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HISTORY | RESEARCH ARTICLE

Virtual approach to a battlefield: Fatarella Ridge 1938. Spanish Civil War

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Abstract: The poliorcetic of the twentieth century was characterized by the use of ephemeral trenches. The transformations caused by agricultural use or urbanization erased the evidence and structures of the combat zones. In the case of the conflict landscapes of the Spanish Civil War, it must be added that the disinterest of the administrations increased the degradation of the archaeological sites. The interest of citizens in the battlefields of the 20th century has increased, and the demand for products and content has led to an increase in academic production and in the interest in cultural industries and tourism. The interpretation of the combat spaces requires the design of elements of didactic intermediation that make accessible to users the knowledge available about said spaces. In this context, virtual archaeology becomes a powerful instrument to recreate and make visible places and situations of conflict. But the didactic virtual recreation of a battlefield requires numerous prerequisites: keeping in mind the archaeological record, the historical documentation, the testimonies of the population, and direct fieldwork in conflict areas. The present work focuses on the virtual 3D reconstruction of the Fatarella Ridge battlefield (14–15 November 1938), where one of the toughest battles of the Battle of the Ebro took place.

Subjects: History; Second World War; Military & Naval History; Archaeology; Heritage

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Keywords: Spanish Civil War; Battle of the Ebro; conflict heritage; virtual archaeology; 3d illustrations; educational illustrations; citizenship

1. Introduction

The Battle of the Ebro, fought between July 25 and 16 November 1938, and won by the fascist forces of General Franco, was the harshest and bloodiest of the Spanish Civil War. The troops of the Spanish Republic and the revolted forces of General Franco, that had the support of Hitler and Mussolini, who contributed large amounts of troops, aviation, and supplies, faced each other. In turn, the republican forces had, at the beginning of the battle, international volunteers and Soviet material (Henry, 1999). The Battle of the Ebro, beyond the fighting, was also a space of confrontation where Germans, Soviets, and Italians experienced the effectiveness of their weapons and their war tactics (Hernàndez Cardona & Rubio-Campillo, 2017). The battle was fought against the background of the expansion of Nazism, which after dominating Austria, threatened Czechoslovakia. Everything indicated that the first combat of World War II was going to be fought in the Ebro, but the Munich pact postponed the international confrontation. The world was aware of the long combat that became symbolic and emblematic of the anti-fascist struggle. (Figure 1)

The republican troops crossed the Ebro River at the end of July 1938 and drove back the Francoist forces which, as of August, counterattacked en masse. At the beginning of November 1938, after three months of fighting, the Republican army began to retreat to their initial positions, crossing the Ebro River again. But this manoeuvre was not easy, the troops of the V Republican Army Corps fell back in disarray. On the contrary, the XV Army Corps, led by Lieutenant Colonel Manuel Tagüeña, withdrew in an orderly manner, saving most of its troops, between November 14 and 16, 1938 (Tagüeña, 1973).

At the beginning of August, the republican advance was paralyzed in front of the population of Gandesa (Mezquida, 1963); it was felt that the battle could be long. Tagüeña decided to build a fortified line in his rear, between Riba-roja, the mountain range of La Fatarella and Ascó, covering a line of about 20 kilometers. (Figure 2a). The defences, formed by trenches and concrete pillboxes, were conceived as a security perimeter in case it was necessary to go back to the other side of the river and to maintain a bridgehead and the presence on the right bank in the moment of withdrawal (Rams & Pérez, 2010). After three months of fighting, it was time to withdraw. As of

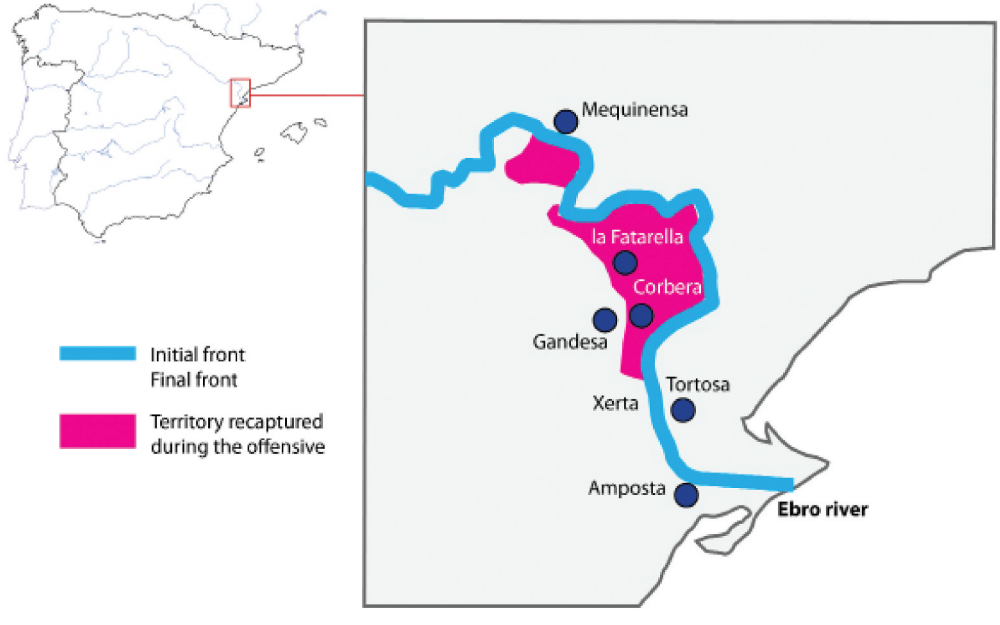

Figure 1. Location of the Battle of the Ebro.

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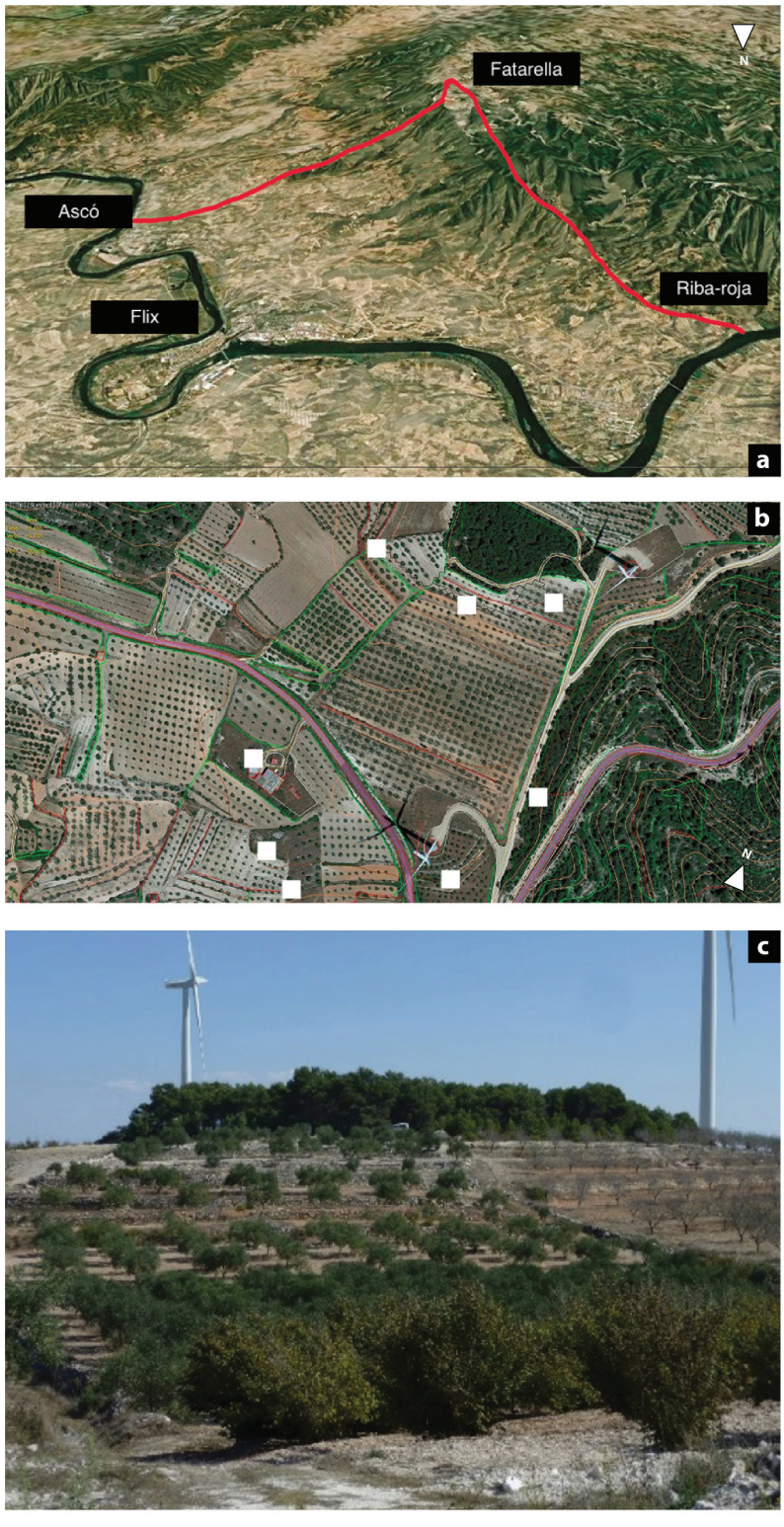

