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To cite this article: L. Rees-Hughes, J. K. Pringle, N. Russill, K. D. Wisniewski & P. Doyle (2016) Multi-disciplinary investigations at PoW Camp 198, Bridgend, S. Wales: site of a mass escape in March 1945, *Journal of Conflict Archaeology*, 11:2-3, 166-191, DOI: [10.1080/15740773.2017.1357900](https://doi.org/10.1080/15740773.2017.1357900)

To link to this article: <http://dx.doi.org/10.1080/15740773.2017.1357900>



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Multi-disciplinary investigations at PoW Camp 198, Bridgend, S. Wales: site of a mass escape in March 1945

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ABSTRACT

The largest escape of German Prisoner of War (PoW) in WW2 was in March 1945 from Camp 198, situated in Bridgend, South Wales, UK. Since camp closure the site has become derelict, and has not been scientifically investigated. This paper reports on the search to locate the PoW escape tunnel that was dug from Hut 9. This hut remains in remarkable condition, with numerous PoW graffiti still present. Also preserved is a prisoner-constructed false wall in a shower room behind which excavated material was hidden, though the tunnel entrance itself has been concreted over. Near-surface geophysics and ground-based LiDAR were used to locate the tunnel. Mid-frequency GPR surveys were judged optimal, with magnetometry least useful due to the above-ground metal objects. Archaeological excavations discovered the intact tunnel and bed-board shoring. With Allied PoW escape camp attempts well documented, this investigation provides valuable insight into German escape efforts.

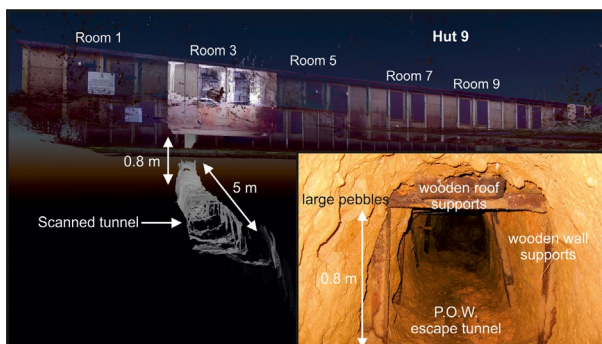
ARTICLE HISTORY

Received 31 January 2017

Accepted 4 July 2017

KEYWORDS


Geophysics; Prisoner of War; archaeology; Second World War; escape; German; South Wales



Introduction

The last twenty years or so has seen the development of conflict archaeology and the application of scientific principles to the investigation of sites of battle,¹ as well as the investigation

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 Supplemental data for this article can be accessed here. [<https://doi.org/10.1080/15740773.2017.1357900>]

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of the infrastructure and fortifications of war, including trenches, dug-outs, foxholes and tunnels,² hospitals, airfields and logistics³ and Prisoner of War (PoW) sites.⁴ These investigations include investigative archaeology, geophysical surveys as well as the consideration of landscape and topography in relation to battle. Such studies have emphasized a growing importance of conflict archaeology and of scientific interpretation informing the understanding of such events.

As part of the investigations of wartime sites, near-surface, multi-technique geophysical surveys have become increasingly popular,⁵ due to their capability to characterize sites rapidly, as well as pinpointing key buried areas of interest for subsequent intrusive investigations.

A developing area of interest in conflict archaeology has been the location and characterizing of PoW camp escape tunnels, as part of a wider interest in the study of PoW camps.⁶ Underground tunnelling has been a popular method for prisoners to escape confinement for centuries, and particularly so during the two world wars, both of which saw mass internment on a scale not seen before.⁷ Such camp escape attempts, whilst mostly unsuccessful (WW2 PoW documented tunnel escapes are summarized in Table 1), were high profile and of great interest to the general public with a large number of accounts published both during and after the conflict⁸ and with arguably the so-called 'Great Escape' of 76 Allied PoW airforce officers in 1944 being the most famous.⁹

There were generally two types of escape tunnels: (1) relatively short tunnels, excavated quickly to enable small numbers of prisoners to go under camp perimeter fences and escape, and which entailed relatively little work, but which were generally poorly concealed¹⁰; and, (2) relatively long tunnels that were meticulously planned, engineered and operated by highly organized and expertly-trained personnel, for example, the well-known WW2 Allied 1944 'Great Escape'¹¹ and the attempted French escape from Colditz Castle.¹²

Whilst there have been a number of multi-disciplinary scientific site investigations undertaken on WW2 Allied PoW escape attempts,¹³ there have been few studies of Axis PoW escape attempts (Table 1). Though there have been some recent studies of German PoW camps in Allied countries,¹⁴ in general there has been low level of perception that Axis troops also attempted to escape, with the single most documented example being the escape of Franz von Werra from captivity in Canada.¹⁵ This is surprising as there were an estimated 3.6 million German soldiers captured during WW2, and there were over 1,026 individual PoW camps in the United Kingdom alone.¹⁶

This paper describes a multi-disciplinary investigation of a mass escape of PoWs from one such WW2 camp in the United Kingdom, namely Camp 198 situated in Bridgend, South Wales, UK (Figure 1 and GoogleEarth™ KML file in Supplementary data). Eighty-three German PoWs are known to have escaped from Camp 198 on 10 March 1945, employing a tunnel dug from Hut 9 that went under the perimeter fence.

The aims of this paper are to: (1), document the multi-disciplinary site investigations carried out at Camp 198; (2), to evidence the techniques and procedures used to locate and characterize the escape tunnel; and, (3), to compare the escape attempt of March 1945 to other documented twentieth-century PoW escape attempts.

Camp 198 background

The site did not become PoW Camp 198 until 1944. It had initially been constructed in 1938 to provide workers' housing for the nearby Waterton Royal Ordnance Factory, before being



Table 1. List of documented WW2 P.O.W. escapes. An estimated 328 escaped with 13 reaching friendly territory ('home runs').

P.O.W. camp, location & country	Escape date	Tunnels (L = Length, BGL = Below ground level)	Escapes & (successful escapes)	Documented information sources
1. Dulag Luft, Oberursel, Frankfurt, Germany	June 1940	Unknown	18	Geck, S. 2008. <i>Dulag Luft/Auswertestelle West: Vernehmungslager Der Luftwaffe Fuer Westalliierte Kriegsgefangene Im Zweiten Weltkrieg</i> , Internationaler Verlag Der Wissenschaften, Berne
2. Camp 13, Swanwick, Derbyshire, UK	20/21 December 1940	L: 13 m	5	Burt, K. Leason, J. 1956. <i>The One That Got Away</i> , Granada Ltd
3. Angler POW Camp, Ontario, Canada	20 April 1941	L: 45 m	28	Chisholm, B., & Gutsche, A. 1998. <i>Superior: Under the Shadow of the Gods</i> , Lynx Images
4. Oflag IV-C, Saxony, Germany	29 May 1941	L: 16 m	12	Reid, P. R. 1952. <i>The Colditz Story</i> , Hodder & Stoughton Pubs
5. Oflag-VII-C, Laufen, Bavaria, Germany	4/5 September 1941	L: 6 m Bgl: 2.5 m L: 44 m	6	Eggers, R. 1961. <i>Colditz: The German Story</i> , Robert Hale, London
6. Biberach an der Riss, Baden-Wuerttemberg, Germany	13 September 1941	L: 2 m	26 (4)	Reid, P. R. 1952. <i>The Colditz Story</i> , Hodder & Stoughton, London
7. Camp R, Red Rock, Ontario, Canada	September 1941	L: 44 m	1	Duncan, M. 1974. <i>Underground from Posen</i> , New English Library, Los Angeles, USA
8. Oflag IV-C, Saxony, Germany,	15–20 January 1942	Bgl: 8.6 m L: 30 m	N/A (Found)	Zimmermann, E. R. 2015. <i>The Little Third Reich on Lake Superior: A History of Canadian Internment Camp R</i> , University of Alberta Press
9. Campo 57, Gruppignano, Udine, Italy	30 October 1942	L: 12 m Bgl: 3–2 m (exit) L: 30 m	19	Reid, P. R. 1953. <i>The Latter Days</i> , Hodder & Stoughton Pubs, London
10. Campo 12, Florence, Italy	29 March 1943	L: 12 m Bgl: 8.5–8 m (exit) L: 54 m	6	Mass escape from Campo di Concentramento Gruppignano, Italy, Available online at: www.3sqquadron.org.au/subpages/canning.htm Accessed 10 December 2015
11. Oflag XXI-B, Eichstatt, Bavaria, Germany	3/4 June 1943	L: 44 m	35	Hargest, J. 1946. <i>Farewell Campo 12</i> , M. Joseph Pubs
12. Stalag Luft VI, Hydekrug, Germany	July 1943	L: 90 m	7	Crawley, A. 1956. <i>Escape from Germany: a history of R.A.F. escapes during the War</i> , Collins Clear-Type Press, London
13. Bowmanville Camp, Bowmanville, Canada	September 1943	L: 125 m	0	Fancy, J. 2010. <i>Tunnelling to Freedom: The Story of the World's Most Persistent Escaper</i> , Aurum Press, London
14. Stalag Luft III, Zagan, Germany	October 1943	L: 102 m Bgl: 8.5–8 m (exit) L: 54 m	3 (3)	WWII POW Camp 30, Bowmanville, Available online at: http://www.camp30.ca/ Accessed 15 December 2015
15. Camp 198, Bridgend, South Wales, UK	10–11 March 1945	L: 12 m	83	Williams, E. 1949. <i>The Wooden Horse</i> , Collins, UK
16. Stalag Luft III, Zagan, Poland	25 March 1944	L: 102 m Bgl: 8.5–8 m (exit) L: 54 m	67 (3)	Phillips, P. 2006. <i>The German Great Escape</i> , Poetry Wales Press, Bridgend
17. Papago Park, Phoenix, Arizona	23 December 1944	Bgl: 3 m L: 41.5 m Bgl: 5.1 m	25	Williams, H. 1976. <i>Come Out Wherever You Are</i> , Quartet Books Ltd, London
Average:			19 (1)	Plummer, S. J. 2015. <i>The Greatest Escape</i> , Lulu Self Publishers, North Carolina
				Brickhill, P. 1952. <i>The Great Escape</i> : Faber & Faber, London
				Moore, J. H. 2006. <i>The Faustball Tunnel: German POWs in America & Their Great Escape</i> , Naval Institute Press, Maryland

