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Case Report

Discovery of a mass grave from the Spanish Civil War using Ground Penetrating Radar and forensic archaeology

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ABSTRACT

An estimated 500,000 people died from all causes during the Spanish Civil War between 1936 and 1939, with a further 135,000 killed after the war ended. There are currently over 2000 known mass burial locations throughout Spain but many more are unknown. This study details the successful search for an unmarked mass grave in mountainous terrain in the Asturias region of Northern Spain. Two approximate locations were known due to eyewitness accounts. A phased site investigation approach was undertaken, which included Ground Penetrating Radar. Results showed a clear geophysical anomaly on 2D GPR profiles. The identified area was subsequently intrusively investigated by forensic archaeologists and human remains were successfully discovered. Careful and sensitive investigations are essential in these approaches where living relatives are involved.

1. Introduction

In April 2014, the Cienfuegos family contacted the research team that comprised of geophysicists, archaeologists and forensic scientists, to assist with their longstanding efforts to locate the grave of their grandfather, who was shot and buried together with probably ten other victims in a mass grave located in Parasimón in the mountains of Lena, in Asturias in the North of Spain.

Around 500,000 people died in total during the Spanish Civil War between 1936 and 1939, with a further 135,000 estimated to be killed throughout Spain for several years after the war ended [1–3]. There are currently known to be over 2000 mass burials throughout Spain (Fig. 1), with many victims having been exhumed and reburied, especially in the Valle de los Caídos "Valley of the Fallen", but these reburials have not been robustly documented or indeed undertaken scientifically [4–6].

Many other mass graves from this period remain whose locations are unknown in Spain. Successful mass grave detection has been undertaken globally, for example, in 19th Century Irish mass burials [7], USA race riot victims [8], World War Two burials [9,10], in post-WW2 Polish repression mass burials [11], the Northern Ireland 'Troubles' mostly isolated burials [12], the 1990s Balkan wars mass burials [13,14], and sadly in active civil wars with both isolated and mass burials [15].

Mass grave geometries are known to be highly varied, taking the forms of a trench, pit, well organised or sectioned and with variable body densities (see [4,5,17]).

Current forensic search methods to detect both isolated and mass clandestine burials of murder victims are highly varied and have been reviewed elsewhere [18], with best practice suggesting a phased approach, moving from large-scale remote sensing methods [19] to ground reconnaissance and control studies before full searches are initiated [20]. These full searches have involved a variety of methods, including forensic geomorphology [21], forensic botany [22] and entomology [23], scent-trained search dogs [24,25], physical probing [26–28], thanatochemistry [29] and near-surface geophysics [30–37].

Geophysical exploration in mountainous terrains is complicated in terms of logistics, data collection and coverage of large areas

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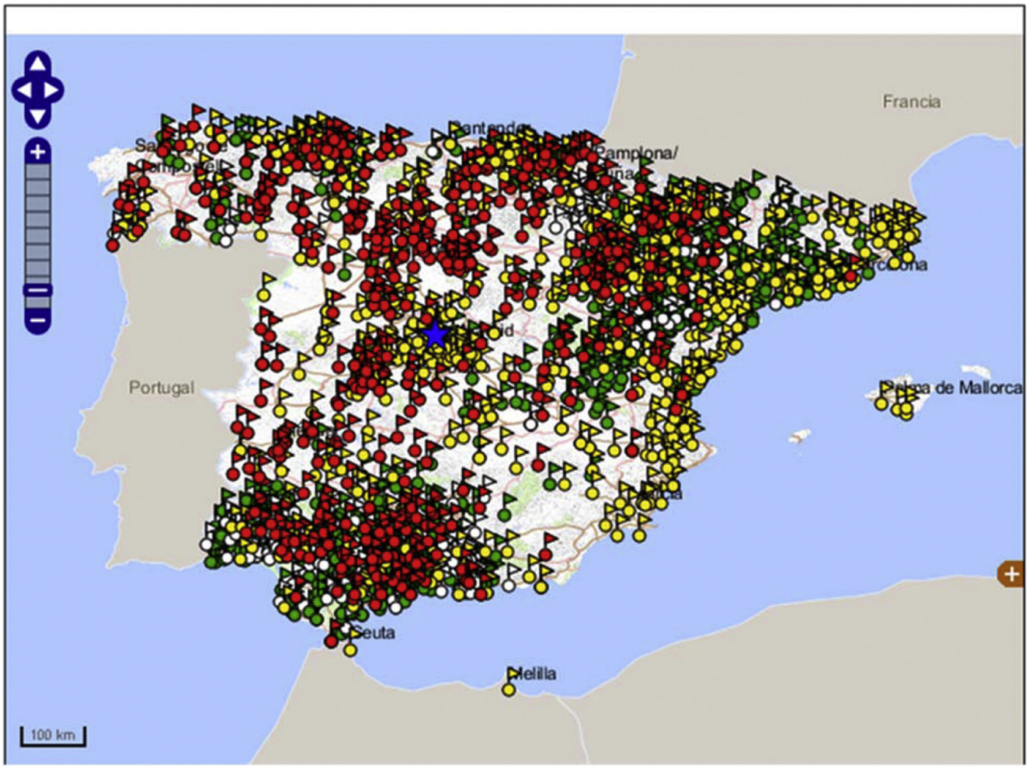