Figure 2. (a) Fortified line "Riba-roja, la Fatarella, Ascó". (J.R. Casals—Didpatri-UB). (b) Raimats area today. In white, the concrete pillboxes are located (ICGC). (c) Grove of elevation 563, the highest of the Fatarella line.

November 14, the divisions of the XV Army Corps fell back and took shelter from the fortified line of Fatarella. The republican troops began to slowly cross the Iron Bridge of Flix. To protect the retreat, several units composed, above all, of volunteers, established the fortified line along Fatarella Ridge. In the Raimats area, the *Pla de Carinyo* plain was the highest point of the line, and in turn, the most vulnerable since it was a plateau that could be crossed by armoured vehicles. (Figure 2b; Figure 2c). For this reason, it was the most fortified sector, with deep defences: two entrenched lines that had numerous concrete pillboxes and long anti-tank moats. If the Francoist troops forced Raimats, they could reach the near limits of the mountain range of la Fatarella that fell towards the Ebro River, and from these positions, they could direct the artillery fire against the accesses to the Iron Bridge of Flix, and destroy the divisions of Tagüeña. For the republicans, it was vital to maintain the line until the bulk of their troops had crossed the Ebro.

On November 14, in the afternoon, the bloody battle of Fatarella Ridge began (Rubio-Campillo & Hernández-Cardona, 2015). Franco's troops of the 82nd division attacked in a whirlwind, the Republicans resisted but lost the positions of the advanced line and some sectors of the second line. When night came the Republicans counterattacked and recovered the upper areas of the defensive line. On the morning of the 15th, the Francoists began the attack again using armour (Pz1 and T26 captured). The tanks approached the concrete blockhouses and fired directly at the embrasures. Republican resistance ceased in the early afternoon. It is not known if there were survivors, but the Francoists arrived late, most of the Republican units were already safe on the other side of the river. The resistance in Raimats had contributed to saving the XV Army Corps (Sospedra-Roca et al., 2018).

Little evidence remained of the bloody battle. On the Republican side, there is only one report from Rojo to Negrín on the withdrawal, and on the Franco side fragmentary reports (of the activity of land and aviation units), as well as the imprecise diaries of the 82nd division that carried the weight of the attacks (Anonymous, 1945).

In the days that followed the combat, the Francoist units proceeded to camp in the area, removing corpses and collecting war material. The residents and owners of the land, who were able to access it when the troops withdrew, recovered various abandoned materials (blankets, boxes, construction material …). A unit of Italian engineers proceeded to study the fortified line and the conquest process and produced a report with photographs of the pillboxes and the impacts they had received (Comando Truppe Volontarie, 1938). During the entire campaign of the Battle of the Ebro, the Italian technicians, and to a lesser extent the Germans, documented everything that could be of interest from the perspective of future conflicts.

In the years that followed, the remains of the line gradually disappeared. The Spanish military blew up the pillboxes, which were clogged. In turn, the rural owners proceeded to do various and successive restructuring of the fields and eliminating the trenches and anti-tank ditches to optimize their fields. The land and oblivion buried the Fatarella line and the memory of the fighting. However, at the end of the 70s of the 20th century, Colonel Martínez Bande (Martínez Bande, 1978), of the Spanish Military Historical Service, published an extensive work on the Battle of the Ebro that included a few photographs of the Italian engineers' reports on the pillboxes of the Fatarella.

In 2005, researchers and scholars of the territory, from the "Lo Riu" association, based on the information from Martínez Bande, began to search for the remains of the forgotten battle. Nobody knew of the existence of the pillboxes; however, it was clear that they had existed since the Italian photographs showed it. Little by little, remains of trenches were located and interpreted and some of the pillboxes began to be located (Solà, 2015).

As of 2010 "Lo Riu" Association and the research group DIDPATRI (Didactics of heritage) of the University of Barcelona, which worked on a horizon of public archaeology, agreed to join forces to document the battlefield and make it accessible, understandable, to the public.

2. Methodology

2.1. General objectives

Around the Battle of Raimats, the DIDPATRI research group developed a program of activities based on the criteria of public archaeology, which established the need to operate in collaboration with the civil society of the territory. Strategic lines were proposed to be developed in parallel that should be adding information that would allow, in a dialectical relationship, to make progress in the identification and interpretation of the battlefield landscape and its evolution. In 2010, the territory was analyzed based on aerial photography and systematic inspection, through fieldwork, of the supposed surroundings of the fortified line that already had first and solid documentation collected by the surveys carried out since 2005 (Rams & Pérez, 2010). As of 2011, the archaeological campaigns and consolidation of structures began, which continued in the following years. The investigations were alternated with socialization initiatives: scientific articles, publications, days of historical recreation, historical memory activities … and the creation of an extensive iconographic program that included 2D and 3D proposals to make the battlefield understandable and what had happened in it. Regarding the dissemination, communication, and didactics, the general objectives that were set were concise:

a) Elaborate a didactic 3D of the fortified line of 1938, with hyper-realistic criteria, easy to interpret, that would allow the integration of the different knowledge that could be obtained from research on the landscape, structures, buildings, and other combat structures and defence of the battlefield.

b) Develop an extensive 2D iconographic program based on *matte-painting* and video that could take advantage of the images generated by 3D as a background to present specific moments and situations in the history of the defensive complex (construction, equipment, combats, destruction …)

c) Project 3D, and the iconography generated to its surroundings, as a communication and dissemination instrument to make known to citizens and productive environments (cultural industries, cultural tourism …) ongoing research, from different supports: publications, web, video, didactic iconography, apps.

d) Provide added value to 3D by progressively integrating graphic information regarding new knowledge provided by historical and archaeological research.

2.2. Archaeological activity

From the first approximations in 2010, and 2011 archaeological work began with the aim of locating trenches, pillboxes, funnels caused by bombs, and various defence structures. Materials were recovered through the use of metal detectors and, in the most critical areas, surveys were carried out using georadar and gradiometers, which did not provide decisive information. The information was conveniently integrated, from GIS, allowing the elaboration of cartographic proposals on lines of sight and enfilade (Rubio-Campillo & Hernández-Cardona, 2015).

At the end of 2011, researchers from the CSIC (Consejo Superior de Investigaciones Científicas) and the University of Barcelona (DIDPATRI) proceeded to excavate the trenches adjacent to the grove that crowned the area of *Pla de Carinyo*, in Raimats. The results were spectacular (González-Ruibal, 2012). The excavations carried out revealed a fierce combat: hundreds of shells, fragments of shrapnel, hand bombs, artillery, and mortar shells. The remains of a Republican combatant were also located (Hernàndez-Cardona, 2018). The archaeological work, although it only involved a small part of the battlefield, uncovered numerous defensive structures: trenches and pillboxes that provided very significant information and confirmed that the Battle of Fatarella Ridge had been a real hell. (Figure 3a; Figure 3b)

Figure 3. (a) Hundred cartridges and pods recovered in the trenches show the hard battle of Raimats (Photo: Didpatri-Ub). (b) Some combatants were buried by the explosions (Photo: Didpatri-Ub)(Photo: Didpatri-Ub).