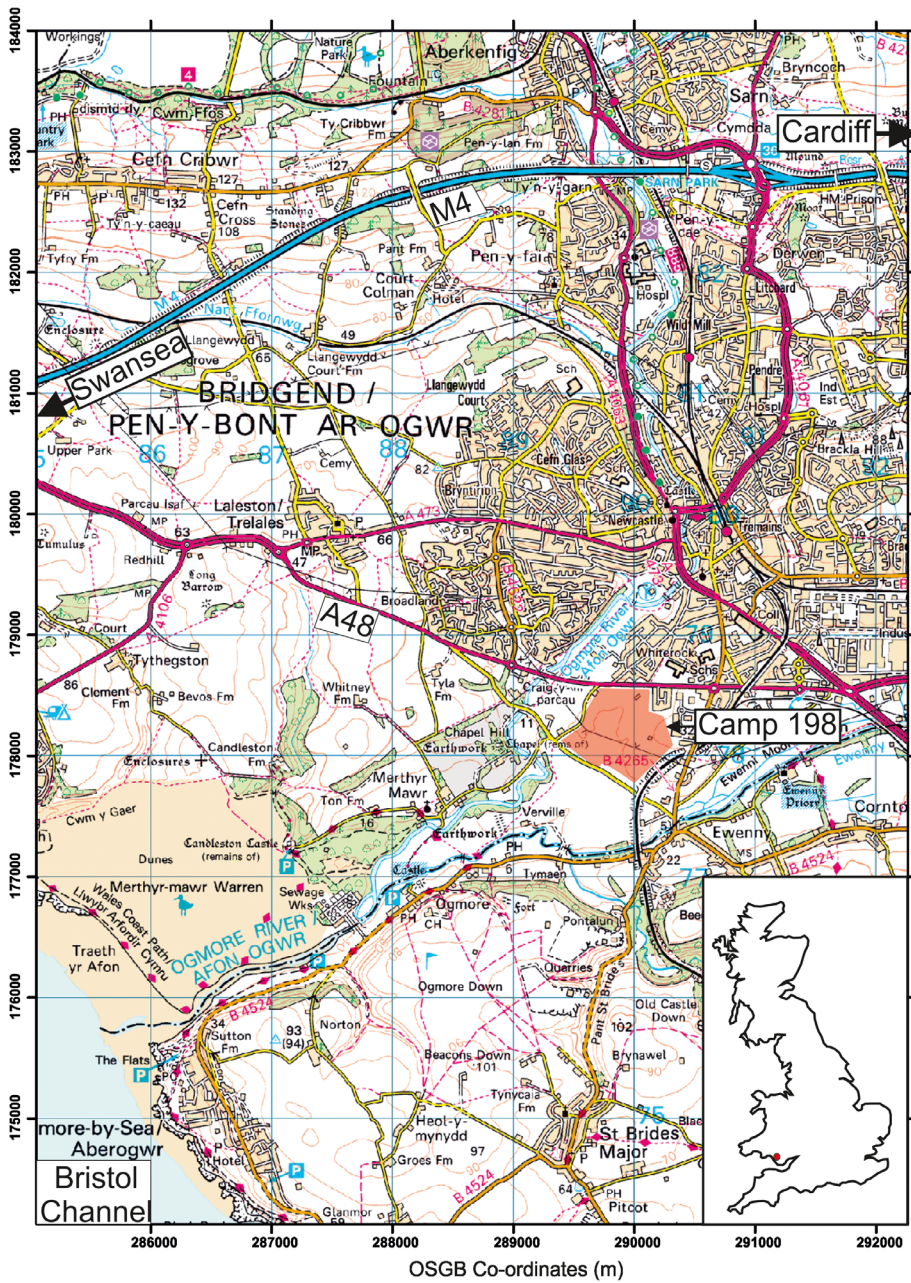


Figure 1. Location map of WW2 Axis PoW Camp 198, Bridgend, South Wales, with UK location (inset). Map courtesy of EDINA™ DigiMap (2016).

used to accommodate US troops of the 109th Infantry Regiment shortly before the 1944 invasion of Normandy.¹⁷ However, following the D-Day invasion, large numbers of German troops were captured, resulting in a requisite need for an increased number of PoW camps to house them. In 1944, the site was established as Camp 198, initially to contain low-ranking German and Italian soldiers captured earlier in the war, but in November 1944, 1,600 German

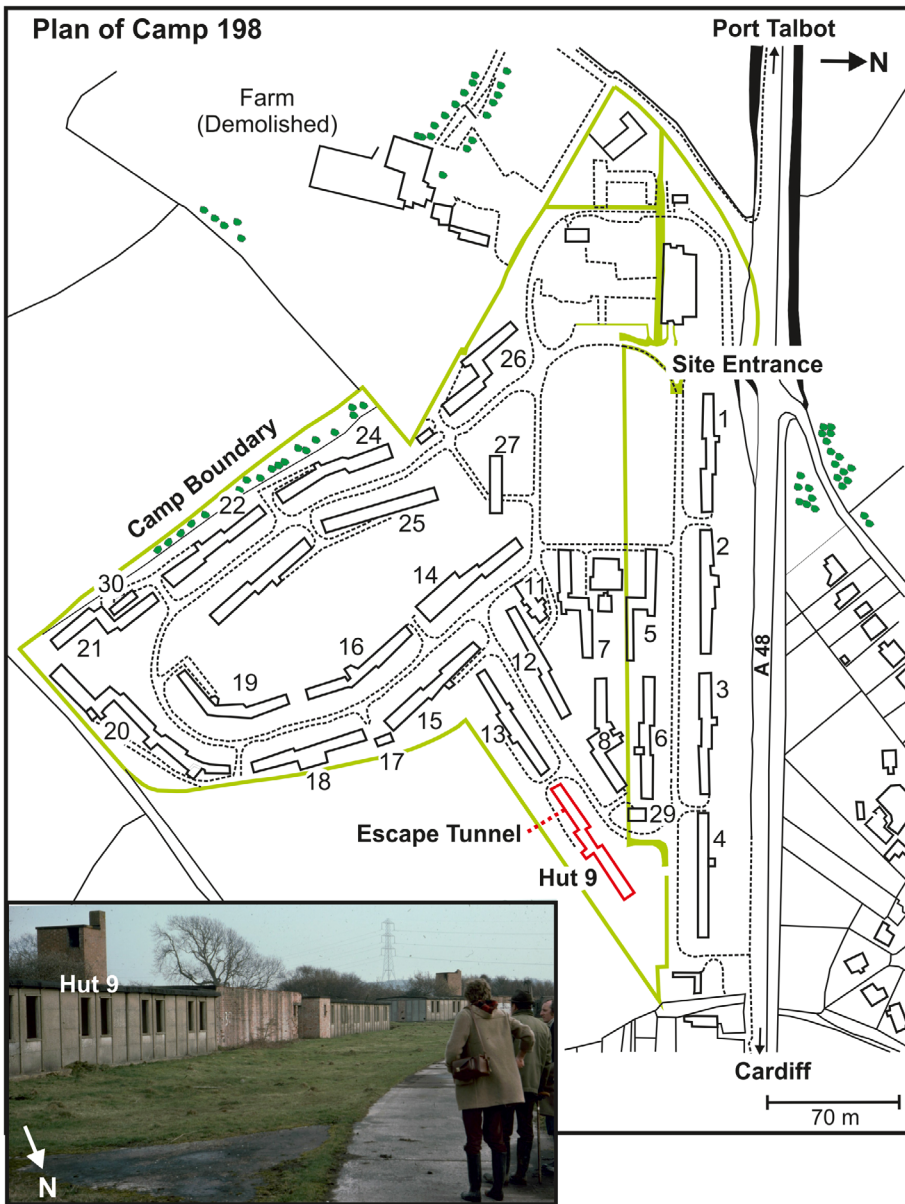


Figure 2. 1945 plan of Axis Special Camp XI that was PoW Camp 198 (see key for detail and Figure 1 for location), with locations shown, with (inset) photograph circa. 1975 taken onsite with main Huts still intact (Hut 9 in foreground), courtesy of Alun Isaac (Cardiff University).

Officers arrived and were interned here.¹⁸ Once fully established and secured, it became a high-security camp (Figure 2).

Camp security measures were generally poor, however; there was a lack of either sentry towers and perimeter fence lighting, and this provided good cover for escape tunnels to be constructed. A German escape organization was quickly set up after the prisoners arrived, with any PoWs with experience in mining identified.¹⁹ Prisoners also petitioned for an

extension to their exercise area, with the intention of gaining areas to conceal excavated material. A hand-excavated escape tunnel was first constructed in Hut 16, but this tunnel was found during a hut inspection (in some ways similar to the discovery of tunnel 'Tom' of 'The Great Escape' fame²⁰). As such, a second tunnel was started in Hut 9 (Room 3), which was adjacent to the perimeter fence (see Figure 2 for locations). On the night of 10 March 1945, 83 German PoWs successfully achieved a mass break out via an escape tunnel. Despite having a greater number of escapers than the Allied Great Escape from Stalag Luft III of the previous year, this German attempt has had very little exposure to date, presumably due to the fact that it was on Allied soil. As with many PoW escape attempts, the escapers employed great ingenuity in their onwards journey. Notably, one stole a car and managed to reach Birmingham, before being captured. Following the escape, the local Police, Home Guard, Army and Air force were mobilized; none of the 83 escaped PoWs managed to get home to Germany, a feat known as a 'home run' by the Allies.

