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On the fringes of Atlantic Rock Art: A multidisciplinary approach to El Riscal (Seville, Spain)

En los márgenes del Arte Rupestre Atlántico: una aproximación multidisciplinar a El Riscal (Sevilla, España)

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Abstract: This paper presents multi-disciplinary research undertaken between 2022 and 2024 at El Riscal, the only rock art station known in Seville (Andalusia, Spain), a territory otherwise very rich in Late Prehistoric archaeological remains. Discovered in the 1980s and first published in the early 1990s, El Riscal presents engraved motifs not documented in other parts of southern Spain, where schematic-style painted rock art is prevalent. The set of methods employed in this research includes petrology, chemical characterisation (XRD, SEM-EDS), digital photogrammetry and digital image analysis, archaeological prospection and archaeoastronomy. The results throw new light on the characteristics and temporality of the site, with a pervasive significance through time. This, in turn, invites a new approach to the geographical distribution of the various traditions and styles present in Iberian rock art. This research also suggests that re-examining previously published rock art sites could lead to a better understanding of styles, chronologies and traditions.

Keywords: rock engravings; El Riscal; Atlantic Rock Art; multidisciplinary research; South Iberia.

Resumen: *Este artículo presenta una investigación multidisciplinar realizada entre 2022 y 2024 en El Riscal, la única estación de arte rupestre conocida en Sevilla (Andalucía, España), un territorio, por lo demás, muy rico en restos arqueológicos de la Prehistoria Reciente. Descubierto en la década de 1980 y publicado por primera vez a principios de la década de 1990, El Riscal presenta motivos grabados no documentados en otras zonas del sur de España, donde predomina el arte rupestre pintado de estilo esquemático. El conjunto de métodos empleados en esta investigación incluye petrología, caracterización química (DRX, SEM-EDS), fotogrametría digital y análisis de imágenes digitales, prospección arqueológica y arqueoastronomía. Los resultados arrojan nueva luz sobre las características y la temporalidad del yacimiento, con una relevancia transversal a lo largo del tiempo. Esto, a su vez, invita a un nuevo enfoque de la distribución geográfica de las diversas tradiciones y estilos presentes en el arte rupestre ibérico. La investigación también sugiere que la reevaluación de yacimientos de arte rupestre previamente publicados puede conducir a mejorar la comprensión de los estilos, las cronologías y las tradiciones.*

Palabras clave: *grabados rupestres; El Riscal; Arte Rupestre Atlántico; investigación multidisciplinar; sur de la península ibérica.*

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1. INTRODUCTION

One of the most outstanding elements of world cultural heritage is rock art. Whether of additive (painting) or subtractive (engraving) nature, rock art often provides the only remaining graphic traces of prehistoric world views. Iberia is rich in rock art, with an extensive record of sites and a remarkable diversity of styles. This includes both Palaeolithic art (with two UNESCO World Heritage sites in Altamira and Foz Côa) as well as late prehistoric art (Neolithic, Copper Age, Bronze Age and Iron Age) with a host of styles and media (Levantine, Schematic, Macro-Schematic, petroglyphs, 'megalithic' art, engraved stelae, etc.) and hundreds of recorded sites. Going all the way back to the beginning of the 20th century (Breuil and Burkitt, 1929), the literature on Iberian late prehistoric rock art is quite extensive, including several hundred papers and dozens of monographs (syntheses in Beltrán Martínez, 1982; Peña Santos, 2001; Escoriza Mateu, 2002; Cruz Berrocal, 2005; Díaz-Guardamino, 2010; García Arranz *et al*., 2012; Bettencourt *et al*., 2017). Regarding archaeoastronomical studies, the very development of this approach is linked to the Iberian archaeological record (*e. g.*, Belmonte, 1999; Belmonte and Hoskin, 2002).

Despite this long history of research, recent methods have provided fresh key evidence to understand Iberian late prehistoric rock art under a new light. Examples of this abound, including the use of digital technologies (Díaz-Guardamino *et al.*, 2015; Cerrillo Cuenca *et al.*, 2019), the application of analytical methods to date and characterise pigments (Carrera Ramírez and Fábregas Valcarce, 2002; Rogerio-Candelera *et al.*, 2018) and specific discoveries providing empirical backing to long-held hypotheses, such as the association of engraved stelae to pathways and burials (Rivera Jiménez *et al.*, 2021; García Sanjuán *et al.*, 2025). Therefore, the re-examination of sites published long ago can lead to improved results and a new understanding of graphical techniques, chronologies and traditions.

In this paper, we present one such case. Discovered more than thirty years ago (Iglesias García *et al.*, 1992; Chacón Cano *et al.,* 1995), the site of El Riscal stands today as the only rock art station known in the province of Seville (Andalusia, Spain), a territory otherwise very rich in late prehistoric archaeological remains. Located near the village of El Madroño, in the northwestern area of the Seville province (Fig. 1), El Riscal is located at 368 masl (Fig. 2), crowned by a 3rd class survey point, very near the boundary with the province of Huelva.

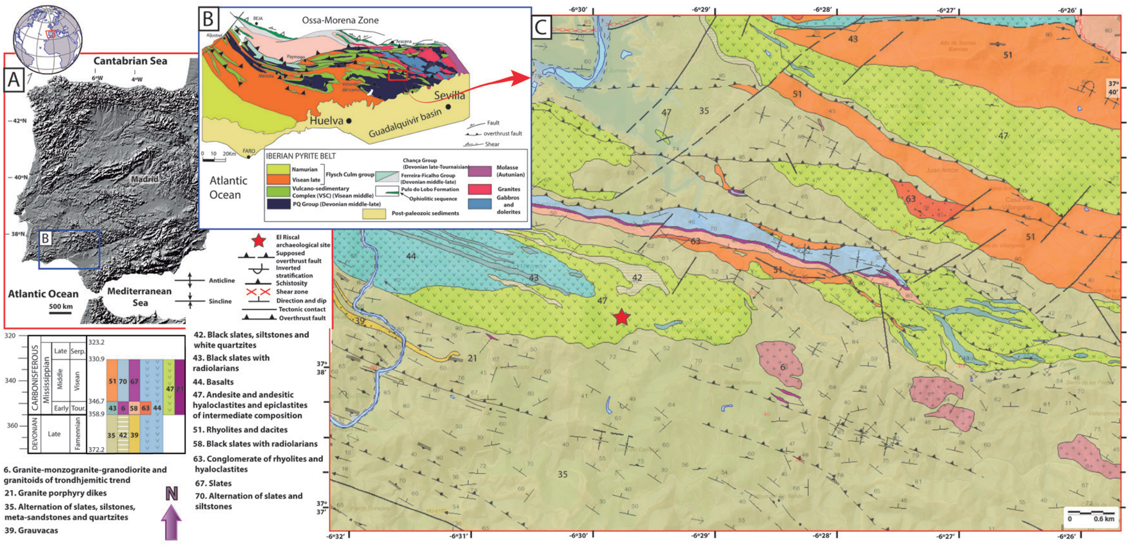

Fig. 1. Geographic and geological location map of El Riscal. (A) Synthetic geological map of the Iberian Peninsula (Rivera Jiménez *et al*., 2021); (B) geological map of the South Portuguese Zone, with the differentiation of the Pyrite Belt; (C) geological map around the archaeological site, modified from the Geological and Mining Institute of Spain (IGME). The geology is superimposed on a digital terrain model based on public domain data from the National Geographic Information Centre (IGN). The red star indicates the location of El Riscal archaeological site, consisting of andesite and andesitic hyaloclastites and epiclastites of intermediate composition. Figure: J. A. Lozano Rodríguez.

