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APPLICATION OF PHOTOGRAMMETRY AND LASER SCANNER ON THE BRONZE AGE STRUCTURES OF THE CASTILLEJOS DE LUNA CIST TOMB NECROPOLIS (PIZARRA, SPAIN)

APLICACIÓN DE LA FOTOGRAMETRÍA Y EL ESCÁNER LÁSER A LAS ESTRUCTURAS DE EDAD DEL BRONCE DE LA NECRÓPOLIS DE TUMBAS DE CISTAS DE CASTILLEJOS DE LUNA (PIZARRA, ESPAÑA)

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Highlights:

- New graphic records in the Bronze Age cist tombs in Castillejos de Luna (Sierra de Gibralmora-Sierra del Hacho, Pizarra, Málaga, Spain).
- The potential advantages of applying 3D techniques in Bronze Age tombs as a medium for image dissemination.
- Analysis of canonical Bronze Age necropolis associated with a settlement, which reflects social hierarchy through individual burials.

Abstract:

The cist tombs necropolis at Castillejos de Luna, in Sierra de Gibralmora-Sierra del Hacho (Pizarra, Málaga, Spain) was known from the graphic documentation and the grave goods of two tombs. New studies have documented nine burials. The aim of this article is to present the new virtualisation work that has been carried out in the necropolis, to generate a new three-dimensional (3D) documentation of the currently known records, which are in acceptable visibility conditions. Using tools to document tombs in 3D offers us great advances in data acquisition and editing, with great precision and realism, thanks to the 3D models generated through techniques such as photogrammetry or laser scanning. Thanks to these tools, it is possible to carry out studies on digital twins and use them as informative material for society. The study this paper describes has generated high quality products for dissemination and future analysis. The results shown here are of metric character, with orientation and geographical location of the structures. In addition, in one of the tombs the authors show the combination of photogrammetric techniques with laser scanners to obtain a single high-resolution 3D model; subsequently a retopology process is carried out to achieve a "light" model with a photorealistic appearance that is both easily manipulated on mobile devices for its dissemination and a guarantee that the general public can enjoy this necropolis in a different way. The preliminary results are published in the web repository of 3D models Sketchfab,

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where the users can see a preview of one of the tombs before and after being optimised with retopology through Blender. The authors provide a socio-historical analysis of Bronze Age necropolises in central Andalusia, within the framework of a debate on the western expansion of the El Argar Culture.

Keywords: virtual archaeology; megalithism; cultural heritage; documentation; photogrammetry; laser scanning

Resumen:

La necrópolis de tumbas de cistas de Castillejos de Luna, en la Sierra de Gibralmora-Sierra del Hacho (Pizarra, Málaga, España) se conocía por la documentación gráfica y el ajuar de dos tumbas. Los nuevos estudios desarrollados han permitido documentar nueve enterramientos. El objetivo de este artículo es presentar los nuevos trabajos de virtualización que se han hecho en la necrópolis, con la intención de generar una nueva documentación tridimensional (3D) de los registros conocidos actualmente, que se encuentran en unas condiciones de visibilidad aceptables. La aplicación de herramientas para documentar en 3D las tumbas nos ofrece grandes avances en la captura y edición de los datos con gran precisión y realismo, gracias a los modelos generados a través de técnicas como la fotogrametría o el escaneado láser. Todo ello tiene el objetivo de poder realizar estudios sobre gemelos digitales y usarlos como material divulgativo para la sociedad. En este trabajo se han generado productos de gran calidad para su difusión y para realizar futuros análisis. Los resultados que se muestran aquí son de carácter métrico, con orientación y situación geográfica de las estructuras. Además, en una de las tumbas se expone la combinación de técnicas fotogramétricas y escáneres láser para obtener, a partir de ambos, un único modelo 3D de alta resolución y, posteriormente, realizar un proceso de retopología; ello ayudará a conseguir, por una parte, que exista un modelo "ligero" con un aspecto fotorrealista, fácilmente manipulable en dispositivos móviles para su difusión y, por otra parte, que la sociedad en general pueda disfrutar de esta necrópolis de una forma diferente. Los resultados preliminares están publicados en el repositorio web de modelos 3D Sketchfab, pudiéndose ver un avance de una de las tumbas antes y después de ser optimizada con retopología de Blender. Se aporta un análisis socio-histórico sobre las necrópolis de la Edad del Bronce en Andalucía central, en el marco de un debate sobre la expansión occidental de la Cultura de El Argar.

Palabras clave: arqueología virtual; megalitismo; patrimonio cultural; documentación; fotogrametría; escaneado láser

1. Introduction

Recent advances in digital and virtual recording have led to the development of new methodologies that complement traditional archaeological recording techniques. These methodologies have greatly improved the quality of archaeological recording, and for this reason they have been used in archaeological fieldwork since the 1980s (Almagro, 1988), although over the last decade they have become more widespread (Laiseka, 2021; Torres, *et al*. 2022; Valle, Fernández, & Rodríguez, 2022), including the implementation of Virtual Reality (VR) systems as a new resource for research, dissemination, and outreach (Domingo et al., 2013a; Domingo et al., 2013b; Torres, *et al*. 2022).

The potential of these 'new technologies', such as unmanned aerial vehicles (UAVs, also known as drones) (Angás & Uribe, 2017), laser-scanning, and photogrammetry makes them eminently suitable for archaeology, and they have thus become part of the standard toolkit of archaeologists. Similarly, their potential for dissemination and outreach has helped to increase social interest in the field (Escrivá Estevan & Madrid García, 2010; Kosciuk, 2012; Domingo, et al., 2013a; Wachowiak & Kara, 2013; Santos Gómez, 2016; Muñoz-Muñoz, A., et al., 2022).

Correctly used, these techniques help us to record archaeological features quickly and accurately, complementing traditional graphic recording methods and contributing to the virtual preservation of archaeological items.

It can be emphasised that these methods are particularly versatile and valuable in sites which, as a result of conservation or musealization issues, need to be buried again after excavation. In these conditions, documenting the archaeological site in 3D makes it possible to further study features and archaeological levels '*in situ*'. Therefore, these recording methods virtually 'rescue' archaeological features in 3D. As such, having a 3D model of sites that are otherwise inaccessible can contribute to carry out further study, analysis, and dissemination (Muñoz-Muñoz, et al. 2022; Portillo-Sotelo, Díaz & Muñoz-Muñoz, 2022), while complementing other scientific disciplines such as geological analysis, pollen studies, dating, etc.

In this regard, it is safe to argue that one of the greatest advantages of new technologies is their non-destructive approach to the preservation of the surface topography of archaeological heritage.

Based on these premises, we undertook the graphic recording of the prehistoric necropolis in Sierra del Hacho, Castillejos de Luna and la Cañada del Sordo (Pizarra, Málaga, Spain), dated to the Bronze Age.

This work was undertaken at the behest of the City Council of Pizarra within a wider project to 'valorise' the municipality's archaeological heritage.

The necropolis has been known for a long time (Garrido, 1981). The article presents the recording of seven tombs with digital techniques (terrestrial photogrammetry, aerial photogrammetry, and laser scanning), which will be of great value in terms of heritage management.

The article also presents a brief interpretation of the site in its immediate geographical context, the hinterland of the Bay of Málaga.

2. The Bronze Age necropolis of Castillejos de Luna

The site is situated in Sierra del Hacho (36º 45' 32'' N and 4º 41' 54'' O), specifically in Sierra de Gibralmora, at an altitude of 135-148 m above sea level (a.s.l). Along with Gibralgalia, this is one of the two hill ranges in the municipality of Pizarra. The town is barely 500 m to the west. The geographical location of the range and its maximum altitude, 449 m, gives excellent views of the valley of the Guadalhorce River, the city of Málaga, and part of the region of the Axarquía (Fig. 1).

The hill range sprawls over 750 ha, including the flat plateau at the top. The Bronze Age site of Castillejos de Quintana is situated to the north, in an area dominated by rough terrain.

Geologically, the range is one of several 'Miocene islands' on the banks of the Guadalhorce River, between the Chorro and the river's lower course. Approximately 6 million years ago, a marine regression led to the continentalisation of the Antequera and Guadalhorce basins.

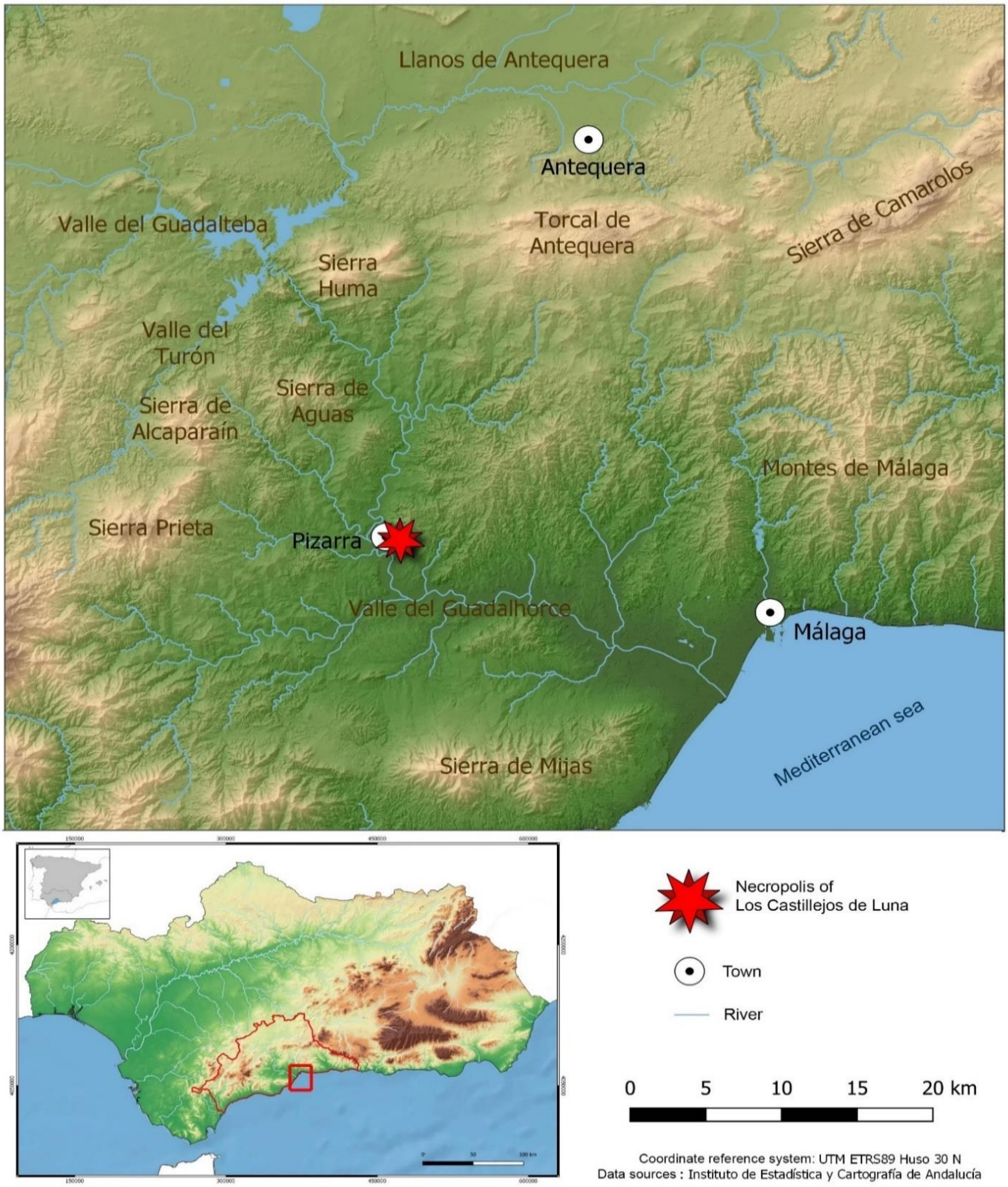


Figure 1: Location map with the necropolis of Castillejos de Luna, in the Guadalhorce Valley and the regions of Guadalteba and V*ega* of Antequera, Málaga, Spain.