After the escapers had been recaptured, Camp 198 was closed, and its 1,600 PoWs were transferred to Camp 181 in Worksop, Nottinghamshire, UK. Camp 198 was subsequently renamed Special Camp XI and used to house high-ranking German Officers after the end of the War before eventually being closed in May 1948.²¹

Site condition and Hut 9

After the camp was finally abandoned in 1948, it fell into disrepair. It is therefore fortunate that Hut 9, the scene of the escape survived. Currently, the site of the camp is overgrown, now comprising mostly a wasteland that has not been developed. An early investigation of the site was carried out in the 1970s by Cardiff University, which found that it was becoming dilapidated and vandalized (Figure 2). They also investigated the tunnel exit location.

By the 1990s, the site was deemed a safety hazard by the local Borough Council with 32 of the 33 prisoner Huts were demolished, with the exception of Hut 9 (Figure 2). The larger site is now being reforested, with the exception of Hut 9 that has been left intact; a 3-m-high perimeter fence has been erected around it. The hut itself is used sporadically for 'wartime weekends' and educational purposes (Figure 3). Unfortunately, due to the afforestation, some saplings and other vegetation have grown over the suspected tunnel location, which has made site investigation difficult (Figure 3(C)).

Desktop studies indicated that the local geology of the site was the Jurassic Blue Lias Formation, comprising a bedrock of interbedded limestone and mudstone, overlain by Devensian glacio-fluvial sand and gravel soils. Field samples obtained onsite during soil auger trial investigations to 0.75 m depth, revealed that the surface soils actually comprised a silty clay loam, with a c. 10 cm thick, black (Munsell soil colour chart: 7.5YR/5/1), organic-rich 'O' horizon, a c. 15 cm thick, silty, grey (7.5YR/7/2) 'A' horizon with coal fragments, and a c. 40 cm thick, dark (2.5 YR/5/4), hard clay-rich 'B' horizon. The PoW tunnel was excavated in these silty clay loam soils, which were quite different to the sandy soils encountered in the Allied PoW 'Great Escape'.²²

An initial site investigation was undertaken within Hut 9 in 2013. Many prisoner hand-drawn graffiti on camp the hut walls had been lost during the camp demolition, but specific graffiti examples, typically poetry, scenes depicting the prisoners' home, or of loved ones (Figure 4) have been removed from other Huts and stored within Hut 9. Most of the huts

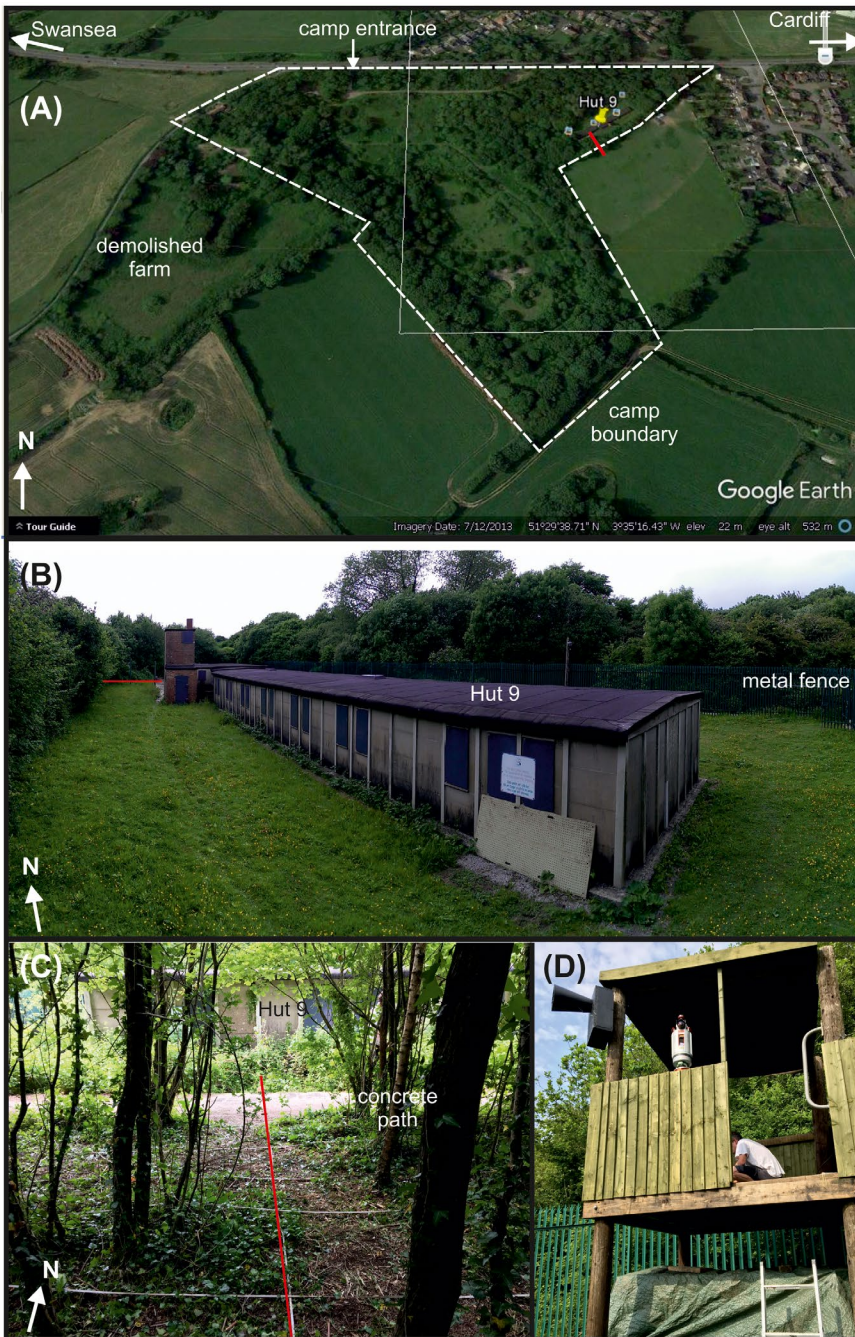


Figure 3. (A) Annotated site map, showing camp entrance, boundary (see Figure 2), and Hut 9 and tunnel location (red line). Courtesy of 2013 GoogleEarth™, (B) Hut 9 photograph (taken from replica watch tower) and approximate tunnel location marked, (C) Site photograph of approximate tunnel location (red line), with some geophysical survey profiles (tapes) and (D) Replica guard tower present on SE corner (in fact none were present during the PoW camp existence) with ground-based LiDAR survey instrument visible.

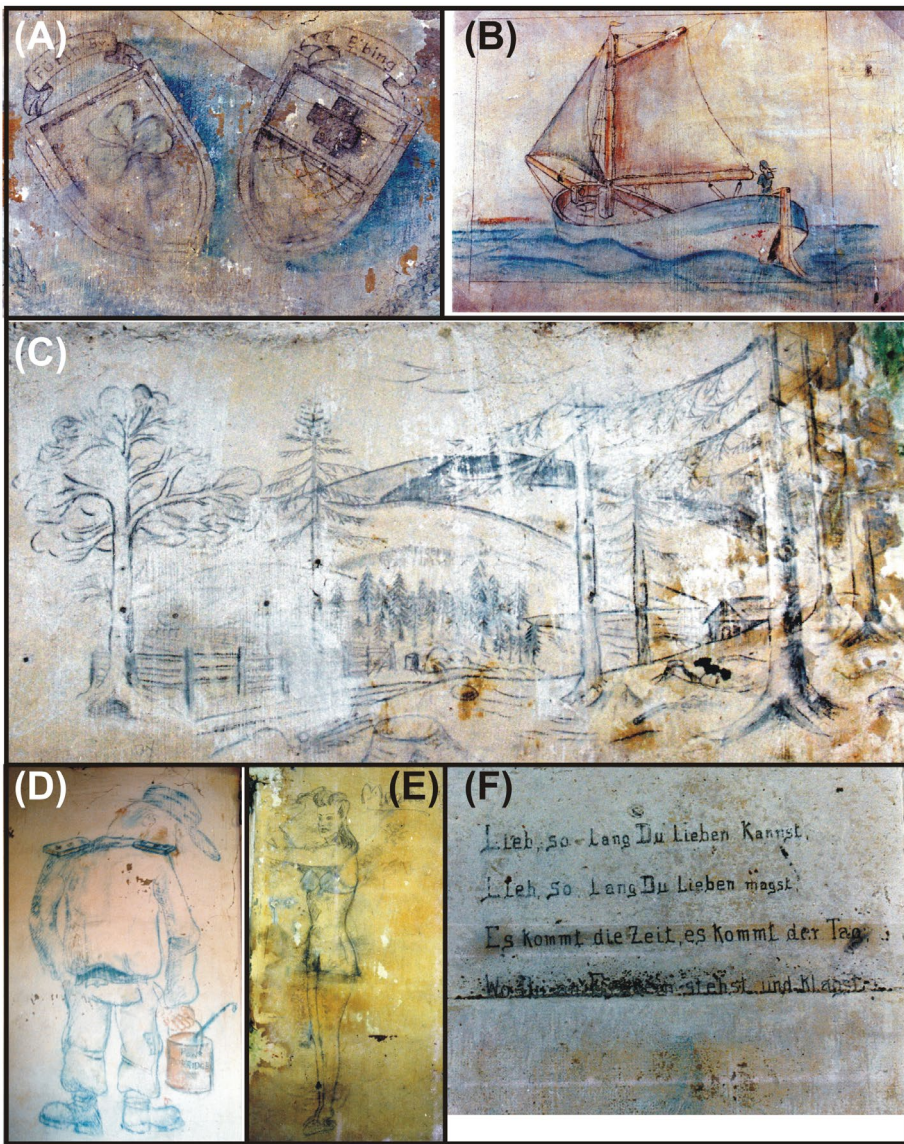


Figure 4. Example of Axis hand-drawn graffiti on camp Hut walls, some of which were saved and remain in Hut 9. (A) City shields of Fürth (Bavaria) and Elbing (East Prussia now Poland), (B) un-identified fishing boat, (C) rural German scene, (D) unflattering sketch of camp guard with 'POW porridge' inscribed on bucket, (E) one of less saucy female sketches and (F) one of the inscriptions, this loosely based on Ferdinand Freiligr's 1845 German poem, who was a champion of freedom and civil liberties; 'Love as long as you can love, love as long as you may, the time will come, the day will come, when you will stand at graves and mourn'.

had the same layout, a central corridor running between 12 prisoners' rooms on either side, each containing bunk beds, and a central shower block (Figure 5).

