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DIGITAL ENHANCEMENT AND PHOTOGRAMMETRIC RECORDING OF LA JOQUERA LEVANTINE ROCK ART (BORRIOL, CASTELLÓ)

MEJORA DIGITAL Y REGISTRO FOTOGRAMÉTRICO DEL ARTE RUPESTRE LEVANTINO DE LA JOQUERA (BORRIOL, CASTELLÓ)

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Highlights:

- Digital image enhancement and other processing techniques reveal previously unseen parts of Levantine figures.
- First three-dimensional reproduction of La Joquera site. The quality replaces physical visits to the site whether for study or dissemination purposes.
- Merging enhanced digital tracings and a photorealistic model, virtual visitors can easily observe an almost invisible art, as it was originally before the paintings faded.

Abstract:

The heritage values of Levantine rock art, as UNESCO World Heritage since 1998 and as an Asset of Cultural Interest since 1985 according to the Spanish Heritage Act, together with its fragile nature, demand developing initiatives aimed at regularly revisiting and monitoring the sites and updating any existing records (descriptions, tracings, photographs, etc.). This is especially important for long-known sites, such as La Joquera, discovered and first graphically recorded in 1930 and for which these records have not been updated for decades. Such revisits should be aimed to: a) asses the integrity of the finds since their discovery or since the last revision; b) test whether current digital technologies can improve previous interpretations and reproductions of the art preserved there; and c) produce accurate three-dimensional (3D) photorealistic models that capture the 3D nature of this heritage and even improve the visualisation of motifs. These integral approaches are relevant to the qualitative and quantitative study of the art, as well as to its preservation and monitoring, and creation of digital archives to ensure a virtual future for Levantine art. This paper reports the technologies and methods used, the challenges faced (in terms of space available, lighting restrictions and the visual interference caused by the protective fence), and the results obtained at La Joquera rock art site as part of the 2D and 3D digital recording of the rock surface, the colour and the motifs depicted. Highlights of this paper include the identification of previously invisible weaponry and adornments of the only archer preserved on this site, as well as some other incomplete remains. Deliverables also include the production of a photorealistic model on which colour-intensified tracings are projected. This facilitates the identification of art that is now extremely faded and offers a closer look at what the site may have looked like originally.

Keywords: Levantine art; rock art; digital archaeology; digital photogrammetry; World Heritage; virtualization

Resumen:

Los valores patrimoniales del arte rupestre Levantino, como Patrimonio de la Humanidad por la UNESCO desde 1998 y Bien de Interés Cultural desde 1985 según la ley de Patrimonio Histórico Español, junto con su fragilidad, exigen desarrollar iniciativas dirigidas a revisar de forma periódica los yacimientos y actualizar los registros existentes (descripciones, calcos, fotografías, etc.). Esto es especialmente importante para aquellos yacimientos que se conocen desde antiguo, como La Joquera, descubierto en 1930 y cuya documentación no había sido actualizada desde hace décadas. Estas visitas deben ir dirigidas a: a) evaluar la integridad de los hallazgos desde su descubrimiento (o desde su última revisión); b) comprobar si las tecnologías digitales actuales pueden mejorar las interpretaciones y reproducciones (calcos) anteriores; y c) generar modelos fotorrealistas tridimensionales (3D) precisos que capten la tridimensionalidad de este patrimonio e incluso mejoren la visualización de los motivos. Estos enfoques integrales son relevantes para el estudio cualitativo y cuantitativo del arte, así como para su conservación y monitorización y para crear archivos digitales que proporcionen un futuro virtual al arte Levantino. En este artículo se exponen las tecnologías y métodos utilizados, los retos afrontados (en términos de espacio disponible, restricciones de iluminación e interferencias visuales causadas por la valla protectora) y los resultados obtenidos en el yacimiento con arte rupestre de La Joquera durante el proceso de registro

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digital en 2D y 3D de la superficie rocosa, del arte y del color. Los aspectos más destacados de este artículo incluyen la identificación del armamento y algún adorno del único arquero conservado en este yacimiento, anteriormente invisibles, así como de otros restos incompletos. También incluyen la elaboración de un modelo fotorrealista sobre el que se proyectan calcos con el color intensificado. Esto facilita la identificación de un arte hoy extremadamente desvanecido y ofrece una visión más cercana del aspecto que debió de tener el yacimiento originalmente.

Palabras clave: arte levantino; arte rupestre; arqueología digital; fotogrametría digital; Patrimonio Mundial; virtualización

1. Introduction

La Joquera rock art site, also known locally as Albaroc cave, is a well-known site in the archaeological literature on Levantine art. Very few motifs have survived, including a singular human with a biconical headdress, prominent thorax and short modelled legs, and several remnants (Porcar, 1932). However, the peculiarities of the only human preserved, popularly known as the "bruixot" (the sorcerer), make it a recurring reference in the study of human representations and their particular headdresses in this rock art tradition (Galiana, 1985: 62; Mesado, 1989; Alonso & Grimal, 2001; Grimal & Alonso, 2001; Domingo et al., 2007). Another unique feature of this site is the type of rock hosting the paintings, as it is the only site in the province of Castelló with Levantine art on 'Rodeno' red sandstone (Sos Baynat, 1981: 84; Soriano et al, 2022: 80). Beyond this province, Triassic red sandstone ('*Buntsandstein*' facies) is also the host rock of the Levantine paintings in the famous site complexes of Albarracín (Benito et al., 1993; Bea & Angás, 2015; Royo, 2023) and Villar del Humo (Cuenca) (Diez-Herrero et al., 2009; Ruiz, 2017). It is also the only site with rock art known so far in the municipality of Borriol and, as such, it is of particular local relevance. The site was discovered by chance in the first half of the last century. It was the first of several sites discovered by the famous Castelló painter and rock art researcher J.B. Porcar, on May 18th, 1930. He soon published the discovery, describing the paintings as a "beautiful human figure and a series of erased stains", that he interpreted as a possible part of another human figure and the back of an animal. He also included the first, and for a long time the only, graphic record (tracing) of the surviving motifs (Porcar, 1932), which has since been systematically reproduced in the literature. It was not until 2001 that Grimal published a new tracing, slightly different to Porcar's (Alonso & Grimal, 2001), but still missing some parts.