The area presented suitable conditions for agriculture on the edges of the valley and on the terraces in the lower course of the Guadalhorce, and marine resources were also immediately accessible. The basins of the Turón, Guadalteba, and Grande rivers were also rich in hunting-gathering and lithic resources (Fernández Ruiz & Márquez Romero, 1985; Ramos Muñoz et al., 1986; Espejo Herrerías & Cantalejo Duarte, 1990-1991; Becerra Martín, 2019).

The Sierra de Gibralmora completely dominates the territory around it: the lower course of the Guadalhorce towards the Grande River; the higher course of the Guadalhorce; the *Vega* of Antequera; and the region of Guadalteba (Ruiz Sinoga et al., 2017). This may have been turned into political and ideological power, as well as into the control of resources and communication routes (Figs. 2 & 3).

(a) (c) (b) (d)

Figure 2: (a) Geographical location of Sierra del Hacho (Pizarra, Málaga); (b) View of the lower valley of Guadalhorce from the necropolis; (c) Town of Pizarra from the necropolis; (d) View of Álora and Sierra de Huma from the necropolis.

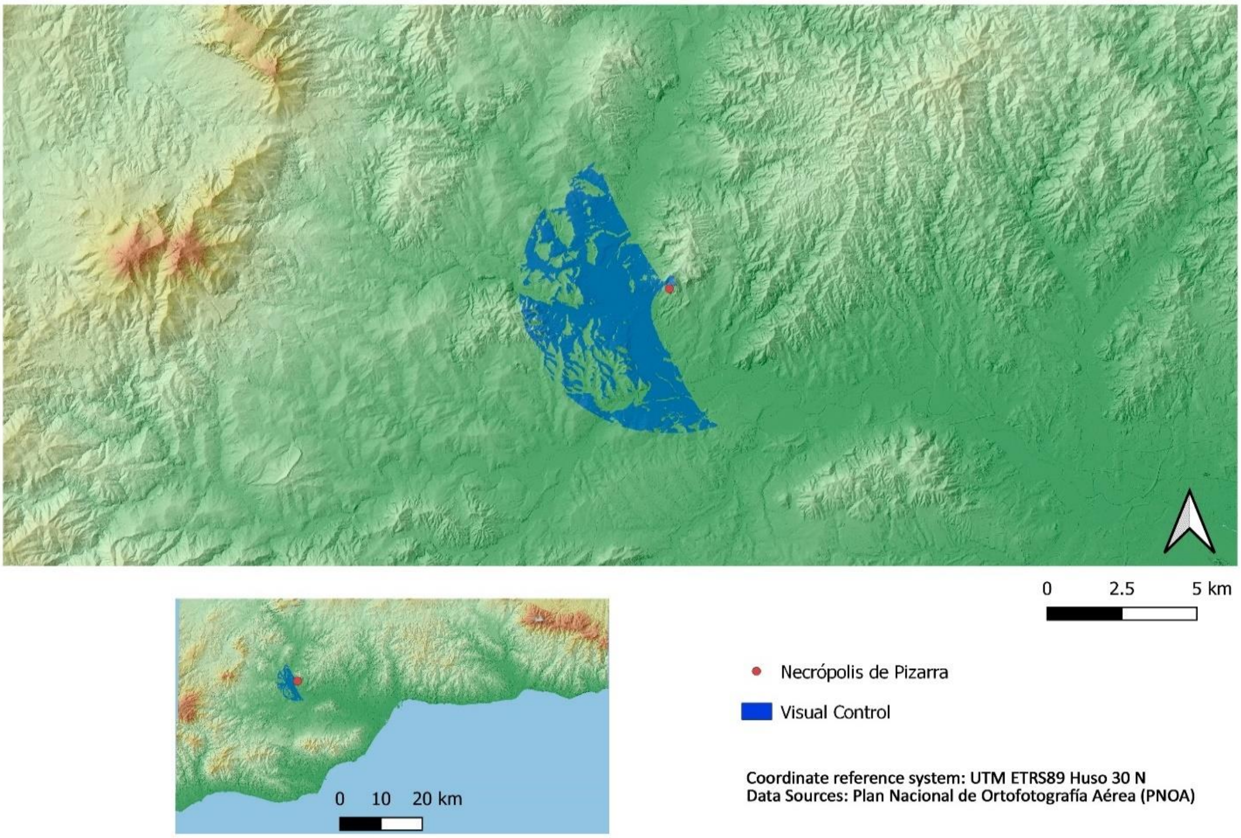


Figure 3: Study of visual basins undertaken by QGIS.

Previous archaeological work at the site resulted in a single article published by Antonio Garrido, in cooperation with Manuel Corrales, Julio Fuentes and the Prehistory and Archaeology Department, Facultad de Filosofía y Letras, Universidad de Cádiz. This paper, presented a series of preliminary results (Garrido, 1981), including information about two cist graves dated to the Bronze Age (Fig. 4) and their associated material. According to the author, the site's chronology spanned the Chalcolithic and the Early Bronze Age (Garrido, 1981).

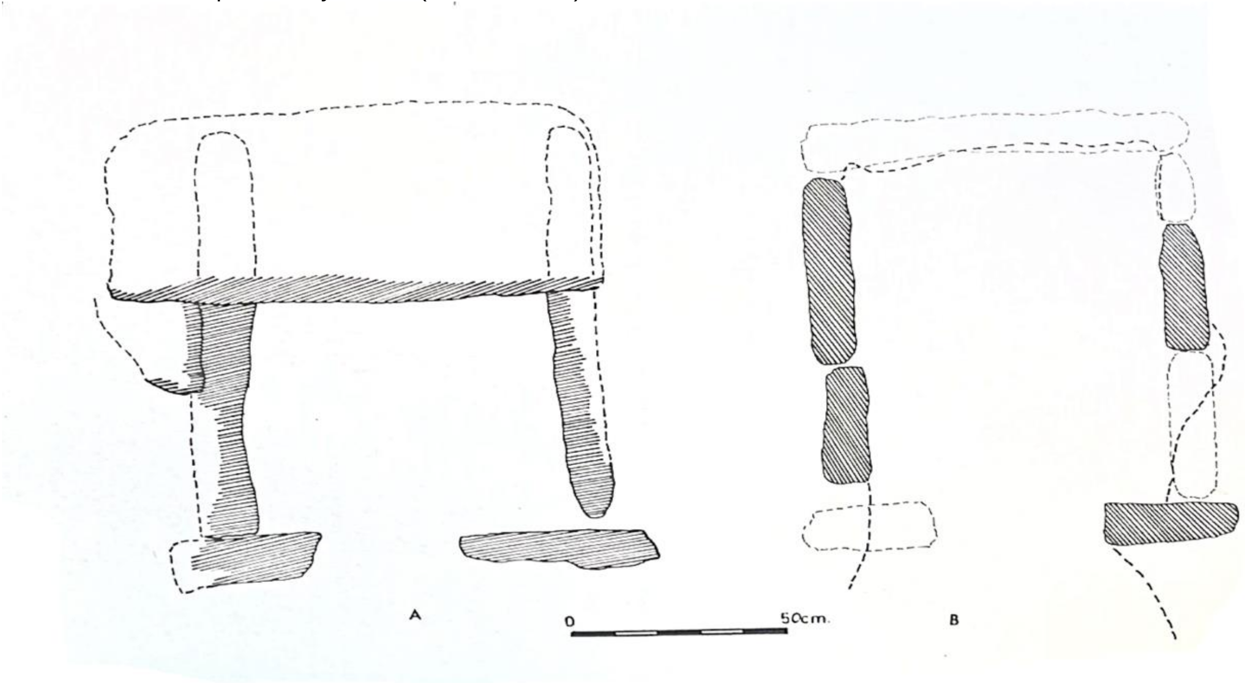


Figure 4: Drawings of the two graves published by Garrido Luque (1981: 44).

Figure 5: Aerial photograph with the position of eight tombs on the slope of Castillejos de Luna, Sierra del Hacho.

Later, the regional government approved the project *Prospección arqueometalúrgica de la provincia de Málaga* (1989-1993), which added new data about the necropolis, including information about nine cist graves (Fig. 5) and a nearby settlement, which Luis Efrén Fernández and his team dated to the Middle Bronze Age. Their research linked the necropolis and the settlement, based not only on physical proximity but also on similarities in their material culture (Fernández Rodríguez et al., 1995; Rodríguez, et al., 2018).

In recent years, the City Council of Pizarra sponsored a project to graphically record the site in detail, which could also increase the necropolis' scientific visibility.

3. Materials and methods

The methodology followed was divided into several steps, including fieldwork and laboratory processing (Fig. 6). The final targets included the generation of 3D models of the funerary structures in the necropolis of Castillejos de Luna.

3.1. Fieldwork

First, on-site visits were undertaken to assess the geographical context and architectural features, with a view to design the most suitable methodology.

Special attention was paid to such aspects as the individual location of each tomb, their immediate surroundings, potential obstacles to recording, dimensions, etc.

During these visits, a series of elements that could later hinder recording tasks were noted. The most significant was the considerable gradient of the slope, which could potentially affect the balance of the technicians and the positioning of laser scanners, as well as the presence of a metal fence around the site, which seriously limited mobility. In addition, the considerable distance between graves and the absence of other archaeological items of interest demanded the generation of a 3D model for each grave instead of a single one for the whole site. These conditions were made worse by the direct sunlight to which the site is exposed, which forms shadows that interfere with 3D modelling.

Terrestrial and aerial photogrammetric and terrestrial 3D laser scanning were used for on-site data collection and the generation of 3D models. The equipment used was as follows:

- *Nikon D5300* reflex camera. Given local conditions, the following camera settings were used: sensitivity ISO 400, Diaphragm f/11; shutter speed 1/500 s and focal length 18 mm.
- *Leica RTC 360* laser scanning at a measuring rate of 2 million points/s with High Dynamic Range (HDR) images.

