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Landmark of the Past in the Antequera Megalithic Landscape: A Multi-Disciplinary Approach to the Matacabras Rock Art Shelter.

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1. Introduction: an exceptional landscape

On July 15th 2016, the General Assembly of UNESCO, gathered in Istanbul (Turkey), approved the inclusion of the Antequera Dolmens Site (Málaga, Spain) in the World Heritage List. This site comprises three megalithic monuments and two natural formations. The megalithic monuments are Menga and Viera (built during the Late Neolithic period) and the El Romeral tholos (erected during the Copper Age). The natural monuments are El Torcal karstic formation, located some 11km south of the megaliths, and the mountain known as La Peña de los Enamorados ('The Lovers' Rock') located 6km east of Menga and Viera and scarcely 2km from El Romeral tholos (Figure1).

The Outstanding Universal Values (OUVs) recognized in the UNESCO Declaration meet selection criteria 1, 3 and 4 which are reflected in the exceptional architecture, biography and landscape of the megalithic monuments and their association with the natural formations. Their architectural design and intrinsic properties make these three megaliths unique. Menga and El Romeral are also the largest stone monuments from the Late Neolithic and Copper Age Iberia and represent exceptional feats of prehistoric engineering (see Lozano Rodríguez et al. 2014 or García Sanjuán and Lozano Rodríguez 2016 for more detailed descriptions). Recent studies suggest that these three monuments had exceptionally long life-histories spanning Late Prehistory, Iron Age, Antiquity, the Middle Age and even Modern History. Menga was repeatedly used as a burial ground between the 4th and 11th centuries AD. Later, it was used as a sheepfold, dwelling or perhaps for water supply through the well inside it (García Sanjuán and Wheatley 2010, Diaz-Zorita Bonilla and García Sanjuán 2012, Aranda Jiménez et al. 2015, García Sanjuán et al. 2016, García Sanjuán and Lozano Rodríguez 2016, Bradley and García Sanjuán 2017, Bueno Ramírez et al. 2018).

The background to our study is the relationship between Menga and La Peña de los Enamorados. This relationship has two major conceptual dimensions: landscape and biography. They are expressed through a complex connection between the architecture, the mountain, the rock art found in it and the visibility patterns between them. As we will show in this paper, there is strong evidence suggesting that La Peña de los Enamorados played an important role in the genesis of Menga, which perhaps makes the Matacabras shelter the most important rock art location of Spanish Late Prehistory. Although previous studies have briefly described this shelter, no integral study of the Matacabras shelter had been carried out until now. In our study, we will first describe the shelter's topography based on the results of high resolution photogrammetry, before moving onto a detailed assessment of the graphic motifs identified through the use of digital image processing and various types of physical and chemical analysis and then looking into the geochemical composition of the surface pottery found nearby. In the discussion, we will evaluate the chronology and the conceptual, visual and symbolic relationship of Matacabras, and the mountain it is part of, with Menga.

2. Background

2.1. Location

Geologically, La Peña de los Enamorados (henceforth, La Peña) is a prominent elevation in the Baetic cordillera, the westernmost edge of the European Alpine mountain system formed in the Miocene. Within the Antequera landscape, La Peña appears as a huge limestone outcrop with a North-South orientation. It rises to 880 metres above sea level, visually dominating the Antequera plain. Its West, East and northern faces present very steep slopes. There is an imposing sheer cliff nearly 100 meters high on its northern face; the Matacabras rock art shelter is located at the foot of this cliff.

La Peña stands somewhat isolated within the Quaternary depression of the Antequera plain. This massive rock belongs to the External Subbetic of Jurassic age and is flanked at the South by the materials of Triassic age belonging to the Antequera Trias (Sanz de Galdeano et al., 2008), and further South still by the elevations of the El Torcal karst system (Jurassic period) that belongs to the Internal Subbetic (Figure 2A). To the North it is bordered by the Guadalquivir complex (Guarnido Olmedo 1977). These materials are rich in abiotic resources that were used throughout Late Prehistory, including flint (Morgado-Rodríguez et al., 2011), marble (Martínez-Sevilla et al., 2011), ophite (Morgado Rodríguez and Lozano Rodríguez, 2011) as well as salt, iron oxides and peridotites (Figure 2A). The wealth of materials in and around this region makes the Antequera Trias unique within the Baetic mountain range, which is probably connected to the high number of archaeological sites.

The lithostratigraphic scheme of La Peña shows (Figure 2B)a succession of dolomites, oolitic limestone as well as red, nodular limestone formed during the Jurassic and pink marlstone and marl-limestone from the Cretaceous period (Garcia Sanjuán et al. 2015: fig.13). The stratigraphic and sedimentological characteristics of the sediments reveal the typical successions of the Internal Subbetic domain, with a pelagic threshold developed over much of the Middle-Late Jurassic. These Jurassic facies (Ammonitico Rosso) present beige to pink colouring and a large amount of pelagic micro-fauna, mainly ammonites. Being less resistant to erosion, differential progression can be seen in the formation of the northern vertical cliff of La Peña, where the Matacabras shelter is located.

Historically, La Peña has been a well-known landmark within its immediate geographical setting, not only due to its commanding visual presence, but also because of its remarkable anthropomorphic silhouette when seen from the West or East, especially when the sun is low, at dawn or at sunrise (Figure 3A). It is therefore not surprising that this mountain has traditionally served as a landmark for terrestrial navigation along the two major routes that cross at Antequera: the West-East route connecting the lower Guadalquivir valley (Seville) with the Granada and Guadix-Baza basins towards eastern Spain (Levant), and the North-South route connecting the Mediterranean (Málaga) to the interior of the Guadalquivir valley (Córdoba) towards the Spanish central plateau. The finding of a Roman milestone belonging to the route connecting Antikaria (Antequera) with Iliberris (Granada) on its southern foot, where the Guadalhorce river flows, proves that La Peña was a major place of transit in Antiquity (Gozalbes Cravioto 1986). With Antequera being a crossroad and major place of transit, La

Peña was the landmark announcing its presence from several kilometres away to those travelling from the East, West or North (it is less visible from the South).

The topographical importance of this mountain is well reflected in the local folklore. The legend that gives the mountain its name very likely originated in the 15th century CE when the Castilian kingdom of Seville and the Nasrid kingdom of Granada fought for control of the region. According to this legend, of which there are various versions, a Muslim man and a Christian woman fell in love, a relationship not accepted by either of their families. After an unsuccessful escape, the lovers decided to take their lives, throwing themselves from the northern cliff of La Peña (Jiménez Aguilera 2006) (Figure3B). It cannot be ruled out that, as so often happens in Iberian folklore, the medieval legend is rooted in much older "pagan" traditions related to La Peña's strongly anthropomorphic silhouette, also portrayed locally as a dormant giant woman (García Sanjuán and Wheatley 2010: 26). In fact, La Peña is a major archaeological complex with evidence of occupation and frequentation throughout the Neolithic, Copper and Bronze Ages (Moreno Aráguez and Ramos Muñoz 1983, Rodríguez Vinceiro et al. 1992, Suárez Padilla et al. 1995), Antiquity (Cisneros Franco and Corrales Aguilar 1994) and the Middle Ages.

2.2. Discovery and Previous Studies

Before its re-discovery in April 2006 caused its definitive inclusion in the on-going research of the Antequera megalithic landscape (García Sanjuán and Wheatley 2009: 139-142), the Matacabras rock shelter had already been cited in a number of publications, first mentioned as "La Peña shelter" (Muñoz Vivas 1991: 509, Maura Mijares 2003, Maura Mijares 2005, Cantalejo Duarte et al. 2010), and later as "Matacabras shelter" (Maura Mijares et al. 2007, Maura Mijares 2011, Martínez García 2013,Bueno Ramírez et al. 2009, Bueno Ramírez and De Balbín-Behrmann 2009, De Balbin-Behrmann et al. 2017). All these references are general and included in a wider research framework.

In summary, although several descriptions of Matacabras have been published to date, all of them are rather fragmented and brief. The longest of these descriptions, published in Spanish by Maura Mijares (2011), is only three pages long.

Therefore, considering the precedents mentioned above, this paper has a threefold aim: (i) to provide the first in-depth multi-disciplinary characterisation of this important site; (ii) to place it within its spatial and chrono-cultural context which is none other than the Antequera megalithic landscape; (iii) to make this knowledge accessible to an international audience through an English language paper.

3. A Multi-Disciplinary Approach

3.1. Topographic Survey

The topography and precise shape of the Matacabras shelter have been recorded using three-dimensional (3D) photogrammetric modelling supported by geo-positioning techniques. Geo-positioning was carried out using a GPSTrimbleR6 receiver using the RTK (Real Time Kinematic) method**,** which connects the equipment in real time to the Andalusian Positioning Network (RAP in its Spanish acronym), with a maximum error of 1 cm. Reference points inside the shelter were located using a Trimble 5600 DR200+ total station as in this area it is not possible to reach the satellite network coverage. Photogrammetric modelling was achieved using Structure from Motion (SFM), which allows three-dimensional models to be obtained from unstructured image data and with un-calibrated cameras (Meyer and Gaspar 2017). This technique enables a 1:1 three-dimensional model with digital realistic textures to be obtained, providing all the necessary data on the studied area at any time. For this study the AgisoftPhotoscan, version 1.2.5. build 2614 (Agisoft LLC, St. Petersburg, Russia) software package was used.

The photogrammetric survey provides a good base for the graphic depiction of the motifs. On the western side of the shelter there are various motifs painted in red which follow a distinctly vertical pattern. This side is significantly affected by black colour run-offs on the walls(Figure 4), caused both by rain as well as irregular water leaks characteristic of the mountain's karst system. Running all along the floor of the shelter, which is rocky and uneven, the photogrammetric model shows up to three deep, subcircular cavities which are possibly interconnected and which are currently filled with sediments. These cavities have not been excavated, but visual inspection and the rendering of the photogrammetric model suggests that they may be human-made (Figure 5) which would reinforce the social and cultural importance of the shelter. Similarly to the case of Matacabras, at the shelters of Buraco da Pala and Fraga d'Aia, in northern Portugal, panels of schematic rock art were found in connection with negative features interpreted as a dwelling and storage area (Sanches 2003:167-168).

3.2. Digital Image Analysis

Following the topographic survey and photogrammetric restitution, a major aim of this study was to produce a new integral drawing of the painted motifs based on different digital imaging techniques. To this end, conventional RGB images taken with a digital Canon EOS 450D camera on a conventional tripod with two bubble levels have been used as primary material. The presence of the black coatings and the difficulty of appreciating the paintings (produced with a red pigment) make it advisable to use a blended focus, which proved to be very useful in mapping both the painting and the black coatings (Figure 6). In order to process the raw images we have used Principal Component Analysis (Portillo et al 2008, Rogerio-Candelera and Élez Villar 2010, Rogerio-Candelera et al. 2010, 2011, 2013) and Contrast Stretch in HSI colour mode (HSI-CS) technique, as well as an improvement of this technique that we denominated HSI-ECS elsewhere (Rogerio-Candelera 2015, Rogerio-Candelera and Linares Catela 2015). In addition, we have applied algebraic techniques such as the ferric pigments index, (for example Sebastian López et al. 2013), as well as additions and subtractions of bands. For these calculations, we used both HyperCube software (US Army Corps of Engineers, Alexandria, VA, USA), specifically targeting this work, with multi- and spectral images and ImageJ software (National Institutes of Health, Bethesda, MA, USA), originally designed for biomedical applications but which has been applied to many other scientific disciplines, including rock art recording.

3.3. Colour Measurement

The colorimetric coordinates of various painted motifs and the rock support (Figure 7) were determined in the CIELAB colour space (http://www.cie.co.at/index.php/Publications/Standards).This was made for two reasons: firstly, to present the colour of the different painted motifs in a reproducible fashion; and secondly, to obtain an initial classification of the pigments which would allow us to draw up a hypothesis on the existence of more than one phase in the elaboration of the panel, while also determining the basic components of the pigment according to the registered colour (Elias et al. 2006).

Colour measurements were performed using a portable spectrophotometer (Microflash, Datacolor International). The optical system of the measuring head uses diffuse illumination from a pulsed Xenon arc lamp with 0^{o} viewing angle geometry. Colour coordinates were obtained in the following conditions: D65 illuminant, 10^{o} observer and specular component excluded (SCE). The measuring area has diameter of 8 mm. Calibration was performed with a white bright tile and a total black light trap. CIELAB method allows characterizing the surface colour by three parameters: L* (lightness/darkness, varying from white, L* = 100 to black, L* = 0), a* (+a* indicating red and –a* green) and b*(+b* indicating yellow and –b* blue), defined by CIE (Commission Internationale de l'Éclairage). Three colour measurements were performed on each selected sampling-spot, two areas of rock support (Stone 1 and Stone 2) and on the painted areas.

3.4. U-Th dating

A major aim of this research was to establish the numerical age of the Matacabras rock art shelter in order to assess its temporal relationship with the building of Menga. To this end, two carbonate deposits (MC1 and MC2) directly overlying red pigment were sampled for U-Th dating. Detailed sampling methodologies are provided in Pike et al. (2012) and Hoffmann et al. (2016), but briefly: sample locations were mechanically cleaned to remove any surface contamination or alteration, then calcite was collected directly into pre-cleaned plastic sample tubes by scraping with a scalpel. Chemical preparation and isotopic analysis by Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS; Thermo Scientific Neptune Plus) was performed at the Ocean and Earth Science analytical geochemistry facilities at the University of Southampton. Methodologies broadly follow those in Hoffmann et al. (2007), except ion exchange chromatography for the separation of U and Th from the sample matrix employed 0.6 ml columns of UTEVA Spec (Eichrom) resin (Horwitz et al. 1992). Procedural chemistry blank values were always less than 0.01 ng ^{238}U, 0.1 pg^{235}U, 0.01 pg^{234}U, 0.01 ng ^{232}Th and 1 fg^{230}Th, respectively.

3.5. Field Emission Scanning Electron Microscopy (FESEM) and Pyrolysis-Gas Chromatography-Mass Spectroscopy (Py-GC-MS).

Three samples of coatings similar to the black ones covering the paintings (labelled MT1 to MT3) were taken by scraping them with a sterile scalpel and stored in Eppendorf tubes for electron microscopy as well Py-GC-MS characterisation (Figure 8). The morphology and elemental composition of the black coating samples were studied using field emission scanning electron microscopy (FESEM) combined with energy dispersive X-ray spectroscopy (EDS). Air-dried samples were directly mounted on sample stubs, sputter coated with gold, and subsequently examined in a FEI's Teneo FESEM (FEI Company, Eindhoven, The Netherlands) equipped with an EDAX (NJ, USA) EDS detector using standard ZAF corrections that allow semi-quantitative microanalysis. FE-SEM examinations were operated in secondary electron (SE) detection mode with an acceleration potential of 5kV and 15kV for EDS analyses.

Py-GC-MS, also known as analytical pyrolysis, was performed using a double-shot pyrolyser (Frontier Laboratories, model 2020i) attached to a GC/MS Agilent 6890N system. Material from the patina taken at the sample MT2 was carefully grounded; 2 milligrams were placed in a small crucible capsule and introduced into a preheated micro-furnace at (500°C) for 1 min. The volatile pyrolysates were then directly injected into the GC/MS for analysis. The gas chromatograph column, oven temperature program and mass spectra acquisition were settled according with the conditions reported by Pereira de Oliveira et al. (2011). Compounds were identified using the NIST 05 and Wiley digital libraries and available literature. The relative proportions of the compounds satisfactory identified were calculated as the percentage of the total quantified peak area (TQPA), using the main fragment ions (m/z) of each product. Only compounds with relative abundances greater than 0.25% were considered. This is a semi-quantitative exercise that allows more detailed description of the results than visual inspection of chromatogram alone.

3.6. Neutron Activation Analysis (NAA) and X-Ray Diffraction (XRD) of associated surface finds.

In order to examine the connection between the Matacabras rock shelter and the Late Neolithic activity area of Piedras Blancas I, which lies barely 100 m below, hand-thrown pottery fragments found of the surface of both sites were examined. Two ceramic sherds from Matacabras and five from Piedras Blancas I were analysed for compositional characterisation under the assumption that a very similar composition would suggest coetaneous activity. Ceramic pastes were sampled following well-established laboratory protocols (Dias et al. 2010, Prudêncio et al. 2009). Ceramic powder and standards (GSD 9 and soil GSS 1) were irradiated together at the Portuguese Research Reactor, Sacavém. Chemical composition was obtained by instrumental neutron activation analysis (INAA) as described elsewhere (Dias et al. 2013). The following elements were obtained: Na,K, Fe, Sc, Cr, Co, Zn, Ga, As, Br, Rb, Zr, Sb, Cs, Ba, La, Ce,Nd, Sm, Eu, Tb, Yb, Lu, Hf, Ta, Th and U.By using chemical contents as variables, geochemical ratios and normalizations were performed, together with multivariate statistical analyses by means of the Statistica software package (TIBCO Software Inc. 2017), even aware of their restrictions due to the limited amount of cases. Some elements were not considered for the analyses due to their behaviour upon firing (Trindade et al. 2011). Mineralogical composition was obtained by X-ray diffraction (XRD) for the bulk material, using a Phillips Pro-Analytical spectrometer with KαCu source. Non-oriented aggregate powders were prepared and scanned at 1° 2θ/min from 2° to 70° 2θ. To estimate quantities, we measured the diagnostic reflection areas, considering the full width at half maximum (FWHM) of the main minerals (Sanjurjo Sánchez et al. 2010, Trindade et al. 2013) and then weighted by empirical factors or calculated parameters (Biscaye 1965).

4. Results

4.1. Digital Image Analysis (DIA)

The Matacabras graphic motifs were probably produced by applying the paint using the tips of the fingers, resulting in lineal motifs approximately 1 cm wide. The colour of the paint is red, for which reason today they do not stand out greatly against the natural reddish colour of the base rock. Consequently, the different original images used to elaborate the drawings present a high degree of correlation among the three bands. Table1 shows the correlation coefficient matrix of a significant image in the group of images, with correlations between the bands higher than 95%. Thus, the information percentage (variance) is very low for the band of the third principal component, with an average of 0.09% (SD=0.03; *n=10*), indicating that this band is the best to represent the painting. Incidentally, this is the element less represented in the images. Graphically speaking, Figure 6B is a good example of this.