Williams has stated that the tunnel entrance was initiated in Room 3 of Hut 9.²³ Removal and disposal of spoil has long been a problem for PoW tunnellers.²⁴ One possible approach is the dispersion and mixing of excavated soils with surface soils in gardens and recreational

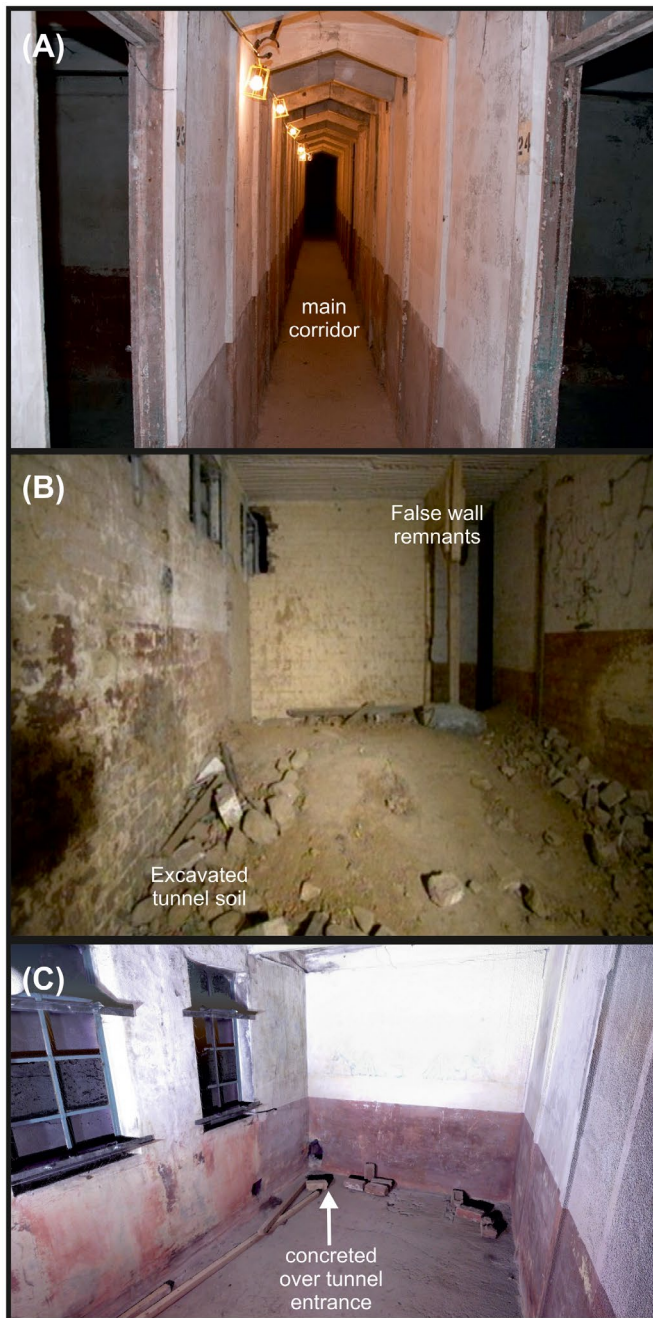


Figure 5. Hut 9 photographs. (A) The main corridor running along Hut 9 with PoW rooms either side, (B) Shower room with prisoner-made fake wall which was used to hide excavated tunnel material and (C) Room 3 where the tunnel entrance was located. (A) and (B) courtesy of Hut 9 preservation group.

areas. For the Allied 'Great Escapers' of Stalag Luft III, the surface soils were distinctly darker than those of a depth, so mixing had to be thorough.²⁵ The German prisoners at Camp 198 experienced similar problems, and it is known that they initially took advantage of garden

plots and the wider camp grounds to get rid of tunnel-excavated material; however, it was soon realized that camp guards would notice the appearance of this extra material.²⁶ Therefore, the prisoners constructed an ingenious false wall in the shower room in Hut 9, providing a means of housing most of this hand-excavated soil, which was hauled from the tunnel on a makeshift skip, before being deposited in the newly created cavity. The camp guards never discovered this.

The fake wall remains and excavated material were still present onsite (Figure 5). However, the tunnel entry point within Room 3 had been filled and concreted over in 1945 (Figure 5). Since the initial investigations, protected Lesser Horseshoe and Brown Long-eared bat species have established themselves in Hut 9; and as such, further investigations within the hut were not permitted.

Near-surface geophysical surveys

Although the PoW escape tunnel entrance location in Room 3 was known, there was some uncertainty on the orientation and exit location of the tunnel, as well as its general condition – given its 70-year age. As discussed above, non-invasive surface geophysical techniques have previously been successful in conflict archaeology sites,²⁷ though used more sporadically in detecting PoW escape tunnels.²⁸ In theory, basic 2D geophysical survey line profiles across a presumed tunnel area should have allowed its location to be determined (Figure 6). However, the site and its vicinity was challenging. As well the presence of a 3-m-high metallic

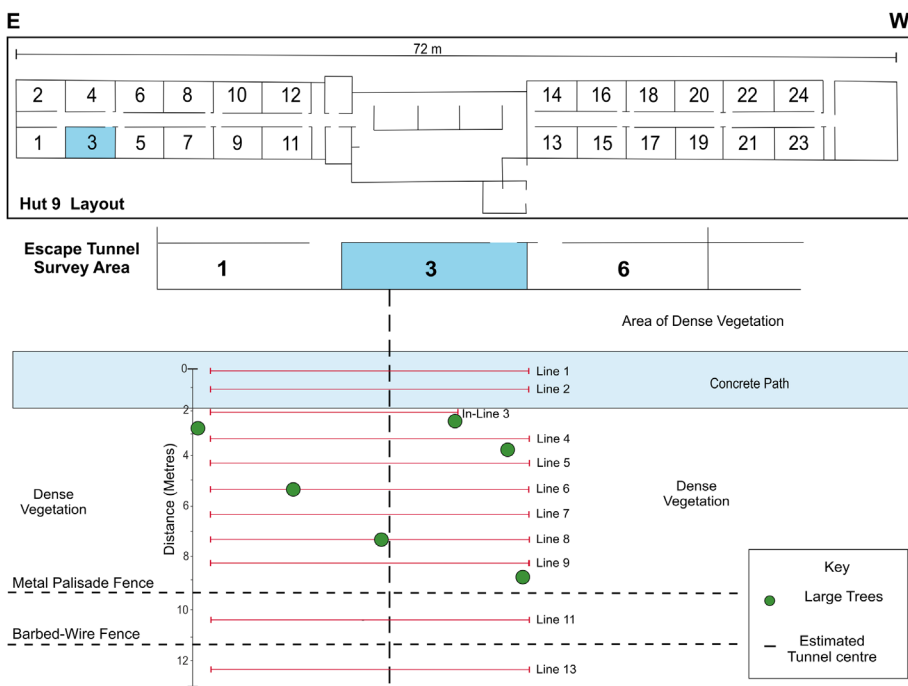


Figure 6. Mapview plan of the suspected PoW escape tunnel area, showing above ground objects of interest, numbered rooms within Hut 9, the 2D geophysical survey line (1–13) positions and the presumed tunnel exit location.

fence, and numerous surface scattered metallic objects in the survey area, it also contained a significant quantity of immature saplings and other vegetation (Figure 3(C)), which, due to the presence of the protected bat population, could not be removed prior to fieldwork.

Ground penetrating radar surveys

GPR surveys are the most popular geophysical technique used in archaeology, as they can detect buried objects up to 10 m below ground level in ideal conditions.²⁹ In 2016, following initial onsite testing of the GPR PulseEKKO™ 1000 system using available 225 MHz, 450 MHz and 900 MHz frequency antennae, 225 MHz frequency, fixed-offset antennae were used to acquire 11 profiles at approximately 1 m intervals (Figure 6). Trace spacings were 0.1 m, using a 120 ns time window and 32 repeat 'stacks' at each trace position. However, profiles at 10 m and 12 m away from Hut 9 could not be collected due to the metal presence and original barbed wire fences. Standard sequential data processing steps were applied to each 2D profile, namely: 1, first break arrival picking and flattening to time-zero; 2, AGC; 3, de-wow filters to optimize the image quality; before, 4, conversion from Two-Way Time (ns) to Depth (m) using an average site velocity of 0.07 m/ns determined from analysis of hyperbolic reflection events.³⁰

GPR results show a consistent, low amplitude, hyperbolic reflection event on 2D GPR profiles up to c. 7 m away from Hut 9, though farther away from the Hut this could not be discerned (see Figure 7). GPR time-slices generated of the data-set did not result in any improvements in target detection from the 2D profiles.