2.3. Oral history, anthropological-ethnographic and landscape research

When the systematic investigations of the battlefield began, there were no people left in the Fatarella who had known the facts directly; but there were descendants of the agricultural owners where the battle took place, who perfectly remembered what their relatives had explained to them regarding how they had found the place and how what happened was related. This made it possible to collect valuable information about the casuistry of different places and the location of cabins, shacks, tracks, and defensive structures, as well as stories about how the defensive line had been built and what the soldiers' relationship had been with the people of the town. The joint surveys with the members of "Lo Riu" generated levels of trust that allowed, from an ethnographic research perspective, to collect information from interviews and participant observation. This information was decisive to conceptually imagine what had been the hardcore of the Fatarella Line in the Raimats area and what its components had been. In collaboration with the owners of the land and with older people who kept various information, the battlefield was surveyed looking for small details that would provide information: current crops, the period in which the new cultivation terraces were built, the existence of barracks vineyard, etc. In some cases, and taking into account the impacts of the recovered pillboxes, it was possible to establish with some precision from where the tanks that attacked the defensive line on November 15 had fired. The average distance could be evaluated at about 50 meters. (Figure 4a)

Figure 4. (a) Archaeologists contrasting information with local historians (Lo Riu Association) (Photo: Didpatri-Ub). (b) Italian engineers visiting the fortifications of Raimats after the battle. The group poses in front of pillbox number 2 (AGMA). (C) Monument erected by Didpatri and Lo Riu in memory of the republican combatants (Sculpture by Mar H. Pongiluppi. Photo. Didpatri-UB).

2.4. Historical documentation

The works to gather historical documentation on the battlefield were constant. The dossier of the Italian engineers of the General Military Archive of Ávila was consulted and photographic information was recovered from the *Ufficio Storico de l'Aeronautica*. Textual sources were also considered. The Italian dossier provided decisive information that made it possible to locate and analyze the pillboxes that closed the exit of the *Pla de Carinyo*. (Figure 4b)

2.5. Museography and socialization processes

In parallel to the research, were developed different socialization actions. Trenches were consolidated; a pillbox was rebuilt, based on experimental archaeology, and monuments were erected in memory of the combatants of the XV International Brigade, 15 Mixed Brigade, and Lieutenant Colonel Manuel Tagüeña. At the same time, numerous historical recreation activities were carried out, with the simulation of advances and combats, which also provided interesting information: more useful routes, lined up areas … The socialization of the acquired knowledge also entailed the holding of conferences, didactic materials, sessions with educational centres, and the publication of articles and books. (Figure 4c)

2.6. 3D didactic iconography

The socialization of the battlefield needed to establish comprehensible proposals for users of a wide spectrum. This implied providing concrete and didactic iconography of the scene of the combats and hypothetical images of how these could have developed. Certainly, there were photographs of elements of the battlefield taken by Italian engineers, but they were taken after the fighting. They showed the effects of the fight, but not enough to give a holistic view of the defensive line. In turn, the generation of group images could become, implicitly or explicitly, another instrument for research and documentation as it allowed locating and making hypotheses about the most diverse casuistry regarding the documented remains. In this sense, the 3D cartographic and iconographic survey was also defined as a scientific research initiative with a didactic projection. The option was to build a 3D model that allowed a holistic perception of

the complex and their different points of view. It would allow the array of weapons and to be an operational instrument to help to continue the research (Sospedra-Roca et al., 2022).

The representation of contemporary fortified lines and 20th-century battles, from a structural and landscape treatment point of view, was not a novelty. The experiences were multiple and many of them had been developed with didactic intentions. They had been represented from panoramic images, Napoleonic Battles and the American Civil War, the battlefields of World War I had been approximated from a photographic panoramic image; and different historical battles had been presented from diagram blocks or infographics (Macdonald, 2015). In turn, some contemporary fortifications, such as the pillboxes of the Maginot line, had been meticulously mapped and drawn, with more or less technical or more or less artistic proposals, in numerous publications that incorporated sections, cuts, interior views, etc. (Allcorn, 2003). The case of Raimats was simpler since the concrete structures were limited to small pillboxes, and the challenge was precisely to represent a deeply entrenched field punctuated by small fortifications.

From a conceptual point of view, the realization of the virtual reconstruction did not present too many difficulties, even though the work was laborious. The different elements and structures had been documented and located from the cartography of the ICC (Institut Cartogràfic de Catalunya). The sketches were contrasted with the opinion of owners and people involved in the environment, making successive corrections. The whole of the 3D allowed the targeting from the most diverse points of view and the generation of virtual flights over the battlefield.

A first survey of the terrain was carried out in 3D from the topography, placing the current structures and communication routes to establish physical references that would allow the reconstruction of the missing parts of the defence and communication lines, complemented with satellite photography for better identification.

The information obtained in the successive archaeological campaigns and in situ recognition of the visible structures made it possible to locate (in most cases with precision), the forts and main defense structures, reconstructing them in section and plan and hypothetically locating the trenches of escape and communication around the unidentified pillboxes. The hypotheses of the little documented elements were established based on the most common models of republican engineering (Group of Fortifications and Works Units, 1938, p. 7–10), but without developing a work based on quadratic error criteria. medium (RMSE) that were not considered necessary.

Once the visual lines of the photographs in the Italian archive had been studied in the field, it was possible to complement the distribution of the structures by establishing reference points that would allow the reconstruction of some of the antitank defence lines and other communication trenches necessary to complete the complex, which came from popular memory, but had not left visible traces. The main access road and other secondary roads were also reconstructed, based on the identification of visual references in old photographs.

Once the general reconstruction of the complex had been validated, we proceeded to texturize and add details based on the photographs of the Italian engineers, which showed the pillboxes, their entrances and the construction process (one of them was half-built during the battle) as well as their camouflage.

All the work was done with the 3D Studio Max software. With this model, images of general and detailed views of the pillboxes were generated, being able, on the one hand, to obtain a real image from the point of view of each pillbox and, on the other, to check the lines of fire from each pillbox in a view in a plant. (Figure 5a; Figure 5b)

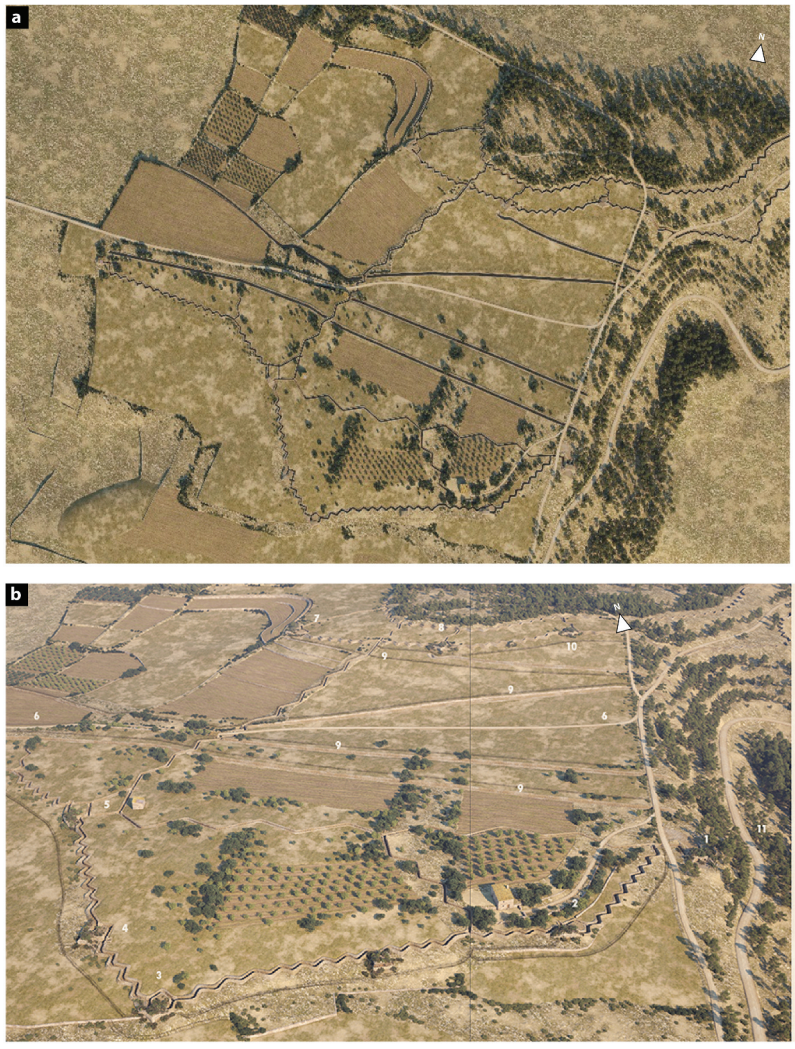

Figure 5. (a) The Raimats battlefield (J.R. Casals—Didpatri-UB). (b) Oblique perspective of the fortified system of Raimats (J.R. Casals—Didpatri-UB). 1. Pillbox 1 with anti-tank artillery and machine guns. 2. Pillbox 5 with machine guns. 3. Pillbox 6 with machine guns. 4. Pillbox 7 with machine guns. 5. Pillbox 8 with machine guns. 6. Road to Riba-roja. 7. Pillbox 4 with machine guns. 8. Pillbox 3 with machine guns. 9. Anti-tank ditches. 10. Pillbox 2 with machine guns. 11. Road to Ascó.

