourist information boards which give some interpretation of the surviving earthworks and the munitions depot operations. Some French academic sources also point to the existence of German supply depots in the FDA, most notably the accounts of intelligence gathering by Resistance operations described by Robine (2004, 2005).

US military archives also proved to be a particularly useful source of information during the early stages of the research. American History documents hosted online at Fold3 (www.fold3.com) provided access to the Foreign Military Studies program and in particular the debriefing records of Colonel Eckstein, the German Officer responsible for logistics to the end of June 1944 in France (Eckstein, 1947). The American Airforce's Historical Research Agency's history of the US 9 AF (written in 1945) presents a day-by-day chronology of events over the whole of the European Theatre of Operations (ETO) giving locations of the majority of air attacks in relation to the campaign. Other specific enquiries were made to both the National Archive Research Agency in Maryland, USA, in order to determine American troop movements in the area, and the American Combined Arms Research Library (CARL) at Fort Leavenworth, which provided a copy of the chronology of events for August 1944. Online sites dedicated to aspects of the US air war, including B26.com (www.b26.com) and 416th.com (www.416th.com) also provided illuminating information on aspects of the bombing campaign.

Using a number of sources, and in particular the German 7th Army logistics diaries from the start of April 1943 to the end of June 1944, it was possible to develop an appreciation of German supply operations in the run-up to the invasion of Normandy and the subsequent campaign. In general, however, it was evident at an early stage in the research that there was comparatively little written about the FDA and logistics operations in the academic literature. Only Hart (1996, 2001) provides a dedicated description and analysis of German logistic operations in Normandy 1944, while Ehlers Jr. (2009) also evaluates the impact of Allied bombing on the transport of supplies into and within Normandy. However, neither makes specific mention of the FDA.

In 2011, I had a chance meeting with Drs Stephan Harrison and David Passmore who were seeking to develop their work on WWII field fortifications in forested landscapes (Passmore and Harrison, 2008). We visited a number of sites within the forest and over the following months we initiated a research collaboration that enabled me to formalize my interests into a study that aimed to contribute to military history, conflict archaeology and the regional heritage.

3. WWII logistics in the Normandy landscape - a literature review

The following review is divided into two parts. The first provides a review of official and academic historical literature spanning the D-Day landings and the Battle of Normandy and focuses in particular on the Allied air campaign and German logistics operations. The second section locates the research within the context of the conflict archaeology literature, with particular reference to studies of WWII landscapes.

3.1 A brief history of the Normandy campaign

3.1.1. Introduction

Much has been written about the Allied preparations for the invasion of Normandy in the summer of 1944. Official histories provide formal accounts of

events from the perspective of the Americans (Harrison, 1951), Canadians (Stacey, 1960) and British (Ellis, 1962) and, while no German official history has been published, the edited volumes by Deist et al (e.g. Volume VII, Part II of Germany and the Second World War; 2006) are considered authoritative and the chapters by Vogel (2006) span the German experience in France during 1944. Historians have written many overall accounts of the Battle of Normandy, including those of Keegan (1983), Hastings (1984), Neillands (2002), D'Este (2004) and recently that of Beevor (2014). Specific aspects of the Normandy Campaign have been the focus of numerous studies and from many points of view, including for example Blumenson's (1961) account of the American advance across France and, in contrast, Ludewig's (2012) description of the German retreat from France. However, an area that has received only limited attention in comparison to the main battles is that of the German logistics operations, and especially the development and operation of supply depots. Three exceptions to this discussion are noteworthy; both Zetterling (2000) and Reardon (2012) pay due attention to the role that German logistics played in the campaign, but the works by Hart (1996; 2001) and Ehlers Jr. (2009) provide the most detailed and thorough analyses yet published. Using a wide range of primary source material, both stress how the German supply network deteriorated under the constant pressure exerted upon it by the Allied air offensive.

3.1.2. Background and Preparation for Invasion

Five beach areas were selected for attack and codenamed Utah, Omaha, Gold, Juno and Sword. These beaches were chosen by the Allies for landing troops and equipment based on their physical and sediment characteristics (notably a sandy substrate with a slight incline, enabling vehicles and materials to be unloaded; Davies 1946). Invasion planning anticipated

there would be an immediate need to re-supply manpower, material and fuel after the beach-head was secured in order to both consolidate the position and enable the drive inland. The port of Cherbourg (Fig. 1) was well defended so an alternative had to be found. Two floating pre-fabricated concrete harbours ('Mulberry' harbours) that could be towed into position were manufactured, and

Pipe Line Under The Ocean (PLUTO) would provide the solution to potential fuel shortages. Inland, the marshy area around Carentan (Fig. 1) presented a physical obstacle to the Allied advance south from the beaches. The countryside of the Contentin peninsular forms a generally rolling terrain, with occasional steep valleys and rivers covered with a tightly-knit hedgerow system called the 'bocage' and this favoured the defender. This type of landscape also extends from east of Granville on the west coast toward Falaise, where the land rises to a height of over 300 metres. South of Caen and towards Falaise (Fig. 1) the countryside consists of long rolling open plains, a landscape which was ideal for both tank and anti-tank operations (Davies, 1946).

In November 1943 Hitler ordered the strengthening of defences on the western European coastline. The Allied intention to invade was evident to the Germans in early 1944, but due to Allied deception plans, the location, date and size of attack was not. As a result, throughout early 1944 the German defences, known as the 'Atlantic Wall', continued to be strengthened along the French coastline. Logistical army support in the form of new supply depots and existing stock holdings were increased (Zaloga, 2013). The Germans had initially relied heavily on the ability of the extensive rail-network to supply its units (Eckstein, 1947) and although its vehicular transportation fleet was partially increased in the months prior to the invasion it was insufficient to counter transportation deficiencies and needs, partly due to shortages created by the German Eastern front (Reardon, 2012). There were also shortages of basic items such as tyres (Eckstein, 1947) and ongoing problems with supporting captured equipment which had been pressed into use (Reardon, 2012). In an attempt to alleviate transportation issues new supply depots were established and also de-centralised (Mark, 1994; Hart, 2001). Many of these depots were positioned in forests (Craven and Cates, 1984) to provide camouflage and protection from air attack. Stocks of munitions in depots were increased by 50 percent in the nine months preceding the invasion although this was not matched with an increase in fuel stocks (USA National Archives and Records Administration (NARA) Records Group 242).

For the Allies, experience in Italy following the landings at Anzio in January

1944 demonstrated that the Germans were able to draw rapidly on military reserves far removed from the battlefield by use of the rail network (Ellis, 1962). In order to limit or prevent reinforcement and re-supply during Overlord a set of bombing objectives were identified in what was named the 'Transportation Plan' (Ellis, 1962), and from March 1944 the Allies attacked the communications infrastructure in order to isolate what was to become the battle area (Ehlers Jr., 2009). In conjunction with this plan, Tactical Target Dossiers (TTD) were developed for areas of France that identified targets that could be attacked on an 'as required' basis; these included airfields, radio and radar installations and logistics targets (Kreis, 1996), including supply depots in the FDA. To-date there has been no attempt to undertake a complete synthesis of logistics depots and Allied attempts to destroy them, and thereby assess the effectiveness of this aspect of the Allied aircampaign.

3.1.3. The Landings and Consolidation

On the morning of the 6 June 1944, after a 24hr postponement due to bad weather, Operation Neptune delivered Allied forces to the five D-Day beaches. Airborne troops had been dropped overnight to capture tactical targets such as Pegasus bridge to the NE of Caen and to the west in the area of Saint Mére Eglise to isolate the Contentin peninsula (Fig. 1). By the end of the first day the Allies were firmly ashore having secured all five beachheads. The Allied bombing campaign prior to the invasion and in the days following the landings succeeded in slowing German reinforcements arriving at the front; in the face of Allied tactical air superiority German ground forces were required to move largely by night and to make effective use of camouflage during daylight hours, greatly restricting their freedom of movement (Gooderson, 1998). Furthermore, initial German reactions to the landings were slow and the failure to deploy vital 15th Army reserves from the Pas-de-Calais area (due to Hitler's belief in the Allied deception plan) allowed the Allies to strengthen their foothold ashore before German reinforcements could arrive in strength. The Americans captured Carentan by 11 June and began their advance toward the harbour port of Cherbourg (Fig. 1).

The two floating Mulberry harbours off Omaha and Gold beaches were

positioned and operational soon after D-Day but a storm on 19 June which lasted for four days rendered the American harbour at Omaha unusable (Ruppenthal, 1953) and damaged the British harbour at Gold, underlining the initial fragility of the Allied supply position. Nevertheless, stockpiles of supplies at the beachheads were successfully created to support operations inland throughout the campaign (Ellis, 1962). The German supply situation was different; crippled by air attack and sabotage (Ellis, 1962), only by special ad-hoc measures could a sustainable defence be mounted. Rail links and road bridges had to be repaired, alternative supply routes had to be found and transportation for the most part had to be undertaken at night to minimise the impact of air attack. It was not until late June that this situation was to improve with deliveries of fuel and munitions being re-established from the Paris region towards the front (Hart, 2001). On 22 June the Americans attacked Cherbourg and the city fell on 27 June (although the harbour was not to become fully operational until 21 September, by which time the campaign was over in Normandy; Ruppenthal, 1958). To the east, an initial Allied campaign objective had been the city of Caen, but here German resistance was strong and included high quality armoured units. The British attack in Operation Epsom to the west of the city on 26 June stalled and Caen was captured on 9 July only after an air attack by heavy bombers, (Neillands, 2002). To the west St Lo was captured by the Americans on 18 July (Fig. 1).

3.1.4. Breakout and Pursuit

By 21 July the area to the south and east of Caen was captured in Operation Goodwood and this opened up the line of advance by British, Canadian and Polish forces south to Falaise. Again heavy air bombardment was employed but the depth of the German lines allowed support to be brought up to slow the Allied advance (Gooderson, 2008). In the west, having paused for re-supply after capturing St Lo, the Americans launched their breakout operation (Operation Cobra) on 25 July through German lines that were being held in the well-defended bocage landscape west of St Lo (D'Este, 2004). After a major aerial bombardment, involving both strategic and tactical air forces, a gap was forced open through the German lines allowing American troops to pour southwards through into central Normandy and into Brittany. While Gooderson

(2008) argues that the German lines were not deep or strong enough to resist the weight of the overall US air and ground assault, Hart (2001) has also argued that the success of Cobra also owed much to German logistics shortages following munitions and fuel expenditure during the Goodwood offensive to the west and also by the bombing of railway bridges over the river Loire to the south.

For the Allies re-supply during the initial phases of the campaign was not generally a problem as the lines of supply were short (Ellis, 1962). However, following the breakout operations, ever lengthening lines of supply in late July and into August caused severe shortages and these were especially acute for the rapidly advancing American forces. The French railway network had been effectively dismembered by the Allied bombing campaign and as the Allies moved inland efforts began almost immediately to reconstitute parts of the network (Wolmar, 2010). However, the rail network remained inadequate for immediate needs and so special measures to supply fuel from Normandy to Chartres by dedicated pipelines from Cherbourg to Alençon and, towards the end of the campaign, road convoys (known as the 'Red Ball' express) were put in place to further alleviate the shortages (Ruppenthal, 1953 and 1958). In contrast to the totally mechanised Allied logistics system, German forces were reliant on a degraded transportation fleet (Hart, 1996) which was supplemented by horse-drawn transportation (Eckstein, 1947). At this time German front line units had to collect their own supplies from depots in the rear areas, and as Allied air power eroded transportation resources the ability to re-supply became more difficult. By 17 July the situation had worsened to the extent that supply deliveries to the largest and most forward munitions depot on the western flank within the St Sever forest (Lager Michel) were terminated (Fig. 1). Deliveries were re-channeled to newly set-up and pre-existing depots such as those in the Petite Forêt Domaniale de Gouffern (Lager Mais) and the FDA (Lager Martha) respectively. Lager Michel could still operate as it was not empty, (UK The National Archives (TNA), HW 5 Series files) but it was not being replenished (Hart, 1996). The problem was that munitions had to be obtained from depots further removed from the front by active troops which both increased supply timescales and further exposed valuable transportation

assets (Ehlers Jr., 2009).

On 30 July Montgomery, the Allied operational ground forces commander, hoping to prevent the Germans from concentrating any armour on the American breakout south, launched Operation Bluecoat by attacking on the centre of the Allied front near Caumont. On 6 August, as the Americans drove east capturing Laval, German supply depots became threatened in both the Le Mans and Alençon areas (Blumenson, 1961). In an attempt to cut the American line of advance, the Germans launched their last major counter-offensive in Normandy at Mortain on 7 August. German logistic preparations had ensured that there were few issues with supply in the initial stages of attack, aided greatly by the location of depots in forest locations close to Mortain (Reardon, 2002). There were German concerns, however, with the 'acute threat' presented to the main supply route between Domfront and Alençon (Vogel, 2006). The attack was stopped by both stubborn American resistance on the ground and well-coordinated air to surface support by the Allied airforces.

On 7 August the British, Canadian and Polish forces moved south in Operation Totalize towards Falaise and on 11 August those Germans remaining in the Normandy battle zone retreated into an ever-decreasing pocket with a single exit which became known as the 'Falaise Gap'. The Americans had moved east in a move to advance on Paris and had captured Le Mans. Then, in moving north to Alençon, they had also captured important German depots (Gersdorf, 1949) in the surrounding forests. On the 14 August the FDA was overrun (USA NARA. Records Group 407) and Lager Martha, the largest (UK TNA, HW5 Series of files) and most westerly munitions depot supporting the German 7th Army was in Allied hands. The Allies also launched Operation Tractable moving south on the northern side of the gap. On 20 August the gap had closed at Mont Ormel and those Germans who had not been surrounded conducted a fighting retreat to the River Seine. On 25 August the German commander of Paris (von Choltitz) surrendered to General Leclerc of the Free French Army, while fighting along the River Seine continued until 29 August. By 31 August the Battle of Normandy was over (Neillands, 2002), and the original Allied plan to capture the River Seine area 90 days after landing had been achieved 10 days ahead of the original schedule.

In summary, it is held that the combination of sound leadership, the ability of the Allies to reinforce and supply their forces and air superiority gave the Allies a decisive advantage (Reardon, 2012 and Ellis, 1962). Prior to invasion the enacting of the Transportation Plan had already crippled the German supply network and the net result of this was a severely degraded German ability to conduct a sustainable defence (Eckstein, 1947; Ehlers Jr., 2009). These conclusions are well established and accepted by military professionals, authors and historians alike, and yet there are surprisingly few dedicated studies of the German logistics operation and its evolution over the course of the campaign. With a more informed understanding of German logistics it may be possible to better comprehend how, based on such unfavorable military and strategic odds over a distance of 240 km, between the landing beaches and Paris, with a dwindling support system, the German army managed to conduct a credible fighting retreat.

3.2. Conflict Archaeology and the Normandy Campaign.

In focusing on the archaeology of WWII this project contributes to the developing interest in 20th century conflict archaeology (e.g. Schofield, 2005; Sturdy Colls, 2015) and the broadening of its disciplinary scope from archaeological studies of battlefields (including the pioneering work carried out at the Little Bighorn National Park in the USA; Scott, 2010) to multi-disciplinary analyses of the full range of military activities in the landscape and its implications for our historical and social understanding of events (Schofield et al., 2006; Lynch & Cooksey, 2007). Globally there is an increasing interest in the archaeological legacy of WWII. For example, Pacific islands occupied by the Japanese such as Saipan (McKinnon and Carrell, 2011) and Kiska (Spennemann, 2012) have been the subject of cultural heritage studies and in the northern Australian coastal region the preparation for a potential invasion by the Japanese has been the focus of work carried out by Reeves et al. (2016). A recurring theme in the conflict archaeology of former battlefields of the Pacific theatre is a focus on the rich underwater legacy of sunken ships, aircraft and

equipment (e.g. McKinnon & Carrell, 2011), and the maritime record of WWII conflict has also attracted some interest in European waters (e.g. McCartney, 2015). In general, however, it is the land-based record of warfare that dominates the conflict archaeology of the period in northwest Europe.

Given the massive investment in static defence lines and military support infrastructure on the coastlines of the English Channel and North Sea during WWII, it is perhaps not surprising that many of the associated concrete and brick structures have survived in the modern landscape, and also that they are amongst the most well-documented aspects of the conflict archaeology of this period. Many of the 'Atlantic Wall' defences remain along the coastlines of France, Belgium and Holland (e.g. Zaloga, 2007; 2013), for example, while in Britain the 'Defence of Britain Project' and the English Heritage commissioned thematic characterization of the UK defence heritage has prompted the most comprehensive audit of WWII archaeology in northwest Europe (e.g. Saunders, 1998; Schofield, 1998). Surveys of this type demonstrate the value of establishing not only the geographical disposition of sites but also those features that are characteristic of particular sites or locations (e.g. Osborne, 2004). In northwest Europe and the Nordic countries there is also increasing interest in the archaeological legacy of PoW, concentration and forced labour camps (e.g. Jasinski et al., 2010; Carr, 2010; Early, 2013; Sturdy Colls, 2015).

Archaeological evidence of the preparations made for the invasion of Europe have been well-documented in the UK (Dobinson et al., 1997; Schofield, 2001), including sites associated with the construction of the Mulberry harbours on the South coast of England (Schofield, 2009), the Pipe Line Under The Ocean – PLUTO – (Searle, 2004), D-Day embarkation sites (Schofield, 2009) and munitions depots (Crutchley et al., 2009). In Normandy itself Carpentier and Marcigny (2014) outline how archaeological investigations of military landscapes both above and below sea level are currently contributing not only to the military heritage of the region but are also informing the history of civil and economic aspects of the campaign and the post-war reconstruction efforts (Clout, 2006). In the battlegrounds of Normandy there has been particular interest in the area of the D-Day landing beaches (e.g. Everett et al, 2006;

Udphuay et al, 2011; Carpentier and Marcigny, 2014) and military landscapes in the assault zone (e.g. Gaffney et al., 2004), including sites of extant defence installations (e.g. radar; Ford, 2004) and contemporary infrastructure (e.g. Pegasus Bridge; Clarke, 2004), many of which have been developed as battlefield tourism and commemorative venues. Inland from the beachheads there are numerous airfield and V-weapon sites that still bear the visible scars of conflict (e.g. Passmore et al., 2015), but for the major battlefields themselves it is usually the case that the physical legacy of combat, including non-hardened field fortifications, shell and bomb craters, and battle-damaged infrastructure has been removed or rendered invisible from the ground by the combination of post-war reconstruction, urbanization and agricultural activities (Passmore et al., 2014). For the most part, therefore, the most conspicuous elements of Normandy's inland military landscapes are cemeteries, memorials, museums, and static exhibits of armoured vehicles and weapons that participated in the campaign.

It is clear that the forests of northwest Europe, meanwhile, have remained largely undeveloped as reserves of archaeological information on WWII, yet they conceal a preserved landscape of earthwork field fortifications and other data which provide a rich military heritage and potential source of information (Passmore and Harrison, 2008; Passmore et al., 2014). In Normandy these environments were not the sites of large-scale ground combat and hence do not feature in the region's battlefield guides, yet they did host numerous large- and small-scale German logistics facilities that in turn were frequently the sites of Allied bombing raids. The papers constituting this thesis represent the first attempts to document and interpret the archaeological trace of these events.

4. Methods and record sources

4.1. Introduction

From initially observing features within the forest on horseback, a scaleable multi-disciplinary method has evolved. This has focused on both a non-invasive (walk-over) field survey and desk-top analysis, the latter consisting of an examination of historical documents (primary and secondary), maps and aerial photographs. Initial field observation of the surface archaeology revealed a considerable number of types of features ranging from craters to bunkers of various dimensions. A working typology was developed to record and classify the various types of military earthworks. This typology was subsequently informed by a wide variety of evidential sources. The types of data obtained are detailed in Table 1.

The determination of the accuracy of historical records has been a challenge to both historians and conflict archaeologists (e.g. Spennemann, 2012; Sturdy Colls, 2015). An accepted method employed by both disciplines – and also this study – is that of Source Criticism (Howell and Prevenir, 2001). This method assesses the veracity of records by weighing and measuring the potential reliability of each of the sources and the way in which data has been handled by determining the 'where', 'when', and 'how' and who produced these records.

4.2. Archaeological Survey

Until now no archaeological studies have been made on the German logistics network that existed before and during the Battle of Normandy (Personal communication: S. Quévillon, Direction Regional Affairs Cultural (DRAC) of Normandy 2014). This work is enabling the first formal assessment of the distribution and survival of logistics sites and, with respect to individual sites, the geographical arrangement, typology and function of constituent features. Accordingly, the archaeological work has adopted an approach and protocols that are broadly consistent with English Heritage's Level 1 survey and recording standards, but with some elements of Level 2's feature recording

approach (English Heritage, 2007). However, the multi-disciplinary analysis of documentary sources and interpretation of these landscapes has been in some cases higher than that normally allowed by Levels 1 and 2.

The rationale for a non-invasive, walk-over archaeological survey and its geographical extent was based upon a number of factors and technical considerations. Survey areas were determined following a desk-based assessment of archival sources in conjunction with historical aerial photographs, modern aerial imagery and topographic 1:25,000 maps; all maps and images were georeferenced in a GIS database in order to confirm and identify positions of craters, depot features and ordnance disposal activities evident on historic aerial photographs. Areas of interest were then subjected to 'ride-over' reconnaissance on horseback, where possible, which gave an added visibility advantage when identifying surviving features.

Factors taken into consideration prior to survey included ease of access, personal safety issues such as contact with wild animals and surveying in dangerous terrain (especially bogs). Permission to access the FDA was freely given by the ONF (Office of National Forests) on condition that no invasive work was conducted – a restriction reflecting the strict laws protecting the patrimony of France, but also the potential for un-exploded munitions. The timing of surveys was conditioned by environmental and climatic factors. Wooded areas with dense leaf canopies all year round limit the amount of light and growth of ground cover and are therefore generally suitable for survey all year round. In contrast, areas with deciduous cover or those which have been lightly planted allow greater light penetration to the ground surface and thus promote understory development, and so fieldwork in such areas is only successful in winter when the ground cover has died back. Light snow coverings in winter months also improved the quality of observation as features stand out more clearly against the background.

Table 1: Source and data types of information obtained for papers.

Archive Type	Location	Name	Paper I	Paper II	Paper III	Paper IV	Paper V	Paper VI
			J. Conflict Archaeology	Int. J. Historic Archaeology	Antiquity	J.Field Archaeology	War in History	Stichelbault & Cowley (eds)
National Public	UK	TNA	--	Al(i,p)	Al(i)	Al(i)	Al(i). A(m)	--
National Public	UK	IWM (Duxford)	--	C(t)	--	--	--	--
National Public	UK	NCAP	--	Al(p)	--	Al(p)	Al(p)	--
National Public	France	IGN	F(p)	F(p)	F(p)	F(p)	F(p)	F(p)
Organisation	France	ONF / Orne	--	F(d)	--	--	F(d)	F(d)
National Public	France	Archives / Orne	F(r)	F(r)	--	--	--	--
National Public	USA	NARA	C(d)	C(d)	C(d)	C(d).A(ws)	C(d).A(ws)	--
National Public	Germany	Bundes-archive	--	C(t)	--	--	--	--
Military	USA	CARL	A(i)	A(i)	--	A(t)	A(h)	A(h)
Military	USA	AFHRA	A(m)	A(m)	A(h,m). Al(i)	A(h,m,p,r). Al(i)	A(h,m,r). Al(i)	A(h,m)
Private	USA	University of Akron	--	--	--	A(m)	--	--
Witness testimonies	France	Books Papers	F(ws)	F(ws)	--	F(ws)	--	--
Public/ Internet	USA	Fold3:B26.com: 416.com	A(h)	A(h)	A(h)	A(h,m,p)	A(h)	--

Archive Name:

The National Archive = TNA
 Imperial War Museum = IWM
 National Collection of Aerial Photography = NCAP
 Institut Géographique National = IGN

Source:

A = American
 Al = Allied
 C = captured German documentation
 F = French

Types of Information:

d = diaries
 h = histories
 l = intelligence reports (SHAEF,RAF, Ultra)
 m = mission-related reports (Air).

p = aerial photos
 r = resistance reports
 t = technical manuals
 ws = witness statements

Office National des Forêts = ONF
National Archive and Records Administration = NARA
Combined Arms Research Library = CARL
Air Force Historical Research Agency = AFHRA

Areas identified for detailed survey were field-walked using search patterns which extended for 100 m into the forest on both sides of forest roads and tracks, although patterns were locally extended deeper into the forest if features were identified close to the margin of transects. All identifiable features in the search areas were located and measured using a combination of GPS and a laser rangefinder and, where appropriate, were described and measured for a- and b-axis length, a-axis orientation and maximum (unexcavated) depth between the feature floor and the ground surface or the top of adjacent berms. No attempt was made to record feature depths below waterlogged surfaces or standing water (where present). The presence of any surface artifacts was noted (Fig. 4) and these aided in the identification of former munitions dumps and fuel depots.

All survey data was integrated into the project GIS database for analysis with the archive of aerial images and map data (A current copy of the FDA project GIS database itself has been passed to the DRAC and requests to access it can be made via the Service Régional de l'Archéologie)
<http://www.culturecommunication.gouv.fr/Regions/Drac-Normandie>.



Figure 4: Evidence of disposal of munitions in the Forêt Domaniale des Andaines. (Photo: Author, 12 January 2016)

4.3. Desk-based investigations

Desk-based investigations for this project have encompassed a wide range of documentary records, modern cartographic data and historic aerial photographs. Documentary evidence has been drawn from both military and national archives from a number of countries and includes wartime military reports and intelligence assessments, technical manuals, witness statements and post-war military analyses. In addition to providing a historical narrative, this material has proved particularly useful for determining the location, context and role of logistics sites. Aerial photographs contemporary with the conflict and especially the immediate post-war period have also permitted the prospection and analysis of archaeological features. Finally, the combination of GIS and modern map coverage of NW France has facilitated the mapping and analysis of sites at scales ranging from individual features and logistics depot layouts to the geographical distribution of entire logistics networks. The complete array of archive records and their utility in the specific papers is summarized in Table 1

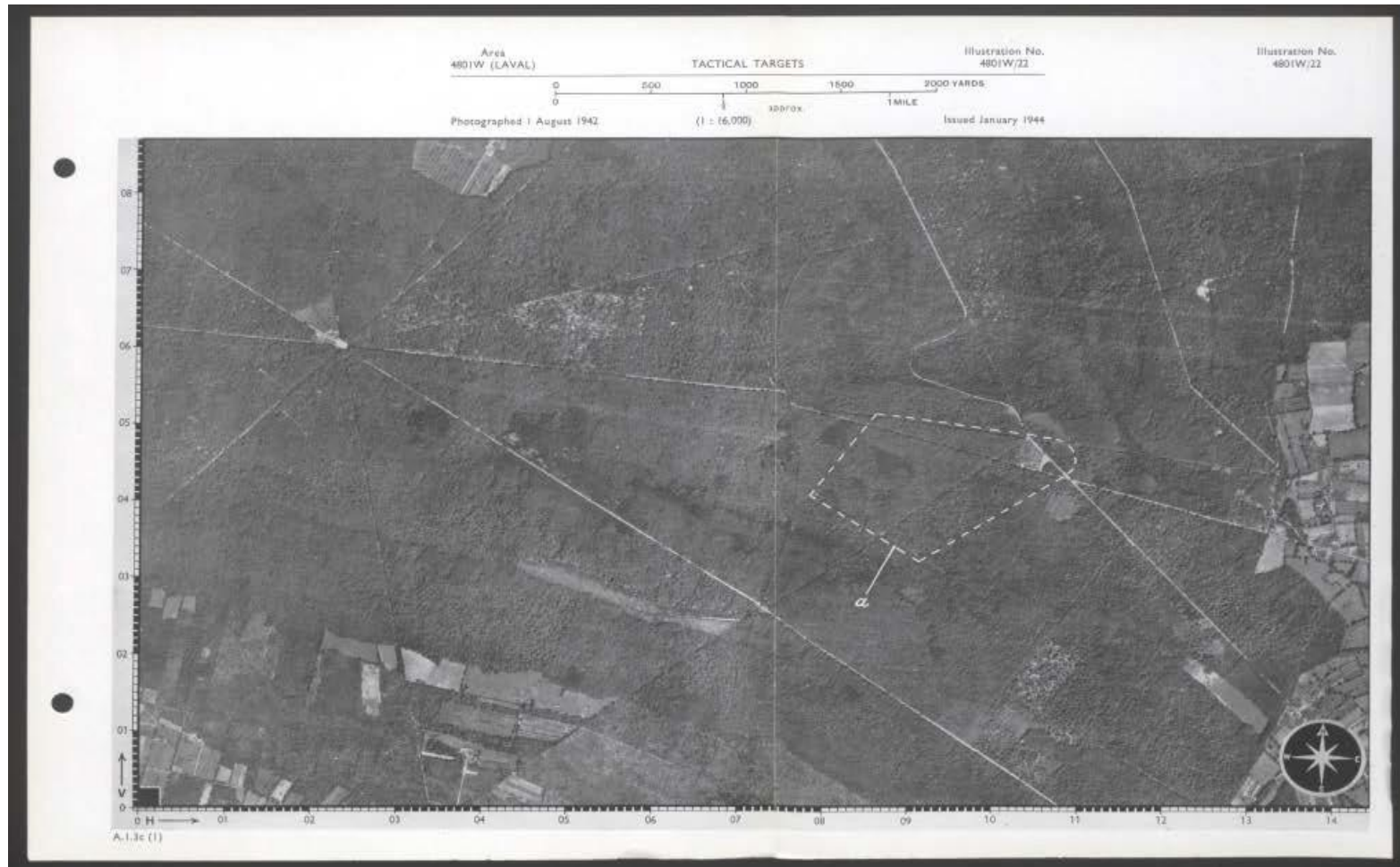
4.3.1. Documentary records

4.3.1.1. *US Military*

The American Air Force Historical Research Agency (AFHRA), located at Maxwell Air Force Base, Alabama, USA (<http://www.afhra.af.mil>), is the archive for the US Airforce. Its records include the official history, mission records and specific operational unit data for the American 9 AF. Mission records for American attacks in Europe (including those over the FDA) are in the form of teletype messages laid out in a rigid pre-determined format. These teletypes had to be analysed using date and time groups to provide a chronological narrative of orders and communications between the American 9 AF Bomber Command and constituent Wings, Groups and Squadrons. In conjunction with the official 9 AF chronology it has been possible, in most cases, to analyse all raids carried out by the 9 AF Bomber Command throughout Normandy and those specifically upon the FDA from the invasion of 6 June through to 14

August. This has required inspection of over 30,000 pages of varying quality teletypes). Map references in mission teletypes may be cross-referenced to locations specified in the TTDs (Fig. 5) which were compiled to include maps, aerial photos and types of targets for zones in Normandy delineated by an area of one degree of latitude by one degree of longitude: the FDA was located in the Laval Sector TTD (Fig. 6).

Figure 5: Photo Map of the Berta 1 fuel depot, Forêt Domaniale des Andaines (TNA, AIR/40/1285)



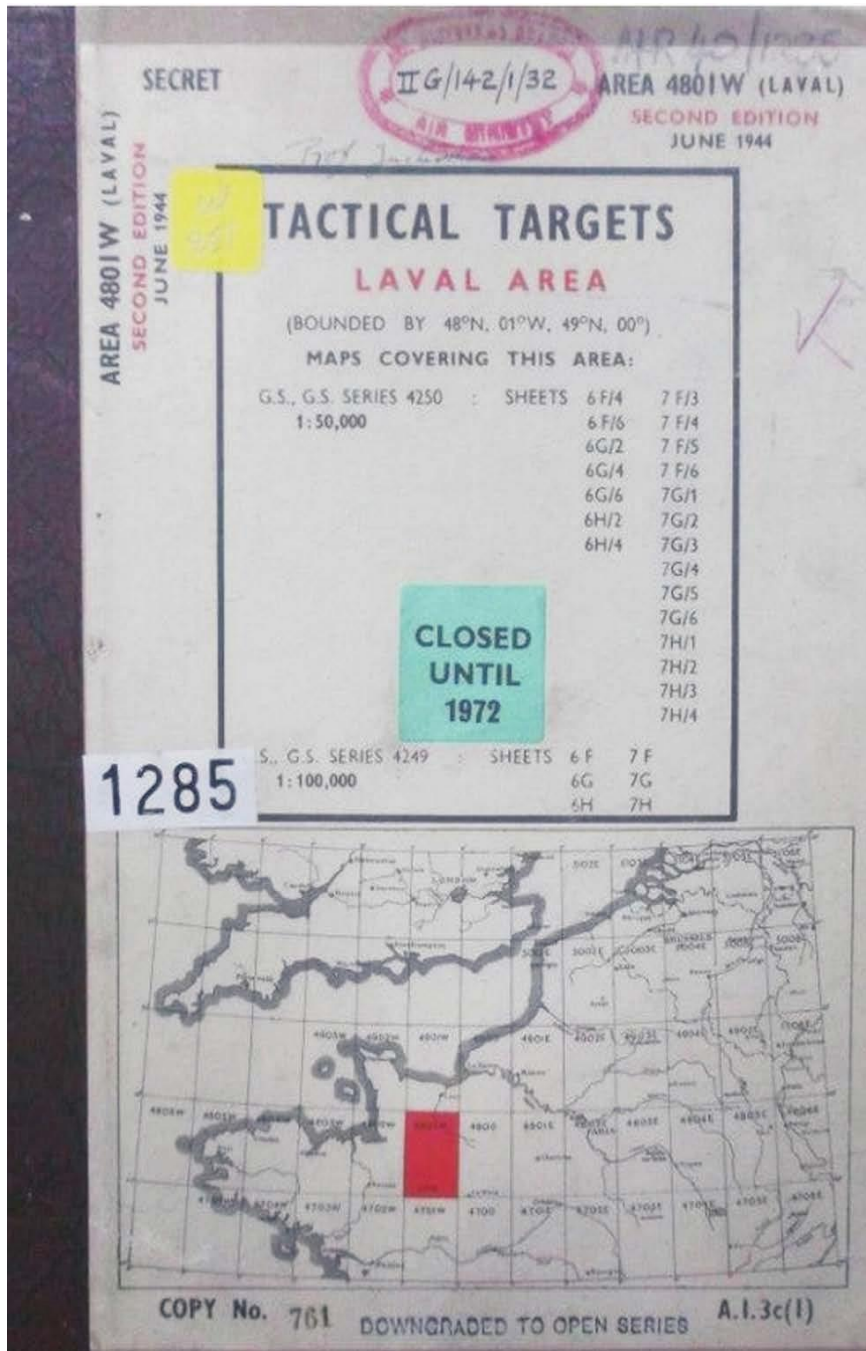


Figure 6: Tactical Target Dossier for the Laval Sector, January 1944, 1st Edition (TNA, AIR/40/1285)

The 9 AF records within the AFHRA which cover operations of aircraft employed in the area were also obtained for the period. When these sources did not give sufficient detail of specific raids, clarification by means of additional information for individual units was obtained from Maxwell including, where available, post-raid bombing records. To determine the effectiveness of offensive operations the 9 AF employed the use of an operational research

section that assessed aspects of operations including weapon types and targeting procedures. One such study was based on a raid carried out on the FDA, (9AF's, Area Bombing for June. AFHRA, B5656. p.66.).

The Combined Arms Research Library (CARL), based at Fort Leavenworth, Kansas, USA (<http://usacac.army.mil/organizations/cace/carl>), is the research center for the United States Army Command and General Staff College (CGSC). Within the collection are histories of units and technical manuals detailing the tactical relationship between air and ground operations of the 9 AF and specific operating characteristics of weapons. Of particular value to the analysis of bomb craters in this project were wartime analyses of bomb crater dimensions (Weapon-Data-Fire-Impact-Explosion data.1945). Finally, held at the National Archives Research Agency (NARA), College Park, USA (<http://www.archives.gov/>), are unit diaries that in many cases provide sequential details of troop activities and movements. These records yielded information on the liberation of the FDA area in August 1944, including positions of munitions dumps and German ordnance disposal activities.

Other non-official sources have also been employed. For example, the University of Akron in Ohio, USA, holds an archive dedicated to the B-26 Marauder aircraft and within this collection are the Beck papers (the chief photographic intelligence officer of the 397th Bomb Group). His dossier on the first raid on the FDA proved invaluable in attributing bomb damage to a specific group of aircraft. The on-line archive of the 416th Bomb Group association in America also provided information on specific air raids over the Forêt Domaniale d'Ecouvès (see Paper V below).

4.3.1.2. *Supreme Headquarters Allied Expeditionary Force (SHAEF) and Royal Air Force (RAF) reports*

Held at The National Archives (TNA) at Kew, London (<http://www.nationalarchives.gov.uk>), are SHAEF records detailing all known aerial attacks on target sites in Normandy with their respective bombing assessments. RAF 2nd Tactical Air Force (TAF) reports on attacks on fuel depots in Normandy are also held here and for the TAF's No 2 Group these

include individual missions. Second TAF records were examined specifically in order to confirm that the FDA was almost exclusively targeted by US forces.

4.3.1.3. Allied Intelligence Reports

Also held at the TNA are communication and intelligence records which consist of low, medium and high level signals that were decrypted and translated by the British at Bletchley Park (Jackson 2002) and this provided the Allies with vital intelligence detailing German operations and supply related information (Bennet, 1979; Hinsley et al., 1998). These decrypts were interpreted, condensed and refined for briefing purposes and reside in the records of the Ministry of Defence communication and intelligence section called the DEFE 3 series. In preparing these briefings specific and more detailed information was omitted and it is access to these records that has been invaluable for assessing aspects of logistics operations in the FDA (see Paper V, Table 8). These archives reside in the records of the Government Communications Headquarters (HW5 series). The HW5 records also assist in augmenting fragmentary German records which were likely to have been compromised during the retreat from France.

4.3.1.4. Captured German Army Records and the Foreign Military Studies (FMS) Program

German Army military diaries which were made at the time as a rolling journal to record and log events can be considered to be accurate records of events from that command's perspective and are detailed in the T311 and T312 series at NARA. Records detailing quantities and locations of supplies and operational situations have also been accepted as reliable (notwithstanding the possibility of transcription errors). Records held at NARA and the Imperial War Museum's repository at Duxford, UK, have also provided primary source documentation ranging from operational diaries to German technical manuals that describe the operation of German logistics units and the design of field works. These manuals provide insights into the recommended layout of depots with regard to the prescribed positioning, spacing and construction methods and proved invaluable when preparing and analyzing field surveys in the FDA and farther afield. References cited by Hart (1996, 2001) have been used as a start point

to provide the historical narrative, and other records revealed during the study have added further texture and detail, including for example quantities and allotment dates of supplies from German depots to front line units. NARA holds copies of captured unit documentation, the originals of which have now been handed back to the German Bundesarchiv. The German 7th Army Logistics diaries for the period June 1943 to the end of June 1944 provide a chronology of events and the evolution of the supply situation. Additional German high command army diaries outline events during the Normandy campaign and their quartermaster records, including details of allocations of supplies into theatre throughout much of the battle. Another useful source of information is the American Foreign Military Studies Program (obtained through Fold3.com) which in the aftermath of WWII produced a comprehensive series of manuscripts detailing "nearly every aspect of the Nazi war effort" (Wood, 2005, p1.) using information from German ex-officers. These manuscripts are especially valuable for illuminating those events for which the formal records have been lost or destroyed. For example, in the absence of the German 7th Army quartermasters diary for August the supply situation during the Mortain counter-offensive information is described in the FMS de-briefing report of the 7th Army Chief of Staff (Gersdorf, 1949).

4.3.2. Witness statement and written accounts

Material derived from eye-witnesses, or by those with a personal knowledge of specific places or events are well established as potentially valuable sources of information in conflict archaeology (Sturdy Colls, 2015) and in the case of this project have aided both the identification of sites and the contemporary Allied intelligence gathering operations. Military personnel who were fortunate enough to escape from enemy territory were debriefed by MI9 and MIS-X for the British and the Americans, respectively, and both organisations worked alongside each other with the shared objective of gathering intelligence (Foot and Langley, 1979). "Escape and Evasion" reports produced by American airmen followed a fixed de-briefing format describing the circumstances of original operation and the subsequent events of their escape including items of intelligence. Three such reports specific to the FDA were made on different

dates and at different locations by a crew of an American bomber which crashed in the vicinity and these include maps and written reports that show a good degree of corroboration. The account of Rougeyron (1947), who worked in a French Escape network, also confirmed the location of a fuel depot in the FDA. During the campaign a British Special Air Service unit operating in the area collated potential target information gathered by French Resistance members, including locations within the FDA, which were subsequently bombed (TNA WO/ 219/2414). From a non-military perspective the timings and dates of major air attacks were recorded in an official daily journal of a forester working for the Service des Eaux et Forêts. Held by the ONF at Bagnoles de l'Orne, this material was used to verify the forest's air raid history. French accounts written in the immediate aftermath of WWII narrate aspects of wartime events, and those gathered by Herval (1947) describe the location of a fuel point within the FDA. It is reasonable to accept their validity as reliable primary source information due to the fact that these were made by participants recounting their experiences of non-controversial events. Resistance reports on the forest obtained from private papers in the Orne Departmental Archive, Alençon, France (Fonds privés Series 371J 1-44. Viel, Almire. 371) also served to verify depot locations within the FDA. Depot sites identified from witness statements and interviews by Hairie (2007) were incorporated into the archaeological search areas.

4.3.3. Aerial Photographs

The IGN website 'Geoportail' gave access to vertical aerial photographs of the study sites from the immediate post-war period (1946-1949) and in a number of locations these showed evidence of depot activity and/or bomb cratering. Aerial photographs were georectified in the project GIS database which allowed the matching of craters and depot features with the results of ground survey. Additional wartime aerial images held in the National Collection of Aerial Photography (NCAP) in Edinburgh, Scotland, were used to verify specific raid damage on particular days and the locations of specific depot features, although the presence of cloud cover sometimes limited the reconnaissance results. Raid photographs themselves taken by the 9 AF from the AFHRA are

sometimes of limited quality but were also used in interpreting overall damage caused.

5. Paper Outlines

Paper I:

Landscapes of Logistics: The Archaeology and Geography of WWII German Military Supply Depots in Central Normandy, North-west France.

David G. Passmore

David Capps Tunwell

Stephan Harrison

Journal of Conflict Archaeology, 8(3), pp.165-92

Abstract

Earthworks associated with WWII German military supply depots are shown to be well preserved on the modern forest floors of the Forêt Domaniale des Andaines in central Normandy, northwest France, and are located within the record of the Seventh Army logistics network developed prior to the D-Day landings in June 1944. Features are typically located alongside forest roads and tracks and collectively amount to a military archaeological landscape that extends for nearly 10 km. Pilot survey of 50 discrete features demonstrates that at least three different storage facilities are evident, with variations in the size and morphology of bunkers that are consistent with the requirements of different types of munitions, fuel, foodstuffs, and vehicles. Numerous bomb craters also record Allied attempts to destroy the facilities. It is concluded that by the standards of WWII archaeology in the northwest European theatre, the FDA has retained an exceptional state of preservation for non-hardened military facilities and combat-related damage.

Contribution to the research / discipline

This paper is the first published attempt (in both the archaeological and historical academic and popular literature) to document the character and scale of a WWII German logistics landscape in a northwest European forest setting. As a pilot study it sets the agenda for the broader research project and expands the inventory of documented twentieth century conflict archaeology landscapes, especially with regard to non-hardened features and projectile

(bomb) impact craters. The logistics feature typology developed here provides the framework for an expanded and updated version that reflects the full survey reported in Paper II.

Personal contribution

- (i) Sole responsibility for original identification of sites in the FDA and mapping of areas exhibiting archaeological evidence of logistics facilities and bomb craters.
- (ii) Sole responsibility for identification, acquisition and analysis of primary documentary source material.
- (iii) Participation in detailed field survey of archaeological features (including primary responsibility for site selection).
- (iv) Participation in development of feature typology and drafting of text and figures.

Paper II:

Landscape Archaeology of World War Two German Logistics Depots in the Forêt domaniale des Andaines, Normandy, France.

David Capps Tunwell

David G. Passmore

Stephan Harrison

International Journal of Historical Archaeology, 19 (2), pp. 233-261.

Abstract

Archaeological survey in the Forêt Domaniale des Andaines has recorded nearly 900 discrete earthwork bunkers, building foundations, trenches, and other features associated with WWII German fuel, munitions and logistics depots. Documentary evidence establishes that these depots were administered from Bagnoles de l'Orne and were a key component of the Seventh Army logistics network before and during the Normandy Campaign of June-August 1944. Post-war survival of features has been remarkably good in this forested setting and it is argued that this likely constitutes one of the best-preserved and most extensive examples of a non-hardened WWII archaeological landscape yet documented in Western Europe.

Contribution to the research / discipline

Building upon the pilot study carried out in Paper I this work reported – for the first time in the academic literature – the findings of an extensive Level 1 archaeological survey of German logistical depots, together with a uniquely detailed set of supporting archive resources. It also presents a robust reference typology of German logistics fieldworks for Army-level depots that may be compared with future survey of similar sites in Normandy and further afield. The work also illustrates how the archaeological record of bomb cratering permits an assessment of the effectiveness of the Allied bombing campaign, while also drawing attention to aspects of depot management and security that require further archaeological and(or) documentary enquiry.

The survey itself has stimulated much interest locally and the ONF (Department of the Orne) is now paying regard to the preservation of logistics features in the regional forests. Furthermore, the local community of Bagnoles de l'Orne is in the process of designing a heritage trail around part of the depot landscape on the northern margins of the town. This will describe the role the depots played in the battle of Normandy and will become part of the Normandy heritage inventory (see also below).

Personal contribution

- (i) Lead author in development of feature typology and in drafting of text and figures.
- (ii) Sole responsibility for identification, acquisition and analysis of primary documentary source material.
- (iii) Sole responsibility for field survey of archaeological features.
- (iv) Sole responsibility for identification of sites in the FDA and mapping of areas exhibiting archaeological evidence of logistics facilities.
- (v) Sole responsibility for development of project GIS and feature database; assisted in the production of maps and figures.

Paper III:

Second World War conflict archaeology in the forests of north-west Europe.

David G. Passmore

Stephan Harrison

David Capps Tunwell

Antiquity, 88 (342), pp.1275-1290.

Abstract

Concrete fortifications have long served as battle-scarred memorials of WWII. The forests of northwest Europe, meanwhile, have concealed a preserved landscape of earthwork field fortifications, military support structures and bomb- and shell-craters that promise to enhance our understanding of the conflict landscapes of the 1944 Normandy Campaign and the subsequent battles in the Ardennes and Hürtgenwald forests. Recent survey has revealed that the archaeology surviving in wooded landscapes can significantly build upon our understanding of ground combat in areas covered by forest. In particular, this evidence sheds new light on the logistical support of field armies and the impact of Allied bombing on German installations.

Contribution to the research / discipline

In this paper the archaeology of logistics and air strikes in the study area are located within the broader context of newly identified, non-hardened WWII archaeological landscapes that have been fortuitously preserved in the forests of northwest Europe. The paper includes only the second published example of a mapped logistics site in Normandy (Lager Max in the Forêt Domaniale de Bourse), together with further examples of extant bomb craters and also presents an audit of known and potential logistics sites (with some examples of pilot archaeological survey) in northwest France.

Personal contribution

(i) Development and implementation of the site prospection approach using

archival sources which combined the use of aerial photography from the IGN archive and Allied targeting information to determine specific forest related locations of depots.

- (ii) Primary participation in detailed field survey of archaeological features (including primary responsibility for site selection) of the munitions depot located at the Forêt Domaniale de Bourse (while also developing and the updating the original feature typology model set from Paper I).
- (iii) Co-participation in the development of the site database for logistics sites in NW France which is published in the paper's Supplementary Data section.

Paper IV:

Second World War bomb craters and the archaeology of Allied air attacks in the forests of the Normandie-Maine National Park, NW France.

David Capps Tunwell

David G. Passmore

Stephan Harrison

In Press: *Journal of Field Archaeology*.

Abstract

Well-preserved bomb craters in the forests of central Normandy, northwestern France, constitute archaeological legacies of combat inland from the D-Day beachheads that greatly extend the inventory of WWII conflict landscapes in northwest Europe. Field survey and analysis of German and Allied documents demonstrates that bombscapes in the Forêt Domaniale des Andaines and Forêt Domaniale d'Ecouves reflect US 9 AF attacks on a German fuel depot and radar installation, respectively, during June-August, 1944. A total of one hundred and thirty-six craters are mapped (Figure 4, p.217), described and linked to specific air raids, bomb types and, for one raid on the 13th June, six specific participating aircraft and aircrews. These landscapes echo the impact of widespread tactical bombing against targets close to civilian population centres, employing civilian and PoW labour. They are therefore well-placed to contribute to wider heritage narratives around the non-combatant experience of aerial warfare in WWII.

Contribution to the research / discipline

This paper develops the potential for analysis of WWII bomb craters that is highlighted in Papers I-III and constitutes the first attempt in the conflict archaeological literature to match clusters of extant bomb craters to the circumstances and aircrew participants of specific air raids. The novel multi-disciplinary combination of ground survey with analysis of detailed primary source documents establishes an approach that is considered to have potential applications elsewhere in WWII 'bombscapes' that survive in European forests.

It is also considered to have the potential to make a unique rural contribution to the increasing focus of conflict archaeology in the experience of non-combatants in aerial warfare.

Personal contribution

- (i) Lead author in the production of text and figures.
- (ii) Sole responsibility for identification, acquisition and analysis of primary documentary source material.
- (iii) Sole responsibility for determination and identification of suitable crater landscapes within the FDA and the FDE.
- (iv) Sole responsibility for field survey of archaeological features within the FDA and the FDE.
- (v) Lead participant in the development and management of the project Geographic Information System (GIS).

Paper V:

A witness in the landscape: The bombing of the Forêt domaniale des Andaines and the Normandy Campaign, NW France, 1944.

David Capps Tunwell

David G. Passmore

Stephan Harrison

In Press: *War in History*.

Abstract

Archaeological survey of well-preserved WWII German supply depots and bomb craters from Allied air raids in the Forêt Domaniale des Andaines, Normandy, has prompted an evaluation of the effectiveness of Allied intelligence gathering and tactical bombing of the German logistics network in advance of, and during the Normandy Campaign of June-August 1944. In conjunction with analysis of primary German and Allied archive sources, published historical accounts and aerial photographs we demonstrate that Allied intelligence knew of the importance of the forest as a major fuel depot and attacked it with at least 46 missions over the period 13 June – 14 August. However, landscape evidence demonstrates that only one of three fuel depot sites in the forest was successfully identified and partially destroyed by bombing. Allied intelligence efforts also failed to gather sufficient evidence to target one of the largest Seventh Army munitions depots in Normandy. Supply depots in the forest thus remained operational until late in the campaign and will have supported the German Mortain counter-offensive of 7-14 August. The limited success of Allied bombing in the Forêt Domaniale des Andaines testifies to the difficulties in striking well-dispersed and camouflaged woodland facilities and supports the argument that the success of air power against German logistics efforts lay primarily in the degradation of the regional communications infrastructure and the Wehrmacht's vehicle fleet rather than the destruction of supply dumps.

Contribution to the research / discipline

This paper presents the most detailed picture yet published of the evolution and operational status of fixed German logistics depot sites throughout Normandy, both before and during the 1944 campaign. The novel contribution of the archaeological work carried out within this program has enabled the evaluation of (i) the scale and importance of the German logistics depots within the FDA during the Battle of Normandy, and (ii) the effectiveness of the American effort to destroy logistics sites from the air. This paper takes a strong historical perspective to reveal, for the first time from German records, failings of Allied intelligence both in the initial targeting phase and in the interpretation of operational intelligence during the campaign which allowed the depot to continue to operate albeit in a degraded form. The approach developed within this paper is applicable to other forested military sites and promises to provide further understanding of the German logistical situation during the campaign.

Personal contribution

- (i) Lead author participation in development in the production of text and figures. Sole responsibility for identification, acquisition and analysis of primary documentary source material.
- (ii) Lead participant in the development and management of the project Geographic Information System (GIS).
- (iii) Sole responsibility for identification for highlighting previously unpublished shortfalls and failures of Allied intelligence in targeting and locating depots within the FDA during the battle of Normandy.

Paper VI:

World War II Conflict and Post-conflict Landscapes in Northwest France: An Evaluation of the Aerial Photographic Resource.

David G. Passmore

David Capps Tunwell

Stephan Harrison

Passmore, D.G. Capps Tunwell, D and Harrison S. (2016) 'World War II conflict and post-conflict landscapes in northwest France: An Evaluation of the Aerial Photographic Resource', in Stichelbaut, B. and Cowley, D. (ed.) *Conflict Landscapes and Archaeology from Above*, Farnham: Ashgate, Ch. 11: pp.185-204.

Abstract

This work explores the use of aerial photographs for investigating landscapes of World War II conflict associated with the Normandy Campaign and the bombing of German military sites in northwest France during 1943 and 1944, and also the lesser known history of landscape rehabilitation and remediation in the immediate post-war recovery period. The primary resource used was vertical aerial photographs at scales between c. 1:1,500 and 1:26,000, taken between 1945 and 1960 and accessible from the online archive hosted by the IGN. Our analysis focuses on rural areas impacted by one or more Allied air raids, either because they witnessed major Allied ground offensives or were the sites of German military installations. Areas of open agricultural land have rarely preserved any visible evidence of bomb damage, but here the photographic record enables analysis of the intensity and character of bombing and the immediate post-war remediation of farmland. Allied air raids also targeted supply depots and V-weapon facilities concealed in regional forests, and here it is demonstrated that forest clearance associated with fires and late- and post-war munitions disposal activities have combined to render formerly camouflaged military sites, bomb craters and remediation landscapes as readily visible on aerial images.

Contribution to the research / discipline

This paper represents an extension of the aerial photographic analysis conducted on the FDA and other regional forest-based logistics sites to an assessment of bomb damage and post-war ordnance disposal activities in the wider Normandy landscape. It is therefore extending our perspective of conflict landscapes beyond the cessation of hostilities and into the period of rural reconstruction and rehabilitation. The analyses presented here also demonstrate how this approach may contribute to the extension and refinement of a logistics feature typology that will inform ongoing archaeological survey and interpretation of depot sites elsewhere in northwest Europe.

Personal contribution

- (i)* Second author in the production of text and figures.
- (ii)* Joint responsibility for analysis of primary documentary source material.
- (iii)* Team participant in site visits.

The FDA Heritage Trail (Projet de valorisation des vestiges de guerre en FDA).

As a direct result of a lecture that I presented during the 70th anniversary of D-Day in Basse Normandie, (2014) and work that I had carried out with the ONF it was decided by the Consul General of the Orne and other interested parties to explore the possibility of creating a forest heritage trail that would highlight the role of the FDA in WWII. The location chosen is on the northeastern margin of Bagnoles de l'Orne on account of the site's accessibility during all months of the year. During the winter of 2014 and the spring of 2015, under the chairmanship of the ONF financial backing was gained from various sources to proceed with the project. In the spring of 2015 graphic designers were commissioned, to develop information panels which utilise an educational approach designed to engage with the young. This trail, which will be the first of its type in Basse Normandie, is due to be inaugurated in 2016 and is intended to highlight and educate the role that the FDA played in the Battle of Normandy.

Personal contribution

- (i) Lead author in development in the production of the original text and figures.
- (ii) Advised on suitable sites for trail locations.
- (iii) Provided the majority of historical archival data and information used in creating the information panels.
- (iv) Participation in the planning process at meetings for the positioning and design of the information panels.

6. Conclusions and future research agendas

6.1. Introduction.

This project has demonstrated that the forests of Normandy locally contain well-preserved yet previously unrecognized conflict archaeology landscapes that belong to one of the most intensively studied and documented WWII campaigns. It has also shown that the analysis of these landscapes may be greatly enhanced by a multi-disciplinary synthesis of established techniques from archaeological, geographical and historical enquiry in order that the landscape evidence may be located within a geographical understanding of the campaign area and informed by the available array of detailed historical records. On the basis of the published outcomes to date and ongoing unpublished work a number of research agendas are currently being pursued and these are briefly outlined below.

6.2. Current archaeological assessment and heritage initiatives.

The survival of German logistical facilities, bombscapes and the wider array of conflict landscapes in forest locations throughout northwest Europe is a fortuitous outcome of several factors. In particular, the traditionally low intensity nature of forestry operations and the periods between harvesting (being measured in decades as opposed to years) have enabled earthworks to remain standing and visible long after they would in an open agricultural landscape. It has to be accepted, however, that increased mechanisation within the forest-based industry will be less conducive to archaeological preservation and both the ONF and the DRAC have acknowledged this as an area of concern. Indeed, the DRAC and tourist organisations have recognised that there is potential in developing the heritage potential of forest landscapes and this project has stimulated the development of only the second heritage trail of its type in Normandy (the first being located in the Forêt Domaniale de St Sever in the Calvados region). Further development of such initiatives will continue to require the balancing of the needs of the environment, commercial exploitation, history, tourism and archaeology, and in this respect will echo the conservation and management values that have been widely applied to earlier twentieth century conflict landscapes (see, for example, the Vimy Declaration; Bull and

Panton, 2000). To this end an informal working relationship has been established with the ONF and the DRAC and this has resulted in the release of LiDAR data to the project which is permitting an ongoing evaluation of WWII conflict landscape preservation in both the Forêt Domaniale de la Londe and Forêt Domaniale de Roumare, near Rouen in the Seine valley (Fig. 1). Outwith the forest-based initiatives currently underway, discussions are ongoing with the DRAC to incorporate forested archaeological landscapes in the Orne department within a newly created WWII heritage register (Lamache et al., 2016), and thereby extend the scope of the heritage register inland from the Atlantic Wall and D-Day beaches to the Normandy interior.

Ongoing work is also seeking to (i) further extend and refine the feature typology and understanding of operational practices across a number of types of German logistics sites at Army, Corps and Divisional levels, and (ii) continue to identify and map Allied bomb damage in forest settings.

6.3. Towards providing a geographic perspective on the importance of German logistics depots during the battle.

Geographical analysis of the distribution and character of logistics sites in both northwest France and northwest Europe continues to be facilitated by ongoing site reconnaissance and survey work, together with an expanded set of historical documentation which includes material that does not appear to have been previously published. This work is aiming to develop a complete picture of depot location and chronology, both before and during the Normandy campaign. A particular challenge to the archaeological analysis of munitions and fuel storage arises from the practice of establishing temporary depots (in response to operational requirements) that were characterized by surface stacking of materials – since these practices did not involve the construction of earthworks they are unlikely to have left any archaeological signature, and hence their identification will be reliant on both documentary records and witness statements. It is anticipated that an enhanced understanding of both depot locations and logistics operations will assist in the analysis of how the presence and location of German logistics depots in northwestern France affected the actual conduct of the Normandy campaign.

6.4. A review of the effectiveness of Allied bombing on the German logistics network in the Normandy campaign.

The surviving archaeological record very clearly contrasts the fortunes of the respective munitions and fuel depots within the FDA and has enabled a deeper and more nuanced analysis of Allied intelligence, targeting and the effectiveness of bombing than is possible from historical documentation alone. Further evidence of the efficacy of the method is also forthcoming from survey work in the Forêt Domaniale de Bourse (Lager Max; Paper III) and Forêt Domaniale d'Ecouves (Paper IV). Accordingly, it is considered that there is excellent potential to extend this approach elsewhere in Normandy and into other forested parts of northwestern Europe. Current work is focusing on the wider area of the Battle of Normandy, especially given that pilot surveys elsewhere in the region would suggest that many, and perhaps the majority, of Army-level German logistics facilities established in forests prior to the invasion have left visible traces on the landscape. LiDAR data, where available, may greatly facilitate ground survey in forested contexts and this is proving to be the case with newly-identified sites in the Lower Seine valley (see 6.2).

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Appendix I

Paper I:

Passmore, D.G., Capps Tunwell, D. and Harrison, S. (2013). Landscapes of Logistics: The Archaeology and Geography of WWII German Military Supply Depots in Central Normandy, North-west France. *Journal of Conflict Archaeology*, 8(3), pp.165-192.

Appendix II

Paper II:

Capps Tunwell, D., Passmore, D.G. and Harrison, S. (2015). Landscape Archaeology of World War Two German Logistics Depots in the Forêt domaniale des Andaines, Normandy, France. *International Journal of Historical Archaeology*, 19(2), pp. 233-261.

Appendix III

Paper III:

Passmore, D.G., Harrison, S. and Capps Tunwell, D. (2014). Second World War conflict archaeology in the forests of north-west Europe. *Antiquity*, 88(342), pp.1275-1290.

Appendix IV

Paper IV:

Capps Tunwell, D., Passmore, D.G. and Harrison, S. (in press). Second World War bomb craters and the archaeology of Allied air attacks in the forests of the Normandie-Maine National Park, NW France. *Journal of Field Archaeology*, 41(3), pp.312-330.

Appendix V

Paper V:

Capps Tunwell, D., Passmore, D.G. and Harrison, S. (in press). A witness in the landscape: The bombing of the Forêt domaniale des Andaines and the Normandy Campaign, NW France, 1944. *War in History*. In press.

Appendix VI

Paper VI:

Passmore, D.G., Capps Tunwell, D. and Harrison, S. (2016). World War II Conflict and Post-conflict Landscapes in Northwest France: An Evaluation of the Aerial Photographic Resource. In: Stichelbaut, B. and Cowley, D. (ed.) *Conflict landscapes and archaeology from above*, Farnham: Ashgate, Ch. 11, pp. 184-204.

Appendix VII

Information panels for the Forêt domaniale des Andaines Heritage Trail (Bagnoles-de-l'Orne).

Appendix I

Paper I:

Passmore, D.G., Capps Tunwell, D. and Harrison, S. (2013). Landscapes of Logistics: The Archaeology and Geography of WWII German Military Supply Depots in Central Normandy, North-west France. *Journal of Conflict Archaeology*, 8(3), pp. 165-192.

Landscapes of logistics; the archaeology and geography of WW2 German military supply depots in central Normandy, NW France

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Abstract

Earthworks associated with WW2 German military supply depots are shown to be well preserved on the modern forest floors of the Forêt dom des Andaines in central Normandy, NW France, and are located within the record of the Seventh Army logistics network developed prior to the D-Day landings in June 1944. Features are typically located alongside forest roads and tracks and collectively amount to a military archaeological landscape that extends for nearly 10 km. Pilot survey of 50 discrete features demonstrates that at least three different storage facilities are evident, with variations in the size and morphology of bunkers that are consistent with the requirements of different types of munitions, fuel, foodstuffs and vehicles. Numerous bomb craters also record Allied attempts to destroy the facilities. It is concluded that by the standards of WW2 archaeology in the NW European theatre, the Forêt dom des Andaines has permitted an exceptional state of preservation for non-hardened military facilities and combat-related damage.