The site sits on a steep slope, and terrain conditions had to be addressed on an individual-grave basis. Three major workflows were established, based on specific topographic conditions:

- Tombs 1A and 2A (A and B for Garrido (1981) and tombs 5A, 6A, 7A and 8A were recorded by photogrammetry and 3D laser scanning).
- Tomb 3A was recorded by photogrammetry; the tomb has not been systematically excavated, and its limits were unclear. In fact, the only visible features were two orthostats that protrude slightly from the ground. As a result, the information available was very limited.

- Tomb 9A was recorded by 3D laser scanning, as terrain conditions were particularly difficult and the tomb was surrounded by thick undergrowth.

Tombs 3A and 9A are not included in this paper, as their recording did not yield new data. Future recording operations must be preceded by intensive clearing of the ground that surrounds the features.

The workflow began with 3D laser scanning, followed by terrestrial and aerial photogrammetry. This sequence was determined by solar conditions throughout the day. Early in the morning, near-horizontal sunlight caused significant shadows and recommended the use of laser scanning for the generation of untextured models.

In general, the laser scanner had to be set in two or three different positions in each grave, so that sufficiently-linked point clouds that covered the whole feature could be generated. The duration of this operation (approximately 1 h), was determined by the quality parameters set. The laser scanner was programmed to generate the highest-quality point cloud, using HDR 360 images and VIS (automated field recording) technology. This work required a total of 2 minutes and 45 s per station.

A minimum of 40 photographs (Tomb 6A) and a maximum of 75 (Tomb 2A) were taken to generate the photogrammetric models. Owing to the small size of the tombs, this number sufficed to generate high-quality models. Tombs 1A and 2A are larger and architecturally more complex, demanding a greater number of photographs – 60 and 75 respectively. The photograph sequence began around the perimeter of the grave, followed by a photographic swipe of the interior and detailed photographs of those features which, because of their position or size, could have remained initially concealed. In total, 368 photographs were taken in the six graves:

- Tomb 1A → 60 photographs.
- Tomb 2A → 75 photographs.
- Tomb 3A → 55 photographs.
- Tomb 5A → 46 photographs.
- Tomb 6A → 40 photographs.
- Tomb 7A → 42 photographs.
- Tomb 8A → 50 photographs.

Finally, drone flights aimed to generate cartographic images, 3D models, georeferenced images, high-precision absolute measurements, digital elevation models (DEM), and digital terrain models (DTM). A *DJI Ground Station Pro* operating in Android was used to set flight paths and shots. Flights operated at a maximum altitude of 5 m above the tombs, with an 80% end lap between images. A flight at an altitude of 20 m over the local terrain was also undertaken to take general site photographs.

3.2. Laboratory work

For the laboratory work and the generation of the 3D models, licensed software was used.

First, the software *Leica Cyclone Register 360*, which allows alignment corrections between different stations (Fig. 7a), and the export of data in pts format (point cloud) or .e57 format (point cloud with texture) was used. These data were automatically stored with the original quality settings. Overall, overlap strength between point clouds was between 50% and 65% and link error (cloud to cloud) was 0.002 m on average.

The point cloud was optimised with *Leica Cyclone 3DR*. This software "cleans" (according to the software concept) the clouds to generate a tidy workspace (Fig. 7b). This results in a smaller file, as the process eliminates peripheral noise, which is of little interest for archaeological interpretation. Afterwards, a solid model or 3D mesh was generated in two-steps (Fig. 7c), with an average distance between points of 0.15 m and the activation of the hole detection tool. In the first step, a simple mesh was generated. In the second, the mesh is refined by cloud interpolation from two inputs (cloud points and mesh). With this, the software generates new points in the middle of the thickest cloud point to refine the models. Deviation error, maximum number of triangles, and minimum triangle size were entered in advance. The 3D model can be exported in various formats (.OBJ is the most common). A 3DPDF file can also be generated to visualise pre-design views, sections, and measurements without the need to use a specific software or platform or a high-performance computer.

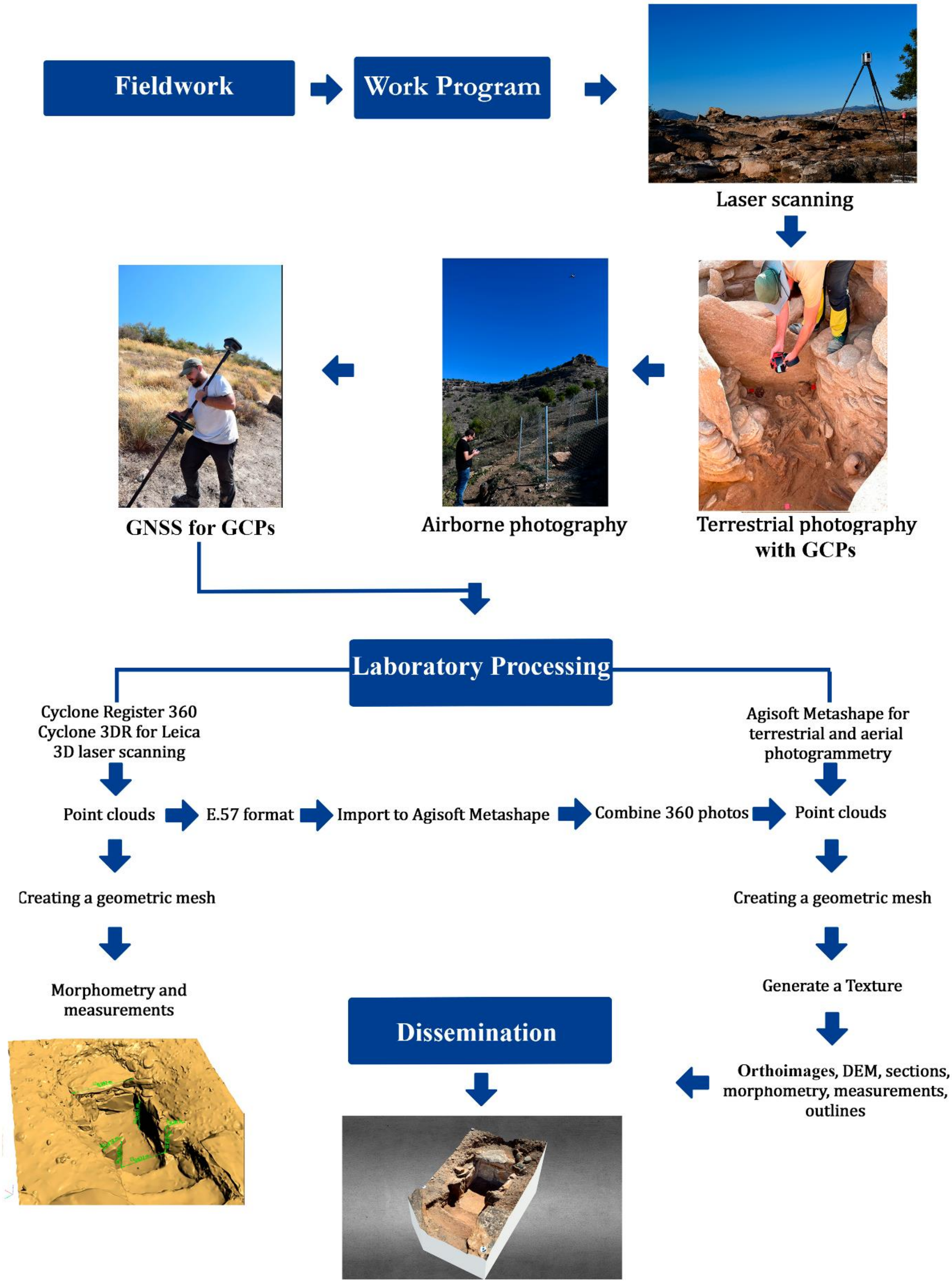
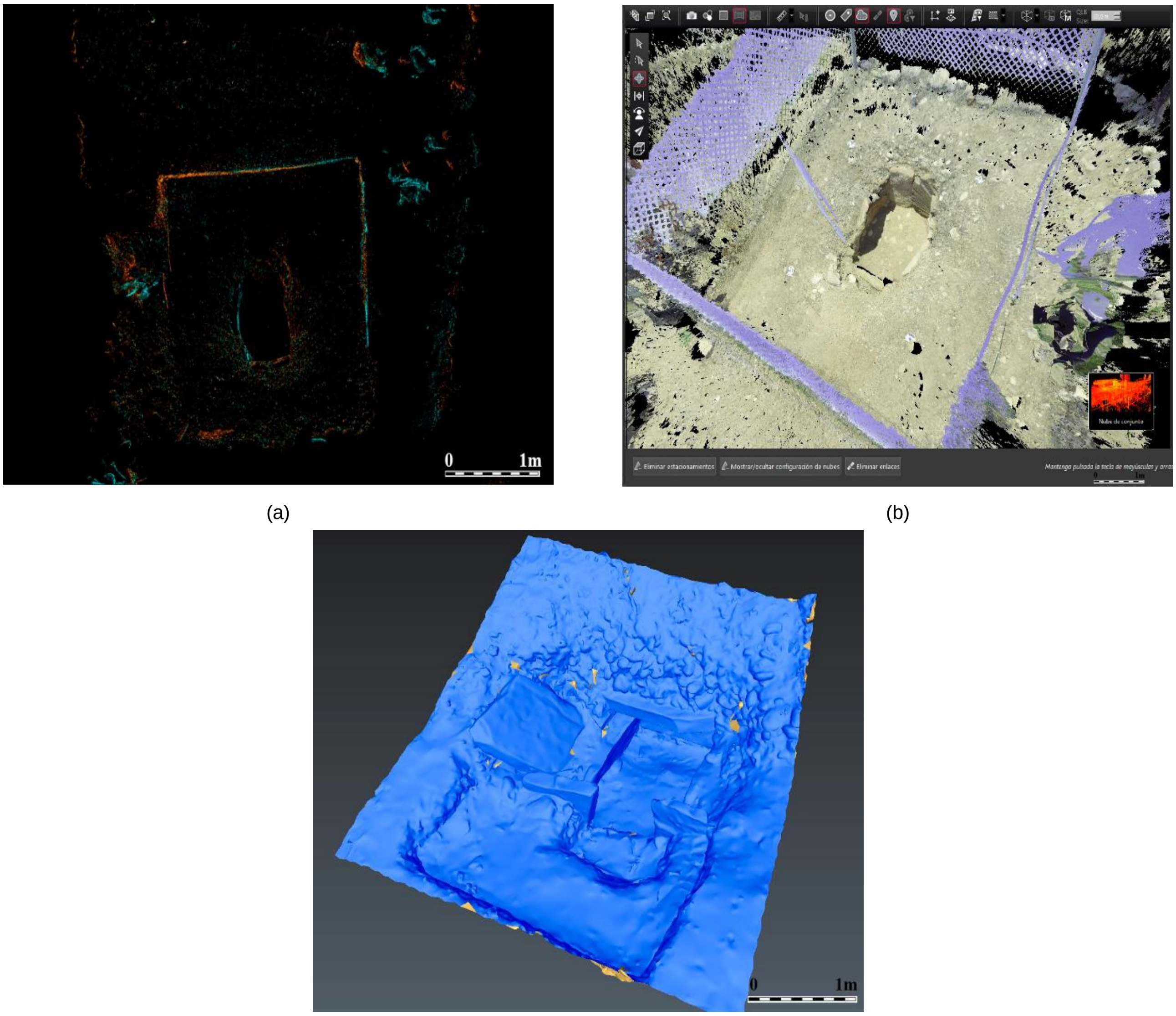


Figure 6: Research workflow.