From a geomorphological perspective, the hill top is a 'tor'-like rocky outcrop with huge boulders exhibiting ruiniform morphology (Migoń *et al.,* 2017) mainly due to thermoclasty. Geologically, the site is located in the South

Fig. 2. (A) Ortophotography of El Riscal; (B) view from the road to El Madroño (Seville); (C) detail of the ruiniform structure. Photographs: T. Rivera Jiménez and M. A. Rogerio-Candelera.

Portuguese Zone, within the Iberian Massif (Fig. 1A). This large palaeogeographic area extends from the Ossa-Morena Zone in the north, to the most recent formations of the Guadalquivir basin in the south. It presents rocks ranging from the Middle Devonian to the Permian and is divided into five palaeogeographic domains, namely 1) Pulo de Lobo Domain; 2) the Iberian Pyrite Belt; 3) the Southwest Portuguese Domain; 4) the Sierra Norte Batholith and 5) the Permian Viar Basin (Fig. 1B).

The Iberian Pyrite Belt (IPB) is located in the central part of the South Portuguese Zone, within a pull-apart intracontinental marine basin filled by a sequence of predominantly felsic volcanic rocks with abundant siliciclastic intercalations, deposited on a shallow marine platform sequence (Conde Rivas, 2016). The IPB is divided into the Phyllite-Quartzite Group (PQ Group) (Med.-Upper Famenian); Volcanic-Sedimentary Complex (VSC) (Upper Famenian-Middle Visean) and Flysch-type Sequence (Culm Group) (Upper Visean) (Fig. 1B).

The VSC is composed of two felsic subunits separated by a massive black shale sulfide horizon. The lower subunit shows pyroclastic features, consisting of dacitic crystalline and vitric tuffs interbedded with a sequence of volcanic shales. The upper subunit is composed of dacite sills, domes and volcaniclastic deposits with subordinate rhyolitic sills and cryptodomes, and rare basic volcanics (Almodóvar *et al.*, 1998). The northern sector of the Pyrite Belt (volcanic sequence), presents a stratigraphic sequence that includes an important basal andesite unit followed by basalt flows and intrusions in sedimentary intercalations and two felsic dome-roof units (Conde Rivas, 2016). In the study area, andesites appear, overlying the alternation of slates, silstones, meta-sandstones and quartzites and underlying the basalts with levels of black slates with radiolarians (Fig. 1C).

Today, El Riscal hill is covered by Mediterranean vegetation dominated by Quercineae (*Quercus ilex*, *Q. suber*, *Q. rotundifolia*) and Cistaceae (*Cistus ladanifer*, *C. salviifolius*). The Cistaceae, particularly, cover densely the terrain, and following the spring rains, access to the rock art station is rendered difficult. The boulders compose a sheltered structure, a "Poor Man's Cave" of sorts (Chacón Cano *et al.*, 1995), with inner and outer spaces in which some of the surfaces were engraved. The first publication of the site (Iglesias García *et al.*, 1992) revealed seven engraved panels (designated as CR1-CR7), arranged in several parts of the shelter. After that publication, the same authors (Chacón Cano *et al.*, 1995) redefined the engravings as belonging to three groups, basically two decontextualized ones (CR1 and CR7), and one group including the rest, although no graphical illustration of the panels were provided.

The purpose of this paper is to present new research, based on a multidisciplinary approach and non-invasive methods, aimed at providing a new understanding of the El Riscal engravings. The results lead not just to a greatly improved record of the engraved surfaces and motifs in themselves, but also to a new analysis and assessment of a little-known rock art style that has hardly ever been documented in southern Iberia.

2. METHODS

The multi-method approach followed in this study was intended to a) enhance the visual record of the motifs; b) detect possible painted areas and characterize possible pigments; c) generate new contextual renderings of the engravings in order to produce updated tracings suitable for a spatial analysis; d) analyse the archaeoastronomical dimension of the site, and e) provide archaeological background through archaeological survey of the immediate surroundings.

2.1. Petrology

Rock samples from areas near the engravings were analysed both macro- and microscopically through thin sections under parallel and crossed nicols, using a petrographic microscope to characterize the rocks on which the engravings were made.

2.2. 3D Models

A complete reconstruction of the geometry of the site was considered of crucial importance, especially because most engravings were widely deteriorated due to weathering and forest fires —about 30 wild fires were counted in the surrounding area between 2004 and 2019[1]. The photogrammetric model of the panels was obtained from photographs taken with a DSLR Olympus E520 camera with a 14-45 mm Olympus Zuiko digital objective (10 MP, f/3.5, 5.6) and an iPhone 12 mini (12 MP, f/1.6, effective focal length 26 mm) for the narrowest areas. The use of mobile phones as a recording tool has demonstrated enough accuracy and efficiency for close range photogrammetry (El-Din Fawzy, 2015; Adamopoulos *et al.*, 2021). The 3D models were obtained by means of Agisoft Metashape Standard Edition (v. 1.7.3) software package. The digitized engravings were also studied under different shaders from the free software package MeshLab (v.2022.02). This tool allows the application of filters in order to highlight morphological characteristics, as well as adjusting the direction and light intensity for an instantaneous highlight of the concavities and convexities of the rock surface.

[1] Ecologistas en Acción (2019). *Llevan tres años intentando quemar El Madroño y al final lo han conseguido* [on line: https://www.ecologistasenaccion.org/125739/llevan-tres-anos-intentando-quemar-el-madrono-y-al-final-lo-han-conseguido/].

2.3. Digital image analysis

The panels were documented by means of a Canon EOS 450D digital camera (12 MP, f/4, focal length 18 mm) for digital image analysis with the aim of identifying areas where pigments were possibly present. Additionally, IR photographs of the reddish panels were also taken by means of a modified Olympus E-500 DSLR camera (extraction of the optical low-pass filters) with two band-pass filters of 850 and 950 nm (Zomei) individually mounted over the lens of the camera. This photographic mode required long exposures. Several Digital Image Analysis techniques were used in order to clarify the elements represented in the engravings. In addition, decorrelation of images by Principal Components Analysis (PCA) (Gillespie *et al.*, 1986; Rogerio-Candelera, 2015a), elaboration of false colour images, as well as contrast stretch of images in HSI colour model (HSI-CS) and application of indexes for the detection of possible ferric pigments (Rivera Jiménez *et al.*, 2021) were employed too.

2.4. Pigment characterisation

Six micro-samples were taken in order to examine the suspected presence of pigments in some of the engravings, in the framework of the contract *Inventario y documentación del arte rupestre de Huelva. Megalitos y otros* (2021 0000667050), *Junta de Andalucía* (Tab. 1). All the extracted samples were studied by X-ray diffraction (XRD) in order to obtain information about their mineralogical composition. The XRD analyses were carried out at Geosciences Barcelona (GEO3BCN-CSIC) by means of a Bruker D8-A25 diffractometer equipped with a Cu X-ray source (CuKα radiation) and a LynxEye position sensitive detector. Measurements were performed by using low-background silicon sample holders, employing large integration times in order to improve the signal-to-noise ratio. Phase identification was carried out by using the DIFFRAC.EVA software in combination with the Powder Diffraction File (PDF-2) and the Crystallography Open Database (COD). Secondary electron microscopy (SEM) images at different magnifications were also acquired in medium-vacuum by using the backscattered electron detector (BSD) of a Hitachi TM4000Plus desktop microscope at GEO3BCN-CSIC. A Bruker Quantax energy dispersive (EDS) X-ray spectrometer was used for elemental analysis of the micro-samples.

Sample id.	Panel	Description
CR2-1	CR2	Sample of possible red pigment
CR2-2		Control
CR4-1	CR4	Sample of possible red pigment
CR4-2		Control
CR8-1	-	Pigmented area in a rock without engravings
CR8-2		Control

Tab. 1. Samples for pigment characterization from El Riscal.

