Multidisciplinary Investigations at P.O.W. Camp 198, Bridgend, S. Wales: Site of a Mass Escape in March 1945

L. Rees-Hughes[1], J.K. Pringle[1*], N. Russill[2], K.D. Wisniewski[1], P. Doyle[3]

[1]*School of Geography, Geology and the Environment, Keele University, Keele, Staffordshire ST5 5BG, U.K.*

Email: l.reeshughes@icloud.com ; j.k.pringle@keele.ac.uk

Twitter: @LReesHughes; @milgeol; @Kris_Forensics

JP ORCiD: 0000-0002-0009-361X

[2]*TerraDat UK Ltd, Unit 1, Link Trade Park, Penarth Road, Cardiff, CF11 8TQ, U.K.*

Email: nick.russill@terradat.co.uk

Twitter: @nickruss

[3]*Department of Earth Sciences, University College London, Gower Street, London, WCIE 6BT, U.K.*

Email: doyle268@btinternet.com

Twitter: @profpeterdoyle

*Jamie Pringle
School of Geography, Geology & the Environment, Keele University, Keele, Staffordshire ST5 5BG, U.K
Email: j.k.pringle@keele.ac.uk
Phone Number: +44 (0)1782 733163

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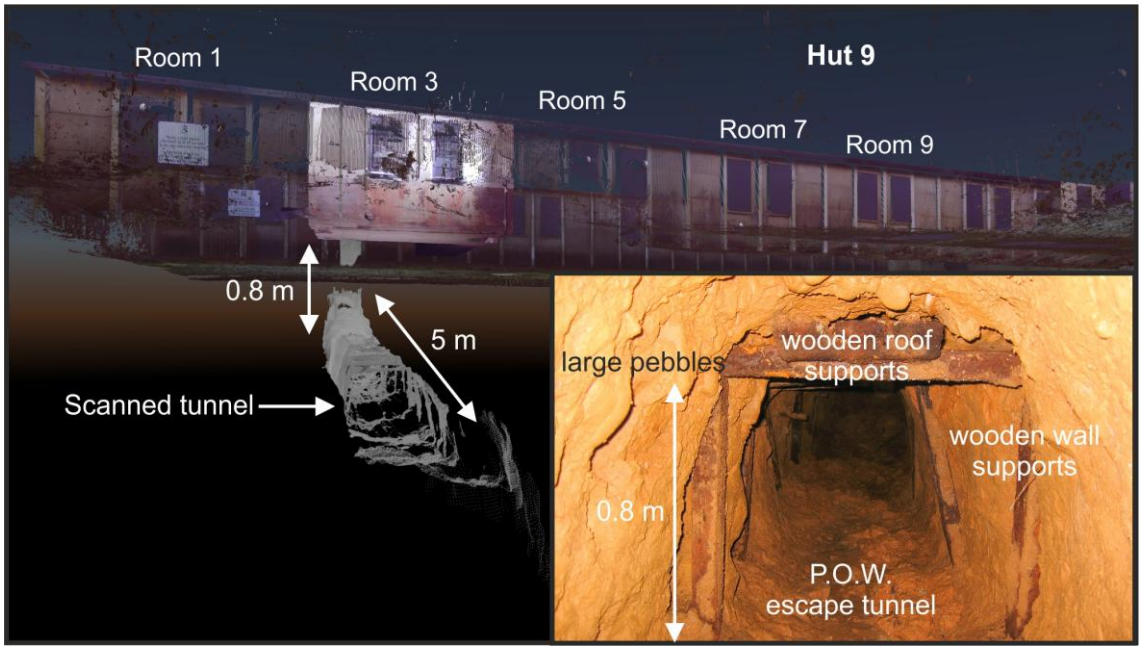
The largest escape of German Prisoner of War (P.O.W.) in WW2 was in March 1945 from Camp 198, situated in Bridgend, South Wales, UK. Since camp closure the site has become derelict, and has not been scientifically investigated. This paper reports on the search to locate the P.O.W. escape tunnel that was dug from Hut 9. This hut remains in remarkable condition, with numerous P.O.W. 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 P.O.W. escape camp attempts well documented, this investigation provides valuable insight into German escape efforts.

Keywords: geophysics, Prisoner-of-War, archaeology, World War II, Escape, German, South Wales

45 GRAPHICAL ABSTRACT



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INTRODUCTION

The last twenty years or so has seen the development of the conflict archaeology and the application of scientific principles to the investigation of sites of battle (see *Pollard and Freeman, 2001*, and *Scott et al., 2007* for overviews, see also *Gaffney et al., 2004; Passmore and Harrison 2008; Saunders, 2011;, 2014; Saey et al., 2016*), as well as the investigation of the infrastructure and fortifications of war, including trenches, dug-outs, foxholes and tunnels (see, for example, *Rosenbaum and Rose, 1992; Doyle et al. 2001, 2002, 2005; Everett et al. 2006; De Meyer and Pype, 2007; Brown and Osgood 2009; Masters and Stichelbaut, 2009; Banks, 2014*; *Banks and Pollard, 2014; Doyle 2015, 2017*), hospitals, airfields and logistics (e.g. *Dobinson et al. 1997; Schofield, 2001; Passmore et al. 2013; Capps Tunwell et al. 2015*) and Prisoner of War (P.O.W.) sites (e.g. *Moore 2006; Doyle et al. 2007, 2010, 2013; Pringle et al. 2007; Doyle 2011; Early 2013; Mytum and Carr, 2013; Schneider 2013*). These investigations include investigative archaeology, geophysical surveys as well as the consideration of landscape and topography in relation to battle that has emphasised 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 (see, for example, *Gaffney et al. 2004; Everett et al. 2006; Pringle et al. 2007; Fernandez-Alvarez et al. 2016*), due to their capability to characterise 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 characterising of P.O.W. camp escape tunnels, as part of a wider interest in the study of P.O.W. camps (e.g. see *Carr & Mytum, 2012* and *Mytum and Carr, 2013*).

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 (see, for example, *Barbour, 1944*; *Evans, 1945; Crawley, 1956*; *Schneck, 1998; Moore, 2006; Doyle 2008, 2011*). Such camp escape attempts, whilst mostly unsuccessful (WW2 P.O.W. documented tunnel escapes are summarised 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 conflict (*Williams 1945, 1949, 1951; Hargest 1946, Brickhill, 1952; Reid 1952, 1956; Burt and Leasor 1956; Rogers 1986*) with, arguably the so-called 'Great Escape' of 77 Allied P.O.W. airforce officers in 1944 being the most famous (*Brickhill, 1952*).

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 concealed (see *Doyle, 2011*); and, (2) relatively long tunnels that were meticulously planned, engineered and operated by highly organised and expertly-trained personnel, for example, the well-known WW2 allied 1944 'Great Escape' (see *Brickhill, 1952; Burgess 1990; Doyle et al. 2007, 2010, 2013; Pringle et al. 2007*) and the escape from Colditz Castle (*Reid, 1952,1953; Eggers, 1961; Rogers 1986; Doyle, 2011*).

Whilst there have been a number of multidisciplinary scientific site investigations undertaken on WW2 Allied P.O.W. escape attempts (see *Doyle et al. 2007, 2010, 2013; Pringle et al., 2007; Doyle, 2011*), there have been few studies of Axis P.O.W. escape attempts (Table 1). Though there have been some recent studies of German P.O.W. camps in Allied countries (e.g. see *Early 2013; Schneider 2013; Zimmermann, 2015*), in general there has been low level of perception that Axis troops, in common with other captives, also attempted to escape, with the single most

documented example being the escape of Franz von Werra from captivity in Canada (*Burt and Lessor, 1956*). This is surprising as there were an estimated 3.6_M German soldiers captured during WW2, and there were over 1,026 individual P.O.W. camps in the United Kingdom alone (*Jackson, 2010*).

This paper describes a multidisciplinary investigation of a mass escape of P.O.W.s from one such WW2 camp in the United Kingdom, namely Camp 198 situated in Bridgend, South Wales, UK (Fig. 1 and GoogleEarth™ KML file in Supplementary data). Eighty-three German P.O.W.s 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 multidisciplinary site investigations carried out at Camp 198; 2, to evidence the techniques and procedures used to locate and characterise the escape tunnel; and, 3, to compare the escape attempt of March 1945 to other documented 20th Century P.O.W. escape attempts.

Figure 1. Here

Table 1. Here

CAMP 198 BACKGROUND

The site did not become P.O.W Camp 198 until 1944. It had initially been constructed in 1938 to provide workers' housing for the nearby Waterton Royal Ordnance Factory, before being used to accommodate US troops of the 109th Infantry Regiment shortly before the 1944 invasion of Normandy (*Williams, 1976*). However, following the D-Day invasion, large numbers of German troops were captured, resulting in a requisite need for an increased number of P.O.W. 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 Officers arrived and were interned here (*Williams, 1976; Phillips, 2006*). Once fully established and secured, it became a high-security camp (Fig. 2).