Although the third principal component is clearly the most suitable in the majority of the images for mapping the painting, possible “false positives” have been controlled using the technique of increasing the contrast, HSI-CS (Gillespie et al. 1986). This technique, developed in the early 1980s to improve the definition of the different image datasets, encompassing the wavelength range to Radar bands (Daily 1983), allows the improvement of the image by intensifying the original colours. Also, the variation of this technique which we have named HSI-ECS (Rogerio-Candelera and Linares Catela 2015) produces a colour contrast that allows us to appreciate details more easily and evaluate whether the elements detected using Principal Component Analysis are reliable or if, on the contrary, they are mere artefacts (Figure 6C). All this has allowed us to elaborate a new tracing of the different elements in the panel (Figure 9).

4.2. Colorimetry

The colorimetric characterization of the Matacabras paintings was used as a complement to the image analysis to test if the colour measurements could enhance the perception of the drawing. Colorimetry itself reveals congruent a* parameter values with the use of iron oxide-based pigments. Likewise, it detects statistically significant differences between the colour of the supporting rock and the pigments. This allows us to evaluate whether some lines undetected prior to this study are really intentionally painted or are artefacts produced by the documentation methods applied.

The colorimetric results showed that the a* value was the main distinguishing feature of the rock paintings, providing the highest chromatic distance between the chromatic coordinates of the natural rock and the painted motifs, the paint values being statistically different from the underlining rock support (Table 2). The only exception was the paint of the great pectiniform motif (Figure 7, sampling points 15 to 17), where the distinction from the rocky substrate was not statistically different - the variability due to the particulate accumulation and the difficulties experienced during the measurement acquisition due to the surface irregularities might explain this result. The analysis of the a* results also showed significant differences between the serpertiform 1, anthropomorph A and the two pectiniforms representations. The enhancement of the coordinate a* (+a* indicating red and –a* green) was expected since natural iron oxide pigments (often termed 'ochres'), were usually the employed pigment in rock art with colour shades between of red and yellow (Gomes et al. 2015). The mineralogical characterization of Western Iberian schematic rock art with similar red shades to those of Matacabras showed that pigments could have different minerals such as goethite or hematite (Gomes et al. 2015). Regarding the b* values no significant differences (p>0.05) could be detected between the paint and Stone 1. However, Stone 2 was significant different from all pictograms except anthropomorph A.

4.3. U-Th dating

Of the two samples collected for U-Th dating, sample MC1 was not processed because its mass was too low for a successful analysis (0.1 mg). Sample MC2 (Figure 10) consisted of three sequential sub-samples (MC2a–c), all of which were large enough for analysis (Table 3). However all are characterised by very low (^{230}Th/^{232}Th), an indicator that detrital thorium, i.e. Th that did not result from in situ decay of uranium, has been incorporated into the calcite – see Pike et al. (2012) and Hoffmann et al. (2016) for further information regarding this issue. High levels of detrital Th contamination typically result in a calculated U-Th age being an overestimation of its true age, and a detrital thorium correction is required. Here we follow typical procedures and use an assumed detrital (^{232}Th/^{238}U) of 1.250 ± 0.625, a value typical of upper crustal silicates (Wedepohl 1995), whilst assuming ^{230}Th and U isotopes are in equilibrium. After applying this correction, the three MC2 sub-samples provide a stratigraphically consistent series of dates from 5.38 ka to 15.85 ka. This correction also reduces the precision of the dates, and after taking this into account the oldest sample indicates that the Matacabras art dates to before 5.82 ka BP (*c* 3800 cal BCE). However, with very high levels of detrital contamination, the corrected date is very dependent on the assumptions used for correction, and we would not normally consider corrected dates with levels of detritus similar to sample MC2 as reliable.

4.4. FESEM-EDS examinations

The FESEM-EDS examinations of the black patinas collected from the vertical surface of Matacabras shelter showed that the bedrock is covered by a discontinuous layer of gypsum crystals (Figure 11A-D). Figure 11B clearly shows that gypsum is the predominant mineral phase, probably due to sulphation processes. Algal-like cells (< 3 µm) are discernible on the surface of large gypsum crystals (Figure11B). Moreover, Na, Cl and K were detected in the black patina, corresponding to salts, mainly halite, which seems to crystallise here (Figure11D). A biofilm composed of algal cells and their metabolic products, particularly extracellular polymeric substances (EPS), are observed in Figure 11E. Diatom cells were scarcely observed in the black patina samples (Figure11F).

The FESEM-EDS data pointed out that the dark-coloured patina at Matacabras is associated with the formation of black crusts of secondary minerals, particularly gypsum, and microbial colonisation. Dark crusts are widespread on stone building surfaces mainly in urban environments (Hermosin et al. 2004, De la Rosa et al. 2017). The increase of atmospheric contamination in these environments accelerates stone deterioration, especially on limestone where loss is primarily related to dissolution of calcium carbonate induced by the solvent action of acid rainwater. Its penetration into the pores hastens the rate of stone deterioration tremendously, first because water is itself an effective deteriorating agent, dissolving, hydrating and hydrolysing minerals, and, secondly because it holds in solution substances (carbonaceous particles, sulphur compounds, soluble salts) responsible for leaching of surfaces, pH reduction, dark crusts and efflorescence (Ordóñez et al. 1997, Papida et al. 2000). Gypsum and salt crystallisation evidence weathering mechanisms on the limestone surface of Matacabras, suggesting that it has been exposed to atmospheric pollutants, such as sulphur-based compounds. Sulphation has been recognised as one of the main causes of stone deterioration in urban areas (Montana et al. 2008, Rivas et al. 2014). The process starts with the formation of gypsum crusts due to the reaction between sulphuric acid from polluted air and carbonate minerals. Although Matacabras is located in a rural environment, it is near an old railroad for carbon and diesel locomotives which have probably increased sulphur-based compounds in the atmosphere. In addition to sulphation, phototrophic microorganisms were also observed in the gypsum-rich patina. Their metabolic activity accelerates the dissolution of the carbonate rock due to the release of organic acids which can etch or solubilise stone minerals. Moreover, the slimy surface of biofilms favours the adherence of airborne particles (salts and air pollutants) and the accumulation of the moisture on the external layer of the stone (Fernandes 2006, Gorbushina 2007).

4.5. Pyrolysis-Gas Chromatography Mass-spectrometry (Py-GC-MS)

The total ion current (TIC) trace and the list of identified compounds with the percentages of TQPA obtained by Py-GC-MS analysis generated at 500°C are reported in Figure 12 and Table 4 respectively. The pyrolysates of the Matacabras black patina reveal a noteworthy presence of organic compounds, which can be broadly grouped into the following categories: carbohydrates (Ch), aromatic hydrocarbons and derivatives (Ar), N-containing compounds (N-comp), lipids (Lip) and Sulphur containing compounds (S).

The pyrochromatogram is dominated by Ch which accounted for 13 different compounds and over 32.8% of TQPA. The most abundant Ch compounds are furfural, furanes and alpha-*d*-glucopyranose (see peaks 5, 8, 10, 12, 27, 28 or 33; Table 4). Most of theseCh were previously reported as common products of metabolic activities of bacteria, algae and fungi on rock substrates (Robert and Berthelin 1986), in pyrolysis of endolithic cyanobacteria (Saiz-Jimenez et al. 1990), lichen thalli (Saiz-Jimenez et al.

1991), fungal melanins (Saiz-Jimenez et al. 1995) and fungi. The presence of levoglucosan (peak 43) has been previously used as marker of biomass burning (De la Rosa et al. 2008).

Aromatic hydrocarbons (Ar) resulted approximately in 20% of TQPA, being dominated by styrene, phenol, toluene, cresols and coumarin derivatives. Anthropogenic pollution sources have been identified as the source of styrene, toluene and numerous light alkyl aromatic compounds, which may derive from pyrolysis or flash vaporisation of bituminous coal. Acetylcoumarin (peak 44) is found naturally in numerous grasses. Dimethylnaphthalene and 9, 10-Anthracenedione, 1-amino-4hydroxy- (peaks 37 and 59 respectively) are polycyclic aromatic hydrocarbons typically associated with incomplete burning of fuel biomass (Schiavon et al. 1995, Standley and Simoneit 1987). Nevertheless, benzenes, phenols and methyl phenols are potential pyrolysis products of many biopolymers including amino acids (Moldoveanu 2010), lignin (De la Rosa et al. 2012), and proteins.

The N-containing compounds (N-comp) summed over 21.3% of TQPA. The highest N-comp peaks correspond to pyridine, methyl pyridines and indoles, which are typical pyrolysis products from amino acids and peptides (Moldoveanu 2010). These compounds have a biological origin, and are typically synthesised by living organisms (Saiz Jimenez et al. 1995).

Lipids (Lip) are constituted by a series of *n*-alkanes and *n*-alkenes and several *n*-alkyl fatty acids. They could derive from microorganisms such as cyanobacteria and fungi, plant tissues or soil organic matter. Neophytadiene (peak 49) is a thermal degradation product of chlorophylls (Saiz-Jimenez et al. 1990). It is very abundant in vegetal resins, in addition it could indicate the contribution of algae, which is in fair agreement with the relatively important presence of heptadecane (peak 46), a predominant constituent of most cyanobacteria and algae (Pereira de Oliveira et al. 2011).

It is also worth noting the presence of sulphur-containing compounds (S). Thiophenes, thiazoles and their derivatives occur in petroleum and coal (Schiavon et al. 1995).

4.6. Neutron Activation Analysis (NAA) and X-Ray Diffraction (XRD) of associated surface finds.

The archaeometric characterisation of ceramic artefacts by means of geochemistry and mineralogy is a well established approach to solve technological and provenance issues in pre-historical contexts (Dias et al. 2017). The XRD results enable to define the mineralogical associations observed for each ceramic fragment (Table 5). Two ceramic samples from Matacabras (CerMC2 and CerMC3) and two from Piedras Blancas I (CerPBI 2-2 and CerPBI 2-4) are differentiated from the other ones due to the presence of calcite (7%<Calcite<21%) associated to higher amounts of quartz, phyllosilicates, alkali feldspars, plagioclase, and traces of anatase(Figure 12). Only in CerMC3 and CerPBI 2-4 samples hematite was detected in traces amounts. Two ceramic sherds (CerPBI 2-1 and CerPBI 2-3) have the higher amount of phyllosilicates (>55%), associated to quartz, and traces of alkali feldspars and anatase. The CerPBI 1-1 sample has a different mineralogical association, with similar proportions of phyllosilicates and quartz (~45% each) and traces of plagioclase, hematite and amphibole. No high temperature phases potentially derived from the calcite or clay minerals (Trindade et al. 2009, 2010) were found in any of the ceramics.

Seven ceramic samples were chemically analysed by INAA(Table 6) in an attempt to establish chemical correlation between the artefacts found at both sites, with the establishment of groups with similar chemical composition, hence allowing the identification of the clay materials (Figure 14A). From a chemical point of view one sample CerPBI 1-1 is completely different from all the others, pointing to the use of more mafic raw materials, as already indicated by the mineralogical results (amphibole), with lower contents of K, Rb, Cs, LREE, Hf and Ta, and higher contents of Fe, Sc, Cr, Co, Zn, As, Sb and Ba(Figure 14B). Two samples from Piedras Blancas I have similar chemical composition (CerPBI 2-1 and 2-3) with higher amounts of Zr, Ga, REE, Ta, Th. The other four sherds analysed comprise samples from both sites (CerPBI 2-2, 2-4, CerMC 3 and 2) with similar chemical composition. Nevertheless sample CerMC2 has higher Cr and Co and lower Zn and Zr contents. It is important to emphasise that these four samples (CerPBI 2-2; 2-4; Cer MC3; 2) are the only ones pointing to the use of calcite-rich raw materials. However, the effect of post-burial chemical alteration must be ruled out as a valid explanation for this observed chemical patterning, and even more detailed studies would help, particularly by scanning electron microscopy. It is important to take into consideration that they all came from the same environment, and only those four are calcite rich. Thus, we may assume the use of different raw materials, and the most relevant, is that.these preliminary analytical results yield groups of ceramic sherds with similar composition at both sites, indicating in some cases similar sources for the raw materials.

5. Discussion

The importance of the Matacabras rock art shelter lies not only in its intrinsic characteristics, but rather in its close relationship with Menga within the wider framework of the key role that La Peña seems to have played in the genesis and design of this great megalith. The almost exact orientation of Menga’s axis of symmetry towards the Matacabras shelter (Figure 15) has been interpreted as the commemoration of a place that had special symbolic significance before the dolmen was built (García Sanjuán and Wheatley 2009, 2010, García Sanjuán and Lozano Rodríguez 2016, De Balbín-Behrmann et al. 2017), although astronomy has also been claimed to play a part in the monument’s orientation (Lozano Rodríguez et al., 2014).

Therefore, an obvious key issue in this respect is determining Matacabras’ chronology. Two immediate problems need to be confronted: firstly, to determine when the paintings were made and the shelter used; and secondly, to find out if distinct phases can be differentiated in the usage of the rock shelter.

In terms of the first issue, radiocarbon dating was ruled out due to the assumed lack of organic material in the red colour motifs (Ruiz et al. 2012). In Iberia, radiocarbon dating of sites with post-glacial graphic art has only been achieved for some megaliths, organic matter in black pigments providing chronologies ranging between the 6th and 1st millennia BC (Bueno Ramírez et al. 2007). In rock shelters, the importance of red pigments has prompted the use of other techniques such as radiocarbon dating of oxalate crusts (Ruiz et al. 2012). Congruently with this assumption, U-Th dating of the calcareous crusts grown over the motifs was chosen as a potentially workable dating method. Although some dates congruent with the multi-stratified character of the sample were obtained, they were demonstrated to be doubtful due to its high detrital thorium content. An attempt to TL-date a knapped lithic artefact found in the proximities of Matacabras also failed (data not shown). The characterisation of some ceramic sherds collected at the surface of Matacabras and the neighbouring site of Piedras Blancas I, however, does point out towards a very similar technological and cultural background for both sites. Ceramics from both sites point to the use of calcite rich raw materials and low firing temperatures. Nevertheless, one ceramic sherd from Piedras Blancas I has a different composition, pointing to the use of non-carbonated and mafic raw materials.

Although none of this evidence secures a numerical date for the paintings themselves, it does throw some light onto the chrono-cultural context of the shelter's use and occupation. Relative dating based on the stylistic characteristics of the Matacabras motifs is an alternative resource. A very wide chronological framework is considered for Iberian schematic rock art: from the Early Neolithic to a late imprecise chronology that can reach historical times. The concept of schematic rock art is in itself clearly an artificial category. In fact, different phases of use in panels have started to be noted – and connected with the biographies of these sites - including Palaeolithic and Post-Palaeolithic art as well as much later, 'Protohistoric' art (Royo Guillén 2015, Luis 2009). In addition, recent research has identified schematic rock art in northern and western regions of Iberia, where it had not been recorded before (Sanches 2016, Figueiredo et al. 2015, Bueno-Ramírez et al. 2016). Indeed, within the schematic rock art phenomenon different nuclei coexist which share a "family resemblance" (Acosta Martínez 1968) such as for example La Alcudia valley and Sierra Madrona mountain range (Ciudad Real) (Fernández Rodríguez 2003) or La Janda (Cádiz) (Mas Cornellà 2005). These probably have chrono-cultural connotations but the scarcity of absolute dates has not enabled them to be defined. In this sense, Juan Vicent García (2008) notes the existing tendency in this field to repeatedly try to answer the same questions regarding the symbolic and artistic aspects of Neolithic material culture (the research agenda).

Following Acosta Martínez (1995), the presence of a big pectiniform element and at least two anthropomorphic figures would typologically characterize the Matacabras rock art as belonging to the Middle Neolithic. Nevertheless, the existence of an important Early Neolithic habitat at El Toro cave (located in El Torcal karstic landscape) in which there is evidence of the use of schematic art on a human skull (Guijo Mauri 2004: 289) and the 'ancient style', perceived in some elements of the composition (such as the serpentiform lines), could take us even further back in time.

Thus, although the chronology for neither Matacabras nor Menga has been precisely established due to the significant problems posed by the empirical record, a temporal precedence of the former over the latter seems likely. The data presented here suggest that Matacabras could have been painted prior to c. 3800 BC, even though, as has been pointed out, the sample used in the U-Th dating is not entirely reliable. The limited radiocarbon determinations available for Menga suggest it must have already been erected by between c. 3800 and 3600 BC (García Sanjuán and Lozano Rodríguez 2016: 8). The chronometric data currently available allows us to consider the possibility that Matacabras could have in fact been in use when the Menga dolmen was erected. Nevertheless, the chronologic relationship between both sites may not necessarily be one of simple diachrony (first Matacabras – then, Menga). On the contrary, this relationship could be synchronic in nature - or the shelter could even be subsequent to the construction of Menga. The view of La Peña from the plain (and from inside Menga) is so spectacular that it may have been one of the main causes of the dolmen's anomalous orientation.

The second chronological challenge to solve is the possible existence of distinct phases of use of the Matacabras shelter. The restrictive scientific policy on rock art painting enforced by Andalusian cultural authorities, in which conservation is prioritised, has prevented us from taking samples of the pigments for their characterization. Therefore, the information we have is essentially incomplete. Nevertheless, we have the analytic information yielded by the colorimetry of the motifs, the qualitative information obtained through digital image analysis and the visual observation of the pigment application technique to attempt to shed some light on this matter. Apart from the stylistic criteria, knowing the composition of the pictorial 'recipe' used can help to verify the existence of different phases in the production of the panels as we know them today. Differences in the composition of prehistoric pigments can be significant in determining the distinct phases in the creation of the panels (Rogerio-Candelera 2014). Digital image analysis, on the one hand, has proven to be a useful tool in producing reliable generalizations based on the optical response of different pictorial recipes (Rogerio-Candelera 2014). At Matacabras, the pigment application technique seems to be very similar across the panel, with lines drawn on using the fingertips, all traces being linear and all the pictorial elements of the panel being approximately 1 cm thick.