Fig. 1. Map of Spain showing current known positions of ~2000 mass graves (see key and text for details).
Modified from [16].

as [37] states. This paper aims are to firstly detail the geoforensic search for an unmarked Spanish Civil War mass grave in the mountains in Asturias in Northern Spain, secondly to document the resulting forensic archaeological excavation and thirdly to compare results to other mass grave search studies in similar environments.

2. Materials and methods

2.1. Desk study and site description

The proposed search area was in the Parasimón area in the mountains of Lena, in Asturias, in the North of Spain (Fig. 2). Two contemporary witnesses stated the approximate location of a mass grave, although not with certainty due to the time elapsed. Previous archaeological investigations had been performed on site in 2013 and they successfully identified the execution location by recovering munition expendables (bullet cartridge cases, cartridges and a few bullets) of the execution firing line, rather than the mass burial site itself [38].

The search for the mass burial site was prioritised in two areas identified by the contemporary witnesses, designated zone A and zone B in Fig. 2. Zone A was considered to be more probable based on previous archaeological investigations [38]. Recovered munitions had also been reported in this area, although initial surface and botanical investigations did not reveal any obvious potential burial sites and it was relatively common for burials to be exhumed and re-buried in other places during this time [4,5]. Zone B is included because other oral testimonies mentioned it as a potential location. However, witnesses statements were of events more than seventy years ago, witnesses were also positioned more than 500 m away from the study sites and the surface terrain has undergone major changes since those times to the present day.

The bedrock geology in this area consists of a calcareous formation of Carboniferous age. Areas A and B are situated on colluvium deposits filling a hollow between two limestone outcrops to the west and east. The colluvial deposits found here are unconsolidated sediments with abundant presence of angular heterolithic rock fragments interspersed in a silty matrix. The thickness of the soil ranges from 10 cm to 30 cm below ground level (bgl), with sparse bushes and grassy vegetation present (see Fig. 2).

2.2. Geophysical data acquisition

Once the main search zones had been identified, trial geophysical surveys were then undertaken to determine which techniques would be appropriate and their respective equipment configurations following best practise (see [18]). From contemporary witness accounts it was not expected that any metallic items would be buried along with the human remains, and this, together with the presence of high voltage cables and a nearby road (Fig. 2), precluded the use of magnetic and electro-magnetic surveys in this study.

A GPR MALÅ^{TM} ProEx System was used to collect 2D trial profiles (Fig. 3). Whilst other authors in similar mountainous terrains (e.g. [37]) had determined 250 MHz frequency antennae to be optimal, the 500 MHz antennae was determined to be optimal here due to better quality data, when compared to 250 MHz data, and for data acquisition logistics in such mountainous terrain and steep slopes. Lower frequency antennae had also been suggested for detection by control simulated clandestine grave studies (e.g. see [40,41]), but the 500 MHz frequency was judged here to be a good compromise between data quality, acquisition time and successful chance of detection due to adequate resolution.