Camp security measures were generally poor, however; there was a lack of both sentry towers and perimeter fence lighting, and this provided good cover for escape tunnels to be constructed. A German escape organisation was quickly set up after prisoner arrival, with any P.O.W.s with experience in mining identified (*Williams, 1976*). 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' fame, see *Brickhill, 1952* for more information). As such, a second tunnel was started in Hut 9 (Room 3), which was adjacent to the perimeter fence (see Fig. 2 for locations). On the night of 10 March 1945, 83 German P.O.W.s successfully achieved a mass break out via an escape tunnel. Despite having a greater number of escapers that 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 P.O.W. 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 mobilised; none of the 83 escaped P.O.W.s managed to successfully escape, so-called 'home runs' by the Allies.

After the escapers had been recaptured, Camp 198 was closed, and its 1,600 P.O.W.s 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 (*Williams, 1976*).

Figure 2. Here

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, much like Stalag Luft III, the site of 'The Great Escape in 1944 (see *Doyle et al. 2007, 2013; Pringle et al. 2007*). An early investigation of the site was carried out in the 1970s by Cardiff University, which found that it was becoming dilapidated and vandalised (Fig. 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 (Fig. 2). The larger site is now being reforested, with the exception of Hut 9 which has been left

intact, and with a 3-m-high perimeter fence erected around it. The hut itself is used sporadically for 'wartime weekends' and educational purposes (Fig. 3). Unfortunately, due to the afforestation, some saplings and other vegetation have grown over the suspected tunnel location, which has made site investigation difficult (Fig. 3c).

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 ~10 cm thick, black (Munsell soil colour chart: 7.5YR/5/1), organic-rich 'O' horizon, a ~15 cm thick, silty, grey (7.5YR/7/2) 'A' horizon with coal fragments, and a ~40 cm thick, dark (2.5 YR/5/4), hard clay-rich 'B' horizon. The P.O.W. tunnel was excavated in these silty clay loam soils which were quite different to the sandy soils encountered in the Allied P.O.W. 'Great Escape' (see *Williams, 1949; Brickhill, 1952; Doyle et al., 2010*).

Figure 3. Here

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 (Fig. 4) have been removed from other Huts and stored within Hut 9. Most of the huts had the same layout, a central corridor running between 12 prisoners' rooms on either side, each containing bunk beds, and a central shower block (Fig. 5).

Williams (1976) has stated that the tunnel entrance was initiated in Room 3 of Hut 9. Removal and disposal of spoil has long been a problem for P.O.W. tunnellers (see *Doyle 2011*). One possible approach is the dispersion and mixing of excavated soils with surface soils in gardens and recreational 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 (see *Williams, 1949; Brickhill, 1952; Doyle et al., 2010*). The German prisoners as 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 realised that camp guards would notice the appearance of this extra material (*Williams, 1949*). 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 (Fig. 5). However, the tunnel entry point within Room 3 had been filled and concreted over in 1945 (Fig. 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.

Figure 4. Here

Figure 5. Here

NEAR-SURFACE GEOPHYSICAL SURVEYS

Although the P.O.W. 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 (e.g. *Masters & Stichelhaut, 2009; Banks, 2014*), though used more sporadically in detecting P.O.W. escape tunnels (although see *Pringle et al. 2007; Doyle, 2011*). In theory, basic 2D geophysical survey line profiles across a presumed tunnel area should have allowed its location to be determined (Fig. 6). However, the site and its vicinity was challenging. As well the presence of a 3-m-high metallic fence, and numerous surface scattered metallic objects in the survey area, it also contained a significant quantity of immature saplings and other vegetation (Fig. 3c), which, due to the presence of the protected bat population, could not be removed prior to fieldwork.

Figure 6. Here

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 (see *Sarris et al. 2013; Dick et al. 2015*). 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 (Fig 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

237 barbed wire fences. Standard sequential data processing steps were applied to each 2D
238 profile, namely: 1, first break arrival picking and flattening to time-zero; 2, AGC; 3,
239 dewow filters to optimise the image quality; before, 4, conversion from Two-Way Time
240 (ns) to Depth (m) using an average site velocity of 0.07 m/ns determined from analysis
241 of hyperbolic reflection events (see *Milsom & Eriksen, 2011* for background).
242 GPR results show a consistent, low amplitude, hyperbolic reflection event on 2D
243 GPR profiles up to ~7 m away from Hut 9, though farther away from the Hut this could
244 not be discerned (see Fig. 7). GPR time-slices generated of the dataset did not result in
245 any improvements in target detection from the 2D profiles.

246 **Figure 7.** Here

247 ***Magnetic Gradiometry Surveys***
248 Magnetic surveys are common in archaeological site investigations (see *Masters*
249 *and Stichelbaut, 2009; Lowe, 2012; Fassbinder, 2015)*. Metal objects were common
250 components of Red Cross Parcels, in the form of tins and other containers, and are often
251 found in 20th Century P.O.W. sites (e.g. see *Doyle et al. 2013; Early 2013*). Such items
252 were very often fashioned into useful items, cooking utensils, containers and similar
253 (see *Doyle 2012* for Allied examples), though obtaining metal tools and other escape
254 aids would have been difficult, though not unknown *(*see *Reid, 1952; Phillips, 2006).*
255 In any case, it is likely that the site would contain a variety of mundane metallic objects.
256 In 2016, following onsite calibration in a magnetically quiet area of the site, a
257 Geoscan™ FM18 magnetic gradiometer was used to acquire gradient data at 0.1 m
258 sample position intervals over the 11 available survey line (Fig. 6). Standardised
259 sequential data processing steps were applied to each profile: 1, removal of anomalous
260 data points due to acquisition issues termed ‘despiking’; and, 2, detrending to remove
261 longer wavelength site trends in the data (see *Milsom & Eriksen, 2011* for background).

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 (Fig. 8). Combining profiles into a mapview contoured plot did not improve the interpretation from 2D profiles alone.

Figure 8. Here

Bulk-Ground Electrical Resistivity Surveys

Bulk ground electrical resistivity methods have also been commonly used in archaeological investigations *(see Thacker and Ellwood, 2002; Terron et al., 2015).* Although depth dependent on probe spacings, generally the method is cheap, easily manoeuvrable, and data are collected rapidly *(see Milsom & Eriksen, 2011* for details*).*

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 0.5m at 0.10 m sample position intervals over the 11 available survey lines (Fig. 6). Standardised sequential data processing steps were applied to each profile by: 1, conversion of resistance to apparent resistivity measurements; 2,removal of anomalous data points due to acquisition issues termed 'despiking'; and finally, 3, detrending to remove longer wavelength site trends in the data (see *Milsom & Eriksen, 2011* for background).

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

Figure 9. Here

Figure 10. Here

286 ***Ground-based LiDAR surveys***

287 Air-based Light Detection And Ranging (LiDAR) surveys of archaeological
288 sites have become more common as archaeological tools in the 21st Century (see, for
289 example, *Johnson & Ouimet, 2014*), with ground-based LiDAR surveys being used (for
290 example, *Entwistle et al. 2009*). Importantly outputs from such surveys produce
291 spatially accurate datasets of sites which can be analysed later, for example,
292 archaeological feature dimensions and 'birds eye' site views as well as allowing
293 integration of other datasets (see *Sarris et al. 2013*).

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

302 LiDAR data also needed to be processed, the simple workflow being: 1, each
303 respective scan position dataset imported into data processing software before; 2,
304 erroneous individual data points removed; 3, manual spatial positioning of each data
305 scan point cloud relative to each other before; 4, multi-station adjustment to improve the
306 respective merged datapoint position accuracy; 5, finalised merged dataset has each data
307 point RGB coloured from digital camera images before; finally, 6, digital screen grabs
308 acquired and digital fly-through paths generated and animations generated.

309

310 **Figure 11.** Here

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 of ~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 (Fig. 12). The tunnel dimensions were ~0.8 m by 0.8 m and exhibited what looked like sawn-off wooden bed legs, each sited at ~0.3 m intervals as both vertical wall and roof supports (Fig. 12). The tunnel itself was only intact for ~ 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 (Fig. 11b). A GoPro video along this tunnel is available as a Supplementary file as is a ground-based LiDAR digital fly-through animation.

Figure 12. Here

DISCUSSION

The first aim of this paper was to document the multidisciplinary site investigations carried out at Camp 198. Desk studies of the 1945 camp layout, using existing maps (Fig. 2) was particularly useful, as other modern investigations of P.O.W. camps have shown (see, for examples, *Doyle et al. 2007, 2013*; *Pringle et al. 2007; Early 2013*). Luckily, Hut 9 was recognised 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 (Fig. 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 site (*Doyle et al. 2007, 2013*; *Pringle et al. 2007*).

Ground-based LiDAR surveys have also proven to be highly useful for such wartime conflict archaeology investigations as others have shown (e.g. *Entwistle et al. 2009; Johnson & Ouimet, 2014*). 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 P.O.W. escape tunnel, which mirrors other researchers' findings (e.g. *Pringle et al. 2007*).