Magnetic gradiometry surveys

Magnetic surveys are common in archaeological site investigations. Metal objects were common components of Red Cross Parcels, in the form of tins and other containers, and are often found in twentieth-century PoW sites.³¹ Such items were very often fashioned into useful items, cooking utensils, containers and similar,³² though obtaining metal tools and other escape aids would have been difficult, if not unknown.³³ In any case, it is likely that the site would contain a variety of mundane metallic objects. In 2016, following onsite calibration in a magnetically quiet area of the site, a Geoscan™ FM18 magnetic gradiometer was used to acquire gradient data at 0.1 m sample position intervals over the eleven available survey lines (Figure 6). Standardized sequential data processing steps were applied to each profile: 1, removal of anomalous data points due to acquisition issues (termed 'despiking'); and, 2, de-trending to remove longer wavelength site trends in the data.³⁴

However, results showed most lines did not gain collectable data due to the numerous above-ground metallic debris present, and what was collectable, did not show significant variation across survey profile lines (Figure 8). Combining profiles into a mapview contoured plot did not improve the interpretation from 2D profiles alone.

Bulk-ground electrical resistivity surveys

Bulk ground electrical resistivity methods have also been commonly used in archaeological investigations. Although depth dependent on probe spacings, generally the method is cheap, easily manoeuvrable, and data are collected rapidly.³⁵

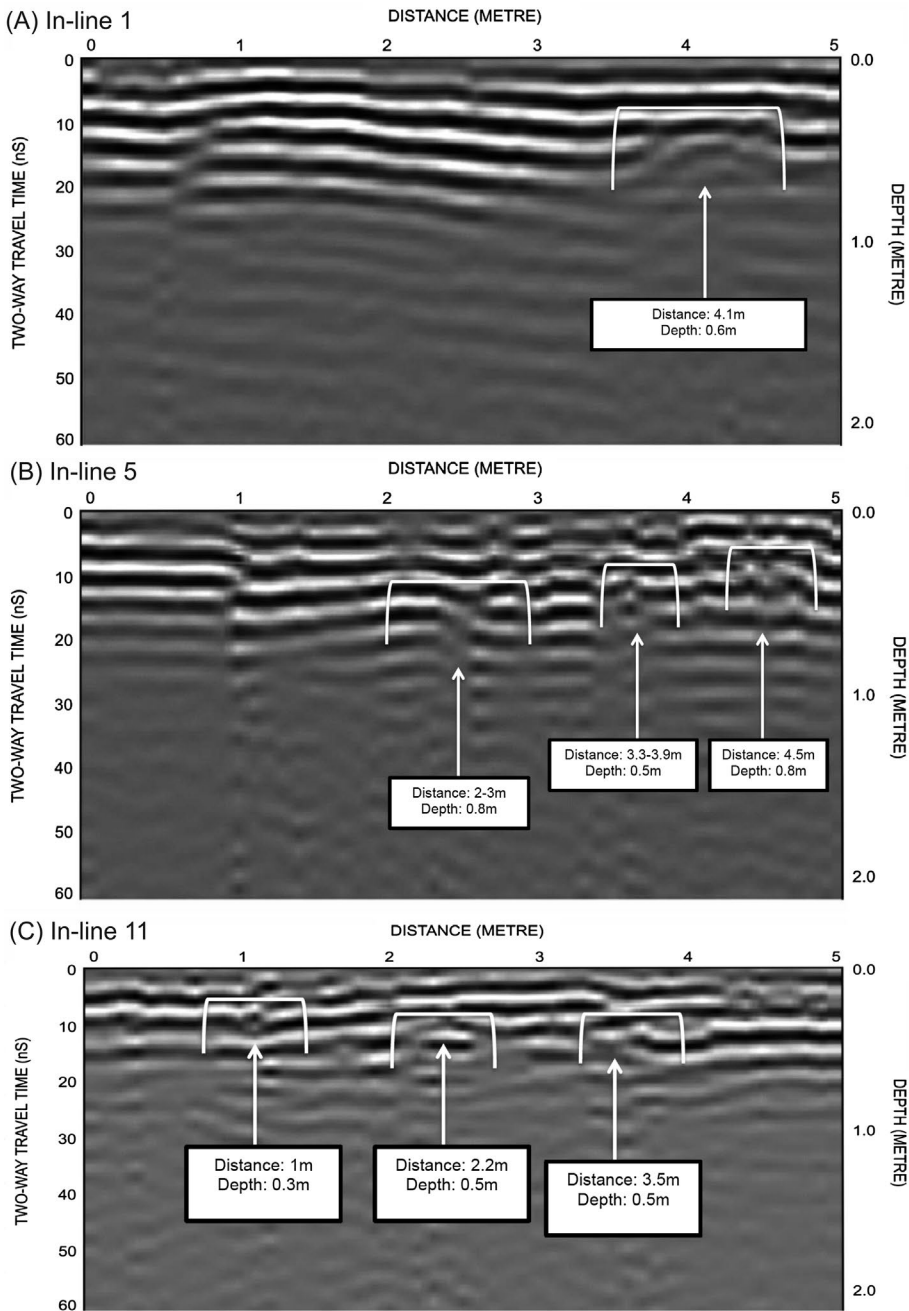


Figure 7. Some GPR 2D processed interpreted profiles acquired over the presumed tunnel location at: (A) 1 m, (B) 5 m and (C) 11 m from Hut 9 (see Figure 6 for location).

In 2016, after testing with different probe spacings, a Geoscan™ RM15-D Resistivity Meter, using a parallel twin probe array setting, was used with a probe separation of 0.5 m at 0.10 m sample position intervals over the eleven available survey lines (Figure 6). Standardized sequential data processing steps were applied to each profile by: (1), conversion of resistance

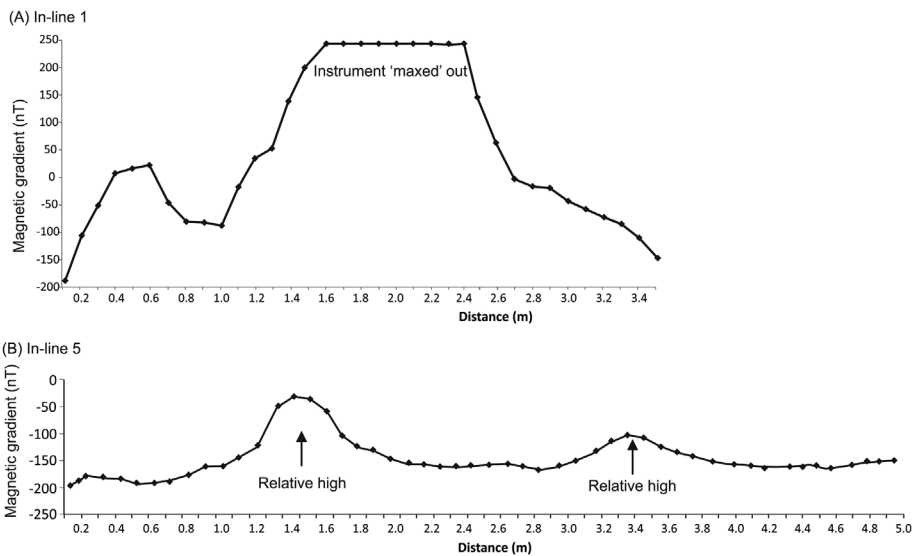


Figure 8. Selected magnetic gradiometry 2D processed interpreted profiles acquired over the presumed tunnel location at: (A) 1 m and (B) 5 m from Hut 9 (see Figure 6 for location).

to apparent resistivity measurements; (2), removal of anomalous data points due to acquisition issues (termed 'despiking'); and finally, (3), de-trending to remove longer wavelength site trends in the data.

Results found both isolated apparent resistance lows and highs, compared to background values, in survey in-lines (Figure 9). Combining profiles into a mapview colour contoured digital surface showed these discrepancies (Figure 10).

Ground-based LiDAR surveys

Air-based Light Detection And Ranging (LiDAR) surveys of archaeological sites have become more common as archaeological tools in the twenty-first century,³⁶ with ground-based LiDAR surveys also being used.³⁷ Importantly outputs from such surveys produce spatially accurate data-sets of sites which can be analysed later, for example, archaeological feature dimensions and 'birds eye' site views as well as allowing integration of other data-sets.³⁸

The Camp 198 site was scanned in 2013, using a Faro™ 3D Laser Scanning system, both outside and inside Hut 9 at various locations to allow a 3D data-set of the site to be generated (Figure 11). It was important to have multiple scan positions to allow overlap of the resulting single data scans to be merged, to avoid any potential data gaps due to any obscuring objects. A digital fly-through of this data-set is provided in the Supplementary data. The area above the tunnel was also scanned in multiple positions in 2016 (Figure 11), using a RiScan™ VZ400i (Figure 5(D)), when the geophysical data-set was collected.

