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A study of the artistic corpus of red cave paintings in El Buxu cave (Cangas de Onís, Asturias, Spain)

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ABSTRACT

El Buxu cave, which is located in the village of Cardes (Cangas de Onís, Asturias), has been studied since the 1980s, with multiple excavations taking place inside the cave. This work has uncovered a complete artistic corpus, marking out several phases of occupation, with paintings dating to the first phases of the Upper Palaeolithic, Solutrean and Lower and Middle Magdalenian periods.

This paper presents a new review of its rock art, documenting all of the red paintings inside the cave, most of which have never been published up until this point. The most notable inclusion is the new description of a zoomorphic figure painted in red, which has previously been interpreted as an aurochs, but whose features are in fact closer to those of a deer or reindeer.

In addition, stratigraphic analysis of some of the paintings has revealed that they are overlapped by Solutrean and Magdalenian engravings and black paintings inside the cave. Elemental analysis was performed on series of red pigments and ochre samples, recovered from various strata using X-ray fluorescence spectroscopy. The resulting dataset was treated using Principal Component Analysis, providing a deeper understanding of the composition of the rock art in El Buxu cave, while uncovering potential correlations between the samples according to their elemental composition.

After comparing additional evidences from other red cave paintings in the region with the red pictographs in the cave, along with the stratification of paint pigments and their relationship with the ochre samples in each stratum, it appears that the red paintings comprise the oldest group of pictures inside the cave and can be broadly dated to the pre-Magdalenian cultural period.

1. Introduction

El Buxu cave (Cardes, Cangas de Onís, Spain) is located in the middle of the Sella River basin, in Asturias. It is situated within a limestone outcrop, 177 m above sea level and just 11 km as the crow flies from Tito Bustillo cave (Ribadesella, Asturias), which shares a similar chronological and cultural framework, and contains similar pictographs. First excavated in 1970 by E. Olávarri, studies of the cave were subsequently taken over by M. Menéndez, co-author of this paper and head of research up to the present day. He reviewed all of the material from the cave and recorded the artistic corpus of black figures and engravings, from the Solutrean and Magdalenian periods (Menéndez, 1984a,

Abbreviations: SEM-EDS, Scanning electron microscopy combined with energy-dispersive X-ray spectroscopy; ESEM-EDS, Environmental scanning electron microscopy coupled with energy-dispersive detector; μXRD, Micro X-ray diffraction; IR, Infrared spectroscopy; FTIR, Fourier transform infrared spectroscopy; XPS, X-ray photoelectron spectroscopy; EDXRF, Energy dispersive X-ray Fluorescence; μED-XRF, Micro energy dispersive X-ray Fluorescence; GC-MS, Gas chromatography-mass spectrometry; ICP-MS, Inductively coupled plasma mass spectrometry; μ-XANES, Micro X-ray absorption near edge structure; μRS, Micro-Raman spectroscopy; EDX, Energy-dispersive X-ray spectroscopy; CRI, Colour rendering index; LED, Light-emitting diode; PCA, Principal Component Analysis.

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1984b). These studies were completed in later years (Menéndez, 1999, 2003, 2012, 2016a, 2016b, 2016c, 2016d; Menéndez and García-Alonso, 2014).

In some of his publications on the cave, Menéndez has highlighted the existence of a possible connection between the Tito Bustillo and El Buxu caves. Some of the evidence suggests that during some stages of its occupation, El Buxu may have been used as a seasonal hunting camp in the mountains. A rise in the hunting of deer over other species, as well as evidence of infants and females across all levels of the site (Menéndez, 2016d; Quesada, 2016; Rojo, 2016), indicate that the residents may have been in contact with other caves along the Sella River basin, as demonstrated by some of the paintings that have been discovered. One example of this is a series of engraved tectiforms with outer fringes, which are also found on the main panel at Tito Bustillo (Balbín, 2014; Polledo, 2011). Along with other quadrilateral symbols, these could be understood as a territorial marking or a unique feature with some symbolic meaning (Menéndez, 2012; Sauvet et al., 2017).

Throughout the Upper Palaeolithic, across the region of Asturias (Spain), a geographic distinction can be drawn between the red symbols found in the eastern area (Balbín, 2014; Balbín and Moure, 1981; Balbín et al., 2005; Mallo and Suárez, 1972; Martínez-Villa, 2014; Polledo, 2011; Ríos et al., 2007; Santamaría et al., 2010; Arias and Pérez, 1994; Rasilla, 2012; Duarte et al., 2019; García-Alonso, 2019; González-Pumariega, 2011; Menéndez, 2016d among others) and the zoomorphic figures and engraved symbols found in the central area of the region, with a slight dispersion towards the east and even into caves in the Cantabria region (Fortea, 1981, 1994, 2001; García-Díez et al., 2008; González-Sainz, 1999, 2000; Jordá, 1969; Fortea et al., 1999; González-Morales, 1990; Rodríguez, 1992). The only exceptions to this distinctive distribution, are the red paintings found in La Peña cave (Candamo, Asturias) (Corchón et al., 2014), which is located in the centre of the region (Fig. 1).

El Buxu cave is located near the sea, in an area dominated by the Gueña River basin and its deep valleys. This mountainous location makes it somewhat isolated from the neighbouring caves in other nearby valleys, although it shares a few specific features with other nearby caves, such as decorated deer hyoid bones, which are similar in workmanship and style to those found in the caves of Tito Bustillo and La Güelga (Menéndez, 2012), or the depiction of tectiforms and curved lines that only appear with outer fringes in El Buxu and Tito Bustillo (Balbín et al., 2022; Menéndez, 2012; Polledo, 2011). These similarities between types of images and decorative conventions with relation to territorial divisions, have also been recorded by other authors in multiple caves across northern Spain (Corchón, 2004; Duarte et al., 2012; Sauvet et al., 2017; Sauvet et al., 2008). In order to confirm any potential contact between those responsible for the images at Tito Bustillo and El Buxu, a study was therefore carried out in 2012 into a selection of ochre samples and paintings from both caves (Hernanz et al., 2012).

A series of black paintings and engravings have been documented at El Buxu, as well as various signs of occupation during the Solutrean period (levels 2 and 3), with a degree of "de-Solutreanisation" or "Magdalenianisation", as classified by Rasilla (1989), (level 1) (Menéndez, 1992; Quesada, 2016).

None of the evidence suggested occupation inside the cave prior to the Solutrean period. There was, however, some evidence of portable art that could be placed in a pre-Magdalenian period. This evidence relates to a series of engraved plaquettes (Menéndez, 1997, 1999, 2016d; Menéndez and Ocio, 1997; García-Alonso, 2019) located in one of the Solutrean levels, which show signs of weathering. This means they may have once formed part of an open-air sanctuary in the 30 m^2 rock shelter located at the entrance to the cave, which has since been destroyed (the current entrance area). The images show some parallels with the linear engravings found in caves in central Asturias (see Fig. 1), which have been dated to the Aurignacian and Gravettian periods, making it possible that there could be some paintings inside the cave that support this idea.

Between 2014 and 2016 (Menéndez, 2016d; Menéndez and García-Alonso, 2014), a series of images were published that demonstrate the existence of a specific period for the red paintings. These include a possible vulva, a symbol in the shape of the letter "E", a marking around the outside of a hole and several finger markings in the Passage area of the cave. While this investigation was being conducted, a zoomorphic shape from the cave was published and described as a possible aurochs (Sauvet, 2015). The author stated that its closest equivalent was the image in Gallery A in La Pasiega cave (Cantabria), placing it in a pre-Magdalenian period, although he also acknowledged that the general consensus places these red figures within a cultural framework between the Gravettian and Solutrean periods (Sauvet, 2015).

This proved to be a turning point towards trying to specify a chronological and stylistic framework based on multidisciplinary studies, including chemical pigment analysis, in order to find out more about the composition of these paintings.

Other authors have underscored the importance of applying a more holistic approach to these types of studies (Garate, 2007). In fact, multidisciplinary studies have now been applied to a wide range of caves in northern Spain, using primarily non-invasive techniques, in order to analyse the chemical composition of cave painting pigments and minerals/ochres recovered from the strata during archaeological excavations.[1] These studies could help to establish a chronological framework and could also be used as an alternative to radiocarbon dating or U/Th dating, when the use of these techniques is not feasible.

Across northern Spain, samples have been studied from paintings found in 12 caves in Asturias: Peña de Candamo (Olivares et al., 2009, 2013, 2014), El Buxu (García-Alonso, 2019; Hernanz et al., 2012, 2018), La Lloseta (Navarro and Gómez, 2003), Tito Bustillo (Hernanz et al., 2012, 2018; Navarro, 2003; Navarro and Gómez, 2003), El Covarón (García-Alonso, 2019) and Pruneda (Hernanz, 2017). In Cantabria: Altamira (Cabrera, 1981; Edwards, 2005; Rull et al., 2014), El Castillo (d'Errico et al., 2016), El Pendo (García-Díez, 2001), La Garma (Gay et al., 2015, 2016), La Lastrilla (García-Díez et al., 2007) have been characterised. Finally, in the Basque Country: Arenaza (Garate et al., 2004) and Ekain (Chalmin et al., 2002) have also been considered.

Ochre samples taken from the archaeological levels or used in the *chaîne opératoire* for pigment treating was only analysed in six of those caves. Three in Asturias: El Buxu, El Covarón and Tito Bustillo (García-Alonso, 2019; Hernanz et al., 2012; Navarro, 2003; Navarro and Gómez, 2003), and three in Cantabria: Altamira (Rull et al., 2014), El Castillo (Múzquiz, 1993), and La Garma (Arias et al., 2011; Catelli, 2018).

Despite these efforts, only a few of these studies found a direct relationship between the ochre samples in the strata and the paint samples, as seen in the Lower Gallery in La Garma (Arias et al., 2011) and El Covarón (García-Alonso, 2019). This was partly due to the wide range of studies and different analytical techniques applied by the various researchers at each site, which made it harder to compare their results.

At some of these caves, samples were taken from the surface, near the paintings themselves or from the *chaîne opératoire*, making it impossible to reliably draw comparisons with the excavation levels. This was the case at Tito Bustillo, where ochre samples were taken from the surface or

[1] The instruments used for the analyses performed were SEM-EDS: Scanning electron microscopy combined with energy-dispersive X-ray spectroscopy; ESEM-EDS: Environmental scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy; μRS: Micro-Raman spectroscopy; FTRS: Fourier Transform Raman spectroscopy; XRD: X-ray diffraction; μXRD: Micro X-ray diffraction; FTIR: Fourier transform infrared spectroscopy; XPS: X-ray photoelectron spectroscopy; EDXRF: Energy dispersive X-ray fluorescence spectrometry; μEDXRF: Micro energy dispersive X-ray fluorescence spectrometry; GC–MS: Gas chromatography - mass spectrometry; ICP-MS: Inductively coupled plasma mass spectrometry; μ-XANES: Micro X-ray absorption near edge structure.

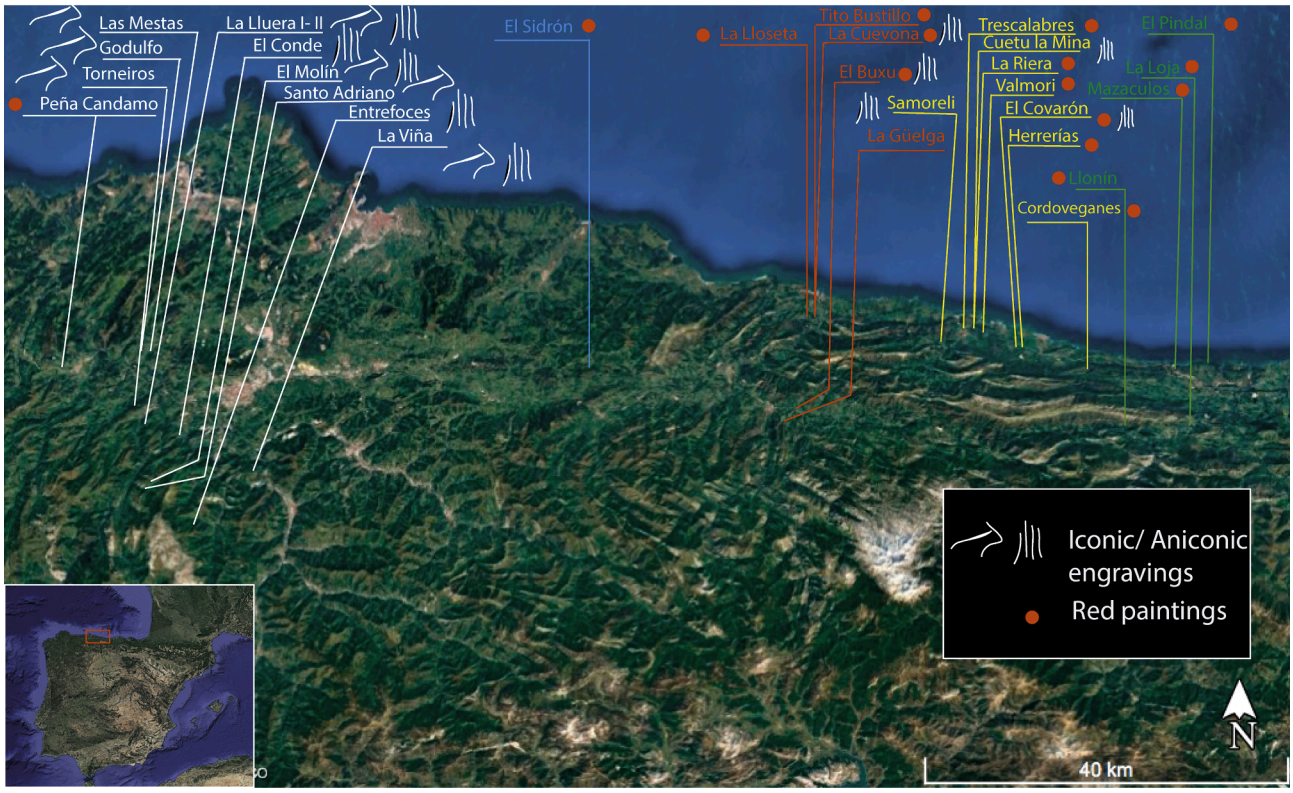

Fig. 1. Map showing the distribution of the main caves containing rock art, dating to the Upper Palaeolithic, in the centre and east of Asturias. The distribution of each group or geographic area is marked in different colours (with the Sella River basin marked in red). This group includes La Güelga cave which, despite not containing any rock art, does contain some interesting portable art. The key details the types of pictographs referred to in this article (modificated map from Google Earth).

from crushing tools found near the paintings, which were dated to the Aurignacian and Magdalenian periods (Balbín and Alcolea, 2009). Similarly at Altamira, the samples taken from deposit areas by H. Breuil and Alcalde del Río could not be aligned with any specific archaeological strata, so even though a connection was later established between the Polychrome Ceiling and the nearby pigment collected by those researchers (Rull et al., 2014), there is no way of determining a specific timeframe for these samples.

In other cases, such as the caves of Arenaza (Basque Country) (Garate et al., 2004) or La Garma (Cantabria) (Arias et al., 2011; Gay et al., 2015, 2016), chemical analyses have proved that pigments were intentionally mixed for painting.

Another key point is that out of the caves analysed, attempts have only been made in two of them – Tito Bustillo and El Buxu – to compare samples from both sites, in order to establish any potential links (Hernanz et al., 2012). Unfortunately, although the authors found similarities between the pigments in both caves, there are still differences that separate them.

The objective of this paper is to record the corpus of red paintings at El Buxu cave (Cangas de Onís, Asturias, Spain). A holistic approach has been applied to achieve this, based on the acquisition of documentation and a structural and stylistic study of the paintings (42 exhibits), in correlation with previously published information, relating to six additional pictographs (Menéndez, 2016d; Menéndez and García-Alonso, 2014; Sauvet, 2015). Additional studies were also carried out on the potential stratification of red colouring used in the paintings, which was found to be situated beneath other black symbols and engravings with a reliable chronology (Solutrean and Magdalenian periods), in order to compare them with the other pictorial evidence.