The second aim of this paper was to evidence the location and characterising of the P.O.W. escape tunnel. As discussed, this was a multidisciplinary research effort, which combined the desk study (see *Williams, 1976; Phillips, 2006*), with modern non-invasive geophysical and ground-based LiDAR surveys. A phased approach was followed (as best practice indicates, see, for example, *Pringle et al. 2012*), 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 datasets, 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 (see *Dick et al. 2015*). 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 (see *Milsom & Eriksen, 2011; Dick et al. 2015*).

As well as locating the P.O.W. 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 (Fig. 7), and also where the electrical resistivity profiles went from an apparent resistivity low to a resistivity high, with respect to background values (*cf*. Fig. 9-10). 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 other wartime site investigators (see, for example, *Everett et al., 2006; Pringle et al., 2007*). Figure 13 summarises the geophysical results.

Figure 13. Here

The escape tunnel was also archaeologically investigated by a mechanical digger ~1 m south of Hut 9 (Fig. 12), which confirmed the geophysical survey data interpretation. It was discovered ~1.5 m bgl within a silty-clay loam with isolated pebbles present. It was found to be filled at both ends, with a ~5 m long section intact which had a ~0.8 m x ~0.8 m square gallery section (Fig. 12). Wooden wall and roof

supports were observed still present in relatively good condition, at intervals of ~0.3 m (Fig. 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 generalised 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 (see, for example, *Pringle et al. 2012*), only the two soil end members (clay 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.

Table 2. Here

The final aim of the paper was to compare the escape attempt at Camp 198 with that of other WW2 P.O.W. 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 P.O.W.s (see Table 1 and Doyle 2008, 2011).

In comparing the two camps and the two mass escapes, it can be established that both sets of P.O.W.s were highly organised, with team members given specific escape task duties (e.g. tunnellers, lookouts, etc., see *Brickhill, 1952* and *Williams, 1976* for respective escape information). 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 P.O.W.s depositing their soil in gardens and Huts, Axis P.O.W.s 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 (see *Williams, 1949; Brickhill, 1952; Doyle et al., 2010; Doyle, 2011*). 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 P.O.W.s managed to escape at night from the respective camps through their hand-excavated tunnels dug under perimeter fences. In both cases, most P.O.W.s were also rapidly recaptured with significant efforts on the part of the respective searching forces, (though it should be noted that there was 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 P.O.W.s escape tunnel was significantly longer (102 m versus 13 m respectively), it was dug deeper, (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 devices – see *Brickhill, 1952*). The Allied P.O.W.s 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 P.O.W. escape than South Wales was for the Axis forces to escape detection. It is known that the Allied P.O.W.s 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 P.O.W.s also deliberately conserved and made escape

material (e.g. food, compasses, escape maps, etc.) that would have significantly aided their escapes.

Although difficult prove at this point, there is some documented anecdotal evidence that suggests contrasts between the Allies and Axis P.O.W.s in their determination to both escape and succeed in escaping, at least at this stage in the war. *Phillips (2006)* 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'".* This contrasts with *Burgess' (1990)* 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?"*

CONCLUSIONS

On the night of the 10/11 March 1945 in WW2, 83 Axis P.O.W.s 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 where 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 multidisciplinary investigation of Camp 198 proved to be successful in identifying and characterising the Axis P.O.W. 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. P.O.W. hand-drawn graffiti and drawings showed P.O.W. contemporary thoughts at this time. A false wall in the shower block had been made by P.O.W.s 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 datasets, namely GPR, electrical resistivity and magnetic gradiometry surveys, finding the potential escape tunnel location and characterising 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 WW2 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 characterise 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.

GEOLOCATION INFORMATION

The study area has the following co-ordinates: 51º29'40"N,3º35'08"W. A GoogleEarth™ KML location file is also included as Supplementary Data.

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 P.O.W. graffiti text translation and research. A SRIF3 equipment bid and a Keele University Faculty of Natural Science equipment

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DISCLOSURE STATEMENT

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

SUPPLEMENTARY FILES

1. GoogleEarth™ KML site location file.

2. Digital fly-through of the 2013 ground-based LiDAR scan dataset.

3. GoPro digital animated footage through the discovered P.O.W. escape tunnel.

These files are available on figshare: https://figshare.com/s/ad3d7436ba661edf0db6

DOI:10.6084/m9.figshare.c.3676951

Retrieved: 19 58, Jan 29, 2017 (GMT)

BIOGRAPHICAL NOTE

Luis Rees-Hughes has a BSc Hons. Degree in Geoscience (2015) and a MSc in Geoscience Research (2016) with Distinction from Keele University.

Jamie K. Pringle is a Senior Lecturer in Geosciences at Keele University, having held previous positions at Liverpool University and Reynolds Geo-Science Ltd. He obtained a PhD from Heriot-Watt University (2003) and a BSc Hons. in Geology from Royal Holloway University of London (1996). Jamie has worked on various military and historical scientific investigations, the most high profile being a site investigation of the 'Great Escape' of WW2 Allied P.O.W.s in 1944 in Sagan, Western Poland.

Nick Russill is Co-Director of Terradat Ltd. and an Honorary Lecturer at Cardiff University. He holds a BSc Hons. Degree in Exploration & Mining Geology from Cardiff University (1992). He has regularly been the geophysics expert on Time Team.

Kris Wisniewski is a Teaching Fellow at Keele University, having a PhD in Forensic Science, and is an experienced site investigator in various forensic and archaeological investigations.

Peter Doyle is Visiting Professor at University College London, Secretary of the All Party Parliamentary War Heritage Group and is a geologist specialising in battlefield terrain from the late nineteenth century onwards. A regular contributor to TV documentaries, Peter was also a visiting lecturer on military geology at the United States Military Academy, West Point, in 2007 and 2014. His many contributions

include multidisciplinary studies of trenches, terrain and military tunnels of both world wars, and he has a special interest in PoW camps, leading the investigations at Stalag Luft III in 2003.

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FIGURE CAPTIONS:

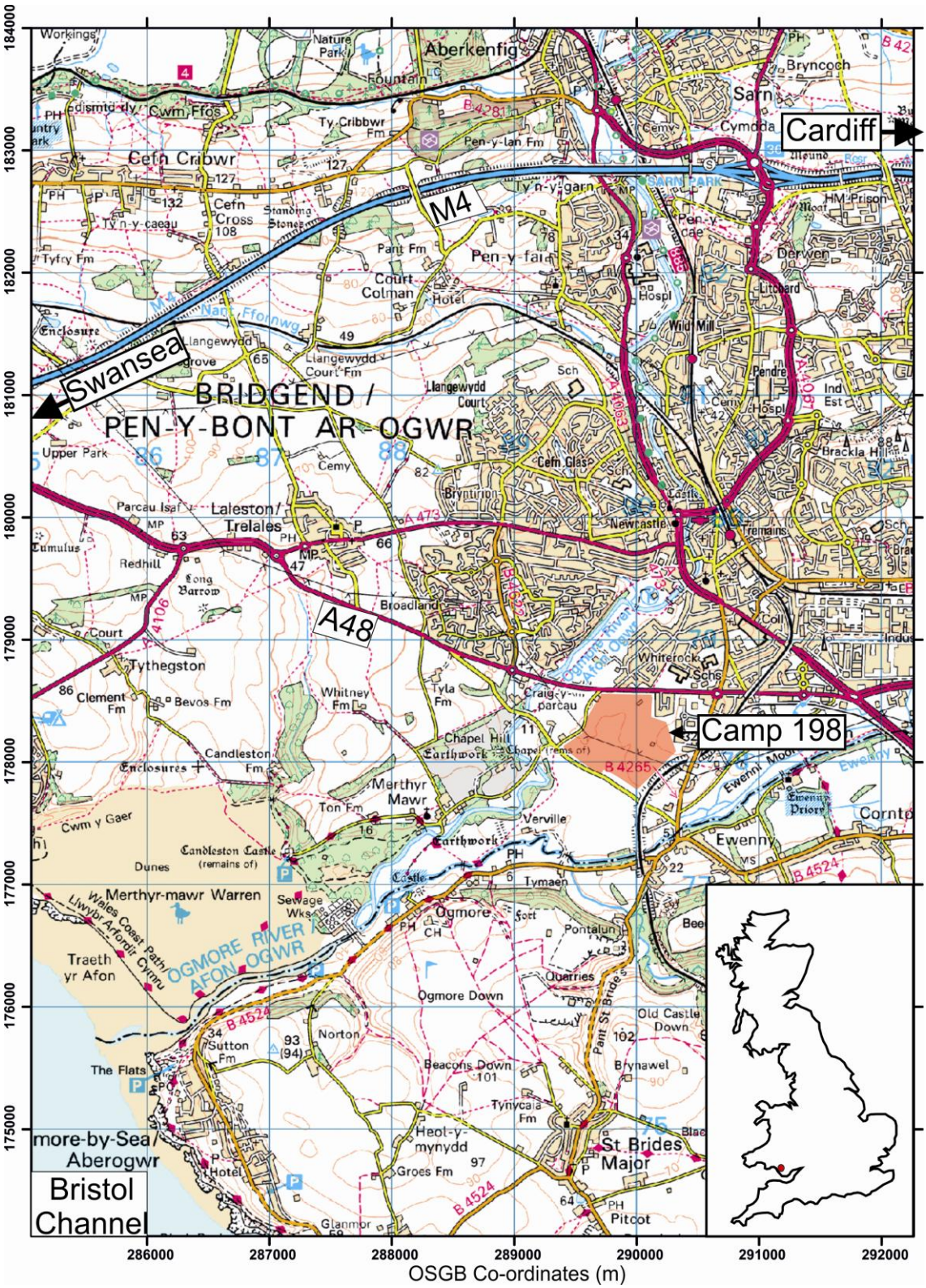


Figure 1. Location map of WW2 Axis P.O.W. Camp 198, Bridgend, South Wales, with UK location (inset). Map courtesy of EDINA™ DigiMap (2016).