LiDAR data also needed to be processed, the simple workflow being: 1, each respective scan position data-set imported into data processing software before; 2, erroneous individual data points removed; 3, manual spatial positioning of each data scan point cloud relative to each other before; 4, multi-station adjustment to improve the respective merged data point position accuracy; 5, finalized merged data-set has each data point RGB coloured from digital

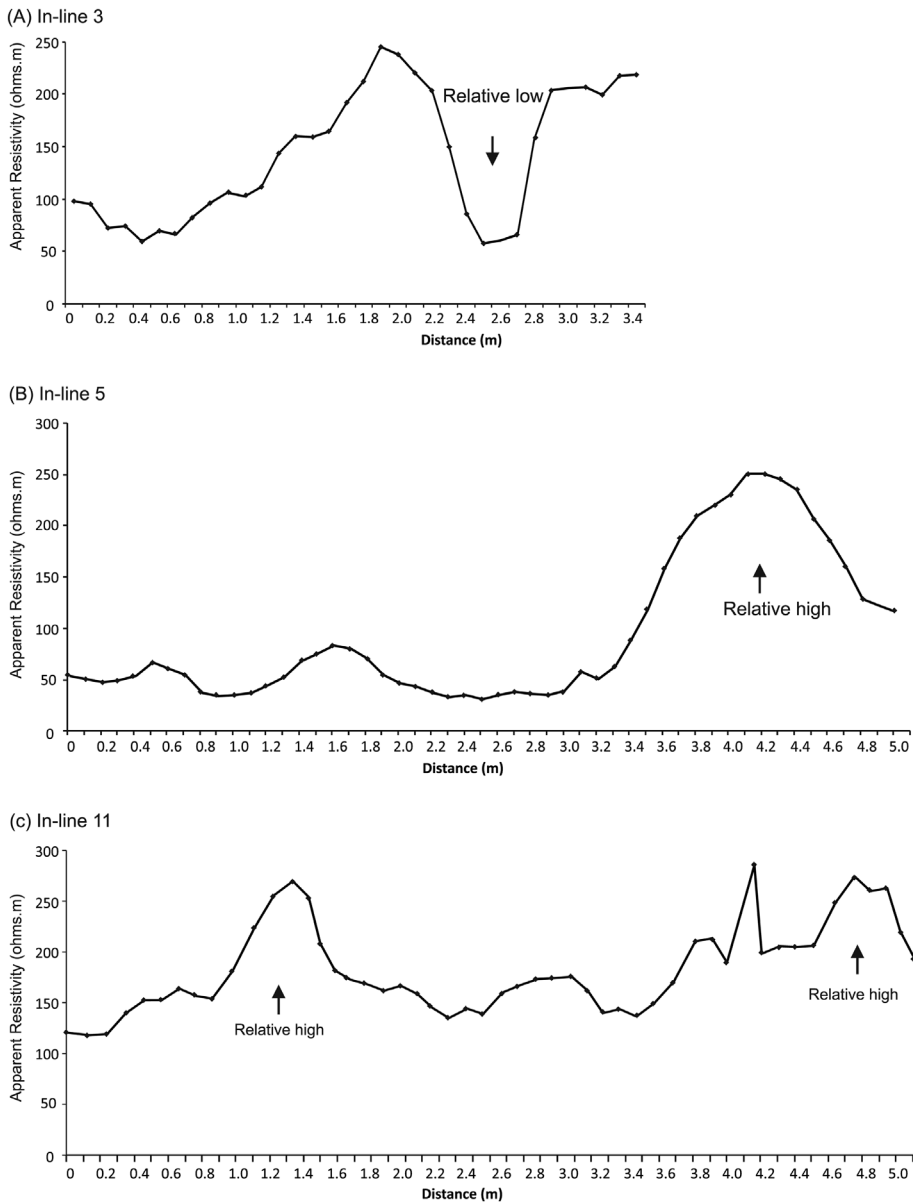


Figure 9. Selected electrical resistivity 2D processed interpreted profiles acquired over the presumed tunnel location at: (A) 3 m, (B) 5 m and (C) 11 m from Hut 9 (see Figure 6 for location).

camera images before; finally, 6, digital screen grabs acquired and digital fly-through paths generated and animations generated.

Archaeological investigations

Careful intrusive investigations were undertaken outside Hut 9 in 2013, with mechanical excavation over the presumed tunnel location. The still-intact tunnel was found at a depth

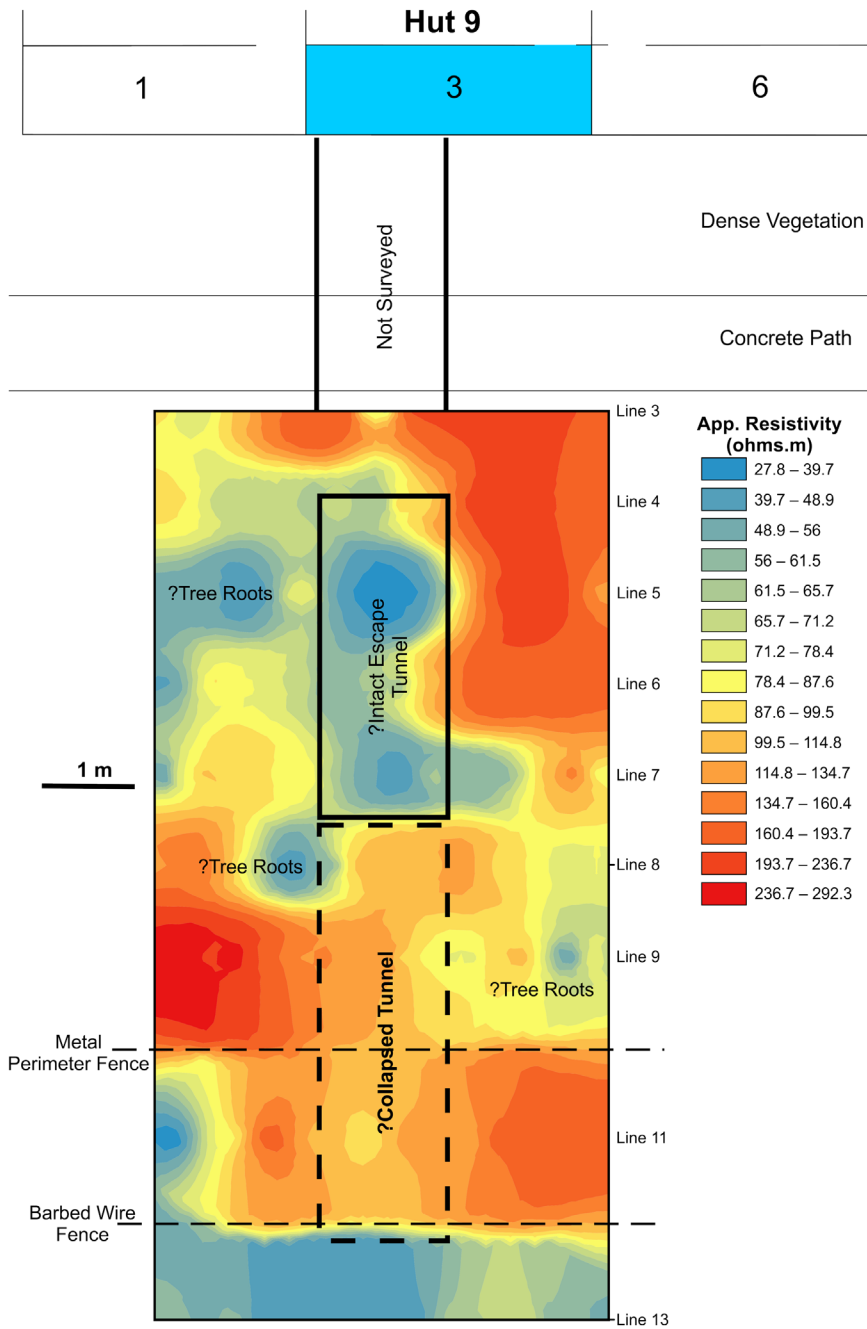


Figure 10. Mapview of the coloured digital contoured surface generated from the 2D apparent resistivity 2D profiles (see Figure 6 for location).

of c. 1.5 m bgl. The soil profile here mirrored what was found by the soil augers, consisting of a silty clay loam, although some pebble-sized stones were also present in the deeper horizons (Figure 12). The tunnel dimensions were c. 0.8 m by 0.8 m and exhibited what looked



Figure 11. Digital screen-grabs of ground-based LiDAR data-sets acquired onsite. (A) Surface data-set showing approximate tunnel position and (B) Tunnel data-set with merged Hut, room and tunnel scans shown. See supplementary data for digital fly-throughs.

like sawn-off wooden bed legs, each sited at c. 0.3 m intervals as both vertical wall and roof supports (Figure 12). The tunnel itself was only intact for c. 6 m from Hut 9 before it was full of soil, presumably back-filled after the escape tunnel was found. This was LiDAR scanned in 2013 (Figure 11(B)). A GoPro video along this tunnel is available as a Supplementary file as is a ground-based LiDAR digital fly-through animation.

Discussion

The first aim of this paper was to document the multi-disciplinary site investigations carried out at Camp 198. Desk studies of the 1945 camp layout, using existing maps (Figure 2) was particularly useful, as other modern investigations of PoW camps have shown.³⁹ Luckily, Hut 9 was recognized by the local Borough Council as being an important historical building when the rest of the camp was demolished in 1993; otherwise this investigation would have been made much more difficult as the rest of the camp is now immature woodland (Figure 2) and thus the identification of specific huts would have been problematic, this having been a major issue in the investigation of the Stalag Luft III tunnel Dick.⁴⁰



Figure 12. Image taken south-eastwards of the P.O.W. hand-excavated discovered tunnel from Hut 9. Note the wooden supports and large pebbles present in the overlying soil which would have made excavated soil disposal difficult.

Ground-based LiDAR surveys have also proven to be highly useful for such wartime conflict archaeology investigations as others have shown.⁴¹ Specifically, the site was rapidly scanned and analysed for later accurate tunnel dimension measurements; later interrogations from various angles; used to integrate different data types; and, for this investigation where there was limited time onsite, to minimally disturb the Hut 9 protected bat population.