This paper ends with a chemical analysis of four red pigment samples, which have previously been analysed using other techniques by Hernanz et al. (2012), as well as a new sample taken from a zoomorphic pictograph. This was carried out in correlation with the 13 ochre samples taken from the cave strata during archaeological excavations. Although the samples were analysed using Raman spectroscopy, no additional information was uncovered as compared with previous publications, which is why this paper only includes the results of the elemental analysis using energy dispersive X-ray fluorescence spectroscopy (EDXRF). In order to establish any possible links between the red paintings and the ochre recovered from the cave, Principal Component Analysis (PCA) was applied to the dataset obtained from the EDXRF study. The results of this analysis were also discussed in relation to the previous results, acquired using Raman spectroscopy for the four red paintings by Hernanz *et al.*, (Hernanz et al., 2012).

2. Materials and methods

For the stylistic analysis of the red paintings, graphical records were acquired on site by taking RAW photographs, using controlled LED lighting. The colour rendering index (CRI) of the LED spotlights exceeded 90 %, which is similar to daylight. This lighting helped to reproduce the images in the same way as our vision system, creating a photographic archive that can help us compare the state of preservation of the pictographs as the years go by.

The photographs were taken using a Canon 70D digital camera with a 50–100 × objective lens, managing the colour, image densitometry, and adding a professional colour chart, *X-Rite ColorChecker Passport,* following a workflow designed by Pereira (Pereira, 2013; 2017). This process has been applied many times when documenting open-air rock shelters (Ruiz et al., 2016; 2019).

The images subsequently had to be digitally processed using specific colour management and restoration programmes, such as *DStretch* (Harman, 2008; Le Quellec et al., 2013) and the *Adobe Camera Raw Plug-in* in order to selectively enhance the red tones. Both working methods

were used and contrasted in an attempt to avoid subjective judgements when interpreting the images. The *X-Rite* colour chart was also used to assess the type of colour reduction carried out in the post-processing of the photographs.

In order to determine overlaps, a 100 × 5 MP digital microscope (*Dino-Lite Edge: AM7115MZTL*) was used with *DinoXcope* imagery software.

The samples previously collected by the UNED team (Hernanz et al., 2012) were used for the new chemical analysis of the pictographs and ochres raised for this investigation. In the study of Hernanz and his team the following pictographs were sampled and analysed: the "E" shaped figure (published as BCI), small markings located in the Passage area (BPB) and the vulva figure in the Great Chamber (BGSI) (Fig. 2). The techniques used in 2012 were scanning electron microscopy combined with energy-dispersive X-ray spectroscopy (SEM-EDS) and micro-Raman spectroscopy (μRS).

A new sample was also included in this study, consisting of a millimetric sample extracted from the head of a zoomorphic pictograph in the Great Chamber (Re/Ce) (Fig. 2). Thirteen ochre fragments recovered from the archaeological excavation of the cave were also studied, with Level 1 dating to a period of transition to the Magdalenian era, and Levels 2 and 3 dating to the Solutrean period (Menéndez, 1992; Quesada, 2016) (the results of this study are detailed in Tables 1 and 2, in Section 3.3).

All samples have been carefully observed under a microscope and photographed (Fig. 3). Sample bx1 was taken from a stone plaquette that was covered with a significant amount of ochre pigment, forming a layer of 1 to 2 mm in thickness. Sample bx12 consists of a combination of ochre and clay, mixed with the remains of small stones and bone fragments. One of these fragments, bx13, shows potential signs of having been scraped or rubbed, as seen in the macroscopic image.

The analytical techniques used in this study in order to classify the pigment samples were as follows: μRS, to study their molecular composition (Ospitali et al., 2006), and Micro energy dispersive X-ray fluorescence (μ-EDXRF), to analyse their elemental composition, being posible to detect traces up to tens of μg/g.

Elemental analysis was conducted using the dual M4 TORNADO (Bruker Nano GmbH, Berlin, Germany) energy dispersive X-ray fluorescence spectrometer (μ-EDXRF), which enables to measure at a lateral resolution of 1 mm or as low as 25 μm. For this investigation, measurements were taken at a lateral resolution of 25 μm. This low spatial resolution was achieved by using a polycapillary lens. The Rh X-ray tube

Fig. 2. On the top of the image: photographs of the sample areas corresponding with their publication (Hernanz et al., 2012, Fig. 2). BCi: "E" shaped **figure** (no. 12 l in this publication); BPB: small irregular marking located in the Passage area (no. 5f in this publication); BPA: 3 finger markings (no. 5c in this publication); BGS1: Vulva figure (no. 23 in this publication). At the bottom of the image, the new collected sample Re/Ce: photograph of the sample area for the zoomorphic figure, analysed for the first time as part of this study (photograph with selective red enhancement).

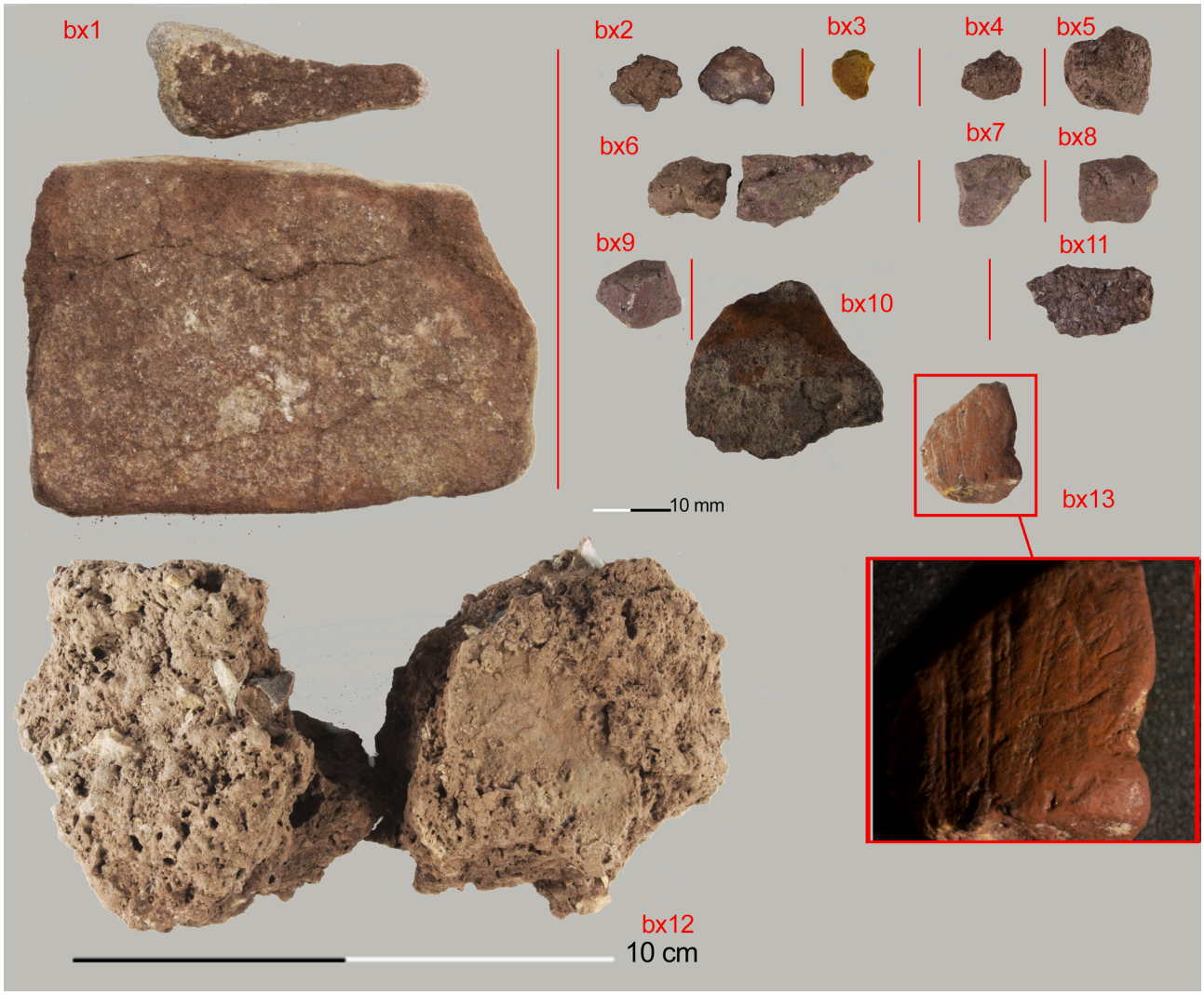

Fig. 3. Photographs of ochre remains which have been analysed using Micro Raman spectroscopy (μRS) and Micro energy dispersive X-ray fluorescence (μ-EDXRF).

was operated at 50 kV and 600 μA. In order to improve the detection of light elements, measurements were taken under vacuum conditions (20 mbar). Each spectrum was treated using M4 TORNADO software, which is able to extract the counts associated with each line of the detected elements. Additionally, semi-quantitative values were also extracted using a quantification method implemented in the instrument.

Statistical analysis of the data was carried out through multivariate analysis, using Principal Component Analysis (PCA) (Omar et al., 2012; Sarmiento et al., 2011). The dataset used to perform the Principal Component Analysis (PCA) included the semi-quantitative data obtained from all the measured samples. For comparison purposes, PCA was also obtained using the Kα or Lα line (depending on the specific element), normalised against the Kαline of Fe, the main element in the pigment and ochre samples. Similar results were obtained from both datasets. This investigation therefore includes the results taken from the dataset of semi-quantitative values. For the PCA, R version 4.2.1 open software (CAMO Software, Olso, Norway) was used. Prior to performing the PCA, the dataset was centred and normalised (1/S weight).

3. Results

3.1. The corpus of red paintings

The cave opening and entrance area lead into a narrow passage, which in turn leads to the four main areas described in the monograph published by Obermaier and the Count of Vega del Sella (1918) (See Fig. 4A). After following a narrow passage for some 70 m, we end up in a room that opens onto an upper gallery, which does not contain any form of rock art. We then pass through another narrow passage into what is known as the Great Chamber, described in 1918 without any allusions to the red paintings within. Today it is obvious that this was the main gallery chosen to display the most significant red paintings, especially in the Niche situated on the north wall. To date, no remains of black paintings or engravings have been recorded in this part of the cave, despite being present in other areas of the cave.

If we head towards the deepest part of the cave, we must first go through a narrow stretch known as the Passage, before we then find most of the finger markings and red markings inside the cave, in areas A, B, C and D. area C contains another recognisable and isolated symbol, the “E” shaped figure (Menéndez and García-Alonso, 2014).

The location of the paintings on the structure of the supporting rock is relevant because of the fact that the position of the paintings has been adapted to suit the original cramped nature of the cave. Decoration does seem to be more focused on the lower ends of the walls and the smaller crawl spaces. This pattern of behaviour deviates from the other black figures in the cave, which tend to appear in the mid to upper areas of the passages and the Niche in area D, which is home to most of the Solutrean and Magdalenian era drawings. This is also the most visible area of the cave.

Area D then opens onto another passage which again leads to the

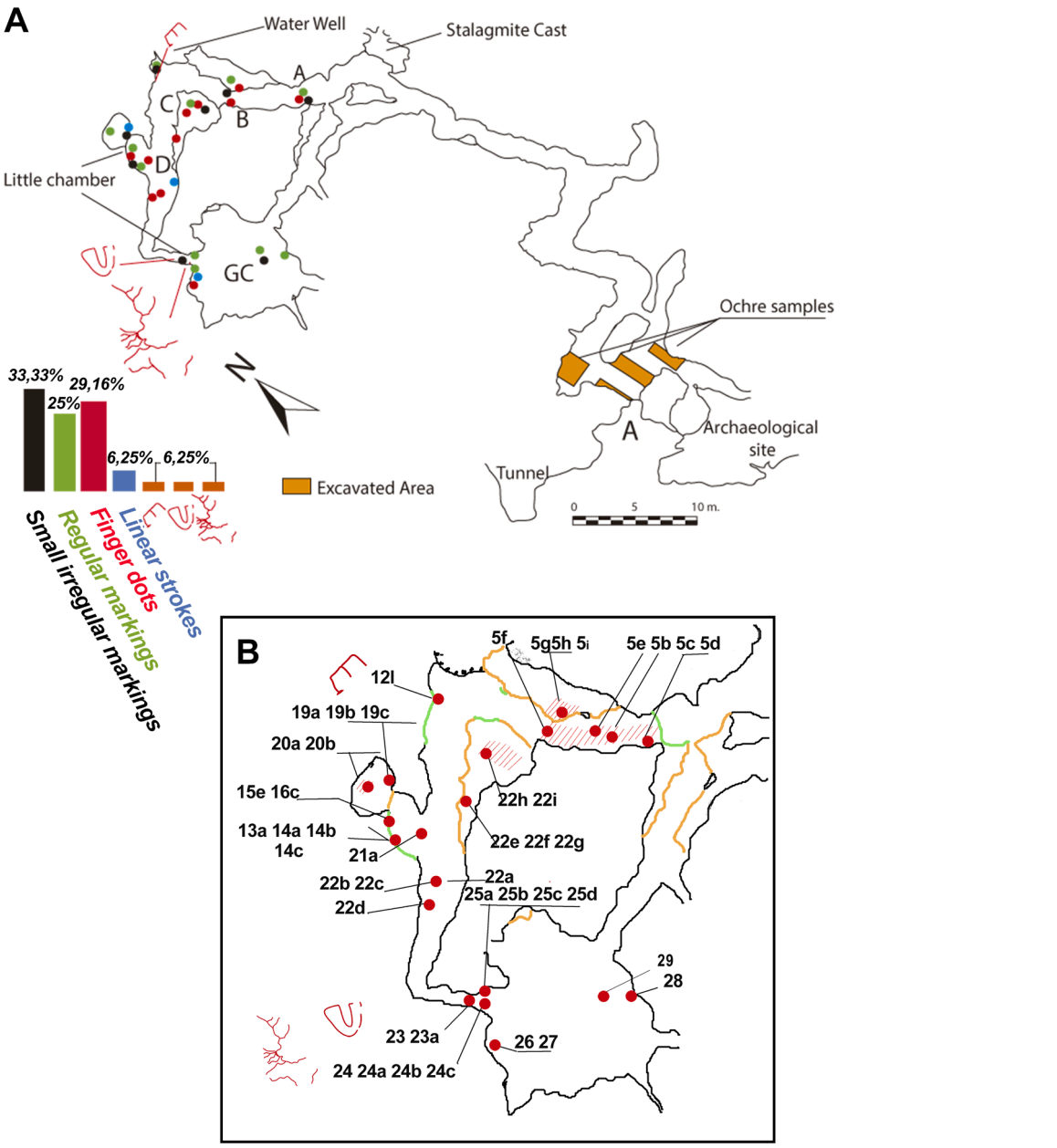

Fig. 4. A) Plan of El Buxu cave showing the different types of red paintings in the cave and the excavation area, where the analysed ochre samples were taken. B) Close-up of the decorated area of the cave, marking out the pictographs and the numbering used for their study (García-Alonso, 2019).

Great Chamber, as well as area A, thereby creating a circular route.

The total number of isolated red figures and markings amounts to 48. The majority of these are small irregular markings (33.33 % of the total), followed by finger markings, small dots (29.16 %) and medium-sized regular markings (25.00 % of the total), which are mostly found in the lower areas of the cave, the small crawl spaces, the two niches and holes, although some are also found in the narrow passageways (Fig. 4B). The paintings were classified by applying some of the parameters used by Medina-Alcaide et al. (2017), who differentiated between the smaller irregular markings and finger markings that are more likely to have been intentional, focusing on their structure and definition.

Only three of the markings comprise significant forms (little straight lines), accounting for 6.25 % of all markings, while recognisable pictographs (zoomorph) and symbols account for just 6,25 % of all markings.

The plan shown in Fig. 4B indicates the different types of red paintings found in the cave, based on the classification and numbering established in previous publications. (García-Alonso, 2019).

A total of fourteen pairs of *finger markings* are recorded in the cave. Occasionally, groups of three finger markings were also observed (Fig. 5A). They are located throughout the whole cave, both in the blind galleries and at the entrances and exits to smaller passageways, where individuals would have had to paint either laying down or crouching. Further sixteen *small irregular markings* (Fig. 5B) finish off the list of small red markings in the cave, which are also found in the passageways such as the Passage area. Therefore, the most likely theory is that they were produced unintentionally, when clothing or a body covered in ochre brushed past the wall. The most notable finger markings and other markings consist of pictographs no. 5c and no. 5f (located on the plan in Fig. 4B), which were used to collect samples BPA and BPB in 2012 (Hernanz et al., 2012).