3. Results

The 3D survey, based on multiple information and documentation, allowed a global understanding of the battlefield with a certain precision. The entrenched complex had a first line composed of a zigzag trench that extended for about 500 meters, to the east, between the clearing of the Ascó road (*Barranc de Rams*) and the slopes of *Lo Raimat del Comte* (*Corralissa del Comte*). This first line was alternated by various pillboxes and machine gun nests. At least five of the pillboxes, with their documented remains, were made of concrete, and the one on the eastern pivot, which covered the entrances to the Ascó road, was prepared to house antitank. These pillboxes were identified with the numbers 1, 5, 6, 7, and 8. (Rams & Pérez, 2010). Between pillboxes 1 and 8 there was a second connecting trench, which gave depth to this first defensive set. (Figure 6a)

The second line of defence was in the northern area of *Pla de Carinyo*, about 250 meters away from the first. It was unfolded in front of the grove of level 563, one of the highest (and flattest) points of the Mountain range of la Fatarella. The complex had two parallel trench lines, separated by about 50 meters. The most backward trench was the evacuation trench. The most advanced trench had three concrete pillboxes; those identified with numbers 2, 3 and 4 (Rams & Pérez, 2010). This set had continuity with the general line of trenches that extended towards Asco in the east and towards Riba-roja in the northwest.

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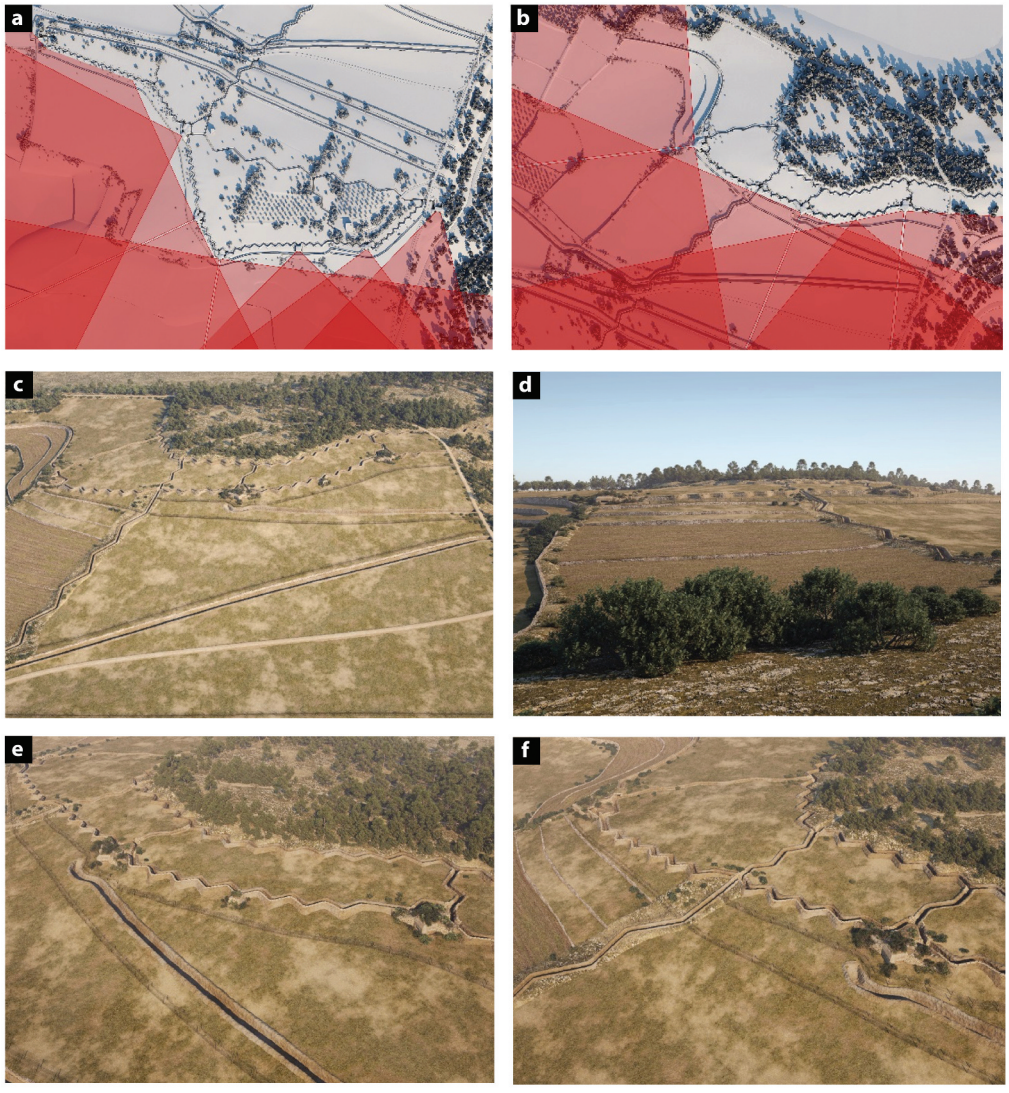

Figure 6. (a): Fire plan of the advanced line of Raimats (J.R. Casals—Didpatri-UB). (b): Fire plan of the second fortified line of Raimats (J.R. Casals—Didpatri-UB). (c): Second defensive line of Raimats oblique perspective in a south-north direction (J.R. Casals—Didpatri-UB). (d): Raimats second defensive line with pillboxes 3 and 4 growing *Pla del Carinyo* (J.R. Casals—Didpatri-UB). (e): Raimats second defensive line. The three pillboxes are distinguished (2, 3, 4), the evacuation trench and the last anti-tank pit that ends in front of the glacis of pillbox 3 ((J.R. Casals—Didpatri-UB). (f): Raimats second defensive line. Pillboxes 3 and 4, the evacuation trench and the transversal communication trench are distinguished (J.R. Casals—Didpatri-UB).

Between the first defensive line and the second, there were important structures. There was a track suitable for trucks that made it possible to connect with Riba-roja through the *Modorres* ravine heading west. Between the runway and the forward defensive ensemble, there were two anti-tank pits. The first, the closest to the trenches, covered the entire line from behind, between Pillbox 1 and *Corralissa del Comte*. The second anti-tank pit covered the flattest area of the *Pla de Carinyo*, about 50 meters from the first ditch. There were no moats in front of the front line, probably because the terraces were already considered sufficient to hinder the advance of the armour vehicles.

Between the runway and the second defensive line were two other anti-tank ditches. The one closest to the road was the longest, the second made access difficult to level 563. Probably this second double system of moats took advantage of the terraced walls of the fields, which were integrated into the defensive logic. And it should be noted that the many dry-stone walls of the agricultural terraces were a formidable anti-tank obstacle. Finally, the complex had another important structural element: a transverse trench that crossed the entire complex, in a north-south direction, and that communicated the advanced trenches with the last evacuation trench. (Figure 6b; Figure 6c; Figure 6d; Figure 6e; Figure 6f)

3.1. The pillboxes

The pillboxes were documented thanks to the photographs in the Italian dossier and the archaeological activity carried out on them. In general, the dimensions of the pillboxes were small, except in the case of pillbox 1, and they were designed to house a machine gun. They were built following the 1938 Eastern Region fortification guidelines and standards (GERO. Grupo de ejércitos de la región oriental, 1938). (Figure 7)

It should be noted that the construction of these pillboxes could not have been easy since it was necessary to transport gravel and bags of cement from the river. The analysis of the concrete shows the presence of very coarse gravels and few iron frames. In some cases, the iron structures are made of improvised material: barbed wire poles and railroad rails.