Non-invasive, surface geophysical methods were also found to be highly useful in both the general characterization of the site, and specifically to locate and characterize near-surface buried objects, in this case the PoW escape tunnel, which mirrors other researchers' findings.⁴²

The second aim of this paper was to evidence the location and characterizing of the PoW escape tunnel. As discussed, this was a multi-disciplinary research effort, which combined the desk study with modern non-invasive geophysical and ground-based LiDAR surveys. A phased approach was followed,⁴³ from desk study to initial site reconnaissance to determine likely areas of investigation and the major site soil type(s), before surveying, and trial profiles collecting different geophysical technique data-sets, then revisiting using determined optimum survey technique(s) and equipment configurations. For example, the GPR 225 MHz frequency antennae were judged optimal, this mid-range frequency having been shown by other studies to detect buried archaeological objects buried at least 1 m depth bgl.⁴⁴ Electrical resistivity survey equipment was judged to be optimally set up with a dipole-dipole 0.5 m probe separation; this is the conventional probe configuration for shallow level investigations.⁴⁵

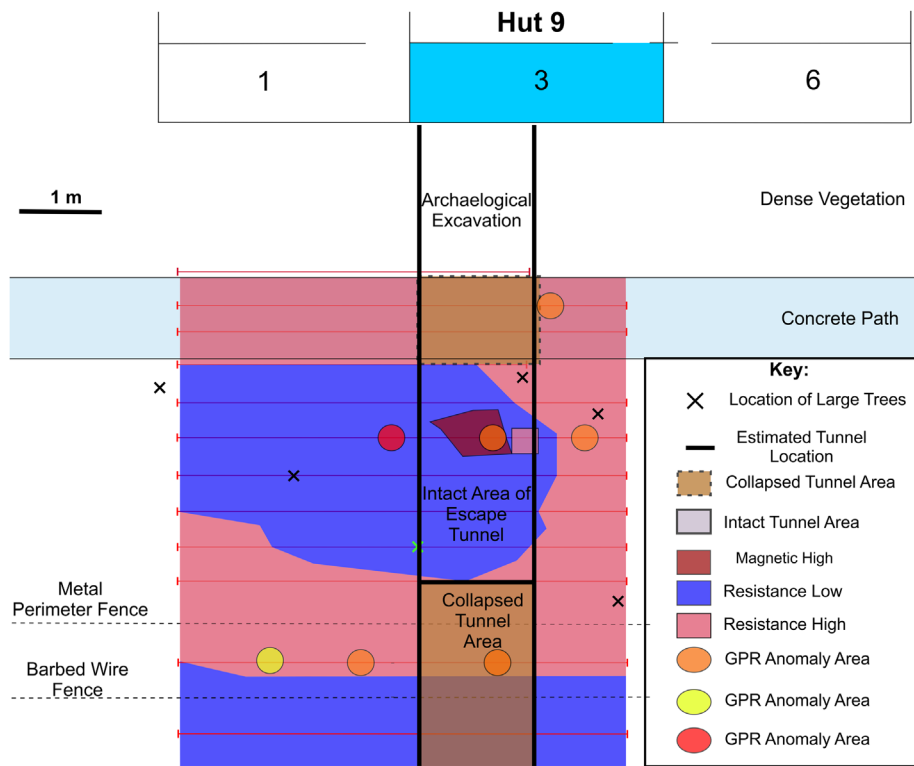


Figure 13. Graphical mapview summary of the near-surface geophysical and archaeological excavation findings (see key and text for details).

As well as locating the PoW escape tunnel position, the geophysical results could even differentiate where the tunnel was still intact or whether it had been filled, indicated particularly by GPR hyperbolic reflection amplitudes being less strong (Figure 7), and also where the electrical resistivity profiles went from an apparent resistivity low to a resistivity high, with respect to background values (cf. Figures 9 and 10). The magnetic gradiometry results were judged the least useful, due to the large amount of above-ground metallic debris present onsite which interfered with the geophysical results. This has also been shown by some other wartime site investigators.⁴⁶ Figure 13 summarizes the geophysical results.

The escape tunnel was also archaeologically investigated by a mechanical digger c. 1 m south of Hut 9 (Figure 12), which confirmed the geophysical survey data interpretation. It was discovered c. 1.5 m bgl within a silty-clay loam with isolated pebbles present. It was found to be filled at both ends, with a c. 5 m long section intact which had a c. 0.8 m x c. 0.8 m square gallery section (Figure 12). Wooden wall and roof supports were observed still present in relatively good condition, at intervals of c. 0.3 m (Figure 12). Once documented, the entrance was then carefully refilled again.

On the basis of this investigation and others presented here and in the literature, a generalized table (Table 2) has been generated to indicate the potential of search technique(s) success for military tunnels, assuming optimum equipment manufacturer/configurations, etc. Whilst soil types have been found to be one of the most important variables in the successful detection of near-surface buried objects,⁴⁷ only the two soil end members (clay

Table 2. Generalized table to indicate potential of search technique(s) success for military tunnels assuming optimum equipment configurations and significant-sized target. Key: ● Good; ○ Medium and; ○ Poor chance of detection success. After Pringle, et al. (2012).

Investigation/ Site Variables Soil type: Sand ○ Clays	Photographs (Aerial)	Site Plans & Historical Images	LiDAR	Soil Sampling	Arch-aeological Prospection	Near-Surface Geophysics				
						GPR	Resistivity	Magnetic Gradiometry	Total Field Magnetometry	Metal detector
Generic Tunnel Ages										
<i>Ancient</i>	○	●	○	○	○	○	○	○	○	○
<i>Medieval</i>	○	●	○	○	○	○	○	○	○	○
<i>WW1/WW2</i>	○	●	●	○	●	○	○	●	○	○
<i>1960s-1970s</i>	○	○	●	○	●	○	○	○	●	○
<i>Modern (21st Century)</i>	●	●	●	○	●	○	○	○	●	●
Tunnel Depths (Below Ground Level)										
<i>0-5m</i>	●	●	●	○	●	○	○	○	●	●
<i>5-10m</i>	●	●	○	○	○	○	○	○	○	○

and sand) are shown for simplicity. This generalized table should be helpful for other wartime site investigators to use as a guide for detecting below ground tunnels.

The final aim of the paper was to compare the escape attempt at Camp 198 with that of other WW2 PoW escape attempts. In this regard, the mass escape from Camp 198 in 1945 can be most easily compared with the Allied mass escape from Stalag Luft III in March 1944. Most other documented WW2 escapes, and certainly those using tunnels, involved considerably fewer PoWs (see Table 1).⁴⁸

In comparing the two camps and the two mass escapes, it can be established that both sets of PoWs were highly organized, with team members given specific escape task duties (e.g. tunnellers, lookouts, etc.).⁴⁹ Both sets of escapers hand-excavated the tunnel using prisoner-made tools, and used hut material to provide tunnel support to prevent cave-ins. In addition, both involved highly inventive with soil disposal, Allied PoWs depositing their soil in gardens and huts, Axis PoWs depositing soil behind a fake wall in an unused hut room. Attention to detail in this manner was a requirement, as differences in soil colour and texture were likely to be spotted and to cause alarm.⁵⁰ In both cases, the escape tunnels were supported by necessity by wooden frames, the wood stolen from the camp itself – either using bed boards (at Stalag Luft III) or legs (at Camp 198). The use of these materials may have dictated the size of the galleries in both camps.

In the end, a similar number of PoWs managed to escape at night from the respective camps through their hand-excavated tunnels dug under perimeter fences. In both cases, most PoWs were also rapidly recaptured with significant efforts on the part of the respective searching forces, (though it should be noted that there were no mass reprisal executions following the escape at Camp 198, in direct contrast to the events at Stalag Luft III).

However, there are differences. The Allied PoWs escape tunnel was significantly longer (c. 102 m versus 13 m, respectively), it was dug deeper, (c. bgl 10 m versus 0.8 m – 1.5 m, respectively), and took longer – a year to complete as camp guards were more vigilant and used a variety of escape detection devices (guard towers with floodlights, dogs and listening devices⁵¹). The Allied PoWs also managed to escape a much further distance than their Axis

counterparts (averages of 470 km versus 44 km, respectively) and with three documented success escapes, though this has much to do with the fact that the UK is an island. Eastern Germany was also significantly less populated at the time of the Allied PoW escape than South Wales was for the Axis forces to escape detection. It is known that the Allied PoWs had a more highly sophisticated operation enabling convincingly forged documents than the Axis prisoners had, meaning it was less possible for them to pass through manned check points. Finally, the Allied PoWs also deliberately conserved and made escape material (e.g. food, compasses, escape maps, etc.) that would have significantly aided their escapes.

Although difficult to prove at this point, there is some documented anecdotal evidence that suggests contrasts between the Allies and Axis PoWs in their determination to both escape and succeed in escaping, at least at this stage in the war. Phillips recounts that four escapees recaptured in Glais, South Wales, stated:

Like so many before them, when caught they gave up without a struggle...when the police arrived John Hopkins was still smiling at how one of the German described the whole adventure. 'It had been a good sport.'⁵²

This contrasts with Burgess' report of the recaptured Group Captain Harry Day who said

And if you want to know why we escape: we prefer death to the dishonour of sitting around passively as prisoners. Do you understand that?⁵³

Conclusions

On the night of 10/11 March 1945 in WWII, 83 Axis PoWs successfully escaped from Camp 198 in Bridgend, South Wales through a hand-excavated tunnel dug from Hut 9 underneath the perimeter fence. All 83 P.O.Ws were eventually recaptured and the Camp was closed due to this escape, although high ranking Axis officers were held there after WW2 before the camp was permanently closed in 1948. Since then the camp has been disused and was finally mostly demolished in 1993, though Hut 9, the scene of the escape, has been preserved.