Introduction

The context, scale and character of the 1944 Normandy campaign have lent its battlefields a special significance for those with a personal or professional interest in the Second World War. Reminders of the region's WW2 heritage are especially abundant in beachhead areas and immediate hinterland where well-preserved examples of concrete bunkers, gun emplacements and other fortifications attest to the strength and scale of the 'Atlantic Wall' defences (Zaloga, 2005; 2007). Beyond the beachheads there are also examples of extant defence installations (e.g. radar; Ford, 2004) and contemporary infrastructure (e.g. Pegasus Bridge; Clarke, 2004) that have been developed as battlefield tourism and commemorative venues. For the most part, however, the most conspicuous elements of Normandy's inland military landscapes are cemeteries, memorials, museums and static exhibits of armoured vehicles and weapons that participated in the campaign. The major battlefields themselves typically host formal battlefield information stands but it is usually the case that the physical legacy of combat, including non-hardened field fortifications, shell and bomb craters and battle-damaged infrastructure has been removed or rendered invisible by the combination of post-war reconstruction, urbanisation and agricultural activities. Accordingly, and with the

notable exception of battle-damaged buildings that survive in some of the regional towns and cities (e.g. Trew and Badsey, 2004; Yates, 2004), appreciation of the WW2 military landscape is usually reliant on photographic and documentary archives (see, for example, Sutton Publishing's 2004 'Battle Zone Normandy' series, edited by Simon Trew).

Contrasting patterns of military landscape survival into the 21st Century are the primary reason that archaeological and heritage management perspectives of WW2 in Normandy and the wider European mainland have tended to focus on static hardened defence lines, including the Atlantic Wall (e.g. Gaffney *et al.*, 2004; Everett *et al.*, 2006; Rose and Pareyn, 1998; 2003; Udphuay *et al.*, 2011), those associated with former national boundaries (e.g. Kaufmann and Jurga, 2002; Allcorn, 2003; Short, 2004), and also larger, extant military installations such as those associated with naval bases (e.g. Mallmann Showell, 2002; Williamson, 2003), air-raid shelters and flak towers (e.g. Richardson, 2008). Previous work by two of the authors (DGP and SH) in the Belgian Ardennes forests has, however, demonstrated that non-hardened field fortifications (earthworks) and shell craters may fortuitously survive in those areas which were forested during the conflict and have escaped intensive management since WW2 (Passmore and Harrison, 2008). Further examples of battlefield remains and other military activities in forested settings have since been forthcoming from work in the Hürtgenwald Forest, Germany (Rass and Lohmeier, 2011) and Finland (Seitsonen and Kunnas, 2009; Seitsonen and Herva, 2011). In this paper we again draw attention to the propensity for forests to preserve the archaeology of WW2 with examples from the Forêt dom des Andaines, in the Basse-Normandie region of NW France.

Here we focus not only on the physical evidence of conflict - in this case the results of aerial bombing - but especially on landscapes associated with the German army's central supply operations serving Normandy and the wider region. In so doing we seek to contribute to the broadening scope of conflict archaeology as its focus of attention moves beyond battlefields to embrace the wider context of the organisation and management of military activities (Scott and McFeaters, 2011). Investigations of archaeological landscapes associated with Operations Neptune (the D-Day landings) and Overlord (the Normandy Campaign) have made an important contribution to this trend, and especially with respect to the infrastructure established to support the preparations, launch and supply of the D-Day landings themselves and subsequent operations in Normandy (e.g. Pareyn and Rose, 2000; Schofield, 2001; 2005). However, while German anti-invasion preparations along the coasts of France, Belgium and Holland (the Atlantic Wall) are equally well documented, relatively little attention has been paid to the opposing logistical facilities in NW France. This is perhaps surprising in view of the critical role of logistics in determining the character of German defence and counter-attack strategies in the Normandy campaign (Hart, 1996) and, although Hart (1996) has outlined the broad geography of the German Army supply chain and depot structure, there has been no attempt to explore the physical size and characteristics of the supply chain, nor the degree to which it survives in the modern landscape. The Forêt dom des Andaines was one of several historic forests in NW France that was used by the Germans for stockpiling military supplies, and in this paper we present some preliminary results of geoarchaeological survey in the forest with the aims of (i) establishing a baseline survey of the disposition, scale and morphology of surviving storage facilities, (ii) reviewing the geography of the logistics network in this part of Normandy, (iii) highlighting the character of bomb damage associated with US Army Ninth Air Force raids on the forest, and (iv) briefly considering the prospects for further study regarding the archaeology and military geography of German Army logistics networks in the regional forests.

Background to the study area

The Forêt dom des Andaines covers an area of c.55 km² centred on the spa town of Bagnoles-de-l'Orne in the Orne département, Basse-Normandie region, NW France, respectively c.68 km and c.80-95 km south of Caen and the Normandy beaches (Figs. 1 and 2). The greater part of the forest lies to the northwest of the town, but the Forêt dom des Andaines is usually taken to include the smaller Forêt dom la Ferté-Macé to the east of Bagnoles-de-l'Orne (Fig. 2). The forest occupies a gently undulating terrain that rises to a maximum elevation of 304m a.s.l. (in the Mont Gérôme) and features NW-SE trending ridges and valleys developed on Neoproterozoic granites, Proterozoic (Brioverian) pre-Cambrian schists and Ordovician sandstones, shales and conglomerates. Comprising a mixed oak, beech and birch woodland with stands of pine, the forest presently serves as a major wildlife and recreational resource at the heart of the Normandie-Maine Regional Natural Park. Following the German occupation of NW France in 1940, however, the Forêt dom des Andaines was one of several large historic woodland areas in the region that were identified as sites for German military supply bases that combined good concealment from Allied air reconnaissance and ready access to important lines of communication.

Responsibility for defence of the region fell to the Seventh Army with headquarters and a supply and logistics chain centred at Le Mans (Fig. 1). From Le Mans the supply chain extended west into Brittany via Laval, Vitre, Rennes, St. Méen-le-Grand and Loudéac, and northwest into Normandy and the Cotentin Peninsula via Alençon, Bagnoles-de-l'Orne, Flers, Vire and St. Lô (Fig. 1; National Archives Record Administration, Captured German Documents – hereafter NARA – microfilm series T312, Roll 1571, Frame 000247; Hart, 1996). By June 1944 and the beginning of the Allied invasion of Normandy the major Seventh Army supply facilities hosted stockpiles amounting to 4318 cubic metres (1.14 million US gallons) of fuel, 18,738 tonnes of munitions and 11,500 tonnes of victuals (rations) (Tables 1 and 2; NARA T312, 1571, 000607). Notwithstanding Hart's (1996) argument that the logistics capacity and infrastructure of the Westheer had markedly failed to keep pace with the expansion of its combat strength following Hitler's Directive 51 in November 1943, the preference for wooded locations for the greater part of this supply effort would imply that substantial parts of the regional forest cover had been transformed into secured, militarised landscapes.

Development of supply facilities in the Forêt dom des Andaines commenced in 1943, largely using civilian labour conscripted into carrying out Service Travail Obligatoire and including PoW's from French North African colonies (Orne Archive, Alençon: Series J, 371j, 1-44). The location exploited a well-developed network of forest roads linking to trunk routes via Couterne, Domfront and la Ferté-Macé, railway links south to Le Mans via Alençon and to the north and east (including the major supply centre at Paris) via Argentan (Fig. 1) and a local airstrip immediately southwest of Bagnoles-de-l'Orne (Fig. 2). By the dawn of the Normandy campaign on the 6th June 1944 the forest was established as the principal supply centre for Seventh Army units in Normandy, especially with regard to fuel stocks; the fuel depot here (Lager Berta) was one of three large Westheer (Führer Reserve) depots in the entire NW France region, holding 967 cubic metres (255,000 US gallons) of petrol and diesel (Table 1), and alone accounting for 83% of Army fuel reserves in the Normandy area north of (and including) Alençon. Also located in the Forêt dom des Andaines was Lager Martha, one of nine regional munitions depots and the second largest depot of the four in the Normandy area with stocks amounting to 2008 tonnes (accounting for 28% of ammunition reserves in

Normandy; Table 2), and Lager Viktor, the largest of four Seventh Army rations depots in the region with 4200 tonnes of stores (equivalent to 36.5% of the total reserves; Table 2; NARA T312, 1571, 000607).

Methods

Fieldwork in the Forêt dom des Andaines was conducted during the winter of 2011 when constructional and dug features could be readily identified on the forest floors, and follows the approach taken by Passmore and Harrison (2008). On the basis of preliminary investigations by one of the authors (C-T) a total of 7 localities were selected for detailed survey and analysis with the aim of establishing a broad typology and geography of feature (depot) types. Between 5-7 feature types in each locality were located using a combination of GPS and a laser rangefinder and measured for a- and b-axis length, a-axis orientation and maximum (unexcavated) depth between the feature floor and the ground surface or, where present, the top of adjacent berms. No attempt was made to excavate or disturb the ground surface in or adjacent to any of the features, although the presence of any surface artefacts was noted. A broad typology of features was made on the basis of planform dimensions, the primary mode of construction and(or) excavation and the relationship of features to nearby roads or tracks. This exercise was also facilitated in some cases by photographic evidence of structures in use during 1944 (Laroze, 2004) and by aerial photographs taken in 1949 (IGN, Ref 1949 F 1416/1716).

Results

Fieldwalking in the Forêt dom des Andaines by one of the authors (C-T) has established that earthworks associated with German supply depots form conspicuous features on the modern forest floors (especially during winter months with the die-back of vegetation) and are present in at least seven discrete areas in the western, central and eastern parts of the forest (Fig. 2). Features are typically located in linear arrays one or two deep that are parallel with, and adjacent to forest roads (Fig. 2), and collectively amount to a military archaeological landscape that extends along one or both sides of forest roads for nearly 10 km.

Archaeological survey has focused on a combined total of 50 discrete excavated and(or) constructional earthworks in 7 localities (Localities A-F) that were selected to capture a full range of feature types in evidence, although it is emphasised here that this represents a very small proportion of the total number of features surviving in the Forêt dom des Andaines (Fig. 2). With the exception of a near-continuous zig-zag trench complex that extends for some 700 m in Locality C (Fig. 2), the sampled features recorded here have an a-axis range between 1-32 m and an unexcavated depth range of 0.5-8 m (Table 3). Figure 3 shows a plot of the feature a and b axes while the full details of individual features for each locality are set out in Table 3. Tables 3 and 4 also assign features to one of 9 discrete feature types that have been interpreted in terms of their origin and function on the basis of the criteria set out above and contemporary documentary accounts of depot locations and function (see above and Fig. 1); these are described in detail in the following sections and are selectively illustrated in Figures 4 and 5.

In contrast to the well-established classificatory schemes adopted for defensive field fortifications (e.g. Fleischer, 1998; Rottman, 2004), we are presently unaware of any formal

typology for features associated with the field storage of military supplies. Here we have adopted the term 'bunker' for both constructional and(or) excavated features, although we recognise that this term is more conventionally applied to roofed installations that are sited partly or entirely underground and are at least partly consolidated. It is also recognised that surviving features will have been subject to some degree of degradation since the sites were abandoned and this will have acted to lower the surface relief of berms, partially infill excavations and soften the edge definition. In some instances features have also been subject to some degree of modification associated with post-war activities, including rubbish dumping (notably in Locality G), road widening and the activities of informal artefact collectors. Accordingly we accept that the feature typology established here must remain provisional in the absence of archaeological excavation and is liable to be modified in the course of on-going survey and archival research being conducted by the authors.

(i) Type Ia and Ib (Munitions)

Type Ia and Ib bunkers are found on both sides of a continuous 2.9 km stretch of the Route Forestière de l'Épinette (D387), an axial road occupying the crest of a northwest-southeast orientated ridge (the Massif de la Ferté-Macé) in the eastern part of the Forêt dom des Andaines between Bagnoles-de-l'Orne and La Ferté-Macé (Figs. 2 and 4). Further features of this type are also located perpendicular to the D387 along 0.7 km of the Route Forestière du Hêtre de la Vierge, and in the eastern extremity of the study area along a 400 m stretch of the Route Forestière de Cossé at Locality B (Figs 2 and 4). In survey Locality (A) Type Ia features are generally found on the gently sloping north-east facing shoulder of the Massif on the northern side of the D387. They are generally spaced between 70-100 m apart and are arrayed in two parallel rows some 12 m and 100 m from the road, respectively (Fig. 4). These are shallow rectilinear pits with a surrounding berm giving depths up to 2.1 m and with a-axes ranging between 9.8-13.3 m (Fig. 4). Two entry/exit points are found at each corner of the road-facing long-axis (Fig. 4) while the opposite (northeast facing) wall typically features a drainage conduit leading to drainage channels running downslope and away from the pit. Type Ib features share the same planform but are generally slightly larger (a-axes between 13.1-13.3 m) and deeper (2-3.3 m) and are found on the southwest side of the D387 (Fig. 6). Here the crest of the ridge offers flat or gently sloping ground, and the features are drained towards the adjacent road via channels cut into the floor of the entry/exit openings.

Contemporary photographic evidence of a stocked bunker in Lager Michel, near Vire (Fig. 1; Laroze, 2004), shows munitions bunkers were provided with planked timber walls, floors and timber/corrugated iron roofs, but in the Massif de la Ferté-Macé the bunkers present little surviving evidence of constructional material with the exception of occasional remains of crude stone facing on vertical interior walls and rare timber planks. However, heavily corroded (steel) shell cartridge cases were evident on the floor of several Type Ia pits with diameters consistent with 37 mm, 75 mm, 88 mm and 105 mm munitions (Table 2), all of which can be associated with contemporary German tank/anti-tank/artillery and possibly anti-aircraft guns. Only one feature of the Type Ib variety contained shell casings, these of the 105 mm type (Table 2). The widespread presence of munitions artefacts in Locality A bunkers, and in similar features elsewhere along the D387 (Capps Tunwell, unpublished data), suggests that this part of the Forêt dom des Andaines served as the core component of munitions Lager Martha (Figs 1 and 2). At present it is unclear whether the differentiation of Type Ia and Ib bunkers is a reflection of differing storage specifications for the various munitions (though here we note that there is little consistency between the size of individual

pits and their associated artefacts), or rather is a product of varying construction styles or phases within the larger depot. Clarification of this issue (and potentially the identification of further feature types) must await the results of ongoing survey and archive work.

(ii) Type II (Fuel)

Type II features form a distinctive suite of rectilinear pits in two discrete areas of the Forêt dom des Andaines, respectively located towards the western margins of the forest near the village of Perrou and in the central part of the forest some 2 km west of St-Michel-des-Andaines (Fig. 2). In the vicinity of Perrou they are present on both sides of a 1km stretch of the D52 as it climbs towards the crest of a narrow ridge forming the southern margin of the forest. To the east in the central part of the forest they are also evident along both sides of a 0.6 km stretch of the Route Forestière du Gué Besnard (Locality D, Figs. 2 and 5). Both of these sites are located on minor roads that connect directly with the D908 which forms the main road between Domfront and La Ferté-Macé and the primary means of accessing the forest (Fig. 2). Type II features survive as elongate shallow pits between 30-32 m long and 4-5 m wide, spaced between 50-100 m apart and located immediately adjacent and perpendicular to the road (Figs. 5 and 7). They are open at the road end but surrounded on the remaining three sides by low berms. Their length and internal width would facilitate the storage of 45-gallon fuel drums that could be readily rolled into position (assuming the pit floor supported wooden planking or runners), and hence both of the Type II sites are interpreted as components of the Westheer (Führer Reserve) fuel depot code-named Berta (Table 1; Figs. 1 and 2). However, at present it is unclear whether the features supported timber framing and(or) additional camouflage, and also whether the fuel drums were stacked in more than one level.

(iii) Type III (Fuel)

Type III bunkers exhibit shallow rectilinear planforms that broadly resemble the Type Ia and Ib munitions pits, but their location in the central and western part of the Forêt dom des Andaines, in the vicinity of the Type II depot clusters, would suggest that these features are also part of the Lager Berta fuel depot (Fig. 2). They are evident as two discrete clusters arrayed on both sides of forest roads. In the central part of the forest at Locality F (Figs. 2 and 5) they lie astride a 0.5 km stretch of the Route Forestière du Gué Besnard immediately north of the Type II site at Locality D (Fig. 2), while to the west at Locality E a larger assemblage of Type III bunkers survive along 2.5 km of the Route Forestière de Juvigny immediately south of the major road junction with the D908 at l'Etoile (Figs. 2 and 5). Type III bunkers form relatively large constructional pits with enclosing berms, having an A-axis range between 14.7-18.8 m, but their depth range is limited to 0.5-2 m. They are generally spaced not less than 50 m apart and lie with their a-axis perpendicular to the road and between 10-50 m distant. The surrounding berms are typically punctuated by a single entrance/exit facing the road, and where located on flat ground they are surrounded by a shallow (c.1m wide) trench that most probably served as a drainage sump. Artefact recovery from surveyed features in Locality E was restricted to a single example of a 45-gallon drum (Table 3), but these bunkers are provisionally interpreted as storage facilities for fuel contained in smaller 20 litre 'Wehrmachtskanisters' (jerrycans).

(iv) Type IV (Victuals)

In contrast to the part-constructional characteristics of Type I-III bunkers, Type IV features have been formed by excavating and(or) quarrying U-shaped embayments into a north-facing valley-side slope on the southern margins of the Forêt dom des Andaines near La Croix Gautier and le Manoir du Lys, 2 km northwest of Bagnoles-de-l'Orne (Locality G: Figs. 2 and 5). A total of 16 pits are evident in this location where they are arrayed in a gentle arc at c.20-50 m intervals following the 230-235 m valley side contour (Fig. 5). Surveyed examples exhibit a-axis lengths between 16.8-22.5 m and widths up to 14.5 m, while the pit walls reach a maximum depth of 5-8 m at their southern (rear) margin and shallow to c.1 m at the pit entrance where they open out to meet an access track (Figs. 5 and 8; Tables 3 and 4). Several of the pits have accumulated post-war rubbish but a variety of corroded tins, steel containers and buckets are considered to be of WW2 origin. In addition, one of the features appears to have been equipped (or has been subsequently modified) with a vehicle inspection pit. To the northeast of the Type IV pit array this site also exhibits the derelict remains of a long (c.20 m) building of concrete construction and steel roof which is considered to be of wartime origin. The combination of pit features, artefacts and building remains at Locality G is provisionally interpreted as the site of a major supply (victuals) facility associated with the largest of the Seventh Army's rations depots in NW France, administered from Bagnoles-de-l'Orne and codenamed Viktor (Fig. 1; Table 2; NARA T312, 1571, 000607).

(v) Type Va and Vb (Vehicle Parks)

Type Va and Vb features in the Forêt dom des Andaines have been identified in four discrete but, by comparison with fuel and munitions sites described above, relatively small clusters (Fig. 2). Both feature types share similar rectilinear planform configurations that are located with their entrances opening out onto adjacent forest roads, and are differentiated on account of their mode of origin as excavated embayments in roadside cuttings (Type Va) or, where located on relatively level ground, as three-sided embanked structures (Type Vb, Fig. 4). Type Va features occur as clusters to the east of the 'Martha' munitions depot at Locality B, 4 km east of Bagnoles-de-l'Orne, and also in the central part of the forest immediately north of Locality F and the Carrefour des Cerisiers (Fig. 2). At Locality B they are excavated at intervals of c.10-15 m into a steep road cutting on the southern side of the Route Forestière de Cossé (Figs. 4 and 9). Here their a-axes range between 7.4-10.4 m and all are orientated at a slight angle to the adjacent road. Feature depths vary between 1.5-4 m, largely due to the uneven relief of the cutting and slope (Fig. 9). A sub-square and shallow depression measuring 2 m by 2 m, located adjacent to the last of the Type Va features in Locality B at the extreme eastern end of the site (Table 2; feature B5) may have been the site of an administrative and(or) guard hut.

Type Vb features are also present in the central part of the forest immediately north of Locality F (in association with Type Va examples), but are the sole constituents of discrete clusters alongside 0.7 km of the Route Forestière de Champsecret (D335) near Locality F and on the southern edge of the forest at Bagnoles-de-l'Orne (Locality C, Fig.2). At Locality C they are arrayed on the northern side of two broadly parallel roads that extend into the forest from the urban fringe (Fig. 4) and in combination extend for some 1 km. A total of 17 examples of Type Vb features have been identified alongside the most southerly (un-named)

road, but these appear to have been partly truncated by post-war road widening and hence do not give a true representation of the original dimensions. On the adjacent forest road to the north (Route Forestière des Treize Neiges), however, Type Vb examples survive in a good state of preservation and exhibit a- and b-axis dimensions ranging between 8.3-9.7 m and 4.5-5.6 m, respectively (Fig. 4). These features are open to the road on their southern margins and are surrounded on their remaining three sides by a low berm, giving a depth range of 1-2 m (Fig. 4).

Their roadside configuration, taken in combination with their size range and the complete absence of artefacts in the surveyed areas, differentiates Type Va and Type Vb bunkers from other storage facilities identified in the study area and hence, while we cannot exclude the possibility of their utility as fuel and(or) munitions stores, they are interpreted here as individual vehicle parks offering readily camouflaged shelter against aerial reconnaissance and attack. Their dimensions are certainly sufficient to accommodate the range of motorised vehicles used by the Wehrmacht for supply transport (including the largest half-tracked vehicles at 8.25 m in length) and it is also interesting to note that at Localities B and C the features were associated with nearby trenches and foxholes that are likely to have served as personnel shelters (Type VI features - see below).

(vi) Type VI (foxholes and trenches)

A variety of small (individual) foxholes and trenches identified in the survey localities have been classified here as Type VI features pending more detailed survey work. They are especially prevalent at Localities B and C where they are associated with Type Va and Vb vehicle parks (Figs. 2 and 4; Table 3). At Locality B they take the form of a line of individual foxholes, measuring 1 m by 1.3 m in plan and spaced 5-6 m apart, that are located to the rear of, and within 10 m of the vehicle parks. At Locality C, by contrast, the Type Vb vehicle parks arrayed along the southern of the two surveyed roads are backed by a near continuous zig-zag trench complex that extends for some 700 m. This trench complex lacks evidence of machine gun or other weapons emplacements that are characteristic of purpose-built German defensive field fortifications (Rottman, 2004) and this, in combination with its location immediately behind and parallel to the series of vehicle bays, suggests it was dug primarily for protection against bombing raids.

In addition to the classified feature types described above, a number of miscellaneous earthworks and features have been identified on the forest floors, including the sites of potential buildings and large, sub-circular depressions that may reflect the sites of explosions associated with contemporary or post-war controlled ordnance disposal. By far the most common of non-constructural features, however, are well-preserved bomb craters (Fig. 2; Table 3). These are evident as individual (stray) features and especially in clusters in the vicinity of the Berta fuel depot, in the central part of the Forêt dom des Andaines (Figs. 2 and 10), where in some instances craters are registering direct hits on Type III bunkers (Fig. 11). Bomb crater diameters range between 7-12 m, although some much smaller examples in Locality F have diameters of 2 m.

Discussion

It is widely recognised that combat elements of the German Army were heavily reliant on forests and smaller woodlands in Normandy for cover and concealment from aerial reconnaissance and attack during the build-up to Operation Overlord and the subsequent break-out campaign (e.g. Zetterling, 2000). What is perhaps less well-appreciated is the German practice of locating the greater component of their logistics network in the region's forest cover; in the case of the Forêt dom des Andaines, for example, this study has documented archaeological evidence for a major hub of the Seventh Army's supply chain, hosting the largest of the Wehrmacht's fuel and victuals depots, and also one of the largest munitions dumps, in the vicinity of the Normandy beachheads. Forest settings allowed the Wehrmacht to develop extensive, non-hardened supply facilities that were readily secured from aerial and local ground observation, while freeing valuable building and labour resources for development of reinforced coastal defences. Post-war, and in common with some other European and Scandinavian forest localities (e.g. Passmore and Harrison, 2008; Crutchley *et al.*, 2009; Seitsonen and Kunnas, 2009; Rass and Lohmeier, 2011; Seitsonen and Herva 2011), they have permitted the preservation of WW2 military landscapes that would not have survived in open agricultural or urbanised contexts. These landscapes are also notable for preserving the field evidence of Allied attempts to bomb the logistics facilities during the Normandy campaign. Indeed, with the notable exception of the site of Pointe du Hoc, on the western margin of Omaha Beach (Everett *et al.*, 2006; Burt *et al.*, 2007), we know of no comparable WW2 context in NW Europe where such extensive landscape evidence of aerial bombing has survived virtually intact. Accordingly, by the standards of WW2 archaeology beyond localities associated with hardened fortifications and other military installations, the military landscapes of the Forêt dom des Andaines are considered here to be quite remarkable in terms of the number, extent and degree of preservation of discrete features.

Archaeology and geography of supply depot facilities

The provisional typology of features developed in this study will undoubtedly require enhancement and modification as field and archival research progresses, but here we argue that there is sufficient variation in the form, size and geographical disposition of storage bunkers and associated field fortifications surveyed to date to permit the differentiation of discrete depot facilities and to provisionally assign them to the specific storage requirements of munitions, fuel and victuals. In the eastern part of the Forêt dom des Andaines (the Massif de la Ferté-Macé) the combination of bunker typology and surface artefacts is consistent with historical references to the location of munitions Lager Martha, while in the central and eastern part of the forest bunker typology can be clearly differentiated into two contrasting types that are interpreted here as being associated with fuel, respectively stored in 45-gallon drums (Type II) and jerrycans (Type III). These form discrete and well-spaced clusters near Perrou in the west (Type II), l'Etoile (Type III) and St-Michel-des-Andaines (both Type II and III; Fig. 2), and are consistent with documentary reference to the Westheer (Führer Reserve) Lager Berta. It is recognised, however, that further research will be required to establish unequivocal links between bunker typologies and specific types of munitions and fuel storage, or indeed whether such differentiation reflected formal Wehrmacht protocol.

In the eastern part of the study area at Localities B (Massif de la Ferté-Macé) and C (Bagnoles-de-l'Orne) (Fig. 2), distinctive three-sided bunkers of excavated (Type Va) and

constructional (Type Vb) origin are interpreted as off-road vehicle shelters. Their location within, or adjacent to Lager Martha suggests they hosted munitions trucks or half-tracks. Two further clusters of Type Va and Type Vb vehicle parks are located in the central part of the Forêt dom des Andaines in close proximity to the eastern component of Lager Bertha (Localities D and F, Fig. 2) and imply an association with transport of fuel. The greater depth of Type Va features will have offered the potential of a higher degree of protection against blast damage for all but direct hits from aerial bombing and may have been the preferred solution for vehicle shelter where suitable roadside embankments were available.

Much larger hillside excavations (Type IV) appear to have been the solution to storage of victuals in the Manoir du Lys area (Locality G; Figs. 2 and 5), and are assigned here to Lager Viktor. In contrast to the munitions and fuel depots in the Forêt dom des Andaines, Lager Viktor appears to have been associated with surviving evidence of at least one brick and concrete building that, perhaps through a combination of size and degree of post-war use, has warranted identification on IGN maps of the area (Fig. 5). These represent the sole examples of hardened facilities identified to date in the study area, although it is recognised that most, and perhaps all depot earthworks were originally provided with some form of canopy or solid shelter and camouflaging, most probably through one or a combination of timber, corrugated iron, canvas and(or) tarpaulin cover.

While a clear distinction of feature types is evident across the different depot facilities in the Forêt dom des Andaines, all recorded earthworks share a locational attribute in being located adjacent to, or within c.100 m of readily accessed forest roads. Only the large Type IV (victuals) pits appear to have required the provision of a dedicated access track that does not appear on IGN maps of the forest, and this most probably reflects the local practice of bunker excavation along the contour of a wooded hillside. In this case, however, there is a short road link to the D235 and connecting routes to surrounding towns (Fig. 2). Stretching along a combined total of some 9.9 km of forest roads and tracks, none of the supply depots identified in the Forêt dom des Andaines lie more than 3.5 km from major road major road junctions at Domfront, Couterne or La Ferté-Macé, or railheads at Bagnoles-de-l'Orne or Domfront (Fig. 2).

Military significance and the archaeology of bombing raids

Mobile units of the Seventh Army began their defence of Normandy after the 6th June D-Day landings with munitions and fuel stockpiles sufficient, respectively, for three weeks and two weeks of combat (Hart 1996). Nearly 11% of munitions stockpiles were located in the Forêt dom des Andaines at Lager Martha, while the forest assumed particular importance for fuel stockpiles with Lager Berta accounting for 83% of Army fuel reserves in the Normandy area north of (and including) Alençon. The significance of the Forêt dom des Andaines as a major military asset was not lost on the Allies and the area was targeted for bombing raids by the US Army Ninth Air Force which, according to Hart (1996), resulted in the destruction of Berta on 13th June. By 14th June there were no fuel stockpiles remaining in Normandy (Hart, 1996). Surveys to date have identified four areas in the central part of the forest where field evidence of air-raids is manifested as clusters (and some stray examples) of well-preserved bomb craters (Figs. 2, 10 and 11). These are most extensively developed in Locality F, near Carrefour des Cerisiers and the most easterly component of Berta and its associated Type III fuel bunkers (Figs. 10 and 11) and here, examples of bunkers that have been directly impacted by bombs (Fig. 11) provide compelling evidence of accurate air-raids. However, it

is striking that other components of Berta, including those at Localities D and E, appear to have avoided direct hits or, in the case of the westernmost depot near Perrou, may not have been targeted at all (Fig. 2). It is likely, therefore, that the practice of dispersing fuel depots across multiple locations in the forest acted to reduce their vulnerability to air raids, although it is accepted that further research is necessary to establish whether all of the depot facilities identified here were concurrently in use. It is also interesting to note that no evidence has yet emerged of bombing raids in the vicinity of munitions Lager Martha, and thus Hart's (1996) reporting of the destruction of several Normandy munitions dumps by air-raids in June 1944 cannot be taken to include the example in the Forêt dom des Andaines. A more detailed analysis of the archaeology of bombing in this area must await further survey work and analysis of the US Army Ninth Air Force archives.

The combination of air-raids and - perhaps especially - the rapid exhaustion of supplies held in the Forêt dom des Andaines during June 1944 is likely to have lessened the military significance of the forest depots during the middle and later stages of the Normandy campaign, but it was not until the period between August 13th and 16th that the area was finally overrun by elements of the US 1st Infantry Division (Combined Arms Research Library – hereafter CARL – Selected Intelligence Reports; US 1st Infantry Division, Vol.1). However, and in contrast to the spectacular landscape of bombing in the forest, there are to date no identified earthworks or features that may be unequivocally associated with ground combat. The many examples of foxholes (Type VIa) and trenches (Type VIb) that have been recorded lie in the immediate vicinity of storage bunkers and especially vehicle shelters, and are interpreted here as functioning primarily as air-raid shelters. While it is recognised that this assumption rests on only limited survey data, it is consistent with records from the US army war diaries that report evidence of combat in the forest to be limited and focused mainly around major crossroads (CARL, Selected Intelligence Reports; US 1st Infantry Division, Vol.1). By this stage of the campaign the Germans were conducting a fighting retreat in the Battle of the Falaise Pocket and their logistics system had virtually collapsed in the face of aerial attacks and a crippling lack of motorised transport (Foreign Military Studies 1945-54, B Series 827, OB West Supply and Administration; Hart 1996; Reardon, 2002). Under these circumstances the remains of the supply depots in the Forêt dom des Andaines, once a key element of the Seventh Army logistics network in Normandy, were probably of significantly reduced military value and hence it would appear that the area was largely abandoned rather than contested.

Conclusions

The array of WW2 German munitions, fuel and victuals supply depots in the Forêt dom des Andaines, and the evidence of Allied bombing raids intended to destroy them, constitute a military landscape that stands in marked contrast to the more familiar range of archaeological, commemorative and memorial sites in Normandy. The archaeological imprint of these activities extend along nearly 10km of forest roads and tracks in the heart of a major national park and in the vicinity of several large towns, and provide further evidence of the propensity for historic forests to provide settings which, in the context of WW2 archaeology in the NW European theatre, have permitted an exceptional state of preservation for non-hardened military facilities and combat-related damage. Yet, and despite the key role that logistics played in restricting German firepower and mobility during the Normandy campaign, these landscapes have no local tourism profile and are absent from regional battlefield tours and guides. To our knowledge this is the first published study to attempt to

describe and classify (albeit on a provisional basis) the range of military earthworks and field fortifications associated with inland military supply depots in Normandy, and also to register the landscape of bombing raids intended to destroy them. At least three different storage facilities are evident, with variations in the size and morphology of bunkers that are consistent with the requirements of different types of munitions, fuel and foodstuff containers, and these can be located within the record of the Seventh Army logistics network developed prior to the D-Day landings in June 1944.

The project contributes to the growing interest in the archaeology of military logistics and, in the case of the NW European theatre of WW2, demonstrates the contrasting approaches and scale of infrastructural investment in supplying the opposing armies. In contrast to the infrastructure developed to support Operations Neptune and Overlord, landscapes of the FDA indicate that German facilities - in the face of overwhelming Allied airpower - were essentially non-hardened and dispersed in densely forested localities with an emphasis on camouflage and ready access to road and rail links. Ongoing fieldwork and archival research will explore further the geography and archaeology of supply depots in the region while seeking to refine the typology of bunkers, their specific functions and capacity. The forests also offer a rare opportunity to marry the archaeological record of Allied bombing with documentary records of specific air-raids, and have the potential to enable an evaluation of the accuracy and effectiveness of US Ninth Air Force raids on German logistics networks in the Normandy campaign.

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Table 4: Summary of feature typology, depot associations and size ranges in the Forêt dom des Andaines

Forest	Location	Depot code	Petrol (cubic m)	%	Diesel (cubic m)	%	Total (cubic m)	%	
Westheer (Führer Reserve) Fuel Depots									
1	Forêt de la Guerche	La-Guerche-de-Bretagne	Bruno	866	24.7	110	13.6	976	22.6
2	Forêt dom des Andaines	Bagnoles-de-l'Orne	Berta	836	23.8	131	16.2	967	22.4
3	Forêt de Branguily	Pontivy	Brigitte	450	12.8	50	6.2	500	11.6
Seventh Army Fuel Depots									
4	--	Jersey	n/a	260	7.4	39	4.8	299	6.9
5	Bois de Pencran	Landerneau	n/a	222	6.3	73	9.0	295	6.8
6	Forêt dom du Gâvre	Blain	n/a	156	4.4	96	11.8	252	5.8
7	--	Guernsey	n/a	168	4.8	47	5.8	215	5.0
8	?	Rennes	n/a	122	3.5	31	3.8	153	3.5
9	Bois de Pannetière	Le Mans	n/a	113	3.2	28	3.5	141	3.3
10	?	Pluvigner	n/a	95	2.7	35	4.3	130	3.0
11	Bois de la Bigne?	Rouxeville (St. Lo)	n/a	58	1.7	30	3.7	88	2.0
12	Forêt Domaniale de St-Sauveur	St. Saviour-le-Vicomte	n/a	46	1.3	21	2.6	67	1.6
13	Forêt de Concise	St. Bertherin (Laval)	n/a	59	1.7	6	0.7	65	1.5
14	--	Alderney	n/a	30	0.9	25	3.1	55	1.3
15	?	Lamballe	n/a	2	0.1	40	4.9	42	1.0
16	?	Quimper	n/a	15	0.4	14	1.7	29	0.7
17	?	Noyers-Bocage (Caen)	n/a	8	0.2	16	2.0	24	0.6
18	?	Domfront	n/a	1	0.0	19	2.3	20	0.5
			Totals	3507	100	811	100	4318	100

Table 1: Locations and inventory of Westheer (Führer Reserve) and Seventh Army Fuel depots in NW France, June 5th, 1944 (NARA T312, 1571, 000607). Forest locations are inferred (where possible) from map evidence. For location map see Fig. 1.

Forest	Location	Depot Code	Stocks (tonnes)	%	
Munitions Depots					
1	Forêt de Rennes	Rennes	Maria	2650	14.1
2	Forêt de Quénécan	Loudéac	Manfred	2516	13.4
3	Forêt de Rennes	Rennes	Moritz	2340	12.5
4	Forêt de la Perche	Loudéac	Mathilde	2135	11.4
5	Forêt dom de St-Sever	Vire	Michel	2109	11.3
6	Forêt dom des Andaines	Bagnoles-de-l'Orne	Martha	2008	10.7
7	Forêt d'Araize	Châteaubriant	Martin	1925	10.3
8	Bois du Roi	Falaise	Margot	1638	8.7
9	Forêt Domaniale	Alençon	Max	1417	7.6
		Total		18738	100
Victuals (ration) Depots					
1	Forêt dom des Andaines	Bagnoles-de-l'Orne	Viktor	4200	36.5
2	Forêt de St. Méen	St. Méen-le-Grand	Venus	2700	23.5
3	urban	Pontivy	Verena	2300	20.0
4	urban	Ploërmel	Venedig	2300	20.0
		Total		11500	100
Clothing Depots					
1	urban	Loudéac	n/a	325	28.5
2	urban	Tours	n/a	285	25.0
3	urban	Flers	n/a	280	24.6
4	urban	Rennes	n/a	250	21.9
		Total		1140	100

Table 2: Locations and inventory of Seventh Army Munitions, Victuals (Rations) and Clothing depots in NW France, June 5th, 1944 (NARA T312, 1571, 000607). Forest locations are inferred (where possible) from map evidence. For location map see Fig. 1.

Site / Locality	Feature no.	Forest plot	a-axis (m)	b-axis (m)	Diameter (m)	Depth	a-axis orientation (degrees N)	Feature class	Artefacts / comments
Bagnoles-de-l'Orne (Martha)									
Locality A	A1		9.8	6.2		2	310	Type Ia (munitions)	
	A2		9.9	6.3		2	320	Type Ia (munitions)	Shell casings (75mm)
	A3		11.3	6.8		2	290	Type Ia (munitions)	Shell casings (37mm)
	A4		10	6.3		2.1	345	Type Ia (munitions)	
	A5		9.8	6.1		1.5	332	Type Ia (munitions)	Shell casings (88mm)
	A6		10.2	6.9		1.5	318	Type Ia (munitions)	Shell casings (88 and 105mm)
	A7		10.3	6.9		1.5	322	Type Ia (munitions)	Shell casings (105mm)
	A8		13.1	8.4		3	310	Type Ib (munitions)	Shell casings (105mm)
	A9		13.1	8.3		3	312	Type Ib (munitions)	
	A10		13.3	8		3.3	240	Type Ib (munitions)	
	A11		13.2	8.2		2	310	Type Ib (munitions)	
	A12		21.7					Unclassified	Semi circular depression with berms
Locality B	B1		10.4	5.8		2.5	360	Type Va (vehicle shelter)	
	B2		9.8	7.5		4	342	Type Va (vehicle shelter)	
	B3		8.6	5.8		1.5-2	355	Type Va (vehicle shelter)	
	B4		7.4	5.9		5	352	Type Va (vehicle shelter)	
	B5		2	2		1.5		Unclassified	hollow to east of parks
	B6-12		1.3	1		0.5		Type VIa (foxhole)	7 foxholes, 5-5.5m spaced, behind vehicle parks
Locality C	C1-17							Type Vb (vehicle shelter)	Series of 17 parks, truncated by road widening zigzag
	C18							Type VIb (trench)	
	C19				10.9	4 to 5		Bomb crater	
	C20		9.7	4.5		1	334	Type Vb (vehicle shelter)	
	C21		9.1	5.4		2	340	Type Vb (vehicle shelter)	
	C22		9.4	5.6		1.5	340	Type Vb (vehicle shelter)	
	C23		8.3	5.1		1	335	Type Vb (vehicle shelter)	
	C24		9.1	4.9		1	340	Type Vb (vehicle shelter)	

Domfront - St.-Michel-des-Andaines (Berta)

Locality D	D1	32.4	4.1	1.5	320	Type II (fuel)	
	D2	32.2	4.2	1.5	320	Type II (fuel)	
	D3	30	4.9	1.5	345	Type II (fuel)	
	D4	30.6	5.1	1.5	310	Type II (fuel)	
Locality E	E1	18.8	7.5	1.5	300	Type III (fuel?)	
	E2	18.4	8	1.5	330	Type III (fuel?)	
	E3	14.7	5.8	1.5	320	Type III (fuel?)	
	E4	16.4	6.2	1.5	290	Type III (fuel?)	
		12.1 /	5.9 /				
	E5	12.5	6.1	1.5	318 / 360	Type III (fuel?)	composite feature
E6	16.5	7.7	1.5	285	Type III (fuel?)		
Locality F	F1	18.2	7.8	2	210	Type III (fuel?)	Impacted by bomb crater (8.7m diameter)
	F2	15.7	6.8	1	20	Type III (fuel?)	Impacted by bomb crater (9.5m diameter)
	F3	14.8	9.9	1	10	Type III (fuel?)	Impacted by bomb crater (10.7m diameter)
	F4	16.5	11	0.5	135	Type III (fuel?)	Impacted by bomb craters (2.5m diameter); remains of 45 gallon fuel drum
	F5	1.1	1			Type VIa (foxhole)	
	F6	1.5	1			Type VIa (foxhole)	
	F7	1.5	1			Type VIa (foxhole)	
	F8	3	3			Unclassified	
	F9			7.3		Bomb crater	
	F10			8.6		Bomb crater	
	F11			8.9		Bomb crater	
	F12			8.7		Bomb crater	

Le Manoir du Lys (Viktor)

Locality G	G1-7					Type IV (victuals)	Western extent of Type IV features
	G8	18.4	11.4	5	45	Type IV (victuals)	
	G9	22	14.5	6	10	Type IV (victuals)	
	G10	16.8	10.8	6	360	Type IV (victuals)	Various tins, containers and buckets
	G11	22.5	14.3	6	335	Type IV (victuals)	
	G12	20.6	14.4	8	328	Type IV (victuals)	Bucket
	G13-16					Type IV (victuals)	Eastern extent of Type IV features

Table 3: Description and interpretation of recorded archaeological features in the Forêt dom des Andaines. See Figs. 2, 4 and 5 for location.

Feature Type	Interpretation	Depot	A-axis size range (m)	B-axis size range (m)	Depth range (m)
Ia	Munitions	Martha	9.8-13.3	6.1-8.4	1.5-2.1
Ib	Munitions	Martha	13.1-13.3	8-8.4	2-3.3
II	Fuel	Berta	30-32.4	4.1-5.1	1.5
III	Fuel	Berta	14.7-18.8	5.8-11	0.5-2
IV	Victuals	Viktor	16.8-22.5	10.8-14.5	5-8
Va	Vehicle shelter	Martha / Berta	7.4-10.4	5.8-7.5	1.5-4
Vb	Vehicle shelter	Martha / Berta	8.3-9.7	4.5-5.6	1-2
VI a	Foxhole	--	1.3	1	0.5
VI b	Trench	--	--	--	--

Table 4: Summary of feature typology, depot association and size ranges in the Forêt dom des Andaines

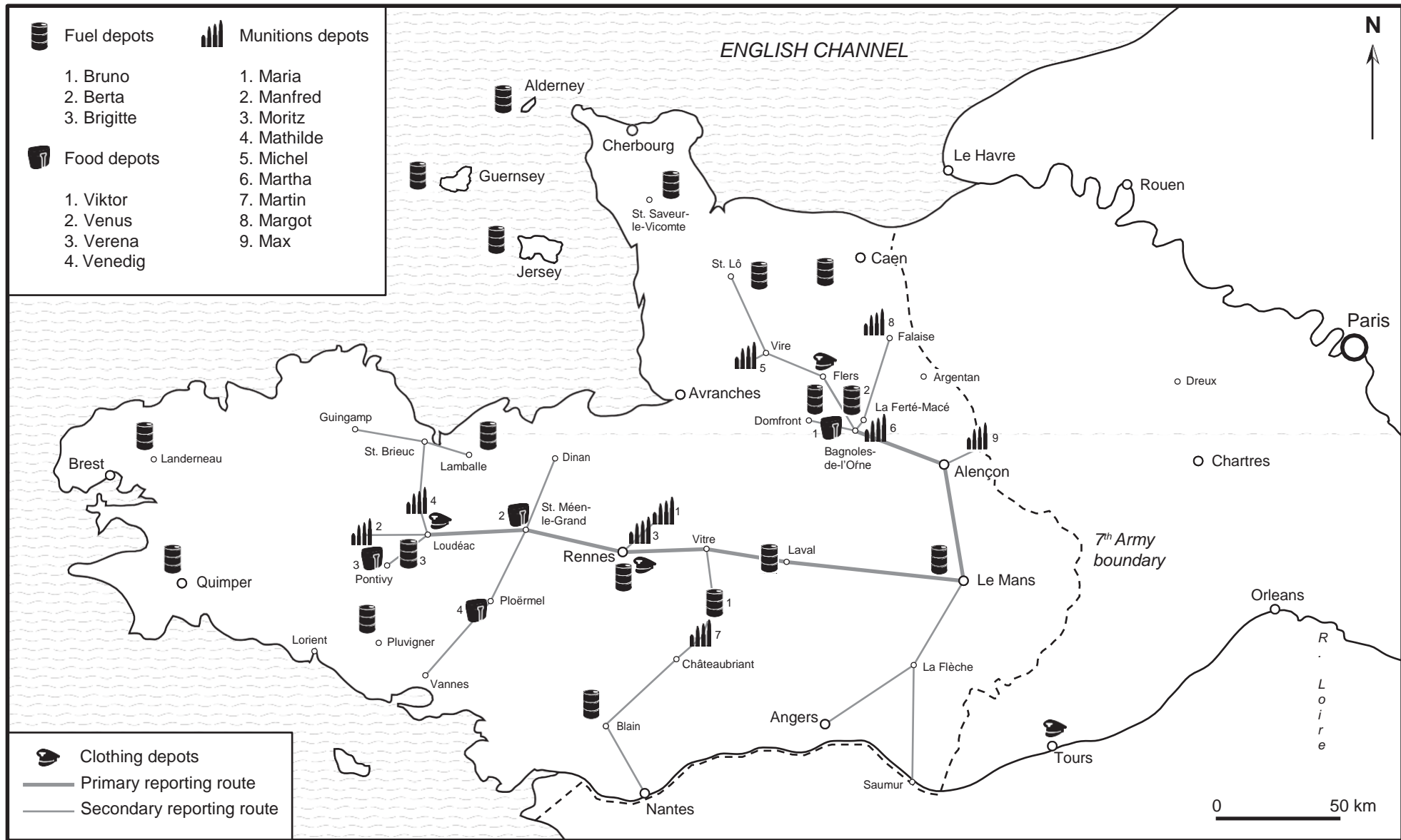


Figure 1: Map of NW France showing location of Seventh Army munitions, fuel, food and clothing supply depots as of June 5th, 1944 (NARA T312, 1571, 000607). Numbered sites are listed with code names.

Also shown are primary reporting routes for logistics command structures.

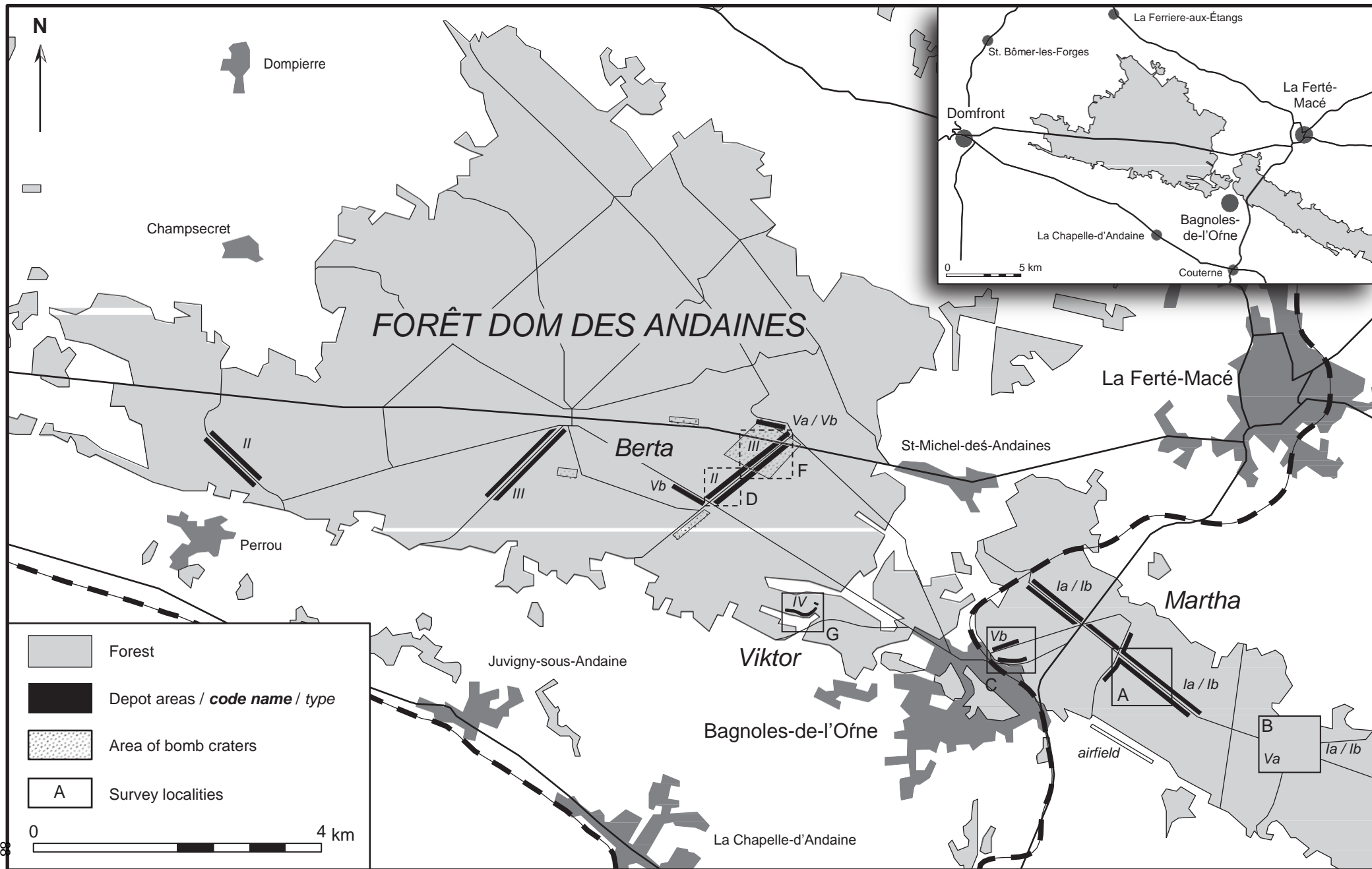


Figure 2: Map of the Forêt dom des Andaines showing major roads, selected forest roads, areas of surviving depot features and bomb craters, and survey localities.

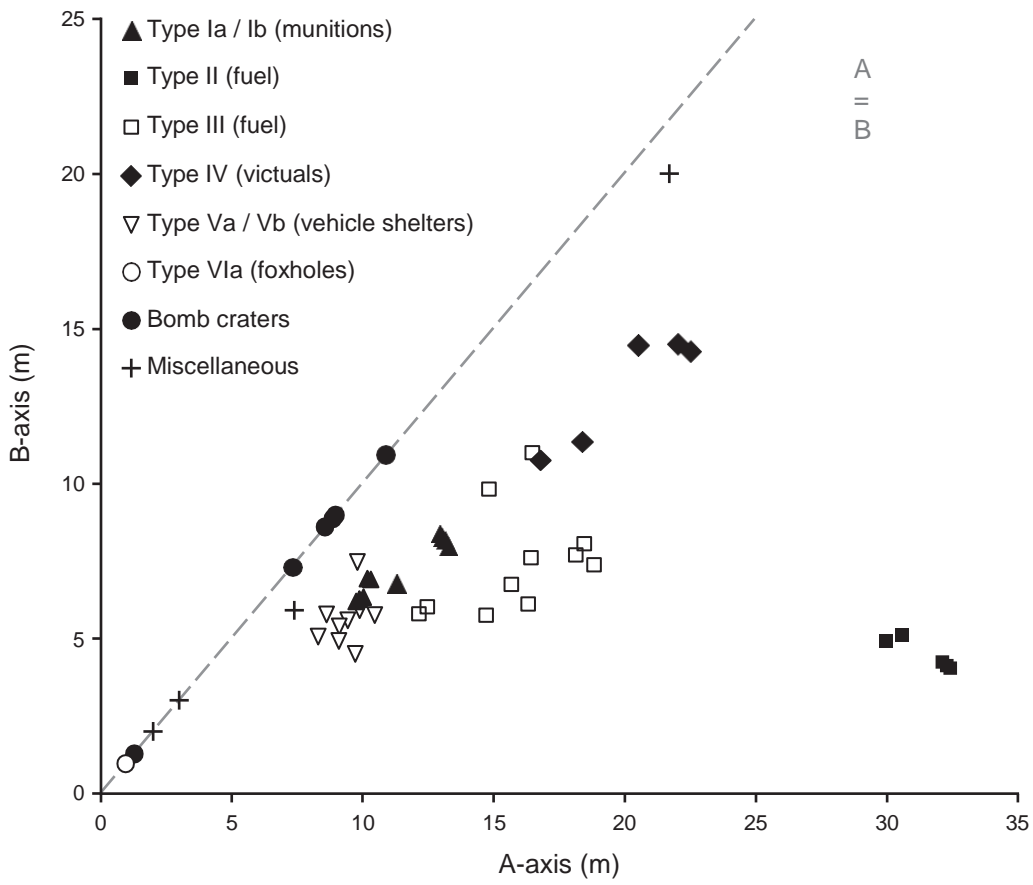


Figure 3: Plot of A and B axis length for feature types recorded the Forêt dom des Andaines.

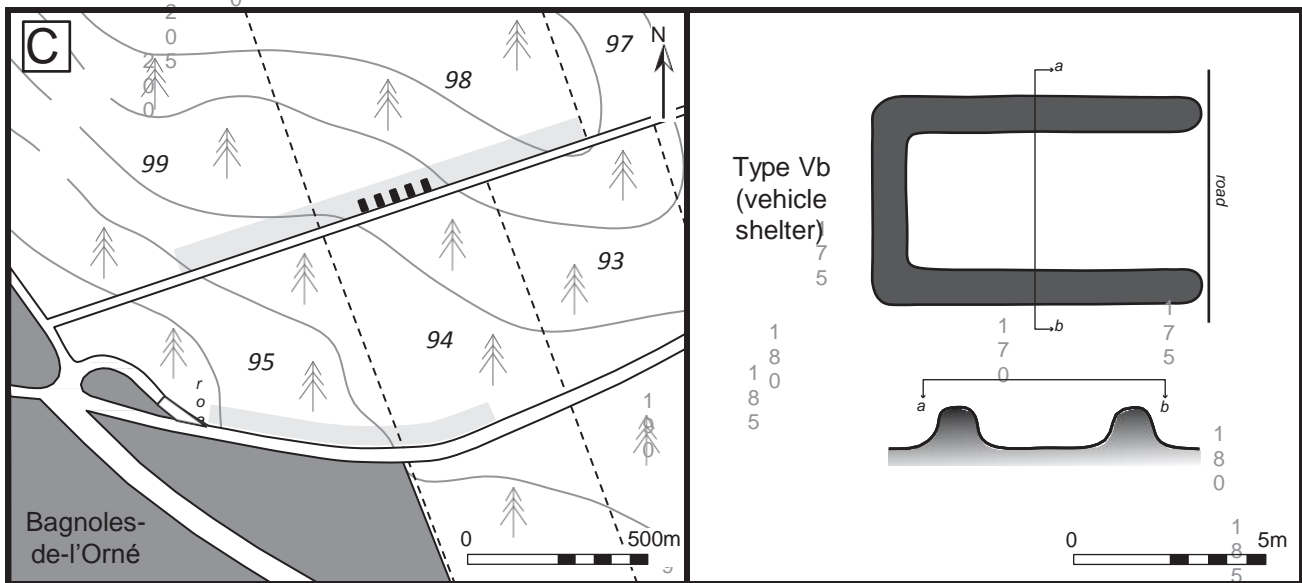
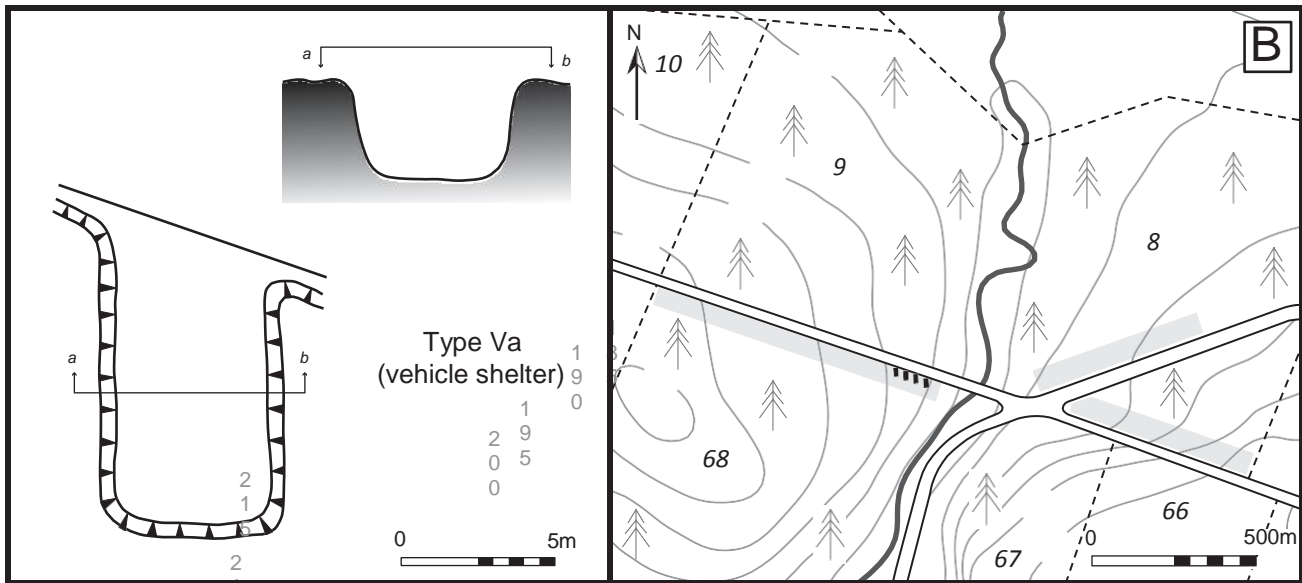
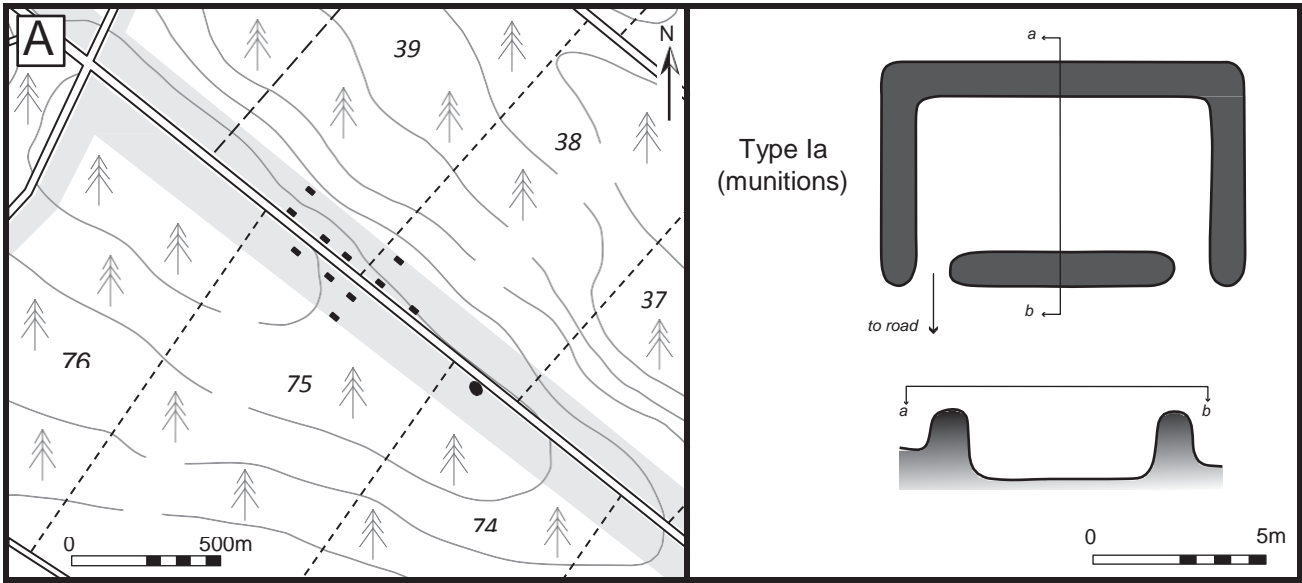


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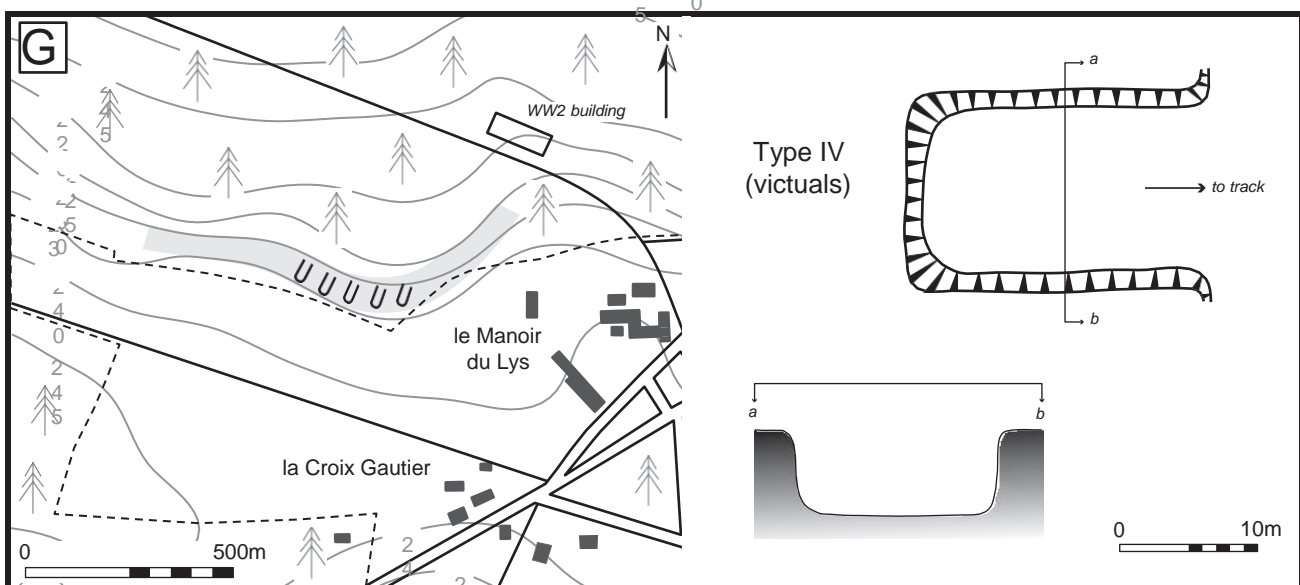
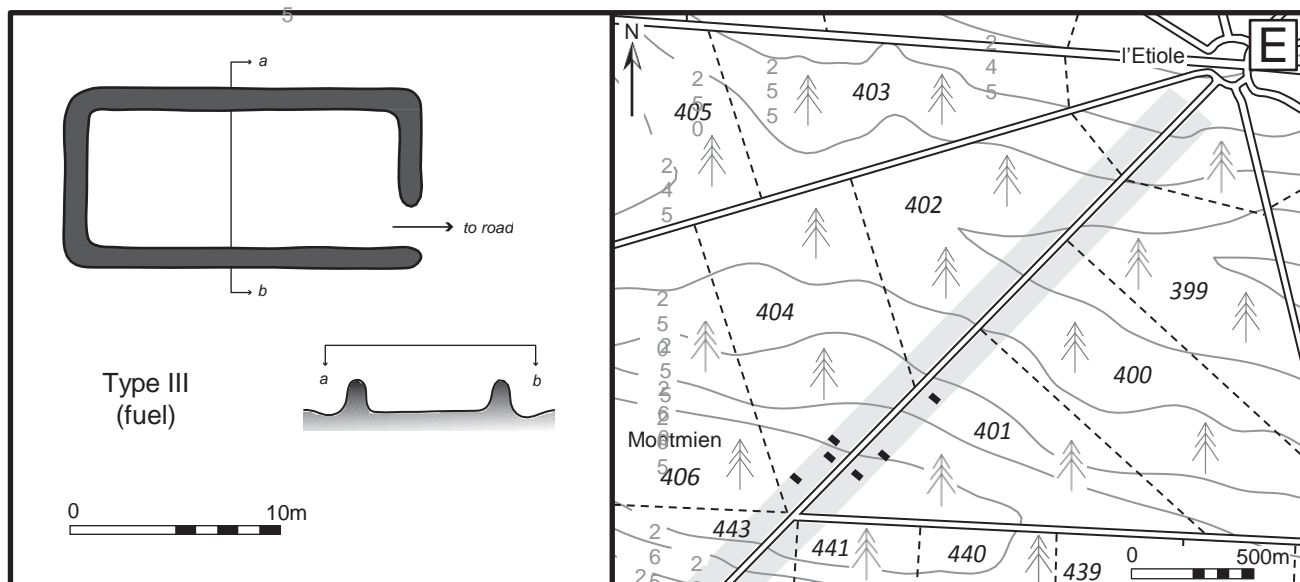
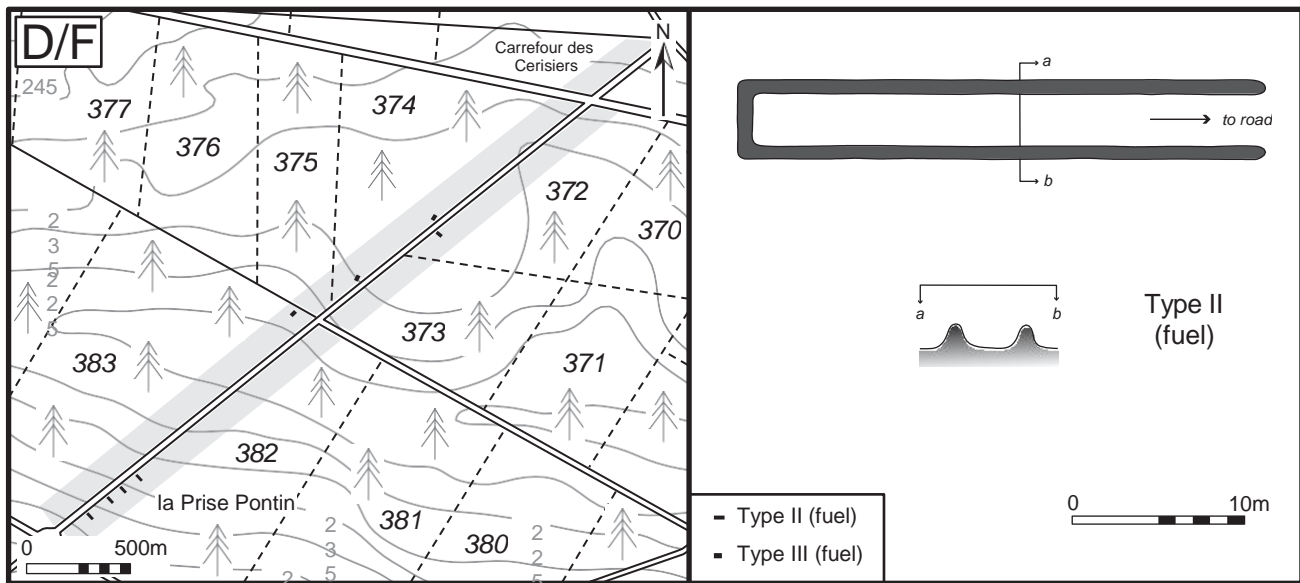


Figure 5: Schematic plans/profiles and locations of surveyed features in Localities D, F, E and G. Shaded areas indicate zones of feature disposition. Features shown on maps have been enlarged for clarity and are not to scale. See Fig. 2 for map of localities.