Between 2005 and 2006 the site was restored (cleaned) by E. Guillamet. This improved the visualisation of the motifs. Before this intervention, fading and poor chromatic contrast between the motifs and the host rock led to reproductions and interpretations that are today improved by digital image enhancement and other processing techniques. For example, Beltran (1985: 140) added to previous descriptions of a fat human and an arrow by noting a bag or quiver hanging from the man's shoulders. However, as discussed later in this paper, current records show no evidence of a bag, only a massive body, and the object held in the hand is not an arrow but a bow. Thus, Beltran's interpretation seems to be misguided due to dirt and poor preservation.

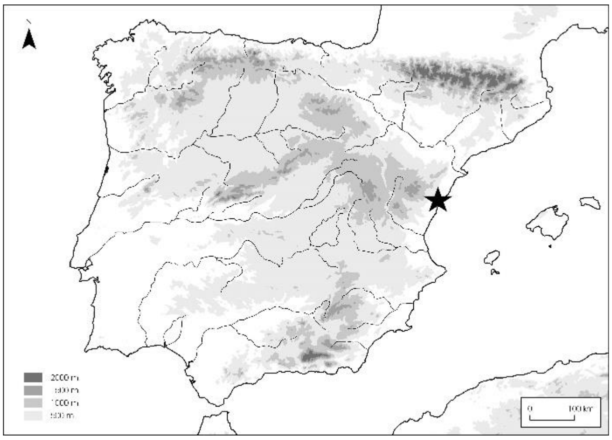
The review of the previous literature, reproductions and interpretations of this site, the recent improvement in the visibility of the paintings after their restoration, and the growing local interest in this site (Palmer & García, 2020) made it necessary to update the existing records. It should be remembered that Levantine art has been World Heritage since 1998, recognizing its exceptional and universal cultural significance. It has also been a BIC (Asset of Cultural Interest) since 1985, which is the highest level of protection under the Spanish Heritage Act (Domingo & Bea, 2016). However, the location in the open air means that it is constantly exposed to both natural and anthropogenic degradation processes that threaten the long-term conservation of the art and the rock (Domingo & Barreda, 2023). Therefore, with the idea of creating a more accurate and updated digital record of the site, and based on our previous experience with both 2D and 3D recording techniques (e.g. Domingo et al, 2013 and 2015, Jalandoni et al, 2018, Brady et al, 2019), we have used state-of-the-art digital technologies to improve visibility and create an accurate 3D surface model of this particular site. The results are important both for scientific research, conservation and dissemination purposes, and for building a digital future for this fragile heritage.

This paper reports on the technologies and methods used, the challenges faced (in terms of available space, lighting restrictions and the visual interference from the protective fence), and the results of our new digital 2D and 3D digital documentation of La Joquera rock art site.

2. Site description

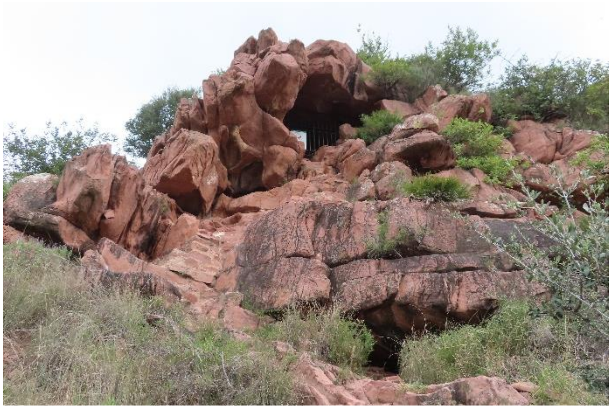
La Joquera site is a small cavity that opens out almost at the top of a hill, 248 m above sea level, on the left bank of the Albaroc ravine. The site is located southeast of the municipality of Borriol, Castelló, in zone 30T and UTM coordinates 750123 m E and 4435580 m N. Today, it is only about 9 km in a straight line from the Mediterranean Sea, making it the site with Levantine art that is closest to the sea in this area to date. The cavity in which the paintings are preserved is small and is the result of the accumulation of blocks of rodeno (Triassic sedimentary rock) (Palmer & García, 2020: 275). These blocks form an overhang that protects the paintings from direct sunlight and rain, which is crucial for their conservation, as this type of rock is particularly sensitive to erosion by water and wind, causing fractures and unique shapes. The inner part of the cavity is irregular, with average dimensions of 1.6 m long, 1.40 m high and 1.40 m deep (Fig. 1).

Between 2005 and 2006 the site was protected by a fence installed directly at the mouth of the shelter (Matamoros & López, 2009). Such fences are installed at Levantine sites to prevent looting, to regulate visits and, in cases such as this, to facilitate visualization of the art from the outside without reaching the wall. While fulfilling its intended purpose, this fence also adds a new challenge to the 3D documentation of the site, as explained below.



(a)

(b)



(c)

(d)

Figure 1: La Joquera rock art site. (a) Map showing the geographical location. (b) Satellite photo showing the location of the site. (c) View of the site from outside. (d) Photograph of the painted panel.

From an archaeological point of view, the only human evidence preserved in the shelter is rock art. There are no sediments or other archaeological remains to help date the site or understand settlement patterns. However, the surrounding area is very rich in prehistoric sites from the late Paleolithic to the Bronze Age, although many of these are decontextualized or known only from surface finds.

If we focus on the chronological range that is central to the debates on the chronology of Levantine art, between the recent Mesolithic and the ancient phases of the Neolithic, in the Borriol area we find Cova Negra, with a Recent Mesolithic occupation (Román & Fullola-Isern, 2020). In addition, Porcar, in his publication on La Joquera, reports the discovery of a trapezoid about sixty meters from the site (Porcar, 1932) which, from a typological point of view, could be attributed to both the Mesolithic and Neolithic periods. In addition, there are about fifteen sites, in caves/shelters and in the open air, with Neolithic materials, mainly from the final stages (G. Aguilella, personal communication).

3. Materials and methods

3.1. Data collection (Abric de La Joquera, Borriol)

In this section we describe the data collection process, both to produce 2D digital tracings of the art and to photogrammetrically survey the site to obtain reliable metric information about the rock art panel and the rock shelter. We also explain the various challenges faced due to the current characteristics of the site in terms of location (on top of a hill, on a steep slope and with no external platform), size (quite small and with a low ceiling) and type of fencing.

As a small cavity, the limited space available inside the shelter was a challenge when it came to setting up equipment. It also affected mobility and limited shooting angles. The morphology of the rear of the shelter, where the two side walls meet to form a corner, hinders proper access for photography. In addition, there is a narrow ledge or niche between the wall and the ceiling at the back of the shelter where no light can reach. This lack of light makes collecting data from these areas difficult. However, as these parts do not preserve any rock art, it was not considered necessary to reproduce them exactly.