The twelve *regular markings* analysed (Fig. 5C) vary in size and are only found on the lower areas of the rock, or in the small crawl spaces of areas B, C, and D. They are occasionally found on small bumps and

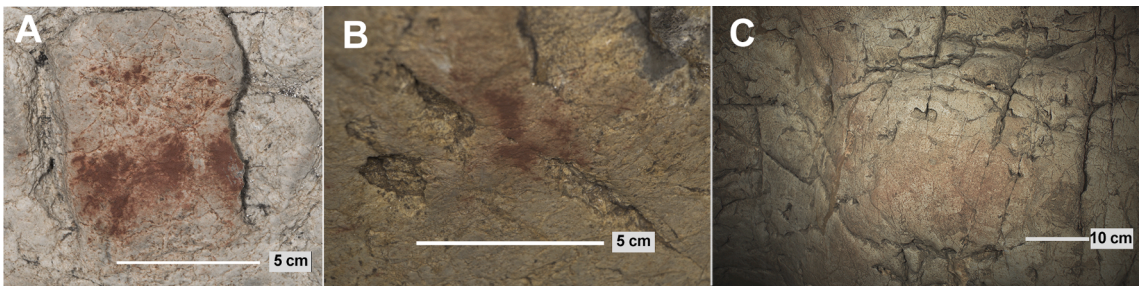

Fig. 5. A) Example of triple finger markings: no. 5c on the plan. B) Small irregular markings: no. 5f on the plan. C) Average sized marking: no. 22i on the plan (photographs with selective red enhancement).

smooth surfaces of the rock. They are very faded, which makes it difficult to determine their workmanship and size. Notably, the rock around many of these markings has previously been touched and perhaps even smoothened or prepared before painting.

The area known as the Passage (areas A-B on the plan) contains a marking that is several metres long, running along a large section of the ceiling (Fig. 6A). This area originally had a floor-to-ceiling height of just 50 to 80 cm (Fig. 6C) and, although the original floor level has been excavated, it is still a low section of the cave today. We therefore have no way of knowing whether the size of this red marking is due to coloured remains being rubbed and spread out over the years when the cave was open to the public, without any protection, or whether it was caused by the ochre-covered bodies of its Palaeolithic inhabitants brushing past.

In the middle of this prolonged marking, a hole in the ceiling appears to have been highlighted. This has previously been categorised as a vulva figure (no. 5b on the plan) (Menéndez, 2016d; Menéndez and García-Alonso, 2014) (Fig. 6B). It is approximately 20 cm long and just a few centimetres wide and, notably. the colouring only appears around the edge of the hole, not inside it. The colour has become very faded if we compare it with previous photographs.

At the entrance to the Niche in the Great Chamber, there is a marking just before the zoomorphic head, which could simply be a faded drawing (no. 24b on the plan; Fig. 7A) that we are now unable to reconstruct. Another average sized marking (approximately 25 cm long) (no. 28 on the plan) is found on a stalagmite, on the south wall of this room (Fig. 7B). In this case, we can deduce that the marking was intentional. It is found some 165 cm above ground level and could have been made using a hand or some form of stamp, but not by blowing or spraying, as the colour only appears on the smoother areas and not in the holes in the crust of the stalagmite. There are also some barely visible markings

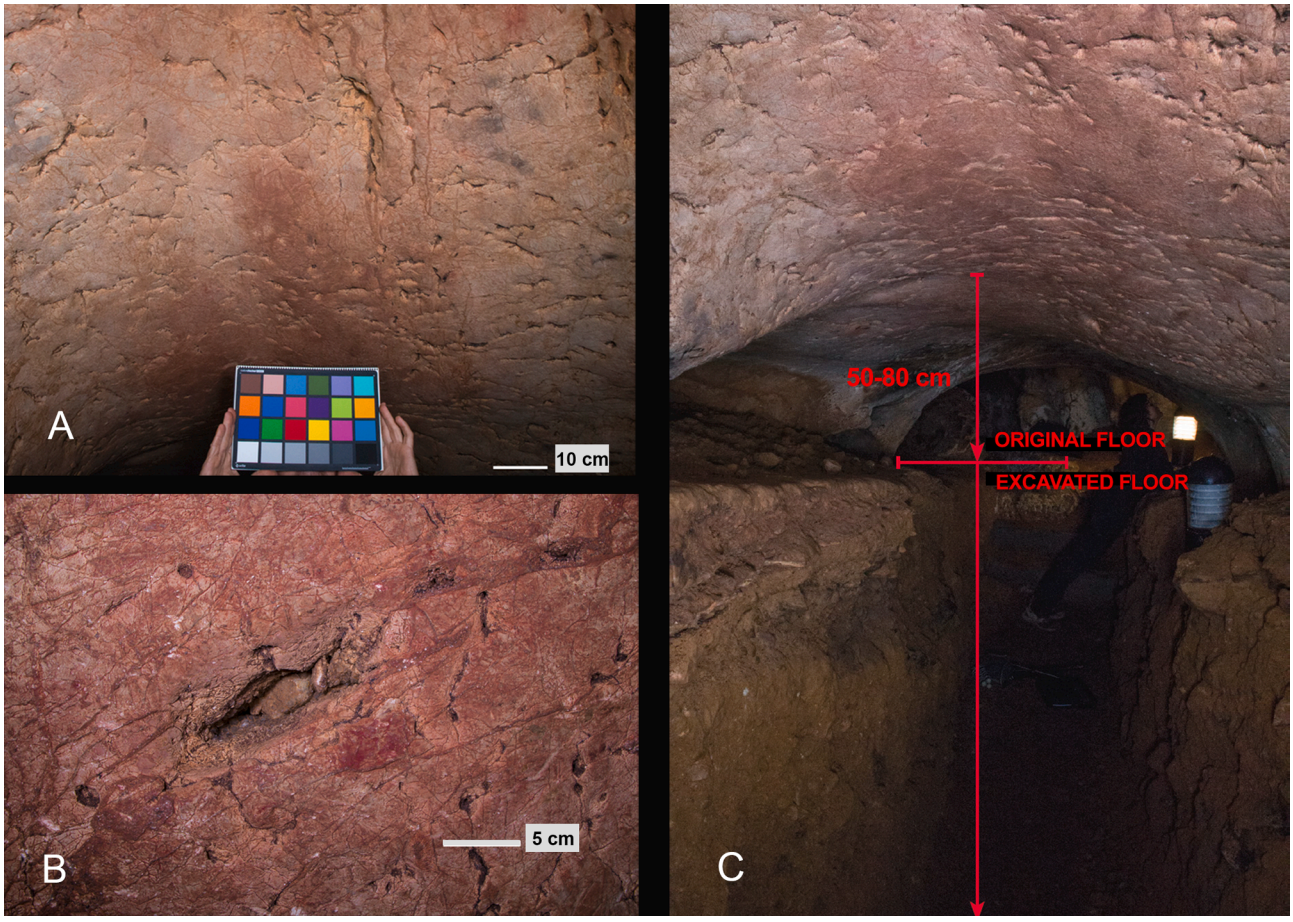

Fig. 6. A) Prolonged marking in the Passage area. B) Red colouring around the outline of a hole; no. 5b on the plan. C) General overview of the Passage and distance from the original floor (photographs with selective red enhancement).

Fig. 7. A) Marking no. 24b on the plan. B) Marking no. 28 on the plan. C) Marking no. 29 on the plan (photographs with selective red enhancement).

around an archway, found on a ledge that crosses part of the room (no. 29 on the plan; Fig. 7C), where the floor-to-ceiling height was originally around 50 cm, but is now lost.

Only three markings comprise significant forms. Firstly, a *small vertical line* (no. 27 on the plan), barely-two centimetres long, drawn on the inside of a hole (Fig. 8A). This is located in a wide passage area of the Great Chamber and is clearly visible near the Niche, where the zoomorph and vulva figure are located. It is situated beneath two finger markings (no. 26 on the plan).

Marking no. 19 on the plan consists of an *angular drawing*, located in the deepest part of the Niche in area D. It measures 5 × 7 cm and faces towards the inside of the space (Fig. 8B). Another *vertical line*, 7 cm long and 35 cm off the ground (no. 22f on the plan; Fig. 8C) is located on the south wall of area D, at the beginning of the passageway, which continues on and is just 3.5 m from the Niche in the Great Chamber. It is notable that there are always several finger dots in the areas near these markings.

The *"E" shaped* figure is located in area C of the cave (no. 12 l on the plan; Fig. 9A, B) (Menéndez and García-Alonso, 2014). Having processed and analysed these images, it is clear that someone intentionally tried to rub off the figure, at some point during the recent history of the cave. As a result, its state of preservation has deteriorated, the tone of the paint is faded, and it may have been mixed with some of the pigment from the black markings around it (marked with a white circle in Fig. 9A). In addition, because the figure was rubbed with water, some of the red colouring has dripped down below the symbol to the ground and has also dripped onto the other black figures and markings, which we will return to later.

The vulva figure (no. 23) (25 × 28 cm) (Fig. 9B and 9C) is located in the Great Chamber, on the edge of a very tight crawl space connected with area D of the cave, opening on the north wall some 128 cm above the ground.

The analysis of this figure in 2014 highlighted its "U" shape, with slightly widened edges. Digital colour restoration has enabled us to see and interpret the right-hand side of the figure, despite its poor state of preservation (Fig. 10) (Menéndez and García-Alonso, 2014).

On the lower part of the west wall of the niche, remains were found of an 85 cm long zoomorph (no. 24 on the plan) (Fig. 11A), whose legs fade into the original floor level. On the opposite wall, there are remains of other red markings that lead inside the space, but they are so minimal that no figures or symbols can be ascertained.

This figure was described by Sauvet (2015) as a possible aurochs, dated to a pre-Magdalenian period. However, a deeper analysis of the colour pigments has enabled us to fully reconstruct this quadruped, which looks more like a possible deer or reindeer, as there are some pigment remains around 40 cm from the animal's head and in front of it, which resemble antlers (Fig. 11B). The photographs of the copy below show the differences between these interpretations as compared with the previous analysis made by the author (Fig. 11C).

The painting is located on the upper part of the wall and is particularly faded, thus part of the antlers and muzzle of the figure went unnoticed upon initial investigation. The animal's head is therefore larger, and the outline is anatomically more accurate and proportionate than in the first copy. The previous analysis also interpreted a brownish-red crust around the animal's rump. In this case, the pigment is primarily spread above this crust, so perhaps the animal's body was once larger. Without a clearly defined loin, it is impossible to tell whether the animal has the characteristic protrusion found on reindeer, which would give us a more accurate conclusion as to the type of animal.

Underneath the abdomen are the tops of the legs, but these are left unfinished, ending in a blackened crust located just above what would have been the original floor of this small room.

The shape of the animal seems to be incomplete, both in terms of the legs and the tail area, which could well have been lost in the crust of the rock. The animal is facing towards the left, with its head below its rump and the length of its loin. Its head is positioned in a typical side profile, but the full outline of the antlers is unclear, as only one of them has been preserved and it covers a wide span.

In terms of technique, the painting was made using red pigment and broad strokes, adjusting and widening the strokes to highlight areas such as the jaw or the tops of the legs. The animal's eye was also highlighted, although today the colour is very faded. Given its state of preservation, it is impossible to determine whether the painting was drawn with one continuous line, by joining dots or by juxtaposing dots. It appears that

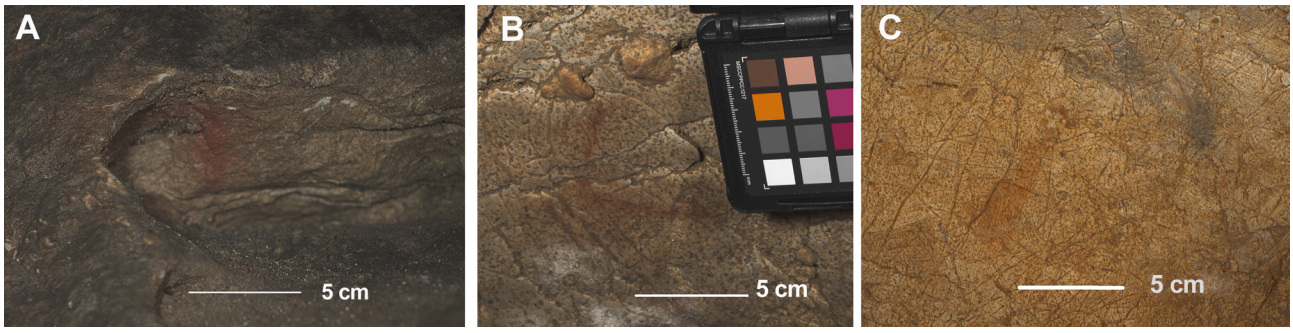

Fig. 8. A) Small linear marking located in the Great Chamber. No. 27 on the plan. B) Angular marking, no. 19 on the plan. C) Vertical marking from area D. No. 22f on the plan (photographs with selective red enhancement).

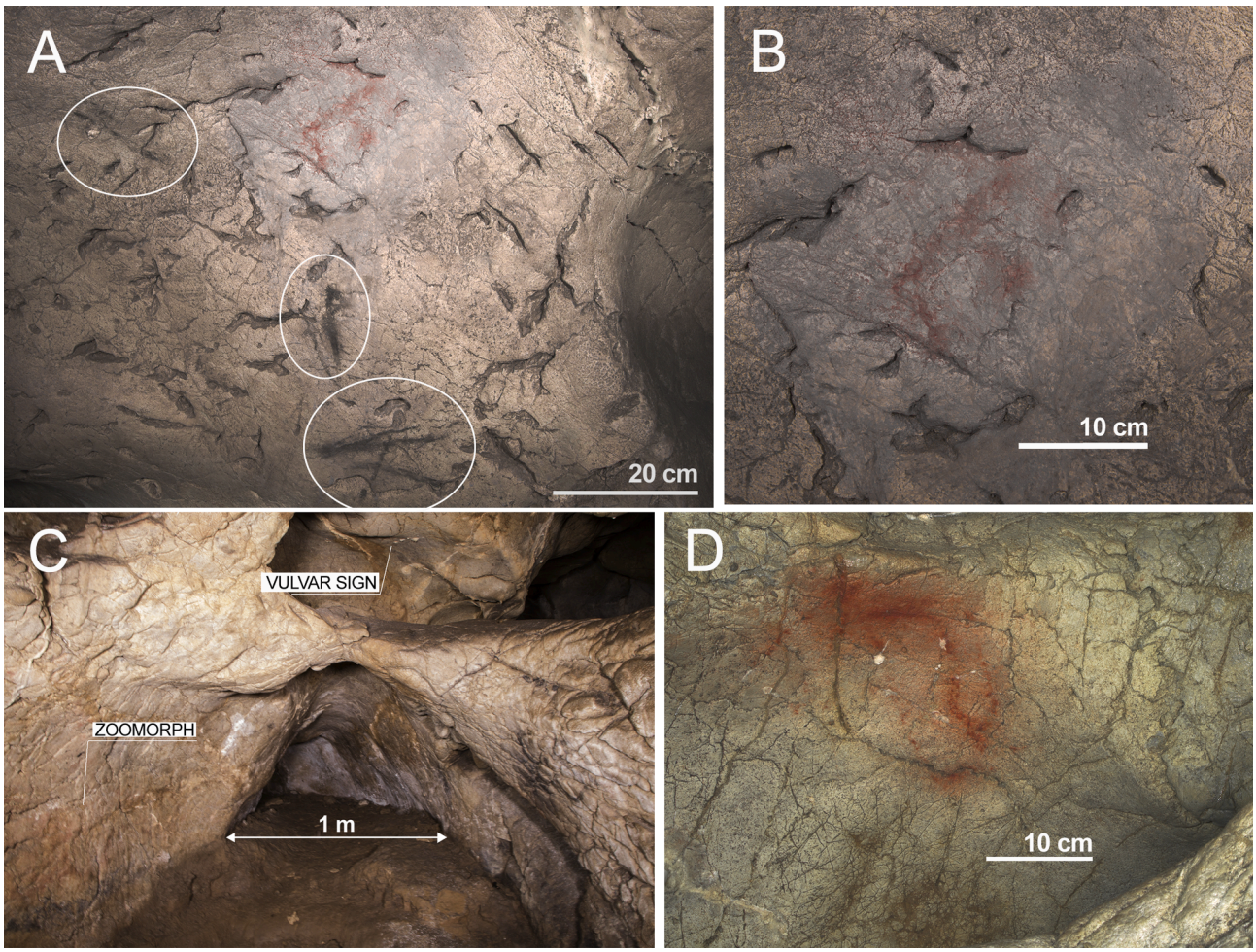

Fig. 9. A) Overview of the "E" shaped figure, no. 12 l on the plan. In circles some other black touches are showed B) Close-up of the "E" shaped figure. C) Niche in the Great Chamber. B) Vulva figure (photographs with selective red enhancement).

there was a continuous line, but it was broken up by the irregular surface of the rock itself, although there are also several clusters of colour that could indicate this technique.