2.5. Archaeological survey

On 8th October 2023, an intensive archaeological survey was conducted as part of a comprehensive review of the site. A team of five surveyors undertook the survey with the aim of identifying potential surface remains of material culture that could assist in understanding the chronology of the rock engravings. The search was performed within a range of 50 m around the location of the engravings, along two sessions of 90 minutes, on the north and south of the engravings, respectively, thus totalling 3 hours of work. Prospectors were spaced a maximum of 1-1.5 m apart and conducted a thorough surface inspection, scraping the topsoil at random locations, and removing surface vegetation and soil in order to increase the visibility of possible material remains.

2.6. Archaeoastronomy

Data for archaeoastronomical analysis were also taken on 8th October 2023. The azimuth data were obtained with a professional compass (SUUNTO 360-R), and thereafter corrected for magnetic declination effects. Such measurements have an accuracy of ¼º. The horizon height measurements were acquired with a professional clinometer of the same brand, with ⅓º accuracy.

3. RESULTS

3.1. Petrological description

Under naked-eye conditions, the rocks at El Riscal have a reddish colour due to surface alteration caused by weathering (Fig. 3A). In fresh section, the rock exhibits a phaneritic texture, characterised by the presence of predominantly melanocratic phenocrystals. These crystals, measuring up to 3 mm, are embedded within a light-coloured, greyish leucocratic matrix (Fig. 3B). Under the petrographic microscope, the rock has a porphyritic-seriate and massive aphanitic texture that ranges from holocrystalline to hypocrystalline. The main mineral association is made up of phenocrystals, mostly of subidiomorphic plagioclase (0.1-4 mm), augite (altered to chlorite), amphibole and iron oxides. Calcic plagioclases (mainly labradorite) show a clear alteration to quartz, epidote, clinozoisite and sometimes sericite in many of their crystals, probably under a regional pre-Variscan hydrothermal environment (Barriga, 1990; Munhà, 1990; Sáez *et al.*, 1999). Metallic ore and rutile were observed inside the plagioclases and augites at the edges. Some volcanic glass and microliths of plagioclase, augite, quartz, metallic ore, rutile and titanite were observed in the matrix (Fig. 3 C-F). Microvesicles measuring up to 1.5 mm were also recorded. These were irregularly distributed and exhibited quartz regrowth in an atoll texture. They were also filled with epidote and even clinozoisite (Fig. 3 C-D). When the texture becomes microcrystalline, the sericite-quartz association prevails along with epidote-chlorite zones (Fig. 3 C-D). The petrographic composition of these lavas is andesitic. Andesite is an igneous rock, meaning it is not malleable or deformable by attrition. However, under intense friction, it tends to fragment or flake. Due to its mineralogy and seriated porphyritic and massive aphanitic texture, andesite possesses medium-high hardness and moderate to high abrasion resistance. It is hard and highly resistant to scratching, requiring the use of controlled abrasives such as flint to be worn.

3.2. The engravings

3.2.1. Location and distribution

The first task involved the identification of the different panels, as described in Iglesias García *et al.* (1992), in addition to the search for other potential, hitherto undetected motifs. The nature of the published tracings was found to be deficient in a number of ways, including the following: (i) lack of a general plan; (ii) rather fragmentary recording (only a detail of each panel was reported); (iii) low-quality hand-made naked-eye renderings of the motifs; (iv) lack of a clear key for interpreting the published drawings; (v) diverging orientations for each of the panels. In order to avoid future misunderstandings, the same designation system followed in that paper has been adopted here.

At first, it was impossible to find panel CR1, described as “three associated circles engraved over a small square rock of approximately 64 × 30 cm, clearly in secondary position and decontextualized with regards to the rest of the groups of engravings”[2]. Fortunately, after some enquiries, the engraved stone was found in the near-by Riotinto Mining Museum (Huelva, Spain). Since the early 1980’s CR1 has been housed in the Riotinto Museum. Consequently, the first publishers of the shelter did not observe this element *in situ*, although this fact was not noted. CR2, CR3 and CR4 were relatively easy to find (though the published tracings were partial and showed an orientation different to the real one), as they were placed in adjacent rocks of the shelter (Fig. 4). These panels, in particular CR2 and CR3, exhibiting the highest number of graphic elements are the most remarkable of the site. Locating panel CR5 proved to be more problematic than expected. After a fruitless search of all the sheltered rock structure, we reached the conclusion that what was designated by Iglesias García *et al.* (1992) as CR5 corresponded to the lower-right part of CR2, as this panel appeared to be ‘interrupted’ by a large boulder that had fallen from the roof of the shelter (Fig. 5).

Panel CR6 was readily identifiable due to its location within the innermost part of the shelter, situated within a crevice set by the largest boulders over CR3 and CR4, which covers other surrounding blocks. These fallen blocks

[2] This is our translation.