Does the absence of significant differences in the optical behaviour of the paint and the technical and stylistic similarity of techniques/styles suggest that Matacabras is a 'fossilized panel' (i.e. a painted composition which has not verified incorporations of other painted elements since its creation [*sensu* Martínez García 2004, 2013])?

No simple answers can be given for these very difficult questions. On the one hand, recent studies have shown that in rock art caves used and re-used over long periods of time the composition of pigments may not have changed much, as is the case of Tito Bustillo, in northern Spain (De Balbín-Behrmann and Alcolea González 2009). On the other hand, the images obtained in this study suggest that the lines of the serpentiform were not only covered by the crust analysed further below, but also that on the upper part (where they are less visible) they could be over-imposed by a schematic motif (see sampling points 15-16 in Figure 6). Apparently there are also serpentiform lines under the great central pectiniform, but these are even less perceptible (left of sampling point 14 in Figure 6). Together with a style of Palaeolithic reminiscence, these superimpositions suggest the existence of a long sequence of graphic art executed by hunters and gatherers at Lands of Antequera (Bueno Ramírez and De Balbín-Behrmann 2016: 472, De Balbín-Behrmann et al 2017).

Therefore, we must keep an open mind to the possibility that a degree of diachrony existed in the elaboration of the Matacabras motifs, including two phases in which the wavy motifs seem to belong to the earlier one (Bueno Ramírez and De Balbín-Behrmann 2016: 472). Only further research, perhaps aided by radiocarbon dating, will help establish this point.

Finally, it is worth noting that both the information obtained through electronic microscopy and characterization of the organic compounds found in the walls of the shelter indicate taphonomic circumstances influenced by the humidity, the proliferation of photosynthetic organisms and atmospheric contamination (which might be related to the existence of a railway nearby since 1869, which once even had had a station near to La Peña). These data are of importance for the future conservation of these important remains of prehistoric rock art.

6. Conclusions

The multi-disciplinary study presented in the previous pages has served to accurately define the graphic material of the Matacabras rock shelter, which had only been perfunctorily described up until now. The data obtained in our study also reveal that a relationship of diachronic precedence between the graphical motifs of the Matacabras rock shelter and the construction of Menga is quite possible, although not strictly necessary for explaining the peculiar orientation of the great megalith. The 'internal' chronology of the panel is a difficult problem. As we have discussed above, some evidence point to a strong stability in the production of the motifs, with similar pigment composition and execution style, while other evidence suggest a possible diachrony, with superimposition of motifs.

Besides its intrinsic properties, which we have examined in detail, Matacabras is of particular relevance due to its geographical position and visual relationship with Menga. In his archaeoastronomy study on prehistoric monuments of the western Mediterranean, Michael Hoskin (2001) had already pointed out Menga's highly unusual nature in that it does not face sunrise, as is common in southern Iberian megaliths, although that does not necessarily mean that the orientation is entirely devoid of other kinds of astronomical significance, as it has been claimed (Lozano Rodríguez et al., 2014). Later investigations demonstrated that Menga's axis of symmetry intersects almost precisely with the foot of the rocky cliff which dominates the northern sector of La Peña de los Enamorados, exactly where Matacabras is (Figure15). This characteristic confers an unusual relevance to Matacabras in term of the design and biography of this great megalithic monument (García Sanjuán and Wheatley 2010: 22-31, García Sanjuán and Lozano Rodríguez 2016: 7-8). In fact, fieldwork carried out in 2006 and 2013 has shown intense Late Neolithic and perhaps (although to a lesser extent), Copper Age activity at Piedras Blancas I, located right below Matacabras. A significant amount of surface material attributable to these periods has been found at Piedras Blancas I, as well as some monolithic blocks described as possible menhirs (García Sanjuán and Wheatley 2009, 2010, Bueno Ramírez *et al*. 2009: 188, García Sanjuán et al. 2015). Also, there is a probable small, megalithic tomb named Piedras Blancas II (García Sanjuán and Wheatley 2009: 139).The rock art shelter of Matacabras, therefore, was far from isolated on its La Peña location: a major locus of activity, including possibly megalithic monuments, was connected to it.

In addition, Lands of Antequera houses a major series of locations with schematic rock art (Figures 16 and 17) which, having already been discovered and described, await high-resolution studies similar to the one presented here. An interesting aspect of this set of rock art sites is the frequency of panels with Palaeolithic and Post-Palaeolithic sequences, both inside caves and in the open-air. The Palaeolithic serpentiforms of La Pileta and Ardales caves are closely connected to those of Matacabras and the Cueva Alta shelter in Cañete la Real. The latter two are located right on natural fissures that accentuate the topographical prominence and visibility of the sites (De Balbín-Behrmann et al. 2017:127). Another interesting aspect is the relationship between painting and engraving at some sites, which is generally not very frequent in Iberian schematic rock art (Bueno Ramírez et al. 2009). In addition, we must note that the motifs present in the region, even if fitting within the 'classic' repertoire of schematic rock art, show local idiosyncrasies such as the pectiniforms. At La Pileta, a direct radiocarbon chronology of the first half of the 3rd millennium BC was obtained on a black pectiniform (Sanchidrián Torti et al. 2001), thus showing a Palaeolithic/Post-Palaeolithic sequence of interest for Matacabras.

In summary, both landscape and long-term biography are elements clearly embedded in the fabric of Antequera's outstanding megaliths, to an extent rarely seen in other prehistoric monuments worldwide. Regardless of its limited conservation, the graphical motifs of the Matacabras rock shelter wonderfully illustrate the complex conceptual relationship that Neolithic societies established between certain conspicuous natural formations, graphical signs and 'monumental' natural formations. The visual association between Menga and Matacabras is unique in Iberia and most probably also in Europe. The future excavation of Matacabras and the key site of Piedras Blancas I, which is intrinsically associated with it, will enable us to shed more light on the complex conceptual, visual and graphic relationships underlying one of the most complex megalithic landscapes in the world.

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Bibliographic References

Acosta Martínez, P., 1968. La Pintura Rupestre Esquemática en España. Salamanca, Universidad de Salamanca.

Acosta Martínez, P., 1995. Las culturas del neolítico y calcolítico en Andalucía Occidental. Espacio, Tiempo y Forma, Serie I, Prehistoria y Arqueología 8, 33-80.

Aranda Jiménez, G., García Sanjuán, L., Mora Molina, C., Moreno Escobar, M.C., Riquelme Cantal, J.A., Robles Carrasco, S., Vázquez Paz, J., 2015. Evidencias de asentamiento y prácticas funerarias en los dólmenes de Menga y Viera en la Antigüedad. La Intervención de 1988. Menga. Revista de Prehistoria de Andalucía 6:253-289.

Biscaye, P.E., 1965. Mineralogy and sedimentation of recent deep-sea clay in the Atlantic Ocean and adjacent seas and oceans. Geological Society of America Bulletin 76:803-832.

Bradley, R., García Sanjuán, L., 2017.Sudden Time? Natural disasters as a stimulus to monument building: From Silbury Hill (Great Britain) to Antequera (Spain). In: Bickle, P., Cummings, V., Hofmann, D., Pollard, J., (Eds.), Neolithic Europe: Essays in Honour of Professor Alasdair Whittle. Oxbow, Oxford, pp. 181-201.

Bueno Ramírez, P., De Balbín-Behrmann, R., 2009.Marcadores gráficos y territorios tradicionales en la prehistoria de la Península Ibérica. Cuadernos de Prehistoria y Arqueología de la Universidad de Granada 19:65-100.

Bueno Ramírez, P., De Balbín Behrmann, R., 2016. De cazadores a productores: Transiciones y tradiciones. In: Del Neolític a l'Edat del Bronze en el Mediterrani Occidental: Estudis en Homenatge a Bernat Martí Oliver, TV SIP 119, València, pp. 465-480.

Bueno Ramírez, P., De Balbín-Behrmann, R., Barroso Bermejo, R., 2007. Chronologie de l'art mégalithique ibérique: C14 et contexts archéologiques. L'Anthropologie 111:590-654.

Bueno Ramírez, P., De Balbín Behrmann, R., Barroso Bermejo, R., 2009. Análisis de las grafías megalíticas de los Dólmenes de Antequera y su entorno. In: Ruíz González, B. (Ed.), Dólmenes de Antequera: Tutela y Valorización Hoy. Sevilla, Junta de Andalucía, pp. 186-197.

Bueno Ramírez, P., De Balbín Behrmann, R., Barroso Bermejo, R., 2016. Graphic Holocene expressions on the Atlantic façade: Portugal. In: Soares, J. (Ed.), Social Complexity in a Long Term Perspective. Setúbal Arqueológica16,pp. 41-64.

Bueno Ramírez, P., De Balbín Behrmann, R., Barroso Bermejo, R., 2018. Steles, time and ancestors in the megaliths of Antequera, Málaga, Spain. Menga. Revista de Prehistoria de Andalucía 8:167-193

Cantalejo Duarte, P., Espejo Herrerías, M.M., Cabello Ligero, L., Becerra Martín, S., Medianero Soto, J., Aranda Cruces, A., Mora Domínguez, J. 2010. Sobre los antropomorfos esquemáticos en Málaga: reflejo de unos grupos sociales que mantuvieron un arte subjetivo. In: Martínez García, J., Hernández Pérez, M.S. (Eds.), Actas del II Congreso de Arte Rupestre Esquemático en la Península Ibérica. Comarca de Los Vélez, Almería, pp. 67-79.

Cheng H., Edwards, R.L., Shen C.-C., Polyak, V.J., Asmerom, Y., Woodhead, J., Hellstrom, J., Wang, Y., Kong, X., Spötl, C., Wang, X., Alexander, C., 2013. Improvements in ^{230}Th dating, ^{230}Th and ^{234}U half-life values, and U-Th isotopic measurements by multi-collector inductively coupled plasma mass spectrometry. Earth and Planetary Science-Letters 371–372, 82–91.

Cisneros Franco, J., Corrales Aguilar, M., 1994.Informe sobre la necrópolis de La Angostura (Antequera, Málaga). Análisis altimétrico, planimétrico y orientación de los enterramientos excavados. Actas del II Congreso Andaluz de Estudios Clásicos, III, Sociedadde Estudios Clásicos, Málaga, pp. 279-283.

Daily, M., 1983. Hue-Saturation-Intensity Split-Spectrum processing of Seasat Radar imagery. Photogrammetric Engineering and Remote Sensing 49(3):349-355.

De Balbín-Behrmann, R., Alcolea González, J.J., 2009. Les colorants de l'art paléolithique dans les grottes et en plein air. L'Anthropologie 113, 559-601.

De Balbín-Behrmann, R., Bueno Ramírez, P., Barroso Bermejo, R., Villanueva Ortíz, P., 2017. Images of the Past in the Lands of Antequera, Málaga, Spain: Palaeolithic to Post-Palaeolithic Transition in Southern Europe. Munibe Antropologia-Arkeologia 68: 115-133.

De la Rosa, J.M., López Capel, E., González-Vila, F.J., González-Pérez, J.A., Manning, D.A.C., 2008. Direct detection of black carbon in soils by Py-GC/MS, 13C NMR spectroscopy and thermogravimetric techniques. Soil Science Society of America Journal 72:258-267.

De la Rosa, J.M., Faria, S.R., Varela, M.E., Knicker, H., González-Vila, F.J., González-Pérez, J.A., Keizer, J., 2012.Characterization of wildfire effects on soil organic matter using analytical pyrolysis. Geoderma 191: 24-30.

De la Rosa J.M., Miller A.Z., Pozo-Antonio J.S., González-Pérez J.A., Jiménez-Morillo N.T., Dionisio A., 2017.Assessing the effects of UVA photocatalysis on soot-coated TiO_2-containing mortars. Science of the Total Environment 605-606, 147-157.

Dias, M.I., Prudêncio, M.I., Valera, A.C., 2017. Provenance and circulation of Bell Beakers from Western European societies of the 3rd millennium BC: The contribution of clays and pottery analyses. Applied Clay Science 146, 334-342.

Dias, M.I., Prudêncio, M.I., Matos, M.A., Rodrigues, A.L., 2013. Tracing the origin of blue and white Chinese Porcelain ordered for the Portuguese market during the Ming dynasty using INAA. Journal of Archaeological Science 40 (7), 3046-3057.

Dias, M.I., Prudêncio, M.I., Gouveia, M.A., Trindade, M.J., Marques, R., Franco, D., Raposo, J., Fabião, C.S., Guerra, A., 2010.Chemical tracers of Lusitanian amphorae kilns from the Tagus estuary (Portugal). Journal of Archaeological Science 37, 784-798.

Díaz-Zorita Bonilla, M., García Sanjuán, L., 2012. Las inhumaciones medievales del atrio del dolmen de Menga (Antequera, Málaga): estudio antropológico y cronología absoluta. Menga. Revista de Prehistoria de Andalucía 3:237-250.

Elias, M., Chartier, C., Prévot, G., Garay, H., Vignaud, C., 2006. The colour of ochres explained by their composition. Materials Science and Engineering B 127, 70-80.

Fernandes, P., 2006. Applied microbiology and biotechnology in the conservation of stone cultural heritage materials. Applied Microbiology and Biotechnology 73, 291-296.

Fernández Rodríguez, M., 2003. Las Pinturas Rupestres Esquemáticas del Valle de Alcudia y Sierra Madrona. Mancomunidad de Municipios del Valle de Alcudia y Sierra Madrona, Ciudad Real.

Figueiredo, S.S., Xavier, P., Silva, A. ,Neves, D., Dominguez Garcia, I., 2015. The Holocene transition and post-palaeolithic rock art from de Sabor valley (Tras-Os-Montes.Portugal).In: Medina-Alcaide, M.A., Romero Alonso, A.J., Ruiz-Márquez, R.M., Sanchidrián Torti, J.L. (Eds.) Sobre Rocas y Huesos: Las Sociedades Prehistóricas y sus Manifestaciones Plásticas. Córdoba, Universidad de Córdoba, pp. 192-203

García Sanjuán, L., Lozano Rodríguez, J.A., 2016.Menga (Andalusia, Spain): biography of an exceptional megalithic monument. In: Laporte, L., Scarre, C. (Eds.).The Megalithic Architectures of Europe. Oxford, Oxbow, pp. 3-16.

García Sanjuán, L., Wheatley, D.W., 2009. El marco territorial de los Dólmenes de Antequera: valorización preliminar de las primeras investigaciones, In:Ruiz González, B. (Ed.). Dólmenes de Antequera:Tutela y Valorización Hoy. Sevilla, Junta de Andalucía, pp. 128-143.

García Sanjuán, L., Wheatley, D., 2010. Natural substances, landscape forms, symbols and funerary monuments: elements of cultural memory among the Neolithic and Copper Age societies of Southern Spain. In: Lillios, K., Tsamis, V. (Eds.)., Material Mnemonics: Everyday Memory in Prehistoric Europe.Oxford, Oxbow, pp. 10-39.

GarcíaSanjuán, L., Wheatley, D.W., Díaz-Guardamino Uribe, M., Mora Molina, C., Sánchez Liranzo, O., Strutt, K., 2015.Evidence of Neolithic activity at La Peña de los Enamorados (Antequera, Málaga): intensive surface survey, geophysics and geoarchaeology at the site of Piedras Blancas I. Menga. Revista de Prehistoria de Andalucía 6, 211-252.

García Sanjuán, L., Aranda Jiménez, G., Carrión Méndez, F., Mora Molina, C., Lozano Medina, Á., García González, D., 2016. El relleno del pozo de Menga: Estratigrafía y radiocarbono. Revista de Prehistoria de Andalucía 7, 199-223.

Gillespie, A.R., Kahle, A.B., Walker, R.E., 1986.Color enhancement of highly correlated images. I. Decorrelation and HSI contrast stretches. Remote Sensing of Environment 22, 343-365.

Gomes, H., Collado, H., Martins, A., Nash, G.H., Rosina, P., Vaccaro, C., Volpe, L., 2015. Pigment in western Iberian schematic rock art: an analytical approach. Mediterranean Archaeology and Archaeometry 15 (1), 163-175.

Gorbushina, A.A., 2007. Life on the rocks. Environmental Microbiology 9, 1613-1631.

GozalbesC ravioto, M., 1986. Las Vías Romanas de Málaga. Madrid, Colegio de Ingenieros de Caminos, Canales y Puertos.

Guarnido Olmedo, V., 1977. La Depresión de Antequera. Cuadernos Geográficos de la Universidad de Granada 7, 39-69.

Guijo Mauri, J.M., 2004. Paleoantropología. In: Martin Socas, D., Camalich Massieu, D., González Quintero, P. (Eds.). La Cueva de El Toro (Sierra de El Torcal, Antequera, Málaga). Un Modelo de Ocupación Ganadera en el Territorio Andaluz entre el VI y el II Milenios ANE. Sevilla, Junta de Andalucía, pp. 287-290.

Hermosin, B., Gaviño, M., Saiz-Jimenez, C., 2004.Organic compounds in black crusts from different European monuments: a comparative study. In: Saiz-Jimenez, C. (Ed.). Air Pollution and Cultural Heritage. Rotterdam, A.A. Balkema, pp: 47-55.

Hoffmann, D.L., Prytulak, J., Richards, D.A., Elliot, T., Coath, C.D., Smart, P.L., Scholz, D., 2007. Procedures for accurate U and Th isotope measurements by high precision MC-ICPMS. International Journal of Mass Spectrometry 264:97–109.

Hoffmann, D.L., Pike, A.W.G., García-Diez, M., Pettitt, P.B., Zilhão, J., 2016. Methods for U-series dating of $CaCO_3$ crusts associated with Palaeolithic cave art and application to Iberian sites. Quaternary Geochronology 36:104–119.

Horwitz, E.P., Dietz, M.L., Chiarizia, R., Diamond, H., 1992. Separation and preconcentration of uranium from acidic media by extraction chromatography. Analytica Chimica Acta 266:25–37.

Hoskin, M., 2001.Tombs, Temples and Their Orientation.A New Perspective on Mediterranean Prehistory. Oxford, Ocarina Books.

Jaffey, A.H., Flynn, K.F., Glendenin, L.E., Bentley, W.C., Essling, A.M., 1971. Precision measurement of half-lives and specific activities of U^{235} and U^{238}. Physical Review C 4, 1889-1906.