(a) (b) (c)

Figure 7: Data processing with Cyclone Register 360 and Cyclone 3DR: (a) Alignment corrections between different point clouds (orange and blue) in *Leica Cyclone Register 360*; (b) Vegetation and fence cleaning process on the point clouds in *Leica Cyclone 3DR*; (c) Final solid 3D model.

The software *Agisoft Metashape Pro v.1.8.4* was used to process photogrammetric models. The algorithms used by this software to calculate orientation and geometry, based on the photographs, can yield high-quality 3D models. The first step was to obtain a sparse point cloud based on camera orientation (Fig. 8a), followed by the generation of a dense point cloud (Fig. 8b), meshing (Fig. 8c), and texturing (Fig. 8d). Maximum quality settings were set, and correction tools, such as the clearing of redundant points and model scaling, were used. Ground Control Points (GPCs) were used to facilitate the overlap between photographs and the determination of coordinates with GNSS for georeferencing. The result was a wide catalogue of digital resources, such as high-quality photorealistic 3D models, DEMs (Fig. 10) and DTMs, elevation curves, orthophotographs, etc. Like *Leica Cyclone Register 360*, *Agisoft Metashape* can be used to generate reports with parameter specifications and results.

This phase ended with the processing of the aerial photographs, using the same photogrammetric software and following an identical workflow, again at maximum quality settings.

The final results are two 3D models of each of the tombs produced by photogrammetry and 3D scanning with a high range of detail.

An innovative methodology was applied to Tomb 2A, namely the combination of the point cloud generated by 3D laser scanning (e.57 format) and photogrammetric processing (Remondino & Campana, 2007; Lerma et al., 2013; Burdziakowski & Tysiac, 2019). Laser scans can be imported into Agisoft Metashape software (version 1.8 and onwards). This complement generates depth maps and RGB and 360 HDR images, merging reflex and scanner images. The processing is similar to that applied in 'conventional photogrammetry'. Cameras are oriented to generate point clouds, dense clouds, and meshes. For texture generation, laser scan images are removed and only reflex camera images are used. This method has yielded very positive results, such as the creation of better sparse and dense clouds, the generation of better-quality 3D models, millimetric morphometric precision, and a photorealistic finish through texturing (Burdziakowski & Tysiac, 2019).

In the same way, a retopology process was used in tomb 2A. This technique involves re-creating a new topology of the 3D model. The aim is to produce a 3D model with a smaller number of polygons while maintaining the visual quality by reprojecting textures. For this, the software Zbrush and Blender were used. The first step was to use the Zbrush software to perform retopology on the model, reducing the number of polygons from 39939644 million faces to 83621 faces. Afterward–s, a texture reprojection through Blender was undertaken, performing a series of loops on the model to 'trim' it and rearrange the polygons. Finally, textures were generated using high poly model to reproject them into the low poly model.

4. Results

These steps resulted in the generation of twelve 3D models of features 1A (Fig. 9), 2A (Fig. S1 in supplementary material), 5A (Fig. S2), 6A (Fig. S3), 7A (Fig. S4), and 8A (Fig. S5). One photogrammetric and one laser scanning model were generated for each tomb. Photogrammetry can yield good quality models and a photorealistic finish, while the 3D laser scanner offers very high morphometric resolution, automatically oriented and scaled, although texturing is less realistic than with photogrammetry. Depending on the needs of the object to be studied and the research targets, different options may be recommended. However, the best approach is always to integrate as many techniques as possible. Figures 9 and S1 to S5 present both models and an archaeological drawing based on the laser scanning model, along with the measures of each orthostate.

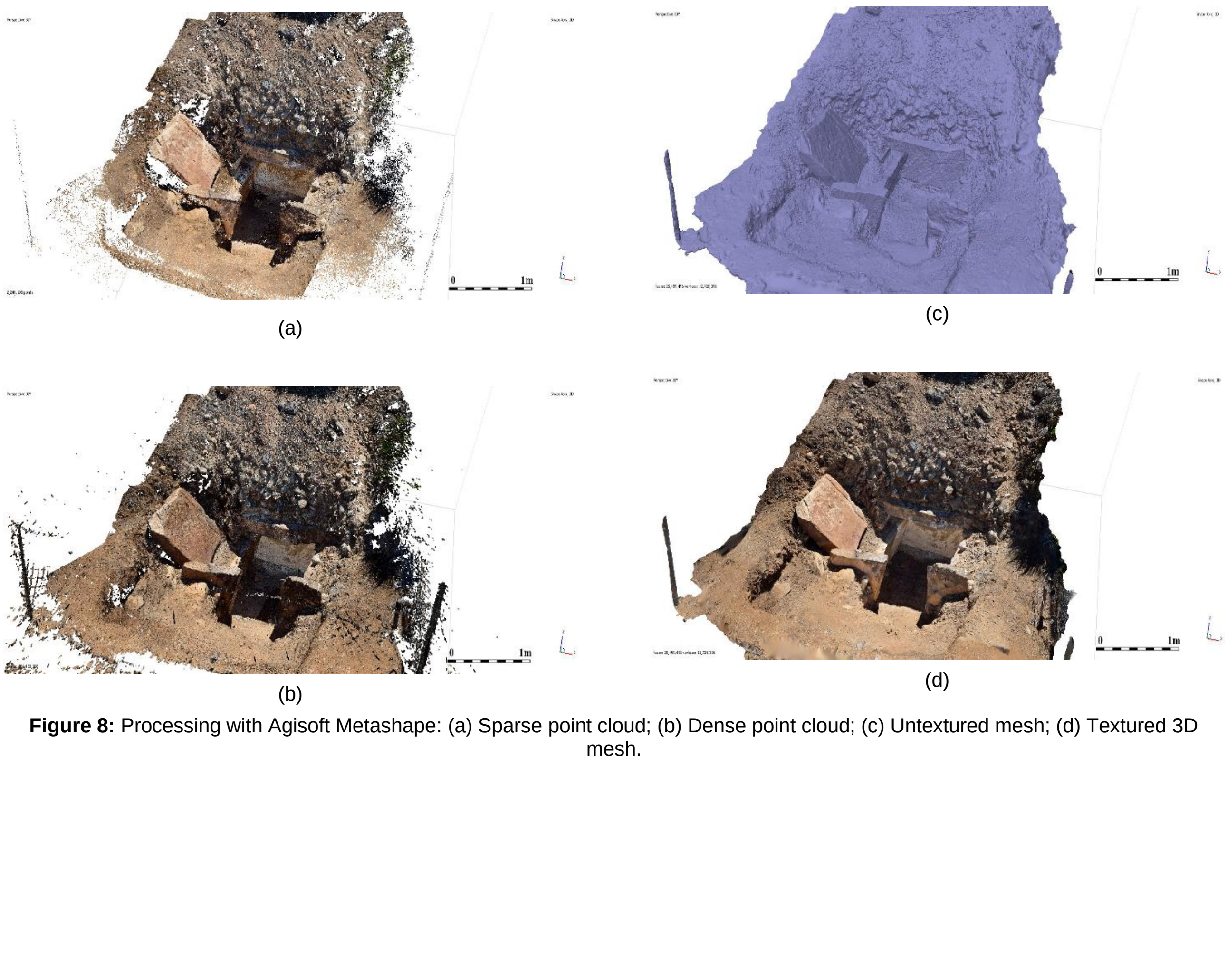


Figure 8: Processing with Agisoft Metashape: (a) Sparse point cloud; (b) Dense point cloud; (c) Untextured mesh; (d) Textured 3D mesh.