Figure 6: Example of Type Ib (munitions) bunker in Locality A, south side of Route Forestière de l'Épinette (D387). Photograph taken from bunker entrance.



Figure 7: Example of Type II (fuel) bunker in Locality D.



Figure 8: Example of Type IV (victuals) bunker in Locality G, near le Manoir du Lys.
Photograph taken from bunker entrance.



Figure 9: Example of Type Va bunker (vehicle shelter) in Locality B, south side of the Route Forestière de Cossé.



Figure 10: Multiple bomb craters in area of Type III (fuel) bunkers, Locality F.



Figure 11: Example of bomb crater associated with direct hit on Type III fuel bunker, Locality F.

Appendix II

Paper II:

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**Landscape archaeology of World War Two German logistics depots in the Forêt
domaniale des Andaines, Normandy, France**

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Abstract

Archaeological survey in the Forêt domaniale des Andaines has recorded nearly 900 discrete earthwork bunkers, building foundations, trenches and other features associated with WWII German fuel, munitions and logistics depots. Documentary evidence establishes these depots were administered from Bagnoles-de-l'Orne and were a key component of the Seventh Army logistics network before and during the Normandy Campaign of June-August 1944. Post-war survival of features has been remarkably good in this forested setting and it is argued that this likely constitutes one of the best-preserved and most extensive examples of a non-hardened WW2 archaeological landscape yet documented in western Europe.

Keywords: Conflict archaeology, Normandy, Logistics, Forests

Introduction

The study of military landscapes and historical archaeology has a long association that has its roots in the investigation of battlefield sites (e.g. Carman, 2005). This association has subsequently contributed to the fast-maturing discipline of conflict archaeology and its embrace of a broader perspective and analysis of military activities and their impact on landscapes, combatants and non-combatants (Forbes et al., 2009; Harrison and Schofield, 2010; Scott and McFeaters, 2011). Influential developments include attempts to conceptualise the geographical space over which military activities and events occur (e.g. Bleed and Scott, 2011), and the allied recognition that aspects of the military defence and support infrastructure, including fortifications (e.g. Osbourne, 2004), military bases and camps (e.g. Balicki, 2011) and PoW camps (e.g. Demuth, 2009), may not only form conspicuous elements of the present landscape but are also those places where the experience of war and military activity were played out for many military personnel and civilian populations (Geier et al., 2011).

Archaeological records of military support infrastructure are most extensively developed in 20th C conflict landscapes in Europe (Schofield, 2004; Forbes et al., 2009). This is perhaps not surprising given the scale of conflicts that have been fought (most notably with respect to WW1 and WW2) or anticipated (e.g. the Cold War), but it also reflects the often high level of material survival in the modern landscape (Coed, 2005) and the legitimisation of 20th C military monuments as a valued component of the heritage inventory (Dobinson et al., 1997; Schofield, 1998). At the time of writing, for example, the centenary of the outbreak of WW1 has lent particular impetus to the recording of a wide range of contemporary military defence and support facilities in Britain, including those associated with training, military hospitals and munitions production (<http://www.homefrontlegacy.org.uk>). To date, however, the most thoroughly documented military landscapes in Britain are those associated with WW2 and owe much to co-ordinated, nationwide recording programmes, notably the Defence of Britain Project (Saunders, 1998) and English Heritage commissioned thematic characterisations of the UK defence heritage (Schofield, 1998). Extensive surveys of this type demonstrate the value of establishing not only the geographical disposition of sites but also those features that are characteristic of particular site-types or locations (Schofield et al., 2006); monument types here include anti-invasion and aerial defence infrastructure (Osborne, 2004; 2008; Dobinson 2001), military bases and camps (Schofield et al., 2006), PoW camps (Thomas, 2003a and b), munitions storage facilities (Crutchley et al., 2009; Francis, 1997), air-raid shelters (Glass 2012) and the facilities associated with Allied preparations for D-Day and the invasion of northwest Europe, including the Mulberry harbour structures and PLUTO (Pipe-Line Under The Ocean) installations (e.g. Dobinson et al., 1997; Searle, 2004; Schofield, 2001).

Certain aspects of the WW2 landscape of continental NW Europe have also been well-documented, especially with respect to the imposing concrete of fixed fortification lines (e.g. Kaufmann and Jurga, 2002; Allcorn, 2003; Short, 2004; Zaloga, 2007) and large-scale military installations such as those associated with naval bases (e.g. Mallmann Showell, 2002; Williamson, 2003), air-raid shelters and flak towers (e.g. Richardson, 2008). In general, however, the wider military support infrastructure in this region has not benefited from the level of archaeological survey deployed in Britain and hence is barely represented in the published literature. In this paper we seek to make a contribution to redressing this imbalance by exploring the landscape archaeology of WW2 military logistics networks in Normandy, France.

The importance of military logistics in the history and geography of warfare has been well-documented (e.g. Lynn, 1993; Van Creveld, 2004) and, in the context of the Allied D-Day invasion and subsequent breakout campaign in June-August 1944, is understood to have been a decisive factor in conditioning the fighting abilities and strategies of both Allied and German forces (e.g. Neillands, 2002). Allied preparations for the Normandy invasion (and their archaeological signature) have been the focus of intensive historical study (Schofield, 2001; see above); once established on the European mainland, however, Allied forces tended to stockpile munitions and fuel containers in non-hardened facilities, including the landing beaches themselves and fields and roadsides inland (Mayo, 1968; Ruppenthal, 1995), reflecting (at least initially) the lack of captured port facilities and the relatively low threat of air attack under conditions of near-complete air superiority. The archaeological and landscape legacy of this activity is likely to be elusive and has certainly not been the focus of published academic enquiry.

Academic interest in German army logistics operations has, by contrast, focused largely on historical analysis of the transport network and Allied attempts to disrupt it (the ‘Transportation Plan’, Gooderson, 1998). Thus, while the supply dumps themselves are frequently mentioned in accounts of the Normandy Campaign (e.g. Isby 2004; Neillands 2002), and especially by Hart (1996; 2001), they have not been subject to a dedicated historical analysis and until recently had completely evaded archaeological attention. Recent work by Passmore et al. (2013; in press), however, has drawn attention to the German practice of locating supply depots in woodland locations that offered concealment from aerial observation, but which have also permitted an unusually good degree of archaeological preservation by comparison with urban and agricultural landscape settings. In particular, reconnaissance survey in the Forêt domaniale des Andaines, in the Basse-Normandie region of northwest France, has documented not only the well-preserved earthworks associated with fuel, munitions and rations depots in the woodlands, but also the bomb craters of Allied air raids intended to destroy them.

This paper builds on this pilot work in the Forêt domaniale des Andaines by presenting the first detailed and extensive survey of an archaeological landscape associated with a German Army (Heer) logistics complex in Western Europe. The survey work presented here aims to establish a base-line audit of this type of archaeological resource and the results are considered in the context of (i) logistics depots as militarised ‘occupation’ landscapes and their wider significance in Normandy’s WW2 heritage, (ii) an evolving typology of earthworks and other depot-related features and, briefly, (iii) the potential for analysing the scale, effectiveness and landscape impact of aerial bombing. In doing so we contribute to an emerging body of work that is demonstrating the propensity of forests to host some of the best preserved non-hardened WW2 landscapes in northwest Europe (e.g. Passmore & Harrison,

2008; Passmore et al., in press; Rass and Lohmeier, 2011) and the Nordic countries (Seitsonen and Herva, 2011; Seitsonen and Kunnas, 2009).

Background to the study area and historical context

The Forêt domaniale des Andaines (hereafter FDA) comprises c.55km² of mixed oak, beech, birch and pine woodland centred on the spa town of Bagnoles-de-l'Orne in the Orne département, Basse-Normandie region, NW France (Fig. 1). The forest covers a series of gently undulating northwest-southeast trending ridges and valleys that rise to a maximum elevation of 304m a.s.l. and is a major timber, wildlife and recreational resource at the heart of the Normandie-Maine Regional Natural Park. Woodland management is the responsibility of the Office National des Forêts (ONF). Harvesting and regeneration cycles vary according to growing conditions and commercial considerations with oak being thinned and then harvested between 50 and 180 years, beech between 40 years and 100 years and conifers after approximately 15 to 80 years (Serge Raison; Raison Bois et Debits, *pers comm*). The relatively low intensity of post-war management regimes is the key factor that has enabled preservation of the WW2 archaeological landscape in this setting.

With the growing threat of an Allied invasion of the NW European coast from 1943, the Heer began to seek forested sites for fixed supply bases that offered both good concealment from Allied air reconnaissance and ready access to the regional road and rail network. Located 85km south of the Normandy coastline, the FDA was selected in mid-1943 as the location for two major supply depots (Lagers), respectively for fuel (codenamed Lager Berta) and munitions (Lager Martha). Depot administration was based in Bagnoles-de-l'Orne (Fig. 1) which subsequently evolved as the central logistics hub (Stützpunkt) for the Seventh Army in the Normandy area. By November of 1943 the logistics officer (Major Lucas) was responsible

not only for depots in the local forest but was also overseeing day-to-day logistics operations at depots further afield (National Archives and Record Administration – NARA - T-312 R1562 000720), and by April 1944 the Stützpunkt had grown to take in depots to the north of Falaise (Lager Margot, 40km from the coast), north-east of Alençon (Lager Max, 90km from the coast) and to the north west near Vire (Lager Michel, 60km from the coast) (NARA T-312 R1570 001124) (Fig. 2).

The Lager Martha munitions depot was established in August 1943 in the forest to the north and east of Bagnoles-de-l'Orne (Fig. 1). Depot development required existing roads to be repaired or upgraded as well as the provision of new roads within the forest and construction of earthwork and timber bunkers for the handling and storage of munitions. Stocks of munitions arrived via the railway station at Bagnoles-de-l'Orne (Rougeyron, 1947) and were transported to Martha by lorry. Munitions stocks at Martha grew from 953 tons by the end of November 1943 (NARA T-312 R 1562 000926) to 2008 tons by the 1st June 1944 (NARA T-312 R1571 000607). A second phase of development was ordered in January 1944 to increase the total depot capacity from 2500 tons to 3500 tons (NARA T-312 R1567 000009). This expansion depot was located 1.5km east of the original depot and for the purposes of this paper is called Martha II (Fig. 1). During the battle for Normandy Martha was engaged in supplying combat units at the front for the entire period up until its capture on August 14th and escaped accurate targeting by Allied air forces despite its location having been reported to Allied intelligence by the French resistance on more than one occasion (Rougeyron, 1947; Series J Viel, Alençon Archives).

Lager Berta was commissioned in April 1943 in order to provide a 1000m³ fuel reserve for the lower Normandy region (NARA T-312 R1557 000133). In addition to the original depot

(hereafter identified as Berta I), located 5km northwest of Bagnoles-de-l'Orne, there were two other fuel facilities established in the FDA, respectively located in the center of the forest (hereafter Berta II) and towards its western margins (hereafter Berta III, completed just over two weeks before the invasion; NARA T-312 R1571 000304) (Fig. 1). Fuel stocks at Lager Berta grew from 500m³ in August 1943 (NARA T-312 R1557 000261) to 967m³ by June 1944 (NARA T-312 R1571 000607) with supplies being routed via a holding depot (Lager Beere) located at the railway station in Domfront on the western edge of the forest (Fig. 2). On the evening of the 13th June Berta I was accurately targeted by the American Ninth Army Air Force in a raid that destroyed 300m³ of fuel (NARA T-311 R14 0014539), and the site was targeted at least 17 times over the period to the 6th August. However, neither Berta II nor Berta III were significantly impacted by air raids.

In addition to fuel and munitions, the Bagnoles-de-l'Orne Stützpunkt controlled food reserves amounting to 4200 tons by June 1944 (NARA T-312 R1571 000607). These stocks were dispersed over three depots, located respectively in Domfront (Viktor I), Bagnoles-de-l'Orne (Viktor II) and 18km to the east near Carrouges (Viktor III) (Figs. 1 and 2). Viktor II was itself dispersed between sites in Bagnoles-de-l'Orne and a location within the forest behind the Manoir du Lys (Hairie 2007; Figs. 1 and 2). Movement of supplies within the forest and out to combat elements was initially facilitated by supply units under the control of the overall depot commander in Bagnoles-de-l'Orne; by the 31st May 1944 there were 64 trucks and 17 fuel tankers based locally (NARA T-312 1571 000456).

Methods

The identification, survey and analysis of logistics depots in the FDA is an extension of pilot work undertaken in the forest (Capps-Tunwell, unpublished data; Passmore et al., 2013) and

draws on a combination of archive documents, aerial photographs and non-invasive field survey. To the authors knowledge no detailed maps of depot features exist in the German records, but Seventh Army Quartermaster diaries from 1943 and 1944 (NARA T-312 – 1557,1562,1570 and1571) specify depot locations and stocking information. More detailed evidence of depot geography has been forthcoming from American records associated with targeting and bombing (Air Force Historical Research Agency AFHRA A5303) and French eyewitness testimony (Hairie, 2007; Herval, 1947). Vertical aerial photographs from the Institut Géographique National (IGN) taken between 1946 to 1949 have also proved to reveal bomb cratering and areas cleared by fire, demolition during depot abandonment and(or) post-war munitions disposal activities, and in some cases it is possible to locate individual munitions and fuel bunkers (Passmore *et al.*, in press).

Analysis of documentary and aerial photographic sources, in combination with fieldwalking, enabled specific areas of the forest to be targeted for detail field survey. Although there has been some degree of earthwork degradation and infilling during post-war times, both constructional and excavated features are generally readily identifiable on the forest floor and especially during winter months when vegetation dies back. Fieldwalking search patterns extended for 100m into the forest on both sides of forest roads and tracks. However, search patterns were locally extended deeper into the forest if features were identified close to the margin of transects. All identifiable features in the search areas were located using a combination of GPS and a laser rangefinder and measured for a- and b-axis length, a-axis orientation and maximum (unexcavated) depth between the feature floor and the ground surface or, where present, the top of adjacent berms. No attempt was made to excavate or disturb the ground surface in or adjacent to any of the features, although the presence of any surface artefacts was noted.

Features were classified using a revised and extended typology based on the pilot work reported in Passmore *et al.* (2013) and included several classes of feature that were hitherto unidentified, including variations on the original bunker types and a range of excavated and built structures. Field survey also extended to impact craters associated with Allied bombing although these results will be reported in a separate paper (Capps-Tunwell *et al.*, in preparation). All survey data, topographic maps and (georeferenced) aerial photographs were compiled in a GIS database that enabled both cross-checking of features identified by field survey and aerial imagery, and also analysis of feature disposition and spacing.

A typology of logistics depot features

Tables I-IV summarise the disposition and typologies, size ranges and depot associations for all archaeological features identified in the FDA, while Figure 3 illustrates the planform and cross-profile characteristics of the major earthwork bunkers and embayments.

Munitions bunkers

Munitions bunkers in the FDA survive as rectilinear, excavated pits with surrounding earthwork berms and have been differentiated on the basis of size into Type Ia and Type Ib features (Fig. 3; Table I). Type Ia bunkers form the vast majority of munitions facilities in Lager Martha with 60 examples located to date (Fig. 3 and 4). These features are on average 9.8m long by 5.9m wide (giving an internal measurement of c.8m by 4m), have an internal depth of 1.8m and are aligned parallel to adjacent forest roads and tracks. Surrounding berms are punctuated by two entry/exit points at each corner of the road-facing long-axis, and bunkers also feature drainage conduits piped through the berm or cut into the floors of bunker entrances and connecting with external drainage ditches.

These bunkers closely conform to formal specifications for munitions storage established in November 1943 (Kriegstagebuch A.O.K. 7 O.Qu /Qu.1; NARA T-312 R1562 000750). Designed to hold a powder weight of 5 tons (known as Net Explosive Quantity, or NEQ - a measure of the explosive power for a given weight), bunkers were specified with internal dimensions of 8m x 4m, an internal depth of 1.5m and two entry/exit points. The floors and internal walls were to be lined with wood planking and external protection by earth berms and a load-bearing ceiling covered with at least 40cm of soil. Later the same month it was specified that bunkers with an NEQ of 5 tons were to be positioned at least 35m apart (NARA T-312 R1562 000756). Type Ib bunkers follow the same pattern as Type Ia but are significantly larger, measuring on average 13.8m by 7.7m and 2.6m deep. Only 6 of these types have been identified in Lager Martha (Table I).

Contemporary photographic evidence of a stocked bunker in Lager Michel, near Vire (Laroze, 2004), confirms the provision of internal timber planking and a roof structure of corrugated iron over a timber frame. In the FDA there is little surviving evidence of constructional material with the exception of occasional pieces of timber framing. However, several bunkers were found to exhibit traces of crude stone facing on vertical interior walls that may have served as an alternative to planking.

Fuel bunkers

Fuel storage in the FDA is associated with two distinctive earthwork patterns, respectively classed as Type II and Type III bunkers (Fig. 3; Table I). Type II features are the most numerous of these bunkers with 79 identified to date. These are elongate, rectilinear and shallow constructional earthworks that connect directly with forest roads and tracks (Fig. 5).

They are open at the road end and are formed on the remaining three sides by a berm up to 1m high and with average planform dimensions of 24.5m by 4.5m (Figs. 3 and 5). Many of the bunkers are immediately surrounded by a shallow ditch. The configuration of these bunkers would seem most appropriate for the storage of Heer-standard 200 litre fuel drums that could be readily rolled into position, and this is supported by occasional field evidence of drum fragments (Fig. 6). Two variants on the Type II bunker have been identified that share similar width and depth dimensions but have differing planform morphology (Table I). Five examples of Type II features have classified as Type II (k) on account of their exhibiting a dog-leg kink in their planform morphology giving at least two angled lengths. Secondly, a single example has been classified as Type II (t) on the basis of its crude 'T' shaped planform.

Type III bunkers in the FDA form a series of shallow, rectilinear pits that resemble Type 1a and b munitions bunkers (Fig. 3), but are classed here as fuel (or related) storage facilities on account of their clear geographical association with fuel depots. They exhibit planforms with average dimensions in the order of 19m by 12m wide and are enclosed by berms with a typical height of 0.8m. In contrast to Type II bunkers these features are set back between 10-30m from the forest roads and are accessed via a single entrance / exit. Neither the Type II nor Type III bunkers appear to have been roofed, but it is likely that they would have been covered with camouflage netting to provide an additional degree of concealment (German Supply troops manual H.Dv 483, dated 8th December 1943; Imperial War Museum, German Army / Air Force Manuals Collection, Documents Archive, Duxford)

Rations / stores bunkers

Type IV features form the largest bunkers recorded in the FDA, being excavated or quarried embayments on average 17.8m long and 10.8m wide cut into wooded hillslopes (Figs. 3 and

7; Table II). They reach maximum depths (average 4.9m) at their rear wall and shallow to c.1m at the pit entrance where they open on to access tracks.

Vehicle shelters

Two types of vehicle shelter have been identified in the FDA; both open directly on to forest roads and share similar rectilinear planform dimensions, averaging 9m by 4m, but Type Va features form embayments excavated into roadside cuttings whereas Type Vb features are constructional with embanked berms on three sides (Figs 3 and 8; Table II). Both types of feature are generally positioned perpendicular or at a slight angle to the road. Interpretation of these features as vehicle shelters is supported by witness statements (Herval, 1947), but it is also accepted that they may have had a secondary use for munitions and(or) fuel storage when operationally expedient.

Control, security and personnel shelter features

A variety of excavated foxhole (Type VIa), trench (Type VIb-e) and dug-out (Type VI f) features have been identified in association with the various logistics depots (Table II; Fig. 9). They are found both in close association with storage bunkers and vehicle shelters, and also dispersed around the margins of the depot areas. The majority of these features broadly conform to earthwork illustrations in the German Fieldworks Leaflet 57/5 (of 15.9.1942/1.6.1944; see also Rottman, 2004) and are suited for one or two occupants. While examples of extended zig-zag trenches (Type VIb) are also in evidence at Lager Viktor and Lager Berta, they are not integrated with weapons emplacements or command and control dug-outs. Accordingly, these features are interpreted as having a primary role as shelter from air-raids or shelling, although they may also have been considered as having a defensive role if required. Only one example of an integrated defensive trench and weapons emplacement

network (Type VII; Table III) has been identified in the FDA, but this is remote from any of the logistics facilities and is perhaps most likely to have functioned as a field training facility (Capps-Tunwell *et al.*, in preparation).

Miscellaneous features

A number of other structures and features have also been included in the feature typology on the basis of their close association with depot complexes. These include concrete foundations and concrete / brick buildings (Type X; Table III) that probably had accommodation, storage or service functions, numerous examples of levelled earth platforms (Type XI; Table III) that may have hosted wooden structures and several large quarries with degraded remnants of internal structures (Type IX; Table III). The latter are considered most likely to have pre-dated the military occupation of the forest, but are likely to have been incorporated into depot activities.

A description of logistics depots in the Forêt domaniale des Andaines

Lager Martha I

Munitions bunkers associated with Lager Martha I are located on both sides of a near-continuous 4.3km stretch of the Route Forestière de l'Épinette (D387), an axial road occupying the crest of a northwest-southeast orientated ridge (the Massif de la Ferté-Macé) in the eastern part of the FDA between Bagnoles-de-l'Orne and La Ferté-Macé (Figs. 1 and 10). Examples are also found alongside a further 1.5km of minor forest roads perpendicular to, and intersecting the D387 to the northeast of Bagnoles-de-l'Orne (Fig. 10). Bunkers are generally spaced between 50-100m apart and form either one or two broadly parallel rows between 10-30m and also c.100m from the road, respectively (Fig. 10). The majority of bunkers are of the Type Ia class (totalling 28 clearly identified and 58 damaged examples; Fig. 4), but five Type

Ib examples are also present along the D387 (Forest Parcel 75) and a further example has been identified to the north of the D387 in Forest Parcel 40 (Fig. 10).

Bunkers are best preserved in the area directly east of Bagnoles-de-l'Orne, but elsewhere they exhibit varying degrees of damage and degradation and these parts of the forest coincide with aerial photographic evidence of forest clearance and burn-out sometime between 1944 and 1946 (IGN 1946 181 V 23 Av). In some areas damage to bunkers is a result of late- or post-war demolitions and ordnance disposal – this is locally the case in Forest Parcels 34 to 39 and 73,74,76,84 and 89 (IGN 1946 181/187 V 23 Av), and also in Forest Parcels 41, 42 (IGN 1949 1416-1716 135) and 73 (IGN 1949 F1416-1716 0135) where fresh demolition craters are evident on 1946 aerial images and survive in the present landscape. It is interesting to note that aerial photography from 1946 (IGN 1946 187 V 23 Av) clearly shows munitions stacks located adjacent to bunkers in Forest Parcels 48-49 and 89 and which are assumed here to be associated with post-war clearance. Ruptured shell casings associated with 37mm, 75mm, 88mm, 105mm and 150mm ordnance are still evident in many of the bunkers that survive on the modern forest floor, and present forestry operations continue to unearth unexploded munitions (Fig. 11).

Several other feature types are also evident in Martha I, including seven examples of Type Va vehicle shelters (Forest Parcels 34 and 42, Fig. 10), numerous personal shelter and security features, especially foxholes (Type VIa), slit trenches (Type VIe) and occasional dug-outs (Type VI f; Fig. 10), and examples of Type XI foundation platforms. Some additional archaeological features have been recorded at Martha I but have not yet been fully surveyed or formally classified. These include a series of degraded berms – possibly forming embayments – set back c.40m from the D387 in Forest Parcel 75 and, towards the eastern

margin of Martha I, in the northern part of Forest Parcels 71 and 72 (Fig. 10), a complex of earthworks forming a large, levelled sub-rectangular area with surrounding embayments. This facility is accessed by a network of forest tracks that link to the D387 and the D20.

Immediately to the east, south of the junction of the D387 and D20, there are also three earthworks cut into the roadside banks. The location and ready accessibility of these features suggest they may have functioned as handling areas for reception and(or) despatch of munitions, including perhaps empty casings and faulty ammunition (the latter in accordance with munitions stowage and handling guidance; Merkblatt 22/6, dated 20/2/1944).

Finally, documentary sources describe three small barrack buildings built near the Carrefour De l'Épinette (Fig. 10) to house colonial prisoners of war who were employed within Martha (Hairie 2007). No traces of these features were evident during fieldwalking, but it is noted that foundation impressions are evident on 1946 aerial photographs (IGN 1946 191 V 23 Av).

Lager Martha II

Lager Martha II is located 1.5km east of Martha I and extends from the junction of the D270 and D387 (Carrefour du Grand Evier) 1km northeast along both sides of the former road (Figs. 1 and 12). Developed as an expansion depot to Martha I, this is a smaller facility with at least 32 well-preserved munitions bunkers (Tables I and IV). The bunker array features a gap in the middle part of the depot and, since there is little apparent evidence of local post-war disposal activity on aerial photographs (IGN 1949 1416-1716 0137), this must either reflect the original depot configuration or is the result of localised forestry operations (Fig. 12). All Martha II bunkers have been classified as Type Ia although they are slightly smaller than those at Martha I, averaging 8.8m by 5.3m, and are shallower in depth (averaging 1.0m; Table I). The three bunkers on the south side of the Carrefour du Grand Evier exhibit a slight

variation on the Type Ia configuration since they are partially excavated into the rising slope (Forest Parcel 67; Fig. 12). Bunker spacing is typically in the order of 40m and along the D270 they form two rows of bunkers respectively set back 10m and 50m from the road. On the south side of the D270 in Forest Parcel 8 three bunkers have been placed around the top of a quarry with their openings facing away from the pit (Fig. 12). Two Type XI earth platforms in the western part of Martha II are located close to the road (Fig. 12) and are presently assumed to relate to local depot access control or administration.

On the western margin of Martha II an array of 14 Type Va vehicle shelters are dug into the southern roadside bank of the D387 (Fig. 12) at a slight angle to the road. Examples at the eastern end of the array also feature shallow platforms cut into the slopes behind and are provided with several foxholes (Type VIa; Fig. 12). A Type VIII foundation platform is located immediately adjacent to the road at the eastern end of the feature cluster and this may reflect a local administration facility or access control.

Lager Berta I

Lager Berta I is located in the central part of the forest 2km west of St-Michel-deś-Andaines and is the most easterly of the three fuel depots in the FDA (Figs. 1 and 13). The depot is based on a 1.3km stretch of the Route Forestière du Gué Besnard, a relatively minor road that connects with the axial D908 forming the main road between Domfront and La Ferté-Macé (Fig. 13). Berta I was repeatedly targeted by Allied air raids during the Normandy campaign and large areas of the forest floor remain heavily cratered to the present day, notably in Forest Parcels 374-378 and also 382-384 (Figs. 13 and 14; Capps Tunwell *et al.*, in preparation). These parcels have been subsequently replanted with conifers although Parcels 382 and 383, being only partially struck, have been left as deciduous woodland (see also Passmore *et al.*,

2013). The level of ground disturbance in these areas has obliterated or degraded the original depot structures such that field survey here is limited to clearly identifiable features only and will no doubt underestimate the original number of bunkers and other possible depot holding facilities.

The majority of fuel bunkers at Berta I are of the Type II variety (43 examples, including five Type II(k) and one Type II(t); Fig. 5), although 15 Type III bunkers have been identified in the northern part of the depot in Forest Parcels 374 and 375 (Fig. 13). Most of the bunkers are located adjacent to, or close to the Route Forestière du Gué Besnard and are spaced at c.30–50m intervals, but the depot also extends along minor forest roads and tracks that are partially visible on 1949 aerial images (IGN 1949 F1416-1716 0052) and which locally are evident on the modern forest floor. An isolated Type II bunker has also been located c.110m from the D355 on the southwest margin of the depot and some 500m distant from the main depot cluster in Forest Parcel 384 (Fig. 13). This area has experienced both aerial attack and post war forestry activity and hence it is possible that this isolated feature was one of a series of features which no longer survive in the landscape.

In addition to fuel storage facilities, Berta I is supported by two large vehicle parks located at either end of the depot, respectively to the northeast in the vicinity of the Carrefour Ferrière and the axial D908 (15 vehicle shelters) and to the southwest along the D355 (24 vehicle shelters) (Fig. 13). Examples of both Type Va (on level ground) and Type Vb shelters (cut into roadside embankments) are present in each of the parks, and at least five further examples of Type Vb vehicle shelters are evident within Berta I itself (Forest Parcels 272, 373 and 375; Fig. 13).

A wide range of Type VIb-f control, security and personnel shelter features have been identified in and close to Berta I. These are clustered in the central part of the depot and in close association with the vehicle parks at the Carrefour Ferrière and the D355 (Fig. 13). Several Type XI earth foundation platforms are also evident in or near the depot, most notably in the area close to the Route Forestière du Gué Besnard, and to the south near the D355 and the associated vehicle park. The function of these platforms remains unknown although the example near the Carrefour des Cerisiers is considered to reflect the site of a guard-house that was identified on an Escape and Evasion map (NARA, E&E report E-380 McConnel, December 1943). The remains of a small concrete structure on the eastern margin of the depot (Fig. 13) are also of interest as the sole example of a ‘hard’ structure found within the Berta complex. The function of this building has not been confirmed but is perhaps most likely to have served as a depot administration facility.

Lager Berta II

Located 3km west of Berta I, Lager Berta II lies astride a 2.5km stretch of the Route Forestière de Juvigny immediately south of the major road junction with the D908 at l’Etoile (Figs. 1 and 15). Depot features here are located in two distinct clusters that are separated by a gap of some 200m (Fig. 15). At present it is unclear whether this gap reflects the original depot configuration or the loss of archaeological features to post-war forestry operations – it is unlikely to reflect bomb damage since aerial photographs taken in 1949 (IGN 1949 F1416-1716 0056) and landscape evidence reveal only isolated craters in Forest Parcel 404 to the north, none of which appear to have struck any identifiable features.

A total of 23 fuel bunkers have been identified at Berta II, there being 11 examples each of Type II and Type III designs and a sole example of a Type II(k) (Fig. 15; Tables I and IV).

Bunker spacing at this site ranges between 30m and 50m. In addition to fuel bunkers there are five Type XI foundation platforms located within the depot, all of which are found in close association with Type II bunkers. A striking feature of Berta II is the near-encirclement of the depot by at least 122 Type VIe slit trenches lying up to 150m from the nearest fuel bunker (Fig. 15).

Lager Berta III

Lager Berta III is developed in the western part of the FDA near the village of Perrou (Figs. 1 and 16). It extends over 2km of the D52 south of its junction with the D908 and close to the southern margin of the forest. A total of 42 fuel bunkers are preserved at Berta III although intensive forestry operations (especially in Forest Parcels 470 and 469) have locally replaced the wartime deciduous cover with conifers and are considered to have obscured at least part of the original depot extent. Berta III fuel bunkers are exclusively of the Type II design, including nine Type II(k) and one Type II(t) variants (Tables I and IV) and are spaced c.30-50m apart. Examples lying adjacent to the D52 open directly on to the road or are connected via a short forest track, while those features forming a second row of installations in Parcel 468 are accessed via a 300m loop of forest track (Fig. 16). Several Type XI foundation platforms have also been identified within the depot area but, and in contrast to depot configurations at Berta I and II, evidence for small-scale control, security and personnel shelter features (Type VIb-c and VIe-f variants) are limited to clusters at the northern and southern limits of the depot (Fig. 16). At least some of these features may have functioned to control access to the depot in addition to providing air-raid protection.

Lager Viktor II

The forest-based component of Lager Viktor II was established on a north-facing valley-side slope on the southern margins of the FDA near La Croix Gautier and le Manoir du Lys, 2km northwest of Bagnoles-de-l'Orne (Figs. 1 and 17). Access to this depot was via a gravel track running off a minor forest road linking the D235 and D335. The greater amount of rations storage at this site was provided by 15 Type IV embayments cut into the north-facing side of the ridge, spaced c.15m apart and opening directly on to the depot road (Figs. 7 and 17). A number of small security and control features are evident at the depot, including a Type X foundation platform at the eastern entrance to the site which is clearly evident on a 1949 aerial photograph (IGN 1949 F1416-1716 0130) and is interpreted here as an administration or guard post (see also Hairie 2007). Some 400m to the northeast of the main depot a discrete cluster of Type VIe features lie adjacent to the link road between the D235 and D335 (Fig. 17) and may have served to control depot access.

The site at the Manoir du Lys is unique in the context of logistics facilities in the FDA in that it appears to have comprised a number of substantial built structures in addition to an array of earthworks. One of these structures survives today as a large derelict brick building on the northeast margin of the site (Fig. 18). Described by Hairie (2007) as a wartime piggery, this building may have some association with a Heer butchery company recorded as being located in Bagnoles-de-l'Orne after retreating from St Lo in June 1944 (NARA T-312 R1562). A rendering tank lies in the immediate locality of this building. To the north and west of the Type IV embayment array there are also nine broadly parallel Type X concrete and brick building foundation platforms (Fig. 17). These features have 28m by 5m rectilinear platforms that are close to the specifications for storage sheds and barrack blocks outlined in Seventh Army Quartermaster diaries (NARA T-312 R 1562 000425).

A large vehicle park on the forest margin immediately east of Bagnoles-de-l'Orne (Fig. 17) is described here in the context of Viktor II, although transport provision based at this central location may also have served other depots in the FDA. The park comprises two groups of Type Vb shelters respectively located adjacent to the D235 (Forest Parcels 93-95) and on the north side of the Route Forestière des Treize Niegés (Forest Parcels 98-99) (Fig. 17). Post-war road widening has locally truncated and partially infilled the entrances to many of these shelters and especially those along the D235. Both groups are associated with numerous examples of Type VI control, security and personnel shelter features, but the D235 site is unusual in that it also features an extended Type VIb zig-zag trench set back 5-10m behind the vehicle shelters and extending for some 400m in Forest Parcels 94 and 95 (Fig. 17). This trench complex does not exhibit any weapons emplacements (*cf.* Bildheft neuzeitlicher Stellungsbau, 1.6.1944) and hence it is interpreted as having a primary role as air-raid shelter.

Discussion

Extended field survey reported here has confirmed the broad geographical disposition of depots and vehicle parks previously outlined in the FDA by Passmore et al. (2013), although they are larger than originally recognised and possessed of a more diverse range of bunker types and, especially, associated security and administration features. It is also evident that depots were not solely established along primary forest roads but also utilised access tracks looping into the forest. In combination, the conflict archaeology landscape in the FDA can now be reported to extend along some 14.5km of forest roads and tracks and comprise at least 898 discrete features (Fig. 1; Table IV). Furthermore, this count excludes the record of individual bomb craters and areas with multiple, overlapping craters which have yet to be fully evaluated. To the authors' knowledge this represents the highest concentration of non-hardened earthworks and field fortifications yet to be formally recorded and published in

western Europe, and secures the status of regional forests as hosting some of the richest, yet least well-documented archaeological resources of WW2 (Passmore et al., in press).

Site preservation factors in the FDA owe much to a combination of circumstances that begins with a strategic decision on the part of the Heer to locate its major logistics facilities in forested locations offering concealment from aerial (and to some extent ground-based) observation and good transport links to the regional road and rail networks. Depots and their associated vehicle parks then appear to have suffered variable, and in some cases little or no damage through deliberate Allied bombing during the Normandy campaign and by demolition and post-war ordnance disposal efforts – all of which have left a landscape legacy that itself augments the conflict archaeology record. Thereafter, the landscape has experienced relatively minor and localised (inadvertent) degradation associated with post-war road improvements and forestry operations. The impact of woodland management appears to have been mitigated, at least in part, by difficulties in harvesting bomb-cratered forest plots and the reduced demand for timber contaminated by shrapnel.

The military landscape of the FDA

In 1944 the siting of depot sites in the FDA will have placed severe limitations on the economic exploitation of the forest resources (see also Pearson, 2006, for a Vichy France perspective) while also constituting one of the most prominent physical landscape manifestations of German occupation outside of the fortified coastal zone. Access to the depot facilities will, however, have been limited to military personnel and a small contingent of civilian and PoW workers (Haire 2007; NARA T-312 1571 000456), and hence it is the perimeter security measures that will have framed the typical civilian perceptions of the

facilities. Small Type XI building platforms located adjacent to forest roads and tracks, sometimes in association with small embayments for barriers or gates, present the most convincing extant manifestation of access control to depots and vehicle parks. Beyond the road and track network, however, the archaeological record is equivocal with respect to perimeter security. Patrolled barbed wire barriers (“Flanders fences”; Seventh Army Quartermasters diary, NARA T-312 R1562 000667) are likely to have existed but have yet to be identified and while foxholes and trenches constitute the most numerous components of the archaeological landscape associated with logistics depots in the FDA, they do not form a clearly defined perimeter to the bunker layout and are assumed here to have the primary role of air-raid shelters. Establishing the character and location of depot boundaries and security measures thus remains a challenge for future work.

Today the military landscape of the FDA is open to public access (within the bounds of forestry operations and the very occasional clearance of freshly exposed live munitions) and the arrays of storage bunkers and vehicle shelters form conspicuous earthworks bounding the forest’s roads and tracks. Indeed, the Viktor II vehicle park and associated trenches on the D235 and north side of the Route Forestière des Treize Nieges, are located on the very periphery of Bagnoles-de-l’Orne. Yet these military landscapes have remained little explored by the archaeological or military history community. This is likely to reflect, at least in part, the primary focus of attention on the high-profile beachhead and battlefield sites in the region, but may also hint at ambivalence on the part of the local community towards a militarised landscape associated with an occupying power in a period that remains within living memory. A consideration of the FDA landscape as an example of ‘occupation archaeology’ raises interesting issues with regard to their perception in heritage narratives and public memory

(see, for example, Pearson, 2006 and Carr's analysis of the Channel Islands; 2010, 2012, 2014) and will be the focus of a follow-up paper.

Enhancing the typology of military logistics features

Extended survey of the FDA has augmented the original feature typology developed in Passmore *et al.* (2013) while also establishing a greatly enlarged database of features and their dimensions (Tables I-IV). The revised typology now includes hardened structures, particularly those associated with Viktor (II), but the vast majority of features in the Forest survive as excavated and/or constructional earthworks. This work has been informed by documentary records of bunker specifications, particularly with regard to the Type 1a munitions bunker, but no record has yet been found to account for the larger Type 1b variant. Formal specifications for the elongate Type II fuel bunkers are also lacking at present but we can be confident that these were designed for storage of 200 litre fuel drums, fragments of which are still to be found in and around the surviving bunkers (Fig. 6). Furthermore, it is interesting to note that the German Supply troops manual H.Dv 483 (dated 8th December 1943; Imperial War Museum, German Army / Air Force Manuals Collection, Documents Archive, Duxford) states that fuel stacks were to be spaced no closer than 30 m and this is consistent with survey data. It remains unclear, however, whether the rectilinear Type III bunkers hosted fuel in different containers (e.g. jerrycans) or were perhaps intended for diesel fuel storage or other materiel. Ongoing work is seeking to address these issues, and encompass new feature types not present in the FDA, by developing a regional perspective on Heer (and also Luftwaffe) munitions and fuel storage practice.

The landscape record of aerial bombing

Investigations of conflict heritage, memory and commemoration in urban bomb sites and landscapes have emerged as a distinctive component of WW2 conflict archaeology, reflecting both the scale of urban destruction in Europe and Japan and - especially - its resonance with regard to the civilian experience of modern warfare (Schofield, 2002; Toyofumi, 1994; Moshenska, 2009; 2013). Comparatively little attention has been paid, by contrast, to the landscape evidence of bombing of non-urban military targets, not least because the targets themselves and associated cratered terrain has rarely survived post-war landscape rehabilitation. Accordingly the bombscapes preserved in the FDA not only constitute a very rare and evocative landscape in their own right (Passmore *et al.*, in press), but also invite analysis of the scale, effectiveness and landscape impact of Allied bombing efforts. Consider, for example, the assumption that the bombing of the FDA on June 13th 1944 succeeded in ‘destroying’ the Berta fuel dump (Hart, 1996, p. 426); landscape evidence suggests this may be accurate with respect to Berta (I) which exhibits considerable – though hardly total – bomb damage, but it clearly does not apply to Berta (II) or (III), neither of which appears to have been significantly hit. It is also interesting to note that the OB West Quartermaster diary of 13th June reports a stock loss to this raid of 300m³ (NARA T-311 R14 014539) which compares to a depot capacity of c.1000m³ (note stocks reported as 976 m³ on June 1st NARA T-312 001571 000607). Accordingly, and while we do not yet know exactly how much of the Berta fuel stocks remained intact after the June 13th raid, we can be certain that the greater part of the facility (when considered across the three constituent depot sites) was undamaged and that it continued to operate for a period after July 2nd (Herval, 1947).

It is also striking that minimal or no bomb damage to bunkers has been identified in the area of Martha (I) and (II) and also the Viktor (II) depot. A more detailed analysis of the bombing

record in the Forest, which will include links to the Allied records of specific air raids, will be reported in a follow-up paper.

Conclusions

The German practice of siting major logistics depots in the Normandy forests for the purposes of concealment has also had the unforeseen consequence of promoting the survival of their archaeological landscapes. Although military earthworks have not been immune from destruction or degradation due to post-war forestry operations (see also Passmore and Harrison, 2008), the remarkable level and extent of preservation in the FDA has permitted mapping and classification of nearly 900 discrete features (excluding bomb-craters) and testifies to the significance of the Bagnoles-de-l'Orne Stützpunkt as a key component of the Seventh Army logistics network during the Normandy Campaign. The archaeological survey reported here represents the most intensive study of a site of this type in the region. Indeed, we believe this may well constitute one of the best-preserved and most extensive examples of a non-hardened WW2 archaeological landscape yet documented in western Europe.

Ongoing work in the FDA and in documentary archives is seeking to refine our understanding of the security, management and operational aspects of the depots and associated vehicle parks, and we also argue that the equally well-preserved landscape of aerial bombing will facilitate an enhanced study of the scale and effectiveness of Allied bombing and its landscape impact. Furthermore, the scale and nature of archaeological preservation in the FDA has prompted reconnaissance survey by the authors that indicates that there are equally good prospects for the preservation of both logistics facilities and the landscape evidence of Allied bombing in the forest and woodlands across Normandy, and also further afield in the hinterland of the Atlantic Wall and the forests of western Germany (Passmore et al., in press).

It is anticipated, therefore, that this work has much to offer our developing understanding of the capacity, organisation and interdiction of the Heer logistics network in the Normandy campaign and likely also the subsequent campaigns in the Western theatre of operations. It is also hoped that this will stimulate a new perspective on Normandy's WW2 heritage inventory that encompasses a wider range of monument types and their associated landscapes.

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Table I: Typology, location, construction and size details for Type I-III features in the Forêt domaniale des Andaines

<i>Feature / Depot</i>	No. of Features*	A-axis (m) Average (max-min)	B-axis (m) Average (max-min)	Depth (m) Average (max-min)
<i>Type Ia (munitions bunker; excavated with constructional berm)</i>				
Martha I	28	9.8 (11.6-8.2)	6.0 (7.3-4.7)	1.9 (2.4-1.0)
Martha II	32	8.8 (9.9-8.4)	5.3 (6.2-4.8)	1.0 (1.5-0.6)
total	60	9.3	5.6	1.5
<i>Type Ib (munitions bunker; excavated with constructional berm)</i>				
Martha I	6	13.8 (19.8-11.3)	7.7 (8.8-6.6)	2.6 (3.0-2.0)
<i>Type II (fuel bunker; excavated with constructional berm)</i>				
Berta I	37	24.8 (46.6-9.0)	4.4 (5.2-3.2)	1.0 (1.4-0.8)
Berta II	11	21.4 (40.3-15.8)	4.7 (5.3-3.8)	0.9 (1.2-0.7)
Berta III	31	28.0 (40.0-18.0)	4.4 (4.9-3.8)	0.9 (1.2-0.3)
total	79	24.7	4.5	0.9
<i>Type II(k) (fuel bunker; excavated with constructional berm)</i>				
Berta I	5	31.0 (34.9-26.9)	4.4 (4.5-3.9)	1.2 (1.6-0.9)
Berta II	1	23.0	5.5	1.0
Berta III	10	30.8 (37.5-19.7)	4.4 (4.8-3.8)	0.9 (1.4-0.7)
total	16	28.2	4.8	1.0
<i>Type II(t) (fuel bunker; excavated with constructional berm)</i>				
Berta I	1	16.3	4.8	1.0
Berta III	1	32.0	4.1	1.1
total	2			
<i>Type III (fuel bunker; excavated with constructional berm)</i>				
Berta I	15	19.0 (20.1-7.1)	11.9 (10.2-7.3)	0.8 (1.0-0.5)
Berta II	11	17.6 (22.6-13.7)	6.2 (7.7-5.0)	0.8 (1.0-0.7)
total	26	18.3	9.1	0.8

Table II: Typology, location, construction and size details for Type IV-VI features in the Forêt domaniale des Andaines

<i>Feature / Depot</i>	No. of Features*	A-axis (m) Average (max-min)	B-axis (m) Average (max-min)	Depth (m) Average (max-min)
<i>Type IV (logistics bunker; excavated)</i>				
Viktor	15	17.8 (19.9-15.9)	10.8 (11.8-9.4)	4.9 (7.0-3.0)
<i>Type Va (vehicle shelter; excavated)</i>				
Martha I	7	9.3 (12.8-7.3)	6.7 (7.5-5.4)	3.9 (4.1-2.7)
Martha II	11	8.3 (9.6-7.6)	5.2 (5.9-4.5)	2.4 (3.2-1.9)
Berta I	22	9.1 (8.8-7.6)	4.6 (5.0-4.9)	0.8 (1.2-0.2)
total	40	8.9	5.5	2.4
<i>Type Vb (vehicle shelter; excavated with constructional berm)</i>				
Berta I	19	9.1	5.4	1.2
<i>Type VIa (foxhole)</i>				
Martha , Viktor	14	1.2 (1.2-0.9)	1 (1.1-0.9)	0.6 (0.7-0.5)
<i>Type VIb (trench, zig-zag)</i>				
Berta, Viktor	6	12.7 (21.6-6.8)	1.6 (2.0-0.8)	0.9 (1.0-0.7)
<i>Type VIc (trench, v-shaped planform)</i>				
Berta, Martha, Viktor	10	4.4 (8.3-2.6)	0.8 (1.0-0.6)	0.7 (1.0-0.5)
<i>Type VI d (trench, complex)</i>				
Viktor	1		(Sited within an area of 560 m ²)	
<i>Type VIe (trench, slit)</i>				
All depots	122	1.9 (2.4-1.2)	1.1 (1.9-0.6)	0.5 (0.9-0.1)
<i>Type VI f (dug-out)</i>				
Berta, Martha	9	3.6 (4.5-2.5)	2.8 (3.9-2.0)	1.1 (1.6-0.2)

* italics indicate figures represent a sample of the feature population

Table III: Typology, location, construction and size details for Type VII-XI features in the Forêt domaniale des Andaines

<i>Feature / Depot</i>	No. of Features*	A-axis (m) Average (max-min)	B-axis (m) Average (max-min)	Depth (m) Average (max-min)
<i>Type VII (trench system)</i>				
Champ de Tir	1		(Sited within an area of 4702 m ²)	
<i>Type VIII (administration / security)</i>				
Berta, Martha	?	2.0	2.0	--
<i>Type IX (administration / support; re-used quarry)</i>				
Bagnoles				
<i>Type X (various; concrete / brick construction)</i>				
Berta, Viktor				
<i>Type XI (unknown; earth platform)</i>				
Berta I	11	9.3 (17.0-6.1)	6.8 (14.0-3.9)	--
Berta II	5	5.9 (7.1-5.2)	5.1 (6.3-4.7)	--
Martha I II	10	7.3 (8.4-6.0)	5.6 (7.5-3.6)	--
total	26	5.6	4.4	

Table IV: Summary of depot feature disposition and numbers in the Forêt domaniale des Andaines

Depot (Location)	Primary Use	Security	Vehicle	Logistics	Accommodation	Munitions	Munitions (damaged)	Fuel	Foundations / Various
Berta I	Fuel	104	43	--	--	--	--	58	17
Berta II	Fuel	122	--	--	--	--	--	23	5
Berta III	Fuel	20	--	--	--	--	--	42	6
Martha I	Munitions	154	7	--	--	34	58	--	19
Martha II	Munitions	15	14	--	--	32	--	--	1
Viktor (<i>Bagnoles-de-l'Orne</i>)	Transport	24	52	1	--	--	--	--	--
Viktor (<i>Manoir Du Lys</i>)	Logistics	21	--	17	9	--	--	--	--
<i>Totals</i>		<i>460</i>	<i>116</i>	<i>18</i>	<i>9</i>	<i>66</i>	<i>58</i>	<i>123</i>	<i>48</i>
									Stützpunkt total: 898

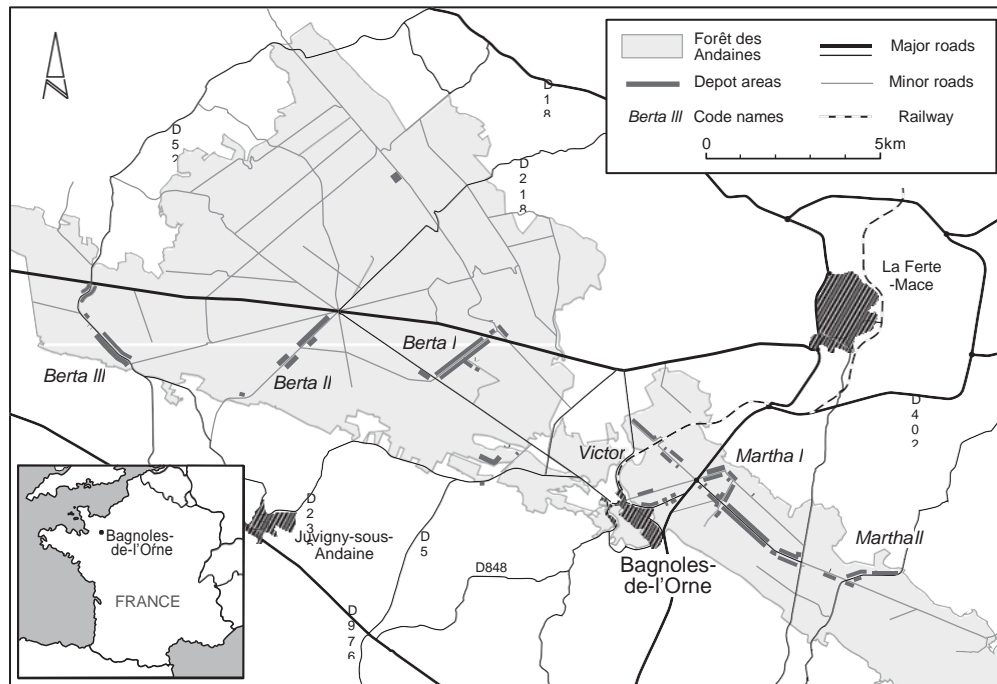


Figure 1. Map of the Forêt Domaniale des Andaines showing location and extent of logistics depots and modern road and rail network.

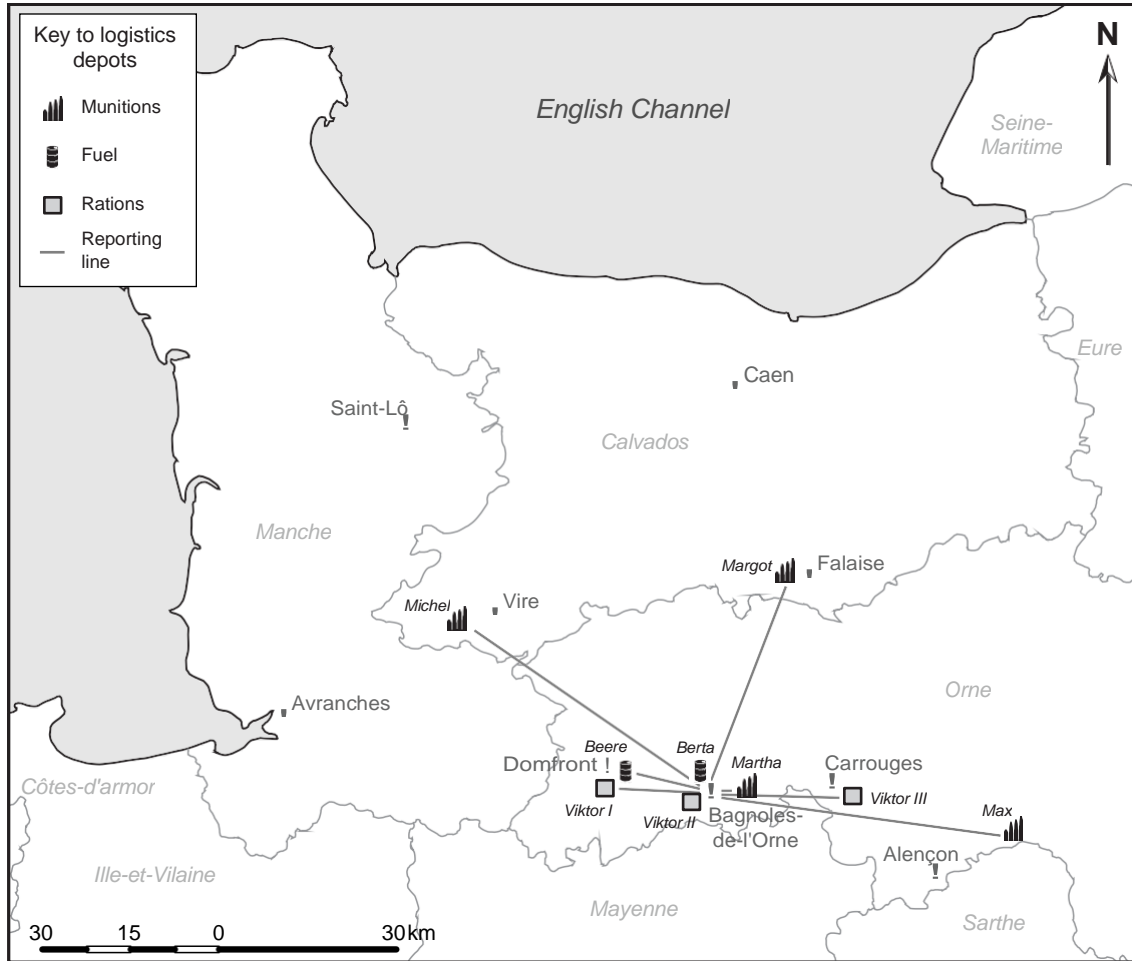


Figure 2. Map of northwest France showing location of Seventh Army munitions, fuel and rations depots (and codenames) administered from the Bagnoles de l'Orne Stützpunkt as of June 5th, 1944 (NARA T312, 1571, 000607).

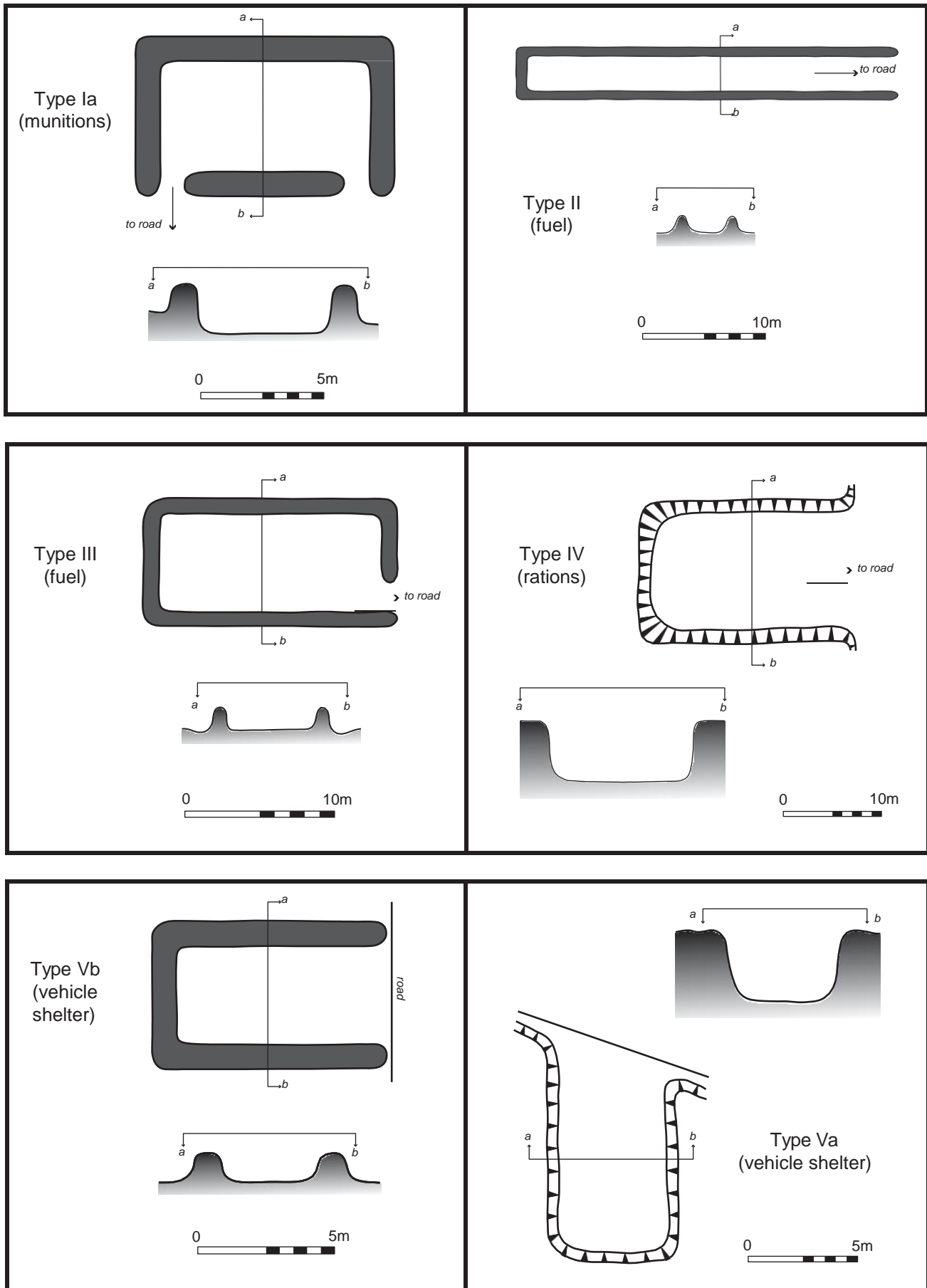


Figure 3. Schematic plans/profiles of the major munitions, fuel and rations bunkers and vehicle shelters identified in the Forêt Domaniale des Andaines. See also Figures 4, 5, 7 and 8.



Figure 4. Example of Type Ia (munitions) bunker in Lager Martha.



Figure 5. Example of Type II (fuel) bunker in Lager Berta.



Figure 6. Remains of 200 litre fuel drums in Lager Berta.