Full GPR survey grids were then acquired in both zones A and B. There were no geophysical anomalies identified in zone B so only zone A results are discussed here. Zone A had nine local grid survey

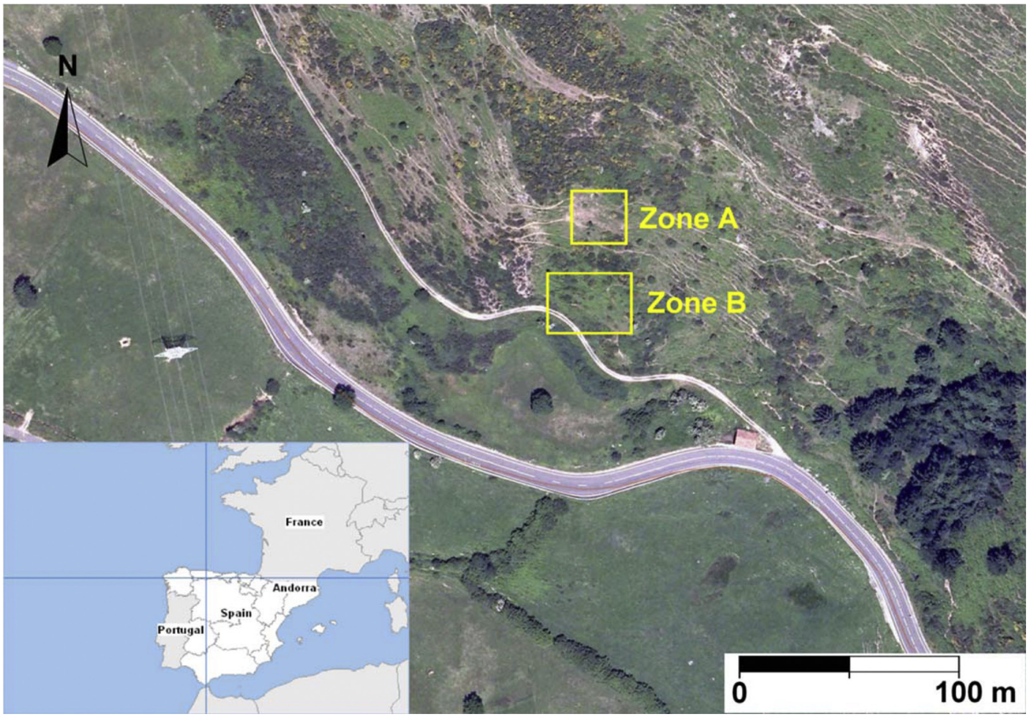

Fig. 2. Aerial photograph showing the mountainous search areas A and B in their surroundings with location map (inset). The centre of the cross in the inset corresponds to the centre of the aerial photograph (43° 00′ 39″ N, 5° 46′ 03″ W).
Modified from [39].

lines (P1–P9) marked and staked, of approximately 27 m at 2 m spacing, orientated Northeast–Southwest (Fig. 4). Four additional perpendicular profiles (P10–P13) of approximately 13 m were also marked and staked (Fig. 4). GPR trace spacings on each 2D profile was 2 cm with automatic stack mode, and a time window of 100 ns was used for all profiles. Standard surveying methods were employed to ensure sample positioning accuracy (see [38]).

Once the 2D GPR profiles were acquired, they were downloaded and imported into REFLEX-Win™ v.6.0 processing software (Sandmeier Scientific Software, Karlsruhe, Germany). For each 2D GPR profile, the first arrival wavelets were first picked and shifted to ensure consistent arrival times at 0 ns. Processing steps were then applied to filter out non target "noise" and optimise image quality. The filtering sequence included the following steps:

Fig. 3. Zone A photograph (looking north) showing the mountainous terrain and the GPR MALÅ™ ProEx system with 500 MHz frequency antennae acquiring data on 2D Profile 3 (see Fig. 4 for location).

(i) subtracting the mean from traces ("dewowing"); (ii) picking first arrivals; (iii) applying static correction and moving the start times for traces in all 2D profiles to 0 ns; (iv) applying a 1D Butterworth bandpass filter; (v) using background removal to reduce any "ringing" effect, and finally; (vi) the gain function was manually adjusted to improve the image quality in each profile.