3.2. Analysis of overlapping paintings and engravings

There is little evidence of black paintings and engravings that overlap with the red paintings in the cave. It would be imprudent to try and organise these markings into different phases based on such little evidence, but this does not mean that they should be ignored. They consist of red markings that are overlapped with an engraving and two black pigment markings, which were dated to the Solutrean and Magdalenian periods by Menéndez (2016d).

The first of the overlaps is located in area C, on one of the black markings (no. 12 m on the plan) located below the "E" shaped figure. This black marking is overlapped by traces of red, which dripped down when attempts were made to rub off the red figure (Fig. 12A). However, a small trace of reddish colouring was found beneath the black trace, by looking under a digital microscope. The photographs show a difference in the colour and shape of both markings, as the red marking is clearly intersected by the black marking, which is above it.

Both exhibits are located near the Niche in area D, on the lower part of the east wall, just below one of the cave's Solutrean-era horse engravings. This marking is classified as no. 13a (Fig. 12B). Underneath one of the engraved black paintings of a deer, we find the third overlap, marking no. 15e. The macro photograph (Fig. 12C) shows how the faded red colour of a regular marking is intersected by an engraved line and a black marking that correspond to the animal's leg.

3.3. Chemical composition of the pigments

As stated in the introduction, an alternative technique was used to re-analyse four samples, taken from the cave paintings included in a study by Hernanz and his team (2012), pertaining to the "E" shaped figure (BCi); finger markings in the Passage area (area B) (BPA); some small markings, also in the Passage (BPB); and the vulva figure, in the Great Chamber (BGSI). Further thirteen ochre samples found in the various strata of the cave, which had never previously been studied, were also analysed (Figs. 2 and 3).

Table 1 lists the data provided in the analysis carried out by Hernanz et al. (2012). According to this data, the main component of all the pictograph samples is hematite, along with other elements typically found in clay. The samples taken from two of the figures (finger markings and a small marking) in the Passage area (BPA and BPB) display the most similarities with each other. However, there are also some differences, such as the presence of wüstite (a non-stoichiometric form of ferrous oxide, possibly derived from clay) in BPB and a different, coarser grain size in BPB (<30 μm).

The researchers also observed a similarity between the two symbols analysed (BGS1: vulva and BCI: "E" shaped figure), which only differed in the presence of amorphous carbon in the "E" shaped figure. However, this element could be the result of the attempt to rub off the figure. This action would almost certainly have smudged particles from the black paintings, which could have added this element to the figure.

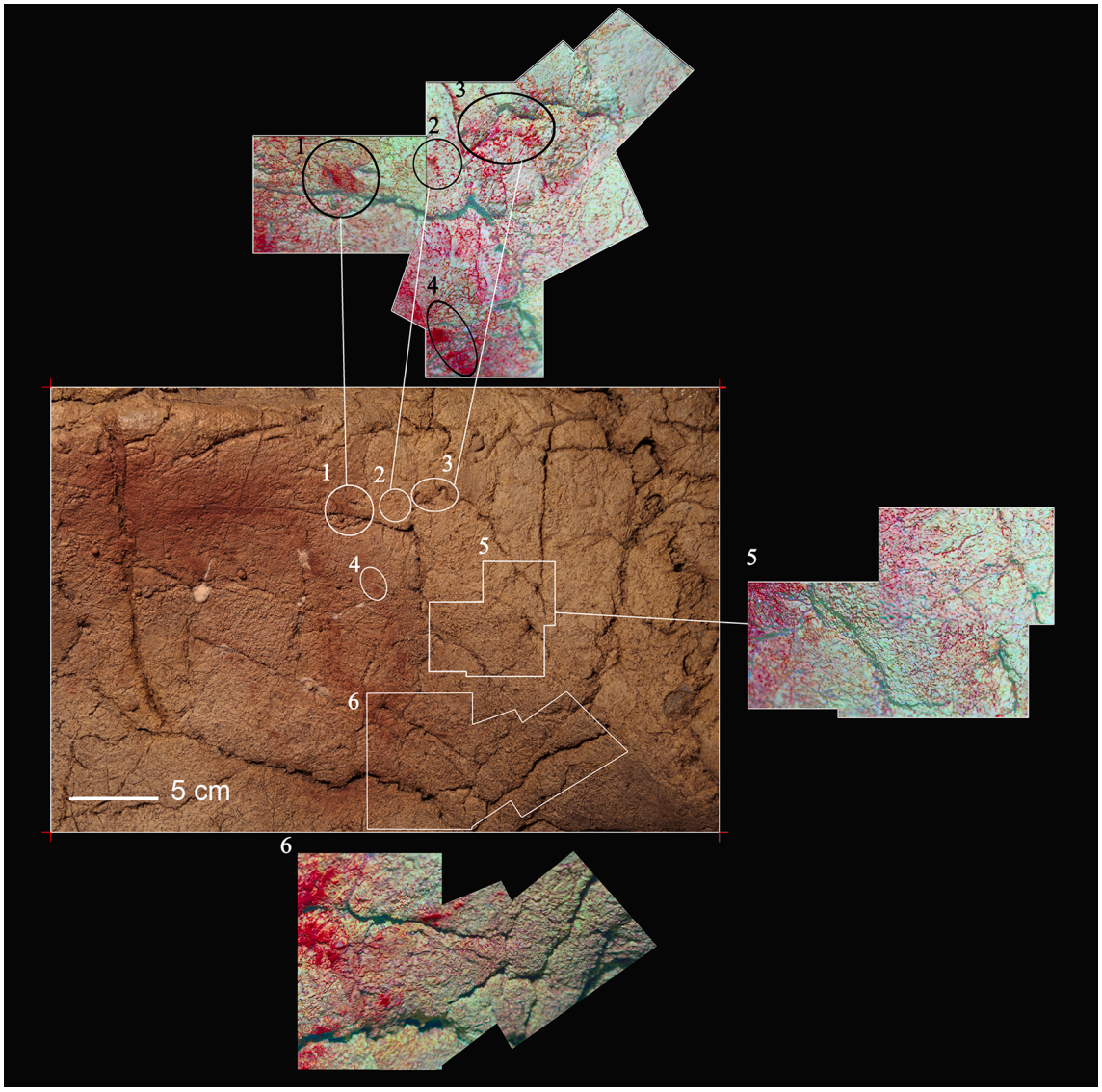

Fig. 10. Process of colour restoration using digital techniques (Menéndez and García-Alonso, 2014).

The data provided by Hernanz and his team indicates that all the pictographs analysed from El Buxu contain some of these compounds: wüstite, Mn oxide phases and amorphous carbon, and, according to the researchers, these additives could have been used to darken the tone of the pigments. Sample BCi ("E" shaped figure) contains amorphous carbon; BPB (irregular markings), BSG1 (vulva) and BCi ("E" shaped figure) contain wüstite, while Mn oxide is found as a secondary minor element in all of the samples. However, there are also several possible explanations for the presence of Mn, considering that the red earth mineral hematite, can also contain a minor presence of Mn. One example of this is that most of the ochre samples taken from the strata also contain this element in trace form or as a minor element (see Table 2).

Tables 2 and 3 provide the results for the major (>1%), minor (between 1-0.1 %) and trace elements (<0.1%) identified in the samples of pigment and red ochre from the strata, using new, previously unpublished analyses carried out by EDXRF spectrometry as part of this study. The sample taken from the zoomorph (Re/Ce) was analysed recently, but the severe restrictions in place due to its state of preservation meant that only a millimetric sample could be taken. It was also impossible to take samples of the supporting rock near the painting, without damaging the whole structure, which would have enabled us to pinpoint its contribution to the elemental composition of the pigments analysed.

Using the dataset including all the semi-quantitative values (numerical variable depending on the sample size, with at least six measurements per sample) derived from the painting and ochre samples, the scores and loadings plot (Fig. 13) was obtained. As can be seen, all the measurements taken from the ochre samples bx1 and bx5 are far away from the rest of the samples. These ochre samples are richer in specific metals (Ti, Ni, Rb, among others) that could be related to potential contamination after they were deposited. In some cases (e.g. the sample from the Zoomorph; Re/Ce), the individual measurements are quite dispersed, which suggests a degree of heterogeneity in the composition of the extracted sample. The poor preservation of the pigment and its mixture with the rocky substrate could have influenced this result.

In terms of distribution, all paint samples are closely grouped together. Considering that a large number of measurements were taken from sample Re/Ce, there is greater dispersion among the individual measurements in Fig. 14.

Most of the ochre samples have a higher concentration of Fe than the paint samples. The lower Fe content in the paint samples could be related to the poor preservation of the pigment, as well as a mixture with the rocky substrate. Considering the variability of Fe levels, this element was removed from the PCA calculations (see Fig. 14).

Some of the elements detected could also be attributed to potential

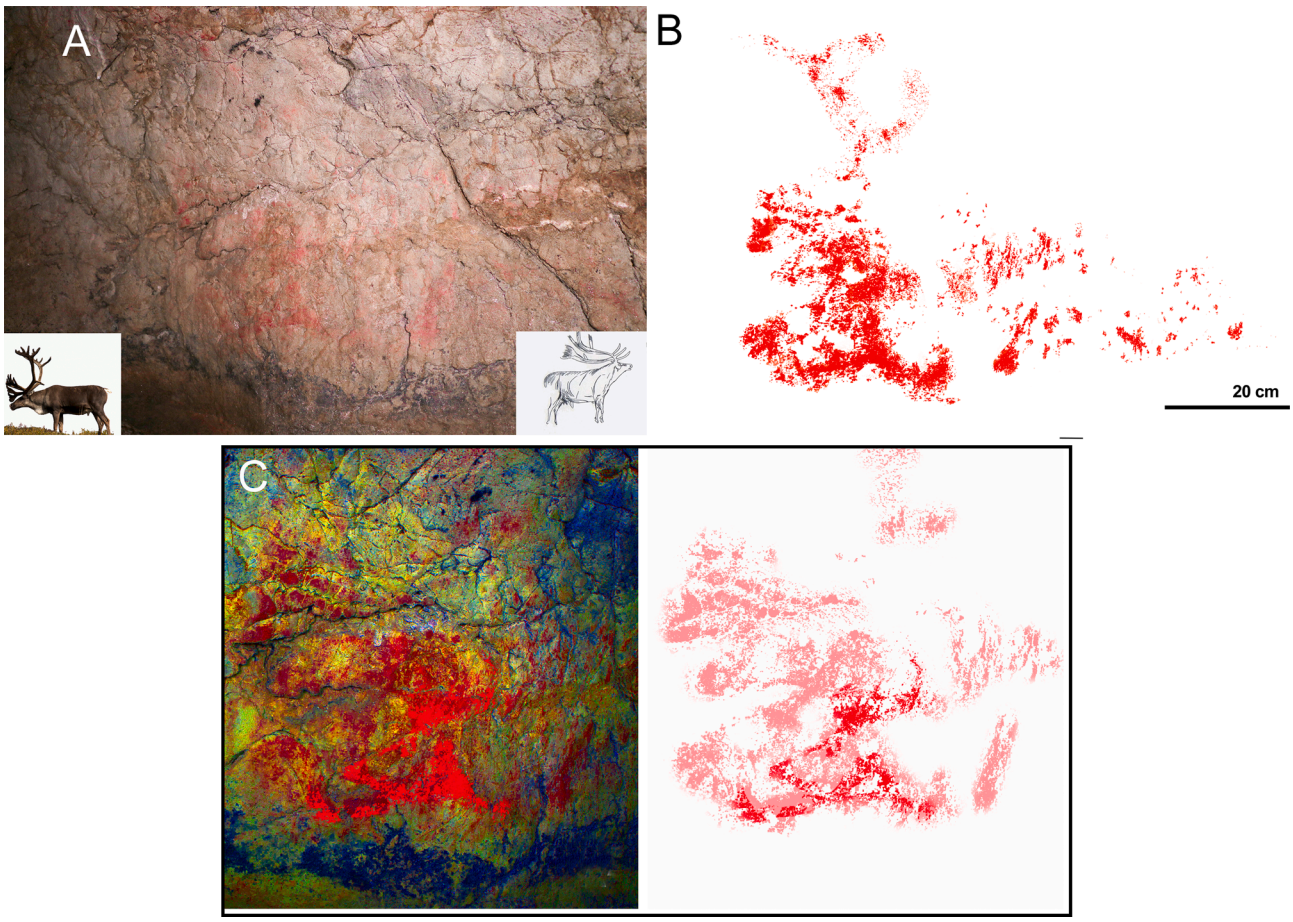

Fig. 11. A) Zoomorph interpreted as a possible deer or reindeer. On the left of the image there is a figure of a reindeer and on the right, a drawing of a deer (Cervus elaphus), recorded in the cave of Altamira (image taken from Bosinski, 1990), for comparison. B) Full copy of the zoomorph remains. C) Head of the quadruped. Part of the antlers are visible, over which part of the copy made by Sauvet (2015) is superimposed. Both copies are superimposed on the right. The latest copy, in the lighter tone, was carried out using a photograph with the DStretch filter.

contamination at a later stage. In this specific case, elements such as Ca, Sr, P and Si were removed from the calculations for this reason.

In level 1, a calcium carbonate crust around the edge of the site was observed. As this crust could also have contaminated the ochre samples, Ca was no longer considered in the PCA calculations. Given that, in some cases, the presence of Sr could be related to Ca in the calcium carbonate (substitutions in the crystalline structure), it was also decided to remove this element. Additionally, since water from the cave was likely used to prepare the red pigment, it could also have helped to generate a micro-crystalline network of additional calcite and bicarbonates, increasing the contribution of Ca in the paint samples.

The presence of P could have been caused by organic matter (droppings or microorganisms). Apatite was not detected by Raman spectroscopy, thus, the possibility of adding crushed bone to the pigment was rejected.

Fig. 14 shows the scores and loadings plot obtained after removing the elements mentioned previously. As can be seen, the measurements taken from the Re/Ce sample (yellow dots in Fig. 14) are located far away from the rest of the paint samples.

The conclusions that can be drawn from the scores and loadings diagram in Fig. 13, are quite similar to the results presented in Fig. 14: the pictographs are located close to each other, except for sample Re/Ce. The latter sample is far from the other samples, due to a higher contribution of elements such as S, K, Ti, V, Mn and Ni. Additionally, as detailed in Table 2, this sample contains a lower variety of elements at trace level. Ochre sample bx6 shows a more similar elemental composition, as compared with sample Re/Ce. In contrast, ochre samples bx8, bx11, bx12 and bx13 are located closer to the rest of the paint samples. However, there is no clear discrimination between the different ochre samples analysed and the group of paint samples.

4. Discussion

4.1. Artistic parallels

The presence of short vertical markings, either in pairs or alone, are more common in pre-Magdalenian paintings than in later stages of the Upper Palaeolithic (Garate et al., 2018). Some of these markings have been assigned in some studies to a topographical meaning and are found in many different caves, such as La Lloseta (Ribadesella, Asturias) (Balbín et al., 2005), Tito Bustillo (Ribadesella, Asturias) (Balbín et al., 2022), La Garma (Omoño, Cantabria) and El Cudón (Miengo, Cantabria) (Corchón and Garate, 2010; González-Sainz, 1999) and have been atributed to a pre-Magdalenian period.