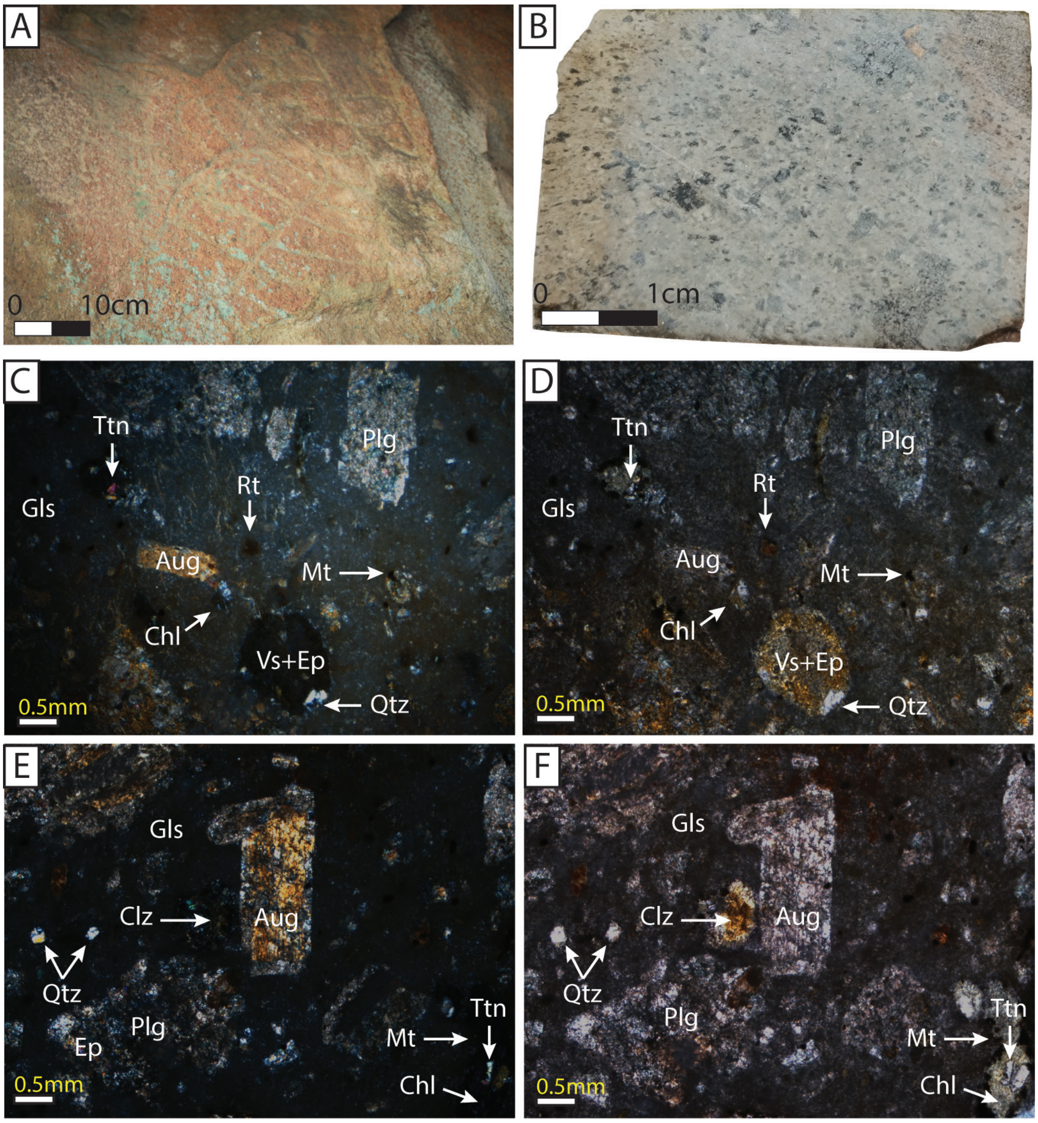

Fig. 3. Petrographic features of the El Riscal andesite. (A) Partial view of CR4. Note the reddish colour of the surface of the stone (Photograph: M. A. Rogerio-Candelera); (B) macroscopic appearance of the original section of the rock, for the preparation of a thin section. Note the porphyritic texture of melanocrate and leucoocrate phenocrystals in a very fine light grey matrix; (C-F) petrographic micrographs showing the porphyritic-seriate texture, with porphyroblasts of augite and plagioclase largely replaced by quartz. Note the microcrystalline and sometimes glassy matrix with the presence of vesicles with quartz overgrowth in an atoll texture and filled with epidote (C and E crossed polars; E and F plane-polarized light). Figure: J. A. Lozano Rodríguez.

configure an approximately piriform cavity which is easily accessible from the outside. There are two other communications with the exterior, one of them practicable and the other one presenting engravings. The published description mentioned two circular elements, designated as A and B. In our review, we found two different things. Firstly, CR6a, a panel featuring at least two engraved circles (coincident with CR6 A and B of Iglesias García *et al.,* 1992). Secondly, what we designated as CR6b, a motif that is difficult to appreciate and is carved in the bottom of a natural narrow crevice left by fallen blocks, which communicates the inner chamber with the exterior (Fig. 6).

As a supporting method in the visual analysis of the petroglyphs, the digitized motifs were also studied by means of different shaders with Meshlab. This digital processing tool was instrumental in distinguishing the intentionally carved and abraded motifs from those produced by weathering. Particularly, the Radiance Scaling shader, with final graphic results quite similar to those produced by Reflectance Transformation Imaging (Carrero-Pazos *et al.*, 2016; López-Menchero Bendicho *et al.*, 2017), allowed a detailed assessment of the peculiarities of the rock surface (Annex 1 - Fig. S1).

Fig. 4. Location of CR2, CR3 and CR4 panels. Photograph: T. Rivera Jiménez.

Fig. 5. Contact between the lower-right part of the rock harbouring CR2, and the fallen rock block. Photograph: M. A. Rogerio-Candelera.

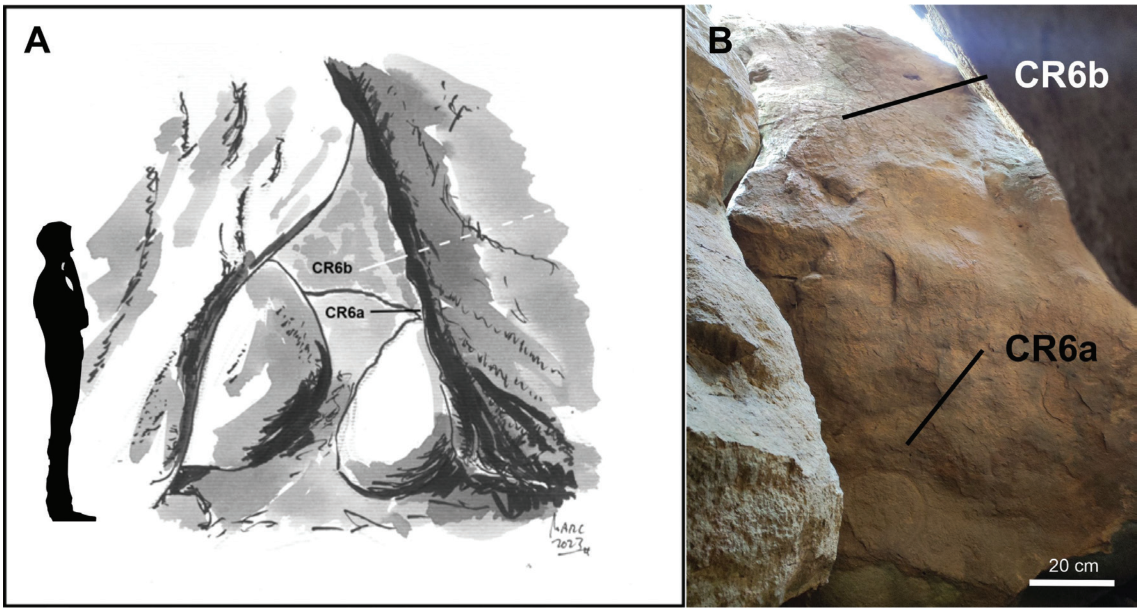

Fig. 6. (A) Scheme of the inner part of the shelter and the location of CR6a and CR6b (Drawing: M. A. Rogerio-Candelera); (B) photograph of the panels CR6a and CR6b. Note the presence of light entering from outside at the upper part of the image (Photograph: T. Rivera Jiménez).

3.2.2. Description of the panels

Panel CR1 shows a composition of three tangent circular forms arranged vertically. One of them (the central one) consists of at least three concentric circles (Fig. 7A). The engravings have a U-shaped section and a thickness ranging from 2 to 4 cm. The panel is in relative good state of preservation, likely due to its long-term storage at the Riotinto Museum, where it has been spared for almost half a century of weathering and other factors, including frequent wild fires.

Panel CR2, located in the north face of the outcrop, comprises a complex ensemble of at least 80 circular motifs arranged in a kind of *horror vacui*, where some circles cut others (Fig. 7B). The poor state of preservation of this set of engravings does not allow to elucidate if there are superimpositions between the motifs. The inter-cutting and super-imposition of the motifs may be indicative of 'maintenance', updating and re-interpretation of the panel, resulting from persistent use over time. The inter-cutting suggests that, far from being something 'finished', the set of engravings was envisaged and used as an 'alive' entity, with newly-made circular motifs cutting pre-existing ones, which were almost invisible.

Panel CR3, situated in the NW face of the rocky outcrop, portrays a totally different picture compared to the preceding two panels. In contrast to the accumulation of circular shapes of CR1 and CR2, CR3 shows a series of linear engravings with a V-shaped section that form reticular or grid-like designs of different lengths (Fig. 7C). In addition to the grids, CR3 shows at least three circles associated with straight lines, as well as other approximately circular elements which are more problematic to interpret. Due to its exposure to weathering and runoff water, CR3 is very deteriorated and most of the motifs are difficult to read, so the use of Meshlab shaders was essential to obtain an acceptable graphic rendering. In the lower area, the panel shows modern graffiti consisting of several letters of the Latin alphabet, engraved with a metal tool.

These are much better preserved than the pre-existing reticular motifs, to which they are superimposed. The presence of modern graffiti is well attested on the shelter. In addition to the previously mentioned example, another instance was found on the exterior surface of the rocky outcrop, which exhibits a cross and a date: 29 N 93 (Annex 1 - Fig. S2), as well as what appeared to be an engraved letter 'E' at the point of a knife, along with several possible cup-marks on the lichen layer that covered another rock in the upper area of the outcrop (Annex 1 - Fig. S3).

Located very close to CR3, and with the same orientation (NW face of the outcrop), CR4 has a similar appearance, although without the presence of circular motifs (Fig. 7D). It is a set of V-section engravings that define reticular motifs, which have a reddish colour on their surface (Fig. 3A). More protected from weathering than CR3, the lines are easier to recognise and follow than in the previous panel.