3. Results

3.1. GPR dataset

No geophysical anomalies were identified in zone B so only zone A results are discussed here. In the 2D GPR profiles collected from South to North (P1–P10), two types of information could be extracted: (a) geomorphological information revealing the internal structure of the colluvial sediments and (b) in three profiles (P3–P5) anomalous geophysical features were detected.

The observed background geomorphological pattern (P8 example shown in Fig. 5b), was:

- Firstly, a "quiet" band of smooth, parallel reflection events from 0 to 10 ns. This "quiet" band could be correlated with the first 10 cm bgl of fine grained top soil.
- Secondly, a sharp contact with underlying "chaotic" reflectors which was horizontal (~10 ns) throughout, except for the north (right) part of profiles where it dips down slightly (Fig. 5).
- Thirdly, below the contact, 2D profiles had discontinuous "chaotic" reflection events down to 60 ns in places, which could be correlated with the 2–3 m thick random accommodation of gravity-driven debris material formed by heterolithic limestone fragments with a silty sedimentary matrix.
- Fourthly, an abrupt loss of signal amplitude was then observed below this "chaotic" band across the whole area (Fig. 5) which was most probably due to the bottom of the colluvium.
- Fifthly, interpreted blue marks correspond to rocks known to be near the surface.

Fig. 4. Zone A sitemap showing key geophysical 2D GPR profiles acquired (P1–P13) with access tracks and bushes/shrub locations also marked. The suggested mass burial site identified from the geophysical survey is marked (red area) together with the archaeological excavation (black rectangle).

In contrast to the background geomorphological features, the observed geophysical anomalies in P3–P5 (Fig. 5a) 2D profiles show quite different characteristics:

- Firstly, the interpreted contact between the top-soil and colluvial sediments (red line in Fig. 5) dips down in the right part of profiles, but this is an artefact of the topographic slope that increases in angle.
- Secondly, there was a clear and significant radar signal attenuation loss about 5 m long along P3–P5 profiles (example shown in Fig. 5a), compared to the areas either side of this position, which will be due to this area having quite different material properties to the background material. This is also shown in Fig. 6.

3.2. Forensic archaeological excavation

An initial forensic archaeological excavation was undertaken over the geophysical survey anomalous area identified in Zone A (see Fig. 4 for location). This was ~1 m by ~5 m and with the purpose of confirming whether or not human remains were present on site. If so, then the procedure in Spain is to report them and then undergo official excavation protocols. Standard logging of the stratigraphic units was also undertaken (see [38,42]).

The trial excavation was successful. A complete left human femur was found in anatomical connection with a pelvis and some phalanges at an approximate depth of 50 cm bgl (see Figs. 7 and 8). The forensic excavation confirmed the existence of the two stratigraphical units identified on the 2D radar profiles: the topsoil with vegetation cover and the underlying continuous yellow-brown, sandy matrix colluvial sediments. The excavation was then halted and the authorities notified for follow-up archaeological excavations.

4. Discussion

This forensic search study for a mass grave from the Spanish Civil War has been successfully undertaken, showing the importance of a careful desk study, including sensitive collection of contemporary witness statements, analysis of relevant modern remote sensing data, then followed by a phased geophysical site investigation approach that worked in difficult, mountainous terrain in Northern Spain. This was in contrast to the unsuccessful similar search study in mountainous terrain for Spanish Civil War mass burials detailed in [37]. The mountainous terrain in this study