However, there are some exceptions to this timeframe, such as the caves at Niaux (Ariège, France) and Etxeberri (Aquitaine, France),[2] which belong to the Late Upper Palaeolithic. As a result, researchers such as González-Echegaray and González-Sainz (1994) believe that this type of drawing was made over a long period of time, spanning multiple cultural eras.

[2] Pairs of red markings have been found at Etxeberri cave, associated with a red horse from the late Magdalenian period.

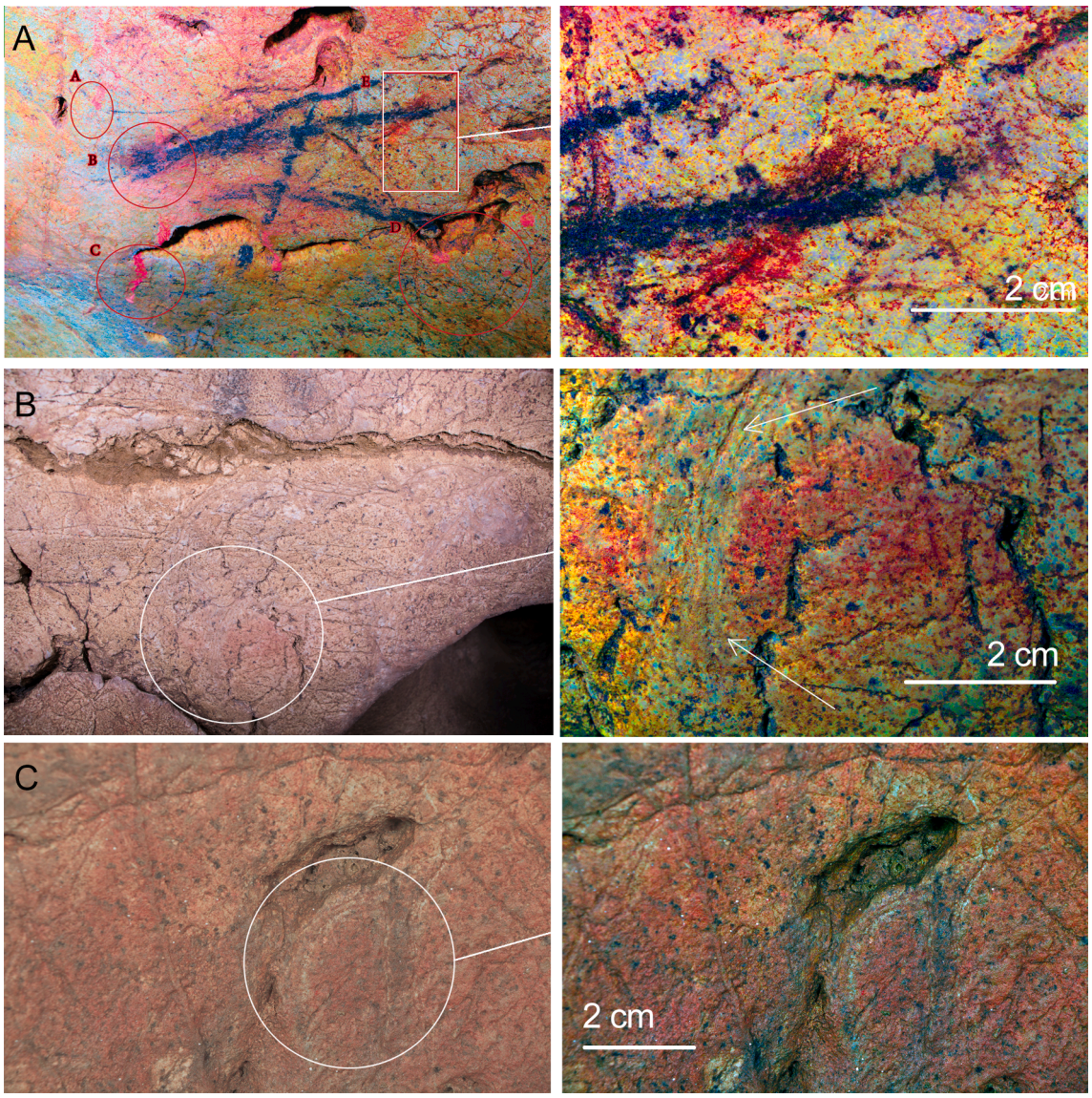

Fig. 12. Macro photographs of the overlaps found. A) Figure no. 12 m, below the "E" shaped figure. The circles highlight the overlapping drips. The rectangle and close-up on the right show the red mark underneath the black marking. B) Marking below the Solutrean horse. C) Marking no. 15e, below an engraved black painting of a deer.

Table 1
Results from Hernanz et al. (2012, p. 1647) corresponding to The Buxu cave (a.c., amorphous carbon; c.c., calcite crystals; h.c., haematite crystals; q.c., a-quartz crystals).

Sample	Mayor elements	Minor elements	Granular size	Cristal structure
BCi	Hematite, calcite, clay, wüstite, a.c.	K, P, Mn	h.c. < 10 μm. c.c. < 100 μm.	Disordered
BPA	Hematite, calcite, clay, α-quartz, a.c.	P, Ni, K, Mg	h.c. < 10 μm. c. c.≈100 μm. q.c. < 10 μm	Ordered
BPB	Hematite, clay, wüstite, calcite	K	h.c. < 30 μm. c.c. < 100 μm.	Ordered
BGS1	Hematite, wüstite, calcite, clay	Mn, K, P	h.c. < 10 μm. c.c. < 100 μm.	Ordered

Table 2
Elemental results obtained from EDXRF in this study; analysis of the samples belonging to pictographs from El Buxu. BCi: "E" shaped figure (no. 12 l); BPA: finger markings (no. 5c); BPB: small markings (no. 5f); BSG1: vulva figure (no. 23); Re/Ce: Zoomorph from the Great Chamber (no. 24).

Sample	Major elements	Minor elements	Trace elements*
BCI	Fe, Ca, Al	Si, P, K, Mn	S, Ti, Zn, As, Sr, Cu, Rb, Br, Ni, Pb
BPA	Fe, Ca, Al, Si	Mg, P, K, Ti, Mn, Ni	V, Cr, As, Zn, Sr, Pb, Ni, Cu, Rb, Y
BPB	Fe, Ca	P, K, Mn	Ti, Zn, Ni, Cu, Sr, Rb, As
BSG1	Fe, Ca, Al	Si, P, Mn	S, K, Sr, Cr, Zn, Ni, Cu, Zr, As, Pb, Ti, V
Re/ Ce	Fe, Ca, Al, Si	P. S. K, Ti. Mn	V, Ni, Zn, Sr

*Up to several μg/g.

El Buxu cave does not contain any identifiable pairs of red markings, which means we cannot draw any parallels in this regard. In terms of the vertical markings in the cave, no clear connections can be made with other caves or time periods, as they are so scarce and are not repeated. By contrast, Ondaro cave in Bizkaia contains a series of drawings dated to the Gravettian period, which follow a repetitive pattern. This pattern

Table 3
Elements present in the red ochre samples, relative to the substrate and their location in the deposit, Level 1: "De-Solutreanisation/Magdalenianisation" (period defined by Rasilla Vives, 1989), Levels 2 and 3: Solutrean (Menéndez, 1992; Quesada, 2016).

Level	Location	Sample	Major elements	Minor elements	Trace elements*
Level 1	**α Zone**	bx10	Al, Si, Ca, Fe	P, K, Ti	Mn, Zn, As, Cr, V, Cu, Sr, Rb, Y, Zr, Br
		bx12 (surface)	Al, Fe	P, Si	Mn, Sb, Sr, Zn, As, Y, Zr, Cu
	Sector C	bx13	Si, Al, Ca, Fe	K, Mn, Ti	Zn, Cu, Sr, As, Cr, Rb, Zr, Y, V, Br
	Sector A	bx11	Al, Si, Ca, Fe,	P, K, Mn, Ti	Zn, Sr, Cu, Ni, Zr, R
Level 2	**α Zone**	bx5	Al, Si, K, Ca, Mn, Fe	P, Ti, Sr, Zn	Rb, Zr, Y, V, Cu, Br, As, Pb, Cr, Ni
		bx6	Al, Si, K, Ca, Ti, Fe	P, Sr	V, Cr, Mn, Zn, Cu, Zr, Rb, Br, As
		bx7	Al, Si, Ca, Fe	P, K, Mn	Ti, V, Cr, S, As, Mo, Pb, Sr, Zn, Cu, Rb, Y
		bx8	Ca, Fe	P, K, Mn, Ti	Sr, As, Y, Zn, Ni, Cu, Zr, Cr, Rb
	Sector C	bx9	Al, Si, Fe	P, K, Ca	Ti, As, v, Zn, Cr, Sr, Cu, Zr, Rb, Y, S, Mn
Level 3	**α Zone**	bx1	Al, Si, K, Ca, Fe	P, Ti, Mn	Zn, Sr, As, V, Cr, Pb, Rb, Cu, Ni, Zr
		bx2	Al, Si, Ca, Fe	P	Pb, Rb, Si, Cr, V, Ti, Zn, As, Rb, S, Sr, Br, Zr
		bx3	Al, Si, Fe, Zn	P, Ca	Pb, Mn, Rb, Si, As, Cr, S, Sr, K, Ti, V, Br, Cu, Ni
		bx4	Al, Si, Fe		Ca, Ti, P, Pb, Sr, Rb, Si, K, Mn, Cr, V, Cu, Zn, As, S

*Up to several μg/g.

enables them to be matched to the groups of short pairs of finger markings and longer markings (Garate et al., 2018).

Instead of those long finger markings, the cave does contain *double and triple finger markings* which, given their location near the entrance and exit to crawl spaces and at the entrance to both niches, could have a topographic meaning too. Their closest parallels are found in other Asturian caves such as Tito Bustillo, in the Long Gallery and the Gallery of the Anthropomorphs (Balbín et al., 2022; Polledo, 2011), as well as La Lloseta (Balbín et al., 2005) and Balmori (Mallo and Suárez, 1972) which have a larger number of these as compared with other symbols, with all cases assimilated to the older stages of the Upper Palaeolithic.

In the Cantabrian region, red dots, both isolated and forming complex motifs are very common in Palaeolithic parietal art. Some researchers classify this type of evidence in four groups (Ontañón et al., 2018), depending on their representation in comparison with other red signs in caves. In this sense, we may classify this cave in the group two, in which the dots are the most common motif, but not the only one. This group is formed by caves like Chufín, el Portillo, La Meaza, Cudón, Calero II and Praileaitz I, all of them attributed to pre-Magadalenian periods.

The *two markings connected to natural holes* recorded in El Buxu, are found in palaeolithic art in various forms. In eastern Asturias, we find several of these markings in caves such as El Covarón (García-Alonso, 2019), taking the form of groups of dots at Mazaculos (La Franca, Llanes) (González-Echegaray and González-Sainz, 1994), La Riera (Posada de Llanes) (Mallo and Suárez, 1972), and La Lloseta (Ribadesella) (Balbín et al., 2005).

The *vulva drawings* are typically dated to the Aurignacian and Gravettian eras, and given that they comprise thematic figures in their own right, they appear throughout prehistoric art in a variety of forms and techniques. In the Dordogne (France), there are multiple engravings of vulva symbols, typically appearing in rounded form and divided by a central line. In terms of structure, the closest resemblances to the marking found at El Buxu – albeit using a different technique – are the examples at La Ferrassie cave (Fig. 15B) and Abri du Poisson (Fig. 15C). Both of these share a similar inverted "U" shape, with a straight or oval-shaped base and open, rounded arms, with an indentation running through the centre, rather than the bisected line found at sites such as

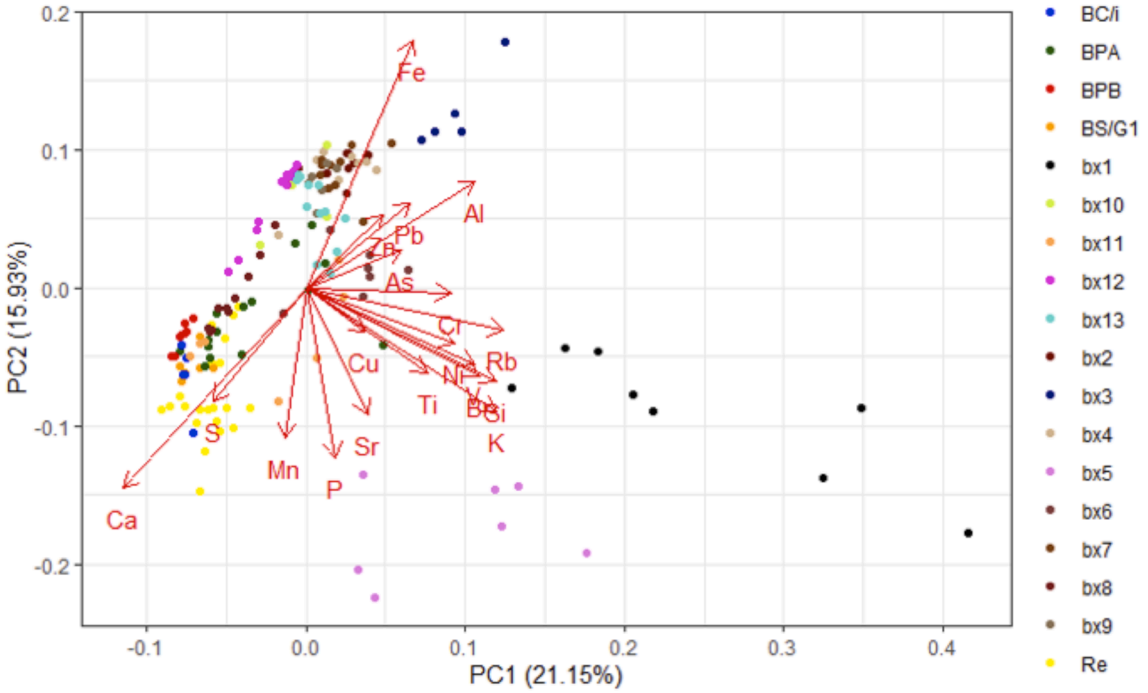

Fig. 13. Scores and loadings plot calculated from the semi-quantitative values for the elements detected in all measurements acquired on all paint and ochre samples.

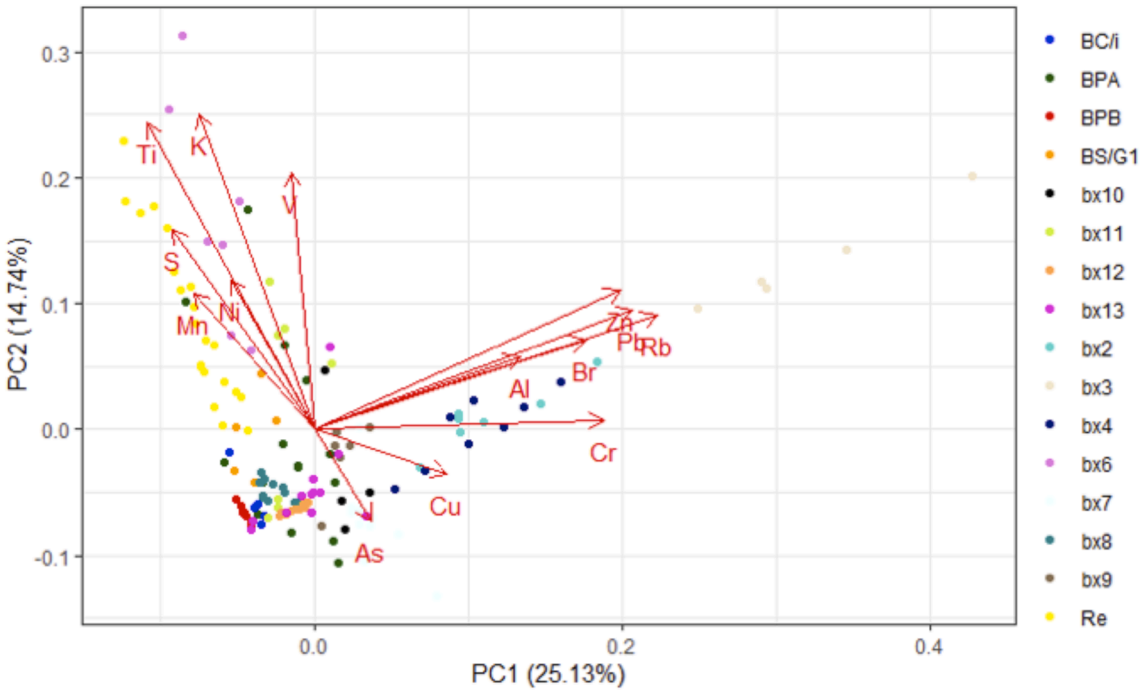

Fig. 14. Scores and loadings plot calculated considering all measurements acquired on all paint and ochre samples, excluding Fe, Ca, P, Si and Sr from the calculation.