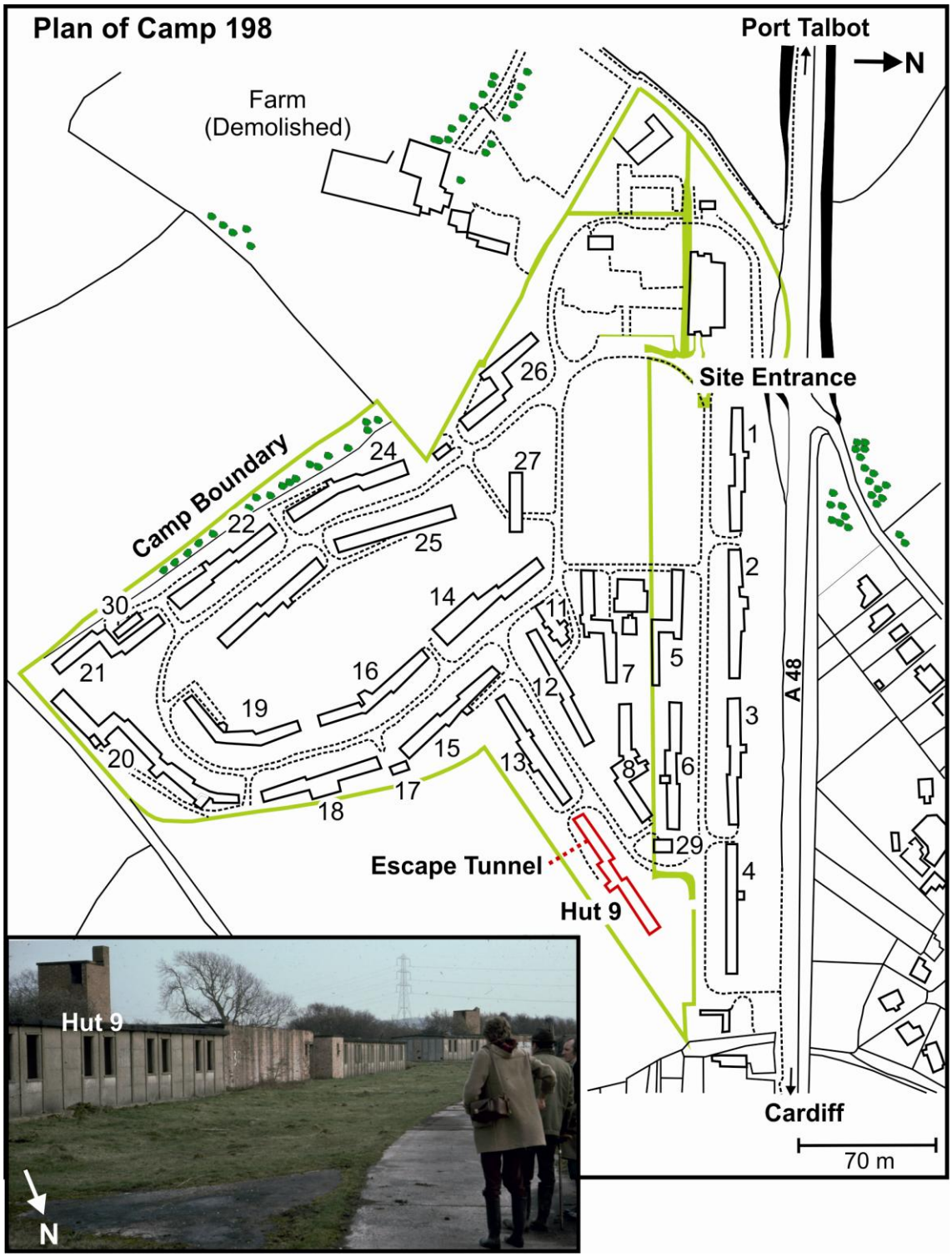


Figure 2. 1945 plan of Axis Special Camp XI that was P.O.W. Camp 198 (see key for detail and Fig. 1 for location), with Hut 9 (boxed) and approximate escape tunnel (line) locations shown, with (inset) photograph circa. 1975 taken onsite with main Huts still intact (Hut 9 in foreground), courtesy of Alun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

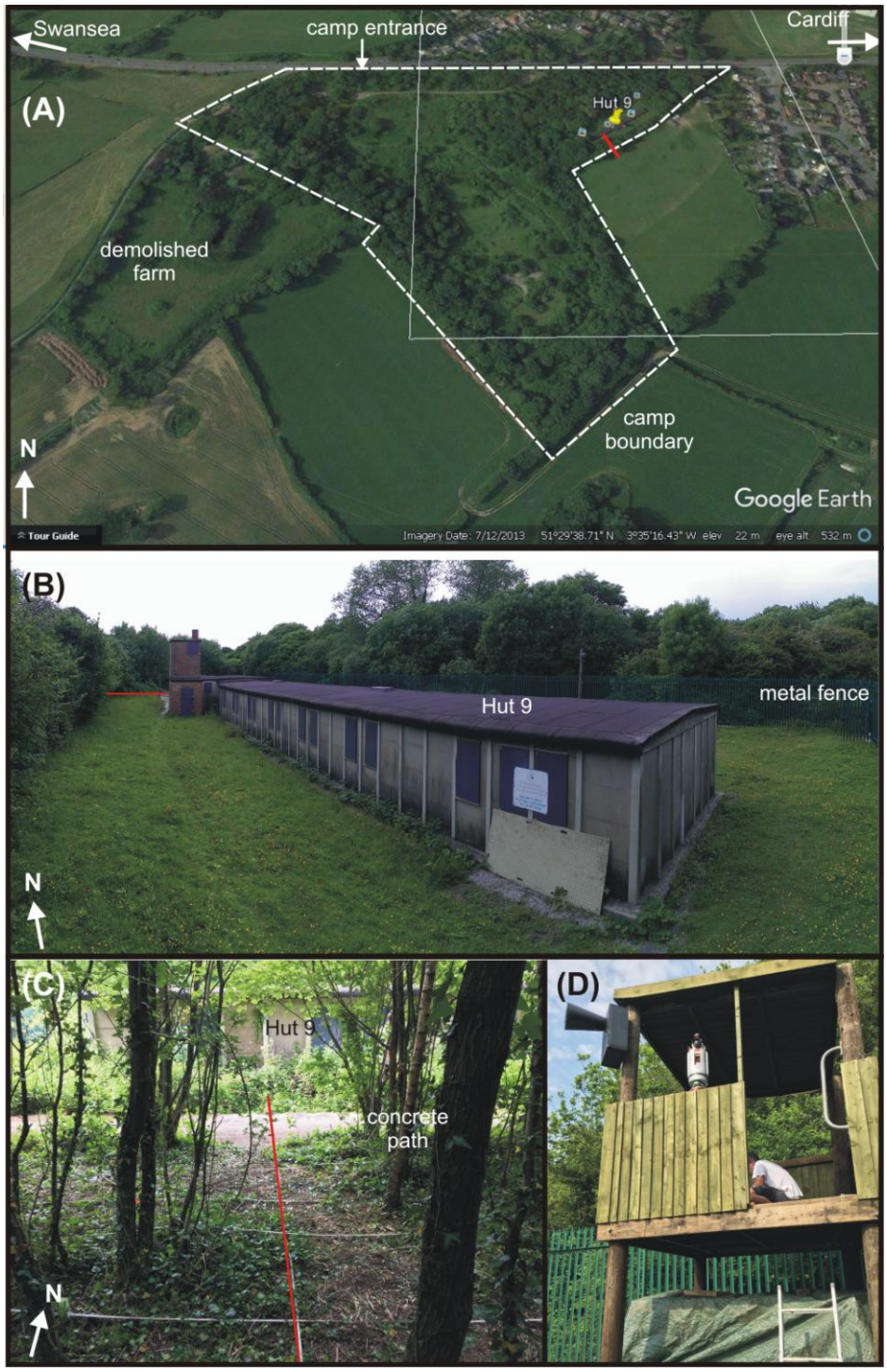


Figure 3. (A) Annotated site map, showing camp entrance, boundary (see Fig. 2), and Hut 9 and tunnel location (red line). Courtesy of 2013 GoogleEarth™. (B) Hut 9 photograph (taken from replica watch tower) and approximate tunnel location marked. (C) Site photograph of approximate tunnel location (red line), with some geophysical survey profiles (tapes). (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.