3.1.1. Pillbox 1

Pillbox 1 is part of the first defensive line. It is not excavated, but contemporary photos exist that accurately report its characteristics. It was an extreme position, on the edge of the *Pla de Carinyo*. Right from the position a steep slope began. The pillbox was of considerable size and was prepared to house anti-tank weapons and a machine gun. The position covered the accesses along the Ascó road and, in turn, the road that bordered the upper limits of the Mountain range of la Fatarella, heading north. (Figure 8a; Figure 8b; Figure 8c)

3.1.2. Pillbox 2

The pillbox that the Italian engineers called N. 2 was located at the eastern end of the second defensive line. This pillbox is not excavated (due to lack of authorization from the property), but it is documented thanks to the photographs of Italian engineers. It was a position with two embrasures for the location of machine guns. The Italian photograph, taken after the assault, shows that the eastern outer face of the pillbox received at least seven artillery hits. (Figure 9a; Figure 9b; Figure 9c)

3.1.3. Pillbox 3

Archaeologically excavated by the CSIC-DIDPATRI in 2011 and documented in the Italian report. Its remains were hidden for years. The pillbox was heavily bombed in the assault on November 15. The exterior received a minimum of twenty hits and heavy machine gun fire. Excavations in 2011 revealed detonations inside of projectiles that had entered through the embrasures, hitting the

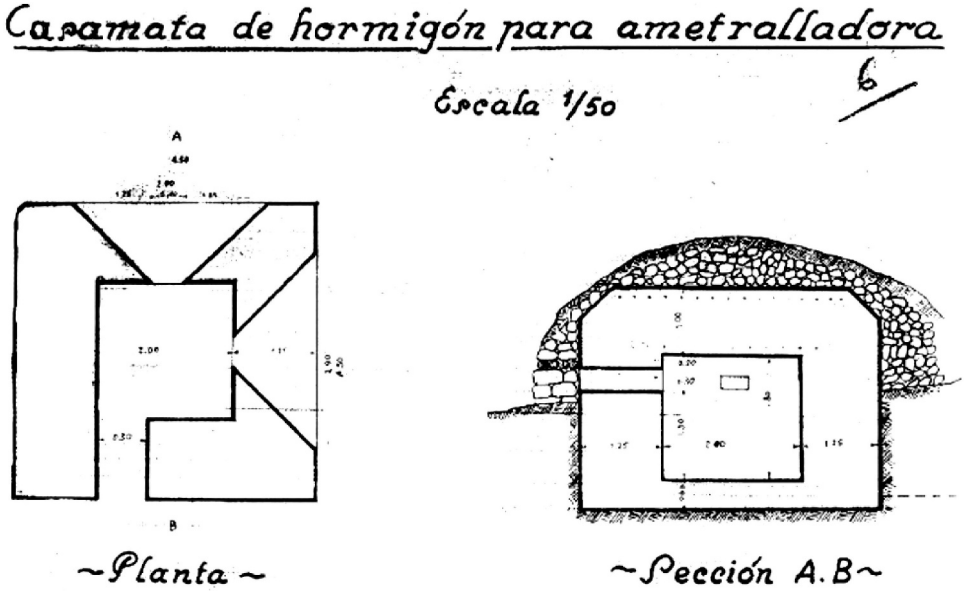

Figure 7. Planimetry of basic pillboxes for machine guns according to the standards of the Republican Army (AGMAV).

Figure 8. (a) Pillbox number 1, for anti-tank artillery and machine gun. The position covers the road from la Fatarella to Ascó (AGMAV). (b) Pillbox number 1 rear view showing the access to insert an anti-tank piece (AGMAV). (c) 3D recreation of Pillbox number 1, which covers the Ascó road and the accesses to level 563 /J.R. Casals—Didpatri UB).

interior walls of the pillbox. Near the position, the remains of a 45 mm projectile, ammunition used by the T-26s, were found, which fired at point-blank range at the pillboxes, less than 50 meters away. This archaeological evidence confirms the Negrín report according to which the tanks directly bombarded the embrasures of the pillboxes. (Figure 10a; Figure 10b; Figure 10c; Figure 10d; Figure 10e; Figure 10f)

3.1.4. Pillbox 4

Unearthed in the excavations of 2011. It is the pillbox at the western end of the upper enclosure. It was rebuilt with experimental archaeology criteria by the "Lo Riu" Association and the DIDPATRI research group between 2014 and 2018. (Figure 11a; Figure 11b; Figure 11c; Figure 11d; Figure 11e; Figure 11f; Figure 11g)

3.1.5. Pillbox 5

It represented the position of the first line of the fortified field. It was recovered by "Lo Riu" in 2008. It has a single loophole lined up towards the La Fatarella road. In the *Ufizzio Storico*, there is a photograph that could correspond to this fortification. (Figure 12a; Figure 12b)

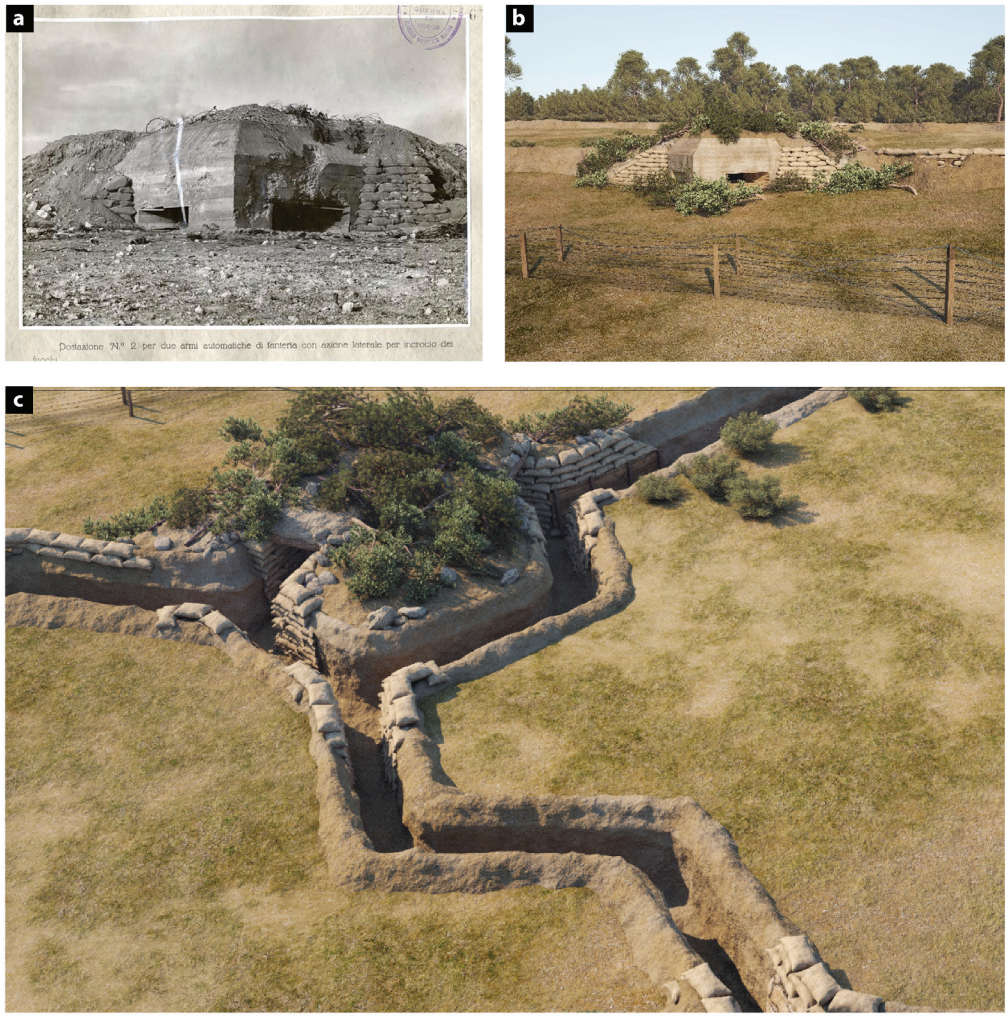

Figure 9. (a) Pillbox number 2. Frontal view showing the impact of the artillery against the embrasures (AGMAV). (b) Pillbox number 2. Front. 3D reconstruction (J.R. Casals—Didpatri UB). (c) Rear view of Pillbox number 2, and adjacent trenches. 3D reconstruction (J. R. Casals—Didpatri UB).