Figure 7. Example of Type IV (rations) bunker in Lager Viktor II (Manoir du Lys). Photo taken from forest track at bunker entrance.



Figure 8. Example of Type Vb vehicle shelter in the Forêt Domaniale des Andaines



Figure 9. Example of Type VIe personnel shelter (slit trench) in Lager Berta. Trench measures 2m by 0.85m.

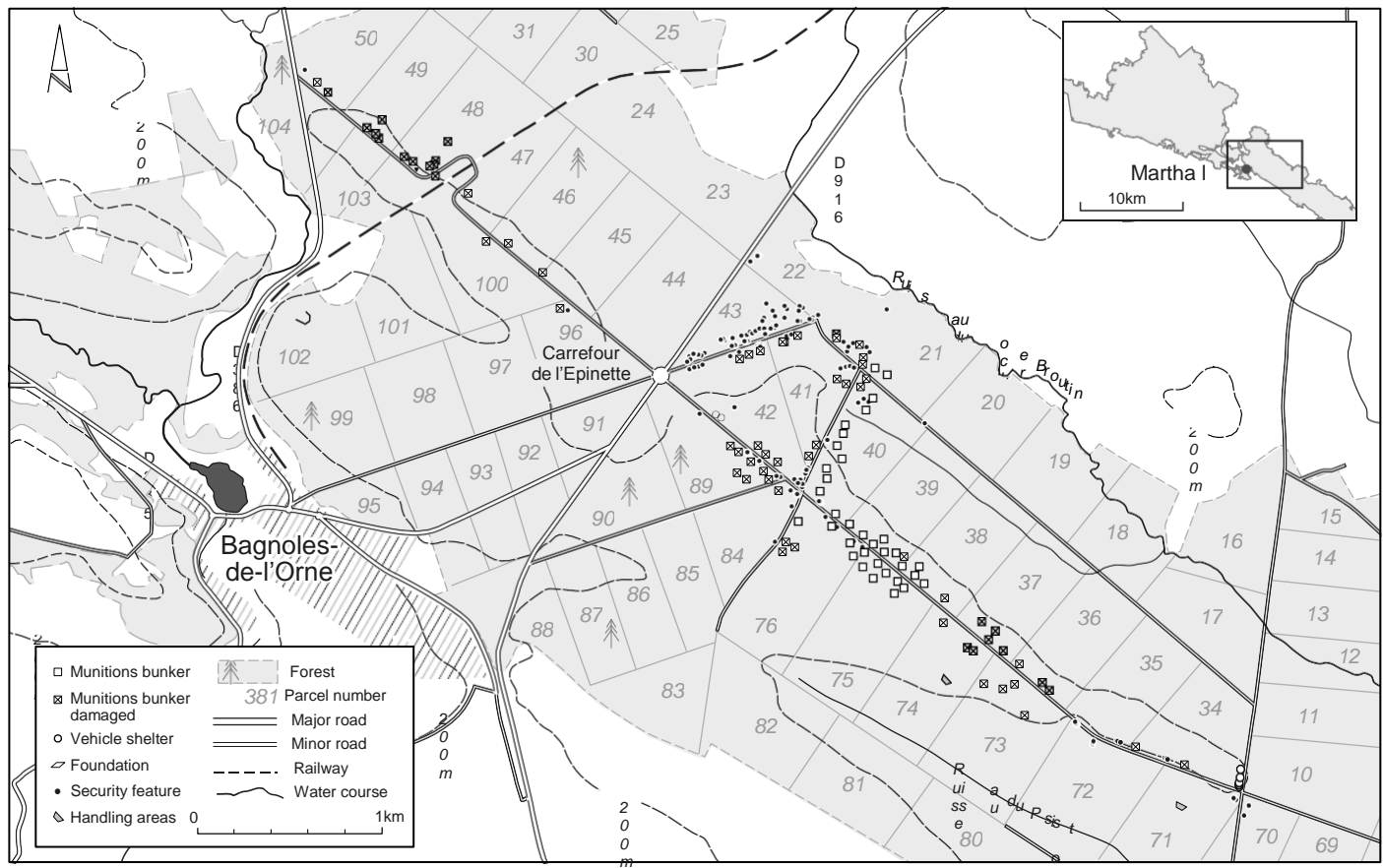


Figure 10. Map of Lager Martha (I), Forêt Domaniale des Andaines, showing location of recorded earthworks and Forest Parcels.



Figure 11. Ruptured 150mm artillery shell casing at Lager Martha (I)

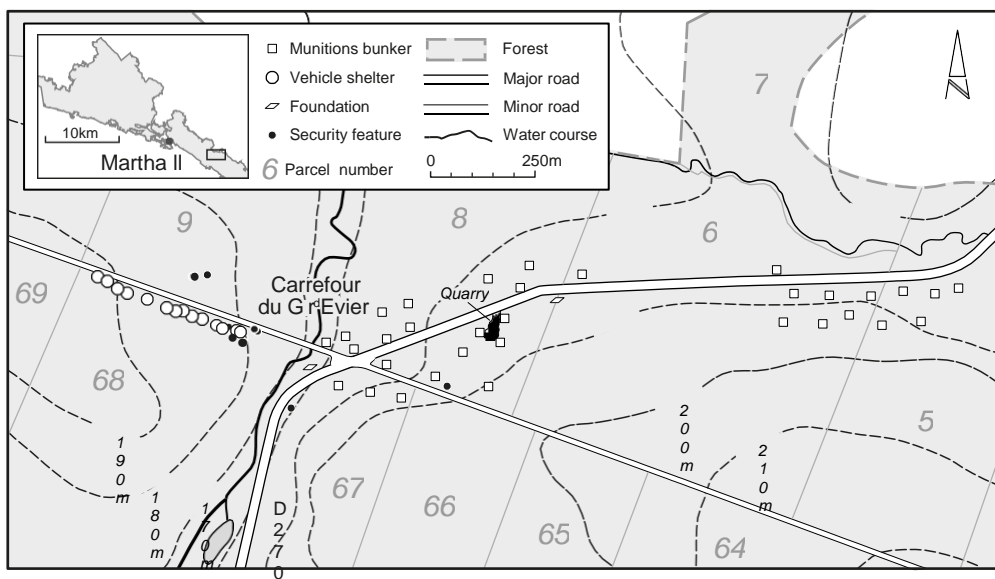


Figure 12. Map of Lager Martha (II), Forêt Domaniale des Andaines, showing location of recorded earthworks and Forest Parcels.

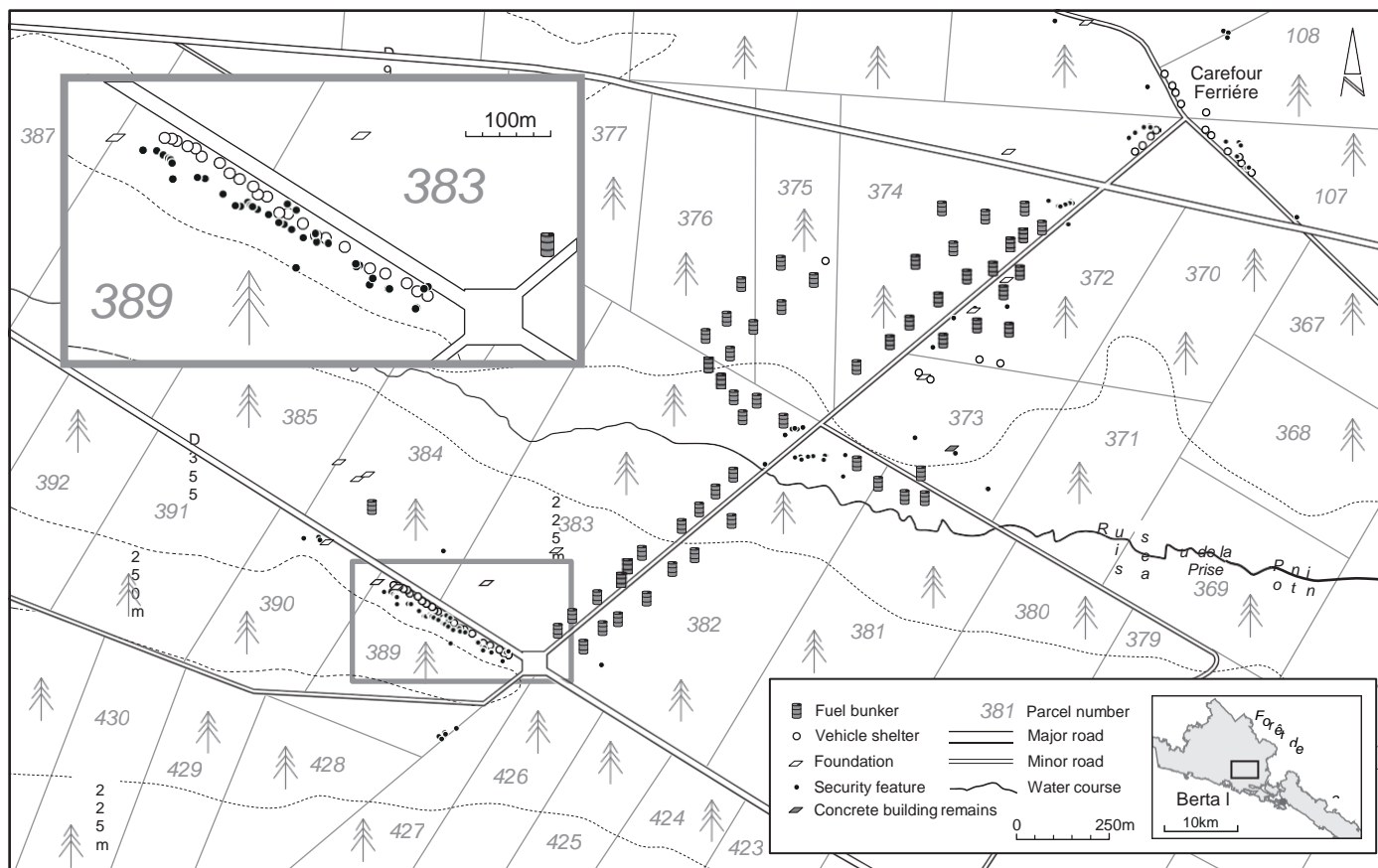


Figure 13. Map of Lager Berta (I), Forêt Domaniale des Andaines, showing location of recorded earthworks and Forest Parcels.



Figure 14. Multiple bomb craters at Lager Berta (I).

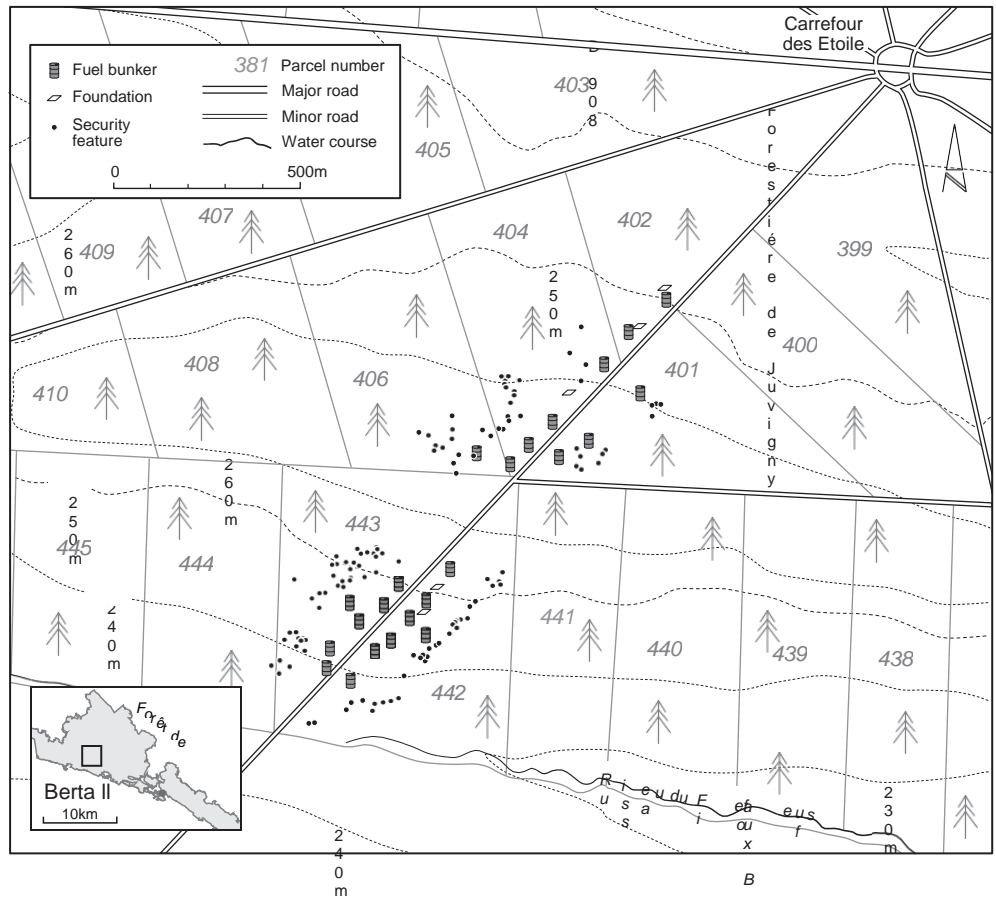


Figure 15. Map of Lager Berta (II), Forêt Domaniale des Andaines, showing location of recorded earthworks and Forest Parcels.

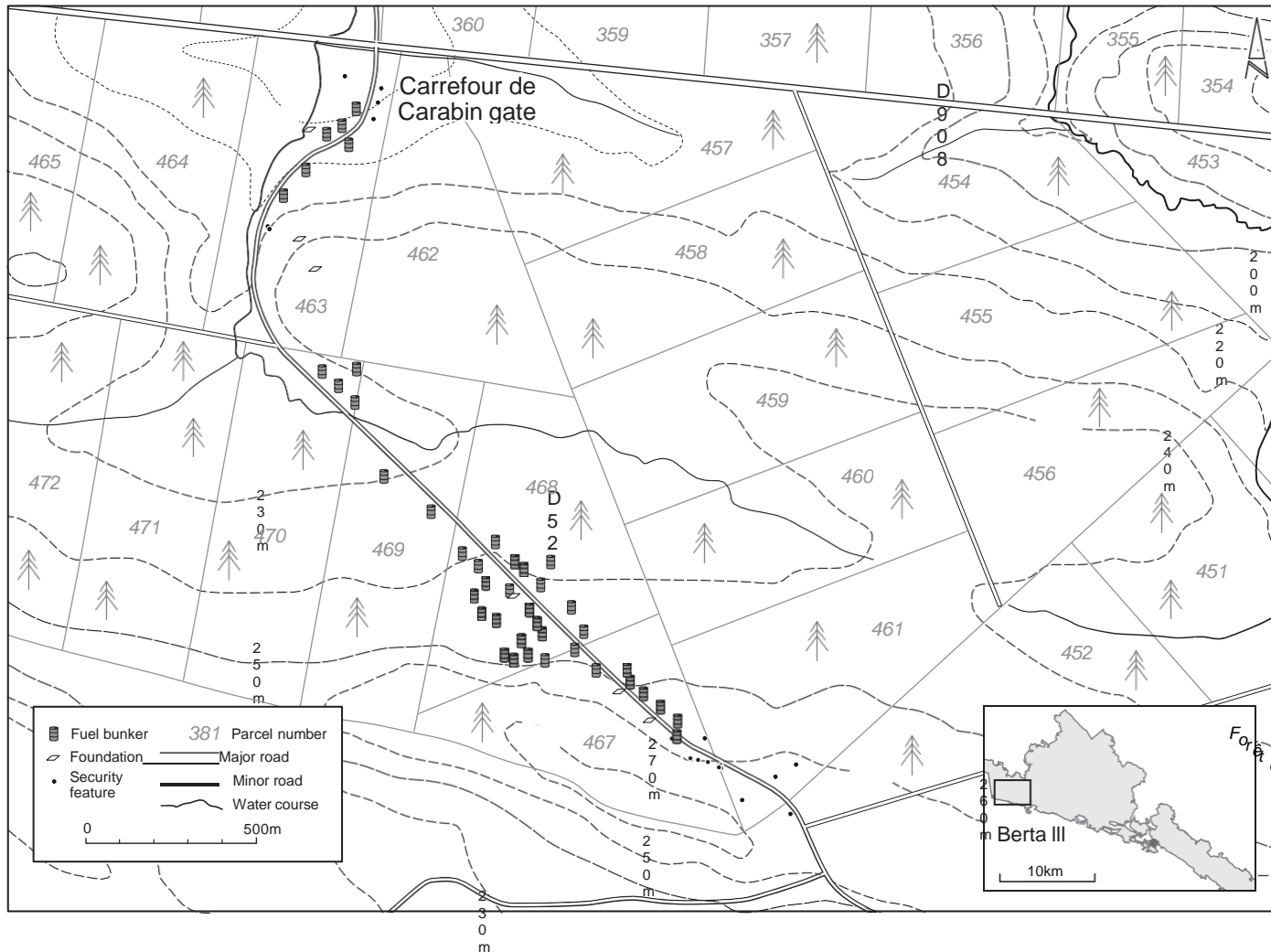


Figure 16. Map of Lager Berta (III), Forêt Domaniale des Andaines, showing location of recorded earthworks and Forest Parcels.

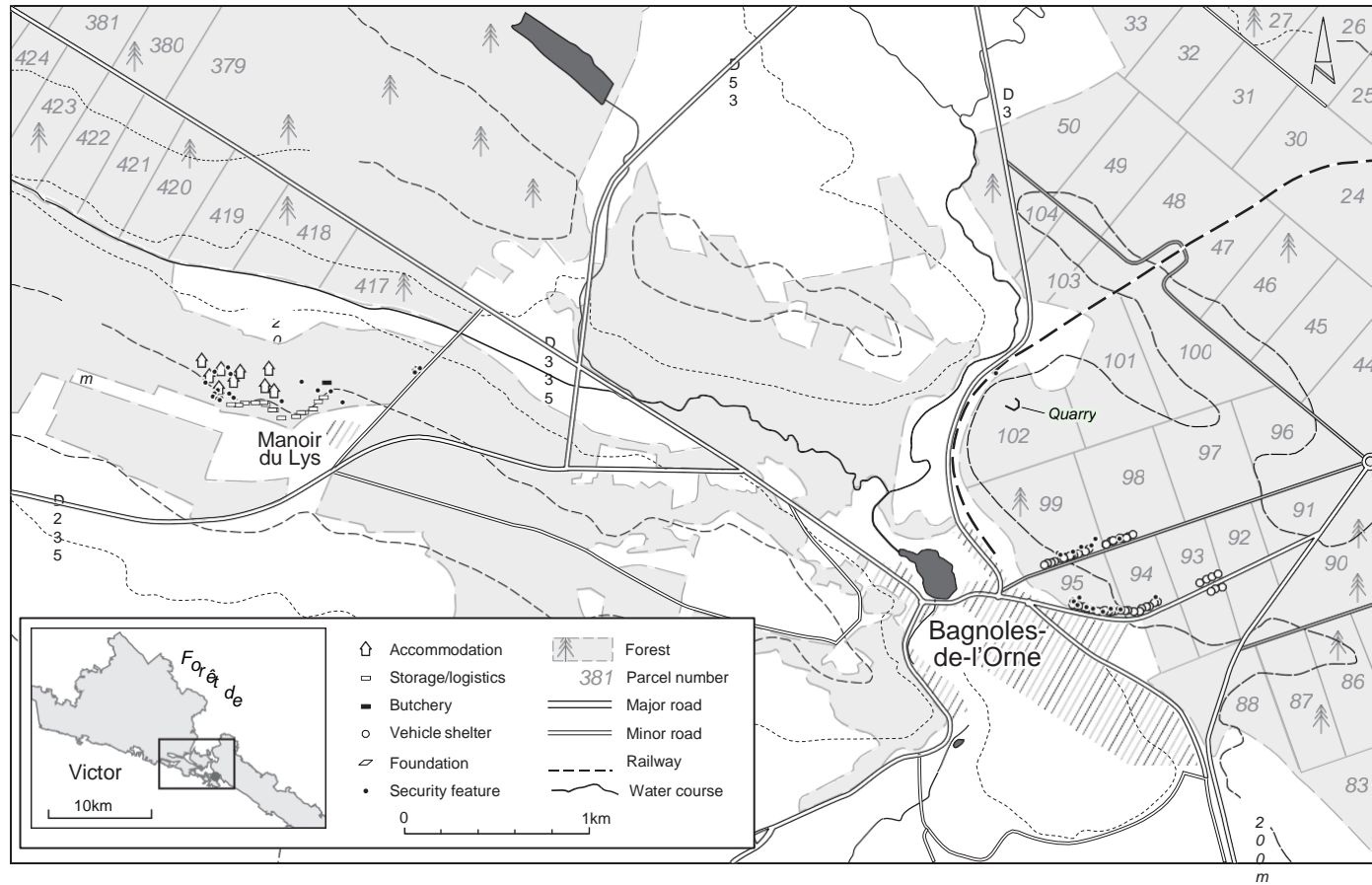


Figure 17. Map of Lager Viktor (II), Forêt Domaniale des Andaines, showing location of recorded earthworks and building remains.



Figure 18. Derelict building at Viktor (II) near Manoir du Lys, Forêt Domaniale des Andaines, formerly used as a butchery.

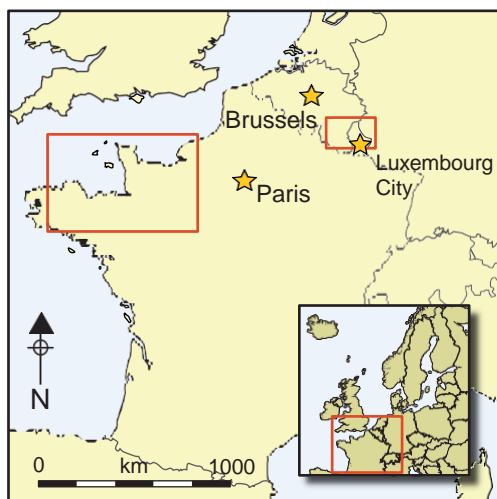
Appendix III

Paper III:

Passmore, D.G., Harrison, S. and Capps Tunwell, D. (2014). Second World War conflict archaeology in the forests of north-west Europe. *Antiquity*, 88(342), pp. 1275-1290.

Second World War conflict archaeology in the forests of north-west Europe

David G. Passmore^{1,*}, Stephan Harrison² & David Capps Tunwell³



Concrete fortifications have long served as battle-scarred memorials of the Second World War. The forests of north-west Europe, meanwhile, have concealed a preserved landscape of earthwork field fortifications, military support structures and bomb- and shell-craters that promise to enhance our understanding of the conflict landscapes of the 1944 Normandy Campaign and the subsequent battles in the Ardennes and Hürtgenwald forests. Recent survey has revealed that the archaeology surviving in wooded landscapes can significantly enhance our understanding of ground combat in areas covered by forest. In particular, this evidence

sheds new light on the logistical support of field armies and the impact of Allied bombing on German installations.

Keywords: Second World War, Normandy Campaign, Ardennes Offensive, conflict archaeology, field fortification, bomb-crater, logistics depot, battlefield

Supplementary material is provided online at <http://antiquity.ac.uk/projgall/passmore342>

Introduction

The archaeology of the Second World War (WW2) in north-west Europe is dominated by concrete and brick. From remote pillboxes and anti-tank cubes (Osborne 2004) to the extensive casemates and bunkers of the Atlantic Wall (Zaloga 2007) and the massive flak towers and air-raid shelters in German cities (Richardson 2008), hardened structures form the most conspicuous and enduring landscape legacy of WW2 conflict. Some of these structures have survived because they have been deliberately incorporated into the heritage inventory, perhaps through achieving a particular resonance at important battlefield sites

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Table 1. Selected WW2 site types in Britain (after Dobinson *et al.* 1997; Saunders 1998; Schofield 2001).

Anti-aircraft defences
Airborne landing precautions
Airfields
Airfield defences
Beach batteries
Coastal batteries and forts
Civil defence (air-raid shelters)
Bombing decoys
Radar sites
Experimental establishments
Factories
Observation posts
Anti-invasion defences (including pillboxes, road blocks, anti-tank ditches)
Resistance cells
Operation Diver sites
Operation Overlord preparatory sites (including Mulberry harbour construction sites, maintenance and repair areas, embarkation sites)

(e.g. the Normandy D-Day beaches), or where they have subsequently facilitated alternative, non-military uses (e.g. Schofield 2004). More commonly, many have survived because they have proved difficult to remove or offer no impediment to modern land-use. Concrete and brick may also still bear the legacy of battle damage associated with gunfire or aerial bombing (Lynch & Cooksey 2007), and in some cases such buildings have also achieved a measure of legislative protection. As the archaeological community has been developing an increasing interest in twentieth-century conflict archaeology (Schofield 2005; Lynch & Cooksey 2007; Moshenska 2013), such structures have become the primary focus of survey and documentation of WW2 landscapes (e.g. Dobinson *et al.* 1997). Indeed, parts of north-west Europe—notably Britain—now have a well-developed classification of military sites and structures (Table 1; Saunders 1998), and many of these have achieved protection as historic monuments.

Concrete and brick constitute only part of the conflict landscape of north-west Europe, however. The nature of ground combat operations in the western theatre of WW2 militated against the development of semi-permanent and extensive networks of trench and bunker systems that typify the western European WW1 battlefield; earthwork field fortifications for shelter and combat were, however, routinely dug by front-line and support troops. In combination with shell- and bomb-craters, these will have formed a substantial part, if not the majority, of the immediate battlefield legacy. However, the detailed topography of such landscapes has rarely survived post-war reconstruction, landscaping and agricultural activity. Consequently, there are very few examples of field fortifications and cratered terrain in the published archaeological record, and they are seldom featured in academic or popular battlefield guides; visitors using Sutton Publishing's 2004 'Battle Zone Normandy' series (edited by Simon Trew) to navigate the beachhead and inland battlefield landscapes of the

Normandy Campaign, for example, will find that mention of extant shell-craters is limited solely to the preserved landscape at Pointe du Hoc (Badsey & Bean 2004).

In this paper, we advocate a rebalancing of the WW2 archaeological research agenda in north-west Europe by highlighting the hitherto little-appreciated geographical setting where contemporary earthworks and cratered terrain have had the potential to survive through to the present—the region's historic forests and woodlands. The prospects for preservation of field fortifications have been previously identified by a pilot study in the Ardennes forests of Belgium (Passmore & Harrison 2008); further examples of battlefield remains and military activities in forested settings are documented in publications on work in the Savernake Forest, England (Crutchley *et al.* 2009), the Hürtgenwald Forest, Germany (Rass & Lohmeier 2011), and also in Finland (Seitsonen & Herva 2011). More recently the authors have demonstrated extensive preservation of major German logistics depots in the *Forêt domaniale des Andaines*, Normandy (Passmore *et al.* 2013; Capps Tunwell *et al.* in press). This paper aims to build on this work by illustrating the nature, extent and research potential of WW2 conflict archaeology in forested parts of north-west Europe, with particular reference to two distinctive types of non-hardened military landscape; first, those that witnessed ground combat and have a legacy of improvised field fortifications, and second, landscapes associated with the logistical support of field armies.

Geographical scope and methods

Previous investigations of Ardennes field fortifications by the authors combined a fieldwork programme with published accounts of WW2 battlefield archaeology, heritage sites and contemporary aerial photographs (Passmore & Harrison 2008). For this paper, we have extended the range of field fortification survey by reviewing: i) academic literature on conflict archaeology and heritage sites; ii) internet-based searches for descriptions and images of forest-based battlefields and military earthworks; and iii) examples of heritage trails and associated documentation that have a WW2 focus. These searches provided the basis for fieldwalking to verify the nature and context of archaeological survival. The geographical scope of the survey extended over several key battlegrounds of the western European theatre of operations between June 1944 and February 1945, including north-west France, the Ardennes forests of Belgium, Luxembourg and Germany, the Hürtgenwald and Reichwald forests of western Germany and woodlands around the Arnhem region of the Netherlands (Figure 1).

Forest survey in north-west France has also incorporated a study of German Army (Heer) logistics depots in the *Forêt domaniale des Andaines* (Passmore *et al.* 2013; Capps Tunwell *et al.* in press). Here we report on an extension of this work that has sought to establish the geography of munitions and fuel depots and their archaeological potential in woodlands across an area of north-west France that witnessed the Normandy Campaign; this area includes the regions of Basse Normandie, Haute Normandie and Bretagne, northern parts of Pays de la Loire and Centre, and the eastern extent of the Ile-de-France and Picardie (Figure 1).

The location and function of logistics depots have been identified primarily using archive documents and aerial photographs (see below), supplemented by field visits and sample surveys at selected sites in order to assess the degree of survival of depot structures and

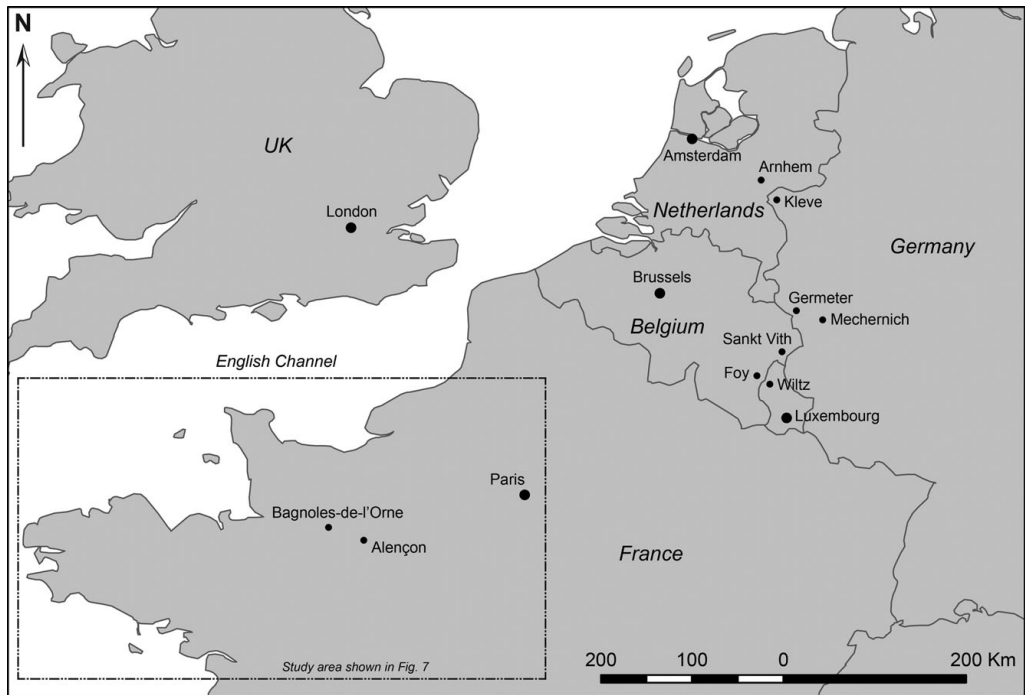


Figure 1. Map of north-west Europe showing study areas and sites mentioned in the text.

bomb-craters. Non-invasive field survey of extant features at logistics depots has focused on the location, planform morphology and relief of earthworks on the forest floor; features were classified according to the typology developed by Passmore *et al.* (2013), which reflects function, planform dimensions, the primary mode of construction and the relationship of features to nearby roads or tracks. Integration and analysis of field survey data, archive maps and aerial photographs has been facilitated using a GIS framework.

Field fortifications in north-west European forests

Small unit actions throughout north-west Europe regularly took place in localised wooded settings that offered cover and concealment; but it is the extensive forests of the Ardennes, in the border region of Belgium, Germany and Luxembourg, and the neighbouring Hürtgenwald area of western Germany (Figure 1), that are most widely recognised for hosting large-scale combat operations in woodland terrain (Miller 1995; Cavanagh 2001). It is these areas that provide the only three examples of mapped (and differentiated) field fortifications known to the authors; below we illustrate these case studies in order to emphasise the preservation potential of combat landscapes in this region.

The first two examples are associated with the German Ardennes Offensive (Wacht am der Rheine', or the Battle of the Bulge) in December 1944 – January 1945. In the Sankt Vith area of eastern Belgium (Figure 1) a forested area of 1.4km² preserves at least 116 discrete features that were assigned to a threefold typology encompassing large

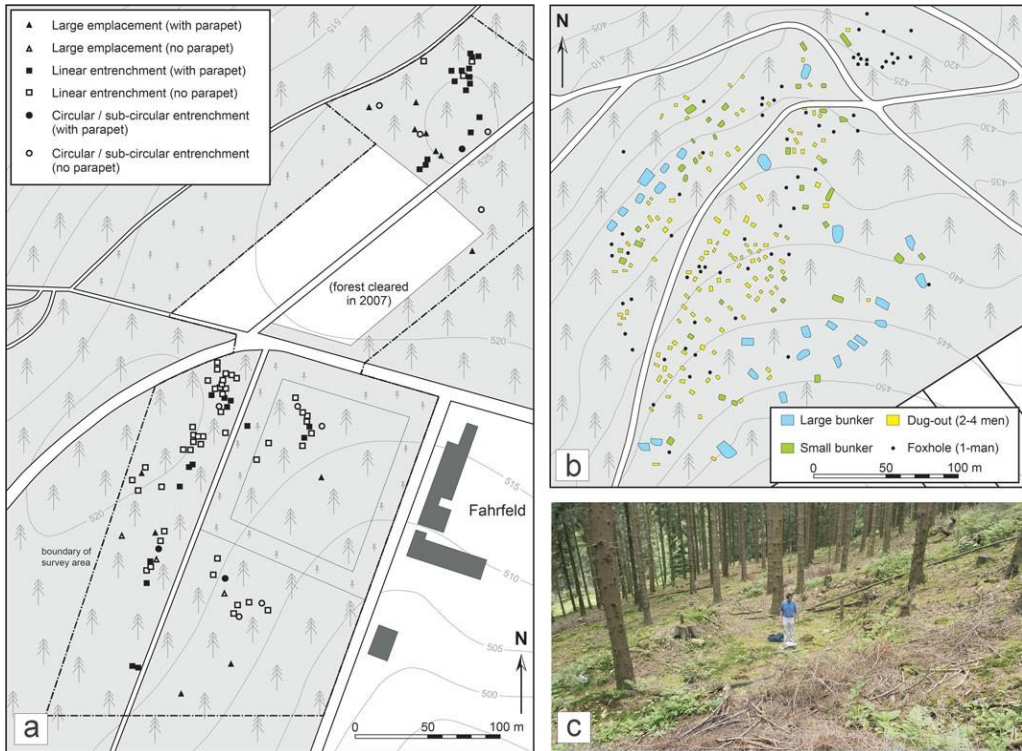


Figure 2. a) Map of the Prumerberg study site, St. Vith, Belgium, showing location and classification of US Army field fortifications (after Passmore & Harrison 2008); b) map of the Hürtgenwald forest near Germeter, western Germany, showing location and classification of US Army field fortifications (after Wegener 2011); c) large bunker at the Germeter study site.

emplacements, rectilinear entrenchments and circular and sub-circular entrenchments or shell-craters (Figure 2a) (Passmore & Harrison 2008). This archaeological data was shown to permit an analysis of the form and disposition of features in the context of field fortification doctrine, documented accounts of combat in the area and the terrain and landscape setting (Passmore & Harrison 2008). The second example is the battleground at Schumanns Eck, near Wiltz in Luxembourg (Figure 1), which saw two weeks of intensive combat between the US 26th Infantry Division and German 9th Volksgrenadier Division. Today, the site has the status of a 'National Liberation Memorial' and features a commemorative monument, detailed information and interpretative boards and a waymarked memorial woodland trail (the Path of Remembrance 1944 - 1945') that guides the visitor through a landscape of abundant and, for the most part, well-preserved foxholes and trenches (Figure 3a - d). While the information presented does not represent an exhaustive survey of features in the vicinity of the trail, it nevertheless constitutes a rare example of a survey that both maps and differentiates field fortifications (including trenches and foxholes), as well as shell-holes and bomb-craters.

To the north-east of the Ardennes battlefields, the US assaults through the Hürtgenwald in late 1944 are a lesser known part of operations in north-west Europe, but nevertheless are notable for having received archaeological attention (Rass & Lohmeier 2011), and are

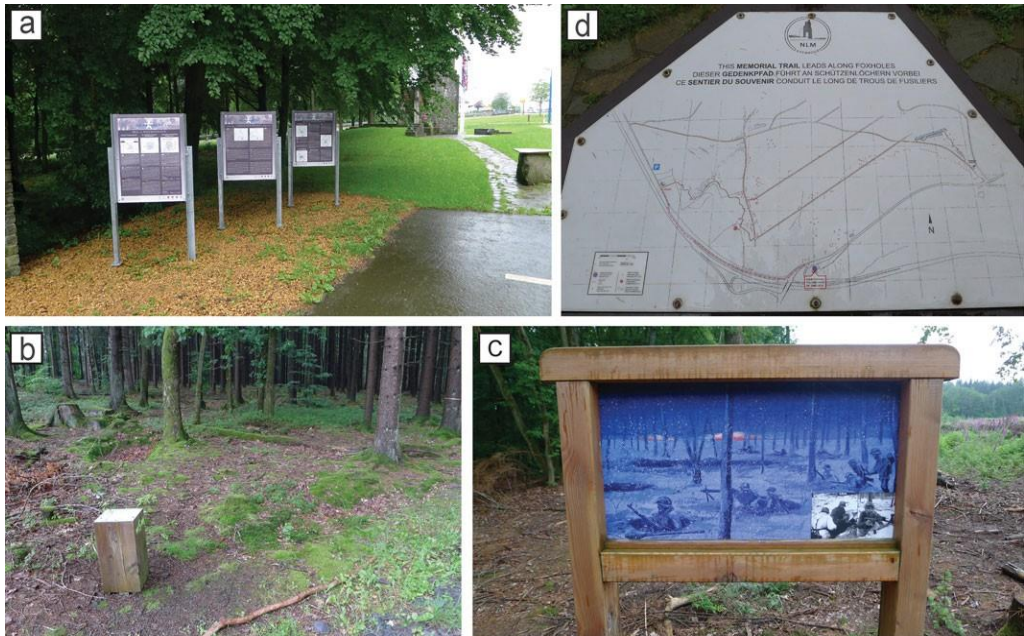


Figure 3. National Liberation Memorial and woodland memorial trail at Schumanns Eck, near Wiltz, Luxembourg (see Figure 1). a) Battlefield information boards at the Memorial car park; b) Memorial trail waypoint; note foxhole at base of tree to centre-left; c) interpretative image and photographs on the Memorial trail; d) map of the Memorial trail (visible to far right of 3a) showing locations of foxholes and trenches.

the location of some especially well developed military heritage trails and associated tourist information (Figure 4). This development owes much to the efforts of regional tourism, education and archaeological bodies (especially the Konejung Foundation and the LVR Office of Archaeological Excavation in the Rhineland), and has a particular focus on the concrete bunkers and other hardened fortifications of the West Wall (e.g. Wegener 2006). However, the Hürtgenwald Archaeological Trail, located in the wooded valley of Weisser Weh, west of the village of Germeter (Figure 4), is similarly informed by a detailed survey of field fortifications in a 0.5km² area of woodland 400m west of the village (Konejung Stiftung Kultur 2011; Figure 2b & c). This survey has mapped over 250 discrete earthworks and differentiates between large and small bunkers, dugouts suitable for two to four men and one-man foxholes (Figure 2b & c). The larger bunkers at this location lack interconnecting communications trenches that are characteristic of German defensive field fortification doctrine (Rottman 2004), and the site is therefore interpreted as an American position (Wegener 2011), most likely that of the 1st Battalion, 112th Infantry Regiment (28th Infantry Division), positioned just behind the front line on 3 November 1944 and immediately prior to the ill-fated attack on Schmidt (Miller 1995).

Detailed mapping of this nature not only illuminates the military history of specific combat events and operations—what Rass and Lohmeier (2011) term ‘micro-history’ but also opens up the possibility of wider comparisons between field fortification practice in differing physical and operational contexts, and between opposing forces. Survey by

the authors has documented field fortifications in many other locations in the wider Hürtgenwald and Ardennes study areas described above, as well as parts of the Reichswald



Figure 4. Map and interpretative board for the Hürtgenwald Archaeological Trail, Germeter, western Germany.

Forest in north-west Germany, wooded battlefields around Arnhem (Netherlands) (Figure 5) and in several parts of the Normandy region (unpublished data). We therefore argue that there is considerable scope for further battlefield survey and analysis in the forests of western Europe and no doubt also in the wooded battlefields of the Eastern Front.

In this respect the recent reporting of exceptionally well preserved earthworks associated with fuel, munitions and rations depots in the historic forest landscape of the *Fôret domaniale des Andaines* (Passmore *et al.* 2013; Capps Tunwell *et al.* in press) is of archaeological significance, not least because the frequent German practice of siting logistics depots in wooded locations established the same long-term preservation potential as is evident for field fortifications.

In seeking to extend this investigation across the wider region we have prioritised the identification of fuel and munitions depots in forested locations; the progress reported here therefore excludes sites that are believed to be exclusively urban. The initial site inventory was extracted from the diaries of the German 7th Army Quartermaster (located at the National Archives Research Agency, Maryland, USA) and augmented and cross-checked with reference to the Allied Tactical Target Dossiers and the records of the 9th Air Force (Air Force Historical Research Agency, Maxwell Air Force Base, Alabama, USA). Potential forest sites were also assessed for evidence of bomb-cratering and areas cleared by fire and disposal activities during German abandonment of depots and post-war munitions clearance, using vertical aerial photographs dating between 1946 and 1952 and accessed via the Institut Geographique National (IGN). In some cases the image quality and degree of post-war

Logistics and supply in the Normandy Campaign

The difficulties in the supply of munitions and fuel experienced by German forces in Normandy, in the face of overwhelming Allied air superiority, have been widely acknowledged as being a significant factor in their defeat (e.g. Vogel 1994). Yet, with the notable exception of aspects of Hart's (1996) analysis of primary source material, the supply depots themselves have not been subject to detailed historical analysis nor, until recently, archaeological evaluation. In

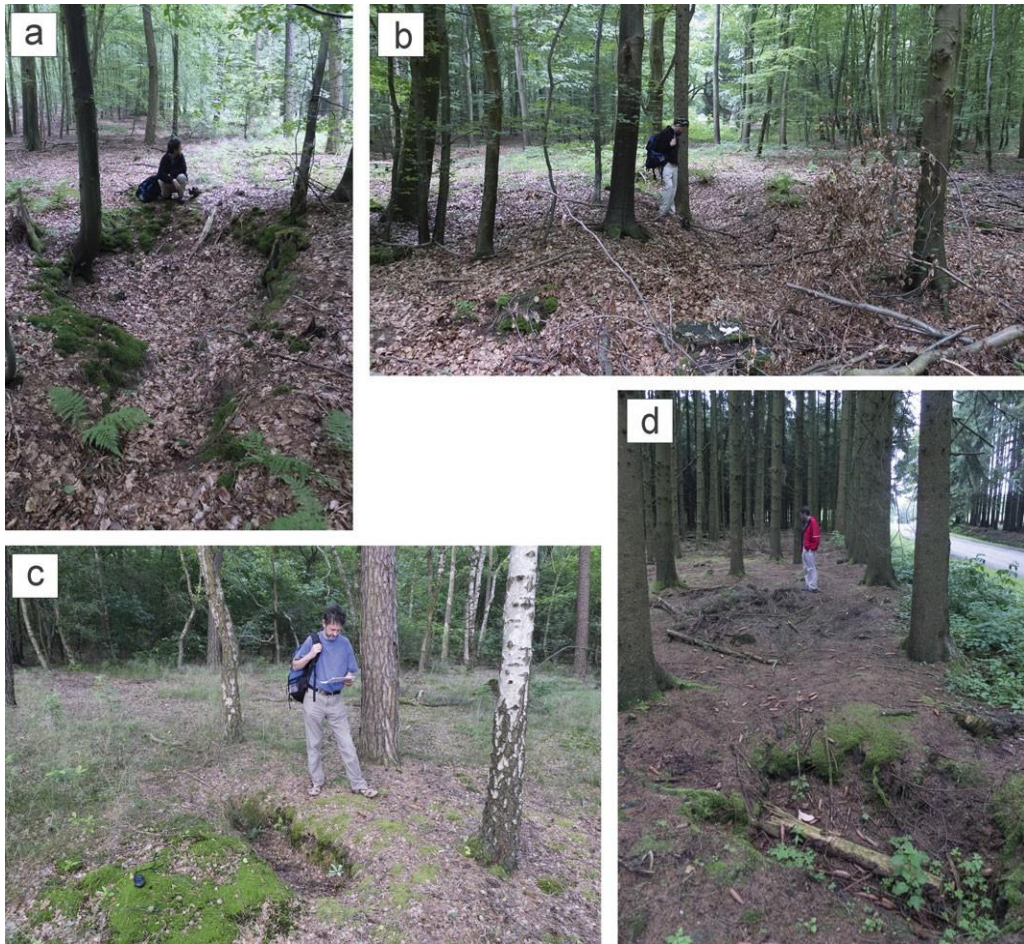


Figure 5. a & b) Weapons pit and zig-zag trench in the Reichswald forest near Kleve, western Germany; c) slit trench in woods near Wolfheze, Arnhem, Netherlands; d) foxholes in woods near Foy, east of Bastogne, Belgium.

clearance and disturbance is sufficient to reveal individual munitions and fuel bunkers (Figure 6).

The geographical location, context and evidence base for fuel and munitions depots is summarised in Figure 7 below and Table S1 in the online supplementary material. This database will require updating as research work progresses and is especially likely to have overlooked relatively small and short-lived dumps associated with divisional stockpiling. Nevertheless, the inventory currently stands at a total of 63 forest-based logistics sites and demonstrates the considerable geographical spread of depot locations with sites positioned throughout the study area. Indeed, most of the larger historic forests in Normandy, and many smaller ones besides, appear to have been exploited to this end. The timespans of depot construction, use and destruction or closure vary greatly and have yet to be fully established, although the concentration of sites in the Caen-Falaise-Argentan region probably reflects the establishment of depots between June and August 1944 in response to the operational

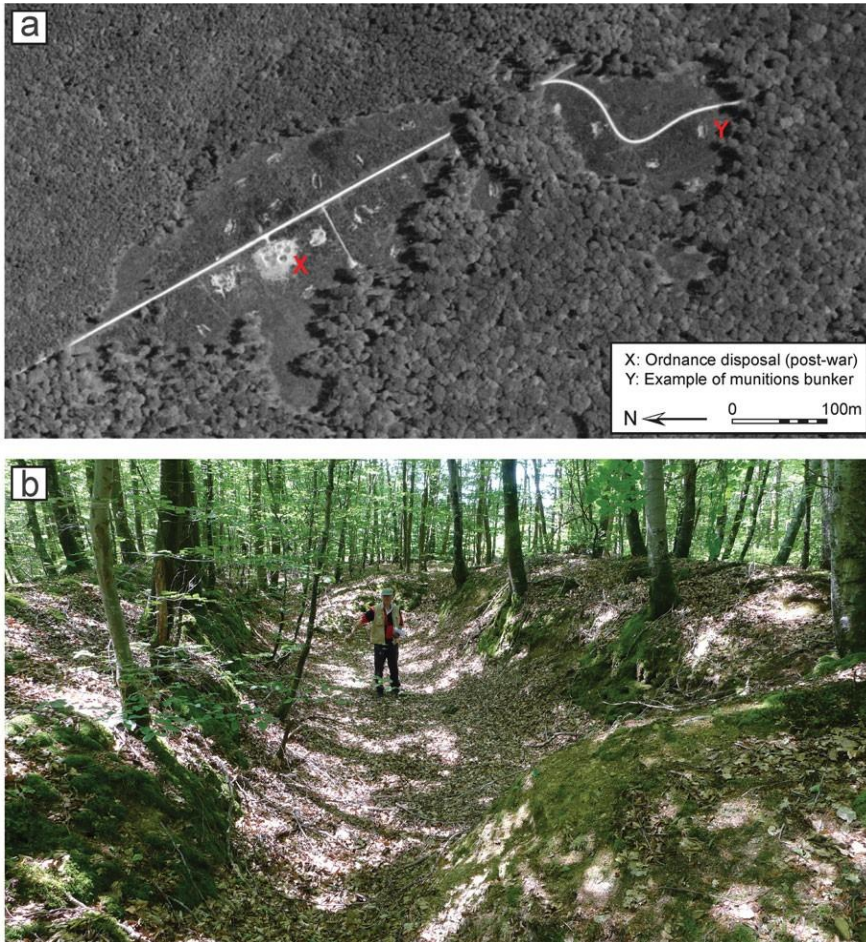


Figure 6. a) Vertical aerial photograph (IGNF C1417-0041.1949_F1417-1717 0439) of the *Forêt domaniale de Perseigne* near Ancinnes (Alençon), Normandy, showing areas of cleared woodland, evidence of post-1944 munitions disposal activity and munitions bunkers associated with *Lager Monika* on both sides of the forest road; b) photograph of munitions bunker at Location Y.

situation following D-Day. However, the 7th Army records for the 5 June 1944 list a total of 18 fuel and 9 munitions depots in its area of north-west France, of which 16 were located in forests (Passmore *et al.* 2013; Figure 7 and Table S1). These records also establish the command hierarchy and reporting arrangements for 7th Army depots at this time (Figure 7).

To date, seven sites have been visited for purposes of archaeological survey and in all cases the forest floors were found to preserve clear evidence of depot-related earthworks (Table S1). While some individual features bore evidence of demolition (conducted during abandonment of the depots) and post-war damage and disturbance, primarily as a result of forestry operations, road improvements and occasional informal (and illegal) excavations, the earthworks for the most part were found to be in a good state of preservation, with larger munitions bunkers exhibiting over 2m of vertical relief (e.g. Figure 6). Full details

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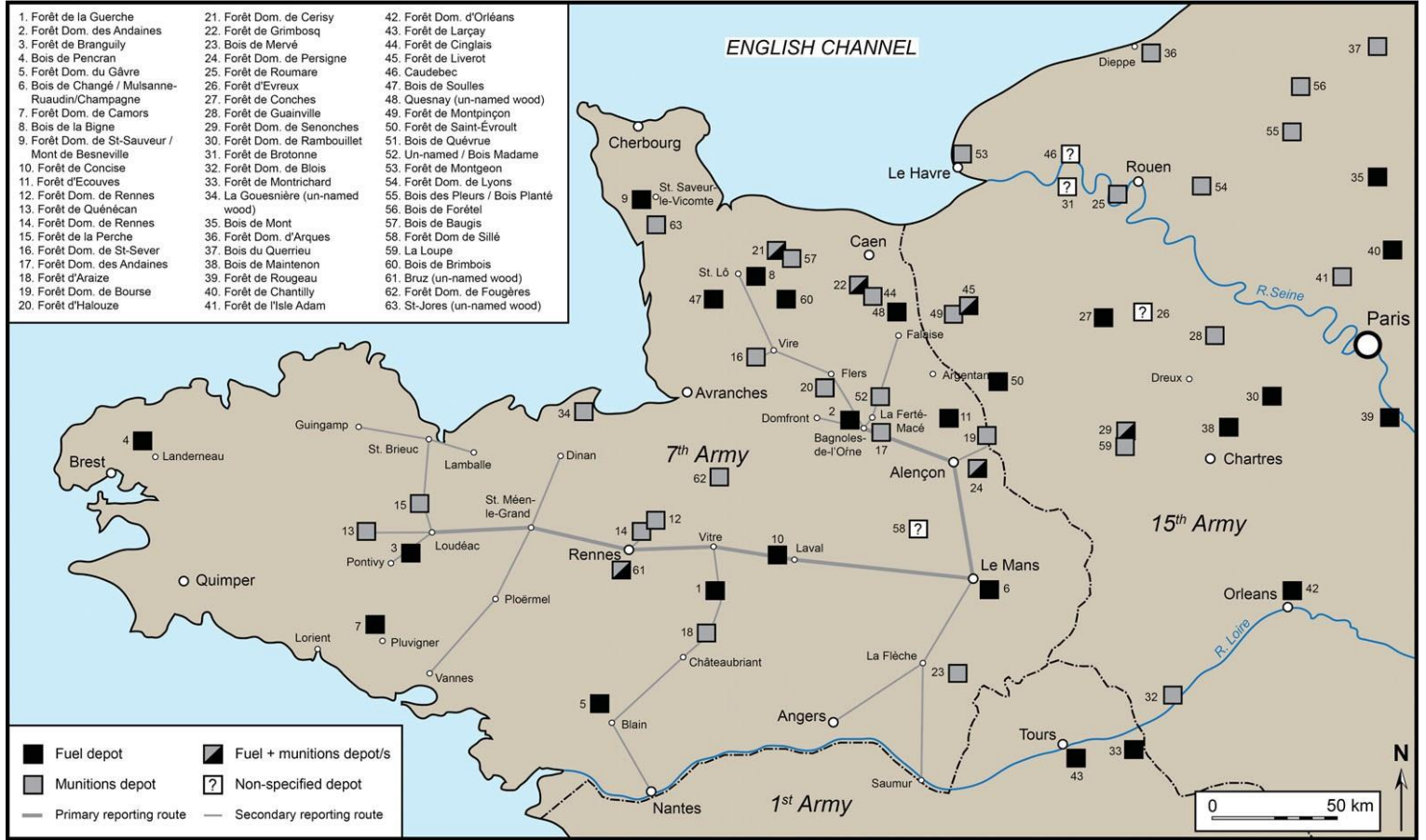


Figure 7. Map of north-west France showing German army group boundaries and location of forest-based fuel and munitions depots, c. 1943–1944. Also shown are the reporting routes for 7th Army depots as of 5 June 1944 (NARA T312, 1571, 000607). Site numbers refer to depots listed in Table S1 in the online supplementary material.

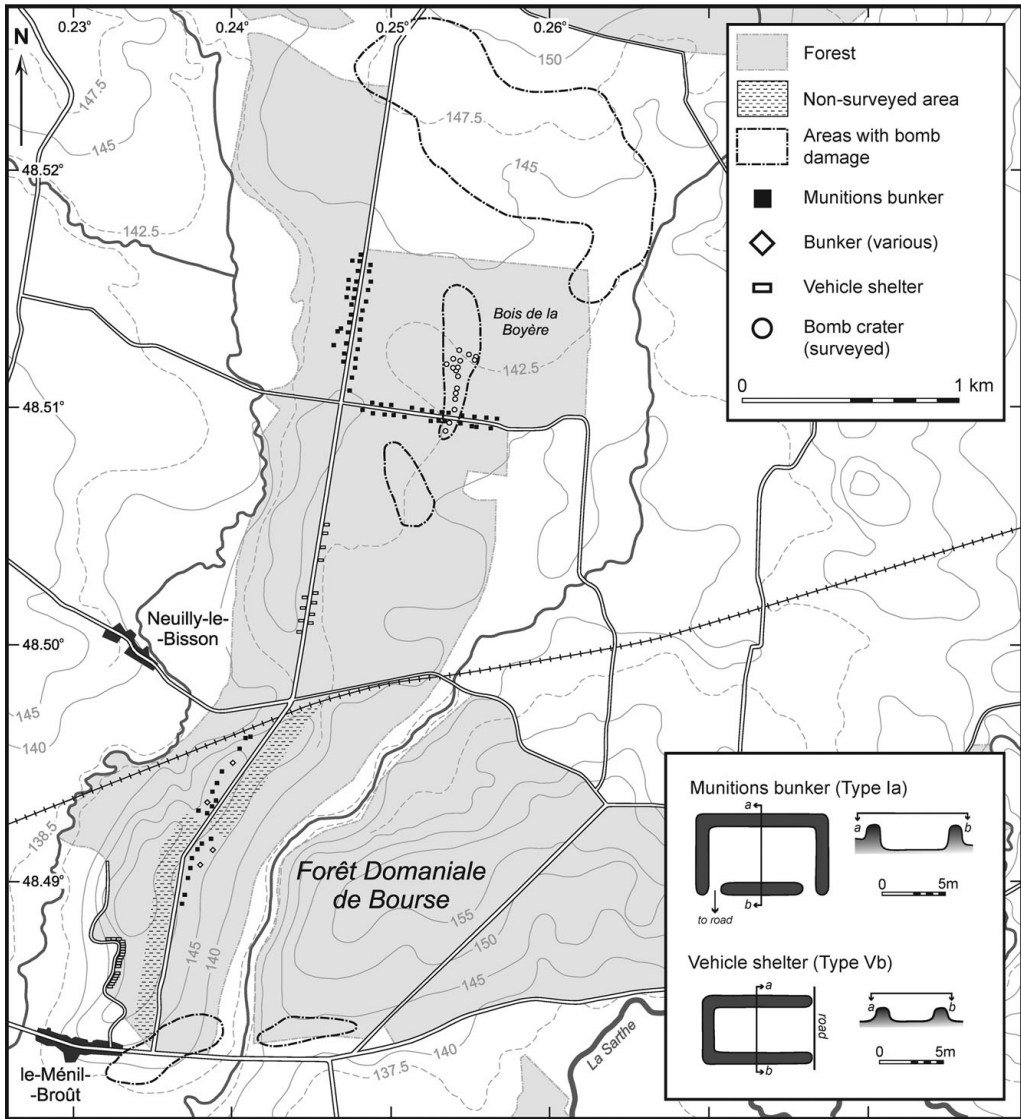


Figure 8. Map of the Forêt domaniale de Bourse near Le Menil-Broût (Alençon), Normandy, showing surveyed locations of extant munitions bunkers and vehicle shelters associated with Lager Max munitions depot. Also shown are areas with evidence of bomb-craters and the locations of surveyed bomb-craters. Inset: schematic planforms and profiles of munitions bunkers and vehicle shelters in the study area. For map location see Figures 1 & 2.

of the surveys will be forthcoming in follow-up papers, including a full survey of depot archaeology in the Forêt domaniale des Andaines (Capps Tunwell *et al.* in press); here we draw on a near-complete survey of Lager Max, located in the Forêt domaniale de Bourse near Le Menil-Broût, 12km north-east of Alençon (Figure 7), in order to illustrate the geography and character of a 7th Army munitions depot (Figure 8).



Figure 9. Photograph of Lager Max munitions bunker in the Bois de la Boyere, Forêt domaniale de Bourse, Normandy.

Munitions Lager 'Max' was one of nine depots administered by the 7th Army in the Normandy region in early June 1944; on 1 June the depot was reported as holding 1417 tonnes of ordnance, amounting to 7.6 per cent of 7th Army stocks (NARA T312, 1571, 000607; Passmore *et al.* 2013). Field evidence of depot facilities at Max includes at least 80 discrete munitions bunkers sited alongside 2.4km of forest roads and not more than 2km from the rail link to Alençon, which passes through the forest (Figures 8 & 9). It should be noted, however, that dense recent forest growth precluded access to approximately half of the roadside terrain in the southern part of the forest and the current audit probably underestimates the original depot provision. The majority of these features conform to the Type 1a (munitions) bunker class that has been described for Lager Martha in the Forêt domaniale des Andaines (Passmore *et al.* 2013; Capps Tunwell *et al.* in press; Figure 8) and when originally constructed were probably provided with planked timber walls, floors and timber roofs (NARA T312 R1562 0750). Max was also provided with two clusters of embanked roadside vehicle shelters, respectively located in the central part of the forest on either side of the main north – south road (12 features) and in the extreme south-west margin of the forest flanking a minor road extending north from Le Menil-Brout (19 features) (Figure 8).

Landscapes of bombing

A striking outcome of survey in the Forêt domaniale des Andaines is the extensive survival of bomb-cratered terrain (Passmore *et al.* 2013), and this is currently being subjected to an in-depth analysis (Capps Tunwell *et al.* in prep. a & b). Archaeological landscapes of Allied bombing are well preserved in other surveyed localities, and may even be a widespread feature of the regional woodlands (Table S1). In the vicinity of Lager Max (Forêt domaniale



Figure 10. Photograph of bomb-crater in the Bois de la Boyere, *Fôret domaniale de Bourse*, Normandy.

de Bourse), for example, aerial photographs taken in 1949 show evidence of bombing in this locality in the form of cropmarks in open fields and as clusters of small canopy openings (occasionally with visible craters) in wooded parts of the study area (Figure 8). The largest area of bomb damage lies in the fields immediately north of the forest margin, which in June 1944 were part of the Luftwaffe's Essay airfield and which were bombed on 17 June 1944 by B-24 aircraft of the 486th Bomb Group (Hennessy 1952). Today there is no visible evidence of this raid in the open landscape, but bombs impacting in the adjacent forest are marked by especially well preserved bomb-craters (Figure 10). Seventeen examples of extant craters have been surveyed in the northern part of the forest (Bois de la Boyere) where they form a north – south array that intersects with munitions bunkers (Figure 8). At the time of survey most of these craters were partially filled with water or mud (Figure 10) and so records of crater depth are minimum estimates, but their surface diameters were reliably found to range between 4 and 10m (Table S2 in online supplementary material). As no bomb exploded within 30m of a munitions bunker, it is unlikely that this part of Lager Max suffered any significant damage.

Discussion

The emerging picture of the work reported above is of a wealth of archaeological landscape preservation in many wooded areas that witnessed combat or other military activity in WW2, and which, with further study, promises to illuminate even some of the most famous WW2 battlefields as well as the lesser-known aspects of the logistical support of field armies. Recognition that field fortifications and shell- and bomb-damaged terrain is more widely preserved than hitherto appreciated promises to expand greatly the inventory and scope of conflict archaeology that deals with the immediate impact of WW2 fighting

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in north-west Europe. Thus, while Schofield's (2005) *Combat Archaeology* has done much to formalise and contextualise the archaeological study of twentieth-century conflict, it is interesting to note that of the broad range of material culture illustrated therein, relatively few examples—notably spent ordnance, damaged building fabric, aircraft crash sites and sunken vessels—can claim to constitute the direct archaeological signature of *combat*. It is therefore the woodlands of north-west Europe that stand to provide the WW2 equivalent of the well-preserved, studied and protected battle-scarred landscapes of WW1's Western Front.

These landscapes also have much to contribute to wider research agendas, including those focused on heritage and memory (e.g. Rass & Lohmeier 2011), military geography (e.g. Woodward 2014) and historical accounts and narratives of conflict (e.g. Passmore & Harrison 2008), as well as complementing studies of the environmental impact of combat (e.g. Steinweg & Kerth 2013). Here we draw attention to two particular research themes that are the focus of ongoing work.

First, the problems faced by the German military logistics effort during the Normandy Campaign are widely recognised in the military history literature (e.g. Zetterling 2000; Reardon 2002), but there have been few attempts to build on the archival analysis reported by Hart (1996), and much remains to be clarified with respect to the scale, character and military geography of logistics efforts in the Normandy Campaign. Forests are likely to play a key role in this undertaking as wooded locales with good transport links in the Normandy region—and possibly elsewhere in the hinterland of the Atlantic Wall—are likely to have hosted Heer fuel, munitions and rations depots. Furthermore, and accepting that our present audit for the most part demonstrates potential rather than proven archaeological survival, it is likely that many of these sites will retain visible evidence of logistics earthworks and bomb-craters, and there is a possibility that some will exhibit near-complete archaeological landscape survival for this period. Ongoing work is focusing on refining knowledge of the design, operation and geographical distribution of supply depots both before and especially after 6 June 1944. At the depot and feature scale there is a need to develop a robust typology of storage bunkers that can be linked to specific functions and capacity. Furthermore, although this effort is currently focusing on the Normandy region, reconnaissance survey by the authors in woodlands near Mechernich, 29km inside the western German border (Figure 1), has identified munitions bunkers similar to those described above and which most probably reflect stockpiling of ammunition in advance of the 1944 Ardennes Offensive (unpublished data). Accordingly, we suggest this approach is likely to be fruitful in other parts of north-west Europe.