There are other additional obstacles and challenges when it comes to photographing from the outside. First, the presence of a protective rods fence at the entrance of the cavity, which restricts the view from the outside and blocks the camera's line of sight. This is an obstacle to outside photography. Furthermore, there is no suitable platform from which to stand outside, as the area is rocky, steeply sloping and has extreme changes in elevation (Fig. 1c). These rocks and the surrounding vegetation have an impact on terrestrial photogrammetric photography using a camera.

Another important consideration is light. Photographing the inside is best done at the beginning and the end of the day. However, as mentioned above, it is important to remember that cracks and nooks remain dark. In the middle of the day, when the sun is high, direct sunlight hitting the floor and wall turn the lit parts of the shelter white, making the photographic process more difficult. We therefore had to constantly adapt to the lighting challenges during the photographic session to achieve a relatively homogeneous result.

3.2. Coded targets and surveying

Having a coordinate system and points with correct coordinates is crucial for building an accurate and integrated 3D surface model for measuring rock art with millimeter accuracy. Control Points (CP) have been used for this purpose (Tahar, 2013; Shortis & Seager, 2014; Yogender & Kushwaha, 2020). In this case study, CPs were distributed and installed as coded targets within the rock shelter and around the main panel containing the art in a standard frame (Fig. 2).

Figure 2: Location of the CPs (red dots) and sample image of the coded targets used inside the rock shelter.

CPs were measured in a local coordinate reference system using a Leica TS-07-R500 total station. The reason for installing the total station outside the rock shelter was twofold. The first was the lack of space inside the shelter for the tripod and the total station. Secondly, from a technical point of view, the targets had to be measured in reflectorless mode. According to the standard and technical capabilities of this total station, the minimum distance that the R500 can measure in Kodak gray 18% - 90% reflective is 1.5 m (Leica Geosystems, 2021). As a result, in a difficult but stable stationing situation, all CPs were measured in direct view from outside the shelter.

3.3. Close-range photogrammetry

Close-range photogrammetry (CRP) was used for digital documentation based on photographs and 3D models in order to better visualize and interpret the rock art motifs preserved in this shelter (Mark & Billo, 2006; Lerma et al., 2010; Nuñez et al., 2012; Domingo et al., 2013; Davis et al., 2017; Jalandoni & May, 2020). Photographs were taken using a Canon R5 full-frame mirrorless camera with a resolution of 8192×5464 pixels, equipped with a Canon RF-16 mm prime lens. The photos were taken at an average distance of 1.2 m from the camera to the art. In this case, the Ground Sample Distance (GSD) is estimated to be 0.3 mm. To minimize camera, shake and capture sharp photos, shots were taken using a tripod, without touching the camera's shutter button and using internal WIFI technology via a smartphone. In the CRP scenario inside the shelter, an attempt was made to maintain orthogonal mode for all scenes (Bryan et al., 1999), resulting in 85 overlapping photographs that were entered into Agisoft Metashape Professional v. 1.8 software for post-processing. After importing the photos, areas that were not needed or that could interfere with the alignment stage were masked. The coordinate file of the CP was entered into the software and after marking the CP on the photos, the photos were oriented.

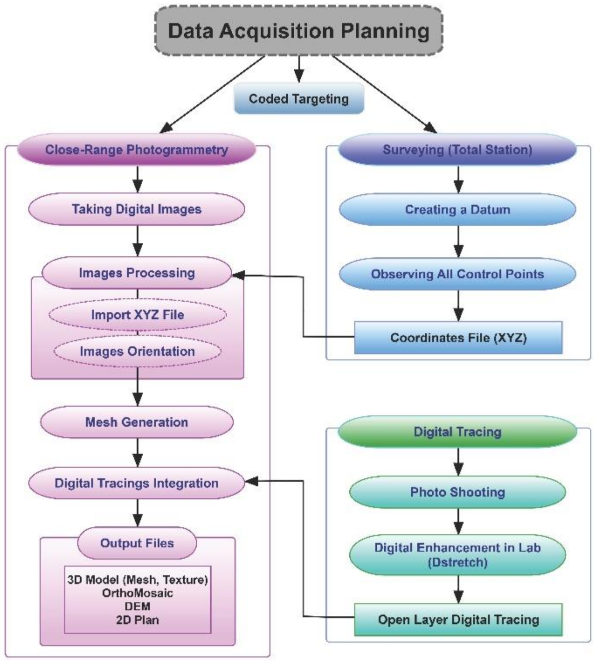


Figure 3: Data acquisition workflow for 3D Modeling of La Joquera rock art site.

After orientating the images, a polygonal surface or mesh of vertices, edges and faces is created from the dens point cloud. In this study, since the area containing the art (and therefore prioritized) is the wall, and it has low topographical surface prominence, it is crucial to perform mesh processing and depth mapping with the utmost precision. Due to the rock art being faded and difficult to observe in the resulting photorealistic model, an additional step has been added to the process This involves integrating a colour-enhanced version of the digital tracings of the artworks (see workflow in Fig. 3 and details of the tracing process in Section 3.4). The aim is to obtain a textured 3D model rendering the rock art fully recognizable. To successfully merge the 2D digital tracings of the painted motifs and display them on the main mesh, as well as to obtain the desired outputs, it is crucial to have a highly precise mesh geometry (Schneider et al., 2018; Park & Lee, 2019). When integrating or merging the 2D digital tracings with the oriented primary images (captured using the 16 mm lens and used in the aligning process of the images to generate the dense points cloud and mesh), it is important to consider two key factors.