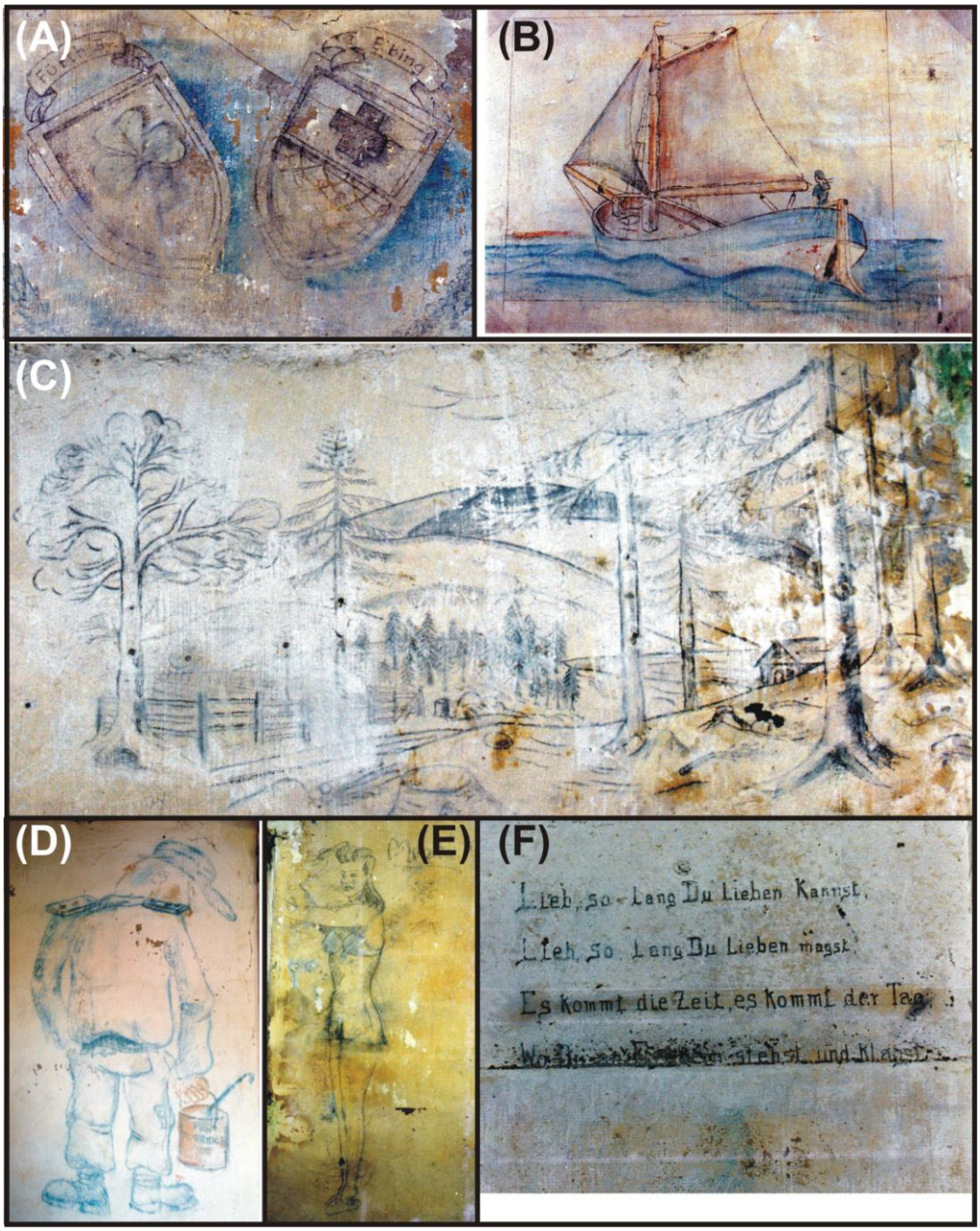


Figure 4. Example of Axis hand-drawn graffiti on camp Hut walls, some of which were saved and remain in Hut 9. (A) City shields of Fürth (Bavaria) and Elbing (East Prussia now Poland). (B) un-identified fishing boat. (C) rural German? Scene. (D) unflattering sketch of camp guard with 'POW porridge' inscribed on bucket. (E) one of less saucy female sketches. (F) one of the inscriptions, this loosely based on Ferdinand Freiligra'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'.