Second, archaeological analysis has much to offer an evaluation of the strategy, effectiveness and landscape impact of Allied bombing of the German logistics network, especially where documentary evidence is ambiguous or fragmentary. Hart's (1996) analysis of the difficulties faced by German forces in transporting fuel and munitions during the Normandy Campaign remains the most detailed available, but landscape evidence in the *Forêt domaniale des Andaines* is beginning to challenge some of his assumptions regarding Allied bombing of the depots themselves (Capps Tunwell *et al.* in prep. a & b). Furthermore, the landscape evidence of the 17 June 1944 bombing of Essay demonstrates the potential for combining bomb-crater surveys with the detailed documentation of specific air raids.

Gaffney *et al.* (2004) have previously recognised that the archaeological evaluation of shell-craters may yield insights into the effectiveness of Allied bombing and shelling strategies, although in this case they were referring to remote-sensing of sub-surface features for assessing parameters such as angle of strike and ferrous object disposition. Here we note that extant bomb-craters in forested terrain are liable to be especially receptive to analyses linking crater size, depth and disposition to records of bomb loads, raid height and bomber flight patterns (Capps Tunwell *et al.* in prep. a).

Conclusions

Writing in 1994—the year of the fiftieth anniversary of D-Day—Chippindale’s *Antiquity* editorial observes that “it is the number and mass of objects that make one aware of the material differences of twentieth-century warfare” (1994: 478). Chippindale would no doubt recognise the vast majority of objects specific to WW2 that have been documented since. But nearly 20 years on, it would appear that we have significantly underestimated the “quantity of stuff” (Chippindale 1994: 478) that remains to be documented in the conflict landscapes of WW2 Europe. In hosting such a well-preserved earthwork legacy of constructional features and explosive impacts, forest and woodland environments stand as a unique resource in the context of WW2 battlefields in north-west Europe. This is true not only in terms of the quantity of material, but also in complementing the concrete and brick of widely recognised conflict landscapes with more ephemeral battlefield and bombscape archaeology. As we witness the seventieth anniversary of D-Day and the liberation battles of north-west Europe, it is to be hoped that the archaeological community will follow the example set by excavation and restoration work on the trenches and bunker systems of WW1; we argue here that regional forests offer an excellent opportunity to do so.

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Appendix IV

Paper IV:

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Second World War bomb craters and the archaeology of Allied air attacks in the forests of the Normandie-Maine National Park, NW France.

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Abstract

Well-preserved bomb craters in the forests of central Normandy, NW France, constitute archaeological legacies of combat inland from the D-Day beachheads that greatly extend the inventory of Second World War conflict landscapes in northwest Europe. Field survey and analysis of German and Allied documents demonstrates that bombscapes in the Forêt domaniale des Andaines and Forêt domaniale d'Ecouves reflect US Ninth Army Air Force attacks on a German fuel depot and radar installation, respectively, during June-August, 1944. One hundred and thirty-six craters are mapped, described and linked to specific air raids, bomb types and, for one raid on the 13th June, six specific participating aircraft and aircrews. These landscapes echo the impact of widespread tactical bombing against targets close to civilian population centres, and in some cases employing civilian and PoW labour. They are therefore well-placed to contribute to wider heritage narratives around the non-combatant experience of aerial warfare in WW2.

Key words

Bomb craters, WW2, Normandy, forests, conflict archaeology

Introduction

The landscape and monument legacy of twentieth century air warfare is proving to be of growing interest to the modern conflict archaeology and military heritage community (Lake 2002; Schofield *et al.* 2011). This interest spans the origins of air warfare and air defence in WW1 (e.g. Lake 2002; Hegarty and Newsome 2007; Whaley *et al.* 2008) to the air bases and air defence infrastructure of the Cold War (e.g. Whorton 2002; Hegarty and Newsome 2007; Schofield *et al.* 2008), and is taken here to extend also to ballistic missile test facilities and launch sites (e.g. Cocroft and Wilson 2006; Cocroft 2009). But most attention has focused on the record of WW2, from the wrecks of crashed aircraft (e.g. Legendre 2001; Holyoak 2002; Deal and Hillier 2007; Fuller and Quigg 2011) to airfield sites (e.g. Adams *et al.* 1997; Lake 2002; Lake and Schofield 2000; Schofield 2009), air defence facilities (e.g. Dobinson 2001; Osborne 2004; Spennemann 2011) and air-raid shelters (e.g. Richardson 2008; Glass 2012). It is striking, however, that direct evidence of strategic and tactical bombing - a characterising feature of WW2 (cf. Schofield 2002) and one that constituted the single most destructive agency in scarring the landscapes of northwest Europe - has to date presented only limited opportunities for archaeological inquiry. In urban Europe, for example, while reminders of conflict are frequently manifested in war memorials and commemorative plaques (Kuipers and Schofield 2004), seven decades of urban renewal has reduced visible evidence of aerial bombing to occasional remnants of bomb-damaged building fabric and, especially, the few examples of ruined buildings and bombsites that have been deliberately preserved in city centres as memorials to civilian casualties and urban destruction (e.g. Schofield 2002; Patrick 2009; Moshenska 2015). In these contexts the legacy of bombing is being explored by developing civilian narratives of the experience of air raids, for example through oral histories (e.g. Portelli 2006) and the archaeology of commemoration and

memory (e.g. Moshenska 2009; 2010; 2015; Rigby 2009).

This interest has not significantly extended to rural areas where civilian loss-of-life was very much smaller and where urban expansion and rapid post-war rehabilitation of farms and agricultural land has also largely eliminated the ruined buildings, infrastructure and bomb-cratered terrain from the modern landscape. In the battlefields of Normandy, for example, the restoration of bomb- and shell-cratered fields was generally accomplished within a few years of the war's end (Clout 2006; 2008; Passmore *et al.* in press). Those few documented areas of cratered landscape in rural northwest Europe that escaped post-war restoration are best known in coastal locations associated with the Atlantic Wall defences in France, most notably perhaps at the preserved D-Day site of Pointe-du-Hoc (Burt *et al.* 2009) and at Cap Blanc Nez Sangatte near Calais. Elsewhere they may also be found associated with abandoned airfields and V-weapon sites (Passmore *et al.* in press) and in some marginal and non-agricultural landscapes including former military training and weapons testing areas (although the latter are typically recording the impacts of bomb testing rather than combat; e.g. Hall 2013; Fisher 2013). In general, however, there are relatively few formal archaeological investigations of such features and hence the documented landscape archaeology of northwest Europe conveys little of the extent or degree of damage wrought by WW2 air raids, and especially that associated with widespread tactical bombing of military targets during the Allied campaign through France, the Low Countries and Germany in 1944-45.

Recently, however, there is emerging evidence from both dedicated ground-based survey (Passmore *et al.*, 2014) and LiDAR-based evaluations of multi-period archaeological landscapes

(e.g. Doneus and Briese 2011; Hesse, 2014) that northwest Europe's forests and woodlands are areas where bomb (and shell) craters may still be preserved and in considerable numbers.

Documented evidence of bomb craters in the Normandy region is associated with Allied tactical air strikes on V-weapon sites (Passmore *et al.* in press), German airfield sites (Passmore *et al.*, 2014) and forest-based fuel depots (Capps Tunwell *et al.* 2015), and ongoing work by the authors has begun to synthesise the archaeological evidence of bomb damage and a wide range of photographic and primary documentation from both Allied and German sources in order to evaluate the history and effectiveness of Allied tactical bombing of logistics targets in the Forêt domaniale des Andaines, Basse Normandie (Capps Tunwell *et al.* in submission). In this paper we turn to the detailed archaeology of bomb-cratered terrain with the aim of evaluating the potential of these 'bombscapes' to record the few minutes of a specific air raid, and thereby contribute to the growing body of work in conflict archaeology that reflects on acts - and costs - of violence that are especially highly resolved both in time and space. This aim is addressed via archaeological survey of craters that are well-preserved in parts of the Forêt domaniale des Andaines and also the nearby Forêt domaniale d'Ecouvès, both located some 80-95 km south of the June 1944 D-Day beachheads. The number, size and geographical disposition of craters is considered with respect to (i) wartime assessment of relationships between bomb crater size and the type of ordnance, fuzing, drop height and ground conditions, and (ii) detailed documentary and photographic accounts of five air raids conducted during June, July and August 1944. We also reflect on the potential of this approach to contribute to wider heritage agendas relating not only to the participants in aerial bombing but also those living and working in the target areas.

Physical geography and military history of the study area

Conflict landscapes investigated here lie within the extensive mixed coniferous, oak, beech and birch forests of the Parc Naturel Régional Normandie-Maine, located in the southern part of the Basse-Normandie region of northwest France (FIG. 1). Much of this forest cover mantles higher elevation, gently undulating terrain between 200-400 m asl developed on Ordovician sandstones, shales and conglomerates with some Neoproterozoic granites and Proterozoic (Brioverian) pre-Cambrian schists. Regional soil cover is dominated by dystric and eutric cambisols with local development of podsols.

Previous investigation of extant bomb craters in this region focused on the Forêt domaniale de Bourse, a relatively small forest area 14 km northeast of Alençon and towards the eastern margin of the Parc (Passmore *et al.*, 2014: FIG. 1). In this paper we focus on sites located in the larger historic forests in the heart of the Parc, respectively the Forêt domaniale des Andaines (hereafter FDA), centred on the spa town of Bagnoles-de-l'Orne, and the Forêt domaniale d'Ecouves (hereafter FDE), located between Alençon and Argentan (FIG. 1). Development of the FDA as a major site for German fuel, munitions and rations depots has been described in detail by Capps Tunwell *et al.* (2015), and the history of Allied attempts to bomb these facilities is documented by Capps Tunwell *et al.* (in submission). Detailed study of bombscapes in the FDA have been undertaken in the central part of the forest at the site of Lager Berta, a major German Army (Heer) fuel depot established in April 1943 in order to provide a 1000 m³ fuel reserve for the lower Normandy region (NARA T-312 R1557 000133). The northern part of this depot facility was to be repeatedly bombed by medium and light bombers of IX Bomber Command, US Ninth Air Force between the 13th June and the 6th August, 1944 (Capps Tunwell *et al.*, in submission).

By comparison with the FDA, the Forêt domaniale d'Ecouves lacked the well-developed road and - especially - rail links offered by Bagnoles-de-l'Orne and was not a focus for Army-level logistics sites. The forest was nevertheless the focus for several air raids during the Normandy Campaign, including attacks by IX Bomber Command on a radar installation at la Verrerie du Gast, located in the central part of the general forest area in the la Verrerie area (FIG. 1).

Woodland surrounding la Verrerie du Gast still bears the landscape evidence of these raids and forms the second of the study sites investigated here.

Data sources and methods

In attempting to link the landscape record of aerial bombing with historical accounts of air raids in the Parc, this study has drawn on archaeological ground survey of craters and a range of contemporary and post-war primary archive documents, aerial photographs and written histories of the US air war over Normandy. Details of the individual datasets and the project synthesis are as follows.

Documentary sources

(I) ALLIED INTELLIGENCE SOURCES, ANALYSIS AND TARGETING INFORMATION

Much of the intelligence gathering, analysis and targeting information obtained for the Allied bombing campaign in preparation for Operation Overlord, and during the early stages of the campaign itself, was synthesised in Tactical Target Dossiers (TTD) that were compiled for geographical sectors covering northern France (Kreis 1996; Capps Tunwell *et al.* in submission). The FDA lay in the Laval sector TTD (4801 W; AFHRA IRIS Ref A5303) and the January 1944 edition accurately identifies the northern part of the Lager Berta fuel depot as one of two targets

in the forest (Capps Tunwell *et al.* in submission). This identification, and its confirmation in the revised June TTD, was to initiate the air raid history and landscape impact that is explored in this paper.

(II) MISSION PLANNING, ORDERS AND DE-BRIEFING

Detailed information on specific raids mounted by the Ninth Air Force may be obtained from Command records (including Field Orders) and Bomb Group raid records, accessible via the US Air Force Historical Research Agency (AFHRA) at Maxwell Air Force Base in Alabama.

Following the decision to mount a raid on a specific target, field orders at Bomber Command and Combat Wing level were forwarded as teletypes down the command chain to individual Bomb Groups with detailed specifications for the mission, including aircraft numbers and formations, bomb loads and fuzing, and the bombing heights and bomb spacing. Post-raid de-briefing reports provide details of aircraft crews and allocations to flights and box formations, together with their individual bomb loads, raid chronologies and a note of those aircraft equipped with cameras.

Aerial photos taken during and after the raid were subsequently used by the unit photographic interpretation officer to determine the flight lines of boxes and the areas impacted by bombs. The results of each flight were detailed and rated from Excellent to Gross.

(III) BOMB TYPES AND CRATER ANALYSIS

The most widely-deployed bomb type deployed by the Ninth Air Force in Normandy was the 500 lb General Purpose (GP) bomb, possessing good fragmentation characteristics and sufficient blast effect to render even near-misses capable of damage or destruction of a wide range of targets (Army Air Forces Evaluation Board in the European Theatre of Operations 1945).

However, the likelihood of these types producing craters in the landscape was critically dependent on the fuze configuration applied to both the nose and tail of these weapons. Figure 2 shows that little or no cratering effect could be expected from bombs configured with instantaneous nose fuzes that were intended to detonate on contact in order to maximise the blast and fragmentation effect; this was the preferred configuration for targets such as troop concentrations, soft-skinned or lightly armored vehicles and rolling stock. Where cratering was the desired effect, notably for attacks against structures, roads and railway lines, a delayed fuze of 0.01 or 0.025 seconds was typically applied (FIG. 2). Long-delay fuzes of up to several hours could also be used against transport infrastructure to disrupt or deter repair work. In practice, and especially where aircraft were conducting armed reconnaissance patrols where the target types were uncertain, bomb loads often comprised a mix of fuze settings.

Wartime analyses of explosion crater dimensions for various soil conditions and ordnance types were conducted by the US National Defense Research Committee and published as Weapon-Data-Fire-Impact-Explosion (WDFIE) data (NDRC 1945). Data charts therein permit typical crater size and depth to be calculated for a range of bomb types, release altitudes and in sand, loam and clay soils and substrates. Some 70 years after the war this same data may be used to assist in differentiating between craters obtained by different ordnance types; Table 1 presents selected values obtained for bomb penetration depth, crater depth and crater diameter for both 250 lb and 500 lb GP bombs dropped from heights of 10,500 ft and 12,500 ft, respectively, using crater size and depth curves developed for loam and clay soils with a delayed fuze in order to permit full bomb penetration depth. WDFIE data charts caution that observed crater diameters and depths may deviate up to 30% from estimated values on account of irregularities in

subsurface trajectories and soil conditions, and hence the data presented in Table 1 include the size ranges obtained using the calculated values with a +/- 30% variance.

(IV) POST-WAR AERIAL PHOTOGRAPHS

Vertical aerial photographs taken during the immediate post-war period have been shown to permit the identification of bomb damage to wooded areas and, where the forest cover has been cleared or felled, features on the forest floor including logistics depot facilities, bomb craters and post-war ordnance disposal activity (Passmore *et al.* 2014; in press; Capps-Tunwell *et al.* 2015). In this study the post-war record of bomb damage in the FDA and FDE was analysed from aerial photograph sorties at a scale of c.1:25,000 dating to June 1949, accessed from the Institut Géographique National (IGN) archive.

Field survey of extant bomb craters

Detailed analysis of the bomb crater landscapes in the FDA and FDE is an extension of archaeological survey of German supply depots in regional forests that have been described in detail by Capps Tunwell *et al.* (2015) and Passmore *et al.* (2014). Crater areas selected for survey (see below) were fieldwalked and all identifiable craters were located using a combination of GPS and a laser rangefinder. Preservation in these settings reflects a limited degree of post-war modification although some degree of degradation and/or modification of crater depth and cross-sectional profile may be expected, and in some cases was clearly evident as a result of forestry operations (e.g. road and track improvements, etc). All craters can be expected to have accumulated some fill of sediment and organic debris, and in some areas were filled with water (reflecting high water tables) or have accumulated variable depths of wood and

leaf litter. Several examples appear to have been used as deliberate repositories of organic waste. No attempt was made to excavate or disturb the ground surface in or adjacent to any of the craters, and accordingly our focus on crater dimensions has focused primarily on crater diameters measured at their widest point on the forest surface, and where possible on maximum extant depth.

Data compilation and analysis

All survey data, topographic maps and aerial photographs were compiled in a GIS database (ArcMap) that enabled both cross-checking of features identified by field survey and aerial imagery, and also analysis of feature disposition and spacing. Aerial photographs were georectified to modern basemap (IGN Carte Topographique TOP 25, scale 1:25,000) control points using ArcMap's georectification tool.

The la Verrerie raids of 8th and 9th August 1944

The la Verrerie study area, located in the central part of the FDE (FIG. 1), hosted a German radar installation in a small clearing in the forest at la Verrerie du Gast that was bombed on 8th and 9th August 1944 by A-20 Havocs of the 410th and 416th Bomb Groups (TNA; AIR 37/397 Allied Expeditionary Air Force Daily Int/Ops Summary No. 203). All three raids were flying on north to north-westerly headings with all but six aircraft at heights between 9,000 and 12,500 ft, and loaded with 500 lb GP bombs armed with delayed fuzes in the nose (1/10 second) and tail (1/100 second). An IGN aerial photograph dated 28th June 1949 (IGNF C94PHQ3791_1949_F1416-1716_0383) shows numerous infilled bomb craters in the open ground and areas of bomb

damage and cratering in the forest to the north and east. This study has focused on two discrete groups of preserved bomb craters located respectively to the east (Survey Area X) and north (Survey Area Y) of the clearing (FIG. 3). Both sets of craters form arrays that are broadly aligned southwest-northeast and are consistent with the raid flight paths described above although on the basis of current information neither can be attributed to a specific date. Crater locations and size classifications are mapped in Figure 3 and plotted as their size rank with depths (where available) in Figure 4. Also shown on Figure 4 is the crater diameter and likely size range calculated from WDFIE data for 500 lb GP bomb types armed with delayed fuzing (see also TABLE 1).

Survey Area X comprises a group of 19 well-preserved bomb craters located in the forest between 150 m and 350 m east of la Verrerie du Gast (FIG. 3). Here the terrain forms the wooded middle and lower slopes (c.9-15% incline) of a small headwater tributary of the la Sennevière river valley. Numerous exposed bedrock boulders in the vicinity of the craters are likely to have been upthrown by blast action and attest to the relatively thin eutric cambisol soil cover in this location, while soils are poorly drained and 13 of the craters are water-filled (FIG. 3). Surveyed crater diameters at this location range in size between 3.6-9.6 m, although 17 of the 19 examples exceed 7 m (FIG. 4) and the mean and median values are 7.7 m and 7.9 m, respectively. Survey Area Y, located in woodland immediately north of la Verrerie du Gast, encompasses a group of 17 craters (with a further seven examples that were too disturbed or overgrown to be formally surveyed) (FIG. 3). This site forms the gently sloping (c.4%) upper valley slope of the la Sennevière river and exhibits drier ground conditions than Survey Area X, such that only four of the craters could not be assessed for depths on account of ponded water.

Craters here form a slightly smaller assemblage than those at Survey Area X with mean and median values of 7.4 m and 7.3 m, respectively, and only two examples are in excess of 8 m (FIGS. 3 and 4). Thus, with the exception of the two smallest craters in Survey Area X, respectively of 3.6 m and 5.5 m diameters, the vast majority of craters at this site are consistent with the likely size range predicted by WDFIE data for ordnance of this type and release height.

Bomb-damaged landscapes in the Forêt domaniale des Andaines

Figure 5 maps the location and extent of Seventh Army logistics depots in the FDA and those areas that have been shown to have been impacted by Allied bombing during the summer of 1944. Impact areas in the western part of the forest, in the vicinity of Lager Berta sites II and III, exhibit only occasional preserved craters and here the evidence of bomb damage is derived largely from post-war IGN aerial photographs (Capps Tunwell *et al.*, in submission). Limited cratering in these areas is considered to reflect bombing patterns dominated by incendiary ordnance or GP bombs with instantaneous fuzing that yield little or no cratering (see also Passmore *et al.*, in press). By contrast, modern landscape evidence of bomb impacts is widespread in the central part of the FDA in the vicinity of Lager Berta I and its associated area of vehicle shelters (FIG. 5). This site was designated as a target area in the January 1944 TTD and delimited as a target box that extends from the Carrefour Ferrière and the D908 at the Carrefour des Cerisiers 0.75 km southwest to the Carrefour Garde Général (FIG. 6a). In the updated TTD of June 1944 the Lager Berta target box was revised to extend along the forest roads radiating from the Carrefour Garde Général in the central part of the depot (FIG. 6a). However, the northern part of the depot now fell within an additional elongate target area extending along the D908 between the Carrefour des Etoile and the forest edge north of

Bagnoles de l'Orne (Figs. 5 and 6a).

The Allied perception of the importance of Lager Berta I as a fuel depot is reflected in the number of bombing raids mounted on the target areas delimited in the TTD's; between June 13th and August 14th the area was subjected to no fewer than 22 attacks by tactical fighter-bombers and - especially - light and medium bombers of the US Ninth Air Force, delivering a total of at least 589 tons of bombs (Capps Tunwell *et al.*, in submission). Attacks were most intensive during mid-late June when the greater proportion (c.71%) of bombs were delivered, and this effort is reflected in the concentration of overlapping and overprinted craters in the northern part of Lager Berta I within the January TTD target area (Figs. 5 and 6a); here the incidence of multiple bomb impacts are judged to preclude any attempt to discern the craters of specific raids. Rather, in seeking to link bomb craters to specific raids we have sought to establish those parts of the FDA that exhibit (i) well-defined groups of discrete craters that appear to be the sole examples of impacts in any one area, and either one or a combination of (ii) in-raid photographs showing bomb detonations that can be matched to extant and discrete craters, (iii) post-raid reports specifying and illustrating bomb damage and(or) (iv) post-war IGN aerial photographs that also show areas of bomb damage and cratering. These conditions were found to be satisfied in two areas marginal to the main impact zone at the Carrefour des Cerisiers, respectively identified as Survey Area A, struck on 13th June and Survey Area B, bombed on 24th July (FIG. 6a).

The June 13th 1944 raid

The raid of the 13th June was the first of the US Ninth Air Force's light and medium bomber

missions to attack logistics targets in the FDA and was intended to strike at aiming points in the Carrefour des Cerisiers area delimited on the January 1944 TTD (FIG. 6a). Between 21:27 and 21:34 the area was struck by 36 B-26B Marauders of the 397th BG flying in two formations ('boxes') of 18 aircraft, each box consisting of three flights of six aircraft in an arrow-head formation (TABLE 2). Bomb loads included both 250 lb and 500 lb General Purpose bombs with 50% armed with instantaneous fuzes and the remainder with delayed fuzes in the nose (1/10 second) and tail (1/40 second) (TABLE 2). The post-raid report (dated 17th June, 1944; B-26 Marauder Archive, Beck Collection, University of Akron, Ohio) includes two aerial photographs that are reproduced in Figure 6b and 6c. Figure 6c is an image taken during or shortly after the raid itself and shows a smoke plume rising from the target area that is associated with the burning of fuel. This image also records the flight paths for each flight during its bomb run (see also Fig 6a). A second photograph, taken sometime after the fires had been extinguished, shows clearly the areas of bomb damage (FIG. 6b). Formation flight paths and bomb damage assessments are combined in Figure 6a which shows that five of the six flights arrived over the target area at headings between 90 and 105 degrees (see also TABLE 2) and these were most likely to have been associated with the damage to fuel bunkers and stocks in the northern part of Berta I. However, the six aircraft of Flight 2, Box 1 required a second run at the target on a heading of 183 degrees and their bombs fell 100-500 m north of the target area (TABLE 2; FIG. 6a and c).

Ninth AF analysis of this raid as a success was confirmed by the German Army logistics staff diary reporting the loss of 300 cubic meters of fuel (NARA, T311 R14, 014539), although the depot continued to operate for a few days after the raid before being shut down as fuel

storage in the FDA was transferred to Lager Beere, also operating in the western part of the forest (Capps Tunwell *et al.*, 2015; FIG. 5). The decision to shut down Lager Berta is likely to have been encouraged by repeated attacks on the site of Berta I by the Ninth AF in the weeks following the 13th June raid and this would also account for the considerable damage to forest cover and overprinting of bomb craters evident on post-war IGN aerial images and field survey, respectively, in this part of the forest (FIG. 7). The extent of bomb impacts here effectively precludes identification of specific raid craters. To the northwest of the target area, however, the area struck by Flight 2, Box 1 on June 13th shows relatively little evidence of additional bomb damage on post-war IGN aerial imagery with the area of cleared forest cover retaining an elongate planform aligned close to the flight's heading of 183 degrees (Figs. 6 and 7).

Accordingly, the rectangular area here highlighted by the 397th Photo Interpretation Officer was used as the basis for delimiting Survey Area A and conduct of detailed field survey. The survey area boundaries were extended slightly during fieldwork to encompass several isolated nearby bomb craters.

Survey Area A spans a small stream valley within forest management parcels 199 and 200 and is bisected by a small un-named tributary stream of the nearby Ruisseau de Mousse (FIG. 8). To the north of the stream (Area Ai) the valley has a relatively shallow slope (8%) with a substantially thinned woodland cover and is poorly-drained with frequent boggy patches. The southern part of the survey area (Area Aii) spans the valley crest and a relatively steep valley side (maximum slope 15%) that is planted with mixed woodland. On June 13th 1944 each aircraft of Flight 2, Box 1 was carrying eight M64 500 lb GP bombs, four armed with instantaneous fuzes and four armed with M103 1/10 second nose fuzes and M101 1/40 second tail fuzes; in

total 48 bombs were dropped from a height of 10,500 feet (TABLE 2). The landscape signature of this ordnance comprises 44 distinct crater depressions in Survey Area A with surface diameters ranging from 3.9 m to 10.5 m and mean and median diameters of 7.8 m and 8.3 m, respectively; these are mapped in Figure 8 and plotted as their size rank in Figure 4. All but two of the craters in the northern sub-area Ai exhibit diameters in excess of 7.9 m and the majority are filled with water or bog (FIG. 8). Four examples appear to have been partially infilled and have depths up to 0.5 m. The two smaller craters, respectively 3.9 m and 7.5 m in diameter, are located near the valley crest. On the southern side of the valley (Area Aii) there are a further two examples of large (>7.9 m) craters on the valley crest, but elsewhere in this area the remaining 17 craters are relatively small with diameters between 4.1-7.2 m (Figs. 4 and 8).

A total of 31 craters in Survey Area A have diameters between 6.4-10.5 m and hence fall within the size range predicted by WDFIE data for 500 lb bombs with delayed fuzing and a drop height of 10,500 ft (FIG. 4; TABLE 1). They are therefore consistent with ordnance dropped by Flight 2, Box 1 on 13th June, although only 24 of the weapons were fuzed for delayed detonation and thus as many as seven craters may reflect delayed detonation of an instantaneously fuzed weapon, or perhaps stray delay-fuzed bombs from a later raid. The remaining 13 craters have diameters between 3.6-6.3 m and are mainly found in the southern part of the survey area (Area Aii; FIG. 8). These smaller craters are more difficult to match with delay-fuzed 500 lb types, although it is considered possible that at least some of these may represent the impact of bombs with instantaneous fuzes achieving some degree of penetration in soft ground. However, since the southern extent of Survey Area A is approaching the primary TTD target area (FIG. 6) it is also possible that some of these impacts reflect smaller 250 lb bombs associated with one or

more of the later raids on Lager Berta.

The 24th July 1944 raid

Survey Area B corresponds to the eastern part of Forest Parcel 107, located on the north side and adjacent to the D908, and bounded to the west by the Route Forestière de la Prise Pontin (Figs. 6a and 9). This area overlaps with the northeast corner of the January 1944 TTD (FIG. 6a) and part of the vehicle park associated with Lager Berta (FIG. 9). Here the conifer-planted and well-drained terrain is relatively flat or gently inclined in its western extent and to the east forms the southwest valley side and footslope of the Ruisseau de Mousse. Valley side slopes vary between six and 20%. On the 24th July this area was impacted by the thirteenth raid mounted by the US Ninth Air Force on Lager Berta, on this occasion by A20 Havoc light bombers of the 410th BG (TABLE 2). The raid attacked on a heading of 120° and from a height of 12,600 ft in two boxes of 16 and 12 aircraft, respectively, flying in flights of four aircraft in diamond formation (TABLE 2). The majority of aircraft carried six 500 lb bombs with delayed nose (1/10 second) and tail (1/100 second) fuzes and aimed on a point marked by bombs dropped by a B26 pathfinder aircraft. The post raid results were assessed as poor, even though 60 percent of the bombs fell in the target area (AFHRA IRIS Refs B5787 and B0517).

A total of 56 craters have been identified in Survey Area B, including 10 pairs of overlapping examples which have been differentiated into individual strikes. The majority of craters here are well-preserved with mean and median diameters of 8.1 m and 8.2 m, respectively, and measurable depths between 1.5-3 m (FIG. 4); only six examples are water-filled and a further seven are substantially infilled with wood and organic debris. Craters are distributed throughout

the parcel and in the western margin of the survey area include six examples which impacted close (less than 20 m) to an array of vehicle shelters and associated foxholes lying alongside the Route Forestière de la Prise Pontin (FIG. 9). One crater, largely infilled but with an evident diameter of 8.5 m, partially overlaps with one of the vehicle shelters. The majority of impacts in this parcel, however, lie outside of the target area. Fifty-two of the craters identified here have diameters between 6.2-11.3 m and are consistent with the size range predicted for delay-fuzed 500 lb bombs with a drop height of 12,600 ft (TABLE 1). The remaining four craters have diameters between 3.9-6.1 m and are found in the western part of the survey area (FIG. 9). These smaller examples may reflect premature detonation of 500 lb ordnance or have reduced crater size on account of impacting variable soil conditions, but it is also possible that they reflect the impact of smaller bombs (most probably 250 lb or 100 lb GP types) dropped either before or after the raid of the 24th July.

While the possibility that some of the craters in Survey Area B may obtain from other raids on the target area cannot be discounted, correlation of many examples with the 24th July raid is further supported by an aerial photograph taken during the raid itself which captures several bomb detonations and immediate post-detonation smoke plumes within the survey area (FIG. 10). Georectification of this photograph with the crater survey has enabled an assessment of craters that closely match the impact points captured by the image and these are also plotted on Figure 10. This shows a good correspondence with 11 of the larger (>8.4 m) craters and supports the interpretation of these examples as dating to the 24th July. The modern imprint of one of these craters is shown in Figure 9.

Discussion

The 136 craters described here represent only a small fraction of the total landscape record of aerial attacks in these areas of the Parc, but are illustrative of this distinctive yet little-studied landscape legacy of the Normandy campaign. At the forest-wide scale, and in combination with archaeological evidence of fuel and ammunition depots and an array of documentary materials, bombscapes have permitted an analysis of the effectiveness of Allied air strikes on a major logistics facility (Capps Tunwell *et al.*, in submission). In specific areas of the FDA that were correctly identified by Allied intelligence as hosting Lager Berta the preservation of multiple, overprinted bomb craters constitute an aggregate record of the many attacks over the period and testify to the scale and intensity of raids on this target area (FIG. 2). Elsewhere in the wider Parc area, however, localised clusters of individual or partially overlapping craters can be demonstrated to capture the few minutes duration of discrete and identifiable air raids. This is most readily achieved at places where the documentary record indicates the site was subject to only a single raid (FDA Survey Area A) and especially where the raid was flown by aircraft armed with a single bomb type and fuzing arrangement (la Verrerie, Survey Areas X and Y). Individual sorties may be rather more difficult to differentiate in landscapes that experienced multiple raids on the same target area, but in the case of the Lager Berta site in the FDA it can be argued that the combination of documentary archives and archaeological survey does permit such resolution in those areas where bombing runs were marginal to the main target area and can be reconciled with detailed in- and post-raid photographic and documentary source material (FDA Survey Area B).

The potential for conflict archaeology studies to draw on military concepts and analytical techniques is well recognised (e.g. Bleed and Scott 2011) and has been argued to extend to the study of projectile fragments (e.g. Gassend 2014) and projectile craters (e.g. Gaffney *et al.* 2004), especially for the characteristic crater shapes of low-angle impacts from artillery shells and even those of relatively high-angle mortar shells (Scott and Haag 2009). These types of craters may be receptive to procedures used in military crater analysis to derive information on the bearing from which the projectile was fired and on the type and calibre of the shell (War Department 1945; United Nations 2003). To date, however, this type of analysis has not been much applied to the archaeological record of projectile craters, in part because many of the techniques are designed for application to fresh, undisturbed impact zones but also perhaps reflecting the paucity of well-preserved craters in the archaeological record of historic conflicts. Many of these techniques are less appropriate for high-velocity aerial bombs with high-angle impact trajectories, but our analysis of Normandy bomb craters has been informed by WDFIE-derived crater size ranges that provide a framework for interpretation and accommodate variables such as soil type, drop height and fuzing.

WDFIE data includes estimates of crater depth but a non-invasive approach to survey in these forested settings, with a combination of frequently waterlogged subsoils and abundant accumulation of leaf and wood debris (including deliberate infilling by forestry operations), precludes a systematic assessment of depth characteristics. Nevertheless, here we note that the majority of crater depths recorded in the survey areas lie within the 1.3-2.4 m range predicted by WDFIE data, while several examples between c.3-3.6 m exceed this depth range (TABLE 1; FIG. 4). One factor giving rise to excessive crater depths may be the presence of waterlogged

ground conditions at the time of impact since this is recognised as enhancing the blast effect (NDRC 1945).

Our emphasis in this study has been on the surface diameter of craters which, unless physically disturbed by tree fall or forestry operations, are unlikely to have been significantly modified under a forest canopy in the seventy years since the event. The majority of craters surveyed across the study areas, and all of the examples at la Verrerie, can be confidently attributed to 500 lb GP bombs fuzed for maximum penetration, and with only few exceptions they lie within the size range given by WDFIE data (TABLE 1; FIG. 4). This wide array of crater sizes is considered to be expected given the influence of variable ground conditions (including soil type and depth, groundwater levels and slope) recognised by the WDFIE guidance and especially in the context of well-forested settings with the additional complications introduced by a tree canopy and the likely presence of fallen or buried timber and tree roots. The lack of craters larger than 9.6 m at la Verrerie is striking by comparison to the FDA and is interpreted here as reflecting the relatively thin soil cover in this part of the FDE such that bombs were most probably detonating near or within weathered bedrock. In the FDA, where both Survey Areas (and especially Area B) may have been impacted by 100 lb or 250 lb bombs in raids other than those considered in this study, it is also accepted that craters less than c.6.2 m in diameter may be difficult to differentiate between GP bomb types smaller than 500 lb and those from larger types that detonated below the ground surface but before achieving maximum penetration (including possibly examples fitted with instantaneous fuzes). Indeed, this may also apply to some craters in the c.6.2-8.9 m range where there is overlap between the 250 lb and 500 lb diameter size range (TABLE 1).

Accordingly, these results indicate that archaeological evaluation of bomb-cratered terrain may permit crater dimensions to be related to the size and type of ordnance, but that attempts to correlate bomb size with crater size must proceed with caution and that robust interpretations are more likely to be achieved where investigations have recourse to archive records of specific air raid histories. Furthermore, it is recognised that cratering is an intentional outcome of high-explosive, GP bombs armed with delayed-action fuzes in order to achieve maximum ground (or structure) penetration; other types of air-dropped ordnance such as incendiaries, fragmentation bombs and GP weapons fitted with instantaneous fuzes are liable to register little or no cratering and hence may not be detectable in the archaeological record (see also Passmore *et al.* in press). However, since high-explosive GP bombs were the most widely used bomb types by the US Ninth Air Force in northwest Europe (Army Air Forces Evaluation Board 1945) it is considered there is high potential for archaeological assessment of cratered landscapes in many forest-based targets struck during the Allied campaigns subsequent to Normandy (see also Doneus and Briese 2011; Hesse 2014; Passmore *et al.*, 2014).

For bombs in excess of 500 lb crater dimensions are likely to be larger than those documented in this study (FIG. 2), and significantly so for weapons such as the British ‘earthquake’ bombs - the 12,000 lb Tallboy and 22,000 lb Grand Slam (capable of generating craters c.30 m and 40 m in diameter, respectively; Hall 2013; Fisher 2013). Craters associated with these weapons can still be found in former bombing ranges in southern England (Hall 2013; Fisher 2013), and also where used against V-Weapon sites (e.g. at Eperlecques, near Watten, France: <http://www.v2rocket.com/start/deployment/watten.html>) and on the Norwegian coastline at

Tromsø where they were used in attacks against the German battleship Tirpitz (<http://en.tracesofwar.com/article/9673/Memorial-Tirpitz.htm>). In the context of attacks on ammunition depots it might be also be anticipated that unusually large craters might arise where bombs detonate in or near bunkers containing live ammunition, but here we recognise the potential difficulties in differentiating between direct bomb strikes and the large craters reflecting post-war detonation of live ordnance associated with munitions disposal activity (see for example Capps Tunwell *et al.*, 2014; Passmore *et al.*, in press).

The ability to resolve the physical evidence of specific raids establishes links between landscape records and air forces conducting the attacks which are liable to be of interest from a heritage perspective, including those historic interest groups related to particular air commands and host airfields, and of course the veteran communities themselves. Indeed, in the case of the 13th June raid it has proved possible to identify the participating aircraft that struck Survey Area A as the six members of Flight 2, Box 1, 596th and 597th Bomb Squadrons, 397th Bombardment Group, US Ninth Army Air Force. In Table 3 we present the original crew list and aircraft details for this flight that at this point in the campaign were based at RAF Rivenhall (AAF Station 168; http://www.b26.com/page/397th_bombardment_group_history.htm) in Essex, southeast England. Although much of this airfield has been lost to aggregate extraction and an industrial estate, the Airfields of Britain Conservation Trust report parts of the perimeter track and airfield buildings (including two hangers) survive in the present landscape (<http://www.abct.org.uk/airfields/rivenhall>).

In drawing attention to those conducting the bombing raids - what Portelli (2006) would term a

‘top-down’ perspective on the bombing history - we also acknowledge heritage narratives drawn from the ‘bottom-up’ that are of particular concern to those with immediate connection to the landscape, and perhaps with memories of the events themselves (see also discussion in Moshenska, 2009). Forest bombscapes may not resonate with the weight of ‘dark heritage’ carried by destroyed towns and cities, but they do serve as a signature of the extension of bombing campaigns beyond the urban and industrial front lines in northwest Europe and into those areas associated with bombing of transport infrastructure and military support facilities. To the military casualties in these areas must be added those from PoW and foreign labour workforces and also the civilian population; indeed, between 50,000 and 67,000 civilian casualties have been ascribed to the result of Allied bombing in support of operations in the Normandy Campaign (Atkinson 2013). We do not yet know how many casualties were contributed by the raids in this paper and work is ongoing with regard to the experience of those living or working in or near the FDA, but their voices are already present in the unpublished journals of forestry workers recording the precise times of air raids in the FDA (and describing the hazards posed by bombs fuzed to explode several hours after impact; Capps Tunwell, unpublished data), and in witness testimony gathered by Hairie (2007) that recalls the aftermath of raids on the Carrefour Ferriere which includes descriptions of destroyed forester’s posts and, lying on the side of the road, the bodies of two or three Senegalese PoW’s who had been working in Lager Berta.

Finally, we note that the survival of bomb craters in the FDA and FDE has been a fortuitous outcome of post-war forestry management practices, aided to no small degree by shrapnel contamination of trees that has rendered many impacted areas as of limited economic potential

for their timber resources. However, in the absence of formal guardianship or management agreements these landscapes have no guarantee of long-term preservation and hence it is to be hoped that the developing interest in twentieth century conflict landscapes will extend to cratered forest floors. In this respect the increasingly widespread availability of LiDAR coverage with its ability to yield high-resolution forest floor topography arguably holds the greatest potential for illuminating the extant landscape record of WW2 bombing.

Conclusions

Archaeological and heritage perspectives on extant shell- and bomb-cratered landscapes forms only a comparatively small proportion of the conflict archaeology literature on account of the rarity of battle-scarred terrain in the modern landscape. The preserved WW1 battlefields of the Western Front have arguably presented most opportunities to do so (e.g. The Vimy Declaration for the Management of Historic Battlefield Terrain; Gough, 2004); cratered landscapes of WW2, by contrast, have offered very little, at least until the relatively recent focus on forested settings (Passmore and Harrison, 2008; Hesse, 2014; Passmore *et al.*, 2014). The case studies described above not only illustrate the character of these most evocative landscapes in the case of Normandy forests but, in constituting some of the few surviving direct archaeological traces of combat inland from the D-Day beachheads, also serve to greatly extend the recognised inventory of WW2 conflict landscapes in Normandy. When considered alongside the documentary record, bombscapes represent violent events that may be resolved to an unusually well-constrained timescale - in some cases as little as a few minutes - and can be linked to specific ordnance types, participating aircraft and aircrews, and ultimately the host airfields. Perhaps of equal significance, however, is the bombscape's ability to echo the impact of widespread tactical

bombing behind the front lines against targets close to civilian population centres, and in some cases employing civilian and PoW labour. They are therefore well-placed to contribute to wider heritage narratives around the non-combatant experience of aerial warfare in WW2. Since the conflict landscapes illustrated here reflect the imprint of the most widely used bomb type by Allied tactical air forces in northwest Europe, it is considered that similar potential is likely to exist for many forest-based targets struck during the Allied campaigns subsequent to Normandy.

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Table 1: Details of bomb penetration range and crater dimensions derived from Weapon-Data-Fire-Impact-Explosion (WDFIE) data (NDRC 1945).

Height (ft)	Soil Type	Bomb penetration depth (m)	Crater depth (range) (m)	Crater diameter (range) (m)
<i>250 lb General Purpose M57</i>				
10500	loam	4.1	1.4 (1.0-1.8)	7.0 (4.9-9.1)
12500	loam	4.3	1.2 (0.9-1.6)	6.9 (4.8-8.9)
<i>500 lb General Purpose M64</i>				
10500	loam	5.2	1.7 (1.2-2.2)	9.2 (6.4-11.9)
12500	loam	5.5	1.8 (1.3-2.4)	8.9 (6.2-11.5)
12500	clay	7.9	0.9 (0.6-1.2)	6.3 (4.4-8.1)

Table 2: Details of US Ninth Air Force raids on Lager Berta, Forêt domainale des Andaines, on the 13th June and 24th July, 1944.

Details of raid	Mission No. 368 / 103: 13 th June, 1944	Mission No. 445 / 141; 24 th July, 1944	
Wing / Bomb Group	98 th Wing; 397 Bomb Group	PFF (Pathfinder)	97 th Wing; 410 Bomb Group
Target position	GSGS Reference VT938019; Tactical Target Dossier Reference: 4801W/H/1	GSGS Reference VT942022; Tactical Target Dossier Reference: 4801W/H/1, 100048.	
Bomb type / number	250lb GP (172), 500lb GP (200)	500lb GP (8)	500lb GP (140)
Formation	Box 1: 3 flights of 6 aircraft in arrowhead formation. Box 2: as Box 1	2 aircraft, 1 leading each Box	Box 1: 4 flights of 4 aircraft in diamond formation. Box 2: 3 flights of 4 aircraft in diamond formation
Aircraft type / number	B26B Marauder (36)	B26B Marauder (2)	A20G Havoc (32 – note only 24 aircraft made the attack)
Box 1 height	10000; 10500; 10000	12600	12600
Box 2 height	10900; 11600; 11000	12000	12000
Time over target	21:27 – 21:34	19:00	19:01
Direction of attack	Box 1: Flt 1 096, Flt 2 096, Flt 3 105 Box 2: all Flights at 090	All flights at 120	
Results of bombing <i>AP: aiming point</i> <i>MPI: Mean Point of Impact</i> <i>DMPI: Desired Mean Point of Impact</i>	Box 1 Flight 1: Good (1300 ft E of AP; 1000 ft E of MPI) Flight 2: Gross (trailing pattern 2100 ft N of DMPI, half in the target area) Flight 3: Fair (trailing pattern 2850 E of DMPI, half in target area) Box 2 Flight 1: Excellent (bombs in pattern on DMPI and AP, all bombs in target area) Flight 2: Good (bombs in trailing pattern 396 ft W of AP, 1005 W of DMPI, half in target area) Flight 3: Fair (bombs in pattern 770 ft W of AP, 1240 ft E of DPMI, all in target area.	Box 1 Poor: bombed on PFF, bursts occurred in wooded area with weight of concentration falling on and near intersection 1500 ft SE of desired MPI, approx 60% were in NE target area Box 2 Poor: concentration approximately 1500 ft SE of DMPI in the same area as that of Box 1. Cloud cover and smoke made accurate assessment difficult. Note: Four aircraft dropped their bombs as accidental release in fields 23 miles WNW of the primary target, SE of Barthelmy village.	
Reference source documents	AFHRA IRIS Refs B5785, B0459. B-26 Marauder Archive, Beck Collection, University of Akron, Ohio	AFHRA IRIS Refs B5787, C0071	AFHRA IRIS Refs A5303, B5787, C0071

Table 3: Details of aircraft and aircrews for Flight 2, Box 1 on June 13th raid on Lager Berta, Forêt domainale des Andaines (Source: AFHRA IRIS Ref B0459). See text for details.

Aircraft (serial / fuselage code / Bomb Group)	Position	Crew details				
		Surname	Forename	Initial	Rank	Number
122	Pilot	Buckler	Orrel	R	1ST LT	0-732505
9F-P	Co-pilot	Eggleston	Glenn	I	2ND LT	0-813681
597	Bombardier / Nav	Cashin	Charles	W	2ND LT	0-744300
	Flgt Eng / Gunner	Zielinski	Eugene	R	S/SGT	15374620
	Radio Op / Gunner	Lott	Albert	G	SGT	18163256
	Armourer / Gunner	Rohweder	William	J	S/SGT	16135719
	Unknown	Ornstein	Jerome		SGT	36236362
123	Pilot	Ellis	Fred	R	2ND LT	0-750358
9F-O	Co-pilot	Goram	James	E	2ND LT	0-815462
597	Bombardier / Nav	Giffhorn	William	E	2ND LT	0-747691
	Flgt Eng / Gunner	Taylor	Alvin		S/SGT	37504154
	Radio Op / Gunner	Meece	Raymond	E	S/SGT	36449888
	Armourer / Gunner	Nichols	Charles	B	S/SGTL	19067735
146	Pilot	Rhodes	William	J	CAPT	0-659485
X2-F	Co-pilot	Collins	William	D	LT	0-693635
596	Bombardier	Joos	Walter	J	1ST LT	0-739552
	Navigator	Hannigan	John	F	1ST LT	0-792465
	Radio Op / Gunner	Maddox	Forrest	L	T/SGT	14119609
	Flgt Eng / Gunner	Wright	Ralph	E	S/SGT	35613547
	Armourer / Gunner	Mcdonald	Elliot		SGT	20820356
147	Pilot	Brendle	George	R	2ND LT	0-687286
X2-G	Co-pilot	Glock	Charles	F	2ND LT	0-816294
596	Bombardier / Nav	Cartmill	John	R	2ND LT	0-759896
	Flgt Eng / Gunner	Naas	Fred	A	S/SGT	16149096
	Radio Op / Gunner	Bunch	Hubert	E	S/SGT	35697810
	Armourer / Gunner	Rico	Joseph	J	SGT	31306525
152	Pilot	Hausman	Robert	A	2ND LT	0-687325
X2-M	Co-pilot	Shoemaker	Floyd	H	2ND LT	0-815982
596	Bombardier / Nav	Jaquez	Arthur	A	2ND LT	0-760125
	Radio Op / Gunner	Davis	William	W	S/SGT	37509546
	Flgt Eng / Gunner	Pinnell	Oliver	S	S/SGT	14134064
	Armourer / Gunner	Byrum	Ernest	G	SGT	39570929
191	Pilot	Overbey	George	D	1ST LT	0-684404
9F-N	Co-pilot	Bennie	Donald	M	F/O	T-61404
597	Bombardier / Nav	Berry	Donald	R	2ND LT	0-750064
On-board camera	Flgt Eng / Gunner	Turner	Floyd	D	SGT	18193802
	Radio Op / Gunner	Bollinger	Robert	D	SGT	19127282
	Armourer / Gunner	Little	Francis	E	SGT	18141052
	Unknown	Stephens	Donald	A	MAJ	0-562130

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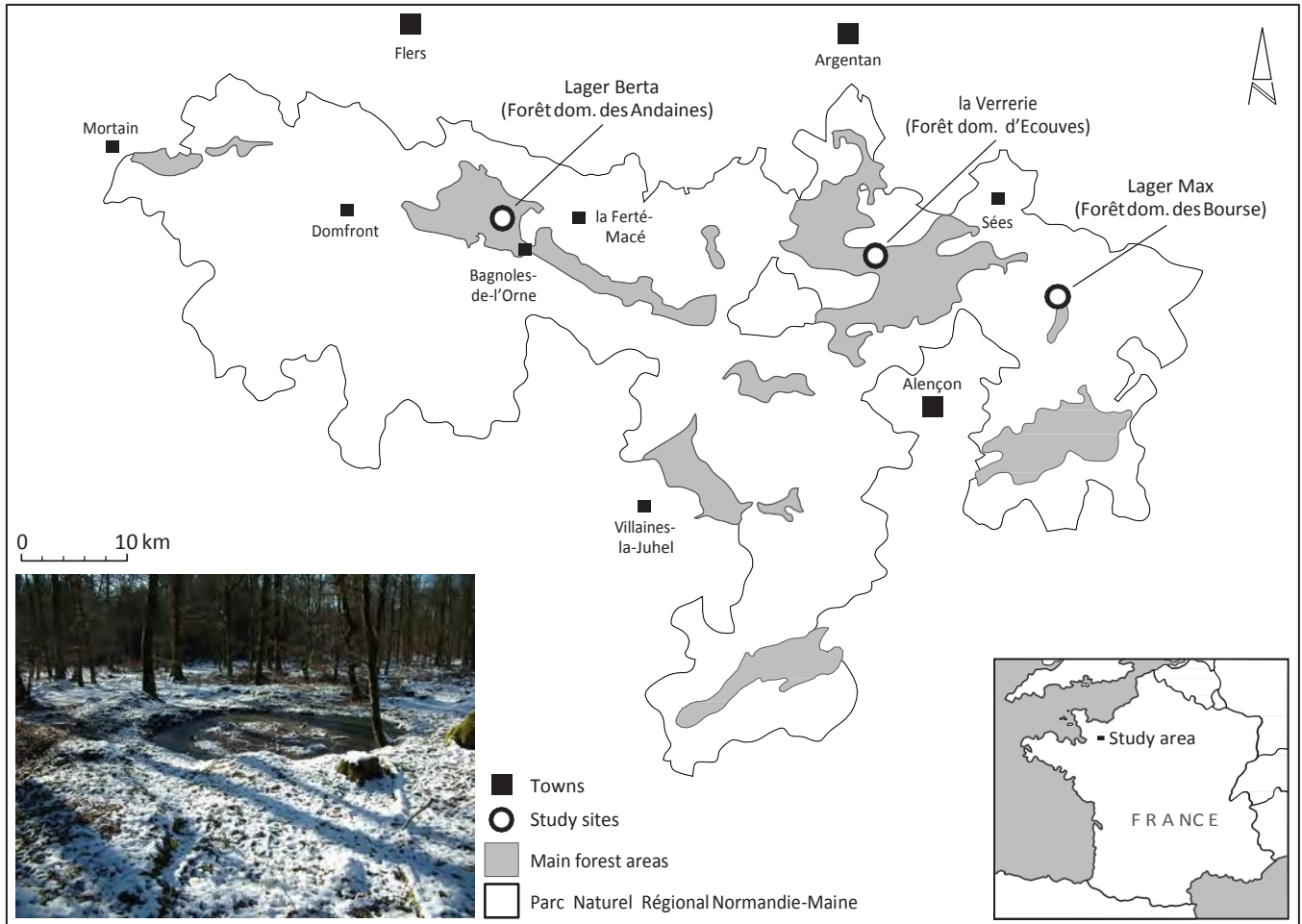


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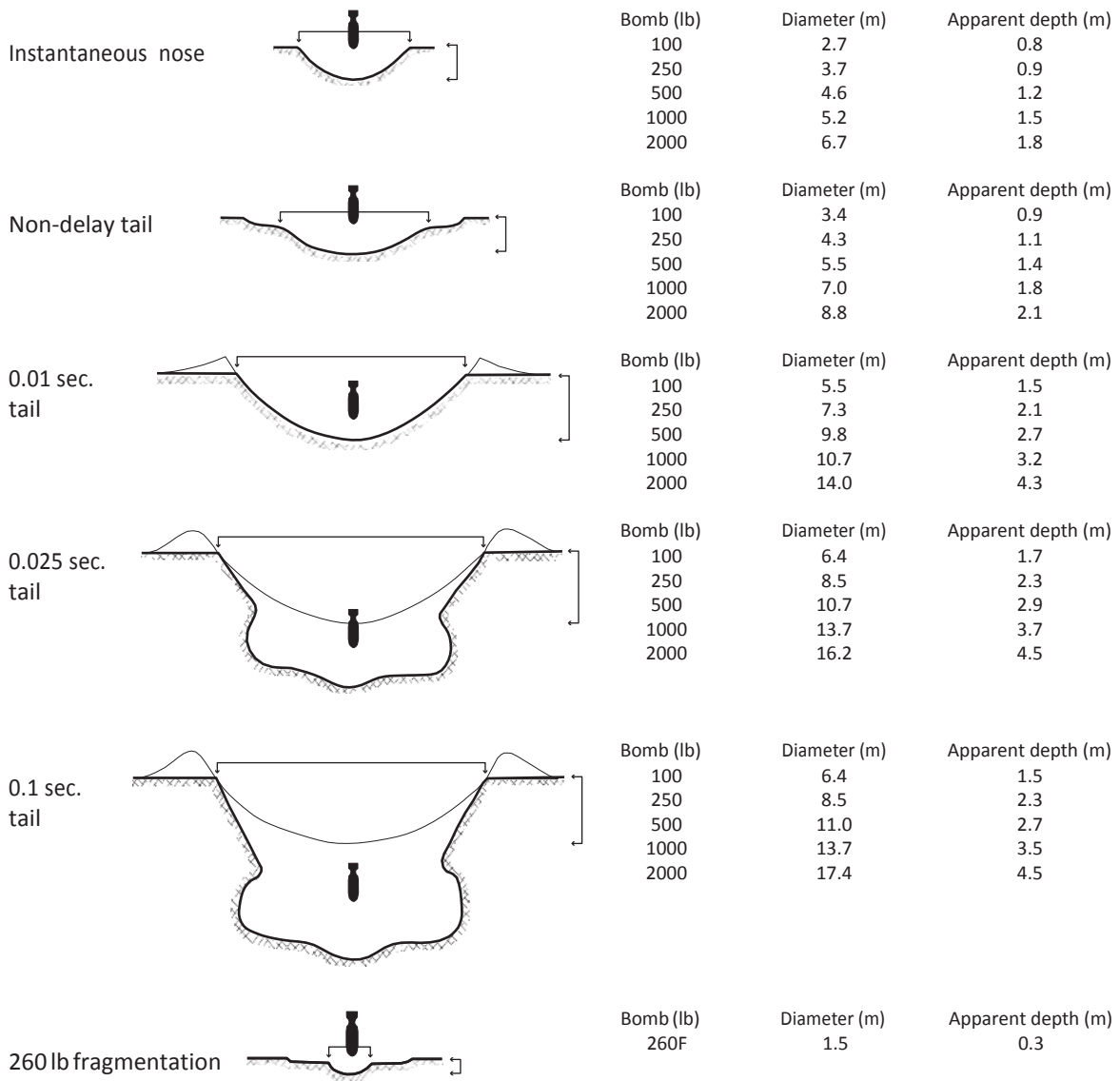


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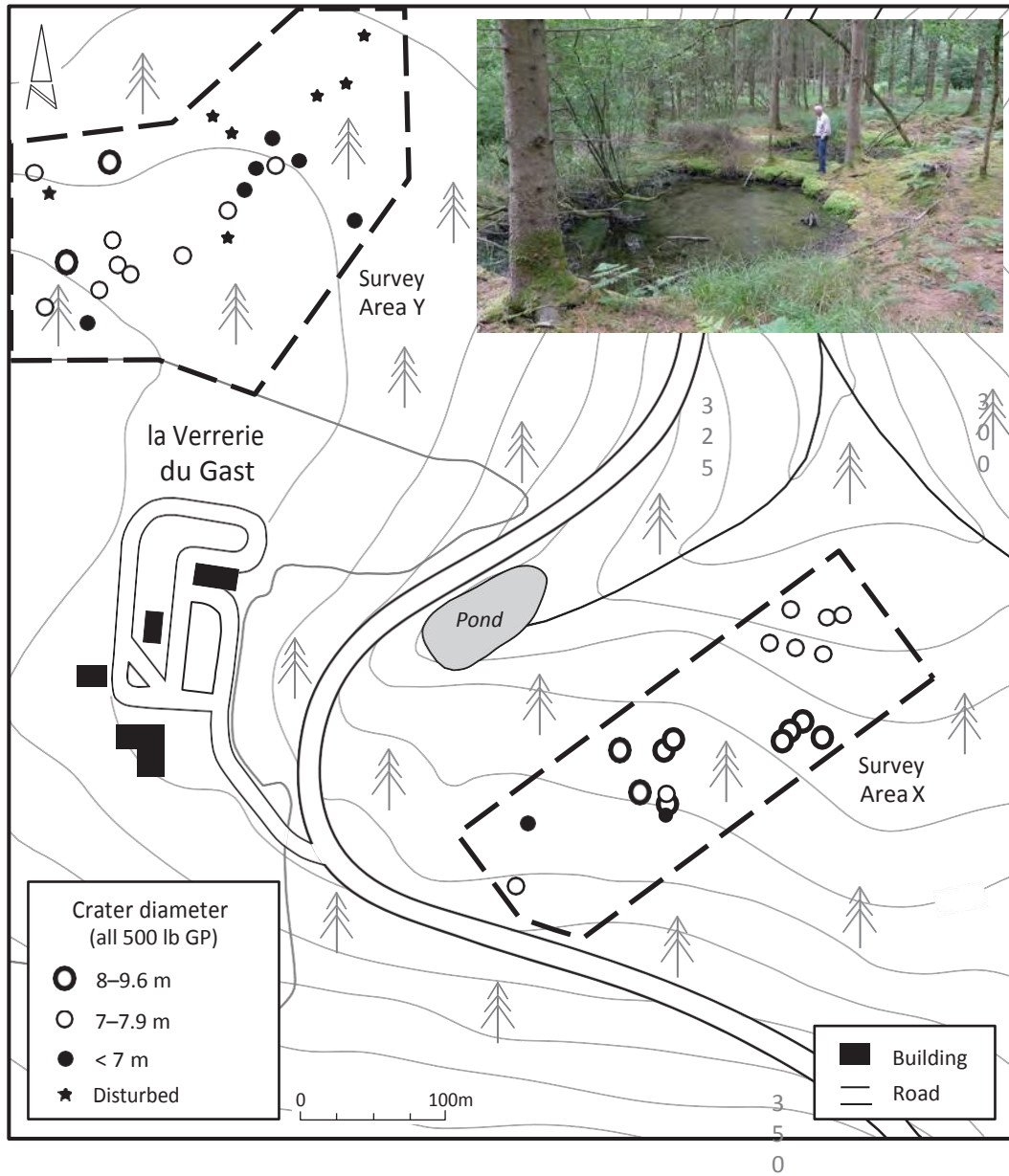


Figure 3. Map of Survey Areas X and Y, la Verrerie (Forêt d'Ecouves) showing location and size classification of surveyed bomb craters. Inset photograph: craters in Survey Area X.