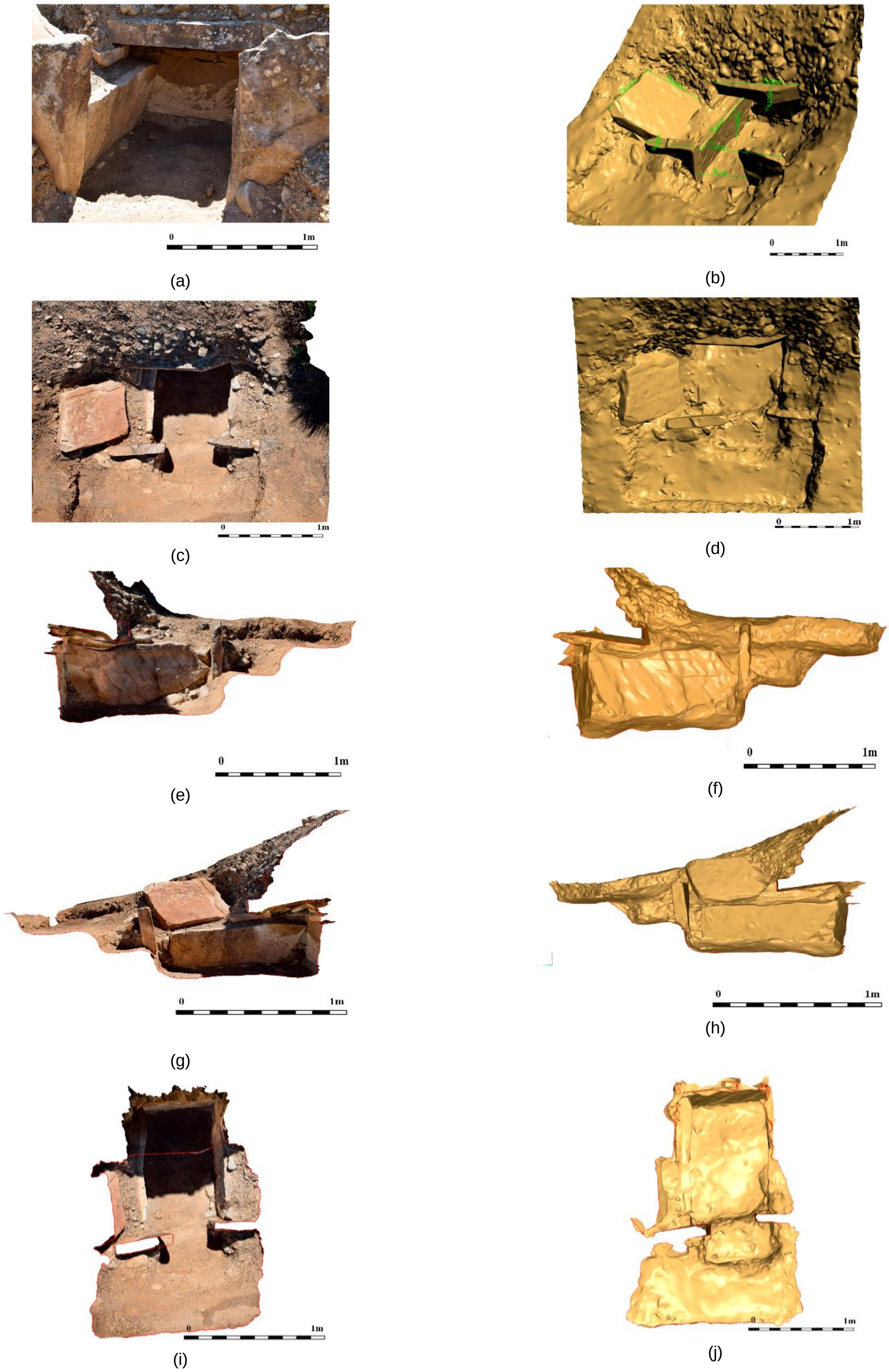


Figure 9: Tomb 1A: (a) Photograph; (b) Laser scanning 3D model; (c) Photogrammetry top view; (d) Laser scanning top view; (e) Photogrammetry south section; (f) Laser scanning south section; (g) Photogrammetry north section; (h) Laser scanning north section; (i) Photogrammetry section Z; (j) Laser scanning section Z.

4.1. Dimensions of orthostates based on 3D models

The tables in the supplementary material (S1-S6) present the dimensions of the orthostates in tombs 1A, 2A, 5A, 6A, 7A and 8A. Data is presented in mm to express the dimensions of orthostates as accurately as possible.

4.2. Location and distance between features

Tables S7 to S13 present the distance between features and the orientation of tombs.

4.3. Orographic assessment of the tombs

Tombs 1A (Fig. 9) and 2A (Fig. S1) are 35 m apart on the western slope of the hill; 1A is lower on the slope and to the south of 2A. The data presented in Table S1 corresponds to the distance between side orthostates (N-S orientation), measured from the external faces. The length refers to the distance between closing orthostates (E-W orientation), also from the outer faces whenever possible, as some tombs are still semi-buried or preserve the covering slab.

Tomb 1A is rectangular in plan (1 m wide x 1.35 m long). It is situated at 135 m asl.

Tomb 2A is also rectangular in plan but larger (1.28 wide x 2 m long). It is situated at 141 m asl.

Tomb 3A is isolated in the central area of the site, in a flatter area of the summit. Its dimensions are uncertain, because only part of a single orthostate is visible. The closest feature is at a distance of 20 m (5A) and the one that is farthest is 49.1 m away (1A). It is situated at 147 m asl.

Tomb 5A (Fig. S2) is on the eastern slope and is 20 m away from both 3A and 6A. The feature is 1.17 m wide x 1.52 m long. It is rectangular in plan. It is situated at 145 m asl.

Tombs 6A (Fig. S3), 7A (Fig. S4), and 8A (Fig. S5) can be regarded as a small cluster, as they are barely 5-6 m apart. Like Tomb 5A, they are on the eastern slope and are the necropolis' northernmost features.

Tomb 6A, is rectangular in plan (1.13 wide x 1.52 m long). It is situated at 145 m asl.

Tomb 7A is also rectangular in plan (1.29 m x 1.51 m long). It is situated at 146 m asl.

Finally, Tomb 8A is 0.97 wide x 1.49 m long. It is the only circular tomb, and thus stands out from the rest. It is situated at 148 m asl.

Based on the location and situation of the tombs, several conclusions can be reached. The tombs are oriented E-to-W. Tombs 1A and 2A, on the western slope, are oriented towards the west. Tombs 5A, 6A, 7A and 8A, on the opposite slope, are oriented towards the east. Tomb 3A is in a flat area, although, since it is only partially visible, the orientation cannot be established, but everything suggests that it is oriented E-to-W like the others (Fig. 10). The size of the structures is fairly standardised. The average width is approximately 1.14 m; the narrowest tomb is 1A, with barely 1 m, and the widest are 2A and 7A, with 1.28 m and 1.29 m, respectively. The average length is approximately 1.40 m; the longest tomb is 2A, with 2 m. Tomb 2A is the largest feature to have been found in the necropolis to date.

The necropolis has a perimeter of 217 m and an area of 12,340.8 m^2. Tombs 6A 7A and 8A form a triangular cluster, with an area of 36.64 m^2. In contrast with these, tombs 1A, 2A, 3A and 5A are isolated, and the minimum and maximum distances between features are 20 m and 50 m respectively.

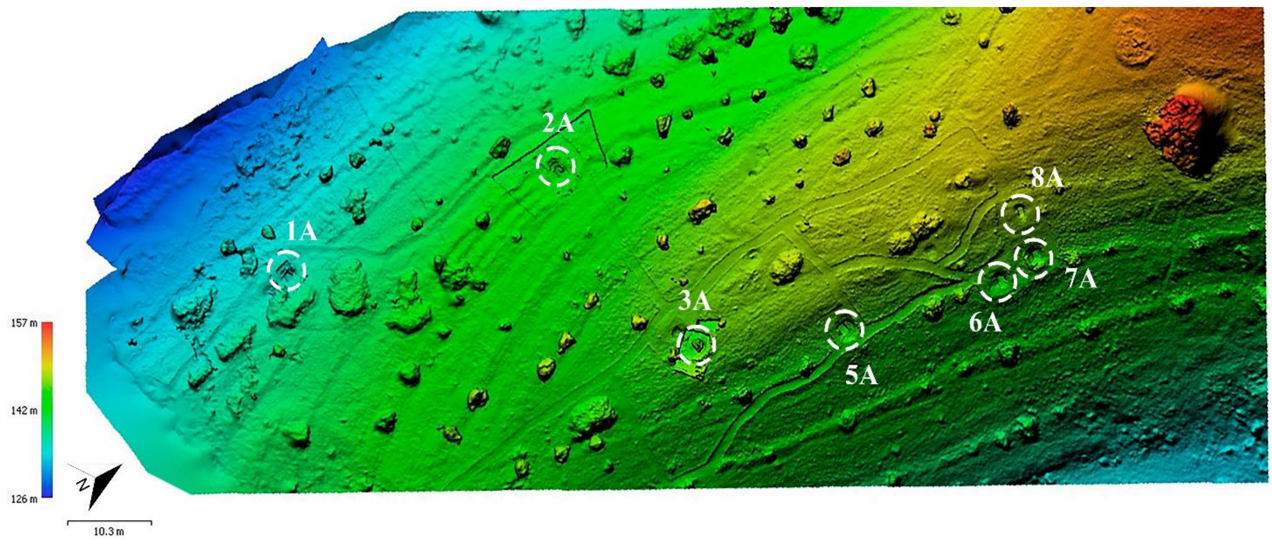


Figure 10: Digital elevation model (DEM).

5. Discussion

The tombs were recorded and – in seven instances – new graphic documentation was generated. The perimeter of the necropolis is 217 m long, encompassing an area of 12340,8 m^2. They are located on the slope (Fig. 2a) of a strategically situated hill that dominates the surrounding territory (Fig. 2b 2c and 2d), both towards the lower Guadalhorce valley-Bay of Málaga and towards the interior regions of Guadalteba and *Vega* of Antequera.

The size of the cists typical (Arteaga, 2000; Arteaga & Schubart, 1990) of Bronze Age tombs and even the Argar culture, with an average length of 1.40 m and width of 1.14 m. Their altitude ranges from 135 m to 148 m.

The necropolis is related to a nearby settlement, located in a neighbouring plateau. The separation of settlement and necropolis differs from typical practice in the Argar culture, in which cist tombs were dug under the houses (Arteaga & Schubart, 1990; Schubart & Arteaga, 1986).

In addition to generating the new models, we needed to contextualise the necropolis within the frame of the Bronze Age in the modern province of Málaga (Ferrer & Marqués, 1986: 254; Marqués & Aguado, 2012).

The relevant historiography has been dominated by historical-cultural and processual approaches. Some socially-inspired landscape studies have, however, been undertaken and, recently, some post-processual models have also been put forward.

No hard data exists to date the necropolis, but the historical context and typological parallels, as well as the material culture, suggest links, albeit peripheral, with the Argar culture, dated to the mid-2nd millennium BCE (Siret & Siret, 1887; Siret, 1891; Lull, 1983; Schubart & Arteaga, 1986; Arteaga, 1992, 2000, 2001, 2002; Lull & Risch, 1995; Vicent, 1995; Cámara & Molina, 2009, 2011; Molina & Cámara, 2004; Aranda et al., 2021a; Márquez et al., 2009).

Several settlements, situated in strategic locations in terms of defence and territorial control, and cist grave necropolises similar to those found in the south-east of the Iberian Peninsula, have been identified in the region of the Axarquía (Malaga) (Fig. 11) (Baldomero & Ferrer, 1984; Ferrer, Moreno & Ramos Muñoz, 1984; Ramos Muñoz, 1988; Ferrer, 2007; Martín & Recio, 2017-2018).

Other Bronze Age cist grave necropolises have been found in the basin of the Guadalhorce River (Baldomero & Ferrer, 1984; Ferrer, 2007: 173; Rodríguez Vinceiro et al., 1992: 239; Aranda et al., 2021b), the Grande River (Fernández Ruiz, 1995, 2004: 281), Antequera (Fernández Rodríguez et al., 1999; Marqués & Aguado, 2012; Rodríguez Vinceiro et al., 2018), and the region of Guadalteba (Fig. 11). They are situated on strategic hilltops, at altitudes ranging from 400 m to 600 m a.s.l. (Ramos Muñoz et al., 1989, 2004).

Bronze Age megalithic tombs (Fernández Ruiz et al., 1997; Fernández Ruiz & Márquez, 2001a, 2001b; Márquez et al., 2009), belonging to tribal communities, and collective burials in artificial caves, for instance in Alcaide (Antequera) (Marqués & Aguado, 2012) and Aguilillas (Campillos), have also been attested (Fig. 11) (Espejo et al., 1994; Ramos Muñoz et al., 1997).

Let us recall that these necropolises often yield abundant metal objects, including punches, daggers, swords, and silver rings. This confirms that weaponry was a symbol of social status (Ramos Muñoz et al., 2004: 317) within the context of incipient class societies (Arteaga, 1992).