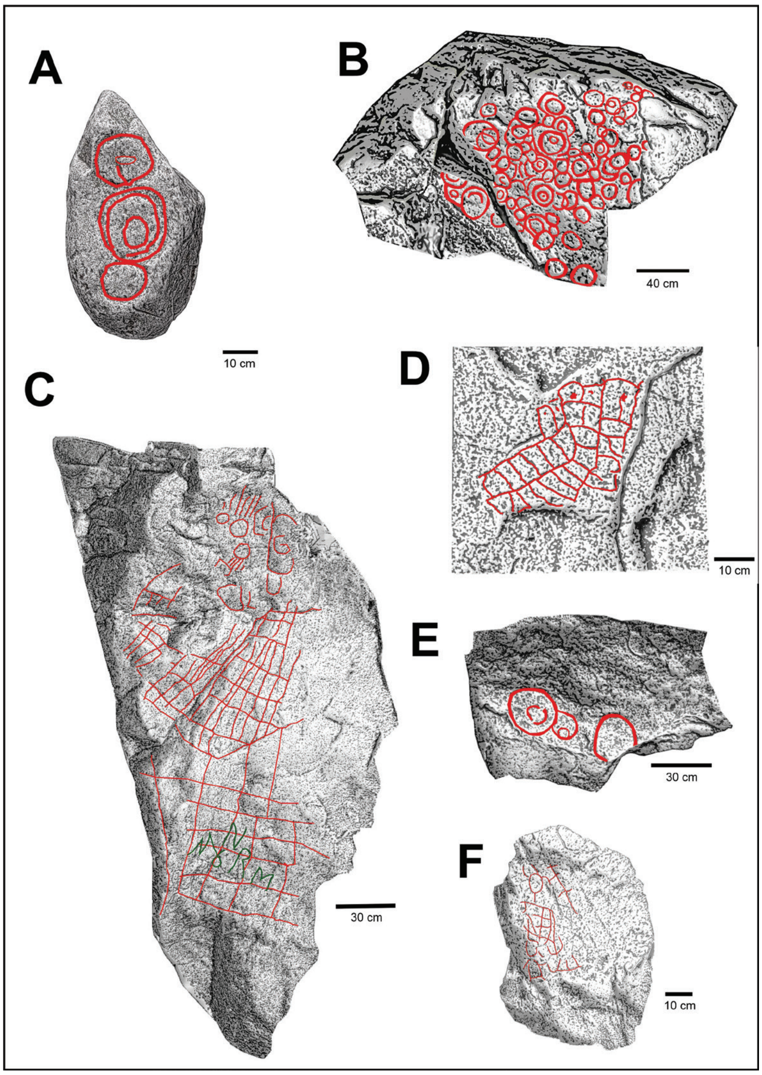

Fig. 7. Tracings of panels (A) CR1; (B) CR2; (C) CR3. Note the historical inscriptions in green; (D) CR4; (E) CR6a; (F) CR6b. Tracings: T. Rivera Jiménez/M. A. Rogerio-Candelera/A. Fuentes Porto.

Regarding panel CR6, it is located in the inner 'chamber' of the outcrop, facing the NE wall. The original publication by Iglesias García *et al.* (1992) reported two circles with a diameter of approximately 24 cm (although only one was included in the drawings). However, three circular motifs were observed, two of which were composed of more or less concentric circles (Fig. 7E). These are U-section engraved motifs, as is the case with the other engravings of circular elements in this shelter.

Finally, at the end of a narrow crevice formed by the various blocks that constitute the shelter (Fig. 6), which opens immediately onto CR6a and is also oriented to NE, there is what we have designated CR6b. This panel, which remained unpublished, consists of a series of engravings of V-shaped reticular and linear motifs similar to CR3 and CR4 (Fig. 7F).

3.3. Digital Image Analysis (DIA)

The elaboration of pseudocolour images from the bands obtained by means of Principal Components Analysis allowed a significant improvement in the visibility of certain motifs (Annex 1 - Fig. S10, for instance), but, in general, due to the scarce differences in hue, the outcomes were poor when compared to those achieved through digital photogrammetrical methods.

The results of the application of a generic ferric pigments index (Sebastián López *et al.*, 2013; Rogerio-Candelera, 2015b; Rivera-Jiménez *et al.*, 2021) following the equation [1] allowed us to remark what was, anyway, evident: that some elements presented a reddish coloration.

$$FPI = \frac{\rho_{(i,R)}}{\rho_{(i,B)}} \quad [1]$$

where FPI is the Ferric Pigments Index, $\rho(i,R)$ is the set of pixel values corresponding to the Red band, and $\rho(i,B)$ represents the set of pixel values of the Blue band in a RGB colour mode.

The goal of this visual analysis was to detect any potential patterns that might suggest the deliberate application of red pigment over the engravings (Annex 1 - Fig. S11). The results of this approach, although not unfavourable, did not reveal any hidden red remains, in contrast to the findings in other applications of these digital image analysis techniques (*e. g.*, Rivera-Jiménez *et al.*, 2021).

3.4. Pigment characterisation

XRD analyses were performed to characterise the composition of the host rocks and also to determine the possible origin of the reddish colours observed in some areas of the sampled panels. Figs. S4 and S6 (Annex 1) show XRD scans for the two samples from engraved areas that exhibit a reddish colour (CR2-1 and CR4-1, see Tab. 1). These two scans, as well as the scans from colourless materials (Annex 1 - Figs. S5 and S7), are dominated by strong peaks of quartz, which is the major mineral in these rocks. In addition, weak peaks from other accompanying minerals also showed up in the scans. Many of the identified phases can be attributed to the original rock: feldspars (albite, microcline), amphiboles (pargasite) as well as other minerals like epidote and clinochlore, which are likely rock-forming minerals of secondary origin. Other minor phases like gypsum were also identified in some of the investigated samples and may be attributed to surface alterations of the host rock.

In the case of the reddish sample CR2-1 in panel CR-2, the XRD scan exhibits a weak, broad peak that may be attributed to poorly-crystalline goethite, which might explain the colour of this sample. However, a similar peak was also observed in the colourless control sample (CR2-2). In contrast, the reddish materials of panel CR-4 (sample CR4-1) did not show any clear signal from goethite. Thus, this iron oxyhydroxide most likely appears due to a specific alteration of the minerals in panel CR-2 and can therefore be discarded as the compound responsible for the reddish colour observed across El Riscal. It is important to note that the rest of the identified phases cannot explain the reddish colours observed in the site. This is the case, for instance, of clinochlore, which typically exhibits a blackish-green colour and which is known to occur in some instances of green earth pigments. Other Fe-bearing minerals like pargasite or epidote are neither expected to account for the observed red colours.

In the case of CR8, a pigmented area not far from the engraved panels, pargasite is the only Fe-containing mineral that has been identified in the XRD scans, both in the pigmented and in the control samples (Annex 1 - Figs. S8-S9). The fact that these samples also show a red colouration points toward a natural origin for the observed pigmentation.

In late prehistoric Iberian rock art, paintings were usually made with hematite pigment (Roldán *et al.*, 2016), which could be of natural origin or the product of a thermic treatment of goethite and other 'ochres' (Perinet and Onoratini, 1987). In the case of El Riscal, the XRD scans did not reveal the presence of hematite in any of the investigated samples. This result was also confirmed with additional SEM-EDS analyses performed on these samples, which did not allow us to identify any clear signal of hematite.