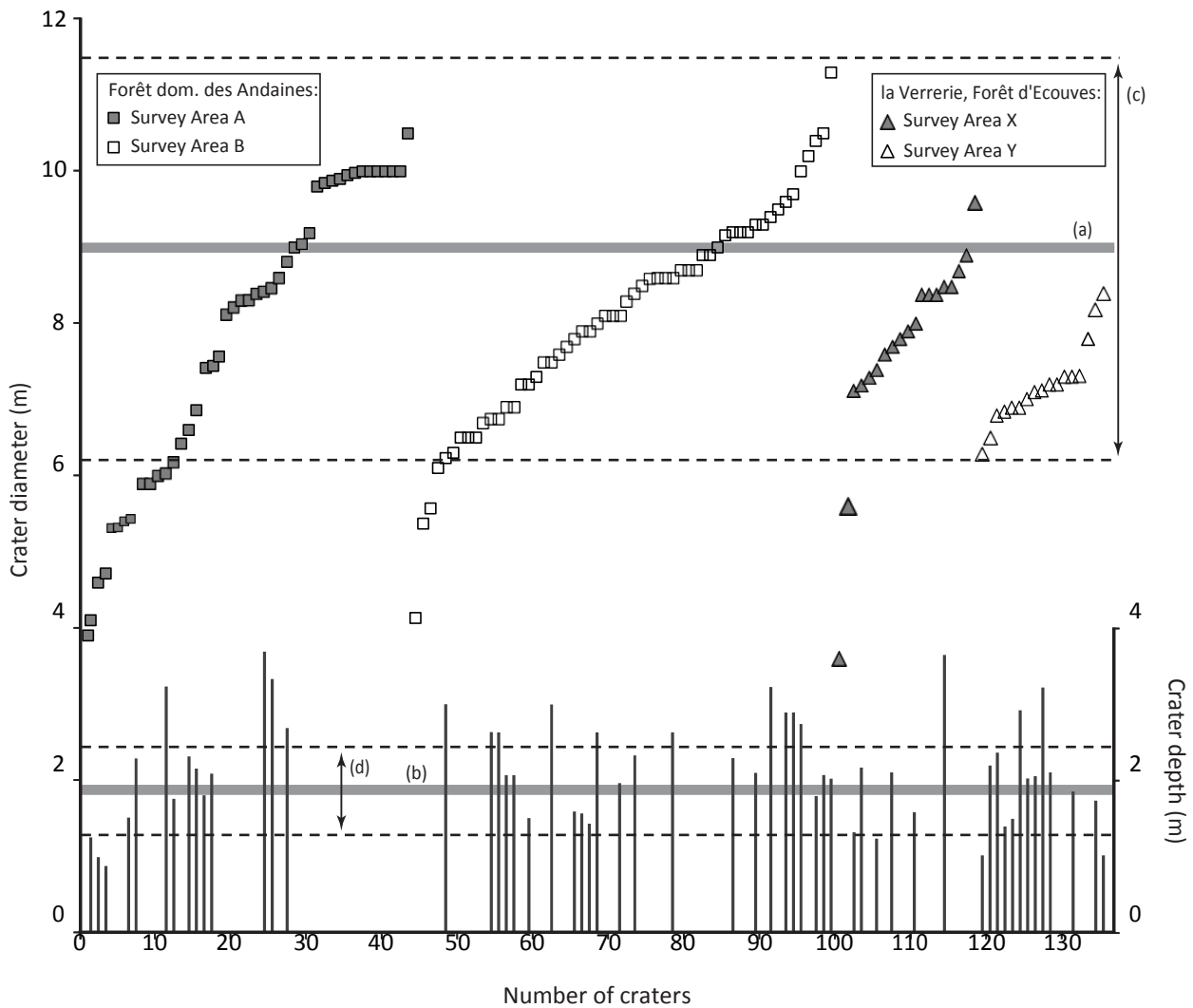


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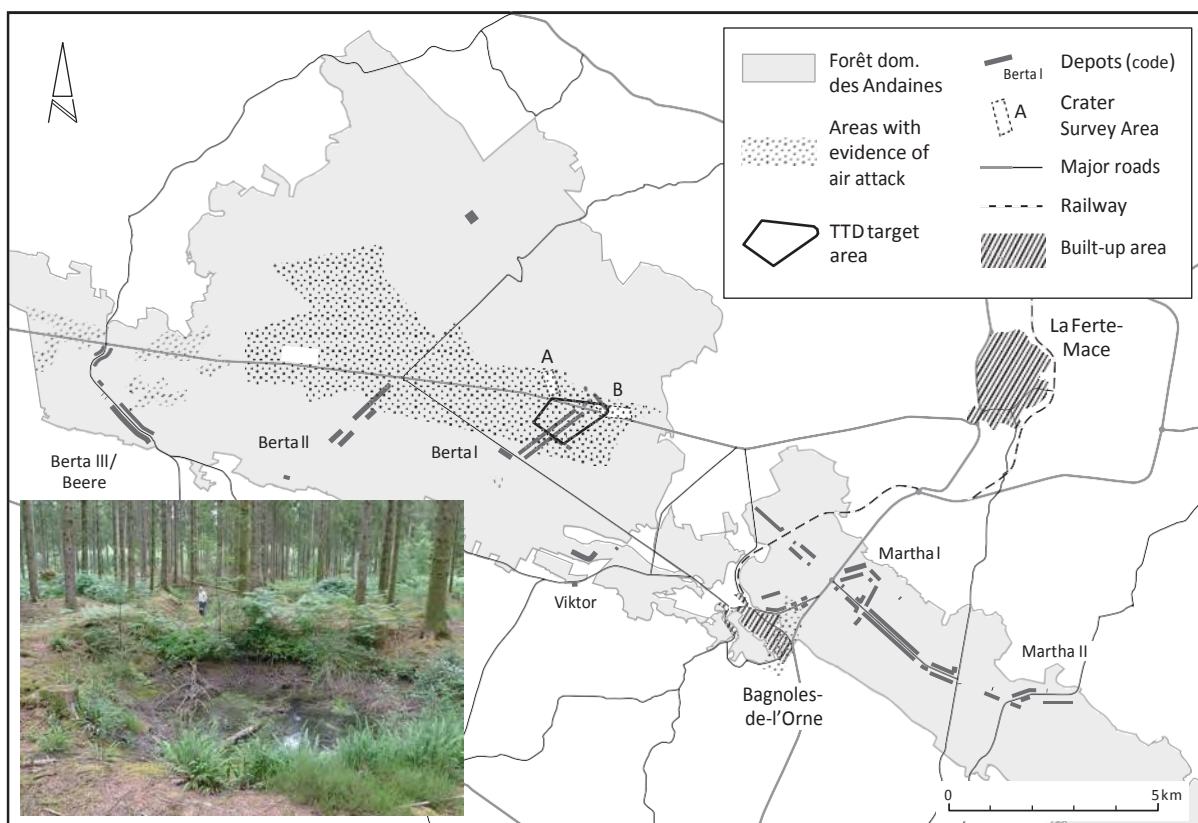
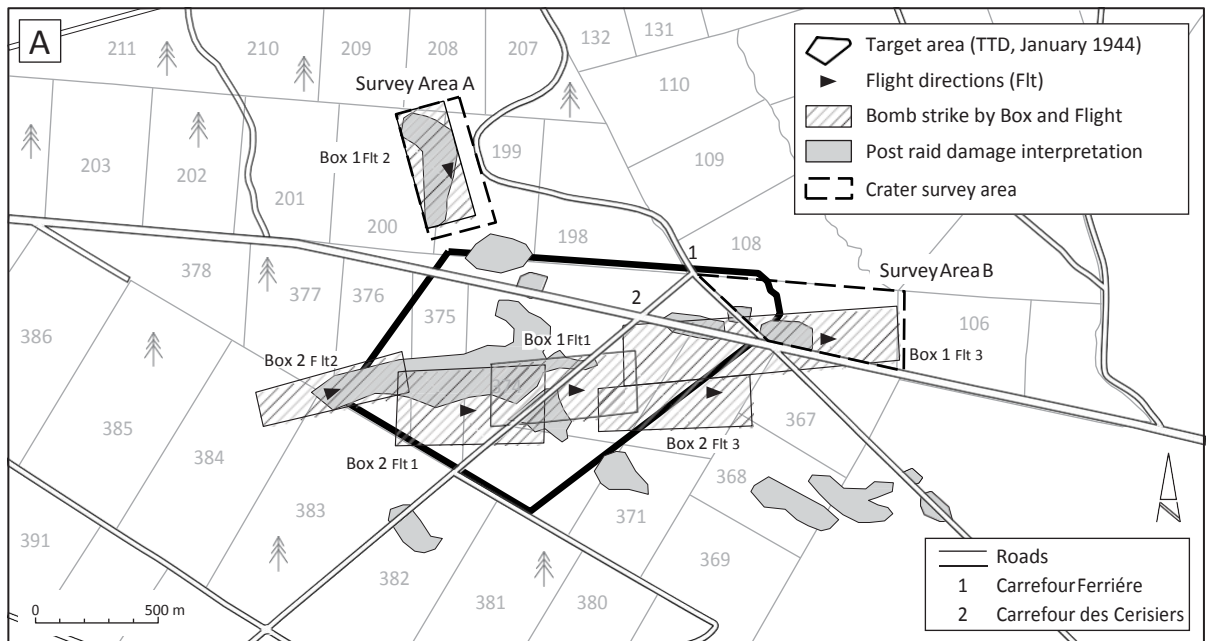


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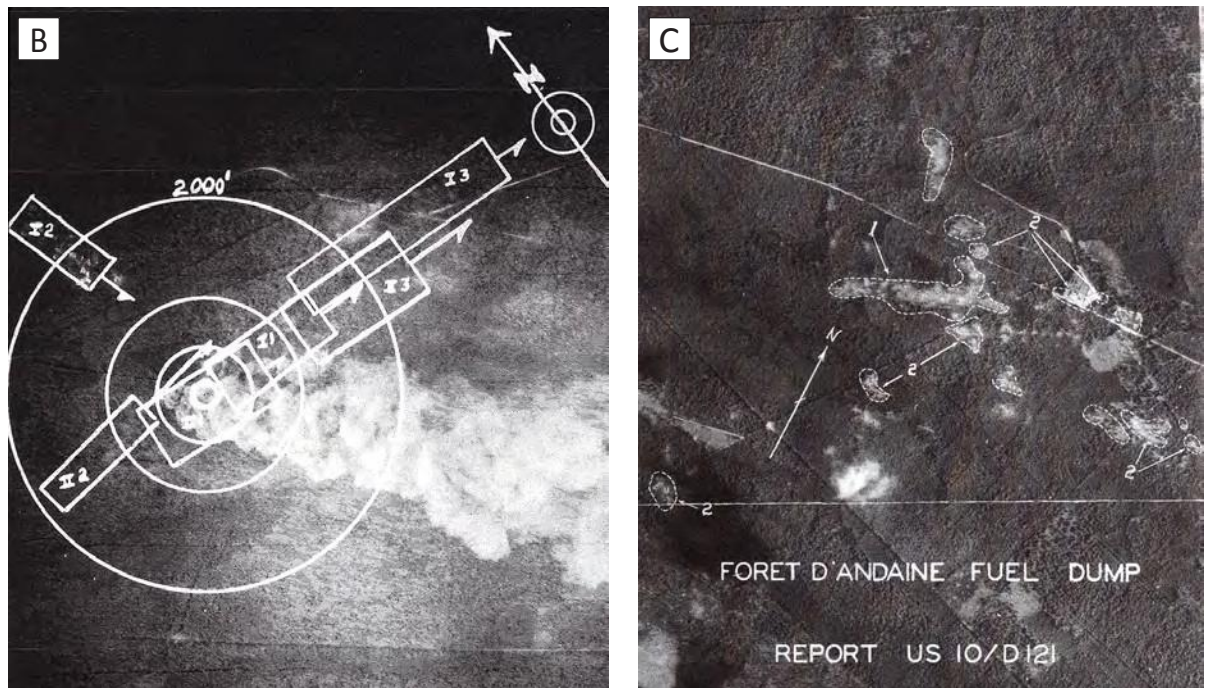


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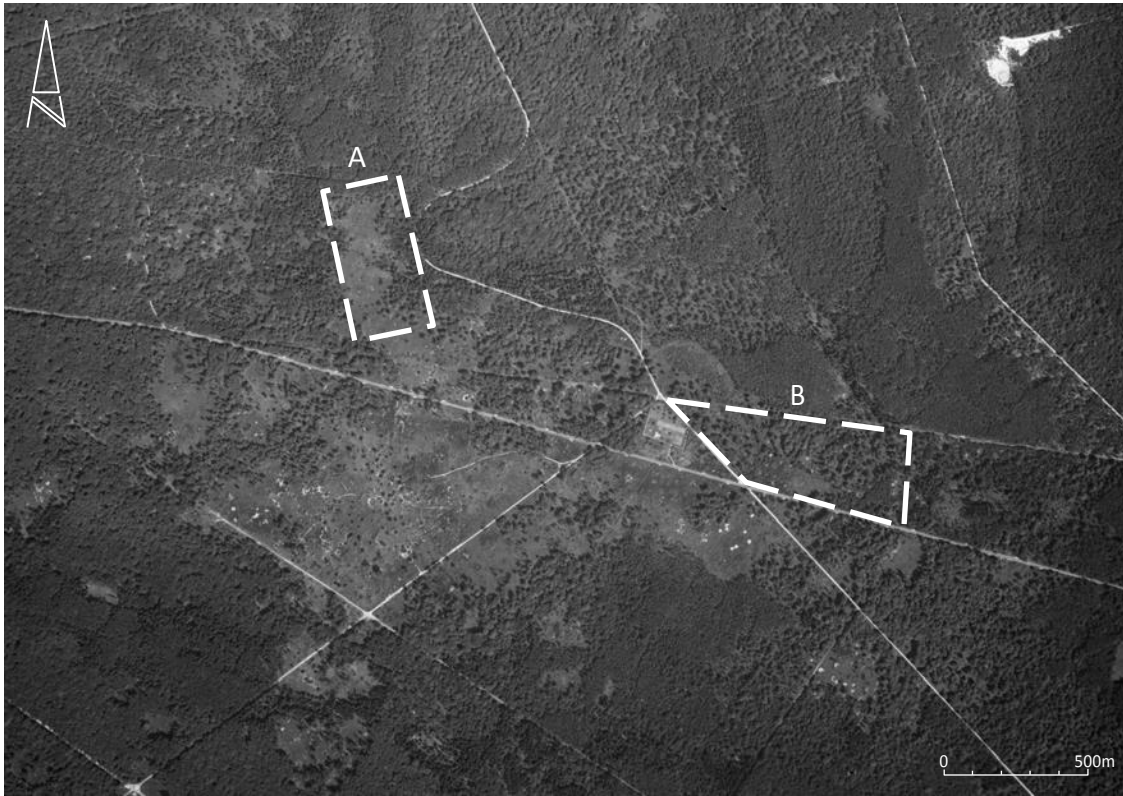


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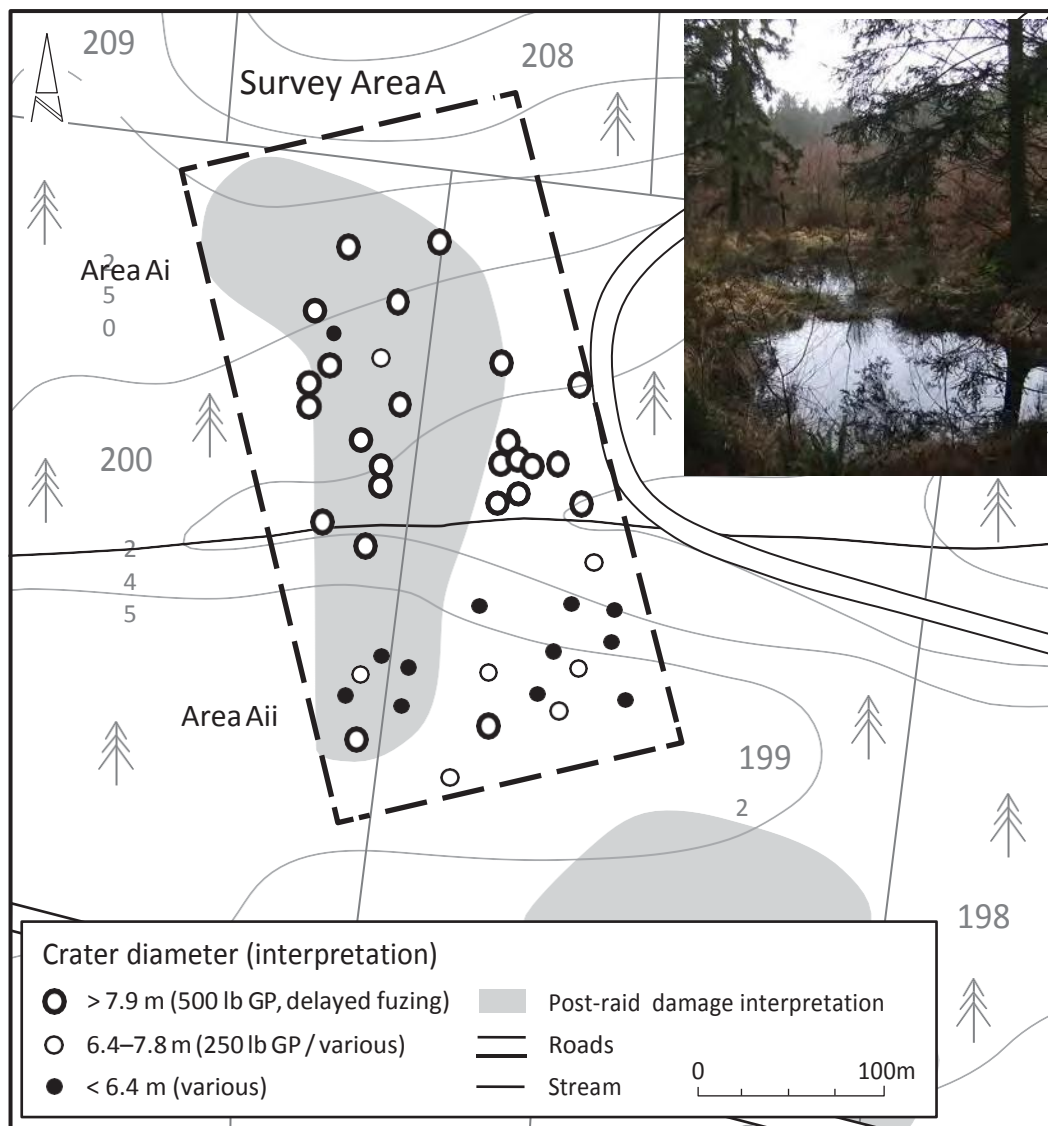


Figure 8. Map of Survey Area A, Forêt Domaniale des Andaines, showing (i) area of bomb damage identified on post-raid intelligence plot (FIG. 6) and (ii) surveyed bomb crater locations and size ranges. Inset photograph: craters in Survey Area Ai

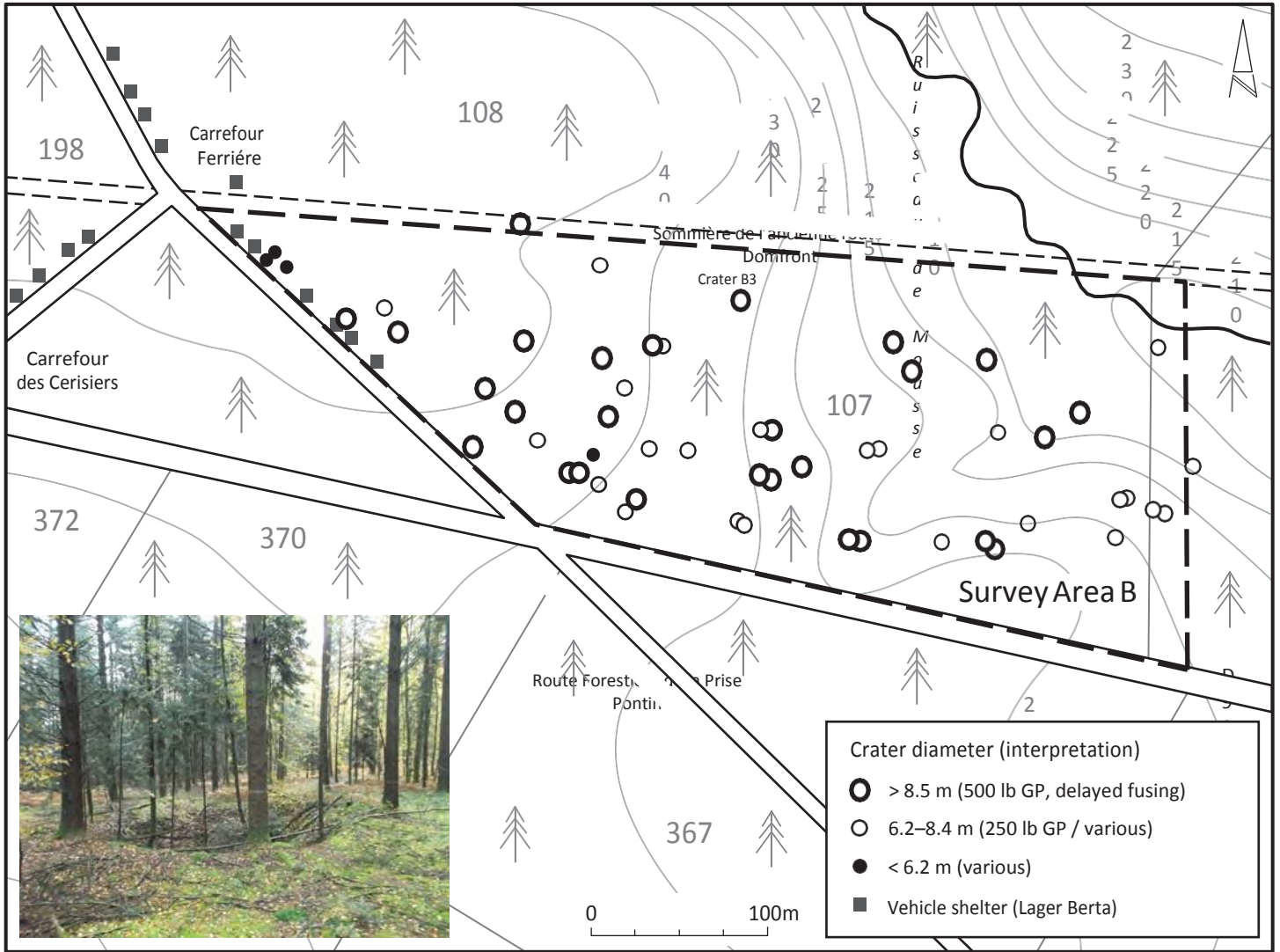


Figure 9. Map of Survey Area B, Forêt Domaniale des Andaines, showing (i) surveyed bomb crater locations and size ranges and (ii) location of vehicle shelters associated with Lager Berta vehicle park (see text for details). Inset photograph: Crater B3 (see labelled site on map).

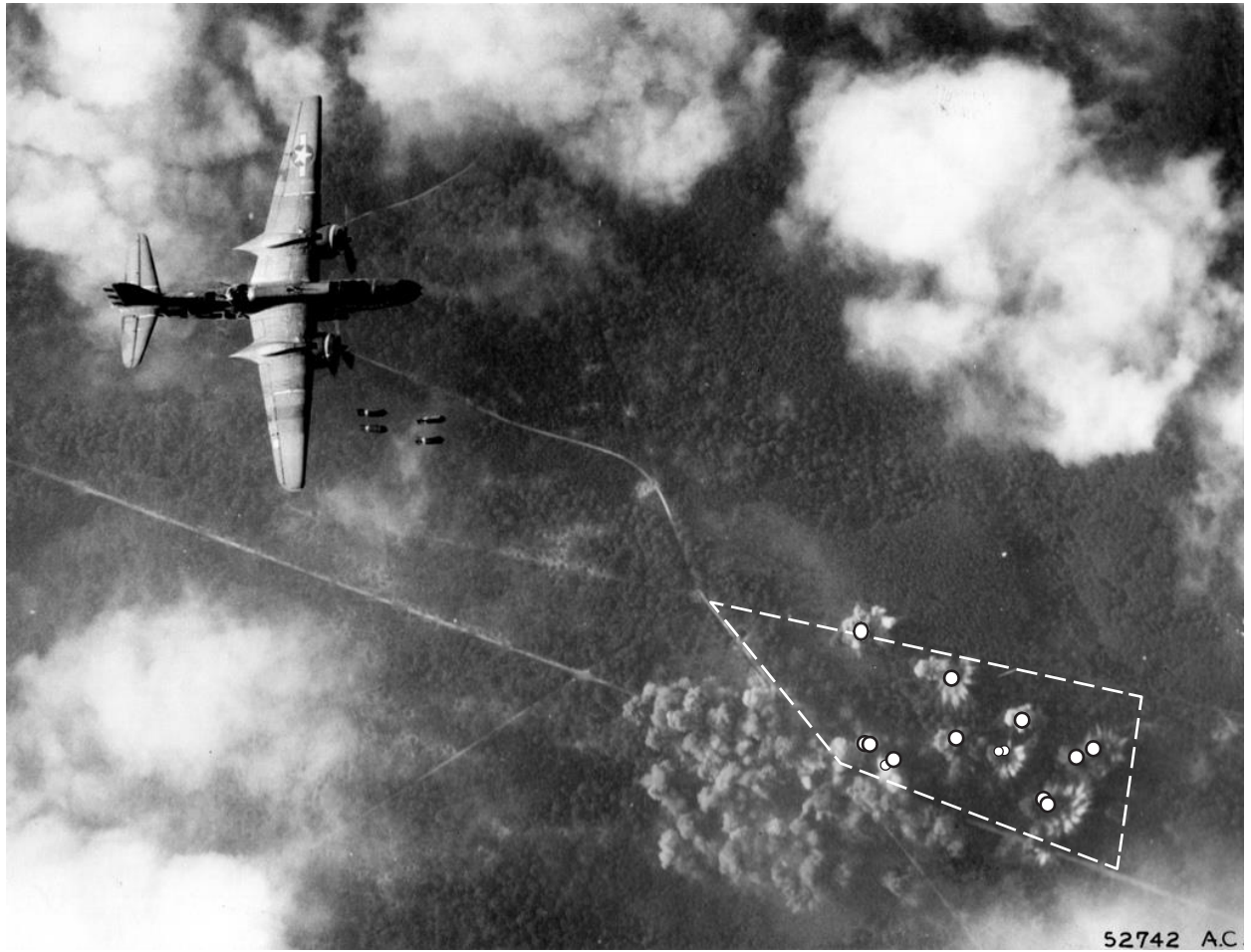


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Appendix V

Paper V:

Capps Tunwell, D., Passmore, D.G. and Harrison, S. (in press). A witness in the landscape: The bombing of the Forêt domaniale des Andaines and the Normandy Campaign, NW France, 1944. *War in History*. In press.

**A Witness in the Landscape: The Bombing of the Forêt domaniale des Andaines and the
Normandy Campaign, NW France, 1944.**

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**A Witness in the Landscape: The Bombing of the Forêt domaniale des Andaines and the
Normandy Campaign, NW France, 1944.**

Abstract

Archaeological survey of well-preserved Second World War German supply depots and bomb craters from Allied air raids in the Forêt domaniale des Andaines, Normandy, has prompted an evaluation of the effectiveness of Allied intelligence gathering and tactical bombing of the German logistics network in advance of, and during the Normandy Campaign of June-August 1944. In conjunction with analysis of primary German and Allied archive sources, published historical accounts and aerial photographs we demonstrate that Allied intelligence knew of the importance of the forest as a major fuel depot and attacked it with at least 46 missions over the period 13 June – 14 August. However, landscape evidence demonstrates that only one of three fuel depot sites in the forest was successfully identified and partially destroyed by bombing. Allied intelligence efforts also failed to gather sufficient evidence to target one of the largest Seventh Army munitions depots in Normandy. Supply depots in the forest thus remained operational until late in the campaign and will have supported the German Mortain counter-offensive of 7-14 August. The limited success of Allied bombing in the Forêt domaniale des Andaines testifies to the difficulties in striking well-dispersed and camouflaged woodland facilities and supports the argument that the success of air power against German logistics efforts lay primarily in the degradation of the regional communications infrastructure and the Wehrmacht's vehicle fleet rather than the destruction of supply dumps.

Key words

Second World War, Normandy, Logistics, Supply Depots, Tactical Bombing

Introduction

The contribution of air power to the Allied success in the D-Day invasion and subsequent Normandy campaign in June-August 1944 was the focus of much contemporary and immediate post-war military analysis, and has continued to attract historical debate since. With the establishment of air superiority over beachheads and hinterland the strategic and – especially – the tactical arms of Allied air forces were able to exercise a decisive role in degrading the combat power of German ground forces. While some aspects of the aerial campaign have been subject to revision, notably with respect to the effectiveness of bomb and rocket strikes on armoured vehicles¹, it is generally accepted that attacks on vehicle columns and the French transport infrastructure, especially bridges and the railway network, were significant in disrupting German efforts to both reinforce and supply combat units.^{2,3}

Allied air forces were also tasked with attacking the network of German supply depots and dumps in the region and yet this aspect of the aerial campaign has received comparatively little attention. While some studies have acknowledged the destruction or damage to at least some of these facilities⁴, there has been little detailed analysis of this aspect of the Allied air campaign, and this despite the evidence that at particular points in the battle for Normandy, for example in the early phases of the Mortain counter-offensive of 7-13 August, German ground forces were at least adequately sustained from nearby supply dumps.⁵ This suggests that the role of the supply depot network in supporting German operations, at least at certain times and places, is worthy of further analysis. The opportunity to do so is now emerging from

¹ See, for example, Niklas Zetterling, *Normandy 1944: German Military Organization, Combat Power and Organizational Effectiveness* (Winnipeg, Manitoba, 2000), p.37.

² R.A.Hart, 'Feeding Mars: the role of logistics in the German defeat in Normandy, 1944', *War In History*, 3 (1996), pp.418–35.

³ Robert S. Ehlers Jr., *Targeting the Third Reich: Air Intelligence and the Allied Bombing Campaigns* (Lawrence, Kansas, 2009), pp.221-44.

⁴ *Ibid.*, p.244.

⁵ Mark J. Reardon, *Victory at Mortain: Stopping Hitler's Panzer Counteroffensive* (Lawrence, Kansas, 2002), p.113.

the recognition that Normandy's forest environments – the preferred location for German supply depots – have the potential to host not only the remarkably well-preserved archaeological landscapes of such depots, but also the bomb craters of raids intended to destroy them.⁶

In this paper we build on work by the authors that has presented the first detailed description of the location, size and configuration of major Seventh Army supply facilities in the Forêt domaniale des Andaines (hereafter FDA), lower Normandy.^{7 8} Located some 85 km south of the Normandy coastline assaulted on D-Day, depots in the FDA were a source of fuel, munitions and foodstuffs for German forces throughout much of the Normandy Campaign and were also the focus of intensive and repeated air attacks by the US Ninth Army Air Force (Ninth AF). Here we present the first multi-disciplinary synthesis of the landscape record of supply depots and bomb craters, primary German and Allied archive sources and published historical accounts with the aims of (i) evaluating the effectiveness of Allied intelligence gathering and analysis with regard to one of the largest supply facilities in central Normandy, (ii) evaluating the degree to which supply depots in the FDA were accurately identified, located and targeted for air attack, (iii) documenting the history of air raids in the forest and the nearby supply depot and railhead at Domfront and (iv) assessing the landscape record of air raids in the FDA. Finally, we locate the logistics facilities in the FDA within the wider geographical and operational context of the German supply network in Normandy and contribute to the evaluation of Allied air attacks on logistics targets in support of the Normandy Campaign.

⁶ D G Passmore, S Harrison and D Capps Tunwell, 'Second World War conflict archaeology in the forests of north-west Europe', *Antiquity*, 88 (2014), pp.1-16.

⁷ D G Passmore, D Capps Tunwell and S Harrison, 'Landscapes of logistics: the archaeology and geography of WW2 German military supply depots in central Normandy, NW France', *Journal of Conflict Archaeology*, 8 (2013), pp.165–92.

⁸ D Capps Tunwell, D G Passmore and S Harrison, 'Landscape archaeology of World War Two German logistics depots in the Forêt domaniale des Andaines, Normandy, France', *Journal of Historical Archaeology*, 19 (2015), pp.233-261.

The German Army logistics network in Normandy

In early June 1944 overall responsibility for military logistics in France rested with the Chief of Staff of OB West (General der Infanterie G. Blumentritt) with command and control of supplies being coordinated by the Quartermaster, Oberst Otto Eckstein.⁹ Located along the northwest coast of France and the Low Countries, Army Group B defended the anticipated Allied invasion with the Seventh Army in Brittany and Normandy (Fig. 1) and the 15th Army extending between Normandy and the Netherlands. Both Armies relied on the services of Eckstein at OB West for commissary and military supplies and maintained a network of railheads and fixed supply depots (Lagers), many of the latter being located in forests for purposes of concealment from Allied aerial reconnaissance. The D-Day landings on 6th June 1944 and the subsequent Overlord campaign would be largely contested in the area initially held by the Seventh Army and it is this region of Normandy that forms the focus of this paper.

Command and control of Seventh Army logistics rested with the Quartermaster's Supply Officer (575 Brigade, Army Supply Command), based at Army HQ at Le Mans, overseeing a network of depots distributed throughout Brittany, Normandy and the occupied Channel Islands (Fig. 1). Administration was exercised via three local Stützpunkts, respectively located at Loudeac and La Guerche-de-Bretagne (near Rennes) in Brittany, and in Normandy at Bagnoles-de-l'Orne (Fig. 1; see Army Supply Command and Stützpunkt reporting channels, respectively).¹⁰ The commanding officer of the Bagnoles-de-l'Orne Stützpunkt was therefore

⁹ OB West Supply and Administration, 15 Jan 1943 - 30 Jun 1944. Otto Eckstein, FMS B-827 (dated 20 January 1948), p.45. Eckstein had been OB West's Logistics officer prior to the invasion and was re-appointed to Germany at the start of July. He was debriefed by US members of the European Theater Operations for the Foreign Military Studies programme.

¹⁰ National Archives and Records Administration (NARA), T-312, R1567, 000153, Stützpunkt Bagnoles 31.1.44.

responsible to the Army Quartermaster's Supply Officer for the day-to-day administration of several Seventh Army supply depots in the Basse Normandy region (Fig. 1).

The Bagnoles-de-l'Orne Stützpunkt lay close to a number of supply depots established in the FDA, a 55 km² area of mixed historic woodland in the Orne département, Basse-Normandie region, some 85 km south of the Normandy coastline (Fig. 1). Relatively low intensity post-war management of the forest has permitted remarkably good preservation of archaeological features associated with supply depots (Fig. 2) and this, combined with archive analysis, has recently facilitated the first full description of the geography and landscape context of a major Seventh Army logistics facility.¹¹

In addition to a large storage facility for food reserves (codenamed Lager Viktor¹²), the FDA hosted two major supply depots, respectively for fuel (Lager Berta) and munitions (Lager Martha)¹³ (Fig. 3). The Lager Martha munitions depot was established in August 1943 in woodland to the north and east of Bagnoles-de-l'Orne (Fig. 3) and was to have an eventual capacity of 3500 tons¹⁴; on 1 June 1944 the depot was recorded as holding 2008 tons of ordnance.¹⁵ The depot was itself supplied via the railway station at Bagnoles-de-l'Orne.¹⁶ Fuel reserves in the forest were hosted at Lager Berta which, while initially commissioned in April 1943¹⁷ as a single facility located 5 km northwest of Bagnoles-de-l'Orne, was by 22 May 1944 dispersed over three discrete sites in the west of the forest (hereafter termed Lager Berta I, II and III: Fig. 3). By 1 June 1944 Lager Berta stocked 967 cubic metres of fuel and held the status

¹¹ Capps Tunwell et al., 'Landscape archaeology of World War Two logistics depots'.

¹² Bevorrung von Munition, Betr.Stf u. Verpflegung u Parke im der 7 Armee, 5.6.44, NARA, T-312, R1571, 000607,.

¹³ Ibid.

¹⁴ Kriegstagebuch AOK7/QU 5.1.44, NARA, T-312, R1567, 000009.

¹⁵ Bevorrung von Munition, Betr.Stf u. Verpflegung u Parke im der 7 Armee 5.6.44, NARA, T-312, R1571 000607.

¹⁶ André Rougeyron, *Agents d'Évasion* (Alençon, 1947).

¹⁷ Aktennotiz: Establishment of fuel depot in the Forêt domaniale des Andaines, 12.4.43, NARA, T-312, R1557, 000133.

of a Führer Reserve Heeres-Betriebstoff-Lager (Army Fuel Storage)¹⁸, but remained under the administration of the Bagnoles-de-l'Orne (Seventh Army) Stützpunkt. However, shortly after the partial destruction of Lager Berta I by an air raid on 13 June 1944 this site appears to have been closed and the remaining facilities at Berta III (and likely also Berta II) subsumed into the operation of Lager Beere (see below). Lager Beere was initially a smaller depot facility located near the railway yards at Domfront, 5 km west of the FDA (Figs. 1 and 3)¹⁹, but much of this operation was relocated into the western part of the forest in late May 1944.

The Seventh Army's Quartermaster's Supply Officer controlled a road transport fleet for moving supplies within and between depots and, when operationally necessary, for onward transfer to corps and divisional stockpiles.²⁰ Some elements of this fleet (3rd Company, 595th Transportation Unit and Fuel Tanker Column 676) were stationed at the Bagnoles-de-l'Orne Stützpunkt and on 31 May 1944 the motorised components of this allocation amounted to 64 trucks and 17 fuel tankers.²¹ Vehicles were sheltered in blast-protected and camouflaged parking facilities established at both the Berta and Martha depots, as well as on the northern margins of Bagnoles-de-l'Orne itself (Fig. 3).

Allied intelligence, target identification and mission planning

Preparations for Operation Neptune (the D-Day landings) and the broader operational requirements of Operation Overlord imposed an additional set of requirements on Allied

¹⁸ Berta was one of three Führer Reserve H.B.L. in the Seventh Army sector, the others being Bruno (near La Guerche-de-Bretagne) and Brigitte (Pontivy); *Bevorrung von Munition, Betr.Stf u. Verpflegung u Parke im der 7 Armee 5.6.44*, NARA, T-312, R1571 000607.

¹⁹ *Captured German Documents; German 7th Army Logistics Diary*, NARA, T312 R1571, 000304.

²⁰ *Handbook on German Military Forces, 1 September 1943*, Military Intelligence Division, US War Department.

²¹ *Stützpunkt Bagnoles 31.5.44*, NARA, T-312, R1571, 000456. These figures exclude horse-drawn transport units.

intelligence gathering activities that hitherto had been focused on strategic air targets and efforts to degrade the capabilities of Germany's oil industry and air forces.²² Of particular importance to the forthcoming invasion was the identification and evaluation of targets intended to disrupt German efforts to reinforce and also supply their combat units in the Normandy area, especially those associated with railway networks but including also roads, bridges and waterways (the 'Transportation Plan'^{23 24}). Other military targets for tactical air operations included the coastal defences in the landing zones, airfields and air defence infrastructure, communications infrastructure, military bases and columns and, of particular relevance here, the network of supply depots.

Central to the intelligence and targeting process was the development of Tactical Target Dossiers (TTD), produced by the Air Ministry Department, Air Intelligence 3(C)1²⁵ and compiled by the Theatre Intelligence Section (TIS).²⁶ Tactical Target Dossiers for northern France were organised by geographical sectors corresponding to approximately 1 degree of longitude and 1 degree of latitude (c.71 km by 114 km) and named after major towns or cities. The FDA lay within the TTD for the Laval sector (4801 W; Fig. 4).²⁷ Target briefs within each TTD were illustrated with annotated target areas on photo-maps in conjunction with the British War Office maps produced by the Geographical Section General Staff (GSGS) and, on occasion, French maps dating back to the 1880s. Dossiers were updated periodically to

²² Ehlers Jr., 'Targeting the Third Reich', p.141-81.

²³ Ibid., p.214-44.

²⁴ Royal Air Force Centre for Air Power Studies. Air Historical Branch (1). Air Ministry RAF Narrative. *The Liberation of North-West Europe, Vol. 1.*

²⁵ The National Archives of the UK (TNA), Kew, London, UK; WO 219/1828. Describes the production and delivery of the Tactical Target Dossiers for Operation Neptune.

²⁶ The TIS developed the target dossiers from a number of sources but the ultimate responsibility for the dossiers rested with AI 3(C). The TIS also passed a variety of other types of intelligence to the SHAEF G2 organisation for processing. TNA; WO 219/1661.

²⁷ Tactical Targets Dossier, Laval Area, 2nd Edition, Air Force Historical Research Agency (AFHRA), A5303, p. 174.

accommodate newly-identified targets and to delete those deemed to be inaccurate or no longer important.

Early intelligence on military targets in the FDA was forthcoming from Escape and Evasion (E&E) reports filed by members of a B-17 bomber crew that crashed close to the forest in July 1943; these yielded maps and descriptions of parts of the Lager Berta fuel depot close to the Carrefour du Garde Général (see Berta I, Fig. 3).²⁸ One of the crew, Olof M Ballinger, provided a detailed map that included not only the location of Lager Berta but also the construction of a munitions depot to the southwest²⁹ and the location and quantities of fuel stocks near the railway yard at Domfront (Lager Beere; Fig. 5). Ballinger's sketch appears to have been influential in designating the northern extent of Lager Berta as one of two FDA target areas in the January 1944 edition of the TTD (TTD-A, Fig. 6a). The brief also noted that fuel was supplied by road from the fuel depot at the Domfront railway yard and was stored both in tanks (possibly underground) and 200 litre barrels in the forest (this was at the time standard operating procedure for the Wehrmacht³⁰). The second target area in the January TTD, identified via interpretation of aerial reconnaissance photographs, was a fuel tank on the southern margin of Bagnoles de l'Orne (TTD-B, Fig. 6a).³¹ Early information specific to munitions storage in the forest appears to have been limited to a detailed location map of part of a munitions depot provided by André Rougeyron, a member of a French E&E network communicating via carrier pigeon in October 1943.³² Since no munitions targets were

²⁸ NARA, Escape and Evasion reports; EE380 McConnel 4/2/44, EE248 Ballinger 4/12/43 and EE328 Howell 1/18/44.

²⁹ Note there is no further documentary or archaeological evidence of the munitions depot shown as under construction on Ballinger's map.

³⁰ Handbook of German Forces, p.216; TM-E 30-451, September 1943.

³¹ This is not believed to be part of the Lager Berta facility.

³² Rougeyron, *Agents d'Évasion*. This is a personal account of Rougeyron's wartime experiences. The map mentioned here arrived at the Willesden Loft in October 1943 (Bletchley Park, Special Section Pigeon Rm. N Pelling, *pers. comm*).

designated in the January 1944 TTD it is presumed here that Rougeyron's report was overlooked or was omitted on account of it lacking corroborative intelligence.

A revised TTD in June 1944 reflected updating of the target intelligence for the FDA, most likely from reports communicated by Resistance workers based in Champsecret (to the north of the forest) over the period March-May 1944.³³ The target area for Lager Berta fuel depot was now focused on roadside areas radiating from a crossroads located in the centre of the depot (TTD-C, Fig. 6a) while the TTD also defined roadside storage of munitions from the Carrefour de l'Etoile in the central part of the forest eastwards astride the D908 to the forest edge north of Bagnoles de l'Orne (TTD-F, Fig. 6a). The January TTD fuel storage target at Bagnoles de l'Orne was deleted and two new target areas designated nearby, respectively for roadside storage of fuel and munitions along forest roads to the northeast of Bagnoles de l'Orne (TTD-D and E, Fig. 6a).

By the time of the invasion in June 1944 allocation of targets was decided on a daily basis by the RAF and USAAF at AEF Headquarters, RAF Stanmore.³⁴ Ninth AF mission planning continued to draw on the TTDs but was increasingly informed by Tactical Target Lists (TTL) coordinated by Major Lucius Buck, a special security officer at AEF headquarters responsible for overseeing the synthesis of existing intelligence with evolving operational priorities and the array of newly-emerging information from ULTRA, photo-reconnaissance, PoW interrogations and updates from air and ground forces,³⁵ the latter including Resistance workers as well as inserted British Special Air Service (SAS) units and American 'Jedburgh' teams from the Office

³³ Orne Departmental Archives, Alençon, France; Series J Fonds Viel.

³⁴ Army Air Forces Evaluation Board in the European Theatre of Operations, 'The Effectiveness of Third Phase Tactical Air Operations in the European Theater', Part 18 (Orlando, 1945), p331. (Combined Arms Research Library). These meetings were held on a daily basis in the run up to the invasion and thereafter through to the middle of August; they consisted of staffs from the US Eighth and Ninth Army Air forces, RAF's Bomber Command, Second Tactical Air Force, Coastal Command, Air Defence of Great Britain and the First Allied Airborne Army.

³⁵ J.F.Kreis (ed), 'Piercing the Fog: Intelligence and Army Air Forces Operations in World War II' (Washington D.C., Air Force History and Museums Program, 1996), p.232.

of Strategic Services (OSS).³⁶ Mission planning in the context of tactical air operations also required a high degree of cooperation between Army commanders and air staff and this process was greatly facilitated by co-locating air and ground-equivalent headquarters. For example, the Ninth AF, under General Hoyt Vandenberg and exercising control over IX Bomber Command's light and medium bomber groups, was for the most part attached to General Omar Bradley's 12 Army Group operating on the right flank of the Allied ground forces in Normandy while IX TAC fighter bomber groups were co-located with the US First Army.³⁷ With the exception of operational decisions made by 12 Army Group or Ninth AF, daily target decisions and field orders for attacks were generally made at army and tactical headquarters³⁸ and were forwarded down the command chain to individual groups in the form of teletypes. The results of raids, again in the form of teletypes, were then sent back up the chain of command.³⁹

A chronology of Allied air attacks on the FDA

Air attacks on the FDA and the adjacent railhead and fuel facility at Domfront were overwhelmingly the concern of the Ninth AF⁴⁰; The majority – and heaviest – of the attacks on the FDA were conducted by light (A-20 Havoc) and medium (B-26 Marauder) bombers of the 97, 98 and 99 Bombardment Wings of the IX Bomber Command, attacking in strengths between one and four Bomb Groups (BG) (36 to 144 aircraft). Also participating in attacks on the forest were fighter bombers (mainly P-38 Lightnings and P-47 Thunderbolts) of the IX

³⁶ Ehlers Jr., 'Targeting the Third Reich', p.231.

³⁷ Ibid., p.232.

³⁸ Ibid., p.234.

³⁹ The teletyped field orders that form the basis of much of the research detailed here in this paper are held at AFHRA

⁴⁰ Comparable medium bombers (Mitchell and Boston aircraft) of the RAF's Second TAF did not attack the forest (TNA; Air 27 Series). It is known, however, that other Allied aircraft were operating in the general area and will have conducted additional localised attacks.

Tactical Air Command (IX TAC). A similar mix of forces was also engaged in raids on Domfront, although here there were contributions by the 2nd Tactical Air Force (Royal Air Force) and the US Eighth Army Air Force. Details of the dates, participating aircraft and targets of all known air raids on the FDA and Domfront are summarised in Tables 1-4.⁴¹

Raids on the Forêt domaniale des Andaines

The aerial campaign against FDA logistics facilities had an inauspicious start on the morning of 13 June with a raid intended for the Lager Berta target area (TTD-A; Fig. 6a); this failed to reach the target area having been diverted when 37 aircraft of the 322 Bomb Group (BG) flew into flak over Le Havre, resulting in 26 aircraft damaged and two lost. On the evening of the same day, however, the second attack on Lager Berta by 36 B-26 aircraft of the 397 BG was on target and yielded impressive results with 'Many crews reporting fires and explosions in the target area and smoke rising up to 3000 feet in the air'.⁴² On the following day the German logistics staff diary reported the loss of 300 cubic meters of fuel (79,252 US Gallons) at Lager Berta.⁴³ The Berta target area (TTD-A, C and also part of F; Fig.6a) was subsequently attacked on no fewer than 15 occasions by medium and light bombers during June and July, delivering bombs totalling 566.3 tons (Table 3), and a further four times during August by fighter bombers of the IX TAC (Table 2; Fig. 6c). It was frequently the case that the area was hit on more than one occasion on the same day, although on the 15 June an attack by P-38 aircraft of the 370 BG obscured the target area with smoke and hindered the bomb runs of a follow-up raid by A-20s of the 410 BG.⁴⁴ With an area of only c.1.4km² this part of the forest was the most frequently and most heavily struck part of the FDA; indeed, in the post-mission

⁴¹ Air raids tabled here include all planned raids and, in the case of Domfront, some AR attacks. It should be noted that there may have been additional AR attacks on the forest that have not yet been identified.

⁴² Mission teletype, AFHRA, B0459, p.352.

⁴³ Captured German Documents; German Army Logistics Diary, NARA, T311 R14, 014539.

⁴⁴ Mission teletype, AFHRA, C0070, p.1295

report of 12 July the crews noted that the area already showed signs of extensive bomb cratering and tree damage (Fig. 7).⁴⁵

Raids on the 22 and 24 June also saw the Ninth AF's medium bombers attacking the fuel target (TTD-B) on the southern edge of Bagnoles de l'Orne (Fig. 6a)^{46, 47}. Attempts to hit the fuel tank obtained mixed results since although the raids missed the aiming point, some bombs struck the town and in doing so hit a building which was used as storage facility for the Seventh Army which then had to be abandoned.⁴⁸ The railway lines in the south of the town were also destroyed (Fig. 8) and reports of considerable smoke after one raid indicated ignition of fuel.

Mid-June also saw the first raids on the FDA in response to TTL's from AEAH Headquarters; three sorties by medium and light bombers attacked a stretch of the D908 and its adjacent forest on the 18 June (Fig. 6b; Table 1) with reports of smoke around the Carrefour de l'Etoile⁴⁹ suggesting ignition of fuel stored in the northern part of the Berta II depot (Fig. 3). On the eve of the German Mortain counteroffensive on 6 August the D908 in the central and western part of the FDA was struck by the last of the medium bomber raids using maximum effort on the forest (Table 2).⁵⁰ The same day was also notable for a series of attacks by fighter-bombers, including two strikes on the forest with napalm (Table 2). By this stage of the campaign the FDA had been attacked by the Ninth AF's light and medium bombers on no fewer than 22

⁴⁵ 416 Bomb Group Mission teletype, AFHRA, B0530, p.1806

⁴⁶ A squadron of P-38s from the 474th Fighter Group escorted the main attack and then struck after the A20s (Mission teletypes, AFHRA, B0332, p.605).

⁴⁷ Removed from the June edition of the Tactical Target Dossier, the fuel tank listed was attacked on the 22 and the 24 June and mentioned as a target in 9th Air Force intelligence evaluation as being relevant on the 28 June. Ref AFHRA B 5680. The tank was however, not subsequently attacked.

⁴⁸ Captured German Documents; German 7th Army Logistics Diary, NARA, T312, R1571, 000572.

⁴⁹ The 410 Bomb Group post-raid report also recorded dropping bombs on a railway line to the SE edge of the forest; the timing of this raid coincides with the first recorded attack on Bagnoles de l'Orne. AFHRA, C0070, p. 1464.

⁵⁰ This being in response to an Operations Request on 5 August noting that fuel and munitions supplies were being taken into the forest from other depots. AFHRA, B5683, p. 894.

occasions since D-Day, earning recognition as a 'familiar' target in the official history of the Ninth AF operations for mid-late 1944.⁵¹

The RAF were also active overnight on 7 August. An attack by Mosquitos from 140 Wing of the Second Tactical Airforce was observed to cause explosions and fire in the area of the D218 immediately NNE of the Carrefour de l'Etoile in the FDA⁵² and is likely to have been responsible for the destruction of the final stocks of fuel held in Beere.⁵³

Thereafter, from the 8 August until the arrival of American ground forces on August 14, the forest continued to be attacked on a near-daily basis by the tactical arm of the Ninth AF. During June and July the Ninth AF's fighter-bombers had been largely engaged in general armed reconnaissance (AR) and fighter sweeps over the region and, with the break-out of American forces in Operation Cobra in late July and the development of a more fluid front, Allied fighter-bomber activity in the German rear echelons intensified. On 13 August, for example, Ninth AF records list 22 AR missions with no less than 247 aircraft operating in the Lower Normandy area and attacking primarily moving targets.⁵⁴ In addition to AR missions the tactical fighter-bombers were also tasked with attacks on specific logistical targets in the FDA. Targets continued to reflect the influence of the June TTD with attacks on target areas D-F (Fig. 6a; Table 2), but the majority of raids over this period were guided by the daily TTLs, with a particular emphasis on targets alongside and near the road network in central and western parts of the FDA (Figs. 6b and c). Roadside storage of fuel and munitions on the margins of Lager Martha to the east of Bagnoles de l'Orne was also designated for attack following

⁵¹ The Army Air Forces Historical Studies (AAFHS) History of the Ninth Army Air Force from April to November 1944 describes the scope and character of operations throughout the battle for France. AFHRA, AAF-HS-36, pgs. 096, 177 and 217.

⁵² Allied Expeditionary Air Force: Post D-Day daily Intelligence/operations summaries (August). TNA AIR 37/397.

⁵³ Intelligence from intercepted German, Italian and Japanese radio communications, WWII. TNA DEFE 3/115. XL5436. DTG 092301Z/8/44.

⁵⁴ AFHRA, B8684, p.263-265.

reports from an SAS team operating in the area.⁵⁵ While increasing in intensity, the switch to fighter-bomber attacks during this later period accounts for the relatively low overall tonnage of ordnance (282.1 tons, Table 2) dropped on the forest by comparison to June (688.2 tons; Table 1).

Domfront raids

Early in 1944 the Allies had confirmed the presence of a fuel depot at Domfront railway yard (Lager Beere; Fig 1) and by March had established that fuel held here was being transferred by road in 200 litre drums to depot facilities in the FDA.⁵⁶ Accordingly, Lager Beere also became an important target for air raids on the regional fuel supply and storage network over the period 21 May to 12 August 1944 (Table 4; Fig. 9). Few details of the two earliest raids in May are available although it was reported that the first of these on 21 May hit the railway station but not the depot itself.⁵⁷ The Germans subsequently transferred fuel stocks from the depot into the FDA and by 24 May the tanks were empty.⁵⁸ Four days later on 28 May the Domfront railyard and fuel storage facility was bombed again and was subsequently targeted on at least 15 occasions up to 12 August while also being inadvertently attacked on 14 June. However, from 24 May onwards the storage facility at Domfront is unlikely to have held significant fuel stocks itself.⁵⁹ Shortly after the bombing of the Lager Berta I site on 13 June it is likely that the administrative arrangements for FDA fuel depots were re-organised with Lager Berta being

⁵⁵ Logistics targets in the FDA were among many potential targets identified by SAS units operating behind the lines as part of Operation Haft between 7/8 July and 11 August 1944. TNA WO 218/191; TNA WO 219/2414.

⁵⁶ SHAEF Theatre Intelligence Section Dossier No 3, 1,3,44, TNA, WO 219/1894.

⁵⁷ Report on examination of "POL" targets attacked by aircraft of Second Tactical Air Force, June-Aug 1944. TNA, WO 291/1366, App. 11, Domfront.

⁵⁸ Ibid.

⁵⁹ The Seventh Army Quartermaster Report of 5 June indicates only 20 cubic metres of fuel (largely diesel) were held at Domfront – the lowest stocks at any of the Army's 15 depots in the region; NARA, T312, 1571, 000607.

shut down and facilities in the western part of the forest (sites Lager Berta II and III) being transferred to the now forest-located Lager Beere (see below).

Perspectives on the effectiveness of Allied bombing in the FDA

Targeting Techniques – the forest problem

In the days and weeks following the D-Day landings on 6 June 1944 the raids on the FDA contributed to an increasingly significant deployment of the Ninth AF light and medium bomber groups against the German logistics network, such that by September 1944 they were mainly occupied by raids against petrol, oil and lubricant (POL) depots, munitions dumps and military vehicle parks.⁶⁰ Many of these targets were first identified through ULTRA decrypts but it was usually the case that other information sources were required in order to define precise locations for air attacks.⁶¹ Accordingly, the definition of actual target coordinates or areas were developed by integrating a wide range of intelligence material including aerial reconnaissance photographs and eye-witness testimonies. Nevertheless, the well-camouflaged forest setting of these targets proved ill-suited to standard 'pin-point' bombing procedures and this contributed to the Ninth AF's decision to introduce 'area bombing' techniques with the intention of distributing a lower density of bombs over a larger designated area than in pin-point contexts.⁶²

For raid-planning purposes, flights were allocated specific aiming points within the target area (Fig. 6c) and were typically configured around a pre-determined line of approach with bomb-release triggered by visual sighting of the aiming point using the aircraft's bomb sight.

⁶⁰ Kreis, 'Piercing the Fog', p.237.

⁶¹ Ibid., p.234.

⁶² Operational Research Section, Ninth Air Force: Area Bombing for June (7 August 1944). AFHRA, B5656.

However, and even in conditions of good visibility and accurate navigation in the bombing approach, a persistent problem faced by bomb aimers in forested areas was the lack of reference points in or around the target areas. In circumstances where especially poor visibility was anticipated, tactical bomber forces in Normandy made use of the radio-transponder based OBOE 'blind' bombing aid. Installed in specialist 'Pathfinder' aircraft the system was generally reliable although it was not designed to be used in total cloud cover or zero visibility on account of the difficulties in maintaining aircraft formation. Three raids on the FDA in July, respectively on the 11, 12 and 24 and all aimed at the Berta fuel depot (TTD-A; Fig. 6a), were led by Pathfinder B-26 aircraft, but all other raids in the FDA required visual sighting by bomb aimers in the main forces (Tables 1 and 2).

The difficulty of sighting forest-based targets was evaluated by the Ninth AF's Operational Research Section (ORS) as part of its assessment of area bombing during the month of June 1944.⁶³ This analysis drew on data from raids on both the FDA and the Foret d'Ecouvès (some 30 km to the east) and in both cases it was found that a higher percentage of bombs were dropped within the target area when (i) the bomb run approach was made over a well-defined ('clear-cut') forest edge that provided a clearly identifiable check-point ahead of the target, and (ii) the target area lay relatively close to the forest edge (Table 5). Experience from the FDA thus contributed directly to the report recommendations for enhancing target identification in forested areas. Three solutions were offered⁶⁴, the first of which required a carefully planned flight-path that entered the forest from a clearly defined edge with a fixed time before 'bombs away'. The second was to carry out an attack as close to the target as possible and subsequently use this bomb-damaged area as a reference point in relation to the actual target (determined using reconnaissance photographs). In the FDA the heavily-damaged

⁶³ Operational Research Section, Ninth Air Force, 'Area Bombing for June', (ORS Report No.56, August 1944). AFHRA, B5656.

⁶⁴ Ibid., p.11-13.

area of Lager Berta (TTD-A) effectively performed this function (see above). Finally, the use of OBOE was recommended as likely to improve the bomb coverage in areas lacking clear sighting points. These recommendations were especially intended for target areas and aiming points designated in boxed areas on the target maps. For attacks that were configured on roads then it was further advised that approaches be made either at an angle to the area to be attacked while sighting on the road, or that the lead aircraft should fly along the centre of the road with groups positioned on either side to maximise coverage.

Archaeological and documentary evidence

While the experience and contemporary evaluation of air raids in the FDA contributed to evolving tactical bombing practice in the ETO during and after the Normandy Campaign, the ORS evaluations were less-well placed to make a considered judgement on the accuracy of intelligence activities and target designations in the first instance, at least not until the target areas were finally overrun by ground forces. The authors are unaware of any such evaluation in the FDA. However, and some 70 years after the event, the availability of field survey data and the remarkable level of archaeological preservation in the forest – spanning both the depot facilities themselves and Allied bomb craters – does permit an analysis of the intelligence effort, the target designations and the landscape record of high-explosive bomb impacts. A detailed analysis of bomb craters associated with specific raids on the FDA will be developed in a separate paper⁶⁵; here we draw on a forest-wide assessment of bomb damage derived from a combination of field survey⁶⁶ and analysis of aerial photographs taken during the period 1946-1950 by the Institute Géographique National.⁶⁷ The correspondence between

⁶⁵ D.Capps Tunwell, D.G.Passmore and S.Harrison, 'Second World War bomb craters and the archaeology of Allied air attacks in the forests of the Normandie-Maine National Park, NW France'. *Journal of Field Archaeology.*, in press.

⁶⁶ See also Capps Tunwell *et al.*, 'German logistics depots'.

⁶⁷ See also Passmore *et al.*, 'Conflict archaeology'.

actual depot locations (as evidenced by archaeology) and TTD / TTL aiming points is shown in Figures 6a-c. Figure 10 illustrates both the depot locations and those areas of the forest floor that currently preserve evidence of bomb cratering or can be shown on aerial photographs to exhibit evidence of bomb damage associated with blast and fire. The extent and character of bomb damage varies from severe damage and cratering associated with multiple raids (Fig. 7) to isolated craters or localised areas of forest clearance likely associated with a discrete aircraft formation (see, for example, Fig. 11).⁶⁸

Undoubtedly the most successful combination of intelligence gathering, targeting and raid effectiveness was achieved in the northern part of Lager Berta I (TTD-A; Figs 6a and 10), an area of c.1.4 km² that was the focus of raids dropping over 550 tons of bombs and amounting to one-half of the total bomb tonnage expended in FDA raids (Table 3). Indeed, this is the sole example of a large logistics facility in the FDA that was correctly identified, located and deliberately hit by one or more air raids (see above). Subsequent updating of the TTD to include the crossroads at the centre of Lager Berta (TTD-C; Fig. 6a) was also accurate, although the southern extent of the depot and its associated vehicle park was not struck at all (Fig. 10). Both the northern extent of Lager Berta I and II fall within the target area along the D908 identified in the June 1944 TTD (TTD-F; Fig. 6a), while Berta II falls entirely within the TTL areas centered on roads radiating from the Carrefour de l'Etoile (Fig. 6b). The latter areas were bombed on three occasions on the 18 June and were associated with reports of smoke around the Carrefour de l'Etoile. Some cratering in the northern part of the facility is most probably associated with these raids (Fig. 10). The third of the major fuel facilities in the FDA, Lager Berta III (administered as Lager Beere by mid-late June) does not appear to have been identified as a target, being absent from the TTD and any of the TTL roadside attacks except where its northern limit approaches the D908 (Figs 6a-c). No evidence of immediate bomb

⁶⁸ Capps Tunwell *et al.*, 'Second World War bomb craters', in press.

damage is found at this site (Fig. 10) although several nearby areas of low-density cratering are interpreted here as reflecting bombs intended for the D908 target areas on the 6 August (Figs. 6b and 11).

Only limited landscape evidence of bomb cratering is evident in the vicinity of Bagnoles de l'Orne (TTD-B, D and E; Figs. 6a and 10), although post-war urbanisation is likely to have eliminated at least some of the damage. Woodland in the area of TTD-D and E does, however, exhibit well-preserved evidence of vehicle shelters which are interpreted as part of the Bagnoles Stützpunkt facility and(or) Lager Martha⁶⁹, and these do not appear to have been impacted by bombs. While intelligence available to the Allies suggested these areas were used for roadside storage of both munitions and fuel⁷⁰, there is no landscape evidence of this immediate area hosting fuel or munitions bunkers that would be consistent with a formal forest-based depot facility (see for example Fig. 2) although temporary storage in vehicle bays cannot be discounted. Woodland margins to the northeast of the TTD-B target area do, however, feature the remains of ruptured 200 litre fuel drums; this may reflect temporary roadside storage that was impacted by the raids of the 22 and 24 June and if so would account for the post-raid reports of smoke following the 410 Bomb Group raid of the 22 June.⁷¹

While Allied bombing had some degree of success against fuel targets in the FDA (and at Domfront), the virtual absence of Lager Martha – one of the largest Seventh Army munitions depots in the vicinity of the D-Day beaches – from the TTD and any of the subsequent TTL (Figs. 6a-c) is striking, especially so given that reports of its location had been received by Allied intelligence as early as October 1943.⁷² However, lacking corroborating evidence and

⁶⁹ Capps Tunwell et al., 'German logistics depots'.

⁷⁰ Tactical Targets Dossier, Laval Area, 2nd Edition, AFHRA, A5303, p215, 218; SAS report from Operation Haft, TNA WO 219/2414.

⁷¹ 410 BG OPFLASH Report 57, dated 23.6.44, AFHRA, B0517, p553.

⁷² Rougeyron, *Agents d'Evasion*, p.60.

given the proximity to Lager Berta (only 6km to the west), intelligence analysts were content to regard this site as covered by the target area at TTD-A.⁷³ As a result, and with the exception of some marginal roadside storage areas, Lager Martha was never specifically targeted by the Ninth AF and there is no evidence of bomb cratering within the limits of this facility (Fig. 10).

Towards an evaluation of the Allied raids on the Forêt domaniale des Andaines

Historical analyses of the German logistics effort have placed much emphasis on the limited stocks of fuel and munitions held in Normandy on the eve of D-Day and on Allied efforts to degrade the French transport network, especially with regard to railway marshalling yards and key railway bridges across the Loire and Seine connecting the Normandy theatre with logistics nodes east of the Seine.⁷⁴ The importance of communications infrastructure as targets for Allied aerial attacks is clearly reflected in the Allied Expeditionary Air Force monthly summaries of operations; these show the total bomb tonnage expended on regional bridges (both road and rail), railway centres and the wider railway infrastructure amounted to around a quarter of all General Purpose (GP) bombs used against targets in support of Overlord for the months of June and July (Table 6).⁷⁵ An early focus of attacks on regional road and rail infrastructure had the dual benefit of disrupting both re-supply and reinforcement of German forces in the battlefield areas, while also presented targets that could be both readily identified and assessed in terms of raid effectiveness.

⁷³ A Theatre Intelligence Section report dated 1st March, 1944, notes in its target listing for the FDA "The reported dump in the FORET DE LA FERTE due to its unconfirmed nature and its proximity to the FORET D'ANDAINNE is listed under the same heading" (TNA, WO 219 /1894, TIC Dossier No.3). The Forêt de la Ferte is the local name given to the eastern part of the FDA.