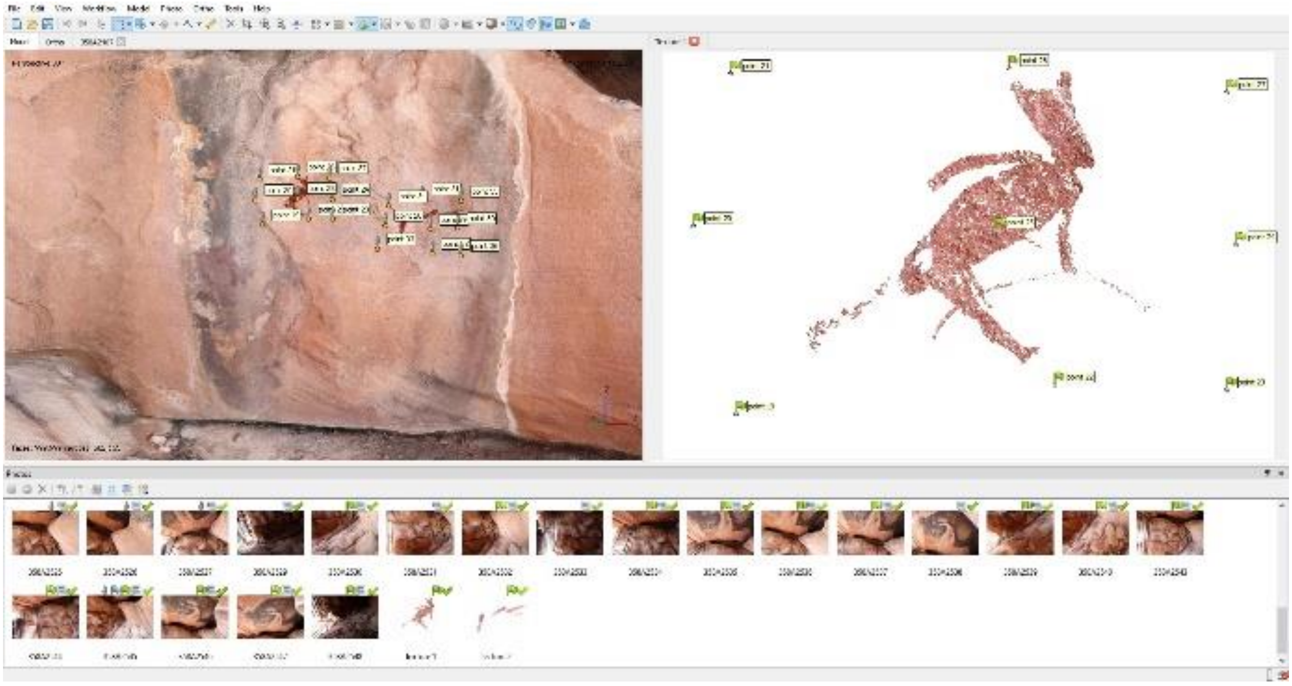


Figure 4: Background photographs used for tracing the art are matched with textured primary images for alignment.

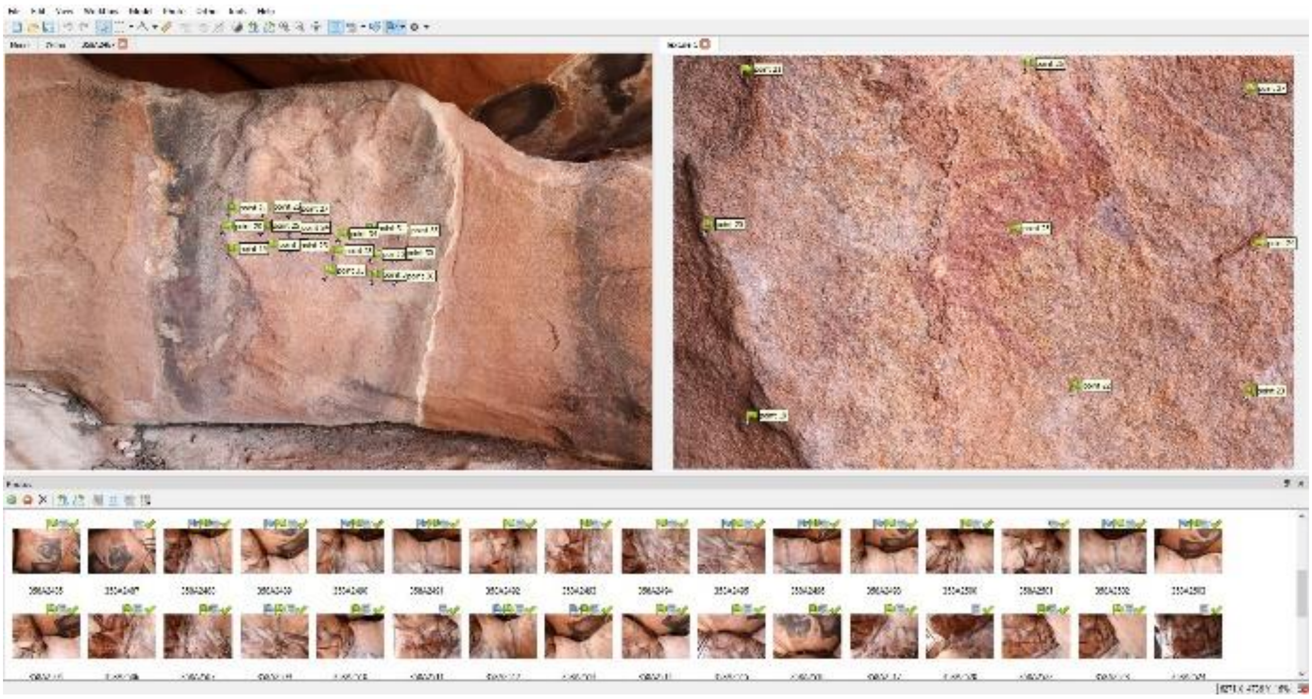


Figure 5: To display only the painted motifs on the 3D model, the background images are replaced by the background-free tracings of the motifs.

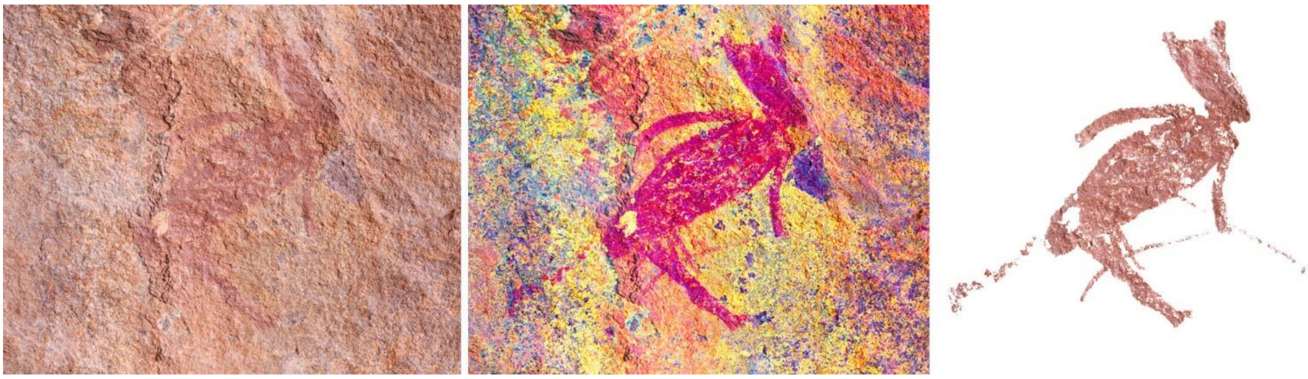
First, the background photographs used to produce the digital tracing (i.e., to separate the rock paintings from the substrate rock) are taken orthogonally and in close-up to minimize distortion and capture the motifs with greater detail. They are therefore at a different scale and shooting angle to the primary images. These digital tracings are saved as a PSD file in an open layer, with the background layer containing the photograph of the motif used for tracing (Fig. 6a in Section 3.4) and another layer including the painted motif isolated from the background (Fig. 6c in Section 3.4). To integrate the digital tracing with the oriented primary images, both layers need to be saved as two separate documents. The subsequent step is to match these images with the primary images that have been already aligned.