Given the absence of iron oxide-based pigments, a possible explanation for the observed red colour in some of the El Riscal surfaces is rubefaction due to weathering or wild fires. It has been attested that, in soils, the hue reddens with increasing temperature, particularly over the range 300-500 ºC, which is a consequence of the transformation of iron hydrous oxides first into maghemite and then into hematite (Terefe *et al.*, 2008, quoting Taylor and Schwertmann, 1974; Mullins, 1977; Cornell and Schwertmann, 2003). Remarkably, rubefaction processes might have given rise to hematite coatings that would be hard to detect by XRD or SEM-EDS, at least with the present experimental conditions and set ups. This situation would be similar to the case of red soils which, as shown by Torrent *et al.* (1983), may exhibit a reddish colour due to the presence of hematite even in minimal amounts. In particular, poorly crystalline Fe oxides and hydroxides in nanoparticle form are ubiquitous in nature, and are responsible for the reddish coloration of many soils and rocks.

Nevertheless, the reddish colour of these samples might alternatively be attributed to the replacement of Si4+ by Fe3+ within the tetrahedral structure of quartz, the main mineral in these rocks (Liu *et al.*, 2023). Such replacement could have been induced by the high-temperatures of a forest fire and would only require trace amounts of iron atoms that would not be detected by the analytical techniques used in this work. In order to confirm or discard this hypothesis, other experimental approaches beyond the scope of this work should be employed.

In summary, the El Riscal rocks show a great compositional and textural homogeneity, both in pigmented and unpigmented areas. S. Cassen *et al.* (2023) found the same problem of homogeneity in the results of the analyses of coloured and control samples when working with the orthostats of the megalithic tombs of Morbihan (France). This highlights the difficulty in determining the actual origin of the pigmentations in rock samples. Their interpretation of reddish areas in rock surfaces lie in the effects of wildfires, in the liberation of the iron contained in micaceous minerals due to the heating. This phenomenon is well attested experimentally in the cave of Chauvet (France) (Ferrier *et al.*, 2014). In the case of El Riscal, more work would be required in order to unambiguously identify the origin of the observed red colours.

3.5. Archaeological context

On the southern face of the hill, with a steep slope that descends between the Pilón and Carrascal brooks, a triangular-shaped stone hammer, measuring 10 cm in length and 8 cm in maximum width (Fig. 8B), was identified alongside a knapped stone tool made of non-siliceous rock, with a retouched edge and a length of 3 cm. A small fragment of slate flake that does not appear naturally at the site was also identified. On the north face of the rocky outcrop on which the engravings are located, topographically a small plateau, a dozen small amorphous fragments of handmade pottery were located (Fig. 8A), as well as several fragments of wheel-made pottery, including glazed earthenware of modern or contemporary chronology.

Overall, although the amount of recovered material is small, and there is evidence of modern and/or contemporary frequentation (which may be related to the construction and maintenance of the survey point that crowns the hill, and which stands on a platform with a staircase made of stone and brick masonry) several of the artefacts found are compatible with a non-specific prehistoric chronology. The stone hammer and the hand-thrown pottery would not be out of place in a Neolithic or Copper Age site, although without more specific data it is impossible to provide greater precision to the chronology of the site and the rock art. No remains of what was previously described as a settlement built on terraces at the top and southern slope, adapted to the relief of the hill, with remains of huts built of branches covered with clay, and associated characteristic materials of the Copper Age (Linares Catela, 2011, pp. 190-191), were found.

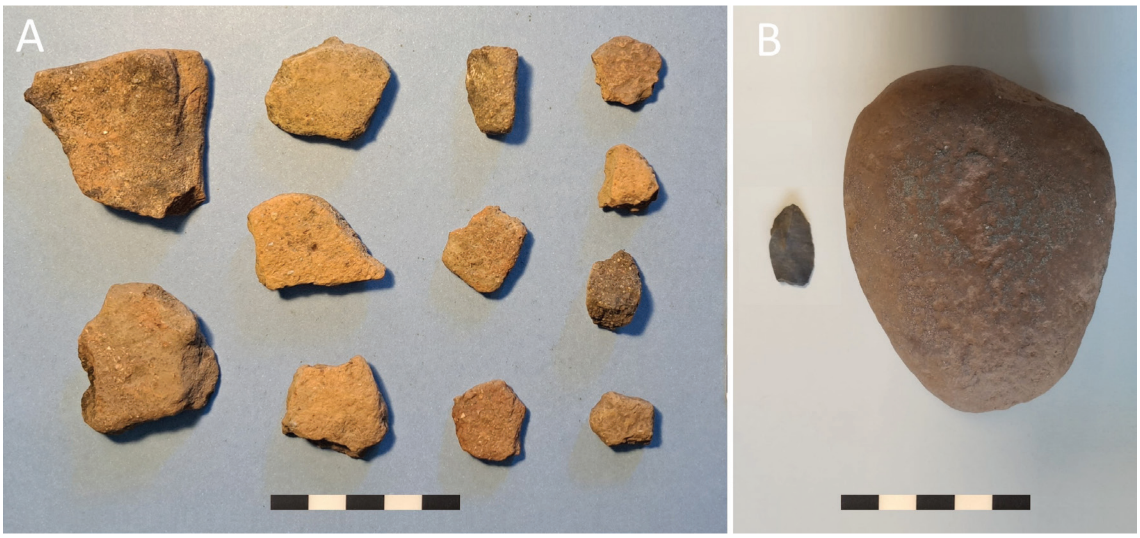

Fig. 8. Surface archaeological material recovered in the archaeological prospection. (A) Hand-made pottery; (B) lithic material. Photographs: L. García Sanjuán and R. Montero Artús.

3.6. Archaeoastronomy

Tab. 2 shows the measurements obtained for the main panels with engraved motifs and the orientation of the main engraved areas. The orientations consist of the window of visibility as seen from the panels. Thus, the range in azimuths provides the extreme positions where the panel faces the horizon or a sky portion can be seen from them. The location of the areas measured in this work is shown in Fig. 9A. Given the orientation, facing an area to the north of the northernmost sunrise (summer solstice), Area 1, with the circular and reticulated motifs, would never be directly illuminated by sunlight. However, in Area 2, the sunrise could be seen directly from the entrance from nearly the autumn equinox to the spring equinox.

Structure	A (º)	h (º)	δ (º)	Dates	Solar events
Area 1 (entrance)	31.25	1.5	–35.4	-	
	44.25	2	–44	-	
CR3 panel	155.25	29	–19.5	Jan 23 / Nov 19	Winter solstice
	128.25	40	0.96	Mar 23 / Sep 23	Equinox
	120.25	31	–1.6	Mar 16 / Sep 27	Equinox
Area 2 (entrance)	80.25	0	7.4	Apr 9 / Sep 8	
	101.75	0	–9.6	Feb 24 / Oct 18	
	118.25	1	–21.6	Jan 12 / Dec 1	Winter solstice
CR6b panel	94.25	35	17.6	May 10 / Aug 3	
	133.25	11	–24.7	Dec 21	Winter solstice

Tab. 2. Data for the engraved structures at El Riscal rock shelter. The columns indicate the name of the structure, the azimuth in degrees (A), the altitude of the horizon in that direction (h) and the astronomical declination corresponding to that direction in the horizon (δ). For those directions that coincide with solar events the dates are indicated in column 5, and the corresponding solar phenomena in the last column.

It is interesting to note that the nearly flat area next to the entrance of Area 1 where the CR3 engravings are located (Fig. 9C), would be directly illuminated during a period nearly coincidental with the winter months (from the autumn equinox to the spring equinox, nearly half a year) at midday. Finally, Area 2 could also be illuminated at astronomical events in this same period of time, and particularly at the winter solstice. The entrances to the shelter show somewhat ambiguous orientations, which is unsurprising, given that these are most probably natural. There is an entrance aligned north of the sunrise arch and another towards the southern part of this arch.