⁷⁴ Hart, 'Feeding Mars', and Ehlers Jr., 'Targeting the Third Reich'. See also W.F.Craven and J.L.Cate, eds., *The Army Air Forces in World War II, Volume Three: Europe; Argument to V-E Day* (Chicago, 1983), p.210.

⁷⁵ Allied Expeditionary Air Force, Monthly Summaries of Operations, June-August 1994, TNA AIR 37/539.

In the face of challenges in identifying and targeting fuel and munitions stores it is perhaps not surprising that attacks on supply depots commanded less than 10% of the total G.P. bomb tonnage during June and July, although by August this effort had risen to 17% and was broadly equivalent to the weight of bombs expended on transportation targets (Table 6). Nevertheless, these targets still involved 4778 aircraft sorties during June and July⁷⁶ and some of these attacks have been recognised as achieving the destruction of major logistics bases, including the fuel depot at Gennevilliers to the north of Paris on 22 June, and subsequently Lager Bruno near Châteaubriant (Fig. 1) on 16 July⁷⁷, although the latter destroyed only 130 cubic metres of fuel.⁷⁸ That the facilities in the FDA were considered an important logistics target can be inferred from the weight of Ninth AF attacks here – of the 22 regional fuel and ammunition sites attacked in June, nearly 27% of sorties and 29% of GP bombs were expended on the forest (Table 7). Landscape and photographic evidence from the FDA would suggest, however, that these efforts were only partially successful. In particular, the failure to target the Lager Martha munitions depot is especially striking and, having escaped even inadvertent bombing, the facility was operational throughout the Normandy Campaign until being overrun by American troops on 14 August 1944.

Rather more effective were strikes on the forest's fuel stocks, but these cannot be taken as comprehensive and the claim of Lager Berta's destruction on 13 June⁷⁹ would appear to overstate the case. Although the northern part of Lager Berta I was struck with the loss of 300 cubic meters of fuel (see above), this is unlikely to have comprised the entire stock at the site and OB West records show the depot lodging a request for 30 cubic meters of petrol on the day after the raid (Table 8). From this point onwards, however, Lager Berta no longer features

⁷⁶ Ibid., p.16 (June) and p.20 (July)

⁷⁷ Hart, 'Feeding Mars', p.426; 431.

⁷⁸ Losses on 16 July were 80 cbm of petrol and 50 cbm of diesel; OB West Tätigkeitsbericht, NARA T 311 R1. 7000818.

⁷⁹ Hart, 'Feeding Mars', p.426.

in the OB West allocation logs for the remainder of June and through July (Table 8). This is taken to indicate the likely closure of the Lager Berta I site and the transfer of fuel storage responsibilities in the FDA to Lager Beere, most probably operating from the facility in western margin of the forest (site Lager Berta III) but likely also from the site at Lager Berta II (Fig. 3; Table 8).

Considered in the context of the wider network of Army-level depots in the Normandy theatre both Martha and Berta/Beere stand out as the most long-lived and well-stocked logistics bases administered by the Seventh Army and Panzer Group West (hereafter PGW). Figures 12 and 13 show that on the eve of D-Day the Berta/Beere and Martha facilities were among eight operational Seventh Army depots in the region but, together with Max/Mimose near Alençon, were the only sites that are known to have continued to function through to early August; the remaining depots, and a further twelve sites that were established by mid-late June, had been shut down (or overrun) by mid-late July. The arrival of PGW in the region was associated with the establishment of an additional six fuel (Fig. 12) and seven munitions facilities (Fig. 13) while it also took over four existing Seventh Army depots, including Lager Max (renamed Mimose) near Alençon.

The limited success of Ninth AF raids on the logistics facilities in the FDA testifies not only to the effectiveness of the German practice of 'methodical dispersal'⁸⁰ of supply depots in forested settings but also the difficulties experienced by Allied air forces in accurately identifying, locating and hitting these facilities.⁸¹ In general, however, many of the depots established in late-June and through July were relatively short-lived sites that were allocated only a small proportion of supplies issued to Army-level bases in the region (Figs. 12 and 13),

⁸⁰ Craven and Cate, 'Army Air Forces', p.223.

⁸¹ Ibid., p.223. See also Eduard Mark, *Aerial Interdiction: Air Power and the Land Battle in Three American Wars*, (Washington D.C., 1994), p.248.

and especially by comparison to the aggregate allocation totals of 3663 cubic metres of fuel (petrol) for Berta/Beere and 3957 tons of munitions for Martha. It is accepted, however, that allocation figures need not accurately reflect the actual quantities arriving at depots, although in the case of Martha it is interesting to note the Seventh Army reporting the depot as holding 4530 tons of munitions on 9 August.⁸²

Considered in the light of the Seventh Army's *daily* requirement of 1000 tons of ammunition and 1500 cubic metres of fuel,⁸³ the depots in the FDA can be seen as constituting significant local supply stockpiles (at least with respect to munitions) within a wider logistics system that has been recognised as inadequately prepared and supported.⁸⁴ The depot network must also be seen in the context of operational circumstances that over the course of the campaign not only saw continued degradation of the transport network – especially the bridges across the Seine and Loire – but also the aggregate effect of Allied air attacks on supply columns that served to progressively diminish the German transport vehicle fleet and hence the ability to get supplies to combat units.⁸⁵ In response the OB West supply chain increasingly turned to issuing fuel and munitions directly to combat units but, since divisional units at the front were required to collect their own ammunition and fuel supplies from depot areas and railheads well outside of the immediate battlefield area, this compounded and exacerbated the problems of re-supply itself.⁸⁶ Thus, while in June all supply allocations to the Seventh Army were routed via its depot network, by the period 15-31 July some 48% of fuel and 58% of munitions allocations were being issued direct to units of the Seventh Army (Table 9).

⁸² Government Code and Cypher School; German Section: Reports of German Army and Air Force High Grade Machine Decrypts (CX/FJ, CX/JQ and CX/MSS Reports). TNA HW5/561 Ultra intercept of Seventh Army signal dated 9 August. As this figure exceeds the 3500 ton design capacity of Martha it is likely that the excess stocks were stored in roadside or forest-floor stacks rather than bunkers.

⁸³ As stated by the Seventh Army Quartermaster on 14 June 1944; Eduard Mark, *Aerial Interdiction: Air Power and the Land Battle in Three American Wars*, (Washington D.C., 1994), p.253.

⁸⁴ *Ibid.*, p.252-253.

⁸⁵ Hart, 'Feeding Mars', p.427.

⁸⁶ *Ibid.*, p.429.

Allocations to PGW in this latter period were even more weighted towards direct issues, respectively totalling 92% for fuel and 65% for munitions (Table 9).

Although these circumstances reflect a diminishing emphasis on fixed Army-level depots in the immediate vicinity of the battlefields, it is argued here that the enduring operational status of depots in the FDA enabled these sites to maintain an influential contribution to the German combat capacity. Although no systematic record of supply outgoings from the depots are available, it is evident from Ultra decrypt reports that Beere, for example, released at least 435 cubic metres of fuel between 27 July and 7 August, and on 9 August Lager Martha allocated to 84 Korps a range of munitions including 3000 stick grenades and 10.5 tons of 88mm high explosive shells.⁸⁷ Lager Martha will have assumed particular importance after 17 July following the cessation of munitions deliveries to Lager Michel, the closest of the Seventh Army munitions depots to the front (Fig. 1), and the subsequent diversion of stocks to the FDA some 70 km to the southeast.⁸⁸

It is recognised, however, that in the face of rapidly deteriorating vehicle stocks throughout the Army – described as ‘demotorization’ by Ehlers Jr.⁸⁹ – geographical factors will have become increasingly significant with respect to the ability of combat units to access these supplies. Both Lager Berta / Beere and Martha were well-positioned to contribute to Operation Lüttich, the Mortain counter-offensive of 7-13 August since, although some specialist munitions types were lacking (e.g. white phosphorous⁹⁰), during the initial phases of the operation both fuel and munitions had been available from well-stocked supply depots in

⁸⁷ Government Code and Cypher School; German Section: Reports of German Army and Air Force High Grade Machine Decrypts (CX/FJ, CX/JQ and CX/MSS Reports). TNA, HW 5 Series Nos. 542, 549, 554, 559 and 560.

⁸⁸ Hart, ‘Feeding Mars’, p.432.

⁸⁹ Ehlers Jr., ‘Targeting the Third Reich’, p.225.

⁹⁰ Reardon, ‘Victory at Mortain’, p.147.

the Alençon area⁹¹ and this includes the FDA, only 45 km east of Mortain. More distant units, by contrast, faced lengthy and dangerous supply runs that would further jeopardise remaining vehicles. One account, for example, describes a return journey of 200 km required by two trucks of the 711 Infantry Division collecting ammunition from Lager Martha from their location on the front to the east of the River Orne - one of these vehicles was stranded at Falaise through lack of fuel.⁹² Other solutions to the lack of dedicated truck and tanker capacity involved deploying alternative vehicles; between 2 July and 7 August, for example, eye-witness accounts describe field ambulances arriving at a field hospital at Perrou (operated by the 9th and 10th SS Panzer and the 271st and 277th Infantry Divisions) with casualties and returning to the front via Lager Berta III / Beere in the FDA to pick up fuel.⁹³

Perhaps the final testimony to the German transport difficulties in Normandy lies in the amount of ammunition left unused in depots and requiring post-war disposal. German troops were detonating remaining ordnance stocks at Lager Martha immediately before withdrawing on the 14 August⁹⁴ yet even these efforts failed to empty the depot since a significant quantity of live munitions were recorded as present in a September 1944 Office National des Forêts inventory.⁹⁵

⁹¹ R.von Gersdorf, 'Avranches Counterattack, Seventh Army, 29 July – 14 August 1944' (US Army, Foreign Military Studies Branch, 1945), NARA: FMS, A921, p.26. Gersdorf was Chief of Staff to the German 7 Army.

⁹² Ninth Army Air Force Intelligence Report to Combat Crews for the period 4th to the 10th August. AFHRA, B5755. p.144. The original journey is distance is recorded as 200 miles but is more likely to have been reported in kms.

⁹³ R.Hervel, '*Bataille De Normandie*' (Paris, 1947).

⁹⁴ The Forest was captured over a two day period by elements of the US First Army meeting with little concerted resistance. Of note however was the advance of the 26th Infantry Regiment who described explosions from the retreating Germans attempting to destroy the ammunition depots which lay within the forest. NARA: Records of the Adjutant General's Office U.S. Army Records Group 407, E427 B5954.

⁹⁵ Records of the Office National des Forêts, Bagnoles de l'Orne, France. An inventory of captured German munitions held at Martha detail significant quantities present in the forest in the September of 1944. A full analysis of this resource is currently in process (Capps-Tunwell, unpublished data).

Conclusions

The restrictions imposed on German ground forces in the Normandy Campaign by fuel and munitions shortages have been well-documented and testify not only to the shortcomings of German preparations for the defence of France but also the overall effectiveness of Allied air power, and especially that of the tactical air forces. In developing a multi-disciplinary landscape approach to these studies, this paper has permitted a wider and more detailed evaluation of German logistics sites than hitherto possible, while also yielding new perspectives on Allied attempts to identify and bomb these facilities. In particular, the combination of archaeological and documentary evidence would suggest that, with respect to the German supply depot network in Normandy, Allied intelligence, targeting and bombing practice during the air campaign was of only limited effectiveness against those sites that had been dispersed and well-camouflaged in regional forests. In the case of the Seventh Army's Lager Berta / Beere fuel depots in the FDA it is evident that while the Allies had successfully identified and repeatedly attacked one part of the facility, two of the sites in the forest suffered only little damage. Furthermore, in the case of Lager Martha it can be demonstrated that Allied intelligence efforts - even with the benefit of a mature photoreconnaissance system, Ultra decrypts and ground-based observations - failed to gather sufficient evidence to adequately target one of the largest Seventh Army munitions depots in Normandy. This facility remained undamaged even by stray bombs and was operational up until its overrun by American forces on 14 August, only seven days before the closure of the Falaise Pocket.

These findings are consistent with late-war analyses of tactical air operations that recognised medium bombers could be "disappointing" against forest-based supply dumps⁹⁶ and also

⁹⁶ Twelfth Army Group considered that "Results from medium bombardment on several ammo and POL dumps in woods in the Falaise area were disappointing". Army Air Forces Evaluation Board, 'Third Phase Tactical Air Operations', Part 14, p.235.

Oberst Otto Eckstein's post-war assertion that air raids on depots in Normandy had little impact on their ability to operate.⁹⁷ Accordingly, at least at certain times and places, these sites enabled combat units to muster sufficient supplies to sustain their defence and on occasion even mount significant operations. Amongst the depots supporting the Mortain counter-offensive, for example, were the major Seventh Army fuel and munitions facilities in the FDA. Yet the achievements of the German logistics operation in sustaining a number of large supply facilities in Normandy did not prove to be a decisive failing in the Overlord air campaign. Indeed, the fact that Allied troops were overrunning unused stocks of material held in depots points not only to their speed of advance but also the difficulties faced by the Germans in transferring fuel and ammunition held in the region out to combat units, and especially those that were fighting at locations more distant from the supply points. This serves to underline the conclusions reached by those confronting these issues at the time⁹⁸ and also more recent historical analyses of the Normandy campaign – that the success of air operations was most keenly felt against the more vulnerable elements of the German logistics chain, most notably the regional communications infrastructure and a Wehrmacht vehicle fleet that was already deficient even before the campaign launch.⁹⁹

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⁹⁷ OB West Supply and Administration, 15 Jan 1943 - 30 Jun 1944. Otto Eckstein, FMS B-827 (dated 20 January 1948), p.58.

⁹⁸ *Ibid.*, p.58.

⁹⁹ Hart, 'Feeding Mars', and Ehlers Jr., 'Targeting the Third Reich'.

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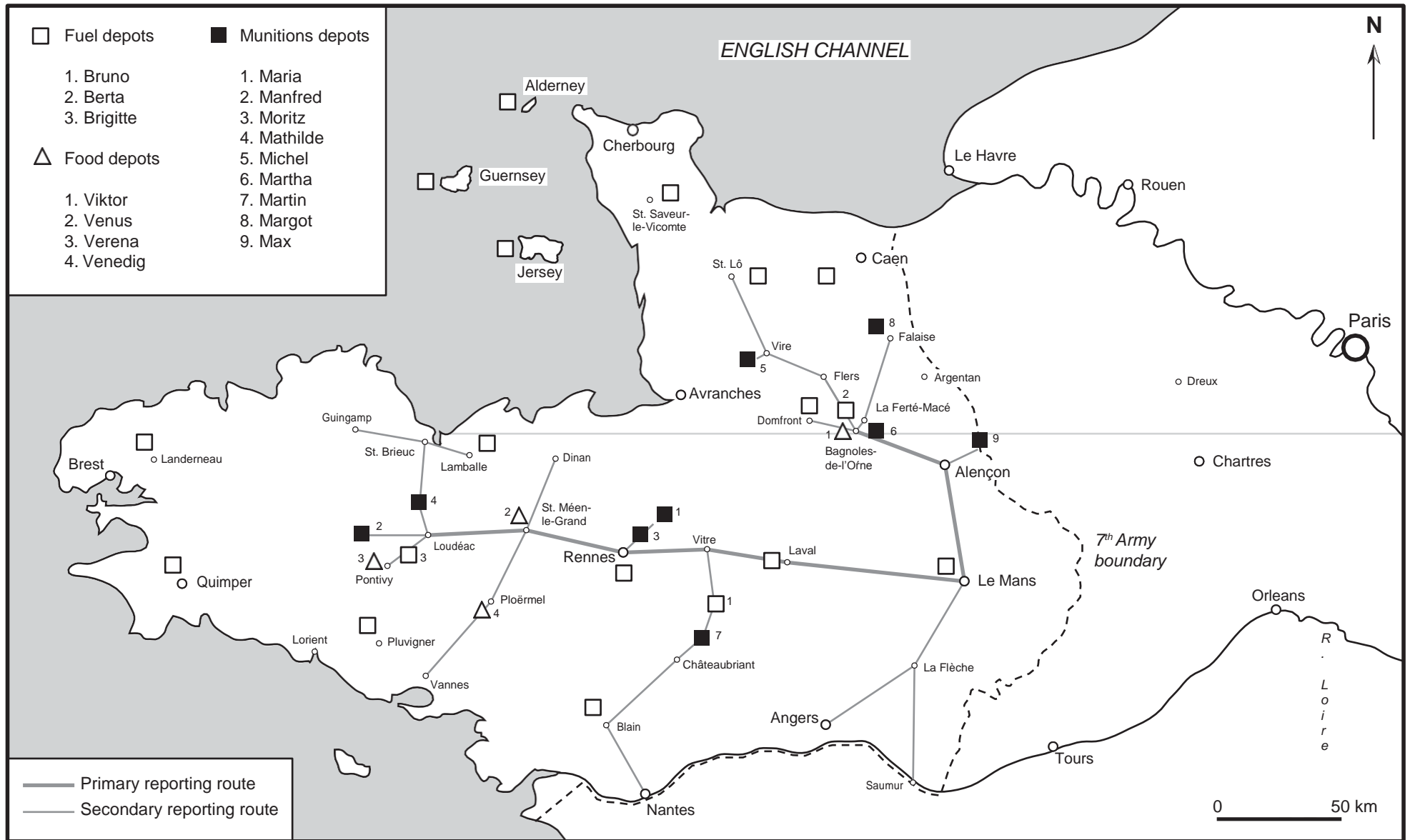


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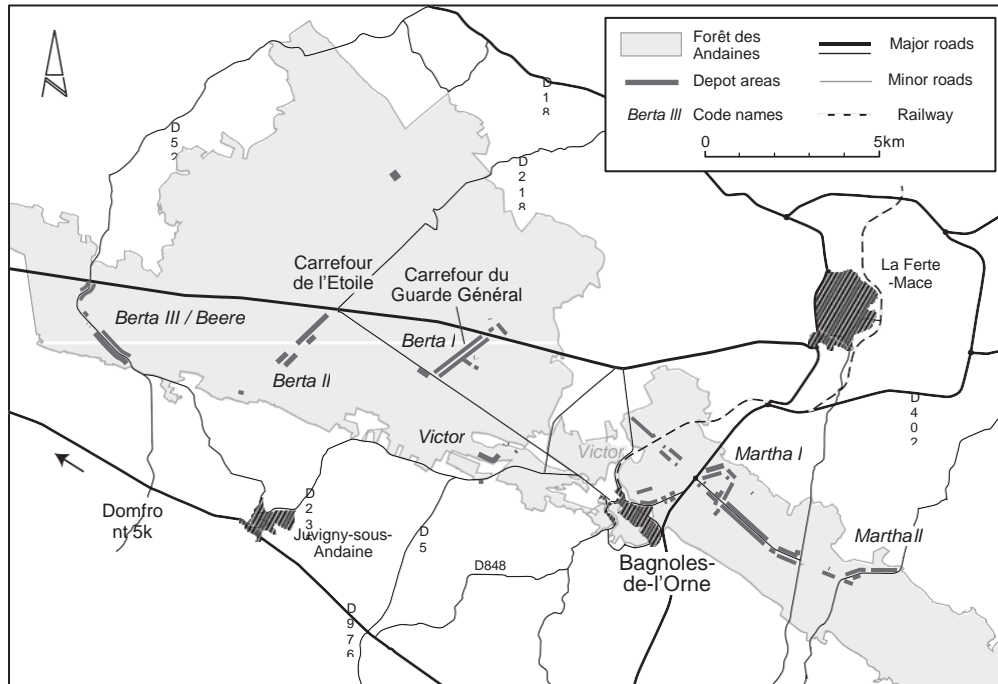


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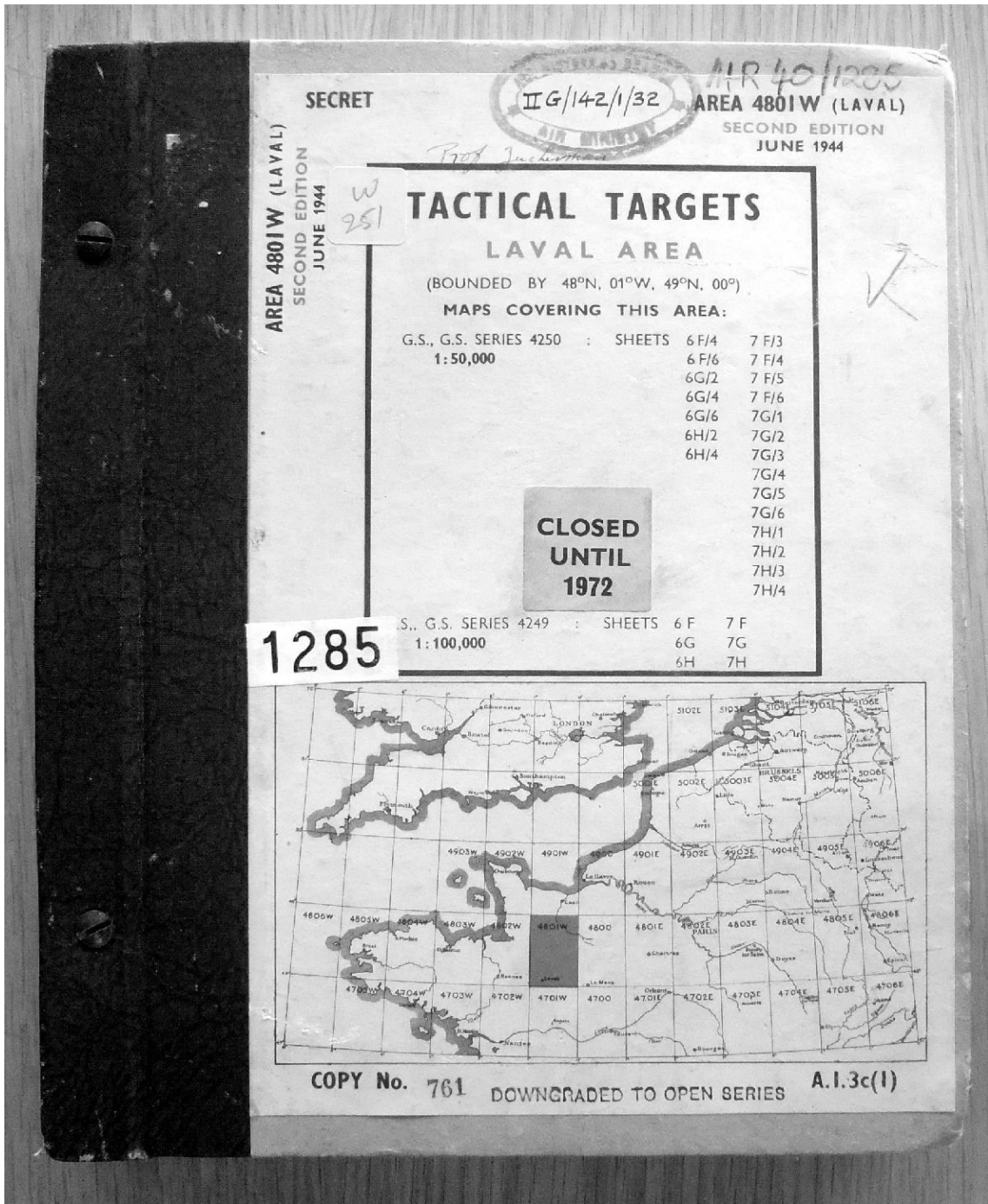


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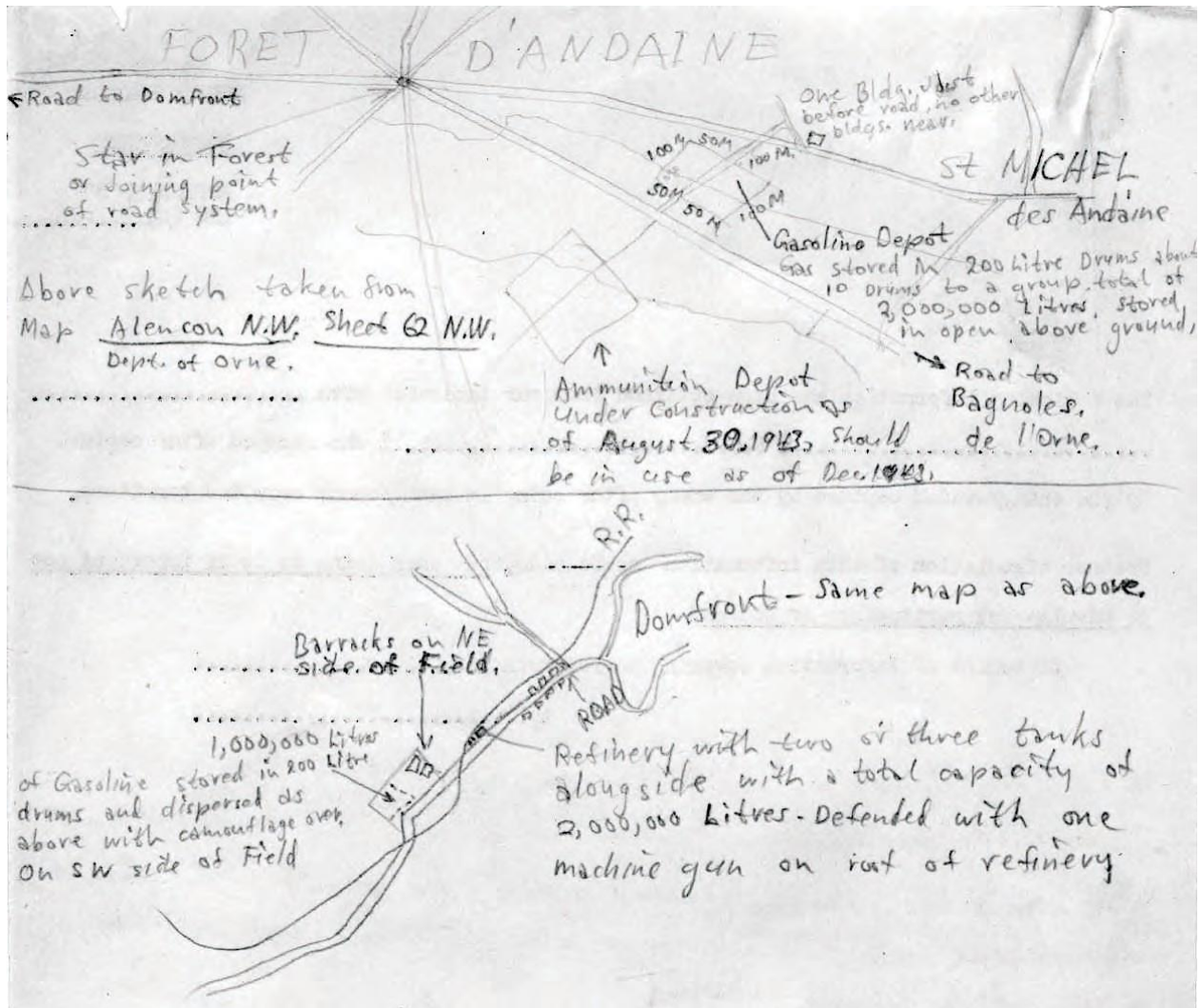


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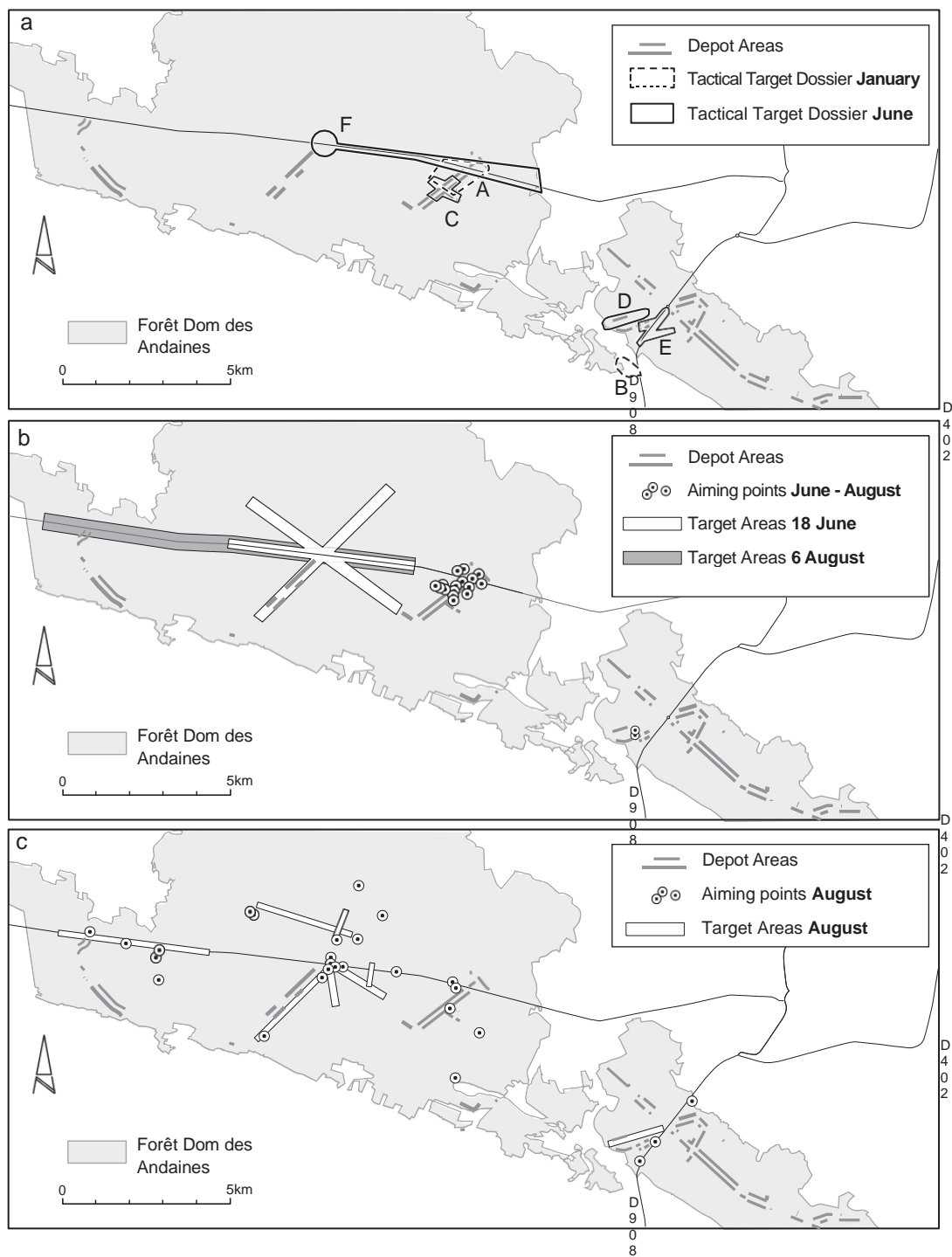


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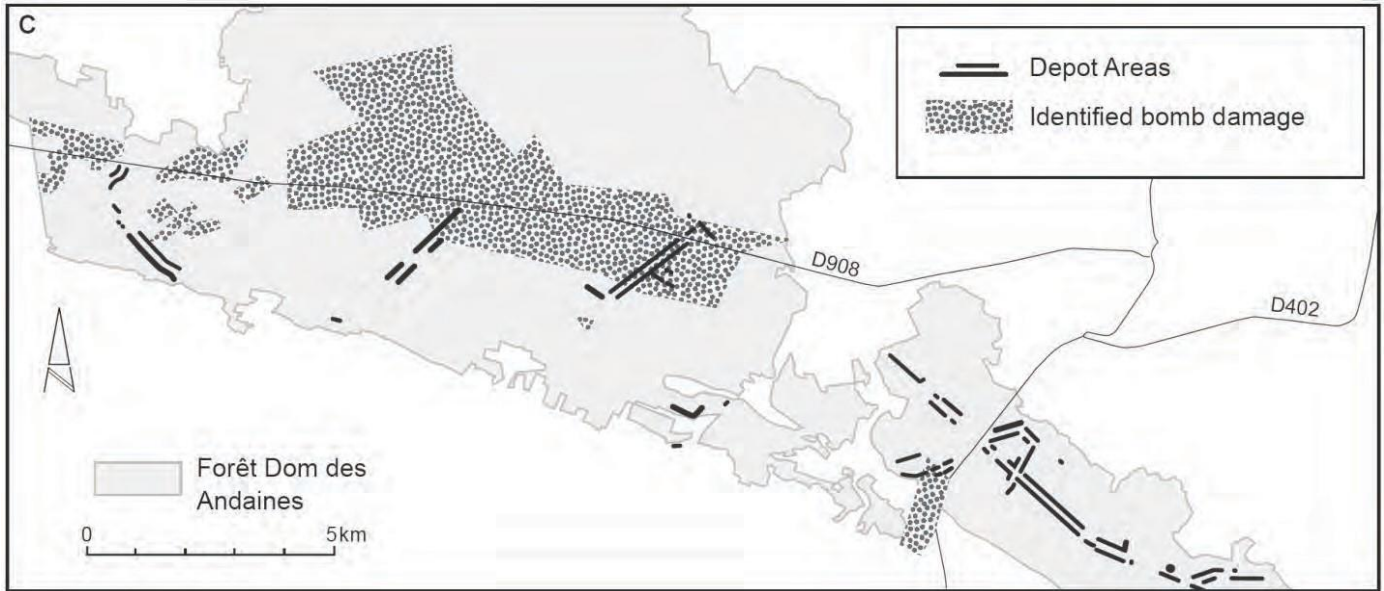


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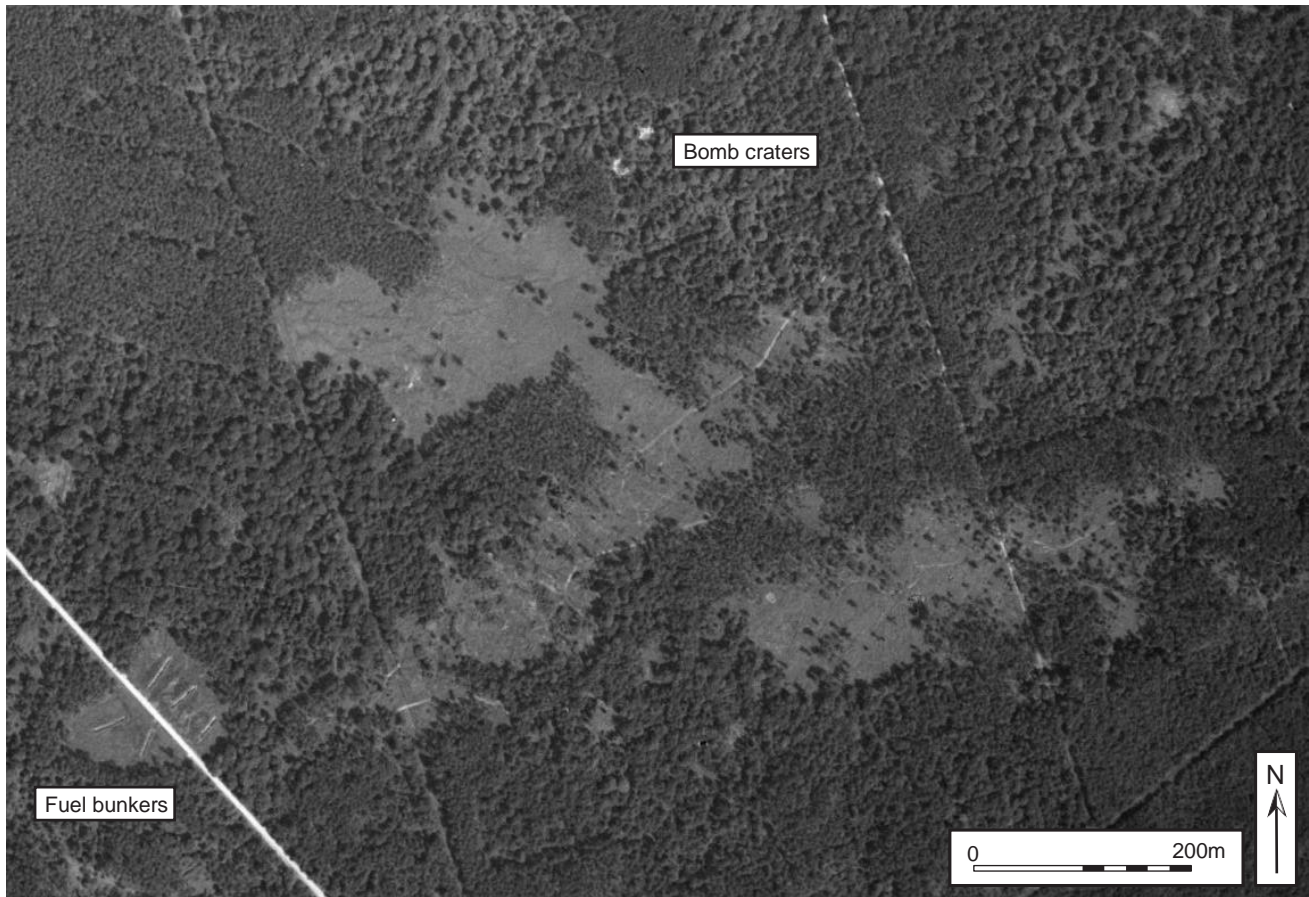


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Figure 12: Seventh Army and Panzer Group West fuel depots in the Normandy area* showing depot codenames, locations, timescales of known operation and fuel allocations (petrol only) from OB West, June 7 – August 8, 1944.

Depots		Holdings on June 1 (petrol, cbm)	Timescales of known operation									Total allocation (after June 1, cbm) / no. of orders
7th Army	Pz.Gp.West		Location (area)	June 7-13	June 14-20	June 21-27	Jun 28 - July 4	July 5-11	July 12-18	July 19-25	July 26 - Aug 1	
		--										2594 (25)
		836										1069 (7)
		866										0 (0)
		--										1011 (18)
		--										1247 (18)
		--										160 (1)
		--										100 (1)
		no data										414 (5)
		--	? ?									no data
		no data	? ?									no data
		--										no data
		--										148 (3)
		--										252 (3)
		--										no data
		--										no data
		--										no data
		113										--
(Holdings)												

* List excludes depots in Brittany (with the exception of Bruno) and supply movements along the coast / River Seine. Also excluded are allocations made direct to Army units.

** Depots known to be active on 12 August – no other data

Source: NARA T-311 R-15. H.Gr. D. 56250/3. Anlagen zum K.T.B. O.Qu. West (O.B. West). Beginn des Invasionszeitraumes 1.6 – 17-8.44; NARA T-312 R-1571. A.O.K. 7/O.Qu./Qu.1. 57355/6. Kriegstachbuch A.O.K.7/ O.Qu 1.6.44 – 30.6.44.

Figure 13: Seventh Army and Panzer Group West munitions depots in the Normandy area* showing depot codenames, locations, timescales of known operation and munitions allocations from OB West, June 7 – August 8, 1944.

Depots		Holdings on June 1 (metric tons)	Timescales of known operation									Total allocation (after June 1, tons) / no. of orders
7th Army	Pz.Gp.West		June 7-13	June 14-20	June 21-27	Jun 28 - July 4	July 5-11	July 12-18	July 19-25	July 26 - Aug 1	August 2-8	
Martha	FDA	2008	[7th Army]									3957 (54)
Michel	St.Sv.d.Calvados	2109	[7th Army]									3615 (66)
Max/Mimose	Alencon	1417	[7th Army] [Pz.Gp.West]									413 (5)
Margot/Melone	Falaise	1638	[7th Army] [Pz.Gp.West]									1728 (20)
Myrthe/Meta	Falaise	--	[7th Army] [Pz.Gp.West]									20 (1)
Monika/Mandel	Alencon	--	? [7th Army] [Pz.Gp.West]									no data
Mond	Livarot	--	[7th Army]									19 (3)
Mina	Coutances	--	? [7th Army]									no data
Maus	Pontorson	--	? [7th Army] ?									no data
Morgen	Pontorson	--	? [7th Army] ?									no data
Mars/Maibaum	St Gauberge	--	[7th Army] [Pz.Gp.West]									50 (1)
Mais	Argentan	--	[Pz.Gp.West]									1592 (25)
Marone	Bernay	--	[Pz.Gp.West]									934 (8)
Malve	Elbeuf	--	[Pz.Gp.West]									no data
Missel**	Montfort	--										no data
Mokka**	Dreux	--										no data

* List excludes depots in Brittany and supply movements along the coast / River Seine. Also excluded are allocations made direct to Army units.

** Depots known to be active on 12 August – no other data

Source: NARA T-311 R-15. H.Gr. D. 56250/3. Anlagen zum K.T.B. O.Qu. West (O.B. West). Beginn des Invasionszeitraumes 1.6 – 17-8.44; NARA T-312 R-1571.

A.O.K. 7/O.Qu./Qu.1. 57355/6. Kriegstachbuch A.O.K.7/ O.Qu. 1.6.44 – 30.6.44.

Table 1: Summary details of US Ninth Air Force raids on the Forêt domaniale des Andaines, June-July 1944 (Sources: AFHRA B5785, B5786, B5787, B5788, B5679 and B5680).

Date	Aircraft Type	Wing / Group	No. of Aircraft	Target Area	Tonnage
13/06/44	B-26	99 / 322	37	TTD (January 1944) (Fig. 6a, Area A)	0.0
13/06/44	B-26	98 / 397	36	TTD (January 1944) (Fig. 6a, Area A)	71.5
15/06/44	A-20	97 / 409	29	TTD (January 1944) (Fig. 6a, Area A)	39.3
15/06/44	A-20	97 / 410	31	TTD (January 1944) (Fig. 6a, Area A)	44.0
15/06/44	P-38	370	16	TTD (January 1944) (Fig. 6a, Area A)	1.5
18/06/44	B-26	99 / 391	36	Tactical Target List (Fig. 6b)	63.0
18/06/44	A-20	97 / 410	35	Tactical Target List (Fig. 6b)	46.5
18/06/44	B-26	99 / 386	36	Tactical Target List (Fig. 6b)	72.0
22/06/44	A-20	97 / 410	36	TTD (Jan / June 1944) (Fig. 6a, Area B)	46.1
22/06/44	B-26	99 / 322	36	TTD (Jan / June 1944) (Fig. 6a, Area A)	69.9
22/06/44	B-26	99 / 391	36	TTD (Jan / June 1944) (Fig. 6a, Area A)	63.6
22/06/44	--	--	--	Unspecified area of Lager Beere*	--
24/06/44	A-20	97 / 416	36	TTD (June 1944) (Fig. 6a, Area B)	43.3
24/06/44	P-38	474	?	TTD (June 1944) (Fig. 6a, Area B)**	--
25/06/44	A-20	97 / 416	34	TTD (January 1944) (Fig. 6a, Area A)	38.5
25/06/44	A-20	97 / 410	32	TTD (January 1944) (Fig. 6a, Area A)	42.5
25/06/44	B-26	98 / 394	24	TTD (January 1944) (Fig. 6a, Area A)	46.6
Total (June)					688.3
11/07/44	A-20	97 / 409	32	TTD (January 1944) (Fig. 6a, Area A)	29.9
11/07/44	B-26	Pathfinder	2	TTD (January 1944) (Fig. 6a, Area A)	2.5
12/07/44	A-20	97 / 410	26	TTD (January 1944) (Fig. 6a, Area A)	34.3
12/07/44	A-20	97 / 416	30	TTD (January 1944) (Fig. 6a, Area A)	37.3
12/07/44	B-26	Pathfinder	4	TTD (January 1944) (Fig. 6a, Area A)	4.0
24/07/44	A-20	97 / 410	35	TTD (January 1944) (Fig. 6a, Area A)	35.0
24/07/44	B-26	Pathfinder	2	TTD (January 1944) (Fig. 6a, Area A)	2.0
Total (July)					145

* German report of strafing attack on Lager Beere (forest-site) destroying 150 cubic metres of fuel (7 AOK Kriegstagebuch, NARA, T312, R-1571, p.000538).

** Escorts for A-20 raid: did not attack target.

Table 2: Summary details of US Ninth Air Force raids on the Forêt domaniale des Andaines, August 1944 (Sources: AFHRA B5788, B5683 and B5684).

Date	Aircraft Type	Wing / Group	No. of Aircraft	Target Area	Tonnage
06/08/44	A-20	97 / 409	36	Tactical Target List (Fig. 6b)	34.3
06/08/44	B-26	99 / 322	36	Tactical Target List (Fig. 6b)	35.8
06/08/44	B-26	99 / 386	36	Tactical Target List (Fig. 6b)	49.7
06/08/44	B-26	99 / 391	36	Tactical Target List (Fig. 6b)	46.9
06/08/44	P-38	370	10	TTD (June 1944) (Fig. 6a, Area C)	24 x 150 Gal Napalm*
06/08/44	P-38	370	13	TTD (June 1944) (Fig. 6a, Area C/F)	24 x 150 Gal Napalm
06/08/44	P-47	366	12	TTD (June 1944) (Fig. 6a, Area C/F)	4
06/08/44	P-47	366	12	Tactical Target List (Fig. 6c)	4
08/08/44	P-47	368	8	Tactical Target List (Fig. 6c)	2
08/08/44	P-38	370	12	TTD (June 1944) (Fig. 6a, Area D/E)	6
08/08/44	P-38	367	12	TTD (June 1944) (Fig. 6a, Area D/E)	4
09/08/44	P-47	50	8	Tactical Target List (Fig. 6c)	
09/08/44	P-47	48, 50 & 368	32	TTD (June 1944) (Fig. 6a, Area E/F)	
10/08/44	P-38	370	12	Tactical Target List (Fig. 6c)	12
10/08/44	P-38	370	11	TTD (June 1944) (Fig. 6a, Area E/F)	11
10/08/44	P-47	50	12	Tactical Target List (Fig. 6c)	5.25
11/08/44	P-38	370	12	TTD (June 1944) (Fig. 6a, Area F)	5.5
11/08/44	P-38	370	12	Tactical Target List (Fig. 6c)	11.75
11/08/44	P-38	367	11	Tactical Target List (Fig. 6c)	7
11/08/44	P-38	474	14	Tactical Target List (Fig. 6c)	13
11/08/44	P-47	50	26	Tactical Target List (Fig. 6c)	13
12/08/44	P-47	368	11	Tactical Target List (Fig. 6c)	
12/08/44	P-47	404	13	Tactical Target List (Fig. 6c)	13
13/08/44	P-47	404	12	Tactical Target List (Fig. 6c)	432 X 20 Frag
14/08/44	P-47	368	8	Tactical Target List (Fig. 6c)	4
Total (August)					282.2**

* Alternative targets in FDA struck

** Excludes fragmentation bombs and napalm

Table 3: Total bomb tonnage dropped on raids for target areas identified in Tactical Target Dossiers for January and June 1944.

TTD / TTL	Target area*	Bomb tonnage**
TTD January 1944	TTD-A (Fig. 6a)	566.3
TTD January 1944	TTD-B (Fig. 6a)	93.4
TTD June 1944	TTD-C, D, E, F (Fig. 6a)	40.5
Tactical Target Lists	Various (Fig 6b-c)	427.1
	Total:	1127.3

*Author codes – see text for details

** Excludes napalm and fragmentation bombs

Table 4: Summary details of Allied air raids on Domfront, May-August 1944.

Date	Units	Aircraft Type	No. of Aircraft	Source / notes
21/05/1944	Not Known	Not Known	Not Known	TNA Air 37/958; 2nd TAF Operational Report Section (27 November 1944).
28/05/1944	Not Known	Not Known	Not Known	TNA Air 37/958; 2nd TAF Operational Report Section (27 November 1944).
02/06/1944	US Ninth Army Air Force	P-47	53	TNA Air 37/850; Attacks on POL Ammunition and Supply Dumps (SHAEF, 9 August 1944).
03/06/1944	US Ninth Army Air Force	P-47	53	TNA Air 37/850; Attacks on POL Ammunition and Supply Dumps (SHAEF, 9 August 1944).
07/06/1944	US Ninth Army Air Force	P-38	Not Known	AFHRA B0344, p. 362. Fuel target.
14/06/1944	US Ninth Army Air Force	B-26	36	TNA Air 37/850; Attacks on POL Ammunition and Supply Dumps (SHAEF, 9 August 1944).
14/06/1944	US Ninth Army Air Force	A-20	38	AFHRA C0070, p. 1645. Raid intended for Flers but bombed Domfront.
15/06/1944	US Ninth Army Air Force	A-20	36	AFHRA B5786, p. 152.
15/06/1944	US Ninth Army Air Force	P-38	16	TNA Air 37/850; Attacks on POL Ammunition and Supply Dumps (SHAEF, 9 August 1944). AFHRA B0342, p. 1372. Part of raid on FDA, carrying 1000lb.bombs
24/06/1944	RAF 2nd TAF	Typhoons	15	TNA Air 37/850; Attacks on POL Ammunition and Supply Dumps (SHAEF, 9 August 1944).
27/06/1944	US Eighth Army Air Force	Not Known	53	TNA Air 37/850; Attacks on POL Ammunition and Supply Dumps (SHAEF, 9 August 1944).
06/07/1944	US Ninth Army Air Force	B-26	36	AFHRA B5787, p. 165. Rail cutting target.
07/07/1944	US Ninth Army Air Force	P-47	c.12	AFHRA B0344, p. 705 Armed Reconnaissance
13/07/1944	US Ninth Army Air Force	A-20	26	TNA Air 37/850; Attacks on POL Ammunition and Supply Dumps (SHAEF, 9 August 1944).
01/08/1944	US Ninth Army Air Force	P-38	11	AFHRA C0027, p. 590/599. Fuel storage target.
01/08/1944	US Ninth Army Air Force	P-38	12	AFHRA C0027, p. 590/599. Fuel storage target.
04/08/1944	US Ninth Army Air Force	P-38	12	AFHRA B0342, p. 1685. Fuel 1719 FDA Stores.
12/08/1944	US Ninth Army Air Force	P-47	12	AFHRA B0491, p. 765-796. Armed Reconnaissance

Table 5: Operational Research Section (US Ninth Air Force) assessment of bombing accuracy for differing directions of approach: Forêt domaniale des Andaines and Forêt d'Ecouves (Normandy), June 1944.

Number of aiming operations	Direction of approach	% of bombs dropped landing in target area
<i>Forêt domaniale des Andaines</i>		
6	From east, over nearest clear-cut forest edge	40
4	From south, over fairly clear-cut forest edge	39
6	From west, across the forest itself	28
<i>Forêt d'Ecouves</i>		
7	Across clear-cut forest edge	45
6	Across forest itself	0

Source: Operational Research Section, Ninth Air Force: Area Bombing for June (7 August 1944). AFHRA, B5656.

Table 6: Summary of target types attacked and weight of bombs (General Purpose types) and rocket projectiles (R.P.) delivered by Allied air forces in support of Operation Overlord during June, July and August 1944. Attacks on fuel and ammunition stocks ('Store bases') are also shown as percentages of bombs and R.P.'s delivered by (i) all Allied air forces and (ii) by the Allied Expeditionary Air Force (A.E.A.F).

	June*		July**		August**	
	Tons of bombs	Tons of R.P. (60 lb)	Tons of bombs	No. of R.P. (60 lb)***	Tons of bombs	No. of R.P. (60 lb)***
Airfields	221	56	3035	--	6918	--
Store bases (fuel dumps, etc)	2278	371	4249	48	15817	198
Industrial centres (factories, oil refineries, etc)	160	14	14	--	348	--
Signals facilities (radar, W.T., etc)	361	2628	14	82	88	143
Coastal defences and gun positions	3215	577	726	5381	2848	4408
Chateaux, headquarters, barracks	501	448	133	102	97	420
Railway centres and marshalling yards	2886	290	11988	48	6213	--
Rail facilities (other than centres and bridges)	--	--	1704	74	1139	102
Bridges and embankments (road and rail)	4701	338	7141	248	7689	260
Road convoys (vehicles, tanks, etc)	860	3120	443	3234	1825	21198
Shipping (in harbour & at sea)	29	904	351	443	4731	3021
Flying bomb targets	1335	--	30545	--	24215	--
Tactical targets & targets of opportunity	11877	8069	23690	10434	20451	5052
Total	28424	16815	84033	20094	92379	34802
<i>% of Store bases as total</i>	<i>8.0</i>	<i>2.2</i>	<i>5.1</i>	<i>0.2</i>	<i>17.1</i>	<i>0.6</i>
<i>% of Store bases as total of A.E.A.F attacks</i>	<i>8.0</i>	<i>2.2</i>	<i>16.0</i>	<i>0.2</i>	<i>14.6</i>	<i>0.6</i>

* Attacks by the A.E.A.F. only

** Attacks by the A.E.A.F., US VIII Air Force and RAF Bomber Command

*** Data reported as number of projectiles

Source: TNA AIR 37/ 539

Table 7: Summary of Allied Expeditionary Air Force raids (total aircraft sorties and tonnage of bombs) on Store Bases (fuel and ammunition) classified as Overlord Targets during June, July and August 1944. Also shown are figures for attacks on fuel and ammunition stocks in the Foret dom. des Andaines as a percentage of the total raids on Store Bases.

	All Store Bases (A.E.A.F. Overlord Targets)			<i>Foret dom. des Andaines</i>	
	Total no. of sites	Total aircraft attacking	Total tons of G.P. bombs	<i>% of total aircraft attacking</i>	<i>% of total tons of G.P. bombs</i>
June	22	1718	2278.5	26.6	29.1
July	49*	2832	3163.5	3.3	3.4
August	63*	5827	15817	2.5	2.9

* includes one site listed as 'miscellaneous'

Source: TNA AIR 37/ 539

Table 8. Orders for fuel and oil deliveries to Lager Berta and Lager Beere, 10 June – 21 July, 1944.
 (Source: Versorgungsübersicht für AOK 7: NARA, T-311, R-15).

Date Ordered	Date Required	Lager	Quantity (cubic m)		
			Petrol	Diesel	Oil
10/06/44	11/06/44	Berta	594	--	--
10/06/44	12/06/44	Berta	210	--	--
12/06/44	14/06/44	Berta	235	--	30
12/06/44	13/06/44	Beere	140	--	--
14/06/44	16/06/44	Berta	30	--	--
18/06/44	21/06/44	Beere	240	--	--
20/06/44	23/06/44	Beere	110	90	--
23/06/44	25/06/44	Beere	330	--	--
08/07/44	10/07/44	Beere	100	30	--
10/07/44	13/07/44	Beere	135.5	10	--
12/07/44	15/07/44	Beere	40	12	--
14/07/44	17/06/44	Beere	60	20	--
15/07/44	18/07/44	Beere	70	10	--
16/07/44	19/07/44	Beere	60	20	--
18/07/44	21/07/44	Beere	50	--	--
20/07/44	23/07/44	Beere	80	20	--
21/07/44	25/07/44	Beere	160	--	--

Table 9: Allocations of fuel and munitions from OB West to Seventh Army and Panzer Group West between 11 June and 31 July, 1944. Note that direct issues required collection by Army units at locations outside the main battlefield area.

Period / Army Group	Allocation	Fuel (cbm)	%	Munitions (tons)	%
11-30 June					
Seventh Army	Depot allocation	3833	100	5057	100
	Direct issue to Army unit	0		0	
	Direct issue (no unit specified)	0		0	
Panzer Group West	Depot allocation	0		0	
	Direct issue to Army unit	0		0	
	Direct issue (no unit specified)	0		0	
Totals		3833		5057	
1-14 July					
Seventh Army	Depot allocation	1164	63	1923	100
	Direct issue to Army unit	413	22	0	0
	Direct issue (no unit specified)	280	15	0	0
	Sub-totals	1856	100	1923	100
Panzer Group West	Depot allocation	276	16	669	72
	Direct issue to Army unit	1127	63	258	28
	Direct issue (no unit specified)	370	21	0	0
	Sub-totals	1773	100	927	100
Totals		3629		2850	
15-31 July					
Seventh Army	Depot allocation	1801	52	4143	42
	Direct issue to Army unit	1164	34	278	3
	Direct issue (no unit specified)	500	14	5356	55
	Sub-totals	3465	100	9777	100
Panzer Group West	Depot allocation	672	8	2315	35
	Direct issue to Army unit	3641	41	1597	24
	Direct issue (no unit specified)	4559	51	2655	41
	Sub-totals	8871	100	6567	100
Totals		12336		16344	

Source: Versorgungübersicht AOK7/Pz.Gr.West, 7015166-7015472; NARA T-311 R-15.

Appendix VI

Paper VI:

Passmore, D.G., Capps Tunwell, D. and Harrison, S. (2016). World War II Conflict and Post-conflict Landscapes in Northwest France: An Evaluation of the Aerial Photographic Resource. In: Stichelbaut, B. and Cowley, D. (ed.) *Conflict landscapes and archaeology from above*, Farnham: Ashgate, Ch. 11. pp. 184-204.

World War II Conflict and Post-conflict Landscapes in Northwest France: An Evaluation of the Aerial Photographic Resource

David G. Passmore, David Capps Tunwell, Stephan Harrison

In: Stichelbaut, B. and Cowley, D. (eds) *Conflict Landscapes and Archaeology from Above*. Farnham, Ashgate, p.185-204 (2016).

Abstract

This paper explores the utility of aerial photographs for investigating landscapes of WWII conflict associated with the Normandy Campaign and the bombing of German military sites in northwest France during 1943 and 1944, and also the lesser known history of landscape rehabilitation and remediation in the immediate post-war recovery period. The primary resource used here are vertical aerial photographs at scales between c.1:1,500 and 1:26,000, taken between 1945 and 1960 and accessible from the online archive hosted by the Institut Géographique National (IGN). Our analysis focuses on rural areas impacted by one or more Allied air raids, either because they witnessed major Allied ground offensives or were the sites of German military installations. Areas of open agricultural land have rarely preserved any visible evidence of bomb damage, but here the photographic record enables analysis of the intensity and character of bombing and the immediate post-war remediation of farmland. Allied air raids also targeted supply depots and V-weapon facilities concealed in regional forests, and here it is demonstrated that forest clearance associated with fires and late- and post-war munitions disposal activities have combined to render formerly camouflaged military sites, bomb craters and remediation landscapes as readily visible on aerial images.

Keywords: aerial photographs, WWII, northwest France, bomb craters, remediation

Introduction

The maturing of aerial photography as a military reconnaissance and analysis tool during World War II has left a legacy of images that have subsequently been widely deployed in the historical and archaeological analysis of the period's conflict

landscapes (e.g. Stichelbaut *et al.* 2009, Cowley *et al.* 2010). To date, aerial images have perhaps been most extensively used in historical accounts and battlefield guides of campaigns in the Northwest European theatre of World War II, especially to illustrate the aerial bombing campaigns of British and German cities (e.g. Overy 2013), V-weapon sites (e.g. Williams, 2013) and the conflict landscapes of the D-Day landings and the subsequent campaigns through France, the Low Countries and eventually Germany (e.g. Herington, 1963, Copp and Bechthold 2011). The use of battlefield and target imagery has also been complemented by increasing interest in the wartime photographic record of a wider range of conflict-related landscapes, for example to assist detection of military grave sites (Abicht 2010) and for analysis of concentration camps (Uziel 2010), prisoner of war (PoW) camps (Doyle *et al.* 2013), military support infrastructure (e.g. Newsome 2009, Easton 2009, 2010) and D-Day preparations in the UK (e.g. Crutchley 2009, Stoertz, 2010, Easton 2010).

These examples all draw on the considerable volume of vertical aerial reconnaissance photographs taken for military purposes during the war itself, but more recent studies have also begun to use post-war images to examine aspects of World War II conflict and its immediate post-war legacy. In France, for example, these include studies of post-war PoW camps (Early 2013, Mytum and Carr 2013) and the author's own work on the archaeology of the German logistics network in northwest France and the efforts of Allied strategic and tactical air forces to bomb the supply depots (Passmore *et al.*, 2013, 2014, Capps Tunwell *et al.* 2015). These investigations have been greatly facilitated by the aerial photographic archive administered and made public by the Institut Géographique National (IGN): here we return to this archive in order to extend the analysis of conflict and post-conflict landscapes in northwest France, with particular reference to sites associated with the Normandy Campaign and the wider array of German military infrastructure.

Having largely escaped significant war damage during the German conquest of France in summer 1940 (with the notable exception of the towns of the Lower Seine; Clout, 1999), large areas of the rural landscape of northwest France were transformed by German preparations for the defence of the continental mainland. Military targets and the wider regional transport infrastructure became the focus of Allied bombing throughout 1943 and 1944 in preparation for, and support of, the D-Day landings and the subsequent battle for Normandy. Extensive additional areas were rendered unusable by ground combat and associated shelling and bombing (in Manche, for example, some

35,000 ha of land was impacted by the D-Day landings themselves; Clout 2006), while the rapid development of Allied airfields, camps and supply depots removed at least a further 200,000 ha of farmland in the Départements of Manche and Calvados alone (Clout 2006).

In the case studies below we present interpretations of aerial photographs spanning the period 1945-1960 with the aims of evaluating (i) the evidence for military installations developed before and during the Normandy Campaign, (ii) the extent and character of Allied bomb damage on agricultural and forested settings (including the battlefields of major Allied breakout operations in the vicinity of Caen and Saint-Lô) and (iii) the process and timescale of post-conflict landscape rehabilitation that in most agricultural landscapes has removed any modern surface evidence of conflict. In capturing the landscape traces of the conflict legacy in post-war Normandy, these images not only illuminate some of the earliest reconstruction activities in what Clout (2008) terms the 'emergency' phase in the region, but also draw attention to the rehabilitation of rural and forested environments which, by comparison to the longer-term history of urban renewal following both world wars (e.g. Clout 1999, Knapp 2007), have received rather less attention from scholars and command little profile in Normandy's conflict heritage (see also Clout 2006, 2008).

The Institut Géographique National Photographic Archive

The primary resources used in this study are vertical aerial photographs taken and archived by the *Institut Géographique National* (IGN). Established in 1940 in replacement of the disbanded *Service Géographique de L'Armée*, from May 1946 the IGN assumed responsibility for a national photograph library (*Centre de Documentation de Photographies Aériennes*; Plu and Ducher 1988) and has since orchestrated the taking and archiving of aerial photographic records of the country with the intention of systematically renewing the countrywide orthophotographic cover every 3-10 years (depending on the speed of development). By 1953 the IGN had accomplished a complete aerial photographic coverage of the national territory at c.1:25,000 (much of this flown by ex-USAF B-17 aircraft; <http://www.ign.fr/institut/dossiers/lhistoire-de-lign>), although many areas physically impacted by the war were the focus of additional larger-scale photographic sorties. Since 2012 the aerial photograph collection has been administered by the *Institut*

National de L'information Géographique et Forestière as a result of the merger between the *Institut Géographique National* and the *L'Inventaire Forestier National* (IFN), although the new body maintains the same IGN acronym.

In contrast to many national or agency collections of aerial photographs that are not well catalogued or difficult to access (Bourgeois *et al.* 2009), a great many of the IGN's historical aerial images are freely available for viewing and download from the IGN's online map service 'Géoportail' (www.geoportail.gouv.fr). IGN images used in this study date to the period 1945-1960 with the majority taken in the four years after the end of World War II. Most are large-scale images in the order of 1:24,000 - 1:26,000 with some at larger scales between 1:4,000 - 1:6,500 offering very high levels of detail. Images have been scaled and rotated for analysis and reproduction using image manipulation and GIS software, while overlapping frames in many sorties have permitted the use of stereoscopic analysis of bomb-damaged features and terrain.