Second, the accuracy of the orientation of the tracings depends on the accuracy of the orientation of the primary images, so the amount of the image alignment error should be taken into account (Bolecek & Říčný, 2015).

To align the tracings with the primary images, the saved copy of the background layer is used first, as only with texture exact matching is possible (Fig. 4). Once matched and aligned with the primary images, background photographs are replaced by the images containing the digital tracings (Fig. 5). The result is a photorealistic 3D surface model complete with color-enhanced tracings displayed on it.

3.4. 2D digital tracing of painted motifs

To document the preserved rock art motifs we used the same camera as for close-range photogrammetry, as outlined in earlier publications (Domingo & López-Montalvo, 2002; Domingo et al., 2013) (Fig. 3). Initially, we captured close-up high-resolution orthogonal photographs of every motif to maximize details and minimize distortion. These photographs were the basis for tracing (isolating the motifs from the rock substrate) (Fig. 6a). The next step is to digitally enhance the images acquired with the Dstretch plugin for the imaging software ImageJ, using a decorrelation algorithm to highlight rock art images (Harman, 2005) (Fig. 6b). This pretreatment is aimed at enhancing variations in colour between the art and the host rock while identifying faded figures or parts of figures, invisible to the naked eye. In the next step, both standard and Dstreched versions of the images undergo processing with Adobe Photoshop CC v. 23.5.1. We use the program's colour range tool to detect and extract the art. The idea is to isolate remains of similar colour ranges, remove the background (the underlying rock surface) and generate a new image with each single painted motif (Fig. 6c).



(a) (b) (c)

Figure 6: Enhancing and manipulating digital images to record Archer 1: (a) Visible light colour image; (b) False-colour image decorrelated with Dstretch plugin to ImageJ, in Dstretch colour space LDS. This colour space is useful for general enhancement and highlights yellow pigments (Harman, 2005). In this case is useful to increase contrast between the archer and the background; and (c) Digital tracing produced in Adobe Photoshop.

(a) (b) (c)

Figure 7: Tracing of Archer 1 by various authors: (a) Porcar,1932; (b) Alonso & Grimal, 2001; and (c) Domingo in this paper.

4. Results and discussion

This section comprises two parts: one with the results of the 2D digital tracing process and art analysis, and the other presenting the results and direct output from CRP.

4.1. Results of the 2D digital recording of rock art motifs

The use of digital image enhancement and processing technologies has allowed for a more comprehensive recording and reproduction of the Levantine paintings preserved at La Joquera site.

Upon comparing our tracing (Fig. 7c) with those previously produced by Porcar (1932) (Fig. 7a) and Grimal (Alonso & Grimal, 2001) (Fig. 7b), we observe some significant differences. The shape and headdress of the human figure remain largely unchanged. We distinguished a small head profile pointed at the chin, adorned with a distinctive high biconical headdress infrequent within the repertoire of Levantine figures. The body is massive. This contrasts with the short but slightly modeled legs, detailing calves and feet in both of them. In addition, an unrecorded line was observed hanging from the waist and extending over the frontal leg. This could represent ornament or male genitalia, both of which are frequently represented in human figures of similar style from the region. The weapons recorded in our digital reconstruction were previously unnoticed. Careful examination unveiled a bow held in the front hand, which had previously been mistaken for an arrow fragment, and the remains of an arrow held across the bow.

The figure's characteristics align with the Cingle style, featuring humans with sizes ranging from 8 to 12 cm tall, less naturalistic than previous Levantine styles and completely disproportionate. Humans in this style often exhibit various facial traits, headdresses, waist adornments, and weaponry (Domingo, 2006). The biconical headdress and prominent torso have a few parallels in the regional context. A similar headdress has been described for the main archer at la Covatina site (Mesado, 1989) and a human from Saltadora VII-53 (Domingo et al., 2007). The globular body with short limbs is also present in particular individuals from abric de Centelles (Viñas et al., 2015), Cingle de la Mola Remigia (Ripoll, 1963) or coves de la Saltadora VII-29 (Domingo et al., 2007).

The Cingle style figures feature in a variety of scenes, depicting activities like hunting, battles, climbing and honey-hunting (Domingo, 2006). It is uncertain whether the La Joquera archer originally appeared in a social or a hunting scene, as the other remains near this figure are incomplete. Today we identify four remnants (Fig. 8), instead of the previously reported two by Porcar (1932). Rather than belonging to animals or humans, as he suggested, they appear more like digital strokes.

4.2. CRP data processing results

4.2.1. Accuracy of reference points and image orientation

Following the methodology described above, a sparse point cloud was created. The value of RMSE (Root Mean Square Error) for Control Points (CP) and Check Points (ChP) is shown in Table 1.

Table 1: Accuracy of the reference points.

Type	*Count*	*X error (mm)*	*Y error (mm)*	*Z error (mm)*	*XY error (mm)*	*Total (mm)*
CP	4	1.02	0.48	0.45	1.13	1.28
ChP	14	0.96	0.95	0.78	1.35	1.5

As shown in Fig. 9, in the resulting mesh, indented parts of the site are marked with a red line. These areas have little to no point density due to insufficient light and data. These gaps affect the creation of a 3D model of the entire shelter, as poor geometry in specific areas, and a lack of points cloud in others disrupt the interpolation for mesh generation. These areas could be recreated manually with modelling software, like Blender, but it does not align with our aims. As the priority of this research is the processing and modelling of the main panel with rock art, which has no holes or gaps, another acceptable and faster solution to complete the 3D model of the missing parts of the rock shelter is extrapolation or hole closure.