3.2. The trenches

The trench lines have left little trace on the ground. In the years that followed the conflict, the agricultural fields were put into operation again and new terraces were implemented that, in a few years, were erasing the traces of the defensive structures. Consequently, the typology of trenches in the Raimats complex is little known. The oral memory of the neighbours, some Italian photos and the trenches excavated in 2011, are the only contributions that allow us to have a rough idea. The trenches followed the patterns of those developed in similar environments. They were built from zigzag lines, to avoid enfilade fire or shrapnel effects if a bomb exploded inside. In the areas excavated in 2011, the layout is perfectly appreciated.

The surroundings of Raimats were agricultural, with deep but stony soils. These characteristics of the terrain made it possible to dig trenches up to a meter and a half deep, reinforced in some areas with sandbags that gave them consistency and optimized defence possibilities. The Italian photographs show the massive presence of sandbags, especially on the flanks of the pillboxes and in the most vulnerable spaces. The photographs also show the massive presence of barbed wire protecting the glacis from the fortifications.

The trenches had covered shelters. In some areas, the parapets were reinforced with walls or dry-stone interventions, the traditional construction technique of the place. In the 3D

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Figure 10. (a): Pillbox number 3. Access trenches (AGMAV). (b) Pillbox number 3. Front view. The photograph shows the artillery shots that were directed against the embrasures (AGMAV). (c) Pillbox number 3. On the walls, you can see the impacts of the projectiles that entered through the embrasures (Photo Didpatri UB). (d, e) Pillbox number 3. 3D reconstruction. You can see in the glacis of the position, the limit of the anti-tank moat (JR. Casals—Didpatri UB). (f) Attack system against pillboxes: direct bombardment against embrasures (Didpatri UB).

Figure 11. (a) Remains of Pillbox number 4. Archaeological excavation, 2011 (Photo Didpatri UB). (b) Pillbox number 4. Rebuilt by "lo Riu"—Didpatri (Photo Didpatri UB). (c) Pillbox number 4. Rear accesses. At the time of the assault, the surroundings of the position were still under construction (AGMAV). (d) Pillbox number 4. Accesses from a covered trench (AGMAV). (e) Pillbox number 4. Located on the western limit of the second line. The dry-stone walls of the terraces act as anti-tank obstacles (JR. Casals—Didpatri UB). (f) Pillbox number 4. Located on the western limit of the second line (Photo Didpatri UB). (g) Pillbox number 4. 3D reconstruction (JR. Casals—Didpatri UB).

reconstruction, these trenches are represented, dug in the ground, and reinforced with sandbags and with the presence of barbed wire. (Figure 13a; Figure 13b; Figure 13c; Figure 13d)

3.3. Anti-tank ditches

We know about the existence of the anti-tank ditches thanks to the testimony of the inhabitants of the area. The *Pla de Carinyo* was the flattest and highest area of Raimats, it was crowned by the smooth 563 elevations, one of the highest points of the Mountain range of La Fatarella. This double

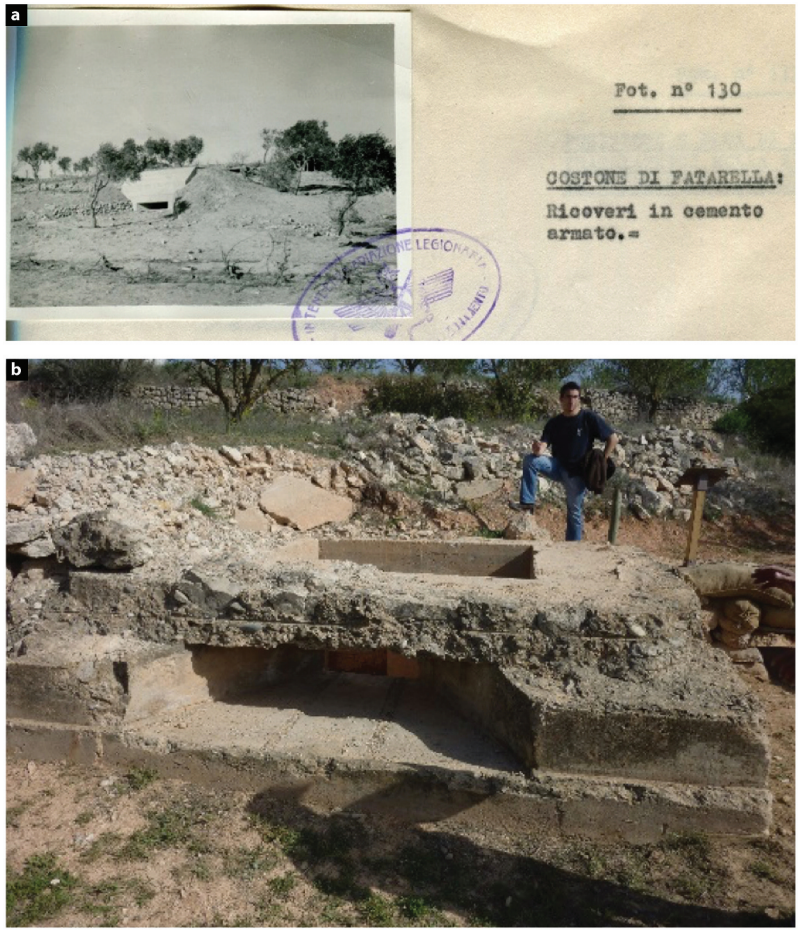

Figure 12. (a) Position with a single frontal embrasure that corresponds, probably, to Pillbox number 5 (Uficcio Storico dell'Aeronautica Militare—ADAR). (b) Pillbox number 5. Pillbox embrasure (Photo Didpatri—UB).

condition of a non-mountainous strategic place gave a high value to the site. In the area, there were some terraces made with dry stone walls, but the fields could be crossed by motorized means and by artillery. For this reason, the *Pla de Carinyo*, by Raimats, was the object of a special fortification. To prevent the passage of armoured vehicles, a total of four anti-tank ditches were built, two on each side of the access road in the direction of the town of Riba-roja. The location of these pits, filled after the conflict, has been established from the oral memory of the residents. On the other hand, some photographs of the Italian engineers of the pillboxes 2 and 3, allow us to observe the access road, and beyond, a parallel ditch (with accumulations of earth on the edges), and further away a second ditch that reaches the glacis of pillbox number 3. In the first term of the photographs, you can see accumulations of earth from another of the ditches. The character of the anti-tank ditch is not debatable, not only because of the descriptions of oral memory but also because of its rectilinear layout, since if they were trenches, they would follow the logic of the zigzag layout. On the other hand, some Italian photographs also document the existence of ditches on the slopes of the nearby Camposines area, in this case with rails driven at 45° of inclination above the ground. (Figure 14a; Figure 14b; Figure 14c)

3.4. Global vision of the battlefield and detailed developments

The sum of the different sources of information allowed an approximate 3D reconstruction of what had been the battlefield of Raimats. Some of the fragmentary aspects made sense in the context of a global vision. The proven or hypothetical location of various pillboxes and machine gun nests allowed an approximation to the fire plan of the set and the visuals and lines from the various defensive positions (Rubio-Campillo & Hernández-Cardona, 2015). Naturally, there were some elements about which there was not much information and which were represented from the