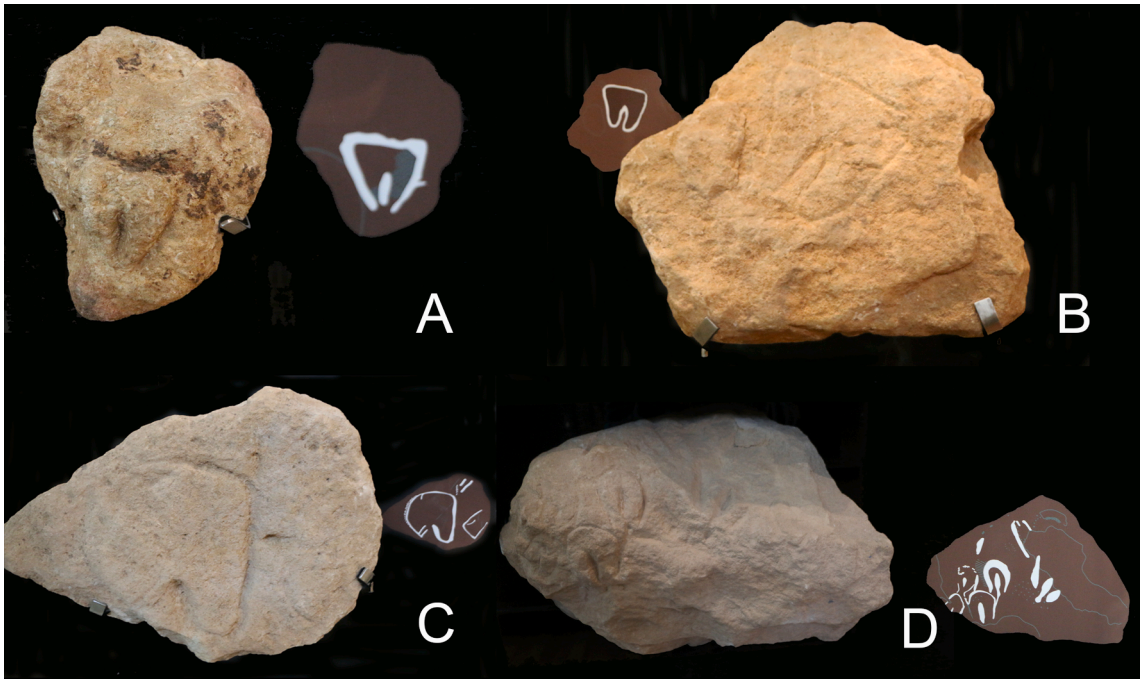

Fig. 15. Engraved vulva figures from the Dordogne caves. A) La Ferrassie (Aurignacian); B) La Ferrassie (Aurignacian); C) Abri du Poisson (Aurignacian); D) Abri du Cellier (Aurignacian) (Musée de la Préhistoire de Les Eyzies. Dordogne)(Photo: B.G.A.).

Abri du Cellier (Fig. 15D) or the first example from La Ferrassie (Fig. 15A). In any case, both of these forms are accepted as symbols representing a vulva.

In Asturias, vulva figures can also be found at sites near El Buxu cave, at Tito Bustillo (Balbín and Moure, 1981; Balbín et al., 2022; panels 1 and 2 of the grouping III) (Fig. 16A) and El Sidrón (Duarte et al., 2019; Rasilla, 2012) (Fig. 16D). At the first site, the figures take a closed or open rounded form within a female outline. At the second site, researchers have defined these figures as omega-shaped symbols, some of which are divided by a base line or bisector. Furthermore in the region of Cantabria there is a vulvar sign in El Castillo cave (Fig. 16E), which is quite similar to the located at Tito Bustillo.

These figures have been dated to the Aurignacian and Gravettian periods (Balbín, 2014; Menéndez, 2014; Bourrillon, 2009; Duarte et al., 2019; Rasilla et al., 2018), so it is quite likely that the figure at El Buxu dates to a similar era.

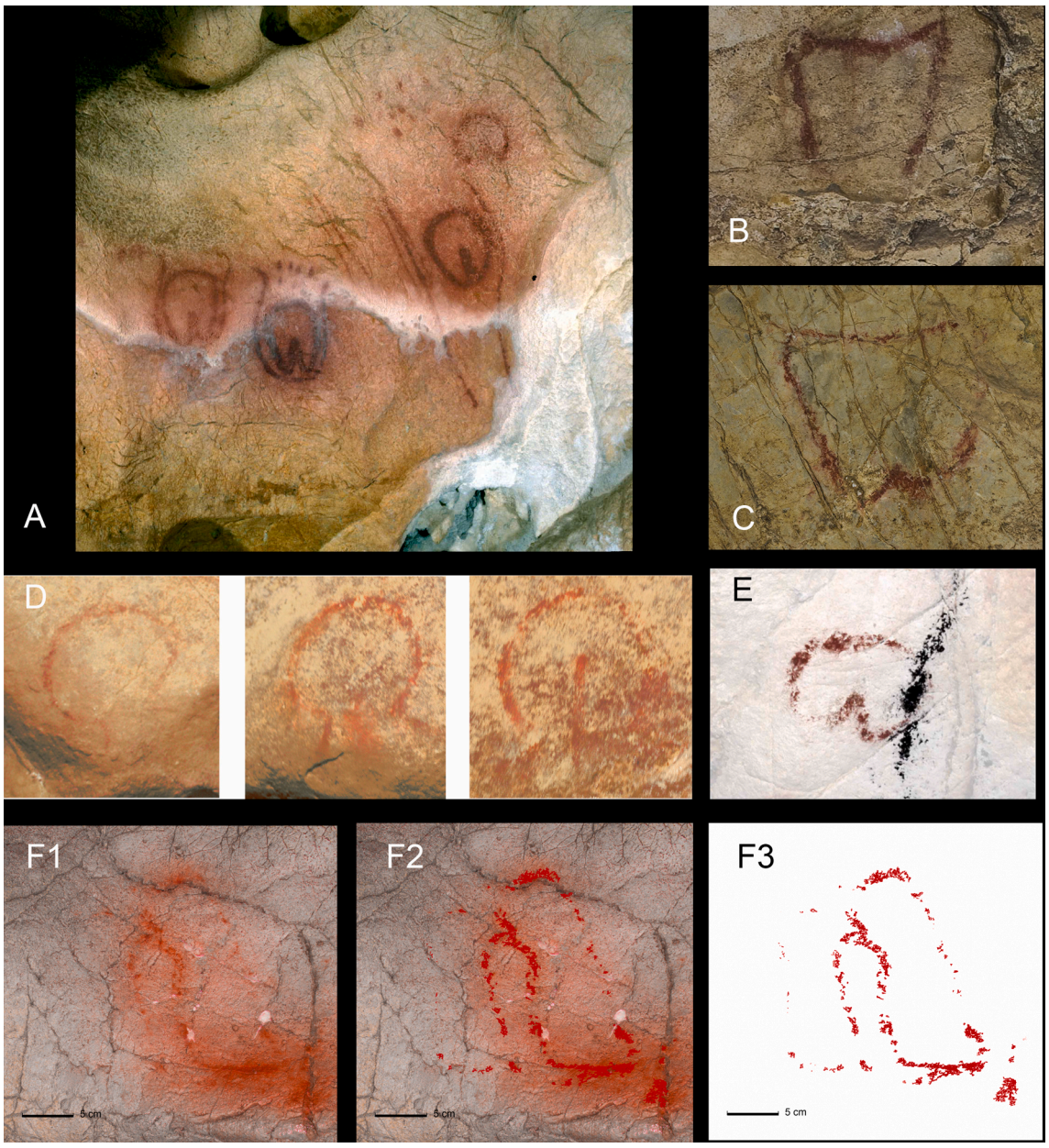

Fig. 16. Vulva figures. A) Tito Bustillo (Spanish Cultural Heritage Institute. National Inventory of Rock Art). B and C) Symbols referred to as 'scutiforms' from El Pindal cave (González-Pumariega, 2011), initially dated to the Aurignacian and Gravettian periods. (Photographs from the Government of the Principality of Asturias; Photo credit: Sergio Ríos); D) Globular or vulva forms from El Sidrón (Asturias) (Samaniego, 2016); E) Vulva sign from El Castillo cave (Cantabria) (Samaniego, 2016); F1)Vulva figure from El Buxu and its respective copies, F2 and F3.

There are also similarities with at least one of the 'scutiforms' painted in El Pindal cave, which were dated to the Aurignacian period in descriptions by Breuil (1952), Jordá (1976) and Jordá and Berenguer (1954), although later publications place them in the Magdalenian period, in line with the overall chronology of the cave (González-Pumariega, 2011) (Fig. 16B and C). Fig. 16 F1, F2 and F3 show the evolution of the vulva copy from El Buxu with a similar structure to some of the previous examples.

We do not know whether the *"E" shaped figure* is a complete symbol, as it has been smudged. However, if we assume it always had that shape, then it is similar to a marking known as the "symbolic inscription" found in Gallery B at La Pasiega cave (Cantabria) (Breuil et al., 1913) (Fig. 17A). There is another similar sign (no. 99 located in XC zone), in Tito Bustillo cave, which is known as "pectiniform" (Balbín et al., 2022) (Fig. 17B). At La Pasiega, this "E" shaped symbol is located on the right-hand side of a larger grouping. The upper and lower lines are slightly open and the only difference with the figure at El Buxu is the two lines in the middle where two tiny dots appear on top, while the figure at El Buxu is drawn with one single line running along the same length as the two ends (Fig. 17C and 17D).

The "inscription" figure has never been dated, but it is located in Gallery A in the cave, which contains a multitude of red markings dated to pre-Magdalenian periods.

As for the *zoomorphic figure*, understood to be a reindeer in this case, a similar drawing is found in Gallery A at La Pasiega cave (Balbín and González-Sainz, 1993; González, 2001). This example has a regular profile, facing to the left, with an oblique biangular form. It has three limbs and a set of well-defined antlers, branching out with the main beam facing forward. The loin and withers are marked, along with a double outline of the hind legs, as well as the chest line. It is drawn with

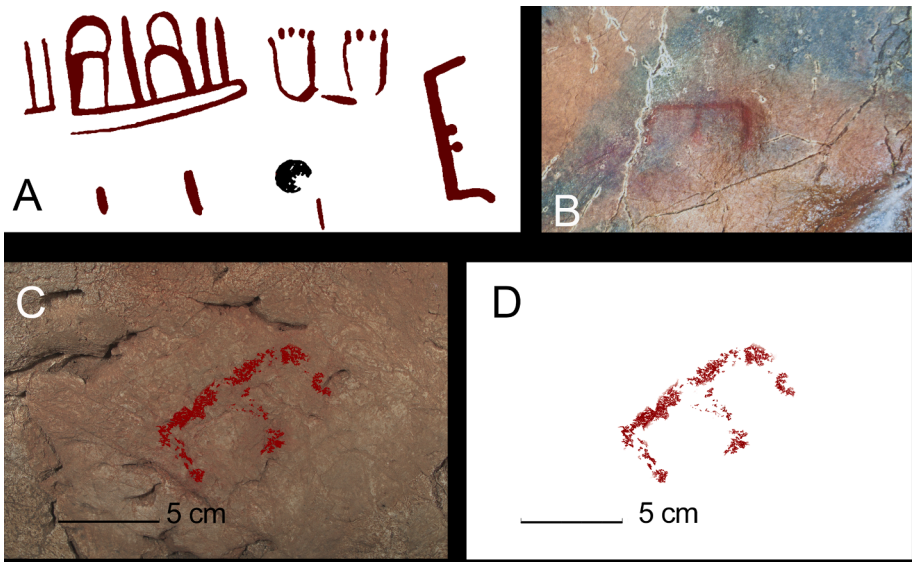

Fig. 17. A) Copy of the "Inscription" from panel no. 49 in Gallery B at La Pasiega (Cantabria) (Breuil et al., 1913); B) Sign no. 99 at XC zone, from Tito Bustillo cave (Balbín et al., 2022); C and D) Copies of the "E" shaped figure at El Buxu.

a fine line, although this is wider in places (Garate, 2010; PAS/A. VIII.138) (Fig. 18A).

Another reindeer is drawn in red on a flat surface in La Lloseta cave, although the image is more faded and uncertain. This drawing has been asimilated to the pre-Magdalenian period (Balbín et al., 2005) (Fig. 18B).

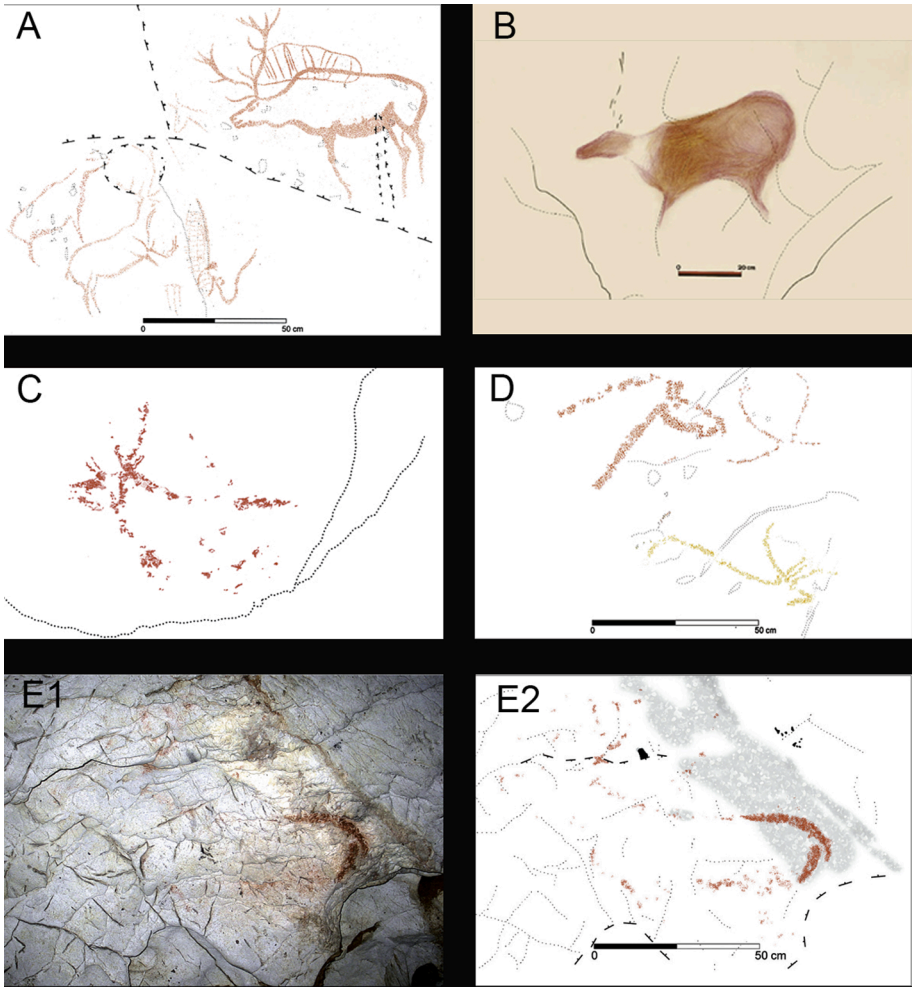

Fig. 18. A) Reindeer from La Pasiega A cave (Garate, 2010, Part II, Fig. 118); B) Reindeer from La Lloseta (Balbín et al., 2005; Fig. 62); C) Deer from El Salitre cave (Garate, 2010, Part II, Fig. 52); D) Deer from La Pasiega cave (Garate, 2010, Part II, Fig. 86); E1 and E2) Deer from El Castillo cave (Garate, 2010, Part II, Fig. 135).