4.2.2. Mesh creation and reconstruction of missing areas

Interpolation clearly allows a more accurate representation of surface data points. By selecting the interpolation mode in the software for the entire rock shelter, some surfaces are interpolated in a circle with a given radius around each point. As a result, some holes can be automatically closed. However, in this case study, there are still gaps or large holes present in the areas highlighted in red, lacking sparse points and dense points cloud. To solve this issue, it is better to model in the extrapolation mode, and estimate and reconstruct them based on nearby data points at the end of the known data (Agisoft, 2022).

As seen in Fig. 10, the walls, ceiling, and floor of the rock shelter, with accurate and complete data, have a strong and dense triangulation using interpolation.

On the other hand, the areas lacking data for which geometry is reconstructed using the extrapolation method, exhibit insufficient density, nor do they display the real surface.

4.2.3. Photorealistic 3D model

After the creation of the 3D surface model, the next step is to produce a texture for the model. This step is done with high quality and the texture atlas features 8000 x 8000 pixels. Now focusing on the images containing motifs, it is important to correctly classify, locate and integrate the colour-enhanced tracings into the 3D model. The user performs the manual matching and integration of digital tracings onto the model. Identifying homologous points between the images containing the tracings and the oriented primary images is crucial. Once the tracings have been oriented, the placement, rotation and scale are solved. Also, note that the areas lacking texture have been reconstructed in the texture processing on the model. The result is shown in Fig. 11.

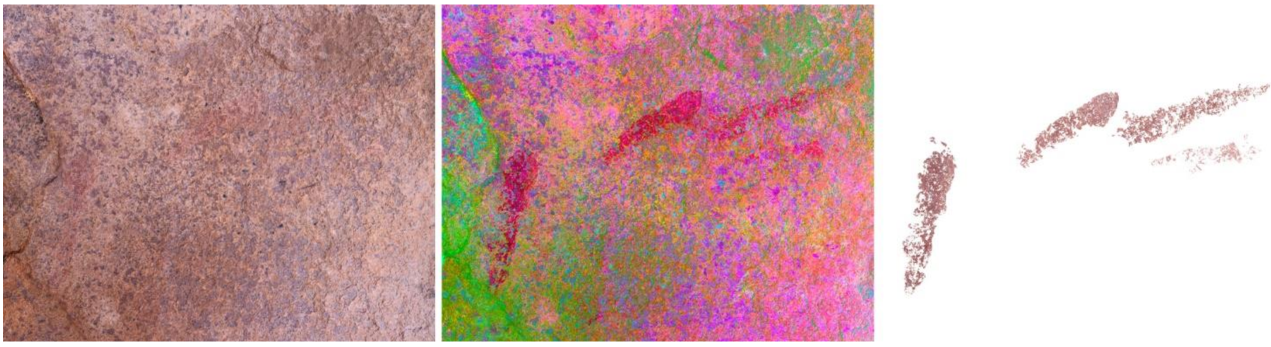


Figure 8: Enhancing and manipulating digital images to record unidentified remains: (a) Visible light colour image; (b) False colour image decorrelated with Dstretch plugin to ImageJ, in Dstretch colour space CRGB. This colour space is effective at enhancing red pigments while suppressing background shades (Harman, 2015); and (c) Digital tracing produced in Adobe Photoshop.

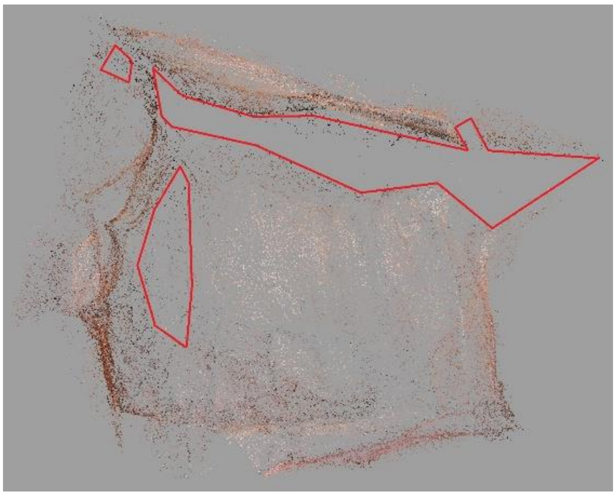


Figure 9: Perspective view of sparse point cloud from the rock shelter. The red lines mark poorly documented areas. These could be completed in subsequent steps through extrapolation or hole closure.

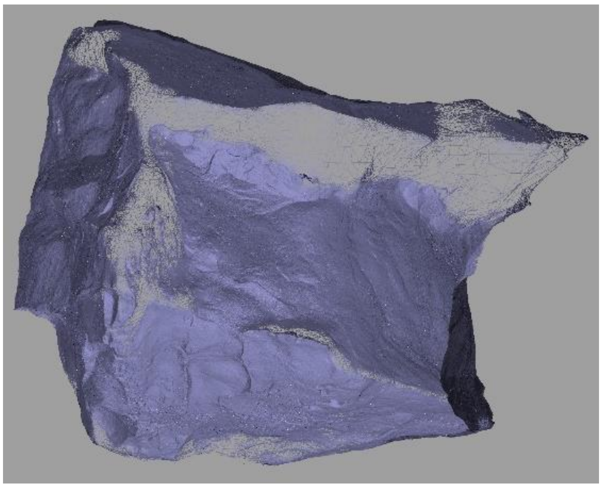


Figure 10: Perspective view of generated mesh displayed in wireframe mode. Note how areas lacking data have insufficient density and do not display the real surface. Such areas require extrapolation for geometry reconstruction.

4.2.4. Orthomosaic

From the models produced, various orthomosaics of the painted panel are created for research, conservation and dissemination purposes. These include, one with texture, showing the current condition of the painted panel (Fig. 12a), one without texture, showing the location of the digital tracings (Fig. 12b), and one combining both layers, displaying enhanced digital tracings on top of the texture. The latter is intended to facilitate the identification of the art and provide a closer representation of how the art was originally intended to look (Fig. 12c). Orthomosaics are produced from an orthogonal projection to the painting panel. In the final orthophotomosaic, the selected cell size will be 0.1 mm. The resulting orthoimages portray the rock art scene to scale and without distortion, at a particular point in time.

4.2.5. 2D plan of the rock shelter

As the coordinates of CP are extracted from surveying and the whole model has a coordinate system and is life-size, the model can be easily used to measure with millimeter accuracy. It can be also used to draw a site plan and cross-sections of the site suitable for archaeological publications. Figure 13 shows the 2D plan of the rock shelter and the vertical view in section A-B, which has been extracted from the 3D model as a shape file. After this, the file is entered into ESRI's ArcGIS software, v. 10.8 for crafting the appearance of the map and adding extra information, such as dimensions, art location, or the main structural features of the site.