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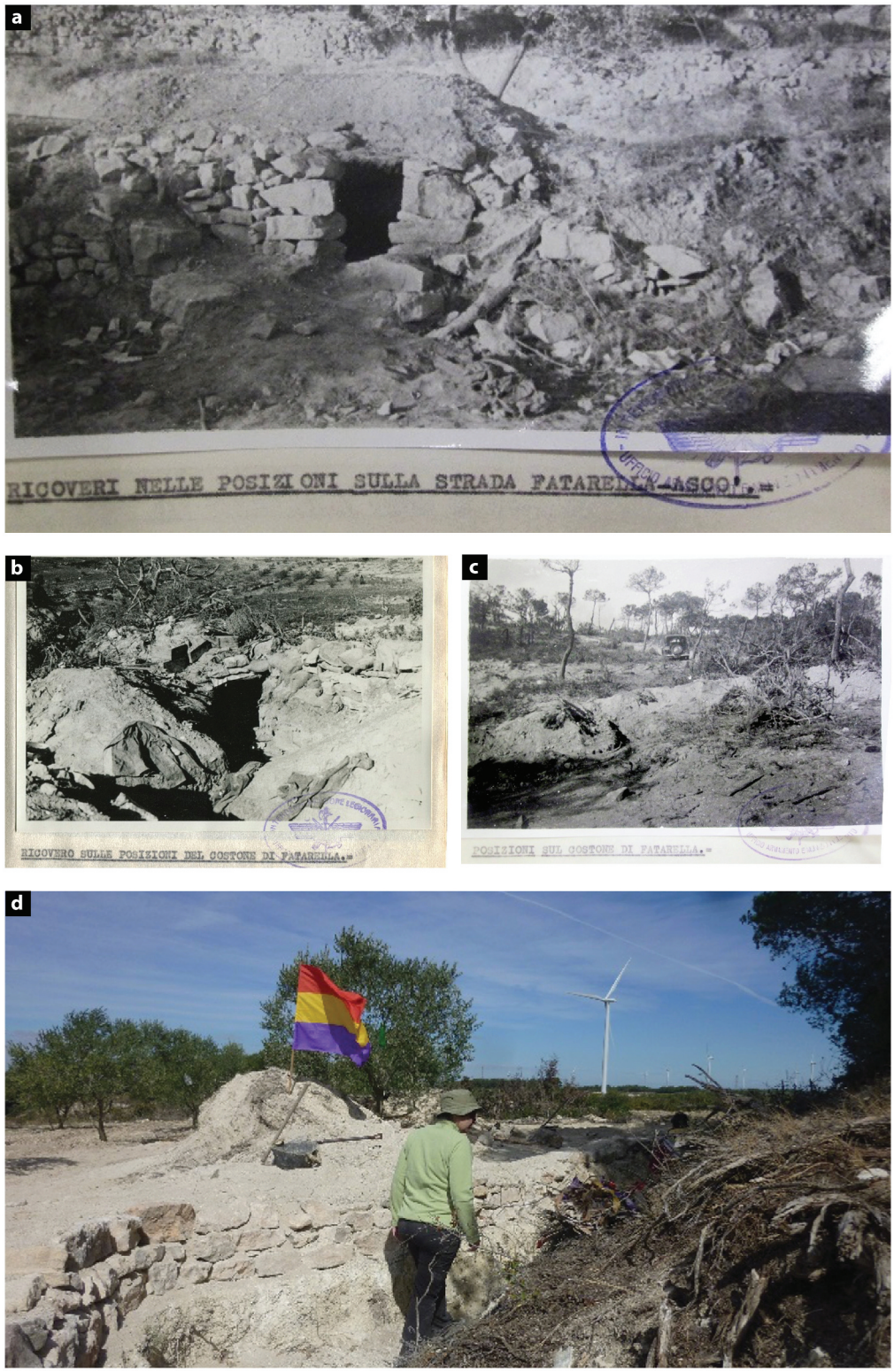

Figure 13. (a) Shelter for soldiers integrated into trench lines (Uficcio Storico dell'Aeronautica Militaire-ADAR). (b) Trenches and refuge in the Fararella line. You can see the diversity of materials used for defense (Uficcio Storico dell'Aeronautica Militaire-ADAR). (c) Positions in the forest at level 563 of Raimats (Uficcio Storico dell'Aeronautica Militaire-ADAR). (d) Consolidation works in the trenches of the second defensive line of Raimats (Photo Didpatri UB).

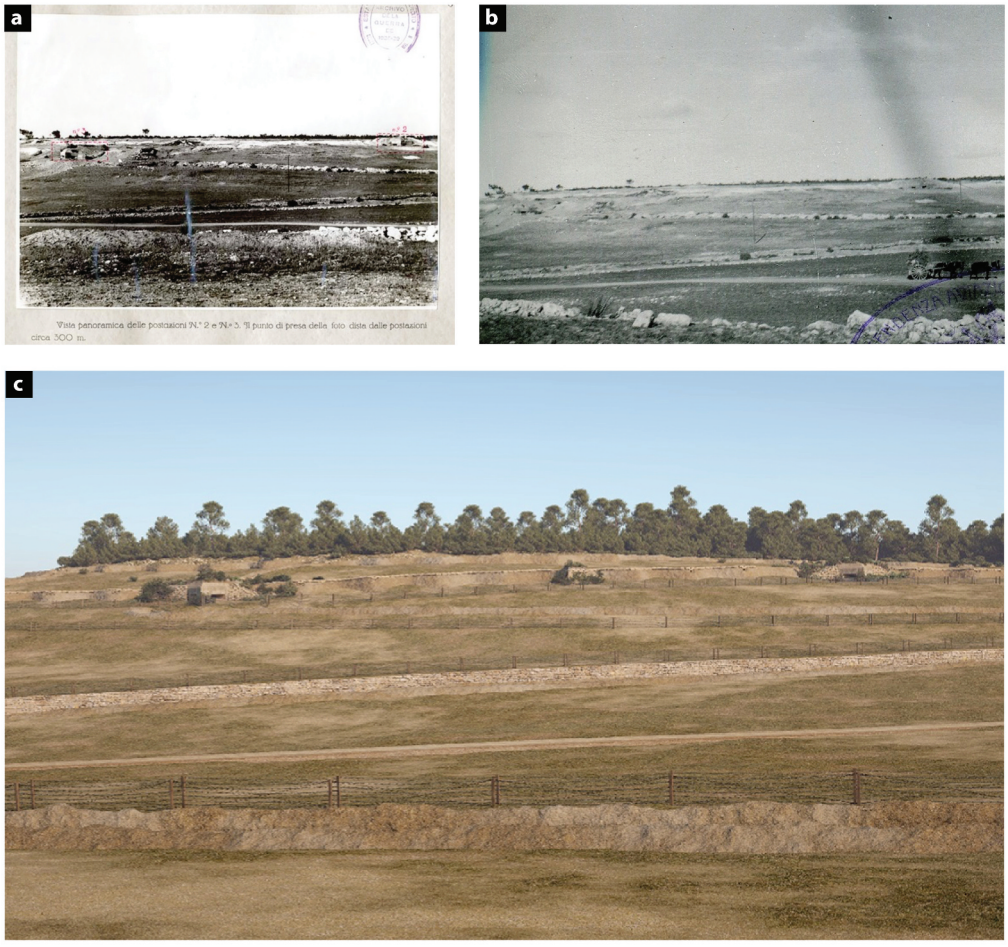

Figure 14. (a) Photograph of the Italian engineers. Front view of the second defensive line of Raimats. The pillboxes are distinguished, also the track and the various anti-tank ditches (AMGAV). (b) Italian photography. Panoramic view of the second line of the entrenched Raimats camp (Uficcio Storico dell'Aeronautica Militar-ADAR). (c) 3D reconstruction of the second line of the entrenched Raimats camp in the sector delimited by Pillboxes number 2 and 3 (JR. Casals—Didpatri UB).

minimum; as in the case of barbed wire, documented by Italian photographs, and common in this type of defensive structure; and that they should probably be much denser than what was evidenced in the 3D proposal.

The 3D iconography provided global technical information about the battlefield that could be reapplied in different media and for different functions: museographic panelling, books and printed material, teaching materials, web, videos, apps, and with different functions: educational environments, cultural tourism and cultural industries (Hernàndez-Cardona, 2018; Hernàndez Pongiluppi, 2019).

But 3D, which, in principle, gave an aseptic view of the scene, was also used to provide information on the events that occurred in the place in mid-November 1938. This implied adding movable, anthropic and environmental elements to the iconography. In this regard, an ambitious iconographic program was developed with the *matte painting* technique, and based on photographs and videos; in which historical recreation groups collaborated. The use of 3D in these proposals as a background was relevant since it was used to select and obtain images of spaces on which, from matte painting, artefacts, machines and human figures were added to represent a certain historical moment.