From a technical perspective, the methodology deployed must be regarded as successful, especially since the only documentation available to date was that published by Garrido in 1981 – and this only included limited information about tombs A and B (1A and 2A). The use of 'new technologies' resulted in the documentation of the nine structures that form the necropolis. New recording systems, such as the combination of photogrammetry and laser scanning, were used to generate the 3D models. Although this methodology has been applied to archaeology and heritage management since the 1980s (Almagro, 1988; Burdziakowski & Tysiac, 2019), and it has recently been used to record various prehistoric contexts (Lerma et al., 2010; Benavides López et al., 2020), their application to Iberian Bronze Age funerary structures is rare.

The new records are a huge leap ahead in the study of these tombs. The potential of virtual recording techniques is 'unlimited', as splendidly illustrated by Naka (2019). The new records cover architectural data and create categorized groups with chronological and socioeconomic implications. In Castillejos de Luna, we have been able to refine the geomorphological and architectural characterization of the features, an aspect that was not fully addressed by Garrido. Other necropolises need to be documented in order to produce a more comprehensive perspective of the period's funerary practices.

Although we were able to produce high quality models and collect new data, the future evolution of these techniques will help to improve archaeological recording and to exploit the potential of different data extraction software packages even further. In addition, the documentation generated will facilitate a more in-depth analysis of the architectural techniques used by the tomb builders.

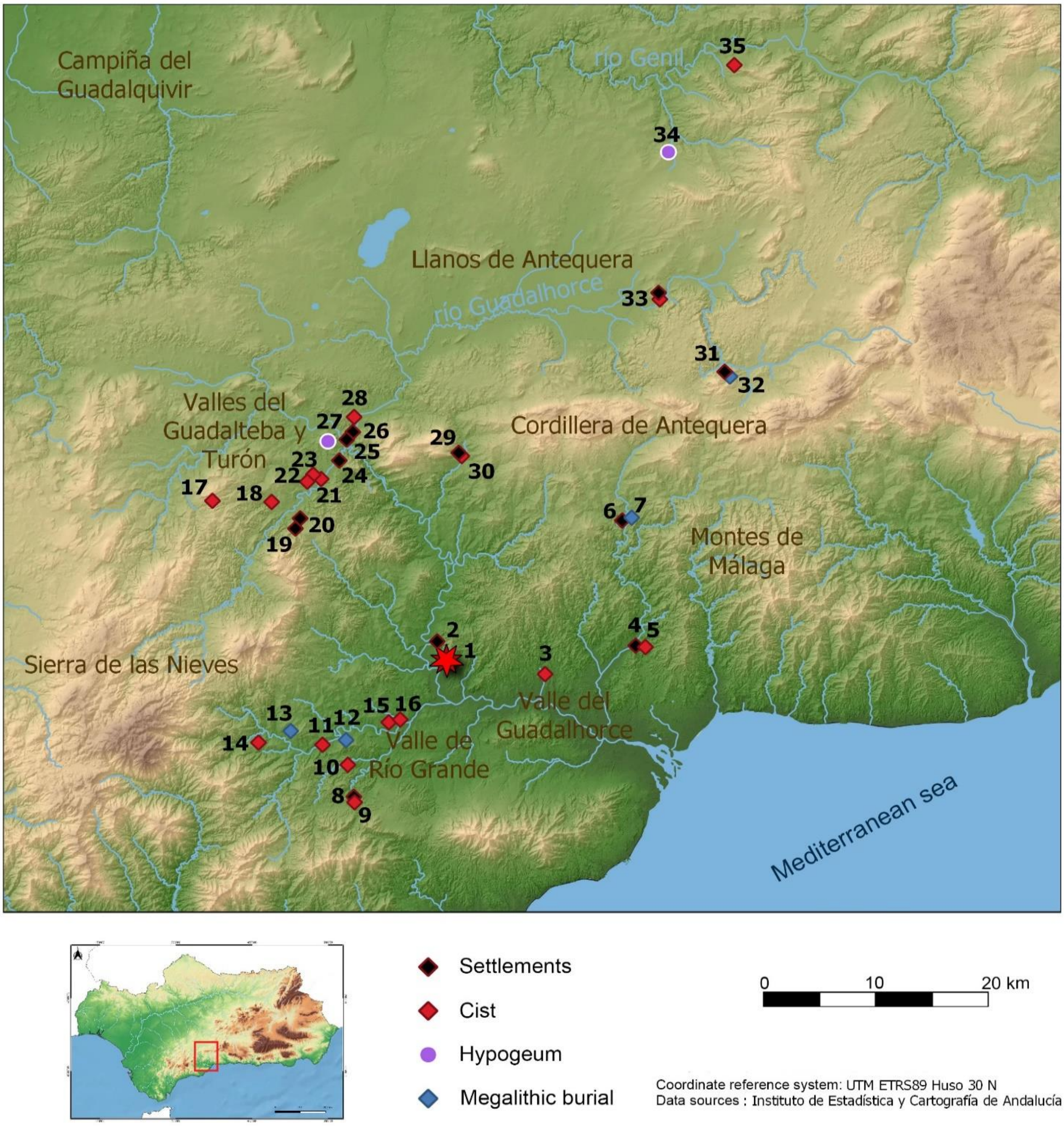


Figure 11: Location map with the necropolises and settlements mentioned in the text. 1. Necrópolis de los Castillejos de Luna (Pizarra). 2. Castillejos de Luna (Pizarra). 3. Cerro Parrado/El Sexmo (Cártama). 4. Cerro de la Peluca (Puerto de la Torre, Málaga). 5. Lagar de las Ánimas (Puerto de la Torre, Málaga). 6. El Castillejo (Almogía). 7. Monsampedro I y II (Almogía). 8. Llano de la Virgen (Coín). 9. Cuesta Blanquilla (Coín). 10. Llano Trillo (Coín). 11. Cerro Mayorga (Coín). 12. Cerrete de la Cañada de Algane (Coín). 13. Tesorillo de la Llaná (Alozaina). 14. Apeado de Tolox (Tolox). 15. Cerradillo (Coín). 16. Malara (Coín). 17. La Bolina (Ardales). 18. Olivar de Jorge (Ardales). 19. El Cerrajón (Ardales). 20. Peña de Ardales (Ardales). 21. Morenito 1 (Ardales). 22. Raja del Boquerón (Ardales). 23. Lomas del Infierno (Ardales). 24. Parque Ardales (Ardales). 25. El Castillón (Campillos). 26. Espolón del Guadalhorce-Kontiki (Campillos). 27. Aguilillas (Campillos). 28. Rodahuevos (Campillos). 29. Los Atanores (Valle de Abdalajís). 30. Cementerio (Valle de Abdalajís). 31. Alto de las Breñas (Antequera). 32. El Tardón (Antequera). 33. Peña de los Enamorados (Antequera). 34. Alcaide (Antequera). 35. Tumbalobos (Cueva de San Marcos).

6. Conclusions

This work is the result of a research programme authorised by the Andalusian regional government in a Bronze Age necropolis in Pizarra (Malaga).

All archaeological research in prehistoric sites must combine research with conservation and dissemination.

The study of this canonical Bronze Age necropolis involved the recording of nine cist tombs near a settlement. It is part of the interesting Bronze Age horizon in the Guadalhorce Valley and the interior of the modern province of Malaga, which is related to the western projection of the culture of El Argar.

The regional government and the city council of Pizarra Town Council are responsible for the protection, conservation, and maintenance of the site and are involved in the defence and maintenance of the site.

The project's target from a historical and social perspective is to use these techniques to gain a better understanding of the archaeological record, including the tombs' locations and mutual relationships.

Terrestrial and aerial photogrammetric and laser scanning techniques were applied to the tombs, in a watershed moment in the study of this type of feature. In addition, the dimensions of orthostates (Tables S1-S6) and the distance between tombs was established (Tables S7-S13).

Photogrammetry and laser scanning yield heavy high-resolution 3D models, which are heavy and hard to reproduce in smartphones and personal computers (Banfi, et al., 2022). For this reason, these techniques still require much fine-tuning.

The following step will be to combine photogrammetric and laser scanning techniques for the generation of oriented, scaled, and georeferenced (to local coordinates) models of tombs 1A, 5A, 6A, 7A and 8A. Retopology - creating a new topology (the way polygons are distributed in the mesh to generate the 3D model) – must be used to optimise the models (Fig. 12) by reducing the number of polygons that form the mesh. Different optimisation methodologies exist to reduce the number of polygons without compromising quality. For instance, open code software *Instant Meshes and Blender* can be used to optimise topology and re-project textures that have the same visual quality as the high-resolution model. In this way, the resulting model is less heavy and the mesh smaller, reducing loading times and visual fluidity in FPS (Frames per second) in mobile devices. This process was undertaken in Tomb 2A (Fig. 12), resulting in a photogrammetric model with fewer polygons and the same visual quality. However, the ultimate aim of the application of these techniques was to improve our records and contribute to a better understanding of the archaeology of prehistoric societies.