5. Conclusions

A comprehensive an updated understanding of the Levantine art preserved at La Joquera site has been achieved through the application of a multi-technique approach to rock art recording (combining digital enhancement and processing techniques, and digital photogrammetry). The methods used are contactless, and therefore have no impact on the art. Used in combination they provide metrically accurate records of the painted panel. Digital imaging techniques have been instrumental in uncovering missing parts of the depicted human figure (specifically ornaments and weaponry), along with other extremely faded remnants, that were previously undetected. Using terrestrial photogrammetry, we have now documented for the first time the 3D nature of the rock shelter used as a canvas. The 3D surface model produced is relevant for several areas of interest, including research (to measure the motifs, panel and space where the art was produced), conservation (to track any changes occurring in the art and the host rock over time) and dissemination (to present the art more realistically to both the global scientific community and the general public through digital media). While so far the current model has been used primarily to identify previously unseen paintings, it could also serve as a foundation for overseeing future painting or bedrock deterioration caused by aging and/or vandalism. Outputs of the digital photogrammetry include a high-resolution photorealistic 3D surface model of the site and the motifs, showing the current conservation status of the site and the art; the same model with colour-enhanced digital tracings on top, along with a site plan and a cross-section suitable for publications.

Constructing a 3D model that integrates colour-enhanced digital tracings confers advantages as it assists in identifying and visualizing rock art sites with severe fading, such as this one. Such digitally enhanced reproductions offer a glimpse of what the site may have resembled in the past. For the sake of scientific accuracy, missing figures or parts cannot be reconstructed.

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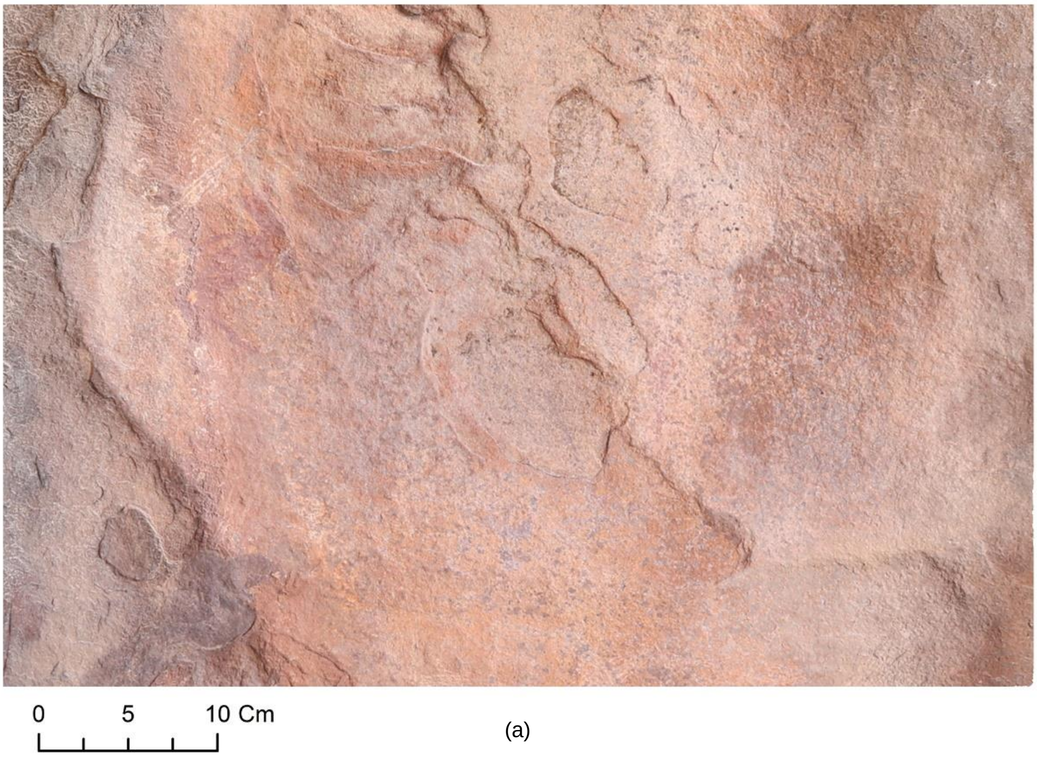
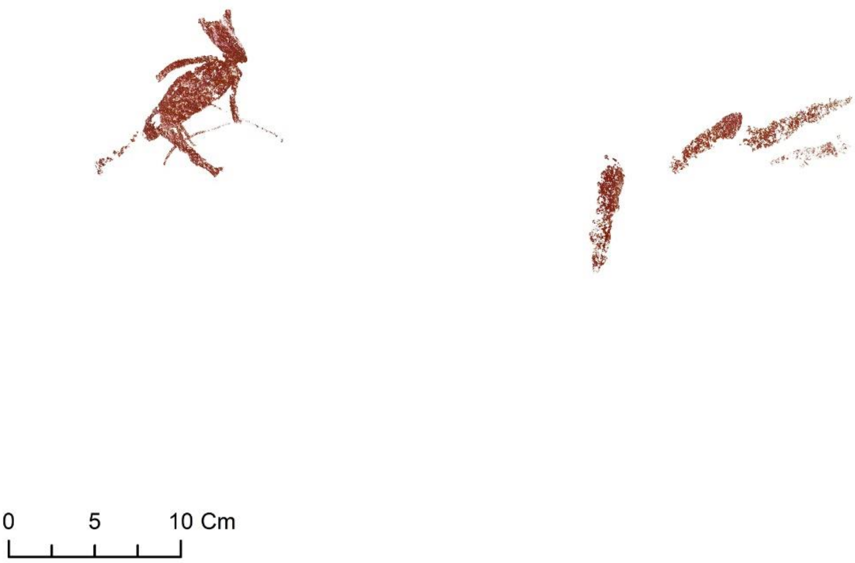
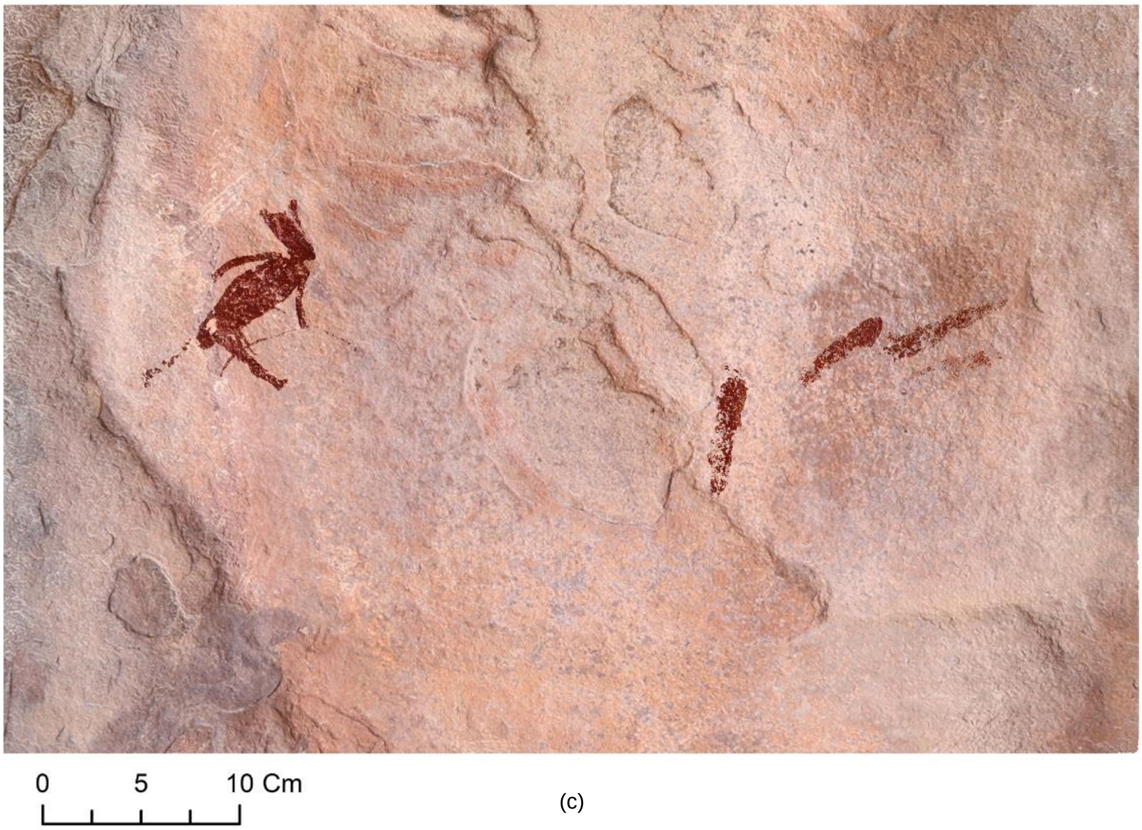
Figure 11: Perspective view of the 3D model of the rock shelter with photorealistic texture displaying the colour-enhanced tracings of the motifs on the right wall. Note how areas that previously displayed insufficient density have been reconstructed through extrapolation.