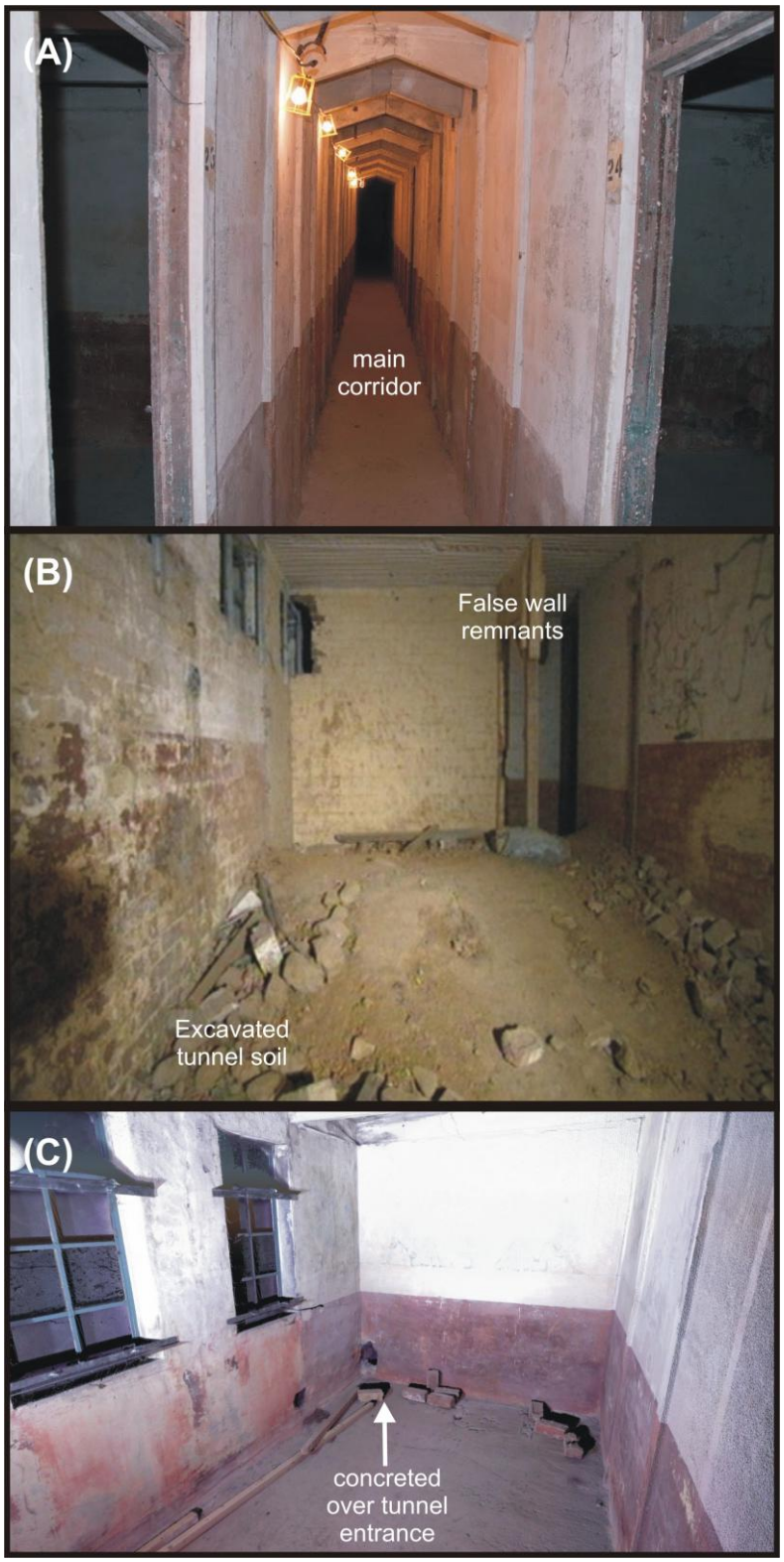
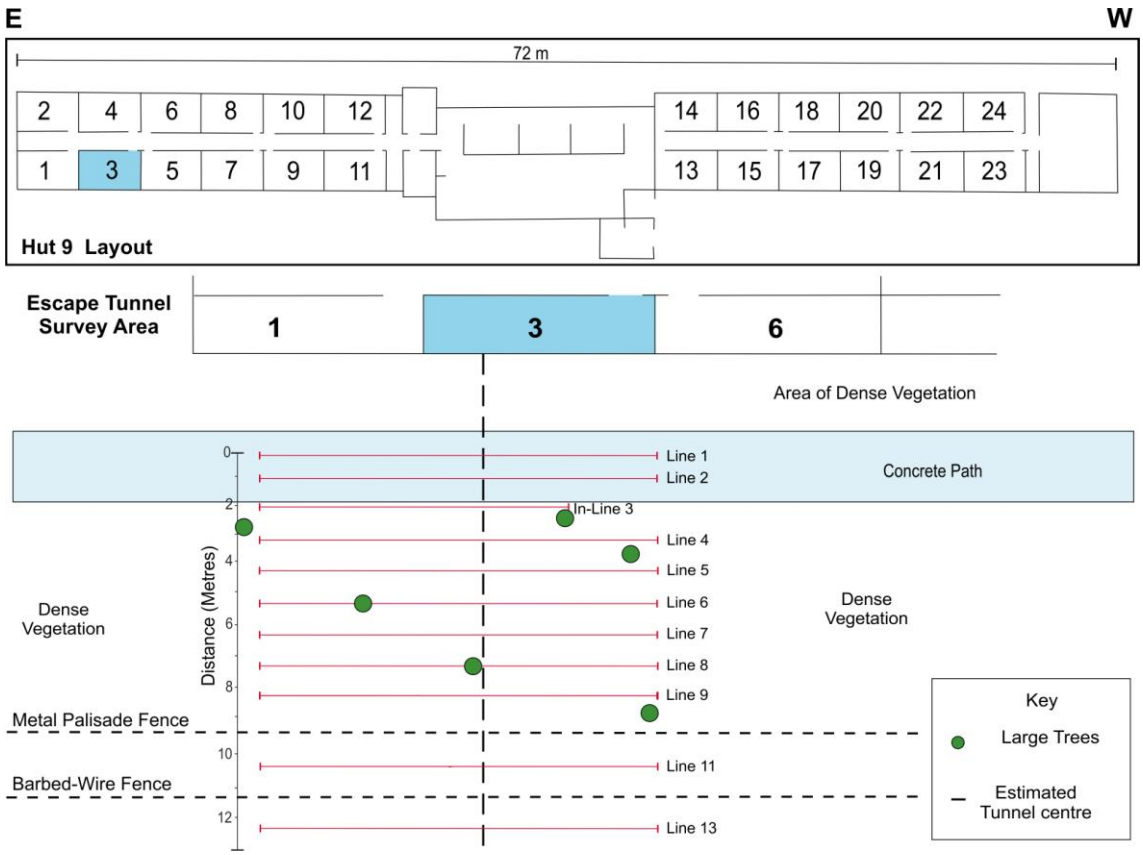
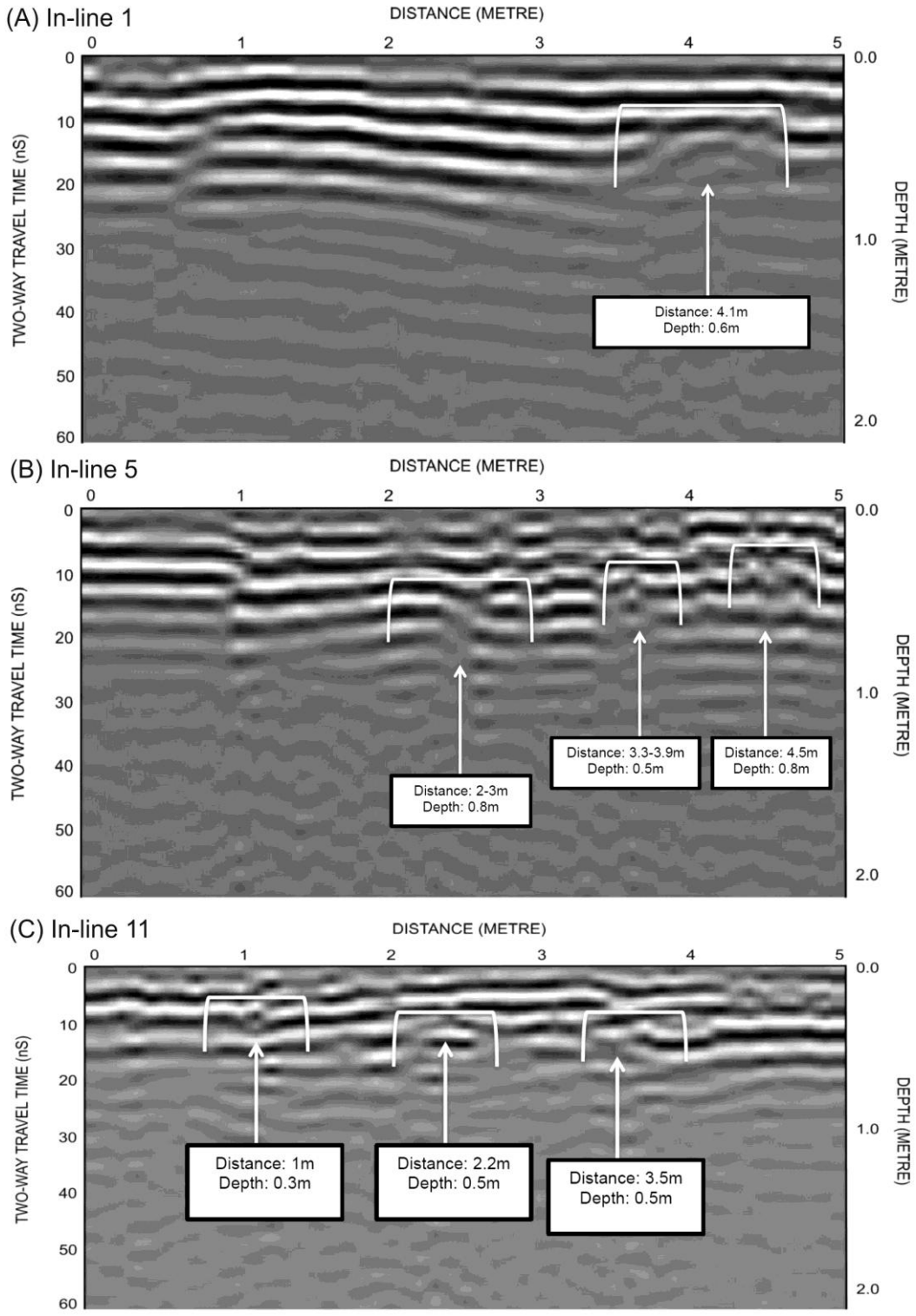


Figure 5. Hut 9 photographs. (A) The main corridor running along Hut 9 with P.O.W. rooms either side. (B) Shower room with prisoner-made fake wall which was used to hide excavated tunnel material. (C) Room 3 where the tunnel entrance was located. (A) and (B) courtesy of Hut 9 preservation group.



819

820 **Figure 6.** Mapview plan of the suspected P.O.W. escape tunnel area, showing above
821 ground objects of interest, numbered rooms within Hut 9, the 2D geophysical survey
822 line (1-13) positions and the presumed tunnel exit location.



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

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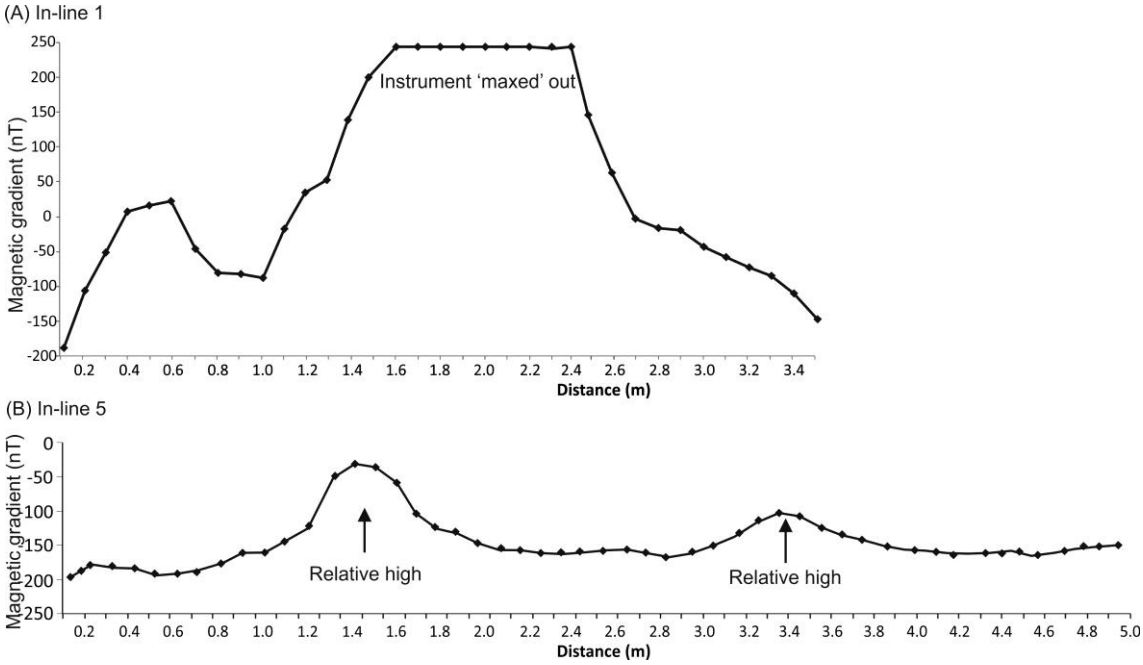
827