4. DISCUSSION AND CONCLUDING REMARKS

The empirical evidence gathered for this study greatly expands previously published descriptions of the rock art present at El Riscal. The new renderings of the motifs and the more precise contextualisation of the panels across the topography of the shelter point to a complex rock art station, with 'indoor' and 'outdoor' engraved panels. Two kinds of engravings were identified: U-section circular motifs, and V-section linear grid designs. An important observation concerns the evidence of overlapping and over-cutting of the engraved motifs in some of the panels, which points to an extended use of the shelter. Two major types of motifs were found, which can be tentatively grouped in two differentiated 'phases' or 'graphic horizons' (although the chronological implications of these 'phases' are far from clear). Horizon 1 is characterised by the presence of circular figures, sometimes with concentric circles (CR1, CR2, CR5, CR6a, and CR7). Conversely, Horizon 2 is predominantly composed of intricate grid designs (CR3, CR4 and CR6b). It is noticeable that the two 'phases' are not mixed and do not occupy the same panels. The formal differences between the motifs of these panels could also be attributable to functional or symbolic variations, and not chronological.

Some of these engravings, in particular CR2 and CR4 panels, show a peculiar reddish colour. However, subsequent analysis has failed to detect any traces of paint. The red colouration is hypothesised to result from thermal transformation of some of the rock minerals, possibly induced by recent wildfires.

High-resolution archaeological survey of the shelter and its immediate surroundings provided some surface findings potentially compatible with activity between the Neolithic and the Iron Age. Particularly, the non-siliceous

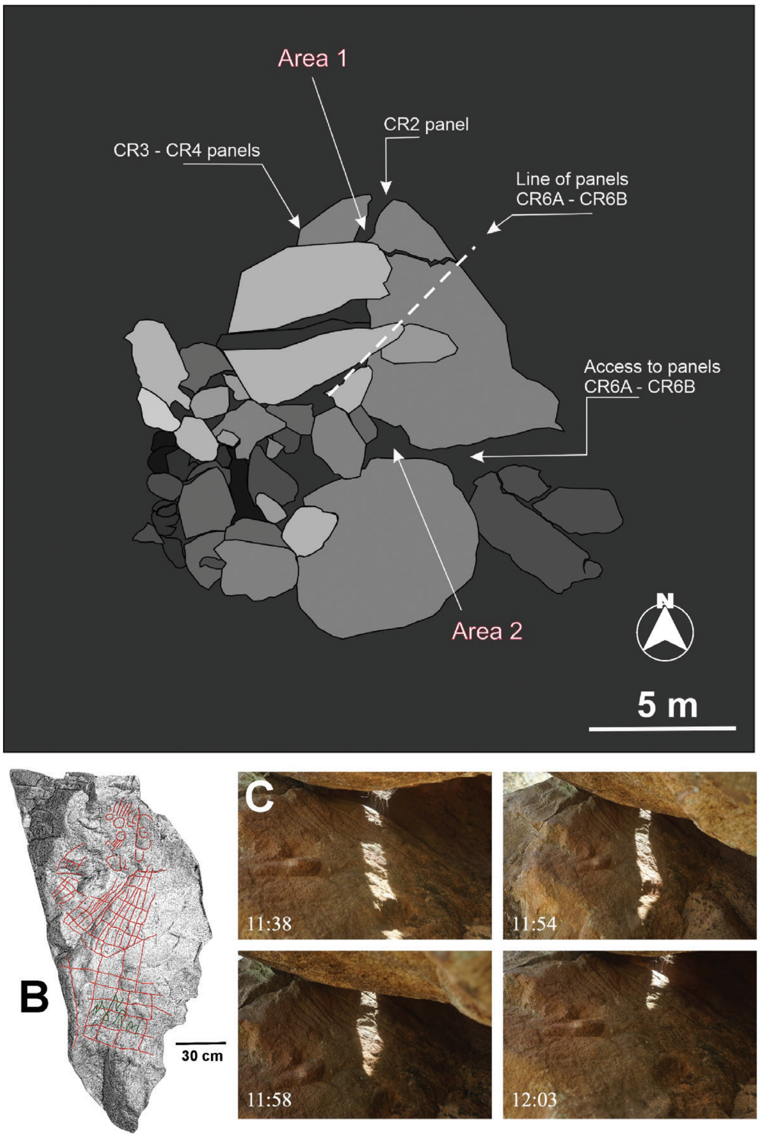

Fig. 9. (A) Scheme of the areas whose orientation was measured for archeoastronomical purposes and the location of the engraved panels (Drawing: M. A. Rogerio-Candelera); (B) CR3 panel (Tracing: M. A. Rogerio-Candelera); (C) illumination sequence of the upper part of CR3 panel on 8th October 2023. Numbers show the time at which the photographs were taken. Different parts of the panel would be directly lit on the previous and subsequent days. Photographs: A. C. González García.

stone utensil and the stone hammer point to a chronology between the Neolithic and the Copper Age, although later chronologies cannot be ruled out. Only future numerical dating of samples obtained through excavation will allow a more precise chronology of the site.

El Riscal currently stands as the only rock art location published for the province of Seville. In Constantina (Seville), some 120 km to the east, a geological site with marine fossils (jellyfish dating to the Cambrian period) called *Piedra Escrita* ('Written Stone') was wrongly interpreted as a rock art station until recently (Mayoral *et al*., 2004). But in the province of Huelva, not far from El Riscal, there are other rock art sites with engraved motifs. These include Los Aulagares (Del Amo, 1974, with updated photographic documentation in Escacena, 2018), in the municipality of Zalamea la Real, some 20 km as the crow flies from El Madroño; Las Tierras (Belén Deamos, 1974), in the municipality of Villanueva de los Castillejos, and Los Azulejos (Pérez Macías, 1988), in the municipality of Santa Ana la Real. The graphic renderings available for these rock art sites follow publication standards of the 1970s, wherein the 2D tracing presents the existing engravings without any consideration of the supporting rock characteristics or shapes. They are mostly based on direct, naked-eye, hand-made tracings, often without the use of a minimum reference scale.

Formally, the engravings at El Riscal are completely different from those at Los Azulejos (Fig. 10C) which are more closely related to the repertoire of the Spanish painted schematic rock art. The art present at Horizon 1 at El Riscal holds a considerable formal similarity to that found at Los Aulagares (Fig. 10A), or even Las Tierras (Fig. 10B), in which circular shapes are clearly predominant. In particular, panel CR1 (Fig. 7A), including the circular motifs arranged vertically, displays a clear similarity to the motifs engraved at Los Aulagares. Interestingly, at least two circular shapes are shown in the tracing of Los Azulejos provided by Pérez Macías (1988) (Fig. 10C).

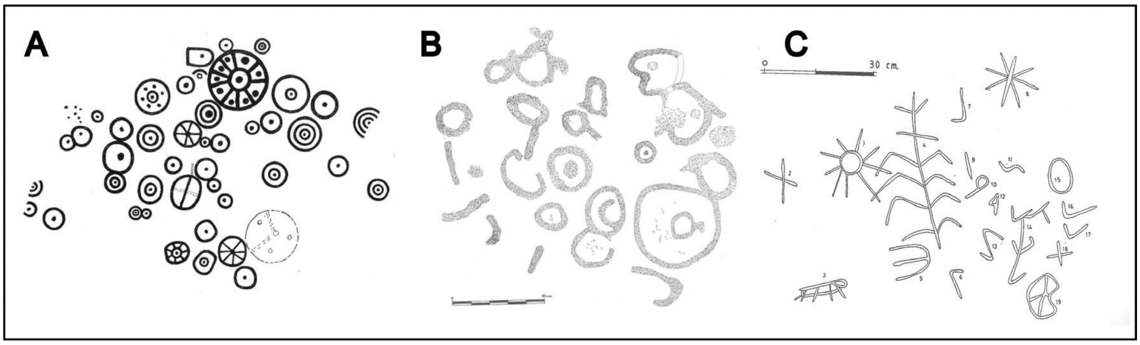

Fig. 10. (A) Engravings of Los Aulagares, after Del Amo (1974); (B) engravings of Las Tierras, after Belén Deamos (1974); (C) engravings of Los Azulejos, after Pérez Macías (1988).