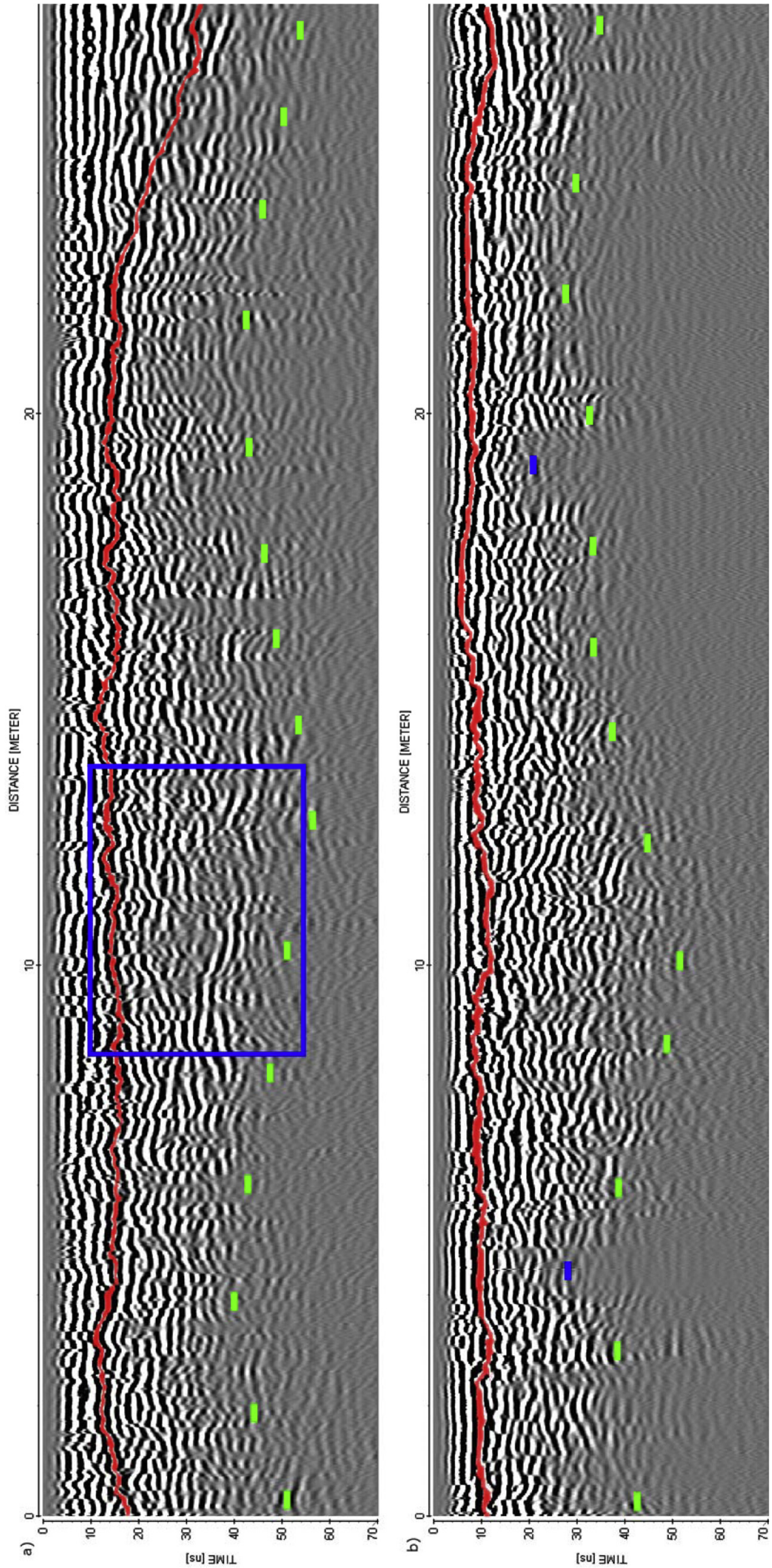

Fig. 5. 2D GPR profiles. (a) Geophysical anomaly examples observed in P3–P5, P4 shown here. Observe the significant signal attenuation inside the blue rectangle that was observed in P3–P5, the spatial positions being marked in Fig. 4. (b) Typical background features shown in P8. Red line indicates contact between soil and colluvium materials, dashed green line indicates the approximate colluvium bottom position and blue dots indicates known large, isolated rock boulders.

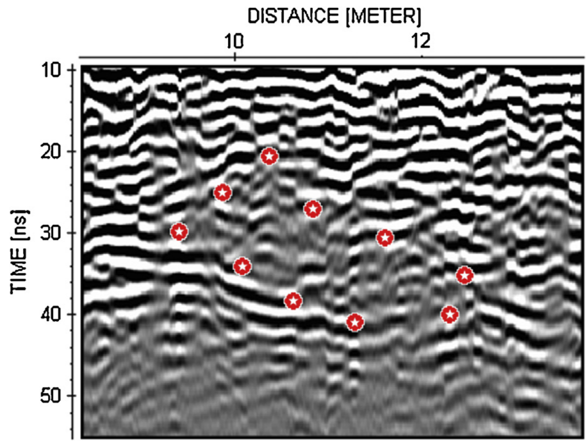

Fig. 6. Detail of the radar signal attenuation area that was observed in P3–P5 2D profiles.