Despite being a difficult site with dense vegetation cover and considerable disturbance, our multi-disciplinary investigation of Camp 198 proved to be successful in identifying and characterizing the Axis PoW efforts to conduct a successful mass outbreak in March 1945 by 83 German P.O.Ws.

A desktop study found a 1945 map showing the camp layout with Hut 9 located. Initial onsite investigations in 2013 located the entrance to the escape tunnel in Room 3, which was concreted over. PoW hand-drawn graffiti and drawings showed PoW contemporary thoughts at this time. A false wall in the shower block had been made by PoWs to hide the excavated tunnel material, remnants of which were still in place. A ground-based LiDAR survey also surveyed Hut 9 and the surrounding area.

A 2016 study then collected near-surface geophysical data-sets, namely GPR, electrical resistivity and magnetic gradiometry surveys, finding the potential escape tunnel location and characterizing whether it was intact or collapsed. This was subsequently confirmed by careful archaeological intrusive investigations.

The tunnel itself was hand-excavated through the silty-clay loam, and was at 0.8 m depth below Room 3 and around 1.5 m bgl at the 13 m tunnel extent beyond the camp perimeter fence. Only the first 6 m of tunnel is still intact. Wooden wall and roof supports, possibly from

bunk beds and chair legs, were regularly placed throughout the investigated part of the tunnel.

This study has added significant new knowledge and information on WWII Axis P.O.W escape attempts, with the first full scale investigation of an Axis escape tunnel, its excavation, dimensions and other characteristics, as well as innovative excavated soil disposal methods. More widely, the study has also provided further evidence of the potential of near-surface geophysical and LiDAR surveys to both detect and characterize historic military tunnels in a range of environments. The tunnel and the surrounding area will now become a listed National monument and be conserved for future generations.

Geolocational information

The study area has the following co-ordinates: 51°29'40"N, 3°35'08"W. A GoogleEarth™ KML location file is also included as Supplementary Data.

Notes

1. For overviews, see Pollard and Freeman, *Fields of Conflict*; Scott, et al., *Fields of Conflict*; for site specific examples, see Gaffney, et al., "D-Day; Geophysical Investigation"; Passmore and Harrison, "WWII Field Fortifications, Ardennes"; Saunders, *Killing Time*; Saey, et al., "EMI on the Western Front".
2. E.g. Rosenbaum and Rose, "Geology and Military Tunnels"; Doyle, et al., "The Underground War"; Doyle, et al., "Geoenvironmental Implications"; Doyle, et al., "Beecham Farm"; Everett, et al., "Pointe du Hoc"; De Meyer and Pype, "Scars of the Great War"; Brown and Osgood, *Digging Up Plugstreet*; Masters and Stichelbaut, "From the Air"; Banks, "Digging in the Dark"; Banks and Pollard, "Beyond Recall"; Doyle, "Trench Warfare in Flanders"; Doyle, "Disputed Earth".
3. E.g. Dobinson, et al., "Monuments of War"; Schofield, "D-Day Sites in England"; Passmore, et al., "Landscapes of Logistics"; Capps Tunwell, et al., "German Logistics Depots".
4. Moore, *The Faustball Tunnel*; Doyle, et al., "Great Escape Tunnels"; Doyle, et al., "Yellow Sands and Penguins"; Doyle, et al., "Stalag Luft III Archaeology"; Pringle, et al., "Multi-Disciplinary Investigations"; Doyle, "Geology of Escape Tunnels"; Early, "La Glaciere, Cherbourg"; Mytum and Carr, *Prisoners of War*; Schneider, "POW Camps in Normandy".
5. E.g. Gaffney, et al., "D-Day; Geophysical Investigation"; Everett, et al., "Pointe du Hoc"; Pringle, et al., "Multi-Disciplinary Investigations"; Fernandez-Alvarez, et al., "Discovery of a Mass Grave".
6. E.g. Carr and Mytum, *Cultural Heritage*; Mytum and Carr, *Prisoners of War*.
7. E.g. Barbour, *Prisoners of War*; Evans, *Escape and Liberation*; Crawley, *Escape from Germany*; Schneck, *Military Mines*; Moore, *The Faustball Tunnel*; Doyle, *Prisoner of War*; Doyle, "Geology of Escape Tunnels".
8. Williams, *Goon in the Block*; Williams, *The Wooden Horse*; Williams, *The Tunnel*; Hargest, *Farewell Campo 12*; Brickhill, *The Great Escape*; Reid, *The Colditz Story*; Reid, *The Latter Days*; Burt and Leasor, *The One That Got Away*; Rogers, *Tunnelling into Colditz*.
9. Brickhill, *The Great Escape*.
10. Doyle, "Geology of Escape Tunnels".
11. Brickhill, *The Great Escape*; Burgess, *The Longest Tunnel*; Doyle, et al., "Stalag Luft III Archaeology"; Doyle, et al., "Yellow Sands and Penguins"; Doyle, et al., "Archaeology of an Escapers' Camp".
12. Reid, *The Colditz Story*; Reid, *The Latter Days*; Eggers, *Colditz*; Rogers, *Tunnelling into Colditz*; Doyle, "Geology of Escape Tunnels".
13. Doyle, et al., "Stalag Luft III Archaeology"; Doyle, et al., "Yellow Sands and Penguins"; Doyle, et al., "Archaeology of an Escapers' Camp"; Pringle, et al., "Multi-Disciplinary Investigations"; Doyle, "Geology of Escape Tunnels".

14. Early, "La Glacerie, Cherbourg"; Schneider, "POW Camps in Normandy"; Zimmerman, *Third Reich on Lake Superior*.
15. Burt and Leasor, *The One That Got Away*.
16. Jackson, *Churchill's Unexpected Guests*.
17. Williams, *Come Out*.
18. Williams, *Come Out*; Philips, *German Great Escape*.
19. Williams, *Come Out*.
20. For details of the discovery of Tom, see Brickhill, *The Great Escape*.
21. Williams, *Come Out*.
22. Williams, *The Wooden Horse*; Brickhill, *The Great Escape*; Doyle, "Yellow Sands and Penguins".
23. Williams, *Come Out*.
24. Doyle, "Geology of Escape Tunnels".
25. Williams, *The Wooden Horse*; Brickhill, *The Great Escape*; Doyle, "Yellow Sands and Penguins".
26. Williams, *The Wooden Horse*.
27. Masters and Stichelbaut, "From the Air"; Banks, "Digging in the Dark".
28. Pringle, et al., "Multi-Disciplinary Investigations"; Doyle, "Geology of Escape Tunnels"; Banks, "Geophysics".
29. Sarris, et al., "Vészto-Mágor Tell"; Dick, et al., "Black Death Burials".
30. For background, see Milsom and Eriksen, *Field Geophysics*.
31. Doyle, et al., "Stalag Luft III Archaeology"; Early, et al., "La Glacerie, Cherbourg".
32. See Doyle, "Necessity" for Allied examples.
33. Reid, *The Colditz Story*; Phillips, *German Great Escape*.
34. For details, see Milsom and Eriksen, *Field Geophysics*.
35. Milsom and Eriksen, *Field Geophysics*.
36. Johnson and Ouimet, "Lost Archaeological Landscape".
37. Entwistle, et al., "Three-Dimensional Visualisation".
38. Sarris, et al., "Vészto-Mágor Tell".
39. Doyle, et al., "Stalag Luft III Archaeology"; Doyle, et al., "Archaeology of an Escapers' Camp"; Pringle, et al., "Multi-Disciplinary Investigations"; Early, "La Glacerie, Cherbourg".
40. Doyle, et al., "Stalag Luft III Archaeology"; Doyle, et al., "Archaeology of an Escapers' Camp"; Pringle, et al., "Multi-Disciplinary Investigations".
41. Entwistle, et al., "Three-Dimensional Visualisation"; Johnson and Ouimet, "Lost Archaeological Landscape".
42. Pringle, et al., "Multi-Disciplinary Investigations".
43. As best practice indicates, see for example Pringle, et al., "Terrestrial Forensic Searches".
44. Dick, et al., "Black Death Burials".
45. Milsom and Eriksen, *Field Geophysics*; Dick, et al., "Black Death Burials".
46. Everett, "Pointe du Hoc"; Pringle, et al., "Multi-Disciplinary Investigations".
47. See, for example, Pringle, et al., "Terrestrial Forensic Searches".
48. Doyle, *Prisoner of War*; Doyle, "Geology of Escape Tunnels".
49. For respective escape information, see Brickhill, *The Great Escape*; Williams, *Come Out*.
50. Williams, *The Wooden Horse*; Brickhill, *The Great Escape*; Doyle, et al., "Yellow Sands and Penguins"; Doyle, "Geology of Escape Tunnels".
51. Brickhill, *The Great Escape*.
52. Phillips, *German Great Escape*.
53. Burgess, *The Longest Tunnel*.

Acknowledgements

Claire Hamm, Wendy Gardner, Robert Jones, Sue Tomlinson and Matthew Harries of Bridgend County Borough Council and Rory McLaggan of Methyr Mawr Estates are thanked for allowing site access. Brett Exton, Richard Williams, Alun Issac, Peter Phillips and Steve J Plummer are acknowledged for historical advice. Ralf Halama of Keele University is thanked for PoW graffiti text translation and research.

A SRIF3 equipment bid and a Keele University Faculty of Natural Science equipment grant funded the geophysics and LiDAR surveying equipment, respectively, used in this study.

Disclosure statement

There is no financial interest or benefit that has arisen from the direct applications of this research.

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