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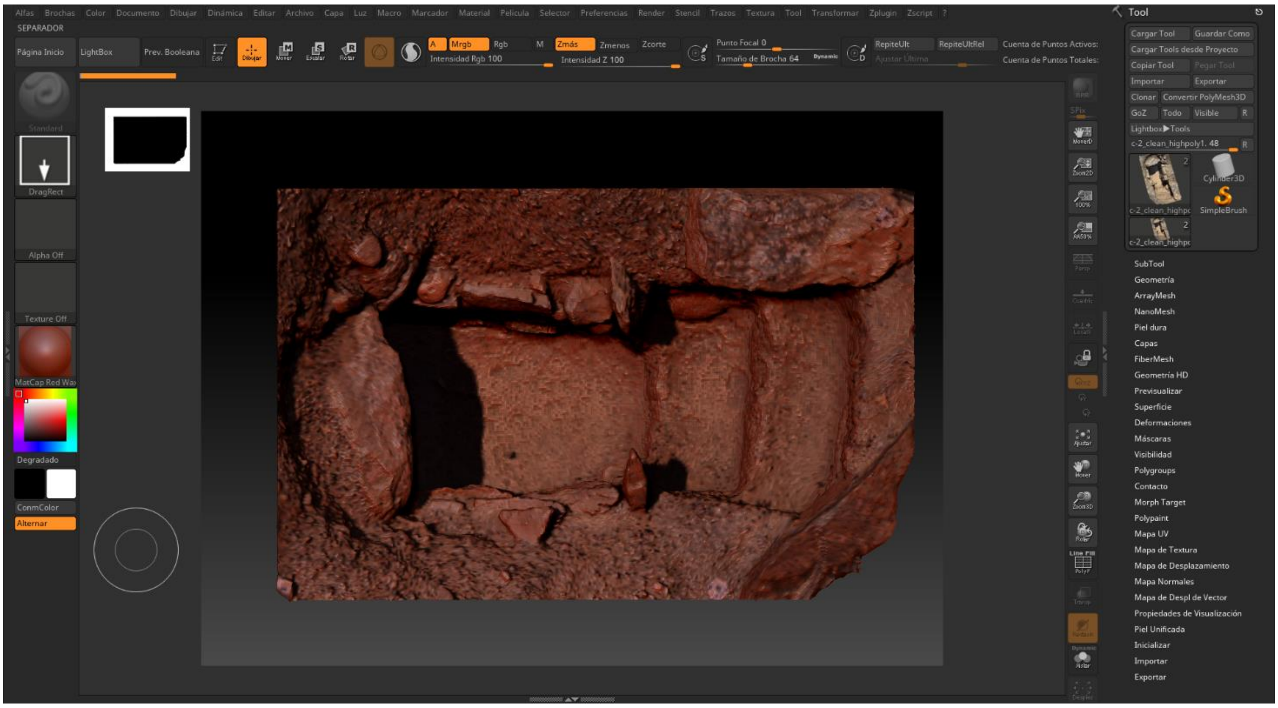
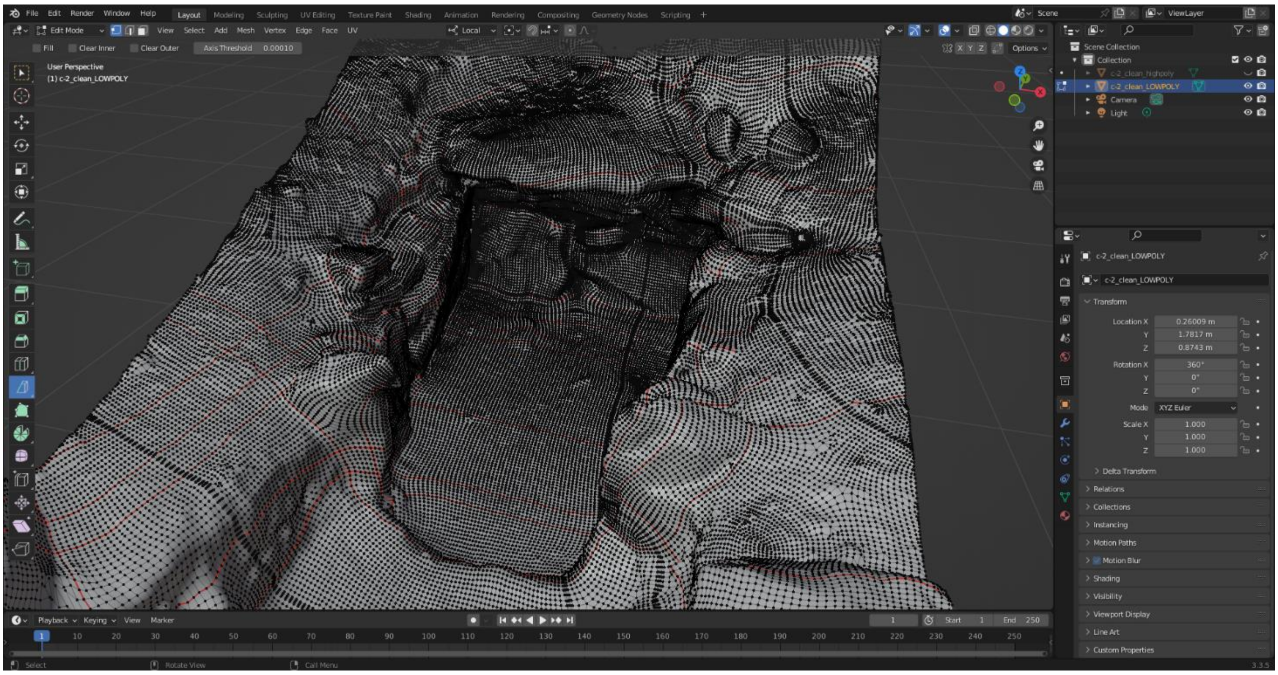
Supplementary files

This article contains supplementary files accesible via https://doi.org/10.4995/var.2023.19126.



(a)



(b)

Figure 12: Optimisation of models for Tomb 2A: (a) Retopology process; (b) Textures reprojection process.

References

Almagro, A., (1988). La representación de la arquitectura a través de la fotogrametría: posibilidades y limitaciones. Fotogrametría y representación de la Arquitectura. X Symposium Internacional del Comité Internacional de Fotogrametría Arquitectónica CIPA (pp. 81-90). Granada.

Angás Pajas, J., & Uribe Agudo, P. (2017). RPAS o drones aplicados al patrimonio cultural: de la documentación geométrica a las imágenes multiespectrales. *La Ciencia y el Arte VI: Ciencias experimentales y conservación del patrimonio, 6*, 68-81.

Aranda, G., Montón, S., & Sánchez, M. (2021 a). *La cultura de El Argar (c.2200-1550 cal. A.C.)*. Granada: Comares Arqueología.

Aranda, G., Milesi, L., & Lozano, A. (2021 b). Las prácticas funerarias de la Edad del Bronce en la provincia de Málaga (España). *Spal, 30-1*, 46-70. https://doi.org/10.12795/spal.2021.i30.02

Arteaga, O. (1992). Tribalización, jerarquización y estado en el territorio de El Argar. *Spal, 1*, 179-208. https://doi.org/10.12795/spal.1992.i1.09

Arteaga, O. (2000). El proceso histórico en el territorio de Fuente Álamo. La ruptura del paradigma del Sudeste desde la perspectiva atlántica-mediterránea del Extremo Occidente. In H. Schubart, V. Pingel & O. Arteaga (Eds.*), Fuente Álamo. Las excavaciones arqueológicas 1977-1991 en el poblado de la Edad del Bronce* (pp. 117-143). Sevilla: Arqueología Monografía. Consejería de Cultura, Junta de Andalucía.

Arteaga, O. (2001). La sociedad clasista inicial y el origen del estado en el territorio de El Argar. *Revista Atlántica-Mediterránea de Prehistoria y Arqueología Social, 3*, 121-219.

Arteaga, O. (2002). Las teorías explicativas de los ‘cambios culturales’ durante la Prehistoria en Andalucía: Nuevas alternativas de investigación. *In Actas del III Congreso de Historia de Andalucía* (pp. 247-311). Córdoba: Publicaciones Obra Social y Cultural Cajasur.

Arteaga, O., & Schubart, H. (1990). Fuente Álamo. Excavaciones de 1977. *Noticiario Arqueológico Hispánico, 9*, 245-289.

Baldomero, A., & Ferrer, J. E. (1984). Las necrópolis en cistas de la provincia de Málaga. *Cuadernos de Prehistoria y Arqueología de la Universidad de Granada, 9*, 175-193.

Banfi, F., Brumana, R., Landi, A. G., Previtali, M., Roncoroni, F., & Stanga, C. (2022), Building archaeology informative modelling turned into 3D volume stratigraphy and extended reality time-lapse communication. *Virtual Archaeology Review, 13*(26), 1-21 https://doi.org/10.4995/var.2022.15313

Benavides López, J. A., Aranda Jiménez, G., Sánchez Romero, M., Alarcón García, E., Fernández Martín, S., Lozano Medina, A., & Esquivel Guerrero, J. A. (2016). 3D modelling in archaeology: The application of Structure from Motion methods to the study of the megalithic necropolis of Panoria (Granada, Spain). *Journal of Archaeological Science: Reports*, 10, 495-506. https://doi.org/10.1016/j.jasrep.2016.11.022

Becerra Martín, S. (2019). El aprovechamiento de sílex durante la Prehistoria reciente de la comarca de Guadalteba (Málaga). Un análisis desde la arqueometría y la tecnología lítica. Oxford: BAR International Series 2920.

Burdziakowski, P., & Tysiac, P. (2019). Combined close range photogrammetry and terrestrial laser scanning for ship hull modelling. *Geoscience, 9(5), 242.* https://doi.org/10.3390/geosciences9050242

Cámara, J. A., & Molina, F. (2009). El análisis de la ideología de emulación: el caso de El Argar. *Cuadernos de Prehistoria y Arqueología de la Universidad de Granada, 19*, 163-194.

Cámara, J. A., & Molina, F. (2011): Jerarquización social en el mundo Argárico (2000-1300aC). *Cuadernos de Prehistoria y Arqueología de Castellón, 29*, 77-104.

Domingo, I., Villaverde, V., López-Montalvo, E., Lerma, J. L., & Cabrelles, M. (2013a). Latest developments in rock art recording: towards an integral documentation of Levantine rock art sites combining 2D and 3D recording techniques. *Journal of Archaeological Science, 40(4),* 1879-1889. https://doi.org/10.1016/j.jas.2012.11.024

Domingo, I., Villaverde, V., López-Montalvo, E., Lerma, J. L., & Cabrelles, M. (2013b). Reflexiones sobre las técnicas de documentación digital del arte rupestre: la restitución bidimensional (2D) versus la tridimensional (3D). *Cuadernos de arte rupestre, 6*, 21-32. http://hdl.handle.net/10251/61250

Escrivá Estevan, F., & Madrid García, J. A. (2010). El mundo virtual en la restauración. Aplicaciones virtuales para la conservación y restauración del patrimonio. *Arché, 4-5*, 11-20. http://hdl.handle.net/10251/30147

Espejo Herrerías, M. M., & Cantalejo Duarte, P. (1990-1991). La Galeota, un taller de sílex calcolítico (Ardales, Málaga). Colección Martín Domínguez. *Mainake, 11-12,* 21-40.

Espejo, M. M., Ramos Muñoz, J., Recio, A., Cantalejo, P., Martín, E., Castañeda, V., & Pérez, M. (1994). Cerro de las Aguilillas. Necrópolis colectiva de cuevas artificiales. *Revista de Arqueología, 161*, 14-23.

Fernández Rodríguez, L. E., Rodríguez Vinceiro, F., Suárez Padilla, J., Santamaría, J. A., Soto, A., Thode Mayoral, C. Von, García Pérez, A., Romero, J. C., Cabello Berdú, S., Barrera, M., & Palomo, A. (1995). Prospección arqueometalúrgica de la provincia de Málaga: campaña de 1992. Sector sur-oriental del Maláguide. Síntesis general. *Anuario Arqueológico de Andalucía /1992, II. Actividades Sistemáticas,* 285-302.

Fernández Rodríguez, L. E., Rodríguez Vinceiro, F., Palomo, A., Santamaría, J. A., Suárez, J., Navarro, I., Arancibia, A., Escalante, M. M., & Ángel, J. M. (1999). Informe preliminar de la excavación arqueológica de urgencia en la necrópolis del Bronce del Cortijo de Rodahuevos (Antequera-Campillos, Málaga). *Anuario Arqueológico de Andalucía/1995. III* (pp. 384-389). Sevilla: Junta de Andalucia. Consejería de Cultura.

Fernández Ruiz, J. (1995). La necrópolis del Llano de la Virgen, Coín (Málaga). *Baetica, 17*, 243-272.

Fernández Ruiz, J. (2004). Uso de estructuras megalíticas por parte de grupos de la Edad el Bronce en el marco del río Grande (Málaga). *Mainake, XXVI*, 273-392*.*

Fernández Ruiz, J., & Márquez Romero, J. E. (1985). El taller de Ardite, Coín (Málaga). *Cuadernos de Prehistoria de la Universidad de Granada, 10*, 103-129.