Jiménez Aguilera, F., 2006. Archidona. La leyenda de la Peña de los Enamorados. Rayya. Revista Cultural de la Comarca Norte de Málaga 2, 11-28.

Lozano Rodríguez, J.A., Ruiz-Puertas, G. Hódar-Correa, M., Pérez-Valera, F., Morgado Rodríguez, A., 2014. Prehistoric engineering and astronomy of the great Menga Dolmen (Málaga, Spain).A geometric and geoarchaeological analysis. Journal of Archaeological Science 41, 759-771.

Luis, L., 2009. Rock art as landart. A diachronic view of the Coa valley (NE Portugal). Post-Palaeolithic rock art. In De Balbín-Behrmann, R., Bueno-Ramírez, P., González-Antón, R., Del Arco Aguilar, C. (Eds.): Grabados Rupestres de la Fachada Atlántica Europea y Africana. BAR 2043. Oxford, Archaeopress, pp.129-147.

Martínez García, J., 2004. Pintura rupestre esquemática: una aproximación al modelo antiguo (neolitización) en el Sur de la Península Ibérica. In: II Simposio de Prehistoria Cueva de Nerja. Nerja, Fundación Cueva de Nerja, pp. 102-144.

Martínez García, J., 2013. Pintura rupestre esquemática en los Tajos de Lillo (Loja, Granada) y el modelo antiguo del Arte Esquemático. In: Martínez García, J., Hernández Pérez, M. S. (Eds.), Arte Rupestre Esquemático en la Península Ibérica. Actas del II Congreso (Comarca de los Vélez, Almería, 5-8 de Mayo de 2010), pp. 89-103.

Martínez-Sevilla, F., Morgado, A., Jiménez Cobos, F., Gutiérrez Rodríguez, M., López García, A., Lozano Rodríguez, J.A. Carrasco Rus, J., 2016. Knapping methods and techniques in the bracelets quarry of Cortijo Cevico (Loja, Granada). Journal of Lithic Studies 3 (2).

Mas Cornellà, M. (2005). La Cueva del Tajo de las Figuras. Madrid, UNED.

Márquez Romero, J.E., Fernández Ruiz, J., 2009. Dólmenes de Antequera. Guía Oficial del Conjunto Arqueológico. Sevilla, Junta de Andalucía.

Maura Mijares, R., 2003. Valoración del fenómeno esquemático en el arte prehistórico de Málaga. In: Actas del II Congreso de Paleontología Villa de Estepona. Paleoantropología y Prehistoria. Pliocénica 3, pp.131-138.

Maura Mijares, R., 2005. Las Manifestaciones Rupestres Prehistóricas en las Cuencas de los Ríos Turón y Guadalteba, Málaga. PhD Thesis, Madrid, UNED.

Maura Mijares, R., 2011. Arte Prehistórico en las Tierras de Antequera. Sevilla, Junta de Andalucía.

Maura Mijares, R., Recio Ruiz, A., Cantalejo Duarte, P., Aranda Cruces, P., Pérez González, J., 2007. Pinturas y grabados rupestres prehistóricos en el abrigo de la Hoya de Archidona, Málaga. Rayya. Revista cultural de la comarca norte de Málaga 3, 11-23.

Meyer, C., Gaspar, D., 2017. Geoposicionamiento, fotogrametría y prospecciones con georradar en el Parque del Olivar del Zaudín, Tomares (Sevilla). In: Vázquez Paz, J., Garrido González, P. (Eds.), El Tesoro de Zaudín: Contextualización Arqueológica del Conjunto Numismático Tardoantiguo de Tomares (Sevilla). Sevilla, Junta de Andalucía, pp. 189-200.

Moldoveanu, S.C., 2010. Pyrolysis of organic molecules with applications to health and environmental issues.Techniques and Instrumentation in Analytical Chemistry 28, 1-724.

Montana, G., Randazzo, L., Oddo, I.A., Valenza, M., 2008.The growth of ‘‘black crusts’’ on calcareous building stones in Palermo (Sicily): a first appraisal of anthropogenic and natural sulphur sources. Environmental Geology 56, 367–380.

Moreno Aragüez, A., Ramos Muñoz, J., 1983. La Peña de los Enamorados. Un yacimiento de la Edad del Bronce en la Depresión de Antequera. Mainake 4-5, 53-74.

Morgado Rodríguez, A., Lozano Rodríguez, J.A., Pelegrin, J., 2011. Las explotaciones Prehistóricas del sílex de la Formación Milanos (Granada, España). Menga. Revista de Prehistória de Andalucía 2, 135-155.

Morgado Rodríguez, A., Lozano Rodríguez, J.A., 2011. La explotación prehistórica de afloramientos de rocas ofíticas del sector oriental del Trías de Antequera (España): un patrimonio natural y cultural a valorar y proteger. In: Peinado, A. (Ed.), Actas del I Congreso Internacional El Patrimonio Cultural y Natural como Motor de Desarrollo: Investigación e Innovación. Universidad Internacional de Andalucía, Jaén, pp. 1503-1517.

Muñoz Vivas, V.E., 1991. Las manifestaciones pictóricas del abrigo Cortijo la Escardadera. Zephyrus 44, 497-510.

Ordóñez, S., Fort, R., GarcíadelCura, M.A., 1997.Pore size distribution and the durability of a porous limestone. Quarterly Journal of Engineering Geology 30, 221-230.

Papida S., Murphy W., May E., 2000. Enhancement of physical weathering of building stones by microbial populations. International Biodeterioration & Biodegradation 46, 305-317.

Pereira de Oliveira, B., De la Rosa, J.M., Miller, A.Z., Saiz-Jimenez C., Gómez-Bolea, A., Sequeira Braga, M.A., Dionísio, A. 2011.An integrated approach to assess the origins of black films on a granite monument. Environmental Earth Sciences 63, 1677-1690.

Pike, A.W.G., Hoffmann, D.L., García-Diez, M., Pettitt, P.B., Alcolea, J., De Balbín, R., Gonzalez Sainz, C., De Las Heras, C., Lasheras, J.A., Montes, R., Zilhão, J. 2012. U-Seriesdating of Paleolithic art in 11 caves in Spain. Science 336, 1409–1413.

Portillo, M.C., Rogerio-Candelera, M.A., González, J.M., Saiz-Jiménez, C., 2008. Estudios preliminares de la diversidad microbiana y análisis de imagen de las manifestaciones parietales de los abrigos de Fuente del Trucho y de Muriecho L (Colungo, Huesca). In:Rovira Llorens, S., García-Heras, M.,Gener, M., Montero-Ruiz, I. (Eds.), Actas del VII Congreso Ibérico de Arqueometría. Madrid, pp. 97-107.

Prudêncio, M.I., Dias, M.I., Gouveia, M.A., Marques, R., Franco, D., Trindade, M.J., 2009.Geochemical signatures of Roman amphorae produced in the Sado River estuary, Lusitania (Western Portugal). Journal of Archaeological Science 36, 873-883.

Rivas, T., Pozo, S., Paz, M., 2014.Sulphur and oxygen isotope analysis to identify sources of sulphur in gypsum-rich black crusts developed on granites. Science of the Total Environment 482-483, 137-147.

Robert, M., Berthelin, J., 1986.Role of biological and biochemical factors in soil mineral weathering. In: Huang, P.M., Schnitzer, M. (Eds.), Interactions of Soil Minerals with Natural Organics and Microbes. Soil Science Society of America (Special Publ. 17), Madison (Wi), pp. 452-495.

Rodríguez Vinceiro, F.J., Fernández Rodríguez, L.E., Clavero Toledo, J.L., Romero Silva, C., Von Thode Mayoral, C., García Pérez, A., Suárez Padilla, J., Barrera, M., Palomo Laburu, A., 1992.Estado actual de la investigación arqueometalúrgica prehistórica en la provincia de Málaga. Trabajos de Prehistoria 49, 217-242.

Rogerio-Candelera, M.A., 2014. Propuesta metodológica para establecer la secuencia estratigráfica de un panel rupestre: La Coquinera II (Obón, Teruel, España). In: Medina-Alcaide, M.A., Romero Alonso, A.J., Ruiz-Márquez, R.M., SanchidriánTorti, J.L. (Eds.) Sobre Rocas y Huesos: Las Sociedades Prehistóricas y sus Manifestaciones Plásticas. Córdoba, Universidad de Córdoba, pp. 330-343.

Rogerio-Candelera, M.A., 2015. Digital image analysis based study, recording, and protection of painted rock art. Some Iberian experiences. Digital Applications in Archaeology and Cultural Heritage 2, 68-78.

Rogerio-Candelera, M.A., Élez Villar, J. 2010. Elaboración de un nuevo calco del cáprido de la Sala de La Hoya (cueva de Altamira) mediante técnicas de análisis de imagen. In: Saiz, M.E., López, R., Cano, M.A., Calvo, J.C. (Eds.),Actas del VIII Congreso Ibérico de Arqueometría. Teruel, SAET, pp. 409-418.

Rogerio-Candelera, M.A., Linares Catela, J.A., 2015. El análisis digital de imágenes como herramienta arqueológica. Estudio de los restos de pintura de los ortostatos del dolmen 3 de El Pozuelo. In: Moreno Oliva, M., Rogerio-Candelera, M.A., López Navarrete, J.T., Hernández Jolín, V. (Eds.), Estudio y Conservación del Patrimonio Cultural. Málaga, TechnoHeritage/Universidad de Málaga, pp. 82-85.

Rogerio-Candelera, M.A., Figueiredo, S.S., Guimarães, P., Baptista, A.M., 2010. Análisis de imagen de pinturas rupestres del yacimiento de Faia (Parque Arqueológico de Vila Nova de FozCôa, Guarda, Portugal). In: Saiz, M.E., López, R., Cano, M.A., Calvo, J.C. (Eds.), Actas del VIII Congreso Ibérico de Arqueometría. Teruel, SAET, pp. 419-427.

Rogerio-Candelera, M.A., Jurado, V., Laiz, L., Saiz-Jiménez, C., 2011. Laboratory and in situ assays of digital image analysis based protocols for biodeteriorated rock and mural paintings recording. Journal of Archaeological Science38, 2571-2578.

Rogerio-Candelera, M.A., Figueiredo, S.S., Borges, A.F., 2013.Cachão da Rapa prehistoric rock art paintings revisited: digital image analysis approach for the assessment of Santos Júnior's tracings. In: Rogerio-Candelera, M.A., Lazzari, M., Cano, E. (Eds.), Science and Technology for the Conservation of Cultural Heritage. London, CRC Press, pp. 261-264.

Royo Guillén, J.I., 2015. Arte rupestre protohistórico en la cuenca media del Ebro: un símbolo gráfico de las élites emergentes de la Edad del Hierro. Cuadernos de Prehistoria y Arqueología de Castellón 33, 97-128.

Ruiz, J.F., Hernanz, A., Armitage, R.A., Rowe, M.W., Viñas, R., Gavira-Vallejo, J.M., Rubio, A., 2012.Calcium oxalate AMS 14C dating and chronology of post-Palaeolithic rock paintings in the Iberian Peninsula. Two dates from Abrigo de los Oculados (Henarejos, Cuenca, Spain). Journal of Archaeological Science 39, 2655-2667.

Saiz-Jimenez, C., Grimalt, J., Garcia-Rowe, J., Ortega-Calvo, J.J., 1991. Analytical pyrolysis of lichen thalli. Symbiosis 11, 313-326.

Saiz-Jimenez, C., Garcia-Rowe, J., Garcia del Cura, M.A., Roekens, E., van Grieken, R., 1990. Endolithic cyanobacteria in Maastricht limestone. Science of the Total Environment 94, 209-220.

Saiz-Jimenez, C., Ortega-Calvo, J.J., de Leeuw, J.W., 1995. The chemical structure of fungal melanins and their possible contribution to black stains in stone monuments. Science of the Total Environment 167, 305-314.

Sanz de Galdeano, C., Lozano Rodríguez, J.A., Puga Rodríguez, E., 2008. El "Trías de Antequera". Naturaleza, origen y estructura. Revista de la Sociedad Geológica de España 21, 3-4.

Sanches, M.J., 2003.Sobre a ocupaçâo do Neolítico Inicial no Norte de Portugal. In: Gonçalves, V.S.(Ed.), Muita Gente, Poucas Antas? Origens, Espaços e Contextos do Megalitismo. Trabalhos de Arqueología 25, 155-179.

Sanches, M.J., 2016. The paintings of “oculadas”figures in the Neolithic and Chalcolithic of Northern Portugal: the study case of Serra de Passos. In: FábregasValcarce, R., Rodríguez Rellán, C., (Eds.), Public Images, Private Readings: Multi-Perspective Approaches to the Post-Palaeolithic Rock Art. Proceedings of the XVII UISPP World Congress (1–7 September 2014, Burgos, Spain) Volume 5 / Session A11e.Oxford, Archaeopress, pp. 50-62.

Sanchidrian Torti, J.L., Márquez, A.M., Valladas, H., Tisnerat, H. 2001. Dates directes pour l’Art Rupestre d’Andalousie (Espagne). International Newsletter on Rock Art 29, 15-19.

Sanjurjo Sánchez, J., Trindade, M., Blanco-Rotea, R., Benavides Garcia, R., Fernández-Mosquera, D., Burbidge, C., Prudêncio, M.I., Dias, M.I., 2010. Chemical and mineralogical characterization of historic mortarsfrom the Santa Eulalia de Bóveda temple, NW Spain. Journal of Archaeological Science 37(9), 2346-2351.

Schiavon, N., Chiavari, G., Schiavon, G., Fabbri, D. 1995. Nature and decay effects of urban soiling on granitic building stones. Science of the Total Environment 167, 87-101.

Sebastián López, M., Palomo Arroyo, M., Rincón Ramírez, J.A., Ormeño Villajos, S., Vicent García, J.M., 2013. Métodos de documentación, análisis y conservación no invasivos para el arte rupestre postpaleolítico: radiometría de campo e imágenes multiespectrales. Ensayos en la cueva del Tío Garroso (Alacón, Teruel). In: La Ciencia y el Arte IV. Ciencias Experimentales y Conservación del Patrimonio. Madrid, Ministerio de Educación Cultura y Deporte, pp. 279-287.

Standley, L.J., Simoneit, B.R.T., 1987. Characterization of extractable plant wax, resin, and thermally matured components in smoke particles from prescribed burns. EnvironmentalScience&Technology 21, 163-169.

Suárez Padilla, J., Fernández Rodríguez, L.E., Rodríguez Vinceiro, F.J., Von Thode Mayoral, C., García Pérez, A., Barrera Polo,M., Palomo Laburu,A., 1995. La Peña de los Enamorados de Antequera (Ladera Oeste). Un importante enclave en la Ruta del Genil hacia la Andalucía Oriental. In:Actas del XXI Congreso Nacional de Arqueología (I). Zaragoza, pp. 73-84.

Trindade, M.J., Rocha, F., Dias, M.I., Prudêncio, M.I., 2013.Mineralogy and grain-size distribution of clay-rich rock units of the Algarve Basin (South Portugal). Clay Minerals 48 (1), 59–83.

Trindade, M.J., Dias, M.I., Rocha, F., Prudêncio, M.I., Coroado, J., 2011.Bromine volatilization during firing of calcareous and non-calcareous clays: Archaeometric implications. Applied Clay Science 53, 489-499.

Trindade, M.J., Dias, M.I., Coroado, J., Rocha, F., 2010.Firing tests on clay-rich raw materials from the Algarve Basin (South Portugal): Study of the mineral transformations with temperature. Clays and Clay Minerals 58, 188-204.

Trindade, M.I., Dias, M.I., Coroado, J., Rocha, F., 2009.Mineralogical transformation of calcareous rich clays with firing: A comparative study between calcite and dolomite rich clays from Algarve, Portugal. Applied Clay Science 42, 345-355.

Vicent García, J.M., 2008. Simbolismo, arte y mundo funerario. In: Hernández Pérez, M.S., Soler Díaz, J.A., López Padilla, J.A. (Eds.). Actas del IV Congreso del Neolítico Peninsular. Tomo II. Alicante, Museo Arqueológico de Alicante, pp. 11-12.

Wedepohl, K.H., 1995. The composition of the continental crust. Geochimica et Cosmochimica Acta 59, 1217–1232.

Captions

Tables

Table 1.Correlation coefficients among the bands of image 5260 of Matacabras rock shelter.

Table 2. Average colorimetric values of the rock support and paint (n=3).

Table 3. U and Th concentrations, isotopic activity ratios and U-Th ages for sample MC2.

Table 4. Compounds identified by Py-GC/MS.

Table 5. Mineralogical composition obtained by XRD on the non-oriented aggregates of the bulk sample of the ceramic paste collected at Matacabras and Piedras Blancas I sites (Spain). Semi-quantification (%) was done by using the diagnostic reflection areas, considering the full width at half maximum (FWHM) of the main minerals (Sanjurjo Sánchez et al. 2010; Trindade et al. 2013) and then weighted by empirical factors or calculated parameters (Biscaye 1965).

Table 6. Concentration of chemical elements obtained by INAA for ceramics of Matacabras and Piedras Blancas I sites (Spain). Major elements (Na_2O, K_2O, Fe_2O_3T) in % and trace elements in µg/g (ppm).

Figures

Figure 1: Location of Matacabras rock art shelter in Iberia (left) and Lands of Antequera with regards to the Neolithic sites known in the region (right). Design: María del Carmen Moreno Escobar.

Figure 2A: A) Geological map of the Antequera region showing the location of various abiotic products used in the Late Prehistory as well as archaeological; Gal: Los Gallumbares (Loja, Granada); Rel: Cerro del Reloj (Montefrío, Granada); CV: Cortijo Cevico (Loja, Granada). 2B) Geological map of La Peña de los Enamorados, where the Matacabras rock art shelter is located. Legend: 1) Triassic (Subbetic (SB); gypsum, clays and dolomites); 2) Late Jurassic (SB; micrite limestones with oncoliths and pellets); 3) Middle Jurassic (SB; oolithic limestones); 4) Upper Jurassic (SB; red limestones with nodules); 5) Cretacic – Paleogene (SB; marls and pink limestone marls); 6) Eocene (Flysch; calcarenites with nummulites); 7) Paleogene (Flysch; brown clays with banks of sandstones with quartzs); 8) Pliocene (Breccia cemented with carbonated pebbles); 9) Quaternary (piedmont, hillside deposits); 10) Quaternary (fluvial and flood plain deposits); a) Minor fault; b) Major fault between domains; c) Concordant normal contact; d) Discordant contact. Design: José Antonio Lozano Rodríguez.