If we understand the figure at El Buxu to be a possible deer, then it would have a greater number of parallels painted in red, using a continual line or a series of dots. Researcher Garate (2010) counted a total of 27 deer painted in red in caves across northern Spain. Of these drawings, the most similar examples are found in El Salitre cave (Miera, Cantabria) (Garate, 2010; SA2/A.I.1) (Fig. 18C), with a complete body facing left, an oblique profile, a full set of antlers and an overlapping dotted line; La Pasiega (Garate, 2010; PAS/ A.I. 13) (Fig. 18D), which faces right, pointing downwards with full antlers, although not branching off in the same way as the deer at El Buxu. Lastly, it is very similar to the deer at the zoomorph of El Buxu, the one located at El Castillo cave (Garate, 2010; CAS/A.IV. 36) (Fig. 18E1 and E2), which has lost part of the front of its chest, its head and part of its antlers. The antlers are horizontal and have a regular profile, facing to the left. Its rump is broadly defined, as are the tail and the start of the hind quarters.

In terms of the chronology of the red zoomorphic figures, whether drawn with fine lines, broad lines, dots or stamping, there appears to be a consensus – after several revisions – around the idea that this tradition spanned a long period of time, developing and acquiring a level of specification among certain groups in the late pre-Magdalenian era, although this tradition could also have started in the Aurignacian period (Garate, 2010). In any event, the caves at El Salitre and La Pasiega A are dated to pre-Magdalenian periods by different authors (Corchón, 1994; Moure et al., 1991). Meanwhile, González-Sainz places the red dotted figures in a wider timeframe, coexisting with other styles in northern Spain, beginning in the Gravettian or Aurignacian period and lasting until the Solutrean (González-Sainz, 1999). This idea is also shared by Garate (2010) in his detailed study of these pictographs.

4.2. Connections between the red pictographs and other graphic elements. Overlaps and location of remains

In terms of the relationship between the different pictographs inside the cave, none of the red paintings overlap with each other, nor do they have any connection with the other black paintings or engravings, beyond three isolated overlaps where they always appear beneath Solutrean-era drawings, meaning that they are older and comprise the earliest artistic expressions recorded within the cave.

As regards their location, they occupy more private spaces such as the Great Chamber and the Niche, far away from the other images found in the cave. The majority of these drawings are found on the lower parts of the walls, in crawl spaces and cramped areas. By contrast, other drawings in the region dated to the Magdalenian era – with several exceptions and differences – tend to appear in open and visible areas within the caves, with a great deal of overlaps. In the so-called "aggregation" caves, such as Tito Bustillo, these drawings appear as scenes with varying zoomorphs and series of images that appear to span long periods of time. At El Buxu, most of the Magdalenian-era drawings are found in the Niche and area D, with obvious overlaps that clearly differentiate them from the red paintings.

4.3. Similarity between red paintings and results of chemical analyses

The features described above seem to indicate some similarities among the red paintings analysed, as compared with the other art found in the cave. In this regard, the elemental composition of the samples taken from the red pictographs does appear to be quite similar. The zoomorphic figure (sample Re/Ce) differs slightly in its composition, due to the presence of specific elements. Considering the poor state of preservation of the sample, the considerable impact of the rocky substrate around it could well have caused the differences found in its elemental composition, as compared with the rest of the paint samples.

Looking at the data from the analysis carried out by Hernanz et al. (2012), there are also certain resemblances between the pictorial samples, especially between BPA (finger markings; no. 5c) and BPB (small irregular marking; no. 5f), as well as between BGS1 (the vulva figure, no. 23) and BCI (the "E" shaped figure, no. 12 l), with the main difference being the presence of amorphous carbon, which, as explained above, could be the result of material being added to it during the attempt to rub off the figure.

Considering the presence of elements that were potentially not included in the original composition of the paintings, which could relate to contaminants or have come from the substrate or the supporting rock, and which could have affected the results of the initial analysis, a deeper analysis was subsequently made with certain elements removed before carrying out the PCA again (Fig. 14). The results from the pictograph samples do not appear to vary greatly, while the ochre samples do seem to be quite different. Scores and loadings plot (Fig. 13), including all elements and variables after removing the elements derived from the rocky substrate and other contaminants, shows the ochre samples as seemingly further away from the paint samples (Fig. 14). The samples tend to draw closer, especially sample bx6 taken from level 2 and others from level 1, although there is no way of confirming a definitive connection between them. In order to clarify this, sampling would need to be expanded to additional pictorial remains, especially those containing possible external elements that could indicate potential additions or contaminations.

Equally, despite the regular nature of the red figures, it is impossible to determine a total similarity among all of these remains. The wide range of irregular markings and a few involuntary finger markings could have been made accidentally, due to a body or clothing covered in ochre rubbing against the surface (Medina-Alcaide et al., 2017). This could have occurred at different times, even during eras when other artistic techniques were being used, which would explain why some of the ochre samples from different strata are closer to this type of pictograph.

5. Conclusions

The primary objective of this investigation was to analyse the different evidence and data provided by the paintings and ochre remains found at El Buxu, adopting a multi-disciplinary approach, in order to shine a light on the story behind the red paintings in the cave, as well as attributing them to a possible cultural and stylistic framework. To this end, a working protocol was developed that brings together all available evidence and data: the data relating to the style, structure and location of the paintings, the evidence provided by the scarce examples of overlapping painted strata, and the potential links that can be made via compositional and chemical analysis of the different pigments in the cave and the ochres found on the strata.

Of this evidence, the closest approximation to a cultural framework is found in the parallels interpreted between the red figures. Firstly, the vulva figure, which has always been connected to the earlier stages of the Upper Palaeolithic, and the zoomorphic figure, which this study has redefined as a possible deer or reindeer, and which can be placed within a broad pre-Magdalenian timeframe, coinciding with other red dotted or linear paintings found in northern Spain.

The very scarce examples of overlapping layers of colour indicate in all cases that the red paintings were the earliest artistic expressions made inside the cave. Perceived preferences in terms of location, context, technique and method, display a unique and isolated evolution, as compared with the other Solutrean and Magdalenian art forms found inside the cave.

In El Buxu cave, finger markings in groups of two or three dots, were painted using only red pigment. However, these smaller markings could have also been involuntary left by the occupants of the cave who were responsible for the Solutrean and Magdalenian paintings and engravings, and not purposefully painted. The chemical similarities found between some of the ochre samples in the Solutrean strata and some of the pictographs analysed, may support this idea, although it has not been possible to establish a clear connection between these elements. A larger sampling is therefore needed, including potential samples of the supporting earth and rock, in order to definitively confirm these possible

connections.

The links drawn among the pigments in the chemical analyses display similarities among the paint samples, except for the case of the zoomorphic figure. This figure's lack of similarity across some of the metrics seems to be caused by the diversity of the sample itself, as well as potential contamination from the supporting rock.

The review of the analyses carried out using new analytical techniques complements the work of previous researchers in this cave and helps add to the range of chemical studies being carried out in caves across northern Spain.

Equally, the level of specificity of these techniques, which provide information on trace elements with sensitivity levels down to tens of μg/g, along with their non-destructive nature, will facilitate the comparison of results from future on-site sampling/analysis carried out in this cave and other caves across northern Spain. However, it would be prudent to establish a systematic methodology when it comes to acquiring spectral data with these techniques, as well as for the subsequent data processing, in order to enable a more direct comparison across all investigations.

CRediT authorship contribution statement

Beatriz García-Alonso: Conceptualization, Investigation, Visualization, Writing – original draft. **Mario Menéndez Fernández:** Conceptualization, Resources, Funding acquisition, Project administration, Supervision, Writing – review & editing. **Silvia Pérez-Diez:** Methodology, Investigation, Formal analysis, Writing – review & editing. **Maite Maguregui:** Methodology, Investigation, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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References

Arias, P., Pérez Suárez, C., 1994. Las pinturas rupestres paleolíticas de El Covarón: (Parres, Llanes, Asturias). Zephyrus: Revista de prehistoria y arqueología 46, 37–76.

Arias, P., Laval, E., Menu, M., González-Sainz, C., Ontañón, R., 2011. Les colorants dans l'art pariétal et mobilier paléolithique de La Garma (Cantabrie, Espagne). L'Anthropologie 115 (3–4), 425–445. https://doi.org/10.1016/j.anthro.2011.05.005.

Balbín Behrmann, R. de, 2014. Los caminos más antiguos de la imagen: el Sella. In: Blas Cortina, M.A. de, Cortina de (Eds.), Expresión Simbólica Y Territorial: Los Cursos Fluviales Y El Arte Paleolítico En Asturias. Real Instituto de Estudios Asturianos, Oviedo, pp. 65–91.

Balbín Behrmann, R. de, Alcolea González, J.J., Alcaraz Castaño, M., Bueno Ramírez, P., 2022. La Cueva de Tito Bustillo. Ribadesella. Asturias. Consejería de Cultura, Política Lingüística y Turismo, Gijón. Asturias.

Balbín Behrmann, R. de, Alcolea González, J.J., González Pereda, M.A., 2005. La Lloseta: une grotte importante et presque méconnue dans l'ensemble de Ardines, Ribadesella. L'Anthropologie 109 (4), 641–701. https://doi.org/10.1016/j.anthro.2005.09.010.

Balbín Behrmann, R. de, Alcolea-González, J.J., 2009. Les colorants de l'art paléolithique dans les grottes et en plein air. L'Anthropologie 113 (3–4), 559–601. https://doi.org/10.1016/j.anthro.2009.09.012.

Balbín Behrmann, R. de, González-Sainz, C., 1993. Nuevas investigaciones en la cueva de la Pasiega (Puente Viesgo, Cantabria). Boletín del seminario de estudios de arte y arqueología 59, 9–38.

Balbín Behrmann, R. de, Moure Romanillo, A., 1981. Las pinturas y grabados de la cueva de Tito Bustillo: El Sector Oriental. Universidad de Valladolid, Departamento de Prehistoria y Arqueología.

Bosinski, G., 1990. Les civilisations de la préhistoire. Les chasseurs du Paléolithique supérieur (40.000-10.000 av. J.C.). Errance, Paris.

Bourrillon, R., 2009. Les représentation humaines sexuées dans Íart du Paléolithique supérieur européen: diversité, reminiscences et permanences. [Doctoral Thesis. Universidad de Toulouse]. Available from: <https://www.sudoc.fr/160104033>.

Breuil, H., Obermaier, H., -Alcalde del Rio, H., 1913. La Pasiega a Puente-Viesgo (Santander. In: Espagne), 4. Impr. artistique. V A. Chene.

Breuil, H., 1952. Quatre cents siècles d'art pariétal : les cavernes ornées de l'âge du renne. Centre d'études et de documentation préhistoriques.

Cabrera Garrido, J.M., 1981. Conservación de la Cueva de Altamira: Sugerencias para un programa de trabajo. In: Altamira symposium. Actas del Symposium Internacional Sobre Arte Prehistórico (1879-1979). Madrid, Asturias, Santander, 1979, Ministerio de Cultura, Madrid, pp. 621–642.

Catelli, E., 2018. La prehistoria del color: Función y significado del ocre en el Paleolítico superior y Mesolítico del suroeste de Europa. [Doctoral Thesis. Universidad de Cantabria]. Available from: <http://hdl.handle.net/10902/15105>.

Chalmin, E., Menu, M., Altuna, J., 2002. Les matières picturales de la grotte d'Ekain (Pays Basque, Espagne). Munibe 54, 35–51.

Corchón, M.S., 1994. Le Solutréen de la région cantabrique. Relations avec le Portugal. In: Le SolutréEn En PéninsuLe Ibérique. Musée Départemental de Solutré, pp. 39–74.

Corchón, M.S., 2004. Europa 16500–14000 a.C.: un lenguaje común. In: Arias Cabal, P., Ontañón Peredo, R. (Eds.), La Materia del Lenguaje Prehistórico. El arte mueble paleolítico en su context. Universidad de Cantabria, Santander, pp. 105–126.

Corchón, M.S., Garate, D., 2010. Nuevos hallazgos de arte parietal paleolítico en la cueva de La Peña (San Román Candamo). Zephyrus 66, 75–102.

Corchón, M.S., Garate, D., Rivero, O., Ortega, P., Hernando, C., 2014. Arte parietal paleolítico de la cueva de La Peña (Candamo, Asturias): Cien años después de Eduardo Hernández-Pacheco. In: Corchón, M.S., Menéndez Fernández, M. (Eds.), Cien años de arte rupestre paleolítico. Ediciones Universidad de Salamanca, pp. 31–51.

d'Errico, F., Dayet Bouillot, L., García-Diez, M., Pitarch Martí, A., Garrido Pimentel, D., Zilhão, J., 2016. The technology of the earliest European cave paintings: El Castillo Cave, Spain. J. Archaeol. Sci. 70, 48–65. https://doi.org/10.1016/j.jas.2016.03.007.

Duarte, E., Rasilla, M. de la, Cañaveras, J.C., Sánchez, S., Santos, G., Rogerio, M.Á., Díez, A.B., 2019. Las grafías parietales rojas de la Galería de las Pinturas de la Cueva de El Sidrón (Piloña, Asturias). In: García Atienzar, G., Barciela González, V. (Eds.), Sociedades prehistóricas y manifestaciones artísticas: imágenes, nuevas propuestas e interpretaciones. pp. 31–42.

Duarte, E., Utrilla, P., Mazo, C., Rasilla, M. de la, 2012. ¿Ecos asturianos en el Magdaleniense de Abauntz? Las interrelaciones cántabro-pirenaicas a través de los motivos decorativos en soporte óseo. Trabajos de Arqueología de Navarra 24, 5–54.

Edwards, H.G.M., 2005. Case study: prehistoric art. In: Edwards, H.G.M., Chalmers, J.M. (Eds.), Raman Spectroscopy in Archaeology and Art History. The Royal Society of Chemistry, London, pp. 84–96.

Fortea Pérez, F.J., 1981. Investigaciones en la cuenca media del Nalón, Asturias (España). Noticia y primeros resultados. Zephyrus 32, 5–16.

Fortea Pérez, F.J., 1994. Los "santuarios" exteriores en el Paleolítico cantábrico. Complutum 5, 203–220.

Fortea Pérez, F.J., 2001. Los comienzos del arte paleolítico en Asturias: aportaciones desde una arqueología contextual no post-estilística. Zephyrus: Revista de prehistoria y arqueología 53, 177–216.

Fortea Pérez, F.J., Rodríguez-Asensio, J.; Ríos, S., 1999. La grotte de Los Torneiros. (Castañedo del Monte, Tuñón, Asturies, Espagne) INORA, 24, Foix, 8-11.

Garate Maidagán, D., 2007. Problemas y Límites actuales en el estudio del arte parietal paleolítico: hacia un enfoque plural. Nivel Cero 11, 47–62.

Garate Maidagán, D., 2010. Las ciervas punteadas en las cuevas del Paleolítico. Una expresión pictórica propia de la cornisa cantábrica. Munibe (Antropología-Arkeología), suplemento 33. Sociedad de ciencias Aranzadi.

Garate Maidagán, D., Laval, É., Menu, M., 2004. Étude de la matière colorante de la grotte d'Arenaza (Galdames, Pays Basque, Espagne). L'Anthropologie 108 (2), 251–289. https://doi.org/10.1016/j.anthro.2004.06.001.

Garate Maidagán, D., González-Sainz, C.G., Intxaurbe Alberdi, I., 2018. Arte parietal paleolítico en la cueva de Ondaro (Narbarniz, Bizkaia). In: Kobie Serie Paleoantropología, 35. Diputación Foral de Bizkaia, Bilbao, pp. 37–48.

García-Alonso, B., 2019. Análisis y documentación de las pinturas rojas rupestres del oriente de Asturias en las cuevas de El Buxu y El Covarón. (UNED). Tesis doctoral inédita. Available from: <http://e-spacio.uned.es/fez/view/tesisuned:ED-Pg-HHAT-Bgarcia>.