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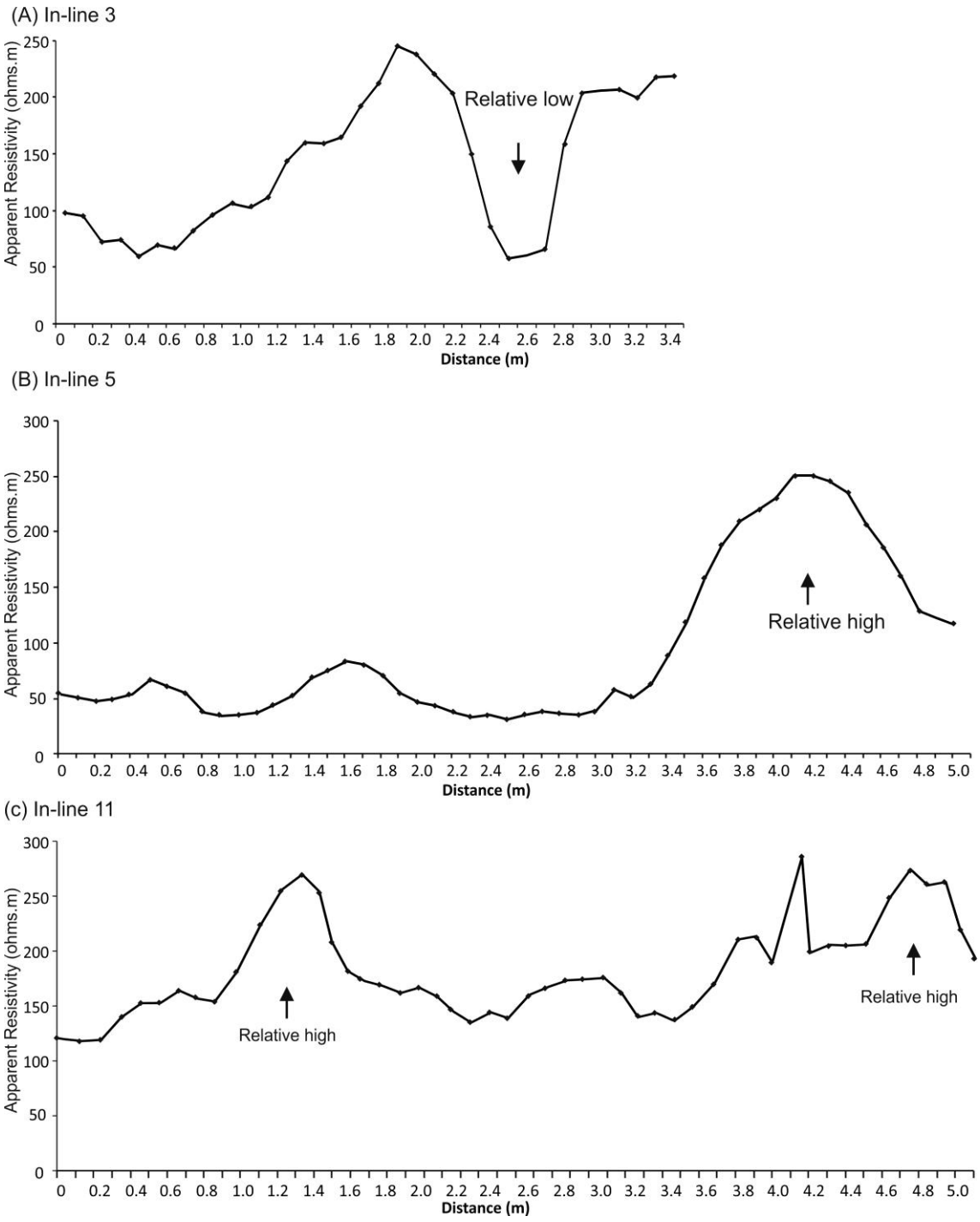
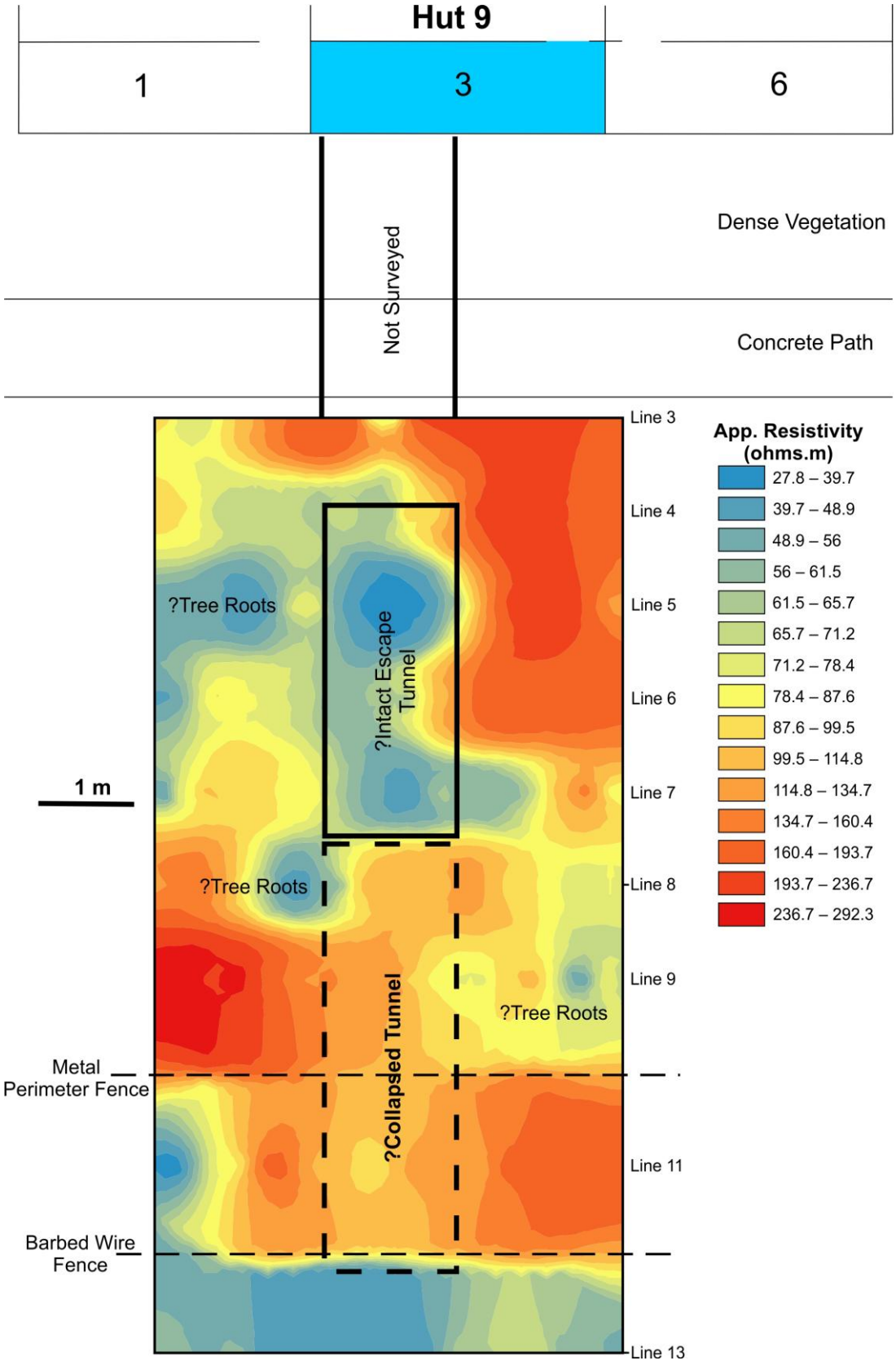
829 **Figure 8.** Selected magnetic gradiometry 2D processed interpreted profiles acquired
830 over the presumed tunnel location at: (A) 1 m, (B) 5 m from Hut 9 (see Fig. 6 for
831 location).