Figure 3: A) The markedly anthropomorphic silhouette of La Peña de los Enamorados, as seen from the East. B) Graphic re-creation of the La Peña de los Enamorados legend published in Basel in 1610 as part of the German edition of the 'Cosmographia Universalis' (first edition 1507). Source: Archive Conjunto Arqueológico Dólmenes de Antequera (CADA).

Figure 4: 3D Views and elevation of the painted area of Matacabras shelter.Design: Diego Gaspar.

Figure 5: Ortophotographic plan of Matacabras shelter. Design: Diego Gaspar.

Figure 6: A) Standard RGB frame of a part of the panel. B) Band corresponding to the third PC. C) ECS stretching in HSI colour space. D) False colour pondering third PC. Design: Miguel Ángel Rogerio-Candelera.

Figure 7: Sampling points for colour measurement over a false colour image obtained by PCA. Design: Miguel Ángel Rogerio-Candelera.

Figure 8: Sampling points for FESEM and Py-GC/MS. Design: Miguel Ángel Rogerio-Candelera.

Figure 9: General tracing of the painted panel of Matacabras shelter superimposed to the 3D model of the shelter. Design: Miguel Ángel Rogerio-Candelera and Diego Gaspar.

Figure 10: MC2 before (a) and after (b) sampling. Dashed black line represents approximate extent of removed calcite. Design: Alistair Pike and Christopher D. Standish.

Figure 11: FESEM-EDS examinations of the black patina collected from the vertical surface of Matacabras Shelter (samples MT1 and MT2). A) General view of sample MT1 showing a discontinuous layer of gypsum crystals. B) Detailed view of gypsum crystals on MT1 sample. C) EDS spectrum recorded in position 1. D) EDS spectrum recorded in

position 2. E) General view of sample MT2 depicting algal cells and extracellular polymeric substances (arrows). F) Diatom cell in sample MT2. Design: Ana Z. Miller.

Figure 12: Pyrochromatogram obtained at 500ºC of MT2 sample. Design: José M. De la Rosa Arranz.

Figure 13: Mineralogical composition obtained by XRD for ceramic samples from Matacabras (CerMC3) and Piedras Blancas I (CerPBI2-1) enhancing the diagnose peaks: PH - Phillosilicates; A – Anatase; Q – Quartz; F – Alkalifeldspars; P – Plagioclase; C – Calcite; H – Hematite. Design: María Isabel Dias and María Isabel Prudêncio.

Figure 14: (A): Tree diagram for Matacabras (MC) and Piedras Blancas I (PBI) ceramics by using the UPGMA (Unweighted pair-group average) as amalgamation (linkage) rule and the Euclidean distances. Sample CerPBI 1-1 is detachable from all the others. Some MC and PBI samples have similar chemical composition. (B): Bivariate plot of the sum of Rare Earth Elements and the sum of the first raw transition chemical elements. Design: María Isabel Dias and María Isabel Prudêncio.

Figure 15: Projection of the symmetry axis of Menga Dolmen, intersecting almost exactly with the basement of the rocky wall of the North sector of La Peña de losEnamorados, where Matacabras shelter is placed. Design: David W. Wheatley.

Figure 16: Location of Palaeolithic and Post-Palaeolithic rock art sites (shelters and caves) at Lands of Antequera. Source: De Balbín-Behrmann et al 2007.

Figure 17: Serpentiphorms located at various sites: A) La Pileta cave (Photo: Pedro Cantalejo Duarte); B) Ardales cave (Photo: Pedro Cantalejo Duarte); C) Laja Alta cave (Photo: Javier Pérez González); D) Matacabras (Photo: Rodrigo de Balbín-Behrmann); E) Detail of pectiniform at Shelter nº 10 of Las Peñas de Cabrera (Photo: Rodrigo de Balbín-Behrmann).

Table 1

Table 1. Correlation coefficients among the bands of image 5260 of Matacabras rock shelter.

	PC1	PC2	PC3
PC1	1	0.99089017	0.96449487
PC2	0.99089017	1	0.98718422
PC3	0.96449487	0.98718422	1

Table 2

Table 2 – Average colorimetric values of the rock support (*n=3*) and paint (*n=3*).

	L*	a*	b*
Stone 1	48.6 ± 10.7 (a)	5.0± 1.2(a)	14.3± 2.1 (a)(b)
Stone 2	58.5 ± 18.3 (a)	4.4 ± 1.3 (a)	14.8 ± 2.8 (a)(b)
Serpentiform 1	50.7 ± 5.5 (a)	16.1± 2.2(b)	11.7 ± 0.6 (a)
Anthropomorph A	57.6 ± 2.3 (a)	10.9± 5.0 (b)	12.9 ± 2.4(a)(b)
Pectiniform	50.4± 6.5 (a)	8.4± 0.9 (c)	11.0± 2.6 (a)
Great pectiniform	59.4± 4.6 (a)	5.9± 2.1 (a)(c)	11.1± 1.3 (a)

Mean values are presented together with the standard deviation (SD) and ANOVA results. Values within each column, followed by the same letters in brackets (a,b, and c) are not significantly different by the Tukey HDS test at $p < 0.05$.

Table 3

Table 3. U and Th concentrations, isotopic activity ratios and U-Th ages for sample MC2.

Lab ID	Sample ID	^{238}U (ng/g)	±	^{232}Th (ng/g)	±	($^{230}Th/^{232}Th$)	±	($^{230}Th/^{238}U$)	±	($^{234}U/^{238}U$)	±	Uncorrected Age (ka)	Corrected Age (ka)	Age Error		($^{234}U/^{238}U)_{initial}$	±	Minimum Age (ka)
														+	-			
UoS-UTh-A156	MC2a	1088.8	68.1	749.7	46.4	0.9834	0.0105	0.2216	0.0024	1.0379	0.0021	26.14	5.38	12.57	5.06	1.0470	0.0073	0.32
UoS-UTh-A157	MC2b	1020.7	59.3	627.3	36.8	1.0493	0.0107	0.2110	0.0028	1.0424	0.0020	24.63	6.38	11.04	5.90	1.0514	0.0067	0.48
UoS-UTh-A158	MC2c	1266.8	73.4	818.1	48.7	1.3602	0.0129	0.2874	0.0032	1.0431	0.0021	35.07	15.85	11.11	10.03	1.0543	0.0074	5.82

Analytical errors are 2σ of the mean. ($^{230}Th/^{238}U$) = $1-e^{-\lambda_{230}T} + (\delta^{234}U_{measured}/1000)[\lambda_{230}/(\lambda_{230} - \lambda_{234})](1-e^{-(\lambda_{230} - \lambda_{234})T})$, where T is the age. Decay constants are 9.1705×10^{-6} a^{-1} for ^{230}Th, 2.8221×10^{-6} a^{-1} for ^{234}U (Cheng et al., 2013), and 1.55125×10^{-10} a^{-1} for ^{238}U (Jaffey et al., 1971).

Table 4

Table 4. Compounds identified by Py-GC/MS

Peak	Retention time (min)	Compound	%
1	2 071	Acetic acid	1.60
2	2 254	Furan, 2,5-dimethyl-	0.91
3	2 477	Pyridine	1.06
4	2 552	Toluene	4.02
5	2 752	Furfural	1.98
5	2 900	Furfural	5.19
6	3 152	Pyridine, 3-methyl-	3.30
7	3 340	Styrene	1.92
8	3 477	Furan, 2,3, 5-trimethyl-	1.93
9	3 552	2H-Pyran, 3,4-dihydro-	1.39
10	3 735	2(5H)-Furanone, 5-methyl-	1.09
11	3 849	2-Pentanone, 3-methyl-	1.64
12	3 917	2-Furancarboxaldehyde, 5-methyl-	3.43
13	4 095	1-Decene	0.84
14	4 163	Phenol	2.26
15	4 318	Pyridine, 3-methoxy	2.85
16	4 535	Uracil	1.64
17	4 620	2-Cyclopenten-1-one, 2-hydroxy-3-methyl-	1.61
18	4 729	Thiophene, 2-methoxy-5-methyl	2.59
19	5 083	p -Cresol	3.89
20	5 186	2,4,5-Trihydroxypyrimidine	2.21
21	5 552	Maltol	1.27
22	5 781	Benzyl nitrile	1.42
23	6 072	2-Heptenoic acid, methyl ester	1.90
24	6 118	Phenol, 3-ethyl-	1.78
25	6 198	2-Acetamidothiazole	1.02
26	6 261	1-Dodecene	0.92
27	6 501	1,4:3,6-Dianhydro-.alpha.-d-glucopyranose	3.85
27	6 769	1,4:3,6-Dianhydro-.alpha.-d-glucopyranose	0.84
28	6 815	Benzofuran, 2,3-dihydro-	4.45
29	7 009	Benzenepropanenitrile	1.26
30	7 370	Picolinamide	1.13
31	7 478	6-Tridecene	0.78
32	7 735	1H-Indole	1.31
33	8 038	2-Furanmethanol, .alpha.-(2-nitropropyl)-	1.08
34	8 250	Nonane, 2-methyl-3-methylene	0.75
35	8 713	2-Tetradecene, (E)-	0.88
36	8 873	7-Methylindole	1.33
37	9 073	Naphthalene, 2,6-dimethyl-	2.67
38	9 301	Nonanoic acid, methyl ester	1.22
39	9 793	Pyridine, 3-phenyl-	1.79
40	9 924	1-Pentadecene	0.86
41	10 141	1H-Indole, 1,3-dimethyl-	1.97
42	10 382	3-Pyridinecarbothioamide	2.37
43	10 936	Levoglucosan	2.20
44	11 153	Acetylcoumarin	2.58
45	12 233	1-Heptadecene	1.36
46	12 308	Heptadecane	1.72
47	12 650	n-alkyl-pentadecene	0.82
48	13 325	1-Octadecene	0.82
49	13 811	Neophytadiene	1.61
50	13 891	8-Methyloctahydrocoumarin	0.65
51	14 119	1,12-Tridecadiene	0.64
52	14 256	Nonadecane	0.77
53	14 410	Hexadecane, 2,6,10,14-tetramethyl,	0.49
54	15 039	Z-11-Tetradecenoic acid	0.68

55	15 954	unidentified branched n-alkene	0.24
56	16 280	1-Heneicosene	0.41
57	17 171	9-Octadecenamide (Oleic acid amide)	0.25
58	17 560	Diclorodibenzofuran	0.23
59	17 714	9,10-Anthracenedione, 1-amino-4hydroxy-	0.30

Table 5

Table 5. Mineralogical composition obtained by XRD on the non-oriented aggregates of the bulk sample of the ceramic paste collected at Matacabras and Piedras Blancas I sites (Spain). Semi-quantification (%) was done by using the diagnostic reflection areas, considering the full width at half maximum (FWHM) of the main minerals (Sanjurjo Sánchez et al. 2010; Trindade et al. 2013) and then weighted by empirical factors or calculated parameters (Biscaye 1965).

	Phyllosilicates	Quartz	Calcite	Alkali-Feldspars	Plagioclase	Anatase	Hematite	Amphibole
CerMC 2	51	25	9	5	5	5	-	-
CerMC 3	30	31	21	4	5	7	2	-
CerPBI 1-1	45	43	-	-	7	-	3	2
CerPBI 2-1	65	28	-	4	-	3	-	-
CerPBI 2-2	35	30	17	4	4	10	-	-
CerPBI 2-3	55	32	-	6	-	7	-	-
CerPBI 2-4	4	65	7	8	7	3	6	-

Table 6

Table 6. Concentration of chemical elements obtained by INAA for ceramics of Matacabras and Piedras Blancas I sites (Spain). Major elements (Na_2O, K_2O, Fe_2O_3T) in % and trace elements in µg/g (ppm).

	CerMC 2	CerMC 3	CerPBI 1-1	CerPBI 2-1	CerPBI 2-2	CerPBI 2-3	CerPBI 2-4
Na_2O	0.47	0.41	0.98	0.47	0.59	0.38	0.60
K_2O	2.41	2.21	1.64	1.98	2.46	2.10	2.32
Fe_2O_3T	7.42	5.35	8.30	7.18	5.07	7.77	5.18
Sc	18.8	13.3	20.5	17.2	12.6	18.3	12.3
Cr	137	77.5	99.9	113	91.7	120	78.8
Co	22.3	18.1	21.3	17.8	15.5	17.6	17.3
Zn	6.63	84.4	132	127	95.3	131	88.8
Ga	17.7	14.7	17.5	19.5	20.0	21.9	18.8
As	4.98	6.85	9.42	7.13	4.87	9.13	7.62
Br	3.19	1.58	3.80	1.39	1.27	2.27	1.20
Rb	66.9	75.6	49.0	61.3	87.5	82.1	95.0
Zr	154	208	190	271	211	224	216
Sb	0.53	0.59	0.65	0.66	0.49	0.50	0.86
Cs	4.58	4.50	2.30	4.63	5.49	5.88	5.67
Ba	559	408	1290	627	322	488	408
La	44.2	35.0	30.1	52.5	34.9	55.4	37.2
Ce	73.4	72.3	58.3	101.0	71.4	88.4	78.7
Nd	34.8	34.9	27.6	45.3	35.3	41.6	33.1
Sm	7.35	6.54	6.45	8.84	6.22	7.96	7.23
Eu	1.43	1.25	1.32	1.75	1.25	1.73	1.33
Tb	1.07	0.83	1.06	1.14	0.65	1.32	0.97
Yb	2.76	2.68	2.65	3.31	2.40	3.29	3.04
Lu	0.26	0.13	0.40	0.52	0.42	0.52	0.44
Hf	4.33	4.79	3.77	6.88	4.46	5.84	5.87
Ta	1.44	1.13	1.04	1.74	1.17	1.85	1.26
Th	11.9	9.95	13.2	13.4	9.79	14.6	11.2
U	1.37	1.63	1.82	2.65	4.74	2.32	2.26

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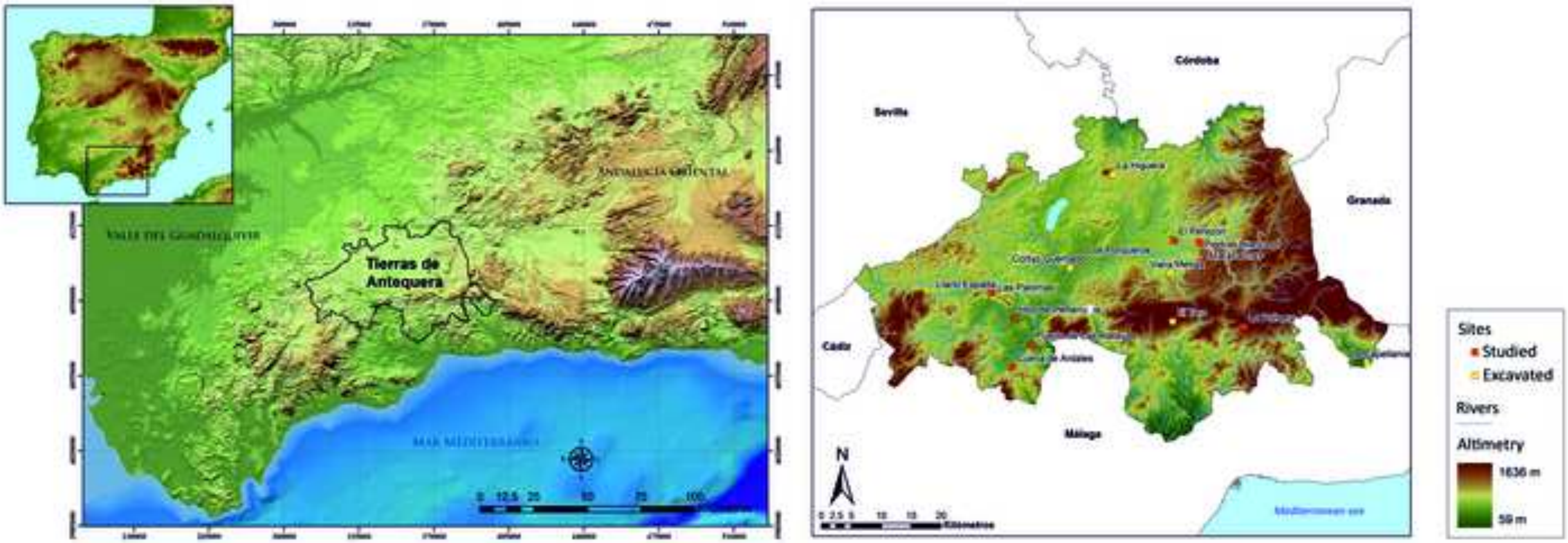