4. Discussion

The battlefields of the 20th century involved very diverse settings and landscapes of disparate dimensions. On the other hand, the resulting defensive structures, preserved to this day, also present a wide range of possibilities: intensity of the bombings, characteristics of the fortifications and post-conflict rural or urban transformations (Masson-Loodts, 2014). Taking these contexts into account, the

possibilities of developing a 3D virtual recreation of controversial spaces can also be very diverse. In general, 3D surveys of 20th-century battlefields carried out with didactic intentions have been limited. The experiences have focused on superimposing analogue iconography on models of the involved territory modelled in 3D (Macdonald, 1986), generating 2D images as a final product. This limited development contrasts with the cartography that has been drawn up on battlefields for research purposes. Historical scenarios in general, as well as those of a warlike nature and especially those of the world wars such as the Somme, Verdun or Normandy, have been the subject of GIS initiatives and detailed cartography, intending to identify and interpret the persistent defensive structures in the current landscape (De Matos-Machado et al., 2019; Hesse, 2014; Devos et al., 2015; Nolan, 2009; Doyle & Bennett, 1997; Doyle, 2017; Gregory, 2003).

In the case of the Battle of the Ebro, a campaign that lasted three months, it must be considered that the area of the fighting covered about 800 km2. In a staggered manner, the fighting took place in various stages of this immense territory. A 3D of this immense space could not be raised that would be meaningful to interpret the various elements and positions at play in space and time.

In Fatarella Ridge the battlefield and its direct peripheries covered about 12 hectares. These dimensions allowed the structures to be reconstructed in some detail and on a recognizable significant scale (in digital or printed options). The case of Fatarella Ridge was interesting, not only because of its dimensions, but also because the structures to be represented, those of a deeply fortified area, with trenches and pillboxes, were common in the context of the Spanish Civil War. It was possible to generate an applicable model. The Fatarella Ridge experience could be a reference to explain and document a type of combat that was very common both in the GCE and in the two world wars. It should be noted, however, that the trenches were very ephemeral structures, and until very recent times they were not considered of patrimonial interest, and as a rule, they disappeared in the years that followed the conflict due to the action of erosion and, above all, due to agricultural, urban or industrial transformations of the landscape. In the case of Raimats in Fatarella Ridge, when the research began, at the beginning of the 21st century, the accumulated agrarian transformations since 1938 had been moderate: some changes in crops and terraces, but even so they erased the trace of the trenches and pillboxes.

In Fatarella Ridge the iconographic recreation of the main lines of trenches arose from the scarce archaeological evidence (excavated trench sectors), oral memory and the position of the pillboxes that had been excavated or located. The fortification manuals of the time were also useful and relevant (Capdevila, 1938; Group of Units of Fortifications and Works, 1938). The cartography of the ICC (Cartographic and Geological Institute of Catalonia) was used as a base, but LIDAR could not be used, as the documentation provided by the Institute did not have a sufficient definition. The positions of the pillboxes could be intuited, but not the trenches, which in general do not exceed 80 cm in width. This situation did not imply that the future research, and didactic proposals, could not be complemented by LIDAR using drones to obtain higher resolution images. It should be noted that this resource (LIDAR from aircraft or drones) has already been widely used to investigate European battlefields (De Matos-Machado et al., 2016; Van der Schriek & Beex, 2017), and elaborate precise cartographies, although there are still no examples of an iconography thought with didactic functionality elaborated from LIDAR.

Concerning the evaluation of didactic 3D models of contemporary battlefields, several variables must be considered. On the one hand, 3D is made from tangible data, but it is still a hypothetical proposal, as there may be undocumented areas reconstructed from logical solutions or parallels. In this sense, its scientific validity could be questioned. This problem requires moderation in the reconstruction of little-known areas. It is also advisable to limit yourself to minimal reconstructions and naturally point out that these are hypothetical reconstructions, which are more or less consistent with existing knowledge, and that you can integrate those obtained in the future. The digital option allows adding the necessary transformations depending on the amount of knowledge that is being produced. Ultimately a didactic 3D is an understandable model of a space, and

its characteristics and content can be adjusted, expanded or corrected at any time. Concerning comprehensibility, empirical experience suggests that it is related to the degree of realism of an iconography that should not incorporate symbolic or abstract elements or simplifications. The shapes and textures must be as close to reality as possible, seeking a photographic or hyper-realistic effect. The resulting 3D can be evaluated, in any case, from interviews with experts from the different sectors involved (teachers, professors, heritage technicians, museum designers, tourist guides, etc.). Questionnaires can also be passed to users to detect understandability.

5. Conclusions

The didactic 3D representation of a 20th-century battlefield must be conceived from a dynamic and changing perception, that is, the iconography can be transformed based on the new information and knowledge generated by the research. The main function of a didactic 3D is to make the controversial space understandable to a broad target horizon, to people who do not necessarily have sufficient preconceptions to interpret from the current landscape, what was a battlefield.

In this sense, 3D is an intermediary element that facilitates the socialization of the knowledge generated by research. This representation process must be implemented from the moment that a minimum of tangible information is available. To proceed with the 3D reconstruction, it is not necessary to wait until the investigation is finished, or that it is well advanced. Recreation, although it may have a very hypothetical profile, helps to communicate to society, and the different agents involved in the valuation and conservation of heritage, the potential magnitude of the controversial site. In this sense, 3D is a particularly useful socialization tool for research teams working from a Public Archaeology and Public History perspective.

Reconstructions of spaces from the past, despite their hypothetical nature, help to understand, and in this sense facilitate educational and citizenship processes. But for the controversial space to be understandable for broad target horizons, it must present maximum realism. Textures and shapes must be easily recognizable, and in this sense, they must be considered with realistic or hyper-realistic criteria. People, even those who may have limited preconceptions on the subject, must understand and acknowledge what iconography proposes. In no case should 3D be considered an artistic work (although it can be approached), it is a technical and functional iconography that seeks to promote understanding based on a representation as close to a possible reality evidenced by fragmentary and decontextualized remains. Its function is to mediate based on contextualizing. The didactic 3D must reflect the basic landscape at a given moment from structures and immovable elements, although some movable elements (artillery pieces, camouflage elements . . .) may appear. Regarding the timing of the base 3D representation, this may depend on the interests of the research team. The most logical thing is to represent the space with the maximum possible integrity. But it could also be considered, according to the needs and objectives of the research team, to present the space after a battle or a bombardment, which would imply reflecting certain war structures (funnels caused by explosions, destruction, etc.). A generic 3D base that shows the integrity, and the logic of the defensive structures system, can always give way to different versions . . . of the same 3D or 2D of the spaces of interest from the point of view considered appropriate. These 2D developments allow the most diverse anthropic elements and furniture to be added using matte painting-type techniques using GIMP-type software. This allows us to represent the complexity of a scene at a given moment, in the case of soldiers acting, armoured vehicles, artillery, smoke explosions, etc.; in other words, a realistic image of a given historical moment.

The didactic 3D allows, as we have indicated, to obtain perspectives from the most diverse points of view and navigations that allow understanding of the controversial space and in this sense, they favour a greater understanding of the heritage object. However, its usefulness and interest also lie in its ability to be reapplied. 3D, its versions and derivatives can be applied to a wide range of communication options: publications, video, panels, museography, websites, and apps that can be applied indistinctly to areas as diverse as teaching-learning, cultural industries, or cultural tourism.

The realization of didactic 3D is understood as organic and functional elements that are generated in the context of an archaeo-historical investigation and have an interest, beyond the socialization of knowledge, in the historical investigation itself. In general, archaeological research raises part of its advances from two-dimensional or photogrammetric cartographic proposals, although the altitude factor can be represented. However, considering height always requires a complex abstraction process. In this sense, 3D, especially when it offers oblique aerial points of view, helps to quickly intuit the most diverse problems, establish overall considerations, and pose questions and hypotheses.

In a conclusion, we can establish that the didactic 3D of complex spaces such as the battlefields of the 20th century is revealed as a useful instrument to socialize knowledge and accompany the historical archaeological investigations themselves.

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