832

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



836

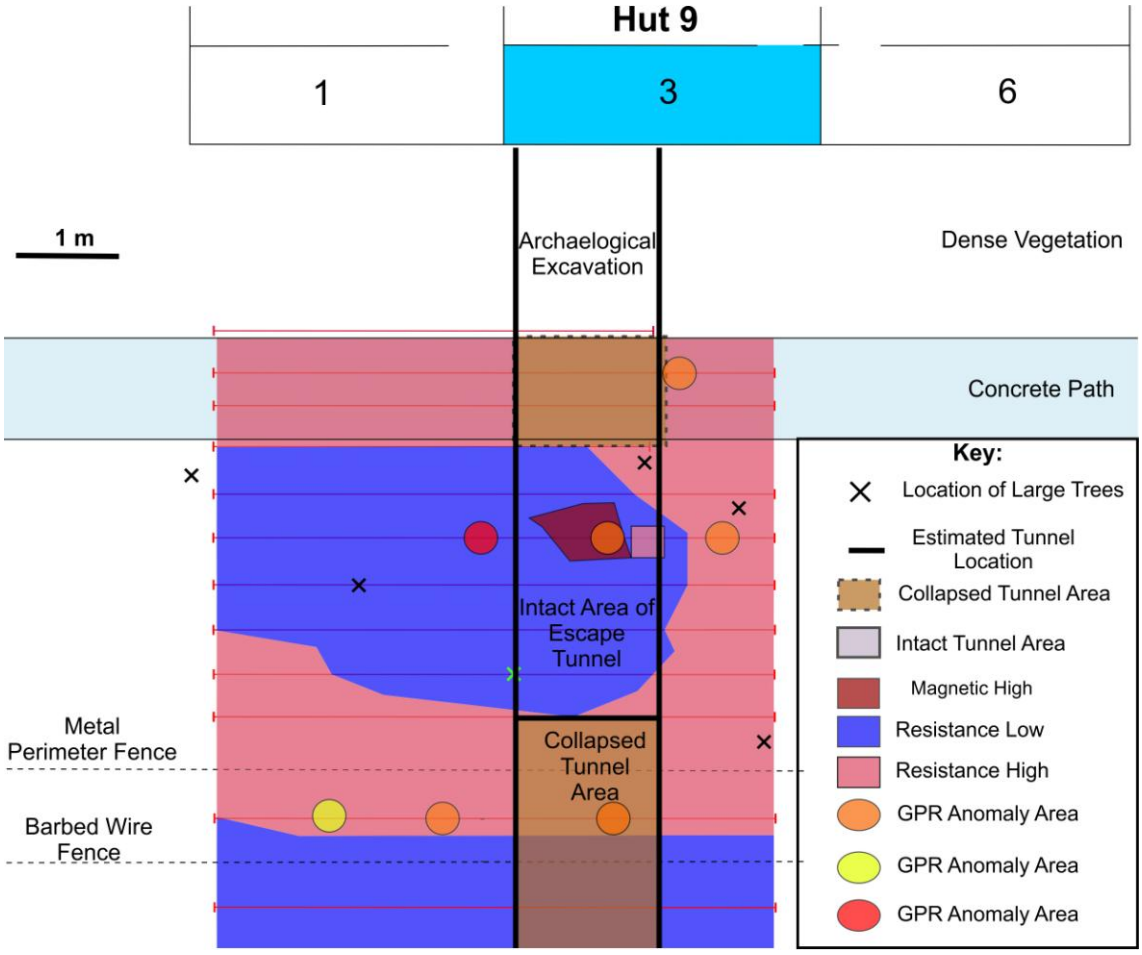
837 **Figure 10.** Mapview of the coloured digital contoured surface generated from the 2D
838 apparent resistivity 2D profiles (see Fig. 6 for location).

839

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

843

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



847

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

850

851 **TABLES**

P.O.W Camp, Location & Country	Escape Date	Tunnels (L= Length, BGL = Below Ground Level)	Escapees & (success-ful escapes)	Documented information sources
1. Dulag Luft, Oberursel, Frankfurt, Germany	June 1940	***Unknown***	18	*Geck, S. 2008. Dulag Luft / Auswertestelle West: Vernehmungslager Der Luftwaffe Fuer Westalliierte Kriegsgefangene Im Zweiten Weltkrieg, Internationaler Verlag Der Wissenschaften, Berne*
2. Camp 13, Swanwick, Derbyshire, UK	20/21st Dec. 1940	L: 13m	5	*Burt, K, Leasor, J. 1956. The One That Got Away, Granada Ltd.*
3. Angler POW Camp, Ontario, Canada	20th April 1941	***L:*** 45m	28	*Chisholm, B., & Gutsche, A. 1998. Superior: Under the Shadow of the Gods, Lynx Images*
4. Oflag IV-C, Saxony, Germany	29th May 1941	***L:*** 16m	12	*Reid, P.R. 1952. The Colditz Story, Hodder & Stoughton Pubs; Eggers, R. 1961. Colditz: The German Story, Robert Hale, London,*
5. Oflag-VII-C, Laufen, Bavaria, Germany	4/5th Sept. 1941	***L:*** 6m ***Bgl:*** 2.5m	6	*Reid, PR. 1952. The Colditz Story, Hodder & Stoughton. London.*
6. Biberach an der Riss, Baden-Wutttemburg, Germany	13th Sept. 1941	***L:*** 44m	26 *(4)*	*Duncan, M. 1974. Underground from Posen, New English Library, Los Angeles, USA*
7. Camp R, Red Rock, Ontario, Canada	Sept. 1941	***L:*** 2m	1	*Zimmermann, E.R.2015. The Little Third Reich on Lake Superior: A History of Canadian Interment Camp R, University of Alberta Press.*
8. Oflag IV-C, Saxony, Germany,	15-20th Jan. 1942	***L:*** 44m Bgl: 8.6m	N/A (Found)	*Reid, PR.1953. The Latter Days, Hodder & Stoughton Pubs, London.*
9. Campo 57, Gruppignano, Udine, Italy	30th Oct. 1942	***L: 30m***	19	*Mass escape from Campo di Concentrame Grupignano, Italy, Available online at: www.3squadron.org.au/subpages/canning.htm Accessed 10th December 2015.*

10. Campo 12, Florence, Italy	29th March 1943	***L:*** 12m ***Bgl***: 3m – 2m (exit)	6	*Hargest, J. 1946. Farewell Campo 12, M. Joseph Pubs.*
11. Oflag XXI-B, Eichstatt, Bavaria, Germany	3/4th June 1943	***L:*** 30m	35	*Crawley, A. 1956. Escape from Germany: a history of R.A.F. escapes during the War, Collins Clear-Type Press, London.*
12. Stalag Luft VI, Hydekrug, Germany	July 1943	***L:*** 44m	7	*Fancy, J. 2010. Tunnelling to Freedom: The Story of the World's Most Persistent Escaper, Aurum Press, London.*
13. Bowmanville Camp, Bowmanville, Canada	Sept. 1943	***L:*** 90m	0	*WWII P.O.W. Camp 30, Bowmanville, Available online at: http://www.camp30.ca/ Accessed 15th December 2015*
14. Stalag Luft III, Zagan, Germany.	Oct. 1943	***L:*** 125m	3 (*3*)	Williams, E. 1949. The Wooden Horse, Collins, UK.
15. Camp 198, Bridgend, South Wales, UK	10-11th March 1945	***L:*** 12m	83	*Phillips, P. 2006. The German Great Escape, Poetry Wales Press, Bridgend* *Williams, H. 1976. Come Out Wherever You Are, Quartet Books Ltd., London.* *Plummer, SJ. 2015. The Greatest Escape, Lulu Self Publishers, North Carolina.*
16. Stalag Luft III, Zagan, Poland	25th March 1944	***L:*** 102m ***Bgl***: 8.5m - 8m (exit)	67 (*3*)	*Brickhill, P. 1952. The Great Escape: Faber & Faber, London*
17. Papago Park, Phoenix, Arizona	23rd Dec. 1944	***L:*** 54m ***Bgl:*** 3m	25	*Moore, J.H. 2006. The Faustball Tunnel: German POWs in America & Their Great Escape, Naval Institute Press, Maryland.*
Average:		**L: 41.5m Bgl: 5.1m**	**19** *(1)*	

852

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

855

Investigation/ Site Variables Soil type: Sand ◐ Clays	Photo-graphs (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										
Ancient	◐	●	◐	◐	◑	◑	◑	◐	◐	◐
Medieval	◐	●	◐	◐	◑	◑	◑	◐	◐	◐
WW1/WW2	◑	●	●	◑	●	◓	◓	●	◑	◑
1960s-1970s	◐	◐	●	◑	●	◑	◑	◑	●	◑
Modern (21st Century)	●	●	●	◑	●	◓	◓	◓	●	●
Tunnel Depths (Below Ground Level)										
0-5m	●	●	●	◑	●	◓	◓	◑	●	●
5-10m	●	●	◑	◐	◑	◑	◑	◑	◑	◐

856

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

859