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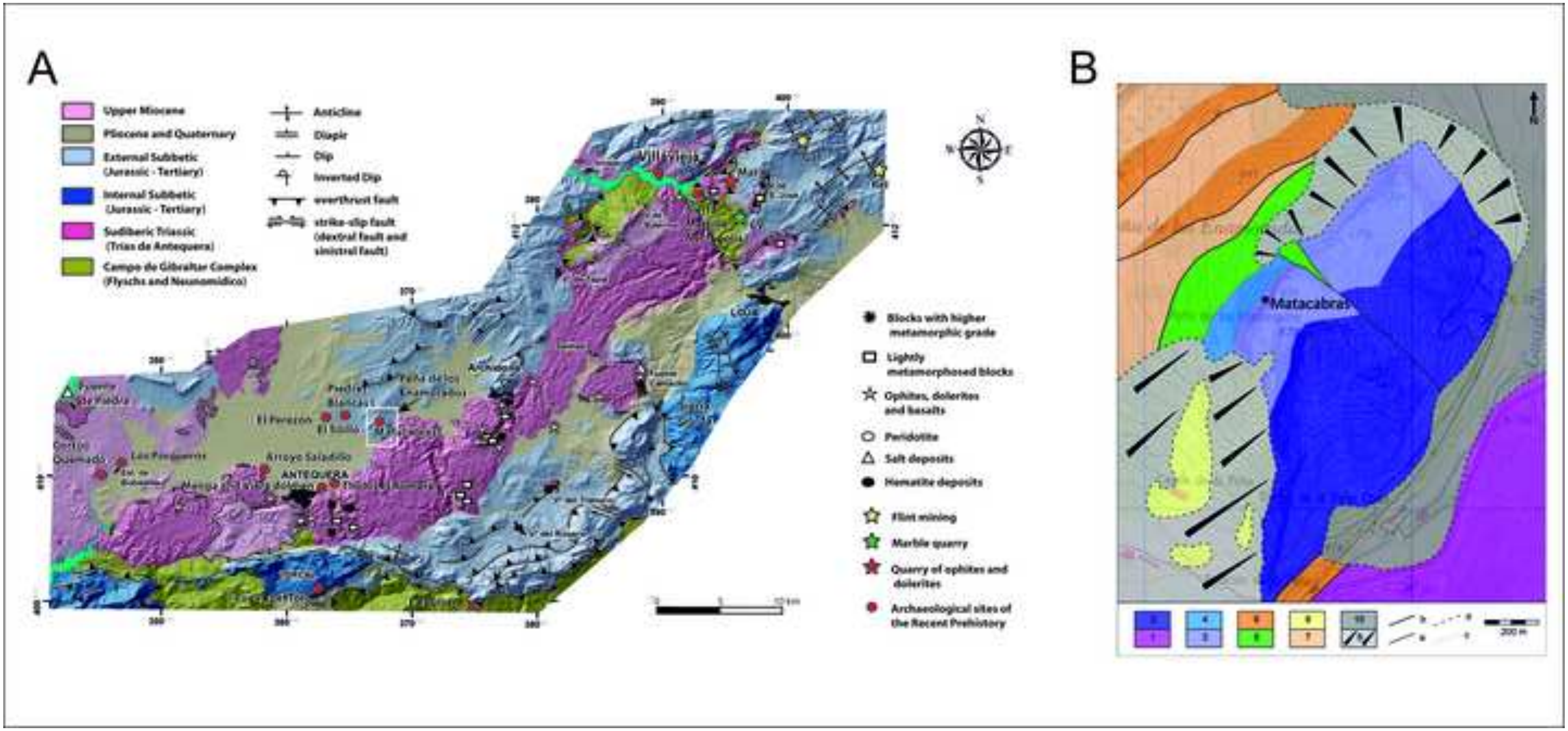

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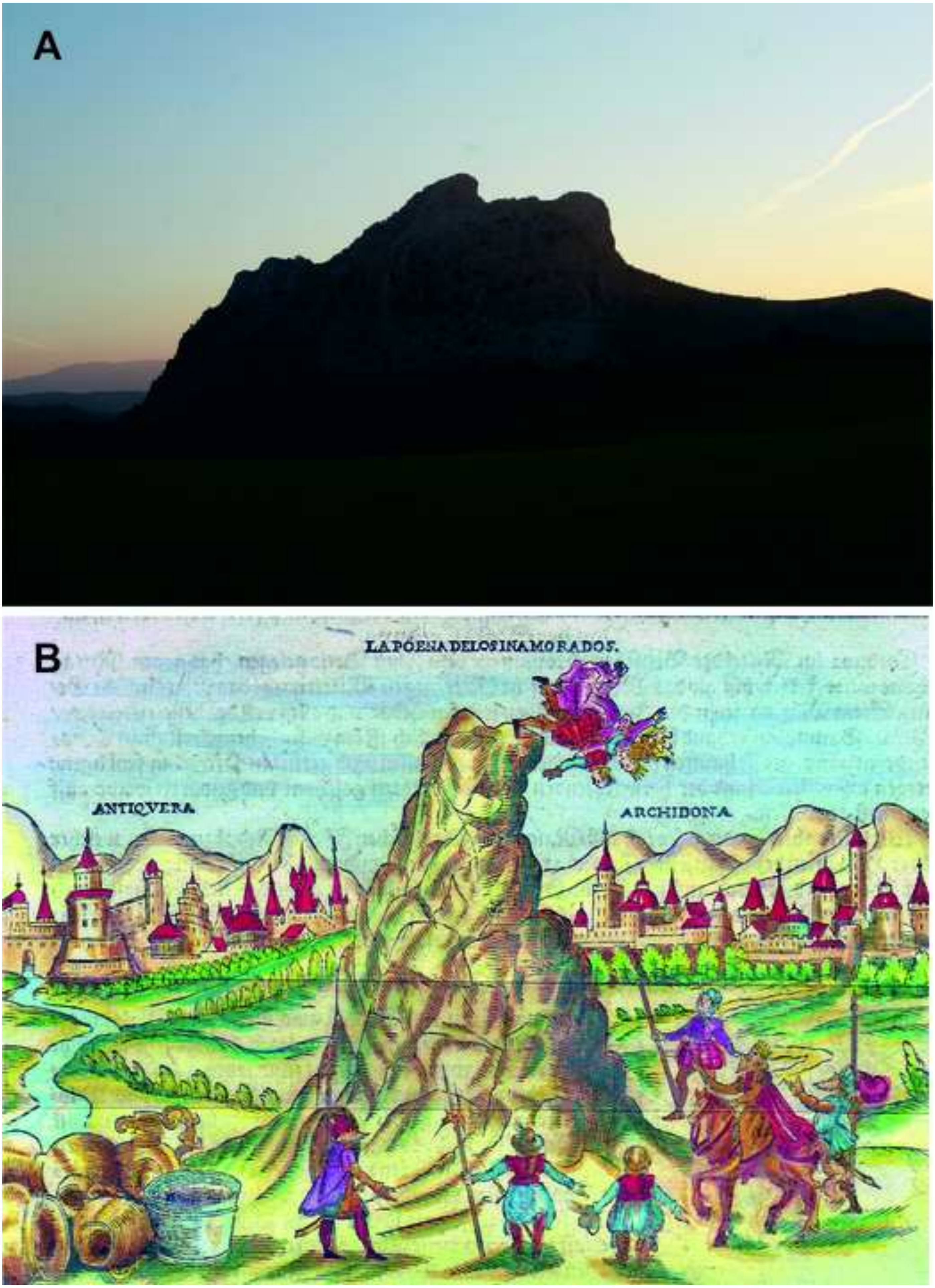

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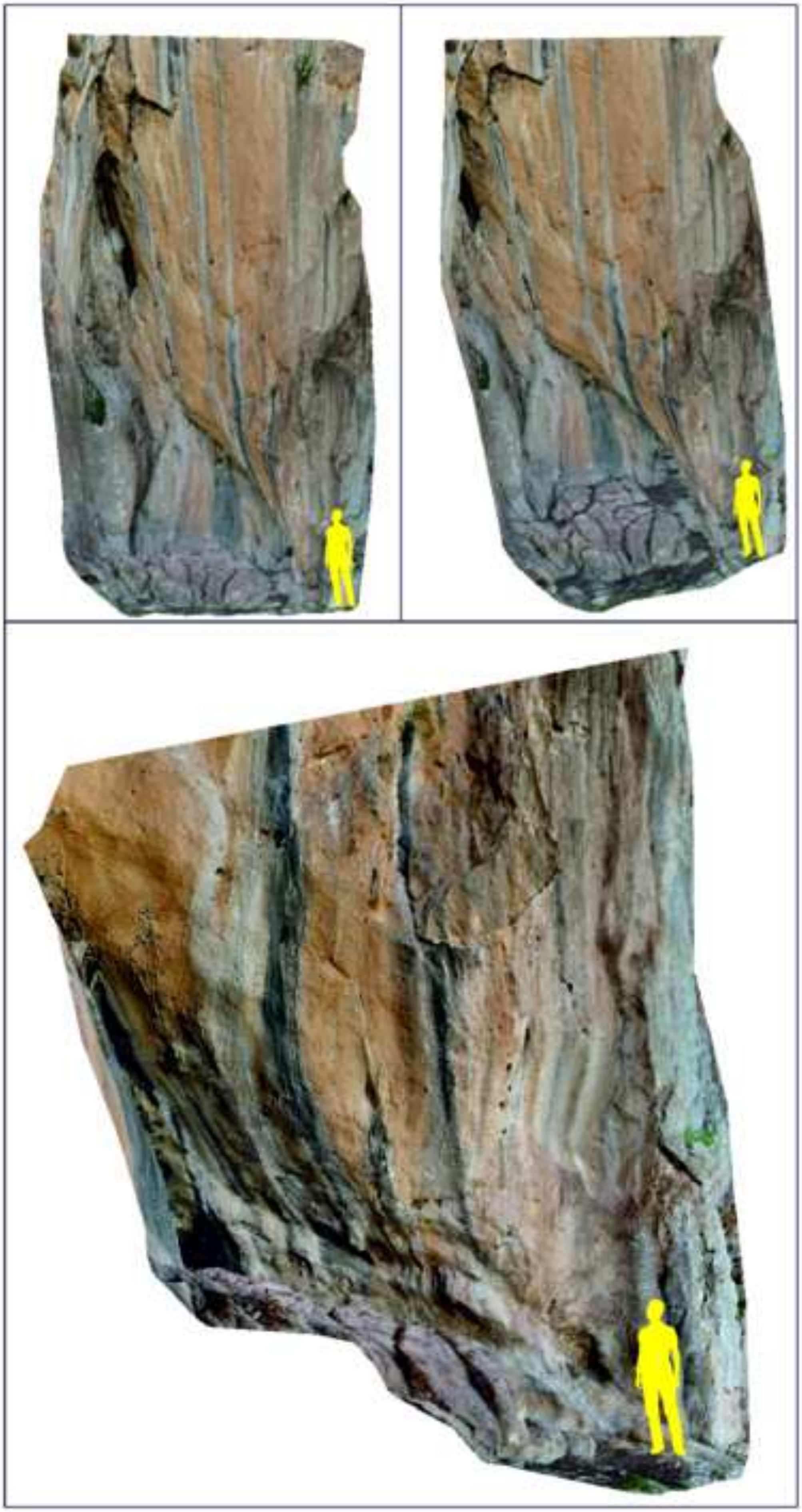

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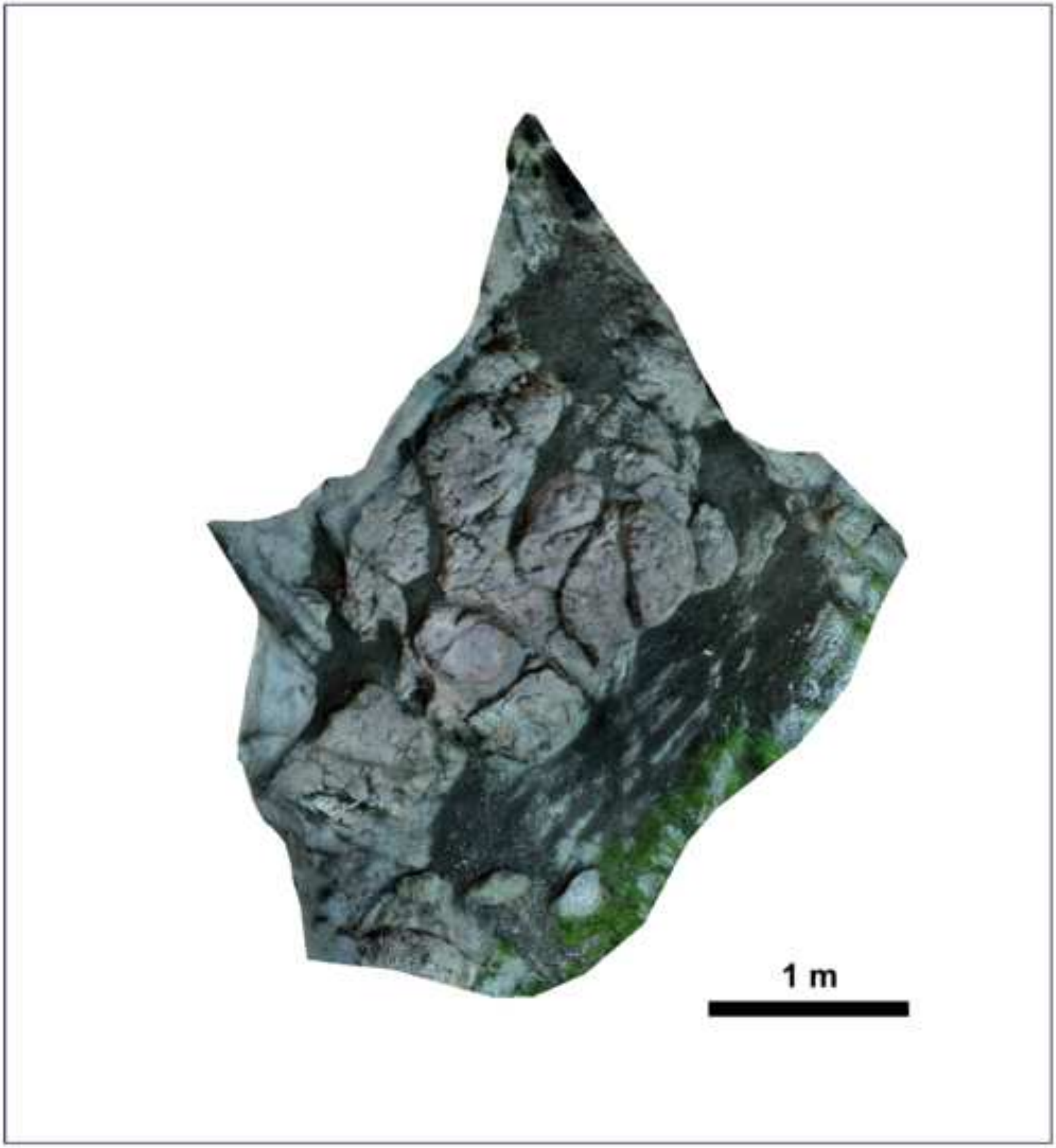

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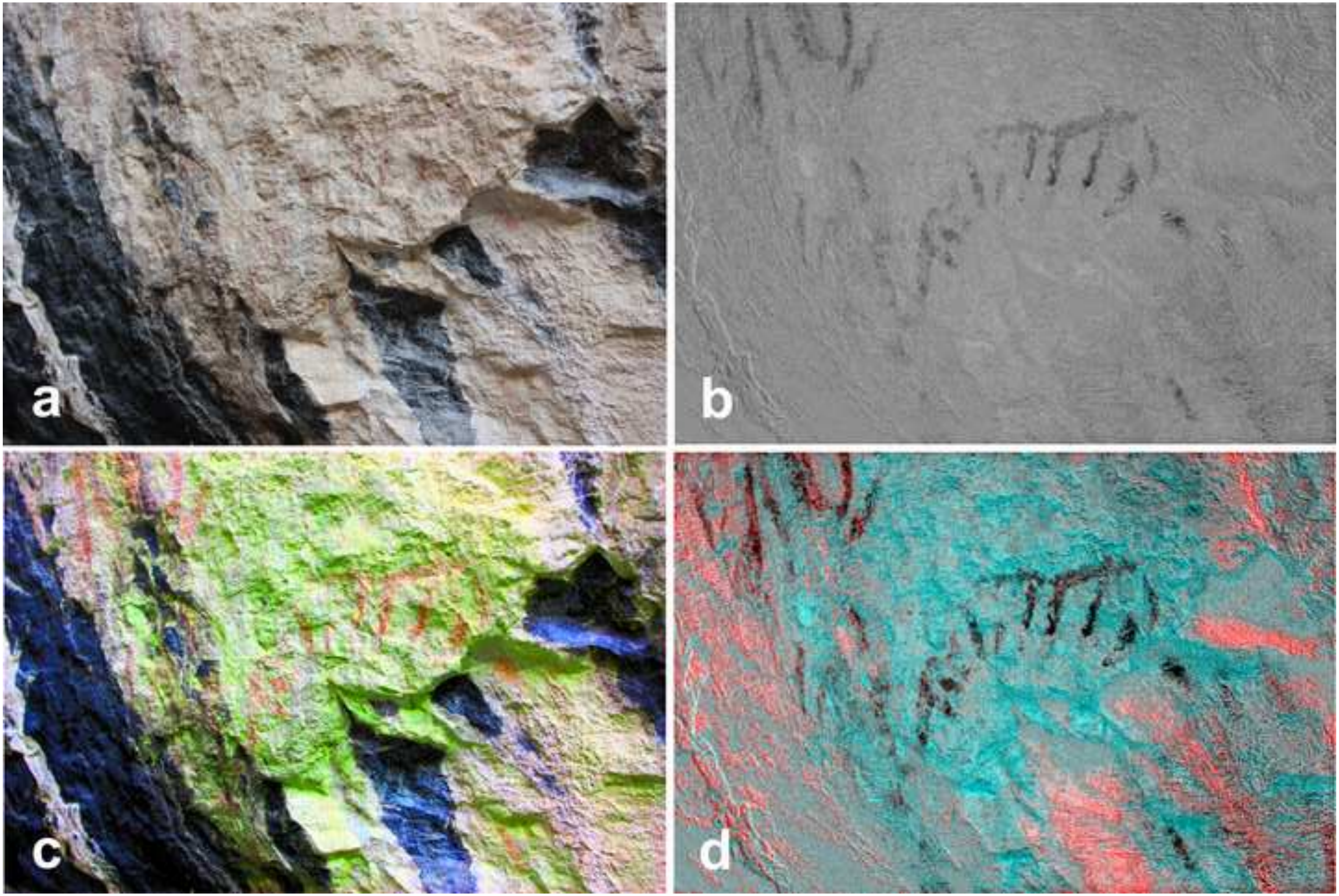