Fernández Ruiz, J., Marqués, I., Ferrer, J. E., & Baldomero, A. (1997). Los enterramientos colectivos de El Tardón (Antequera, Málaga). *II Congreso de Arqueología Peninsular. T. II (Neolítico, Calcolítico y Bronce)* (pp. 371-380). Zamora, Spain.

Fernández Ruiz, J., & Márquez, J. E. (2001 a). El sepulcro megalítico del Tesorillo de la Llaná de Cerro Ardite, Alozaina (Málaga). *Spal, 10*(1), 193-206. https://doi.org/10.12795/spal.2001.i10.13

Fernández Ruiz, J., & Márquez, J. E. (2001 b). *Megalitismo en la cuenca del Río Grande (Málaga).* Colección Textos Mínimos. Málaga: Servicio de Publicaciones Universidad de Málaga.

Ferrer, J. E., Moreno, A., & Ramos Muñoz, J. (1984). Cistas de la Edad del Bronce excavadas en el algo valle del Vélez. *Baetica, 7*, 121-134.

Ferrer, J. E., & Marqués, I. (1986). El Cobre y el Bronce en las tierras malagueñas. In O. Arteaga (secretario de actas), *Actas del Congreso Homenaje a Luis Siret (1934-1984)* (pp. 251-261). Sevilla: Consejería de Cultura. Junta de Andalucía, Sevilla.

Ferrer, J. E. (2007). *La Prehistoria malagueña.* Málaga: Prensa Malagueña. Diario Sur.

Garrido, A. (1981). *Un enterramiento en cista en el término de Pizarra*. *Arqueología de Andalucía Oriental: site estudios.* Málaga: Publicaciones del Departamento de Prehistoria y Arqueología. Universidad de Málaga.

Kosciuk, J. (2012). Modern 3D scanning in modelling, documentation and conservation of architectural heritage. *Journal of Heritage Conservation, 32*, 82-88.

Laiseka, I. (2021). Aproximación al análisis funcional de los picos líticos de Las Aguilillas (Campillos, Málaga). (Master's Tesis. Universidad Autónoma de Barcelona).

Lerma, J. L., Navarro, S., Cabrelles, M., & Villaverde, V. (2010). Terrestrial laser scanning and close range photogrammetry for 3D archaeological documentation: the Upper Palaeolithic Cave of Parpalló as a case study. *Journal of Archaeological Science*, 37(3), 499-507. https://doi.org/10.1016/j.jas.2009.10.011

Lerma, J. L., Cabrelles. M., Navarro, S., & Seguí, A. E. (2013). *Modelado fotorrealístico 3D a partir de procesos fotogramétricos: láser escáner versus imagen digital*. *Cuadernos de Arte Rupestre,* 6, 85-90. http://hdl.handle.net/10251/61249

Lull, V. (1983). La "cultura" de El Argar (Un modelo para el estudio de las formaciones económico-sociales prehistóricas). Madrid: Akal.

Lull, V., & Risch, R. (1995). El estado argárico. *Verdolay, 7*, 97-109.

Marqués, I., & Aguado, T. (2012) *Los enterramientos de la Edad del Bronce en la provincia de Málaga.* Málaga: Servicio de Publicaciones. Universidad de Málaga.

Márquez, J. E., Fernández Ruiz, J., & Mata, E. (Coords.) (2009*). El sepulcro megalítico del Tesorillo de la Llaná. Una estructura funeraria singular en la cuenca media del Río Grande*. Málaga: Servicio de Publicaciones. Universidad de Málaga.

Martín, E., & Recio, A. (2017-2018). Frontera y territorialización durante la Edad del Bronce en el ámbito de la Axarquía (Málaga). *Mainake, XXXVII*, 5-42.

Molina, F., & Cámara, J. A. (2004). La cultura de El Argar en el área occidental del Sureste. In L. Hernández & M. Hernández (Eds.), *La Edad del Bronce en tierras levantinas y zonas limítrofes* (pp. 455-470). Alicante: Ayuntamiento de Villena.

Muñoz-Muñoz, A., Fernández-Sánchez, D., Gómez Sánchez, M. L., & Vijande, E. (2022). Una visión tridimensional de la necrópolis megalítica de Trafalgar. In D. Bernal-Casasola, J. J. Díaz, E. Vijande, J. A. Expósito & J. J. Cantillo (Eds.), *Arqueología Azul en Trafalgar. De la investigación al turismo sostenible* (pp. 95-105). Junta de Andalucía. Editorial UCA.

Naka (2019). Outstanding Universal Value of the Mozu-Furuichi Kofun Group. Retrieved May 03, 2023, from https://www.mozu-furuichi.jp/jp/img/promotion/allure/leaflet_001/en_2019_naka.pdf.

Portillo-Sotelo, J. L., Díaz, J. J., & Muñoz-Muñoz, A. (2022). Por tierra y aire. Escáner 3D y drones para digitalizar el Trafalgar romano. In D. Bernal-Casasola, J. J. Díaz, E. Vijande, J. A. Expósito & J. J. Cantillo (Eds.), *Arqueología Azul en Trafalgar. De la investigación al turismo sostenible* (pp 106-122). Junta de Andalucía. Editorial UCA.

Ramos, J., Espejo, M. M., & Cantalejo Duarte, P. (1986). *Taller calcolítico del Castillo del Turón*. Málaga: Ayuntamiento de Ardales.

Ramos Muñoz, J. (1988). *El poblamiento prehistórico del Alto Vélez hasta la Edad del Bronce*. Málaga: Excma. Diputación Provincial de Málaga. Biblioteca Popular Malagueña.

Ramos Muñoz, J., Espejo, M. M., & Cantalejo, P. (1989). Morenito I, un enterramiento de la Edad del Bronce. Ardales (Málaga). In *XXI Congreso Nacional de Arqueología, Ponencias y Comunicaciones* (Vol. I, pp. 409-428). Zaragoza.

Ramos Muñoz, J., Espejo, M. M., Recio, A., Cantalejo, P., Martín, E., Durán, J. J., Castañeda, V., Pérez, M., & Cáceres, I. (1997). La necrópolis colectiva del Cerro de las Aguilllas (Ardales-Campillos, Málaga). Inferencias socioeconómicas. *Revista Atlántica-Mediterránea de Prehistoria y Arqueología Social, 1*, 159-180.

Ramos Muñoz, J., Martín, E., & Recio, A. (1998). La arqueología de la muerte. Reflexiones sobre las formas de concebir a los 'muertos' en los estudios prehistóricos. In S. Domínguez, A. Recio, E. Martín. & J. Ramos (Eds.), *El dolmen del*

Cerro de la Corona de Totalán. Contribución al estudio de la formación económico-social tribal en la Axarquía de Málaga (pp. 15-25). Málaga: Servicio de Publicaciones del Centro de Ediciones de la Diputación de Málaga.

Ramos Muñoz, J., Espejo, M. M., & Cantalejo, P. (2004). La formación económico social clasista inicial (Milenios III y II a.n.e.) en los entornos de Ardales (Málaga)". In *II-III Simposios de Prehistoria Cueva de Nerja. III. Las primeras sociedades metalúrgicas en Andalucía. Homenaje al profesor Antonio Arribas Palau* (pp. 309-320). Málaga: Fundación Cueva de Nerja.

Remondino, F., & Campana, S., (2007). Fast and detailed digital documentation of archaeological excavations and heritage artifacts. In A. Posluschny, K. Lambers, I. Herzog (Eds.), *Layers of Perception* (pp. 36–42). Computer Applications and Quantitative Methods in Archaeology, Berlin, Germany.

Rodríguez Vinceiro, F., Fernández Rodríguez, L. E., Clavero Toledo, J. L., Romero Silva, J. C., Thode, C., García, A., Suárez, J., Barrera, N., & Palomo, A. (1992). Estado actual de la investigación arqueometalúrgica prehistórica en la provincia de Málaga. *Trabajos de Prehistoria,* 49*,* 217-242. https://doi.org/10.3989/tp.1992.v49.i0.543

Rodríguez Vinceiro, F., Murillo Barroso, M., Fernández Rodríguez, L. E., & Montero Ruiz, I. (2018). Metalurgia prehistórica en tierras de Antequera y su contexto andaluz. *Zephyrus*, *81*, 93-115. http://dx.doi.org/10.14201/zephyrus20188193115

Ruiz Sinoga, J. D., Senciales, J. M., Asensi, A., & Díez, B. (2017). Capítulo 1: La geografía física de la provincia de Málaga". In J. D. Ruiz, F. B. Galacho & J. F. Martínez (Eds.), *Itinerarios geográficos por la provincia de Málaga. Homenaje al profesor D Emilio Ferre Bueno* (pp. 7-39). Málaga Umaeditorial.

Santos Gómez, S. (2016). El empleo de las tecnologías 3D en la conservación del patrimonio y su aplicación en la realización de reproducciones de bienes culturales. *Observar. Revista Electrónica de Didáctica de Las Artes*, *11*(1), 97-114.

Schubart, H., & Arteaga, O. (1986). Fundamentos arqueológicos para el estudio socioeconómico y cultural del área de El Argar. In O. Arteaga (secretario de actas*), Actas del Congreso Homenaje a Luis Siret (1934-1984),* (pp. 289-307). Sevilla: Consejería de Cultura. Junta de Andalucía.

Siret, E., & Siret, L. (1887). *Les premiers âges du metal dans le sud-est de l'Espagne*. Amberes. Kessinger Publishing.

Siret, L. (1891). *L'Espagne préhistorique*. Almería: Junta de Andalucía y Arráez Editores.

Torres, M., López-Menchero, V. M., López, J., Torrejón, J., & Maschner, H. (2022). Digitization and virtual reality projects in archaeological heritage. The case of the archaeological site of Motilla del Azuer in Daimiel (Ciudad Real). *Virtual Archaeology Review, 13*(26), 35-146. https://doi.org/10.4995/var.2022.15004

Valle, P., Fernández, A., & Rodríguez, A. A. (2022). Lost archaeological heritage: virtual reconstruction of the medieval castle of San Salvador de Todea. *Virtual Archaeology Review, 13*(26), 22-44. https://doi.org/10.4995/var.2022.16178

Vicent, J. (1995). Problemas teóricos de la arqueología de la muerte. Una introducción". In R. Fábregas, F. Pérez, C. Fernández & J.A. Abásolo, (Eds.), *Arqueoloxía da norte. Arqueologxía da Morte na Península Ibérica desde as orixes ata o Medievo* (pp 15-31). Xinzo de Limia: Concello de Xinzo de Limia.

Wachowiak, M., & Kara, B. V. (2013). Scanning and replication for museum and cultural heritage applications. *Journal of the American Institute for Conservation, 48*, 141-158 https://doi.org/10.1179/019713609804516992