Landscapes of aerial bombing

Landscapes of northwest France bore witness to the full range of Allied aerial bombing technology in late 1943 and 1944, ranging from combat air support (CAS) and armed reconnaissance missions flown by fighter-bombers to dedicated and often repeated attacks by light, medium and heavy bombers on military targets and transport infrastructure behind the front lines. Case studies below include some of the most heavily-bombed areas in the region inland from the D-Day beachheads. We begin with two examples of large-scale attacks by heavy bombers, taking place over minutes or hours in direct support of major Allied ground offensives. Thereafter the focus switches to examples of attacks on fixed military sites and installations, characterised by raids of smaller numbers of aircraft (and usually medium bombers) but repeated on multiple occasions over the course of weeks or months before and during the Normandy campaign. Examples span readily identified sites such as the Luftwaffe airfield at Conches-en-Ouche, and others that were concealed in forests, including the V-weapons site at Bois Carré and German munitions depots at Maintenon and in the Forêt domaniale des Andaines and adjacent to Conches-en-Ouche airfield. We also consider the site of an Allied temporary airfield at Lavieille, near Saint-Lô which escaped any significant bombing but which nevertheless had a considerable impact on the immediate landscape.

Ground Offensives

Some of the most heavily-bombed rural landscapes in Normandy had no intrinsic military significance until their geographical context aligned with major ground Allied ground assaults. This was the case in the vicinity of the village of Cagny, 9 km southeast of Caen (Figure 1) and one of several potential strongpoints bombed by Allied aircraft ahead of the planned armoured breakout of Operation Goodwood on 18 July 1944. This was also true of the landscape north of La Chapelle-en-Juger, 9 km west of Saint-Lô, that was bombed on 25 July in advance of the Operation Cobra breakout by the First US Army (Figure 1). Both sites have been subjected to detailed historical study on account of their importance in the offensive narratives (e.g. Gooderson 1992, Carafano 2009) but are considered here on account of the photographic record of bomb damage and subsequent recovery.

(i) Cagny

The raid on Cagny took place early in the morning of 18 July 1944 by 106 heavy bombers of the RAF dropping a total of 650 tons of bombs (Gooderson 1992; Moore 2007). Many of the bombs dropped in support of Goodwood were fitted with instantaneous fuses in order to avoid deep cratering of the ground that would hinder armoured operations, and it has been argued that all of the bombs dropped on Cagny were so fitted (Gooderson 1992). The characteristic blast rings of such bombs can indeed be seen on an aerial reconnaissance photograph of Cagny taken shortly after the raid (Figure 2a; see Ford *et al.* 2004). The majority of bomb impacts shown in this frame, however, are evidenced by well-defined craters and scatters of debris that are more consistent with the use of delayed fusing and bomb detonation below the ground surface (Figure 2a). Furthermore, an IGN aerial photograph of Cagny taken on 12 October, 1945 (Figure.2b) shows that while there is little or no evidence of cratering in the locations impacted by bombs with instantaneous fuses, most of the craters associated with delayed fuses still survive in the landscape around the village except for occasional fields where craters appear to have been already infilled by this date.

A series of exceptionally large-scale images (1:1,500) taken of Cagny exactly one year later in October 1946 illustrate the degree and nature of ongoing field restoration efforts (Figure 3). Irregular patches of bare earth or young grass with track or tyre

marks in Figure 3a shows recently-infilled craters in pasture near the village centre, although it is interesting to note that at least two craters survive in the adjacent scrub. Ploughed and cultivated fields on the northwest margin of the village also show evidence of infilled craters although here the process appears to be more advanced with the craters evident as circular cropmarks or slight depressions (Figure 3b). Later post-war IGN images (not shown here) show that by August 1947 examples of extant craters are limited to only occasional examples in scrubland or rough pasture and from 1955 even cropmark evidence is limited.

(ii) *La Chapelle-en-Juger*

On 25 July 1944 the village of La Chapelle-en-Juger lay in the centre of a rectangular target area of c.17 km² sited over the German front line west of Saint-Lô (Figure 1) and designated as the focus of the Operation Cobra breakout by the First US Army (Carafano 2009). In addition to strikes by fighter- and medium bombers, 1,495 heavy bombers of the US Eighth Air Force delivered 2,060 tons of high explosive and 2,346 tons of fragmentation bombs in and around the target box and, while not eliminating German opposition, the raid weakened resistance sufficiently such that by 27 July the US forces had broken through and were poised to exploit to the south, thus achieving the long-awaited breakthrough on the Normandy front. Figure 4 is an extract from an IGN aerial photograph taken on the 25 July 1947 showing the landscape between La Chapelle-en-Juger north to the D900 between Saint-Lô and Périers which effectively marked the front line prior to Operation Cobra. This image testifies to the intensity of the Operation Cobra raids with few fields appearing to have escaped bomb impacts, but considerable field-by-field variation in the nature of damage and the degree of restoration to agricultural use is evident. Here we present a fourfold classification of damage/restoration as follows (Figure 4):

- a) Occasional isolated circular depressions, approximately 6-7 m in diameter with dark interior shading, are evident in some fields and are interpreted as craters that have escaped infilling and persist in the landscape as small ponds or wetlands. Their survival may reflect a functional use for livestock watering or habitat diversity.
- b) Relatively small (c.3-4 m) circular or subcircular lightly-shaded and shallow depressions are interpreted as small disturbances of bare earth or young grass that

most likely reflect bomb impacts with little or no cratering. Some of these features may reflect the impact of instantaneously-fused bombs although other possibilities include fragmentation or incendiary bomb types.

- c) Numerous relatively large (c.10 m) sub-circular or irregular patches of very light shading, present as both discrete and merged examples but with no surface depression, bear a close resemblance to freshly-infilled craters at Cagny (Figure 3a) and are also interpreted as areas of bare earth or young grass that reflect infilling and levelling of bomb damage.
- d) Relatively large (c.10 m) circular crop- or soil marks with no surface relief reflecting infilled and levelled craters are abundant in fields in the central and eastern part of the frame and are most probably amongst the earliest fields to be restored to agricultural use.

Comparison of the 1947 image with IGN photographs dating from 1955 (not shown here) show evidence of bomb damage a decade after the war to be limited solely to faint cropmarks in some, though by no means all, impacted fields.

Bois Carré V- Weapon Site

Bois Carré, near Yvrench, Picardy (Figure 1) was one of six sites near the French Channel coast photographed on 3 November 1943 and identified as potential V-weapon facilities by a dedicated section of the Allied Central Interpretation Unit (ACIU) based at RAF Medmenham (Le Maner 2009, Williams 2013). Distinctive V1 launch ramps and storage bunkers (the latter nicknamed 'Ski Sites' on account of their planforms) in and immediately adjacent to woodland at Bois Carré became the reference objects used subsequently to identify a further 95 V1 sites in NW France following a photographic sortie on 22 November (Le Maner 2009). All of these sites were subsequently targeted by an Allied bombing campaign codenamed 'Crossbow' and Bois Carré was attacked on at least 10 occasions between 31 December 1943 and 19 June 1944 by medium and light bombers of the RAF and US Ninth Air Force (Robertson *et al.* 2013).

An aerial reconnaissance photograph taken on the 28 June 1944 (Figure 5a) clearly demonstrates the extent and accuracy of the bombing effort; numerous bomb craters within the facility, including several direct hits on structures, attest to the success of the raids which ultimately forced the abandonment of the site before any

successful launch of V1 missiles (Le Maner 2009). The aerial reconnaissance images also show, however, that the majority of bombs fell on the patchwork of open field systems surrounding Bois Carré with few individual fields escaping at least some degree of bomb damage (Figure 5a). Post-war IGN images show that the configuration of field systems remains largely unchanged over the next eight years with the majority of craters having been infilled by October 1947, although many examples appearing to remain extant to the north and east of the wood (Figure 5b). By April 1952 rehabilitation is sufficiently advanced such that the visible traces of craters appear to be largely limited to cropmarks (Figure 5c) and, while many of the installation structures and associated bomb craters in the woodland area have survived to the present day, the modern agricultural landscape surrounding the site shows no extant evidence of the raids.

Airfield Sites

Newly-constructed or expanded military airfields were a conspicuous feature of Normandy's rural landscape during World War II but presented very different scenarios for their landscape legacy depending on whether they were occupied by German or Allied air forces. Many German airfields, being developed and expanded over the years since the occupation of Normandy in 1940, were provided with extensive hardened runways and support facilities and were amongst the most heavily bombed landscapes of the Normandy region.

Developed from a former French airfield between 1941 and 1943, the airfield at Conches-en-Ouche was located 3 km south of the town with two hardened runways and numerous dispersal hardstands located off a perimeter taxiway (Figures 1 and 6; deZeng IV 2014). During the Normandy campaign the airfield hosted Luftwaffe fighters and fighter bombers and was the target of at least 14 raids by heavy and medium bombers of the USAF between August 1943 and July 1944 (Robertson *et al.* 2013). Following abandonment of the airfield after the German retreat from Normandy the facility returned to agricultural use and by 1 July 1947 much of the northern area retained evidence for bombing as cropmarks only, while cratering in other parts of the airfield is in the process of being infilled and levelled (Figure 6a). Runways and other hardened facilities, by contrast, are likely to have been deemed too expensive to remove and with little incentive to repair they remain extensively cratered. A

distinctive cluster of craters and disturbed ground near the center of the airfield (Figure 6a) is interpreted as evidence of ordnance disposal by controlled detonation (see also below). By March 1960 the runways still exhibited extant bomb craters but the field areas retain only faint cropmark evidence of the wartime bombing legacy (Figure 6b).

The rehabilitation of permanent airfield sites in Normandy to an operational capacity was greatly accelerated if Allied air forces adopted these fields for their own use but, and especially early in the campaign, Allied aircraft based in Normandy were typically operating from temporary Advanced Landing Grounds (ALG) that were rapidly developed in convenient agricultural areas by engineer units. In contrast to German airfields these facilities generally escaped intense bombing owing to the relative weakness of the Luftwaffe at this time, but the construction of runway and hardstand facilities nevertheless had a marked impact on local rural landscapes both during and after the conflict. An example of this impact is captured by IGN images dating to August 1947 at Lavieille, near St-Georges-d'Elle, 9 km northeast of Saint-Lô (Figures 1 and 7). These reveal the site of ALG A-19, constructed between 31 July and 13 August 1944 by the 818th Engineer Aviation Battalion, IX Engineer Command (USAF, 1945) and typical of many such facilities constructed to a standard template throughout this part of Normandy at the time. The airfield facilities have been recorded as comprising a 1.524 m by 36.5 m runway of bitumen/hessian mat (including a 427 m compacted earth extension) encircled by a three-mile taxiway with 75 hardstands and a network of access roads and storage facilities (USAF 1945). The airfield was operational from 14 August until its closure on 7 September 1944, during which period it hosted P-38 Lightning fighter-bombers of the 370th Fighter Group. By September 1947 the imagery clearly shows the airfield facilities and surfacing have been removed and the site is in the process of being returned to agricultural use, including the restoration of former field boundaries and minor roads (Figure 7). Nevertheless, the detailed planform of the runway and many elements of the encircling facilities are clearly evident as disturbed or bare earth surfaces within the surrounding pasture. Several small fields within the perimeter taxiway, however, show little or no evidence of disturbance and these retained their field boundaries and orchards during the period of airfield construction and operational use. The rehabilitated field systems and road network at this site exhibit no modern surface evidence of their previous military

history and serve to emphasise the value of the aerial photographic resource as a landscape analysis tool.

Munitions Storage and Disposal Landscapes

The utility of aerial photographs as a study aid in forested settings may seem surprising given that German logistics facilities typically used densely forested woodland sites in order to conceal them from aerial observation (Passmore *et al.* 2013, 2014, Capps Tunwell *et al.* 2015). However, forest clearance associated with fire (especially that induced by air raids), demolition efforts by retreating German forces and late- and post-war munitions disposal activities have on occasion combined to render many military and bombing landscapes readily visible on aerial images. A striking example may be found at Maintenon (Eure-et-Loire Department) where a major Luftwaffe munitions storage facility (Middlebrook and Everitt 2014) developed in woodlands on the margins of the town is extensively visible on 1949 aerial images. Two further examples of munitions facilities described below benefit from the availability of relatively large scale aerial images (c.1:4,500-1:6,500) which capture high-resolution details of munitions facilities and disposal activities in woodland locations. These are respectively the Seventh Army munitions depot codenamed Lager Martha, located in the *Forêt domaniale des Andaines*, near Bagnoles de l'Orne, and the munitions (bomb) dump attached to the Luftwaffe airfield at Conches-en-Ouche (Figure 1).

(i) Maintenon

The primary Luftwaffe munitions facility at Maintenon comprised two adjacent and linked sites to the east and west, respectively, of the Maintenon railway station and marshalling yard (a third and smaller facility on the southwest edge of the town is not shown here). Figure 8 presents an interpretation of the depot road network and individual munitions bunkers where they can be identified on the aerial image of 14 April, 1949, accepting that the map is most likely an underestimate of the number of bunkers prior to bomb damage and disposal activity. The western site is smaller (c.2 km²) with bunkers some 8-12 m in length orientated both perpendicular and parallel to the road network. To the east the larger of the sites extends over about 5 km² and features over 75 bunkers that appear to be larger than those to the east (up to c.16 m in length) and lying perpendicular to the depot roadways. At this stage it is not known

how bunker size and configuration relates to differing ordnance types.

The Maintenon depots were targeted on at least two occasions by both RAF and USAF bombers in April and August 1944, respectively, and nearby bridges and oil facilities were also attacked (Robertson *et al.* 2013). Numerous bomb craters are still evident in the depot areas even some five years after war, notably in those areas flanking the railway lines and station, and are particularly well-preserved in the floodplain of the La Voise river immediately to the south of the sites (Figure 8). Within the depot area itself, however, a good proportion of ground disturbance is likely to reflect activity in the late- and post-war period. In particular, conspicuous in the area of some bunkers, especially in the easternmost part of the eastern depot, are dense clusters of very small craters that are interpreted here as ordnance disposal by controlled detonation rather than bombing (Figure 8). Several very large craters and associated disturbed ground on depot roads near the railway station appear to correspond with the pattern of bunker locations and, while explosions associated with direct bomb strikes cannot be discounted, these features are also deemed likely to reflect deliberate disposal detonations. Finally, a large area of disturbed ground or bare earth with numerous craters can clearly be seen in the open area between the La Voise and the southern margin of the depot woodlands (Figure 8). Accordingly, the overall impression is one of intensive ordnance disposal activity continuing for many years after the cessation of hostilities and rendering large areas of former woodland and adjacent open ground as unusable for forestry, agricultural or recreational activity.

(ii) *Forêt domaniale des Andaines / Conches-en-Ouche*

Lager Martha, located in the *Forêt domaniale des Andaines* to the north and east of Bagnoles de l'Orne (Figure 1) was one of the largest German Seventh Army munitions depots in Normandy at the time of the D-Day landings. This facility escaped bombing raids before or during the campaign and continued to function until it was overrun by American troops on 14 August 1944 (Capps-Tunwell *et al.* 2015). Munitions bunkers are especially well-preserved in the forest and the combination of archaeological survey and IGN aerial photograph analysis has permitted the geography of the depot to be mapped in detail (Capps-Tunwell *et al.* 2015). Although retreating German forces were recorded as detonating munitions before abandoning the depot, significant amounts of live ammunition were reported as remaining on-site by forestry workers (Capps-

Tunwell, unpublished data) and occasional live shells continue to emerge during modern forestry operations. Large-scale aerial images taken by the IGN in April 1946 (Figure 9) reveal patches of cleared woodland in parts of the depot area with a series of large, discrete craters; since the depot was neither bombed nor shelled during its occupation these craters are interpreted as the sites of controlled ordnance detonation, although it is unclear whether some or all of the craters were caused by retreating German troops or post-war disposal teams. The location of the craters closely matches the configuration of munitions bunkers that survive as earthworks in many parts of the depot and hence it is likely that these reflect *in-situ* detonation of individual bunkers.

A similar pattern of ordnance disposal activity can also be seen on IGN images of 14 April 1948 at the site of the airfield ammunition (bomb) dump at Conches-en-Ouche (see above; Figures 1, 6a and 10). Storage facilities here were in hardened (concrete) bunkers located within woodland adjacent to the airfield's western perimeter, but by 1948 these bunkers had been demolished and some, as indicated by large crater depressions on either side of the access road in the northwest part of the depot, appear to have been used to detonate live ordnance. Evidence of explosive demolition of munitions bunkers mirrors practice at Lager Martha (Figure 9) and Maintenon (Figure 8).

Discussion

With a first complete post-war photographic cover of France achieved in the years up to 1953, and in combination with localised, very large-scale images taken during the same period, IGN aerial photographs constitute an unusually detailed and accessible resource that permits investigation of lesser-known aspects of World War II conflict landscapes. The case studies presented here highlight two areas of ongoing research promise. Firstly, and while the ability of aerial photographs to record military structures such as fortifications and (as demonstrated at Conches-en-Ouche) airfields is well established, their potential to reveal details of military earthworks and cratering associated with bomb damage and ordnance disposal in *forested* settings is only just beginning to be explored (Passmore *et al.* 2014). While some of these landscapes remain well-preserved in present day forests and may be subject to archaeological survey, others have been degraded or lost completely to urbanisation and mechanised forestry operations (as is the case for parts of the Maintenon munitions facility) and here the

aerial photographic archive may constitute the sole means of accessing these landscapes.

It is perhaps ironic that the potential for aerial photographic analysis of logistics facilities in this context is contingent on woodland clearance which, at least in part, reflects fire and blast damage associated with bomb strikes intended to destroy them. A key additional factor, however, appears to be extended or sustained clearance to facilitate landscape remediation and late- and post-war ordnance disposal. This would certainly seem to be the case at Maintenon where – exceptionally – the aerial images permit a near-complete mapping of the depot roads and bunker network (Figure 8). Abandoned munitions depots will have demanded considerable clean-up operations in their own right (as attested by post-war forestry records from parts of the *Forêt domaniale des Andaines*; Capps Tunwell, unpublished data), but the utility of these sites as storage and disposal centres for unexploded bombs and shells collected from the surrounding areas is also likely to have rendered them as active disposal sites for some time after the war. Indeed, Clout's (2006) observation that in May 1948 some 2,000 tonnes of recovered munitions were being stored in 10 depots in Calvados alone gives some idea of the scale of the activity. Case studies developed here would appear to confirm ongoing disposal activity in April 1946 in the *Forêt domaniale des Andaines*, April 1948 at the former bomb dump at Conches-en-Ouche airfield and as late as April 1949 at Maintenon.

Forest-based ordnance disposal activities constitute part of a wider research agenda that will benefit from IGN aerial images – that of the reconstruction of war-damaged landscapes in northwest France, and especially those in rural areas. Much of the restoration of farmland was accomplished as a matter of priority after the cessation of hostilities with a particular impetus being provided by the need to clear minefields, unexploded ordnance and combat-related debris as well as restore food production. Clout's (2006; 2008) analysis of Lower Normandy indicates that while the reconstruction of many farmsteads was still in progress well into the 1950's, the filling of bomb craters in the region was largely undertaken during 1945-46. The case studies presented here would appear to broadly support this timescale for farmland although at La Chapelle-en-Juger, Bois Carré and Conches-en-Ouche the crater filling process appears to remain ongoing into 1947. Many of these areas exhibit field systems with differing timescales of crater infilling, perhaps as a reflection of local landownership, land-use requirements and other factors, that demonstrate the process of reconstruction

was by no means uniform. Furthermore, bomb craters were to persist for longer periods in some floodplain localities (e.g. Maintenon, Figure 8) and other marginal agricultural landscapes, and especially in forests and woodlands where many survive to the present day (Passmore *et al.* 2014).

The two years after the war also saw work begin to return land requisitioned for Allied camps, supply bases and airfields back to their owners, often with improvements and adjustments to roads and field boundaries (Clout, 2008). This process was generally completed by about 1950 (Clout, 2008) and photographic evidence at Lavieille shows that restoration of ALG-19 was well advanced by the summer of 1947, but not so far as to remove the detailed impression of the runway and associated facilities (Figure 7). Here, as in the case of bomb-damaged agricultural landscapes beyond the regional forests, modern land surfaces bear little visible evidence of their wartime legacy. Accordingly, it falls to the documentary archive, and especially aerial photographs, to enable an assessment of the extent and character not only of the World War II conflict landscape itself, but also the landscape of rehabilitation.

Conclusions

In the fortifications, battlefields and cemeteries of the D-Day beachhead, northwest France hosts one of the most famous, conspicuous and enduring conflict landscapes of World War II. Yet by far the greater part of its wartime legacy lies inland where, with the notable exception of installations like V-weapon sites and forest-based logistics networks, there are few visible traces of conflict in the modern landscape. The case studies presented here demonstrate that the IGN's unusually comprehensive, accessible and at times very high resolution post-war aerial photograph archive has the potential to illuminate conflict landscapes that are contemporary with the war itself, and which in some cases would be difficult – if not impossible – to analyse by any other means. Simultaneously, and perhaps of equal significance here, they extend our perspective of conflict landscapes beyond the cessation of hostilities and into the period of rural reconstruction and rehabilitation. In doing so they may contribute to an aspect of the physical legacy of World War II that has received relatively little attention in the conflict landscape literature.

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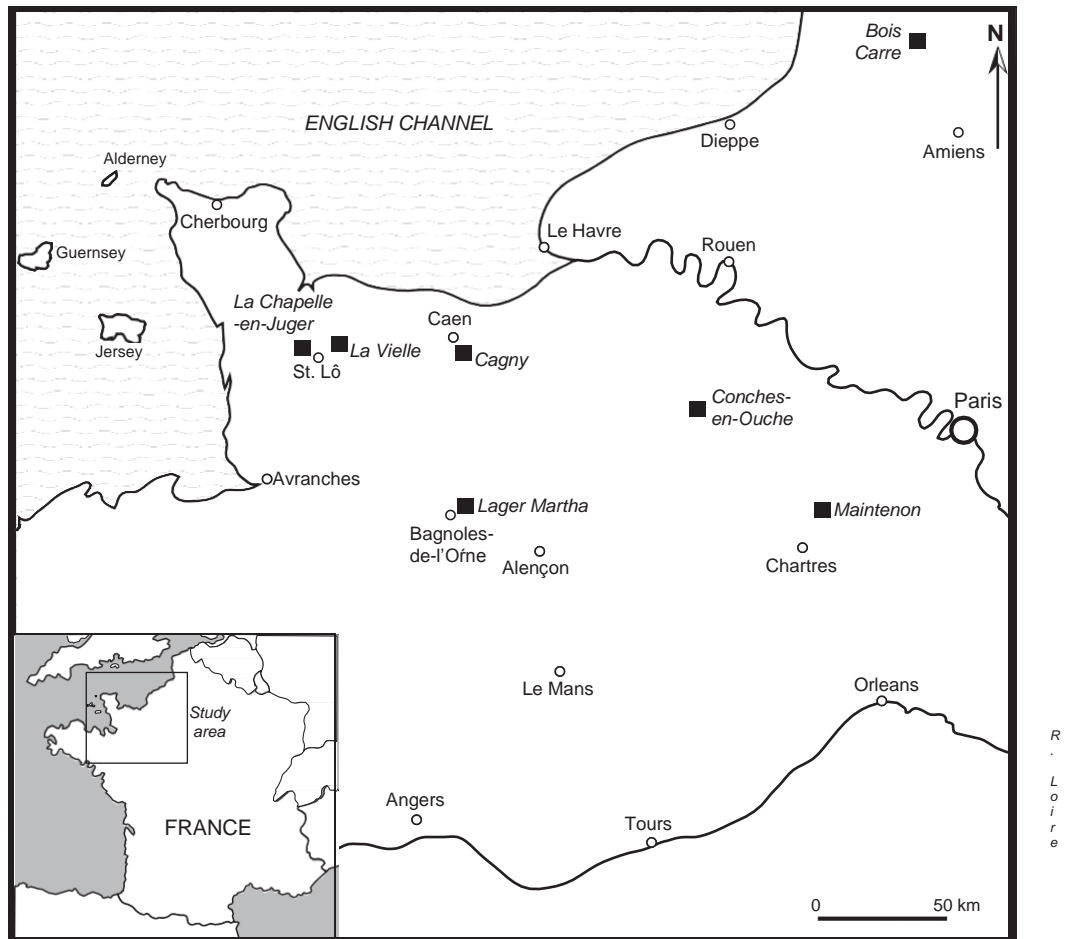


Figure 1: Map of NW France showing locations of case study sites.

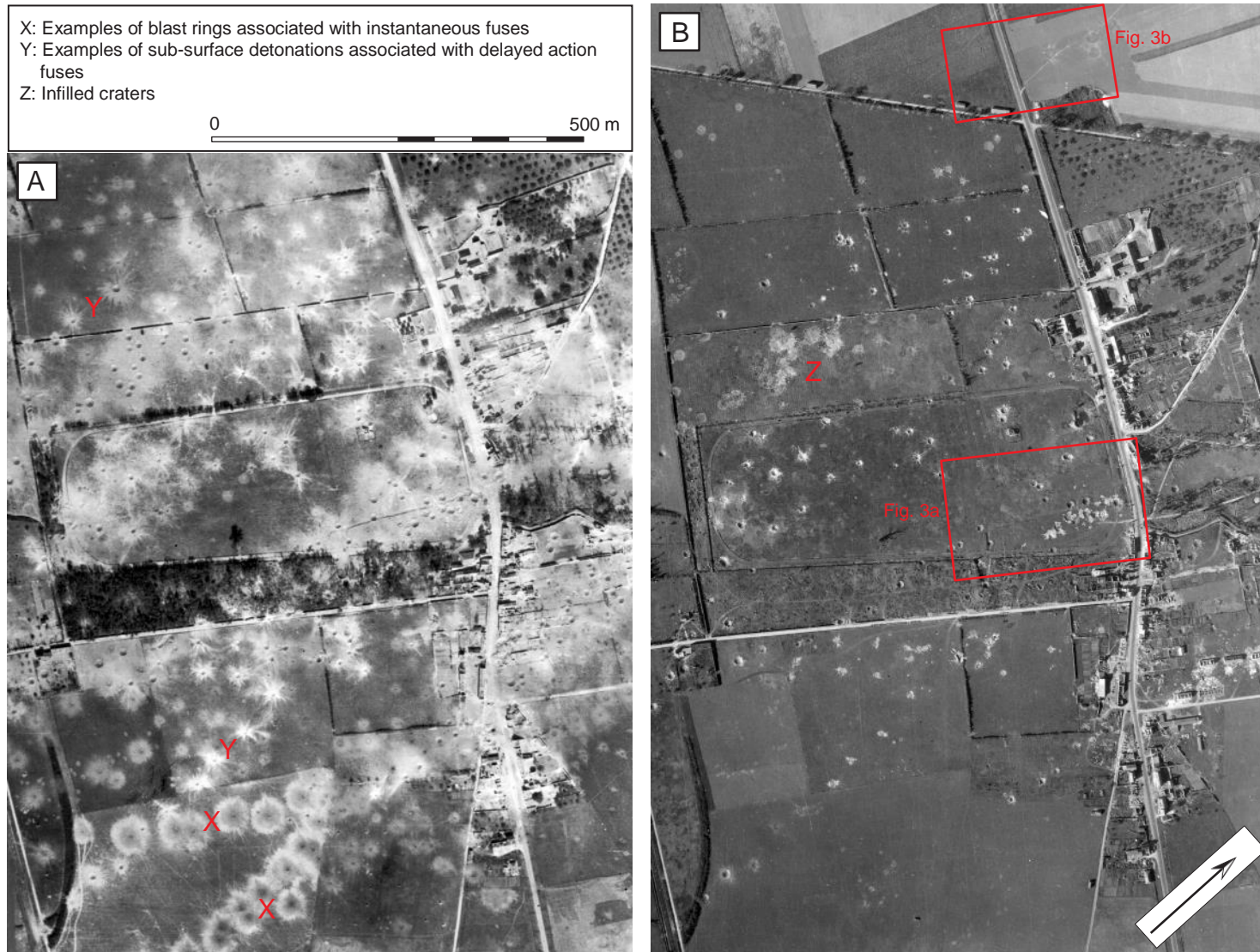


Figure 2. A) Aerial reconnaissance photograph of Cagny (IWM CL477) taken on the morning of July 18th, 1944 following bombing in support of Operation Goodwood. B) Aerial photograph of Cagny taken on 12th October, 1945 (IGNF C1612-0091_1945_CDP216_0747) showing cratering associated with bombs fused with a 0.25 second delay. Note lack of evidence for cratering associated with bombs with instantaneous fuses (see text for details). Inset frames show location of Figure 3a and b.



Figure 3: Aerial photographs of infilled bomb craters in fields at Cagny taken on 12th October 1946 (see Figure 2 for location): A) IGFN C1612-0291_1946_CDP2202_4120; B) IGFN C1612-0291_1946_CDP2202_4124).



Figure 4: Aerial photograph dated 25th July 1947 (IGNF C1213-0071_1947_F1213-1313_0023) of La Chapelle-en-Juger (lower frame), near St.Lo, showing extant and infilled bomb craters associated with Operation Cobra.

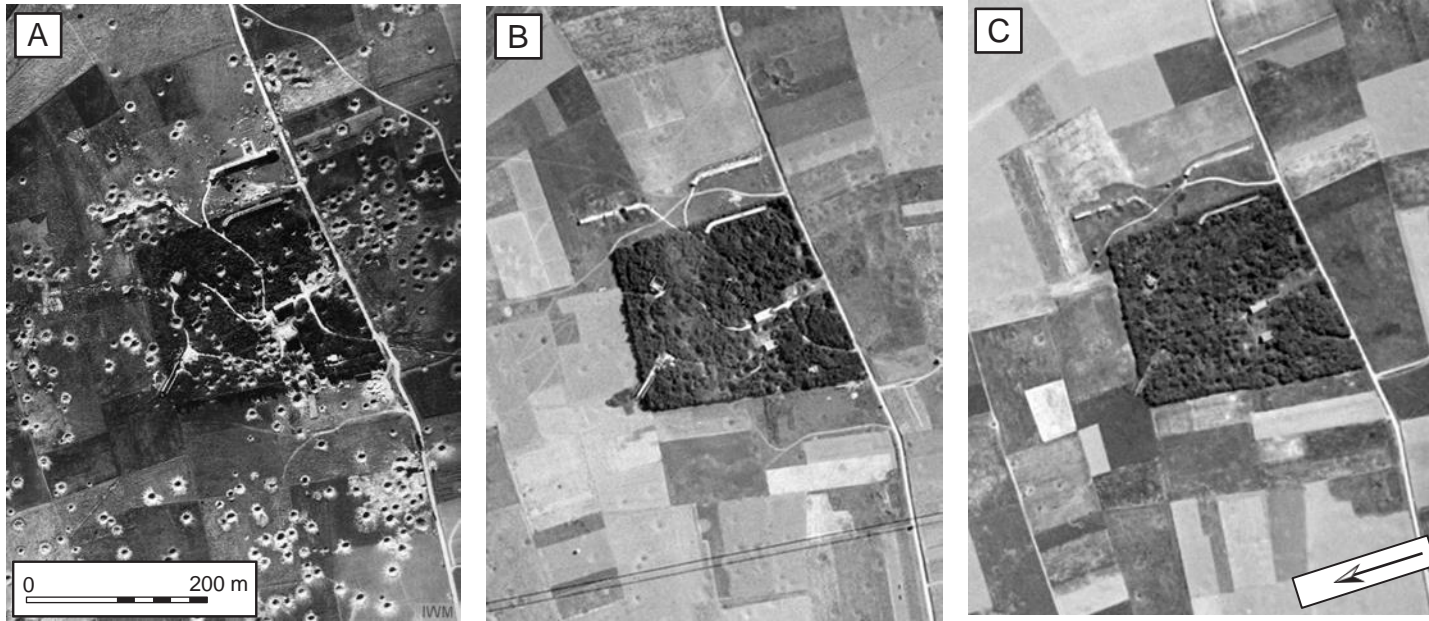


Figure 5: Aerial photographs of V-weapons facility in Bois Carré, near Yvrench, Picardy: A) Reconnaissance picture dated 28th June, 1944 (IWM: HU 92984) showing bomb craters of raids between 31 December 1943 and 19 June 1944; B) IGN image dated 2nd October 1947 (IGNF C2207-0031_1947_F2207-2307_0165); C) IGN image dated 29th April 1952 (IGNF C2007-0061_1952_F2007-2307_0062).

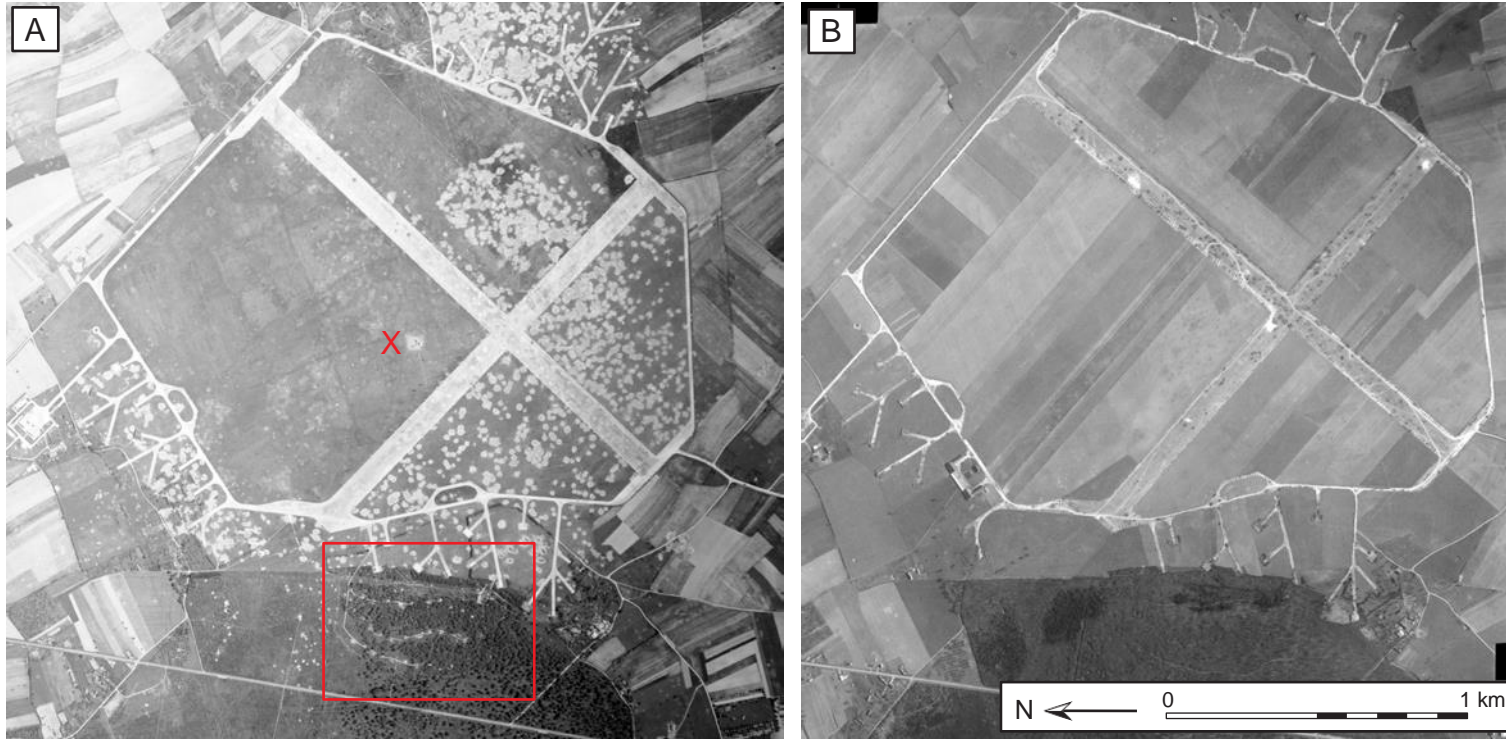


Figure 6: Aerial photographs of ex-Luftwaffe airfield at Conches-en-Ouche, Haute-Normandie: A)IGN image dated 1st July 1947 (IGNF C1914-0011_1947_F1914-2115_0054); B) IGN image dated 7th March 1960 (IGNF C1914-0041_1960_F1914-2214_0011). Inset frame shows location of airfield ammunition depot (Figure 10). Locality X (6a) marks ordnance disposal activities.



Figure 7: Aerial photograph dated 9th August 1947 (IGNF C1411-0051_1947_F1411-1612_0057) showing site of former Allied Advanced Landing Ground A-19 at Lavieille (St-Georges-d'Elle), near Saint-Lô. Inset: Photograph of the present site of airfield, taken from location X looking south along the former runway.

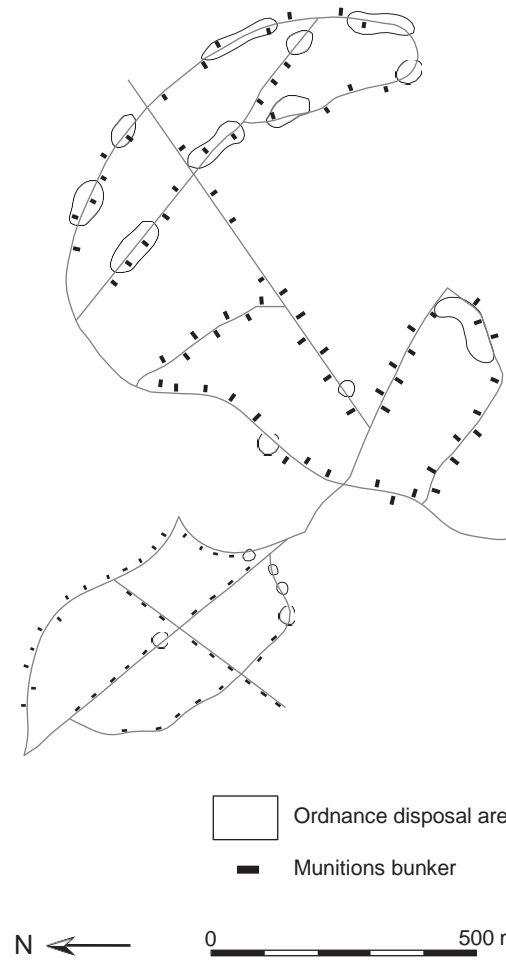


Figure 8: Aerial photograph dated 14th April 1949 (IGNF C1816-0011_1949_F1816-2116_0014) and interpretation of Luftwaffe ammunition depots at Maintenon. Locality X marks off-site ordnance disposal area.



Figure 9: Aerial photograph dated 23rd April 1946 (IGNF C1516-0081_1946_CDP2017_0186) of the Route Forestière de l'Épinette (D387), Forêt domaniale des Andaines, near Bagnoles de l'Orne showing ordnance disposal activities. Detonation craters most probably correspond to sites of former munitions bunkers (see text for details).

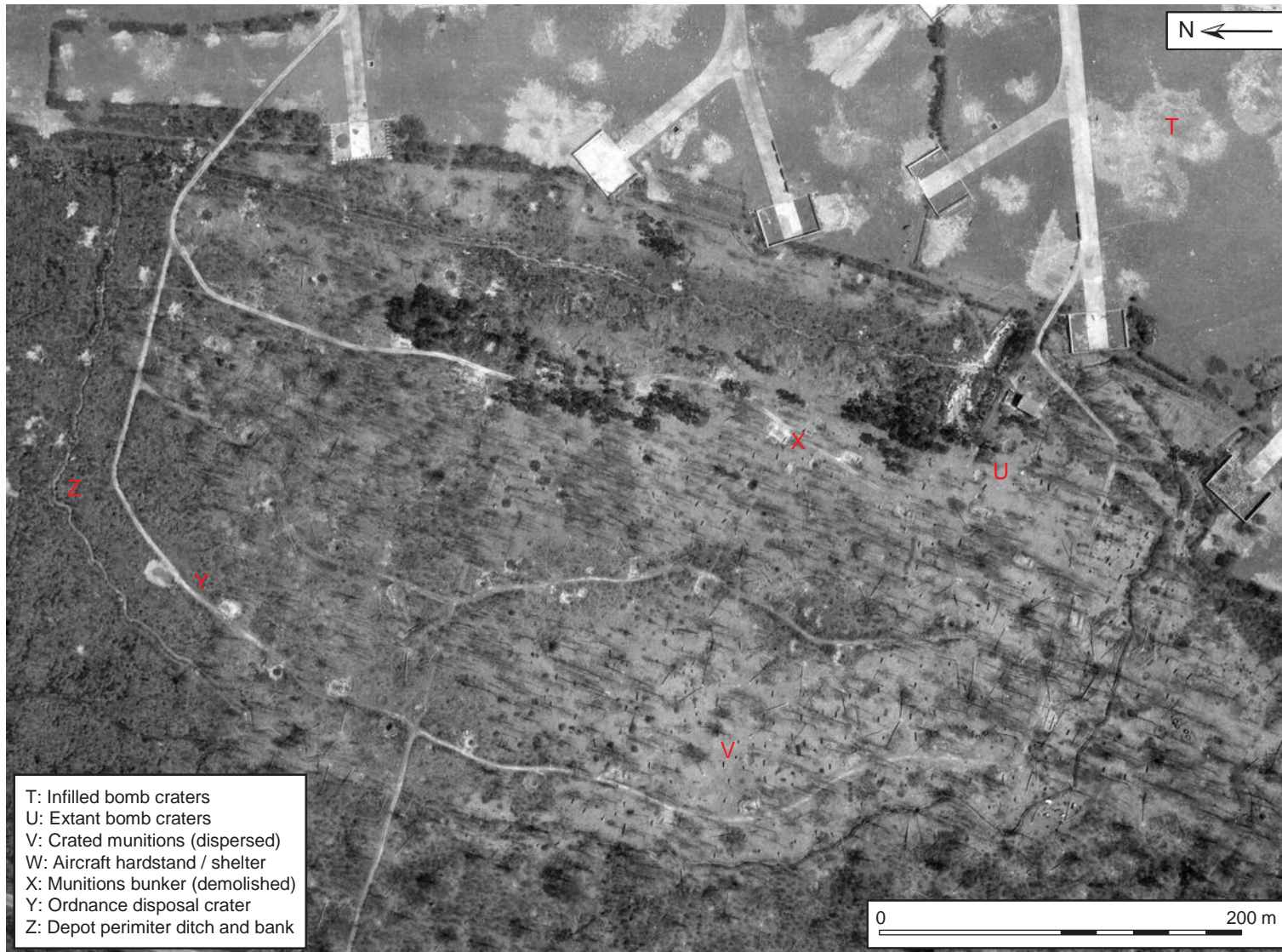


Figure 10: Aerial photograph dated 12th April 1948 (IGNF C1914-0061_1948_CDP3013_0035) of ammunition (bomb) depot on western margin of Luftwaffe airfield at Conches-en-Ouche, Haute-Normandie (see Fig.6 for context). Note focus of clearance and disposal activity in southern part of the depot.

Appendix VII

Information panels for the Forêt domaniale des Andaines Heritage Trail
(Bagnoles-de-l'Orne)

Panel Two. Details a brief description of the types of depots and locations in the FDA and quantities of stores held in 1944.



**D-DAY
NORMANDIE**
TERRE DE LIBERTÉ

Les dépôts en forêt domaniale des Andaines en 1944

La forêt domaniale des Andaines a été le plus important dépôt de munitions et de carburant de Basse-Normandie entre Juin et Août 1944. Trois types de dépôts existaient durant la seconde guerre mondiale : dépôts de munitions, de carburant et de vivres, la plupart étant dissimulés en forêt, à l'abri des reconnaissances aériennes. Le développement de ces sites de stockage a nécessité d'importants travaux d'amélioration des routes existantes, la création de nouvelles routes en forêt et la construction de bunkers pour les stockages. Avant le débarquement, les stocks de munitions appelés « Lager Martha », arrivaient par chemin de fer en gare de Bagnoles de l'Orne, puis par camion après les bombardements des voies ferroviaires et de la gare. Les stocks de munitions sont passés de 953 tonnes en Novembre 1943 à 2008 tonnes au 1er Juin 1944. Les dépôts de carburant, nommés « Lager Berta », alimentaient la Basse-Normandie et constituaient une réserve de 500 000 litres en Août 1943 et 967 000 litres en Juin 1944. Il y avait 3 sites de stockage principaux, au cœur de la forêt des Andaines. Le carburant était livré par camions citernes ou en fûts de 200 litres, en provenance de la gare de Domfront.

Between June and August 1944 the Andaine forests had the biggest ammunition and fuel depots in the whole of Basse Normandy. Three types of these depots existed during the second world war, ammunition, fuel and supply depots, most of which were hidden in the forests out of sight of any reconnaissance aircraft. To develop these sites, supply bunkers had to be built and new and important changes to existing forest roads had to be made. Before the débarquement, stocks of ammunition called " Lager Martha " arrived by train at the Bagnoles de l'Orne train station but had to be delivered by trucks after the bombing of the station and railway lines. The stocks of munitions rose from 953 tons to 2008 tons in June 1944. The fuel depots called " Lager Berta " which served the Basse Normandy made up a reserve of 500,000 litres in August 1943 rising to 967,000 litres in June 1944. There were three major sites in the heart of the Andaine forests which were supplied by fuel trucks or trucks carrying 200 litre drums from the train station at Domfront.

Zwischen Juni und August 1944 war der Wald von Andaines das wichtigste Munitions- und Treibstofflager der Basse-Normandie. Während des zweiten Weltkrieges gab es drei Lagertypen: Munitionslager, Treibstofflager und Vorratslager, die bevorzugt im Wald, im Schutz vor feindlichen Flugzeugen gelegen waren. Die Errichtung dieser Lager erforderte eine Verbesserung der bestehenden-, sowie den Bau von neuen Strassen und Bunkern im Wald. Vor der Landung der Allierten kam die Munition, genannt " Lager Martha " per Zug zum Bahnhof von Bagnoles de l'Orne und nach dessen Bombardierung per Lkw. Die Munitionsbestände vergrößerten sich von 953 Tonnen im November 1943 auf 2008 Tonnen am 1. Juni 1944. Die Treibstofflager, genannt " Lager Berta ", versorgten die Basse-Normandie und beinhalteten ein Volumen von 500 000 Litern im August 1943 und 967 000 Litern im Juni 1944. Es gab drei Hauptlagerplätze im Wald von Andaines. Der Treibstoff wurde vom Bahnhof aus Domfront in Tankwagen oder 200L-Fässern geliefert.



Question : Quel prénom féminin a été utilisé pour désigner les dépôts de munitions ?

- A Martha
- B Charlotte
- C Carla

Die bei Munitionslagerung in den Wäldern
 a) eine Anfertigung von 200 l. Tankwagen
 b) eine Verfüllung von 200 l. Tankwagen
 c) eine Verfüllung von 200 l. Tankwagen
 d) eine Verfüllung von 200 l. Tankwagen
 e) eine Verfüllung von 200 l. Tankwagen
 f) eine Verfüllung von 200 l. Tankwagen
 g) eine Verfüllung von 200 l. Tankwagen
 h) eine Verfüllung von 200 l. Tankwagen
 i) eine Verfüllung von 200 l. Tankwagen
 j) eine Verfüllung von 200 l. Tankwagen
 k) eine Verfüllung von 200 l. Tankwagen
 l) eine Verfüllung von 200 l. Tankwagen
 m) eine Verfüllung von 200 l. Tankwagen
 n) eine Verfüllung von 200 l. Tankwagen
 o) eine Verfüllung von 200 l. Tankwagen
 p) eine Verfüllung von 200 l. Tankwagen
 q) eine Verfüllung von 200 l. Tankwagen
 r) eine Verfüllung von 200 l. Tankwagen
 s) eine Verfüllung von 200 l. Tankwagen
 t) eine Verfüllung von 200 l. Tankwagen
 u) eine Verfüllung von 200 l. Tankwagen
 v) eine Verfüllung von 200 l. Tankwagen
 w) eine Verfüllung von 200 l. Tankwagen
 x) eine Verfüllung von 200 l. Tankwagen
 y) eine Verfüllung von 200 l. Tankwagen
 z) eine Verfüllung von 200 l. Tankwagen

Stèle en hommage aux pilotes alliés abattus en 1944



Jacques de Loriston



Vestige d'un site de stockage de munitions.

Réponse à la question : A



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Panel Three. Describes the types of surviving military features that can be seen in the landscape on the heritage trail.





Le camouflage des militaires et de leurs véhicules

Les véhicules militaires étaient régulièrement stationnés en forêt pour mieux se protéger des raids aériens. Ces emplacements ❶ se situaient à proximité de Bagnoles de l'Orne, à partir de la gare et en direction des dépôts de munitions qui se trouvaient en forêt. Dans le périmètre de la photographie aérienne datant de 1946, il y avait 38 emplacements, répartis le long de la route forestière des Treize Neiges. En complément et à proximité de ces emplacements, des tranchées creusées en « zig-zag » ❷ permettaient aux soldats d'assurer la surveillance et la défense du matériel et des troupes au sol. Plus de 70 ans après, nous retrouvons ici quelques traces de ces aires de camouflage.

To protect them from air raids, soldiers and military vehicles were regularly stationed in the nearby forests. These locations ❶ were near the Bagnoles de l'Orne train station and in proximity of the munitions depots in the forest. In an aerial photograph taken in 1946, 38 of these locations can be seen stretching along the Treize Neiges forest road. Trenches were dug in a « zig zag » ❷ line nearby to allow observation and to defend the ground troops and protect the material. 70 years after we can still recognize traces of these camouflaged areas.

Die Militärfahrzeuge wurden regelmäßig im Wald stationiert, um sich besser vor Luftangriffen zu schützen. Diese Standorte ❶ befanden sich in der Nähe von Bagnoles de l'Orne, vom Bahnhof in Richtung des Waffenlagers, das sich im Wald befand. Innerhalb des Gebietes der Luftaufnahme von 1946 gab es 38 solcher Standorte, die sich über die Längeder Route forestière (Waldstrasse) von "Treize Neiges" erstreckten. Zusätzlich gab es in der Nähe im Zick-Zack ❷ angelegte Gräben, die es den Soldaten ermöglichten, die Überwachung und Verteidigung des Materials und der Bodentruppen zu gewährleisten. Siebzig Jahre später sind immer noch Spuren dieser Verstecke sichtbar.





Tranchée en "zig-zag" pour la protection de la population civile et des allemands




Camion Allemand BORGWARD 3t 1944
Jacques de Loristan

Question : Quel était le rôle d'une tranchée ?


Réponse: A une cache pour les soldats
B une cache pour les sangliers
C une cache pour les munitions

Réponse à la question : A



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Panel Four. Outlines the efforts of the Allies to destroy the depots in the FDA during the Battle of Normandy.



**D-DAY
NORMANDIE**
TERRE DE LIBERTÉ

Les bombardements en forêt domaniale des Andaines

La forêt domaniale des Andaines a servi de lieu de stockage et de camouflage d'engins militaires, de munitions, de carburant et de vivres pour les allemands. Elle a donc constitué une cible privilégiée pour les forces alliées. En Juin 1944, pas moins de 46 attaques ont été enregistrées. Ces attaques étaient effectuées par un à quatre groupes de bombardiers, soit 36 à 144 avions (B26 Marauder et Havoc A20). Au total, plus de 1 150 tonnes de bombes ont été lâchées sur la forêt. Le poids des bombes variait entre 50, 125, 250 et 500 kg. A titre d'exemple, le 18 Juin 1944 le carrefour de l'Etoile a été bombardé par 107 avions alliés. L'attaque la plus importante s'est déroulée le 6 Août 1944 quand les avions ont attaqué la route principale de Domfront à La Ferté Macé. En avant du front, l'activité aérienne sur les lignes arrière allemandes s'est intensifiée. Les missions de reconnaissance engagées par la 9ème Air Force qui couvraient la Normandie en Juin et Juillet 1944 se sont concentrées sur des cibles logistiques. Le 13 Août 1944 l'activité a atteint son maximum avec 22 missions de reconnaissance et 247 avions bombardiers qui ont attaqué les cibles mobiles.

The Andaine forests were used by the Germans to camouflage military vehicles, ammunition, fuel and supplies, therefore making it a prime target for the allied forces. In June 1944 no less than 46 air raids were recorded. These raids were made by 1 to 4 groups of bombers using B26 Marauders or A20 Havocs. A total of more than 1.150 tons of bombs varying from 50, 125, 250 to 500 kilos were dropped on the forest. For example, on the 18th of June 1944, the crossroads at l'Etoile was bombed by a group of 107 allied planes. The most important raid was made on the 6th of August when allied planes bombed the main road from Domfront to La Ferté Macé. The aerial offensive on the German rear battle lines was intensified and reconnaissance missions made by the 9th Air Force, who covered Normandy in June and July 1944, concentrated on military supply vehicles. On the 13th of August 1944 activity rose to a maximum with 22 armed reconnaissance missions and 247 bombers attacking mobile targets.

Der Wald von Andaines diente als Lagerplatz und Versteck von Militärfahrzeugen, Munition, Treibstoff und Nahrung für die deutschen Soldaten. Somit war es ein privilegiertes Ziel für die Alliierten. Allein im Juni 1944 wurden 46 Angriffe gezählt. Diese Angriffe wurden von bis zu vier Gruppen von Kampfbombern, also 36 bis 144 Flugzeugen (B26 Marauder und Havoc A20) ausgeführt. Insgesamt wurden mehr als 1150 Tonnen Bomben auf den Wald geworfen. Das Gewicht der Bomben variierte zwischen 50, 125, 250 und 500 kg. Als Beispiel wurde am 18. Juni 1944 "le carrefour de l'Etoile" (die Sternkreuzung) von 107 Alliierten Flugzeugen bombardiert. Der wichtigste Angriff ereignete sich am 6. August 1944 als die Flieger die Hauptstrasse von Domfront bis La Ferté Macé bombardierten. Im Rücken der deutschen Front intensivierten die Alliierten den Flugbetrieb. Die Erkundungsmission der 9. Air Force Division, die sich im Juni und Juli 1944 über die Normandie erstreckte, konzentrierte sich auf logistische Ziele. Am 13. August 1944 erreichte die Aktivität ihren Höhepunkt mit 22 Erkundungsmissionen und 247 Kampfflugzeugen, die mobile Ziele erfassen.



La route des Treize Neiges et la route de la Ferté Macé ① ② ont été identifiées par les alliés en juin en tant que cibles potentielles de stockage de munitions et de carburant. La zone a été attaquée mais pas détruite.

Avion bombardier en action au dessus de la forêt domaniale des Andaines - Carrefour des pépinières. Modèle Douglas A20 HAVOC Avion polyvalent d'attaque, bombardier léger et chasseur nocturne - vitesse maxi : 550 km/h - autonomie : 1750 km

24 juillet 1944

Bagnoles de l'Orne





Question :
Quelle armée a libéré Bagnoles de l'Orne ?

Réponse: A l'armée américaine
 B l'armée anglaise
 C l'armée française

Réponse à la question : A



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Panel Five. Describes how the Germans operated the depots using both French colonial Prisoners of War and enforced local labour.



Baraquements pour les prisonniers de guerre

Des prisonniers de guerre coloniaux français (sénégalais, marocains, ...) ont été mobilisés par les allemands pour réaliser des travaux manuels : construction d'aires de stockage de matériels, déplacements de munitions, ... Plus de 30 prisonniers travaillaient ici aux dépôts de munitions de l'« Epinette ». Au début de l'année 1944, les allemands ont remarqué que l'humidité altérait les munitions. Les obus en acier subissaient une forte corrosion. Dans la zone de stockage des munitions de la 7ème armée allemande, des femmes, appelées les « requises », furent ainsi réquisitionnées pour nettoyer et frotter les munitions.

The prisoners of war from the french colonies of Senegal and Morocco were mobilized by the germans to serve as manuel labour during the constuction of depots for supplies and ammunition. More than 30 prisoners work at the depot in Epinette. At the beginning of 1944, the germans realized that from high humidity levels the shells made from iron were corroding. In the 7th German Army zone, women, called "Les requises" were requisitioned to scrub and clean the ammunition.

Die Kriegsgefangenen der französischen Kolonien (Senegalesen, Marokkaner,...) wurden von den Deutschen als Zwangsarbeiter für den Bau von Materiallagern und zum Transport von Munition eingesetzt. Mehr als 30 Gefangen arbeiteten hier im Waffenlager von L'« Epinette ». Zu Beginn des Jahres 1944 stellten die Deutschen fest, dass die Feuchtigkeit die Waffen beschädigte. Die Stahlgranaten waren stark von Korrosion befallen. Im Gebiet der 7. deutschen Armee wurden Frauen, die man "Requises" nannte, eingesetzt um die Waffen zu reinigen und zu bürsten.



de la région
Jacques de Loriston



Bâtiment occupé par les prisonniers de guerre, à proximité des dépôts de munitions de l'Epinette.

Les requises mobilisées pour nettoyer et frotter les munitions.



Les requis étaient mobilisés, chaque jour, pour la réalisation de travaux manuels : création d'aires de camouflage, d'aires de stockages de munitions et carburant, de tranchées. Chaque jour le maire devait désigner un nombre de requis imposé par les allemands.

Question : Qui étaient les requises et les requis ?

- A des résistants
- B des personnes contraintes au travail journalier
- C des prisonniers de guerre

Réponse à la question : B




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Panel Six. Highlights the targeting of Bagnoles de l'Orne with the subsequent effects of damage to the town and civilian casualties.

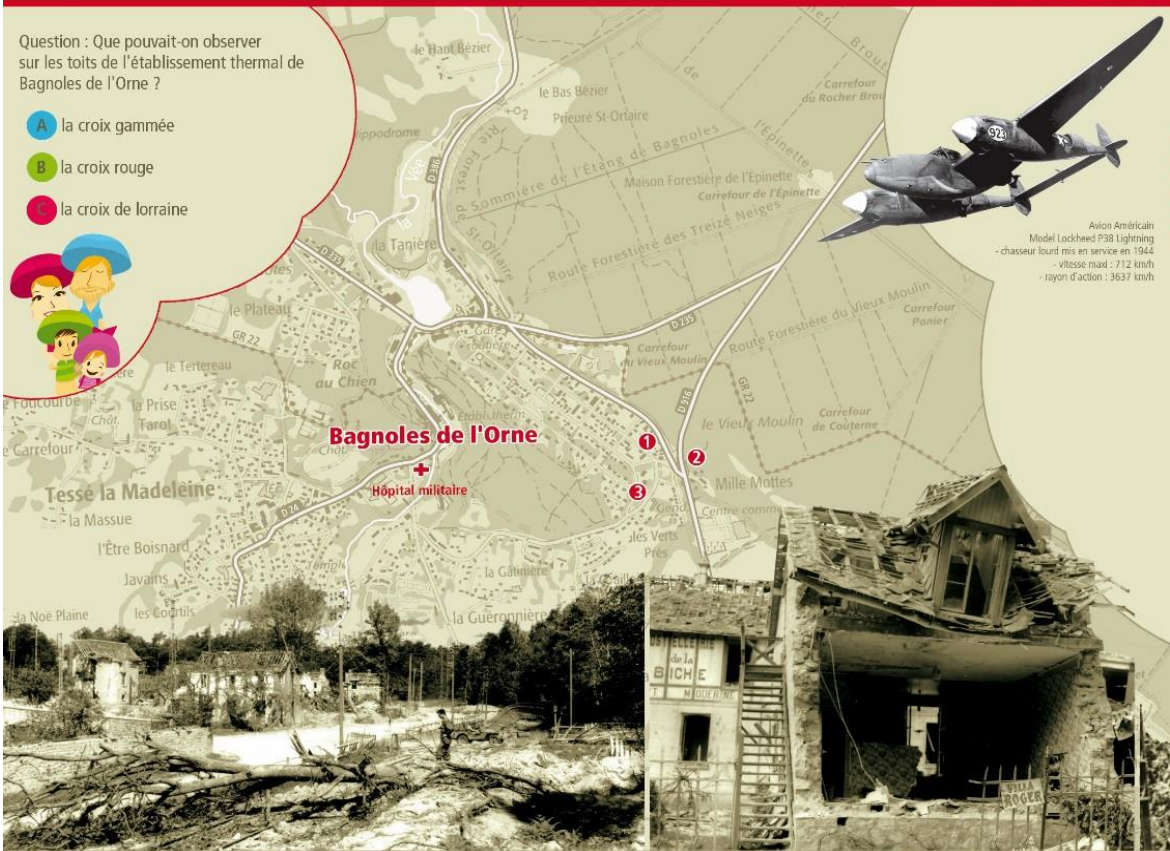


**D-DAY
NORMANDIE
TERRE DE LIBERTÉ**

Bagnoles de l'Orne sous les bombes en 1944

Question : Que pouvait-on observer sur les toits de l'établissement thermal de Bagnoles de l'Orne ?

- A la croix gammée
- B la croix rouge
- C la croix de lorraine




Avion Américain
 Model Lockheed P38 Lightning
 - chasseur lourd mis en service en 1944
 - vitesse max : 712 km/h
 - rayon d'action : 3637 km/h

Les 18, 22 et 24 Juin 1944, les alliés bombardent la station thermale de Bagnoles de l'Orne. 35 victimes civiles sont recensées. La gare et le quartier du Petit Bagnoles comportant l'ancien hôtel de ville, l'école, le hameau de la Gâtinière et la maison communale sont dévastés. Le statut de « ville Croix Rouge » de Bagnoles de l'Orne devait l'épargner mais un stock de carburant à hauteur du Quartier « Belle Epoque » a tout de même constitué une cible pour les alliés. Bagnoles de l'Orne est libérée le 14 Août 1944 par les américains de la 1ère division 26ème régiment d'infanterie.

During the 18th 22nd and 24th of June 1944, allied planes bombed the thermal spa at Bagnoles de l'Orne, claiming 35 civilian victims. In the Petit Bagnoles district, the train station, old municipal buildings, school, the Gâtinière hamlet and the town hall, were all completely destroyed. The Red Cross statue of Bagnoles de l'Orne was untouched but a fuel depot in the Belle Epoque area made a important target for the allies. Bagnoles de l'Orne was liberated on the 14th of August 1944, by american soldiers from the 1st division of the 26th regiment.


Am 18., 22. und 24. Juni 1944 bombardierten die Alliierten den Kurort Bagnoles de l'Orne. 35 zivile Opfer wurden gezählt. Der Bahnhof und das Viertel "Petit Bagnoles" mit dem alten Rathaus, der Schule, die Häuser von La Gâtinière sowie das Gemeindehaus wurden zerstört. Der Status "Ville Croix rouge" (Stadt des roten Kreuzes) hätte Bagnoles de l'Orne vor Angriffen schützen sollen, aber ein Treibstofflager auf Höhe des Viertels "Belle Epoque" stellte trotzdem ein relevantes Ziel für die Alliierten dar. Bagnoles de l'Orne wurde am 14. August 1944 vom 26. Infanterieregiment der ersten Division der amerikanischen Armee befreit.




1 Bombardement des lignes ferroviaires au nord de Bagnoles de l'Orne réduisant ainsi les voies de communication et de transport

2 Bombardement de l'Hôtel de la Biche en plein cœur de Bagnoles de l'Orne


3 Mairie de Bagnoles de l'Orne après les bombardements




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Réponse à la question : B