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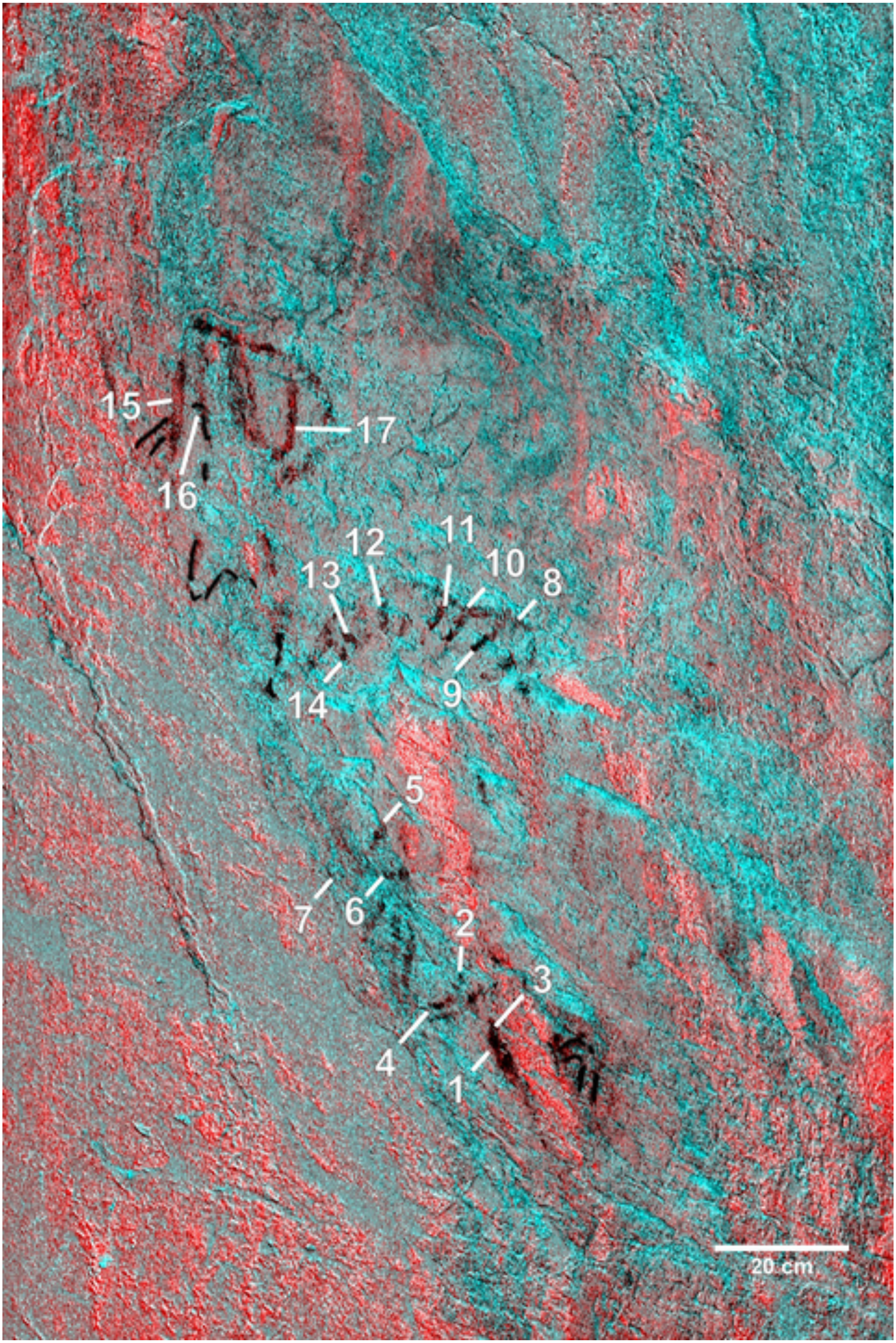

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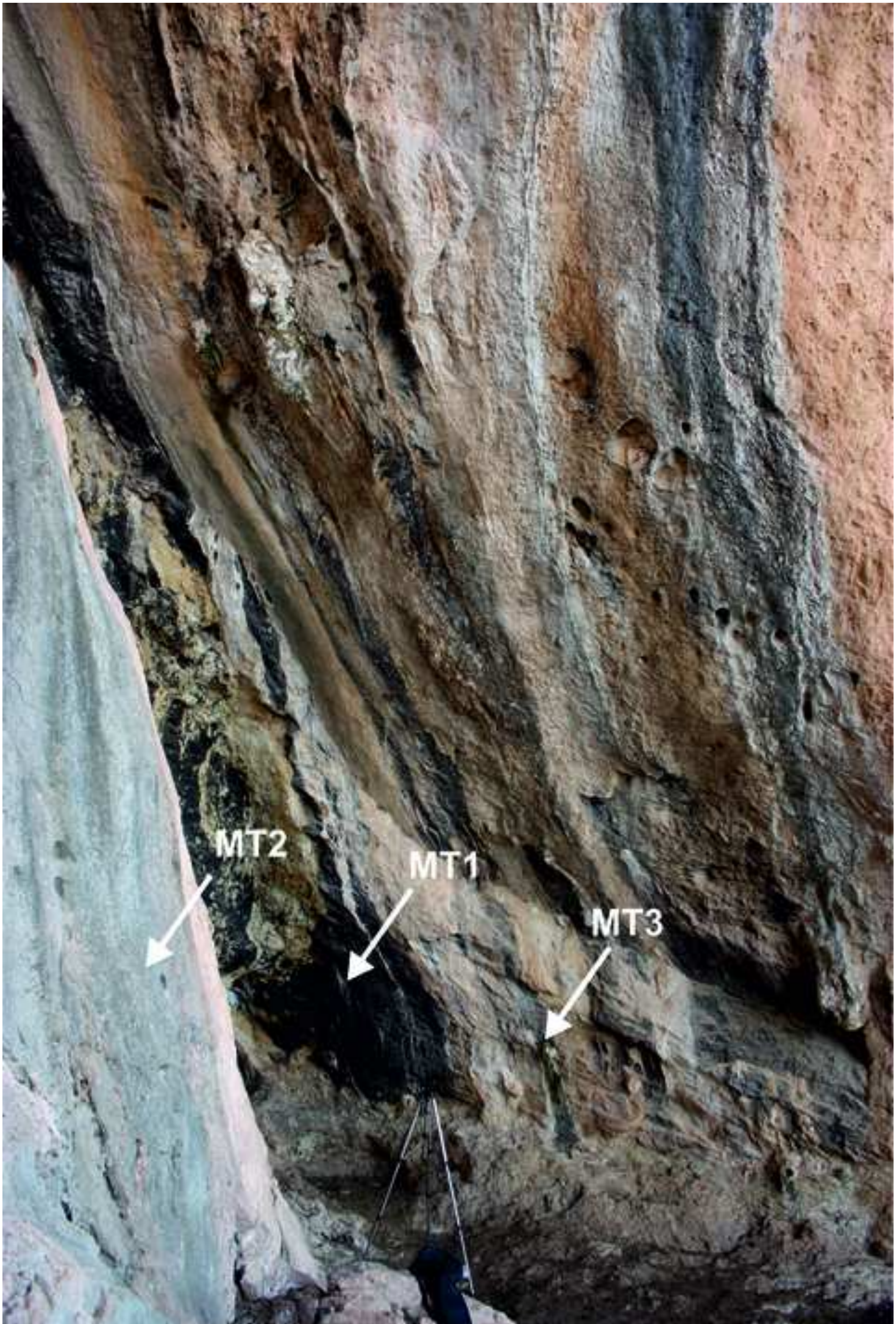

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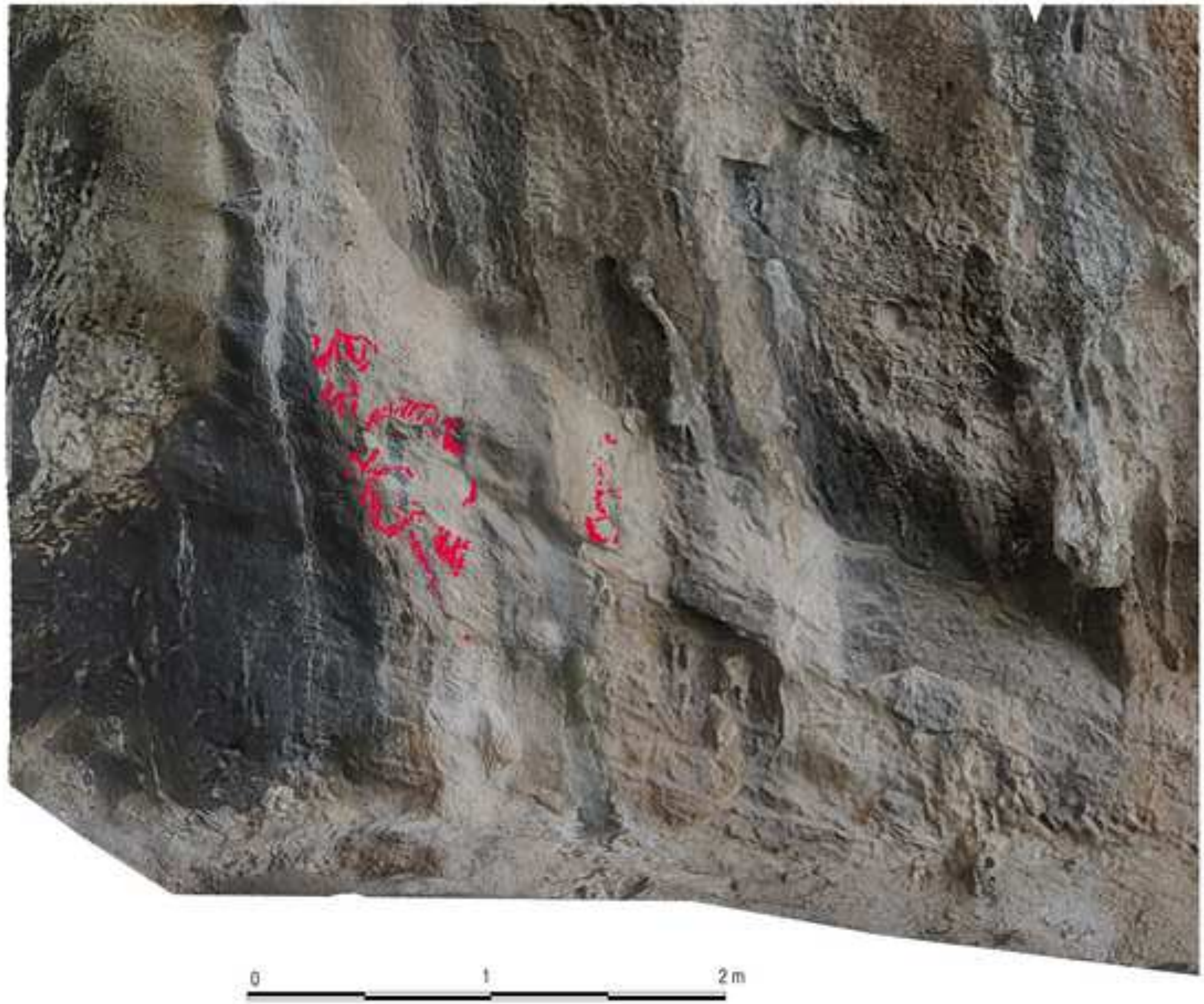

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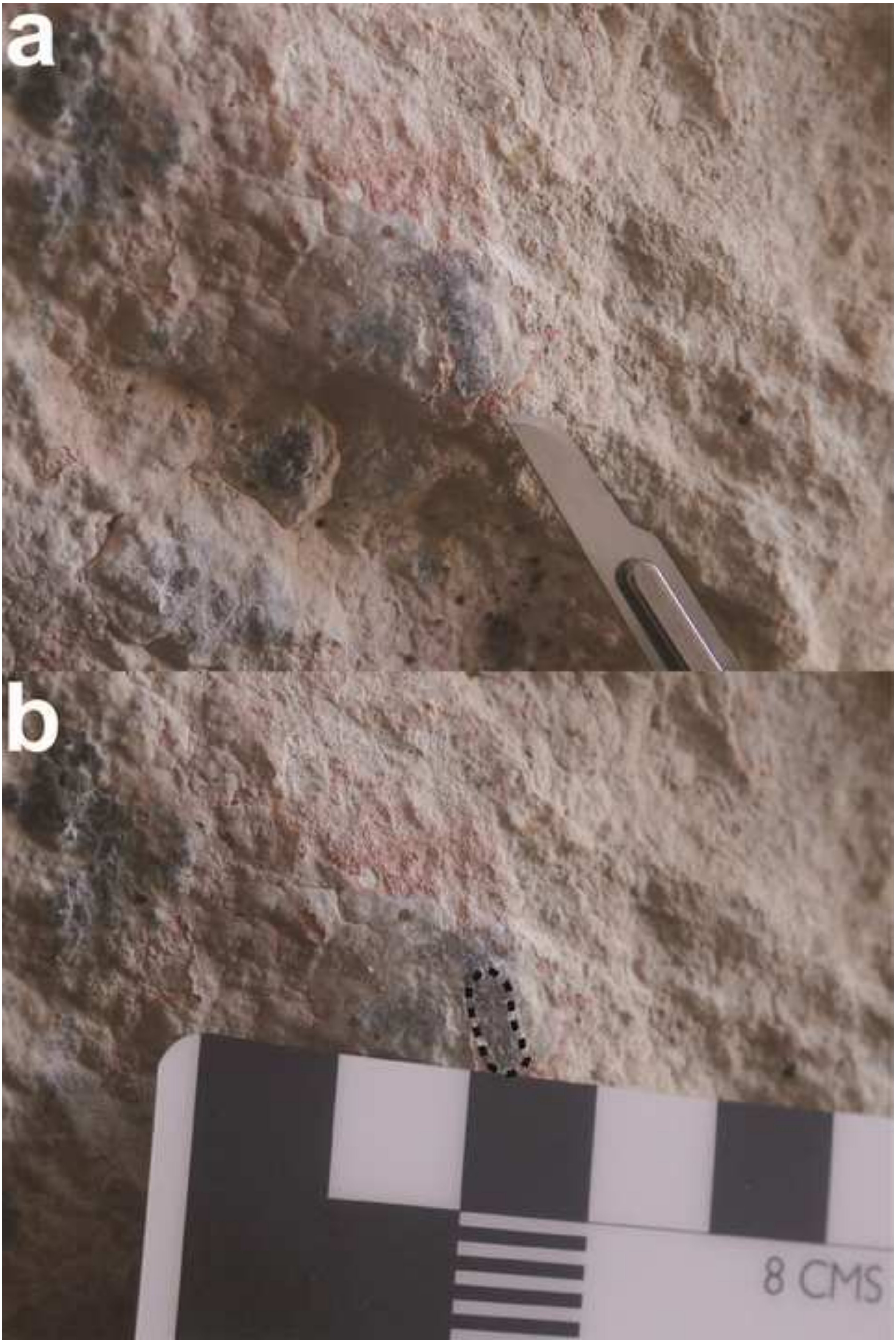

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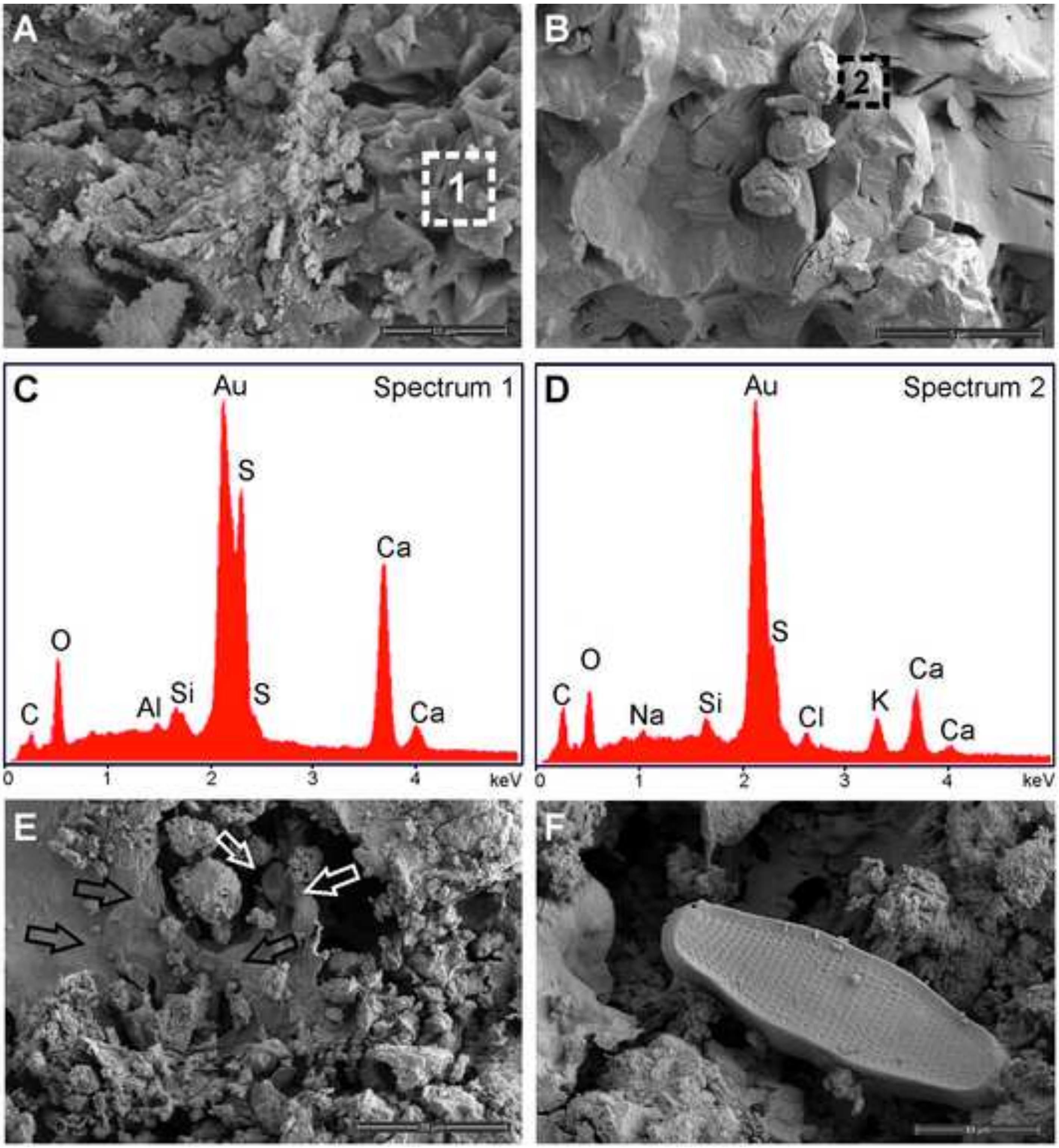