Fig. 7. Photograph of the trial excavation in zone A (Fig. 3 for location) showing the successful detection of buried human remains, note the femur position
Source: Cienfuegos family.

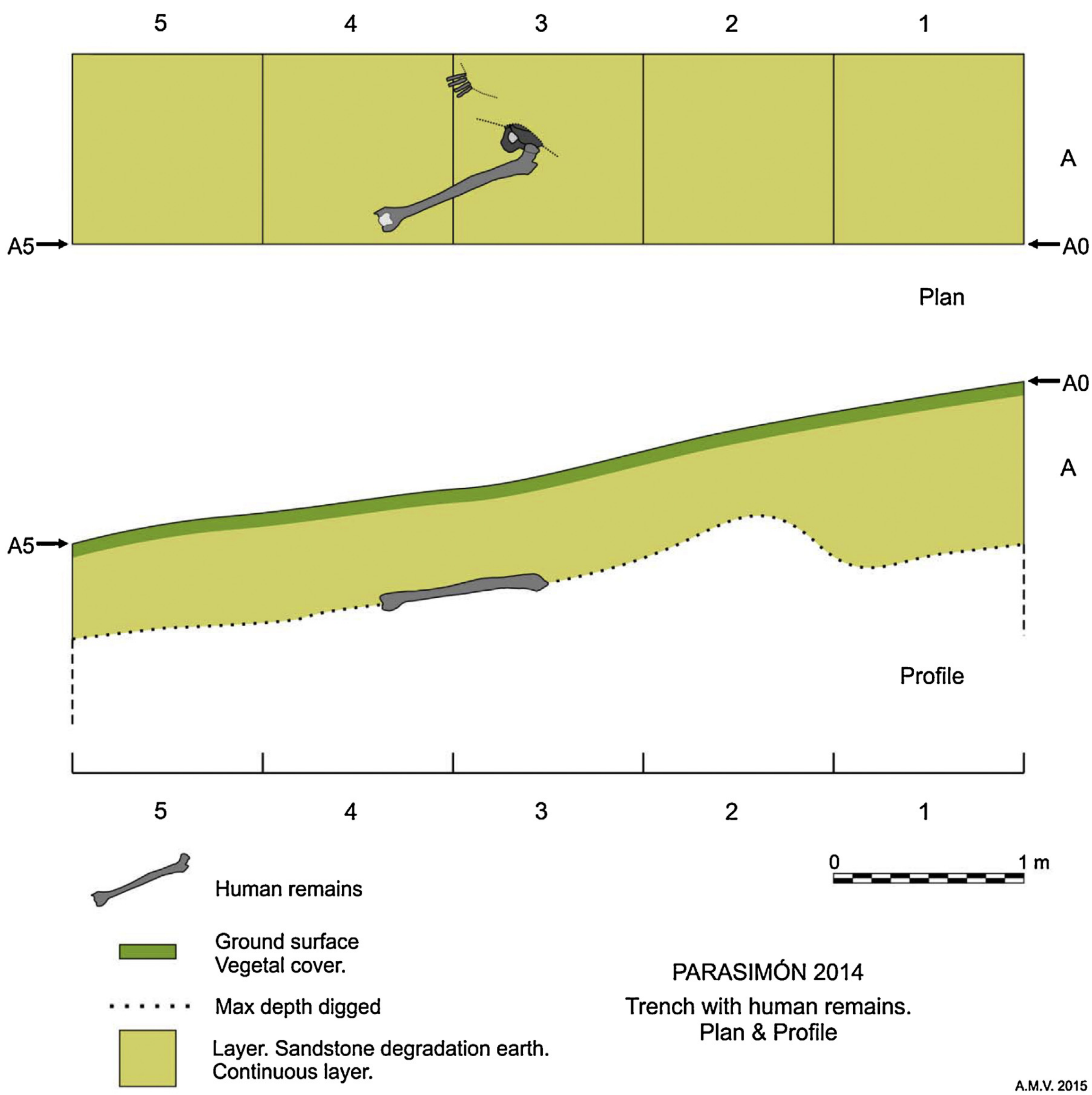

Fig. 8. Plan view, and vertical cross-section, of the trial forensic archaeological excavation, showing the discovered position of the femur, pelvis and phalanges human remains (see key).