Given the lack of precise dating and the dearth of background information on prehistoric rock art for the western Andalusian provinces of Seville and Huelva, it is difficult to contextualise the style recorded at El Riscal within the wider Iberian framework. In general, painted rock art of the schematic style is quite abundant across central and southern Spain (Acosta Martínez, 1968; Martínez García, 2022). To the east of El Riscal, schematic rock art abounds in the provinces of Málaga (Maura Mijares, 2011) and Córdoba (Bernier Luque, 1969); to the north, in Badajoz (León and García Verdugo, 1984; Domínguez García and Aldecoa Quintana, 2007); and to the south-east, in Cádiz (Breuil and Burkitt, 1929; Topper and Topper, 1988; Carreras Egaña and Caballero García, 2006). And yet, save for Los Azulejos, this style is conspicuous by its absence in Huelva and Seville (and, further to the west, in Portugal). The El Riscal motifs, like those at Los Aulagares, are formally more akin to the engraved motifs, usually described as petroglyphs, found in north-west Iberia (Peña Santos, 2001; Bettencourt *et al*., 2017) or the British Isles (Bradley, 2023), where circles in isolation or forming complex arrangements are common.

Thus, a non-comprehensive list of rock art sites with motifs similar to those found at El Riscal should include Outeiro dos Lameiros (Baiona), Pedra da Serpe (Valga), A Pedreira 2 (Caldas de Reis), Monte Xiabre 2, and Sobreiras 4 and 5 (Vilagarcía de Arousa) (Cabrejas Domínguez *et al*., 2008), or Aldea Deiro (Vila Nova de Arousa) in Galicia; and others such as Monte das Fortes, and O Escarabelhão (Valença do Minho) (Bacelar Alves and Reis, 2017), Moulães, Pereiras, and Monte da Porqueira 2-3 (Monção), Penedo dos Sinais (Valdez and Oliveira, 2005-2006), Quinta do Paço (Cardoso, 2013), and Citânia dos Briteiros (Guimarães), or Laje dos Sinais (Carvalhas-Barcelos) (Cardozo, 1951) and Pedra Escrita (Serrazes) (Sobrino Lorenzo-Rua, 1957) in northern Portugal. These and more examples are published in the website "Megaliticia"[3]. The recent discovery of engraved stelae of the 'warrior' type in Huelva (Rivera Jiménez *et al*., 2021; García Sanjuán *et al*., 2025), firmly places this territory within the general background of the late prehistoric stelae known along the basins of the main Iberian rivers draining into the Atlantic (the Guadalquivir, Guadiana and Tagus). Therefore, it is unsurprising that the best analogues for the motifs found at El Riscal are not found in the Levantine or schematic styles, which are deeply-rooted in central, southern and eastern Spain, but rather from the western tradition visible in northern Portugal and Galicia.

Atlantic and schematic art represent two distinctive rock art traditions within Iberia, and (variously arranged) circles are a pervasive image, strongly characteristic of the former (Bacelar Alves, 2012, p. 198). In this sense, it is worth noting that circles (often concentric) interpreted as 'shields' are one of the most recurrent motifs in late prehistoric 'warrior' stelae, a form of rock art of strong Atlantic distribution (Hernando Grande, 1976; Díaz-Guardamino,

[3] https://megaliticia.blogspot.com/.

2010). They are also found in the 'megalithic art' present in the Soto dolmen (Trigueros, Huelva), located 60 km to the south-west of El Riscal (Obermaier, 1924). The reticulate motifs are also present in a variate sample of Atlantic rock art sites, as those already quoted of Monte dos Fortes, O Escarabelhão, Pereiras, and others.

Certainly, the interpretation of rock art encompasses a multitude of factors beyond the formal variability of the motifs. Landscape settings, context and association to other archaeological remains carry as much interpretative weight, or more, than the motifs themselves. In the case of Huelva, however, the presence of schematic (Los Azulejos) and Atlantic (El Riscal) rock art within the same territory points to the kind of 'border' or 'fringe' interaction between styles already noted for Galicia (Bradley and Fábregas Valcarce, 1998, 1999) and, with a different definition, in other areas (Bueno Ramírez *et al*., 2009; Collado Giraldo and García Arranz, 2013; Santos-Estévez *et al*., 2020). Needless to say, we do not conceive the term 'border' in a literal sense (as in the political border of a modern state, for example) but rather as a zone of transition between regions where different styles prevail. This is consistent with the very geographical position of sites like El Riscal or Los Azulejos, which are within the Atlantic hydrological domain, but relatively adjacent, and well connected, with the Mediterranean.

Though it is tempting to try to 'identify', or connect, the circles as specific forms (whether they be landforms, shields or other artefacts or more abstract ideas), and there is no shortage of such interpretations in the literature– Iberian late prehistoric stelae are a supreme example of this–, no attempt will be made here to it. While greatly enhanced, the new 'image' of El Riscal is still partly blurred, as chronology and context are yet poorly understood. Regardless of the specific meanings, which of course would have changed over time, the site appears to have remained a local focus of activity for an extended period of time. As noted for north-west Iberia, in the Bronze Age and Iron Age, new carvings were certainly created or added onto previously existing motifs, a process of renewal or re-appropriation of sites and pasts (Bacelar Alves, 2012, p. 208).

This phenomenon could well have been connected with the periodical frequentation of the site at specific times of the year. The archaeoastronomical analysis shows that some of the engravings may have been illuminated at particularly relevant moments during the year. In this regard, the CR3 engravings appear as particularly interesting, and the location seems to have been chosen so that they could be illuminated during a period of time each day in the course of the winter months. In Iberia, a similar phenomenon has been noted at A Ferradura, in Galicia, north-west Spain (García Quintela and Santos Estévez, 2008), as well as in other places, like inside the chamber of some megalithic tombs in Ireland (see Prendergast *et al.*, 2017 for a recent review). Elsewhere, it is worth mentioning Fajada Butte (New Mexico, USA) (Sofaer *et al*., 1979; Williamson, 2015). This suggests that there might have been ritual areas connected to specific periods of interest for the people who made the engravings. It would also be interesting to verify whether Area 2 would be directly lit a few hours after the winter solstice sunrise.

Fresh, multi-disciplinary research undertaken between 2022 and 2024 at El Riscal (Seville, south-west Spain) has greatly expanded the understanding of this remarkable site, further emphasizing its importance to comprehend the geographical distribution of Iberian rock art traditions and styles, and providing suggestive evidence that underlines its pervasive significance through time. The results presented demonstrate the importance of re-studying specific rock art sites in the light of novel methods and techniques. Furthermore, they underscore the need for additional research to address new, more precise questions.

SUPPLEMENTARY FILES

The following supplementary material is available on this journal's website:
- Annex 1. Figs. S1-S11.
- Annex 2. CR2 & CR3 interactive 3D record.
- Annex 3. CR4 interactive 3D record.

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DECLARATION OF COMPETING INTERESTS

The authors declare that they have not known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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AUTHORSHIP CONTRIBUTION STATEMENT

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Alba Fuentes Porto: investigation, methodology, writing-original draft, writing – review & editing.

Timoteo Rivera Jiménez: funding acquisition, investigation, methodology, writing – original draft, writing – review & editing.

Jordi Ibáñez Insa: investigation, methodology, writing-original draft, writing – review & editing.

José Antonio Lozano Rodríguez: investigation, methodology, writing – original draft, writing – review & editing.

César González García: investigation, methodology, writing – original draft, writing – review & editing.

Raquel Montero Artús: investigation, writing – review & editing.

Leonardo García Sanjuán: conceptualisation, investigation, methodology, writing – original draft, writing – review & editing.

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