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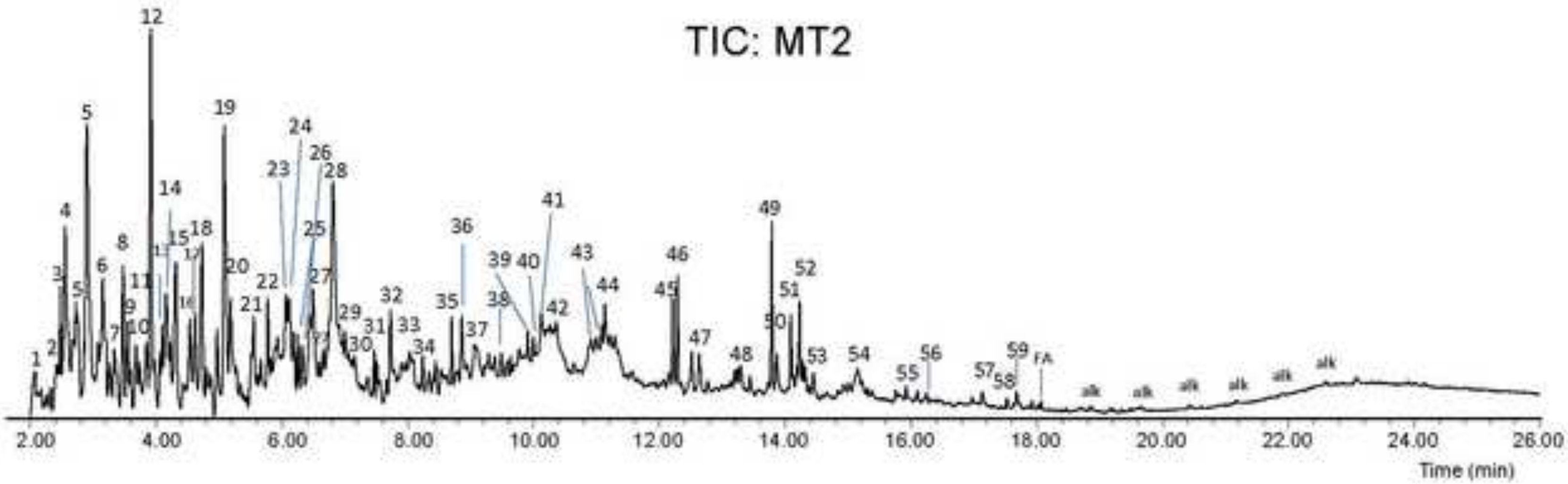

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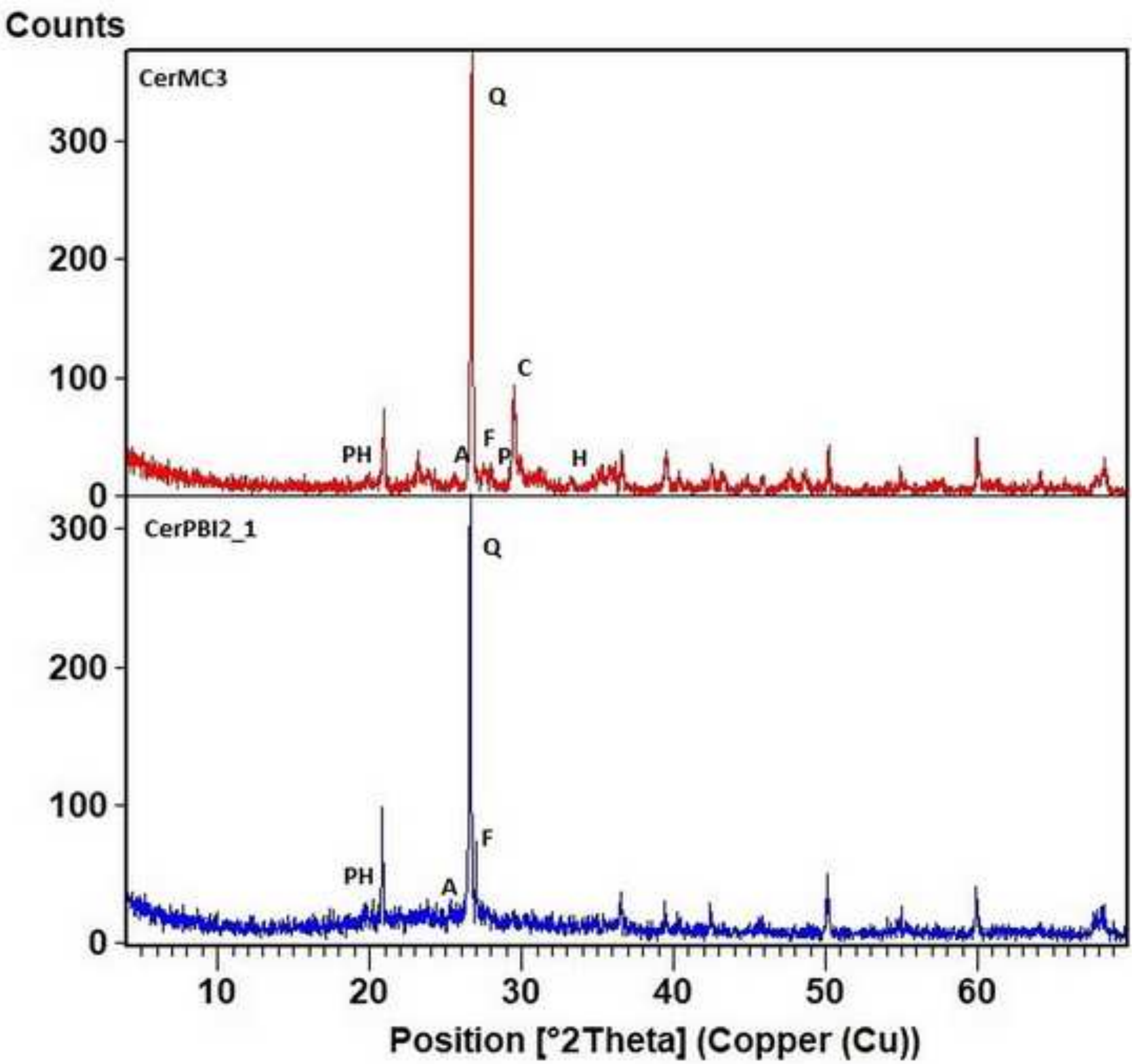

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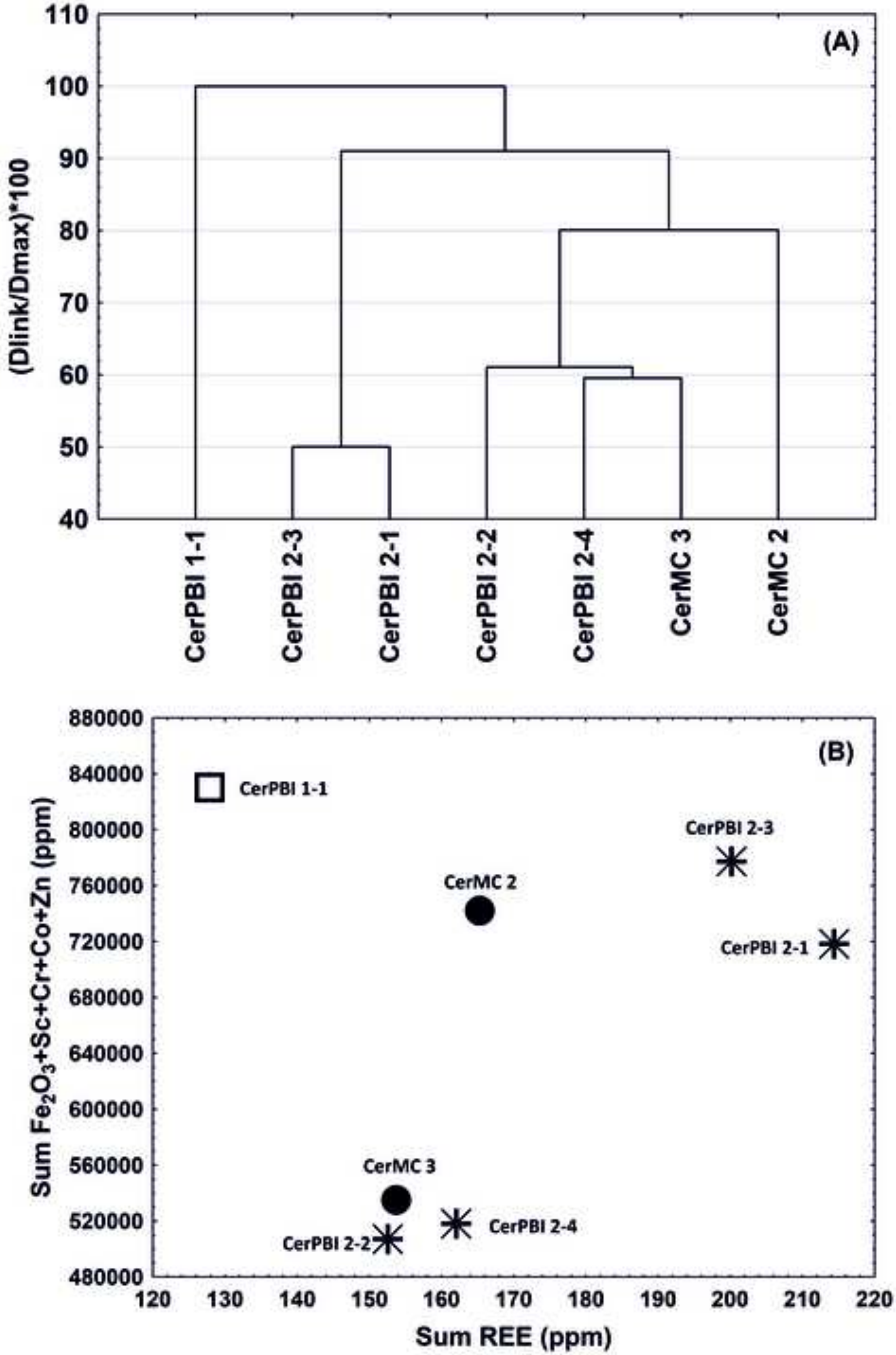

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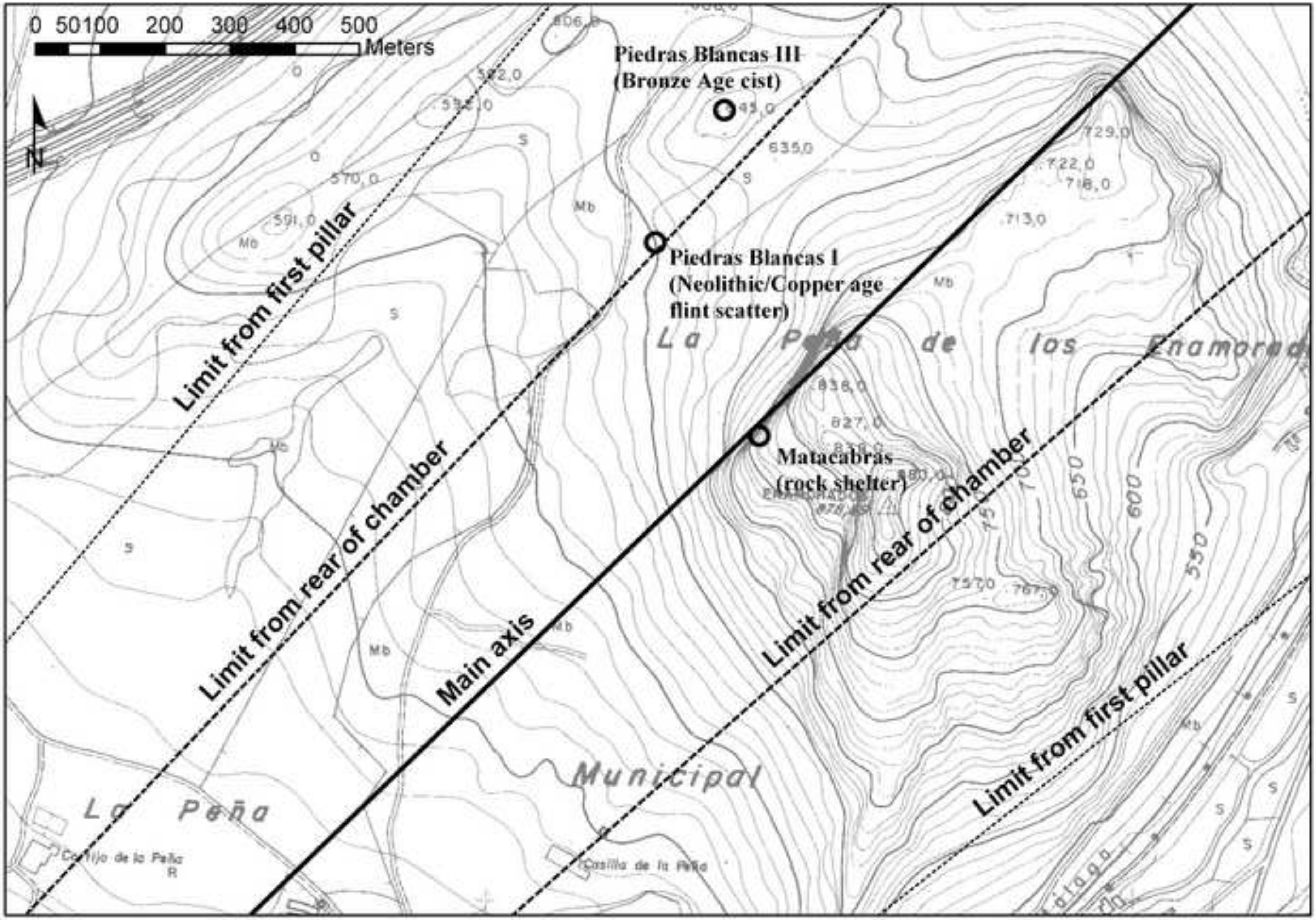

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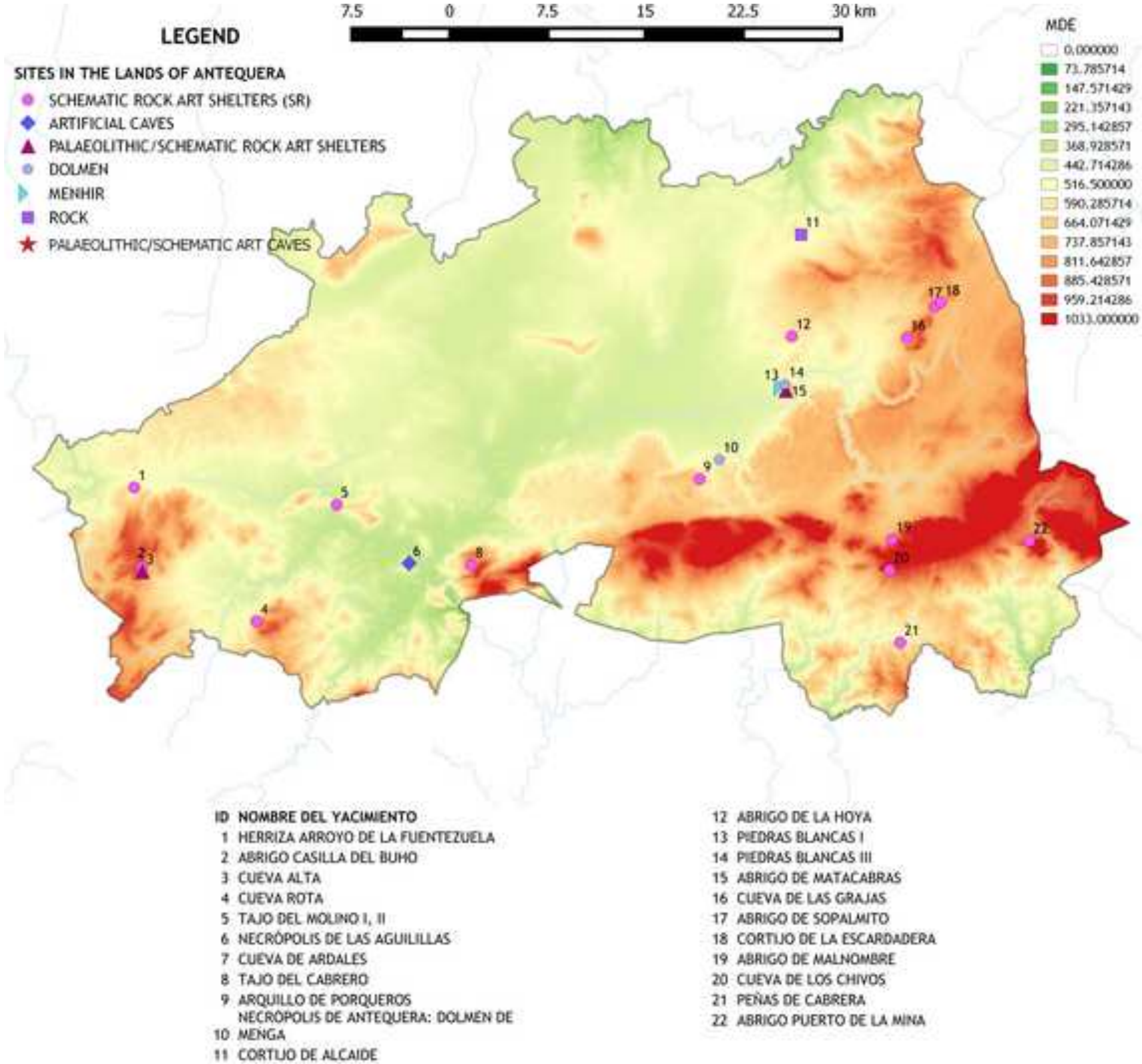

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PALAEOLITHIC/SCHEMATIC ART CAVES
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