necessitated a mid-range GPR frequency antennae to be employed, which would normally decrease the likely penetration depths below ground level, when compared to lower frequency antennae (see [41]), and also resolve other non-target anomalies in the study area. However, the significant radar signal attenuation loss observed in similar spatial positions in three 2D profiles allowed an anomalous area to be identified, targeted and a successful forensic archaeological excavation to be employed. It also did not need a 3D GPR datacube to be created in contrast to the Novo et al. [37] study, because the shape of the anomalous area was traceable using only three 2D profiles. Whilst contemporary witness statements can be of critical importance, the passage of time, the changing landscape and the uncertainty of the exact burial position make a non-invasive site investigation, such as the use of forensic geophysical surveys, an important tool to verify potential grave positions before intrusive site investigations are initiated, even in such difficult mountainous terrain.

It is relatively rare that identified anomalous areas in forensic geophysical surveys are subsequently ground-truthed and the searched-for human remains successfully identified. This study is therefore important to provide survey information and search considerations for other forensic search teams, either working in Spain or in other similar mountainous terrain environments elsewhere, to improve their successful forensic search detection rates. Whilst the searched-for victims were buried over 70 years ago, the initial trial forensic archaeological excavations documented in this study still recovered human remains that look to be relatively well preserved albeit in a skeletonised state. The forensic archaeology recovery results therefore give hope that other mass graves of similar burial age could still hold important forensic evidence and hopefully victim identification.

The results and materials of the investigation have been sent to the Cienfuegos family and to the Spanish Judicial Police. A plaque tribute has been installed in the vicinity of the mass grave. The site shown in this study will hopefully be revisited, following the necessary Spanish permissions, to allow careful exhumation and identification of the human remains before reburial by the victim's families.

There are few published studies to forensically search for mass graves, and fewer still in such difficult mountainous terrain search areas. Brown [13] has documented a successful search for a mass grave located in wooded hilly terrain in Bosnia, Eastern Europe, but using 2D Electrical Resistivity Imaging (ERI) geophysical methods rather than GPR. ERI 2D profiles take comparatively longer to acquire than GPR 2D profiles, and can also be affected by varying soil moisture percentages that can give non-target geophysical anomalies, but they can penetrate relatively deeply in ideal ground conditions down to 50 m bgl that is significantly more than the typical GPR penetration depths of 10 m (see [43]). Electrical resistivity surveys can also work much better in clay-rich soils than GPR surveys, for example [18]. Ruffell et al. [7] successfully used a combination of geomorphological and GPR techniques to locate and characterise a 19th Century Irish human mass burial, albeit these were closely spaced individual burials and the relatively flat surface nature of the site topography did reveal most of the burial locations which were significantly different to the mountainous terrain of this study. Witten et al. [8] used a combination of magnetic and GPR surveys to characterise a 1920s mass burial site in the US, but again the site specifics of flat topography and sandy soil made the magnetic and GPR methods optimal in this investigation. Finally Ruffell and Kulessa [44] used low-frequency GPR to both locate and characterise modern animal mass burial sites in the Republic of Ireland in a peatland soil environment with relatively flat topography. This study therefore provides important information to add to published literature about optimal search methods, techniques and equipment configurations for search teams in difficult mountainous terrain.

5. Conclusions

A forensic search for a mass grave from the Spanish Civil War was undertaken in mountainous terrain in the Asturias region of Northern Spain. Following a desk study, analysis of contemporary witness accounts, initial site reconnaissance and archaeological work, two areas were identified for further investigation. A GPR survey using 500 MHz frequency antennae was undertaken on 2 m spaced survey lines. Significant loss in radar signal attenuation was observed in specific areas in 3 adjacent 2D profiles. Subsequent trial forensic archaeological intrusive investigations were undertaken and the first human remains were successfully located and described. It is now important for the victim's family that the discovered human remains are carefully and sensitively exhumed, correctly identified and properly reburied.

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