(a)

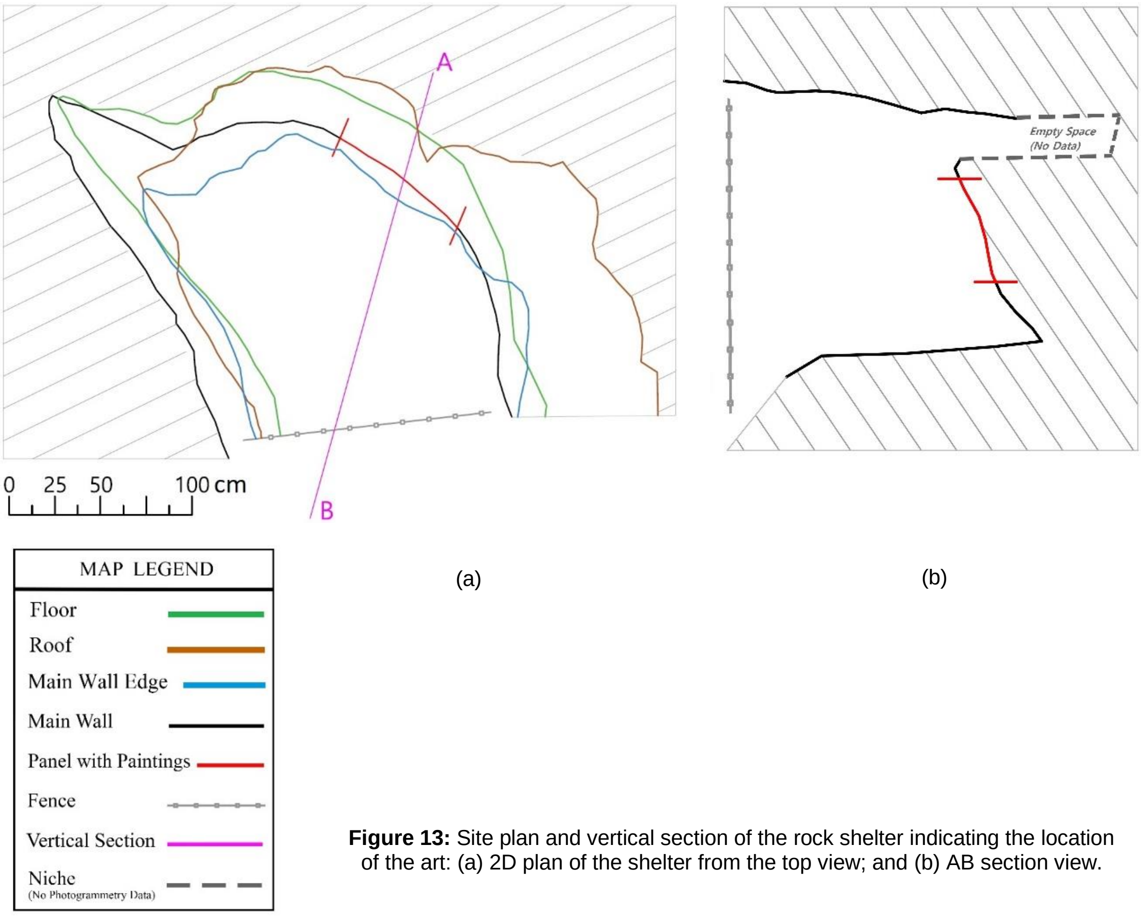


(b)



(c)

Figure 12: Orthomosaic details: (a) View with the main texture layer (photorealistic model); (b) View with the art layer (colour-enhanced tracings to facilitate visualization) and (c) View with both layers active.



(a)

(b)

Figure 13: Site plan and vertical section of the rock shelter indicating the location of the art: (a) 2D plan of the shelter from the top view; and (b) AB section view.

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