García-Díez, M., 2001. Estudio de la materia colorante de las pinturas «del friso de las pinturas». In: Sanguino, J., González, Montes Barquín, R. (Eds.), La cueva de El Pendo: actuaciones arqueológicas 1994–2000, Ayuntamiento de Camargo. Gobierno de Cantabria, Santander, pp. 237–248.

García-Díez, M., Gómez, G., Vergés, J.M., 2007. Estudio de la materia colorante de las pinturas de la cueva de La Lastrilla. In: Muñoz, E., Montes, R. (Eds.), Intervenciones Arqueológicas en Castro Urdiales. Tomo III: Arqueología y arte rupestre paleolítico en las cavidades de El Cuco o Sobera y La Lastrilla. Ayuntamiento de Castro Urdiales, Gobierno de Cantabria, Castro Urdiales-Santander, pp. 267–273.

García-Díez, M., Eguizabal Torre, J., Arrizabalaga, A., 2008. La Cueva de Venta Laperra. El grafismo parietal paleolítico y la definición de territorios gráficos en la región cantábrica. Diputación Foral de Bizkaia.
Gay, M., Alfeld, M., Menu, M., Laval, E., Arias, P., Ontañón, R., Reiche, I., 2015. Palaeolithic paint palette used at La Garma cave (Cantabria, Spain) investigated by means of combined *in situ* and synchrotron X-ray analytica methods. J. Anal. At. Spectrom. 30 (3), 767–776. https://doi.org/10.1039/C4JA00396A.
Gay, M., Müller, K., Plassard, F., Cleyet-Merle, J.J., Arias, P., Ontañón, R., Reiche, I., 2016. Efficient quantification procedures for data evaluation of portable X-ray fluorescence – Potential improvements for Palaeolithic cave art knowledge. J. Archaeolog. Sci.: Rep. 10, 878–886. https://doi.org/10.1016/j.jasrep.2016.06.008.
González, R., 2001. Art et space dans les grottes paléolithiques cantabriques. Jérôme Millon, Grenoble.
González-Echegaray, J., González-Sainz, C., 1994. Conjuntos rupestres paleolíticos de la Cornisa Cantábrica. Arte Paleolítico. Complutum 5, 21–43.
González-Morales, M.R., 1990. El abrigo de Entrefoces. 1980-1983. Excavaciones Arqueológicas en Asturias 1983-1986, (1), Principado de Asturias, pp. 26–36.
González-Pumariega Solís, M., 2011. La cueva de El Pindal 1911-2011. Estudio de su arte rupestre cien años después de Les Cavernes de la Région Cantabrique. Ménsula Ediciones, Gijón, Asturias.
González-Sainz, C., 1999. Sobre la organización cronológica de las manifestaciones gráficas del Paleolítico. Perplejidades y algunos apuntes desde la región cantábrica. Edades 6 (2), 123–144.
González-Sainz, C., 2000. Representaciones arcaicas de bisonte en la región cantábrica. Spal 9, 257–277.
Harman, J., 2008. Using Decorrelation Stretch to Enhance Rock art Images. Recovered Agosto 2015, de http:// dstretch.com/AlgorithmDescription.html.
Hernanz, A., 2017. Pictorial matter. Physicochemical studies of prehistoric pictorial materials, In: Garate, D. (Dir.), Unzueta, M. (Coord.), Redescubriendo el arte parietal paleolítico. Últimas novedades sobre los métodos y las técnicas de investigación. Bizkaiko Foru Aldundia-Diputación Foral de Bizkaia, Kobie Serie Anejo, 16, Bilbao, pp. 101–114.
Hernanz, A., Gavira-Vallejo, J.M., Ruiz-López, J.F., Martín, S., Maroto-Valiente, Á., de Balbín-Behrmann, R., Alcolea-González, J.J., 2012. Spectroscopy of Palaeolithic rock paintings from the Tito Bustillo and El Buxu Caves, Asturias, Spain. J. Raman Spectrosc. 43 (11), 1644–1650. https://doi.org/10.1002/jrs.3145.
Hernanz, A., Gavira-Vallejo, J.M., Martin, S., Maroto-Valiente, A., de Balbín-Behrmann, R., Alcolea-González, J.J., Bueno Ramírez, P., 2018. Estudio espectroscópico de pinturas rupestres de la Cueva de Tito Bustillo (Ribadesella, Asturias). Arpi 07, 32–48.
Jordá Cerdá, F., 1969. Los comienzos del Paleolítico superior en Asturias. Anuario de Estudios Atlánticos 1 (15), 281–321.
Jordá Cerdá, F., 1976. Guía de las cuevas prehistóricas asturianas. Ayalga Ediciones, Salinas (Asturias).
Jordá Cerdá, F., Berenguer Alonso, M., 1954. La Cueva de El Pindal (Asturias). B.I.D.E.A., 23, 337–364. Oviedo.
Le Quellec, J.L., Harman, J., Defrasne, C., Duquesnoy, F., 2013. DStretch® et İamélioration des images numériques: applications à İarchéologie des images rupestres. Les Cahiers de ÍAARS 16, 177–198.
Mallo Viesca, M., Suárez Díaz-Estébanez, J., 1972. Las pinturas de las cuevas de La Riera y de Balmori. Zephyrus 23, 19–37.
Martínez-Villa, A., 2014. Nuevas evidencias de arte rupestre en el Paleolítico del valle Sella-Güeña: contexto y territorio. In: Cien años de arte rupestre paleolítico. Ediciones Universidad de Salamanca, pp. 301–318.
Medina-Alcaide, M.Á., Garate Maidagán, D., Sanchidrian Torti, J.L., 2017. Painted in red: In search of alternative explanations for European Palaeolithic cave art. Quat. Int. 491, 65–77. https://doi.org/10.1016/j.quaint.2016.08.043.
Menéndez Fernández, M., 1984a. La cueva de El Buxu: el arte parietal. Boletín del Instituto de Estudios Asturianos 38 (112), 755–802.
Menéndez Fernández, M., 1984b. La cueva de El Buxu. Estudio del yacimiento arqueológico y de las manifestaciones artísticas. Boletín del Instituto de Estudios Asturianos 38 (111), 143–185.
Menéndez Fernández, M., 1992. Excavaciones arqueológicas en la Cueva del Buxu (Cardes, Cangas de Onís). Excavaciones Arqueológicas en Asturias 1987-90 (2), Consejería de Educación. Cultura y Deporte, Principado de Asturias, pp. 69–74.
Menéndez Fernández, M., 1997. Historiografía y novedades del arte mueble Paleolítico en la Península Ibérica. Entemu Serie I 10, 129–173.
Menéndez Fernández, M., 1999. La cueva de El Buxu, Cangas de Onís: campaña de 1998 y resumen de los trabajos anteriores. Excavaciones Arqueológicas en Asturias 1995-98 (4). Consejería de Educación, Cultura y Deporte, Principado de Asturias, pp. 69–73.
Menéndez Fernández, M., 2003. Arte prehistórico y territorialidad en la cuenca del río Sella. In: Balbín Behrmann, R., Bueno Rodríguez, P. (Eds.), El arte prehistórico desde los inicios del siglo XXI: Primer Symposium Internacional de Arte Prehistórico de Ribadesella. Asociación Cultural Amigos de Ribadesella, pp. 185–200.
Menéndez Fernández, M., 2012. Territorialidad y territorio en los estudios paleolíticos. In: Arias Cabal, P., Corchón Rodríguez, M.S., Menéndez Fernández, M., Rodríguez-Asensio, A. (Eds.), El Paleolítico Superior Cantábrico: actas de la Primera Mesa Redonda, San Román de Candamo (Asturias), 26–28 de abril de 2007. Universidad de Cantabria, pp. 13–20.
Menéndez Fernández, M., 2014. Desde Candamo hasta la cueva del Pindal: un siglo de estudios del arte paleolítico en Asturias. Entemu 18, 205–226.
Menéndez Fernández, M., 2016a. Neandertales y humanos modernos: 30 años de investigaciones en el valle del Sella. In: de Blas Cortina, M.A. (Ed.), De cuevas y castros: cuatro líneas actuales de trabajo sobre fases paleolíticas, protohistóricas y antiguas en Asturias. Real Instituto de Estudios Asturianos, pp. 45–72.
Menéndez Fernández, M., 2016b. Arte rupestre paleolítico en la cueva de El Buxu (Asturias, España), en el centenario de su descubrimiento. Cuadernos de Arte Prehistórico 2016 (2), 7–31.
Menéndez Fernández, M., 2016c. La cueva de El Buxu y su emplazamiento. In: Menéndez Fernández, M. (Ed.), La Cueva del Buxu (Cangas de Onís, Asturias) en el centenario de su descubrimiento. Excavaciones arqueológicas en Asturias. Monografías IV. Consejería de Educación y GEA, Oviedo, pp. 16–18.
Menéndez Fernández, M., 2016d. El arte rupestre. In: Menéndez Fernández, M. (Ed.). La Cueva de El Buxu (Cangas de Onís, Asturias) en el centenario de su descubrimiento. Excavaciones Arqueológicas en Asturias. Monografías IV. Consejería de Educación y GEA, Oviedo, pp. 66–109.
Menéndez Fernández, M., García-Alonso, B., 2014. El nuevo horizonte de pinturas rojas de la cueva de El Buxu, Asturias, España. In: Corchón, M.S., Menéndez Fernández, M. (Eds.), Cien años de arte rupestre paleolítico. Centenario de la cueva de la Peña de Candamo. Ediciones Universidad de Salamanca, pp. 63–73.
Menéndez Fernández, M., Ocio Zapata, P., 1997. Novedades en el arte mueble y su relación con el arte rupestre en la cueva de El Buxu (Asturias). In: II Congreso de Arqueología Peninsular: Zamora, del 24 al 27 de septiembre de 1996. Fundación Rei Afonso Henriques, pp. 173–184.
Moure Romanillo, A., González-Morales, M., González-Sainz, C., 1991. Las cuevas de Ramales de la Victoria (Cantabria). Arte rupestre paleolítico en las cuevas de Covalanas y La Haza. Universidad de Cantabria, Santander.
Múzquiz Pérez-Seoane, M., 1993. Análisis de los pigmentos de la Cueva del Castillo. In: Cabrera Garrido, V. (Ed.), El origen del hombre moderno en el sur oeste de Europa. Universidad Nacional de Educación a Distancia (UNED), Madrid, pp. 259–262.
Navarro Gascón, J.V., 2003. Nuevos resultados obtenidos en el estudio de pigmentos y posibles materiales colorantes de las pinturas de la Cueva de Tito Bustillo. In: Balbín Behrmann, R., Bueno Ramírez, P. (Eds.), El arte prehistórico desde los inicios del siglo XXI: Primer Symposium Internacional de Arte Prehistórico de Ribadesella. Asociación Cultural Amigos de Ribadesella, pp.173–184.
Navarro Gascón, J.V., Gómez González, M.L., 2003. Resultados analíticos obtenidos en el estudio de pigmentos y posibles materiales colorantes de las pinturas de la Cueva de Tito Bustillo. In: Balbín Behrmann, R., Bueno Ramírez, P. (Eds.), El arte prehistórico desde los inicios del siglo XXI: Primer Symposium Internacional de Arte Prehistórico de Ribadesella. Asociación Cultural Amigos de Ribadesella, pp.161-172.
Obermaier, H., la Vega del Sella (Conde de), 1918. La cueva del Buxu (Asturias). Museo Nacional de Ciencias Naturales, Madrid.
Olivares, M., Murelaga, X., Castro, K., Garate, D., Hernando, C., Corchón, M.S., 2009. Análisis no destructivo de la materia colorante mediante instrumentación Raman portátil en el arte parietal de la cueva de La Peña (Candamo, Asturias). Excavaciones Arqueológicas en Asturias 2003–2006 (6), 187–192.
Olivares, M., Castro, K., Corchón, M.S., Garate, D., Murelaga, X., Sarmiento, A., Etxebarria, N., 2013. Non-invasive portable instrumentation to study Palaeolithic rock paintings: the case of La Peña Cave in San Roman de Candamo (Asturias, Spain). J. Archaeol. Sci. 40 (2), 1354–1360. https://doi.org/10.1016/j.jas.2012.10.008.
Olivares, M., Castro, K., Corchón, M.S., Garate, D., Murelaga, X., 2014. Estudio mediante instrumentación no invasiva y portátil de pinturas rupestres paleolíticas: el caso de la cueva de La Peña de San Román de Candamo (Asturias, España*)*. In: Corchón, M.S., Menéndez Fernández, M. (Eds.), Cien años de arte rupestre paleolítico: centenario del descubrimiento de la cueva de la Peña de Candamo. Ediciones Universidad de Salamanca, pp. 245–254.
Omar, J., Sarmiento, A., Olivares, M., Alonso, I., Etxebarria, N., 2012. Quantitative analysis of essential oils from rosemary in virgin olive oil using Raman spectroscopy and chemometrics. J. Raman Spectrosc. 43 (8), 1151–1156. https://doi.org/10.1002/jrs.3152.
Ontañón, R., Montes, R., Morlote, J.M., Muñoz, E., 2018. Cueva Auria (Peñarrubia, Cantabria, Spain): a new cave with Paleolithic rock art in Northern Spain. International Newsletter on Rock Art 80, 11–18.
Ospitali, F., Smith, D.C., Lorblanchet, M., 2006. Preliminary investigations by Raman microscopy of prehistoric pigments in the wall-painted cave at Roucadour, Quercy, France. J. Raman Spectrosc.: International Journal for Original Work in all Aspects of Raman Spectroscopy, Including Higher Order Processes, and also Brillouin and Rayleigh Scattering 37 (10), 1063–1071. https://doi.org/10.1002/jrs.1611.
Pereira Uzal, J.M., 2013. Gestión del color en proyectos de digitalización. Marcombo. Ediciones técnicas, Barcelona.
Pereira Uzal, J.M., 2017. Nuevas perspectivas en la documentación gráfica de arte rupestre. Kobie. Serie Anejo 16, 41–50.
Polledo González, M., 2011. El arte paleolítico de Tito Bustillo. Cazadores y artistas en el Pozúl Ramu. Ménsula Ediciones, Asturias.
Quesada López, J.M., 2016. El yacimiento arqueológico del Buxu y su excavación. In: Menéndez Fernández, M. (Ed.), La Cueva del Buxu (Cangas de Onís, Asturias) en el centenario de su descubrimiento. Excavaciones arqueológicas en Asturias. Monografías IV. Consejería de Educación y GEA, pp. 39–52, Oviedo.
Rasilla Vives, M. de la, 1989. Secuencia y crono-estratigrafía del Solutrense cantábrico. Trabajos de Prehistoria 46. https://doi.org/10.3989/tp.1989.v46.i0.585.
Rasilla Vives, M. de la, Rosas, A., Cañaveras, J.C, Lalueza-Fox, C., 2012. La cueva del Sidrón (Borines, Piloña, Asturias). Gobierno del Principado de Asturias. Consejería de Cultura y Turismo, Oviedo.
Rasilla Vives, M., Rosas, A., Cañaveras, J. C., Lalueza-Fox, C.L., Duarte, E., Sánchez Moral, S., Estalrrich, A., García Tabernero, A., Santos, G., Huguet, R., Bastir, M., Suárez, P., López Tascón, C., Fernández Cascón, B., Ríos, L., Pérez Criado, L., García-Martínez, D., Cuezva, S., Fernández Cortés, A., Muñoz, C., Silva, P.G., Rodríguez Pérez, F.J., Ferrando, A., 2018. La cueva de El Sidrón (Piloña): campañas de

excavación, investigación y difusión 2013-2016. In: Excavaciones arqueológicas en Asturias 2013-2016, pp. 9–20.

Ríos González, S., de Castro, G., Valdés, C., de la Rasilla Vives, M., Fortea Pérez, F.J., 2007. Arte rupestre prehistórico del oriente de Asturias. Ediciones Nobel, S.M. Llanera.

Rodríguez Asensio, J.A., 1992. Excavaciones arqueológicas en la cueva de La Lluera II, San Juan de Priorio, Oviedo. In: Excavaciones arqueológicas en Asturias 1987-90, pp. 29–32.

Rojo Hernández, J.R., 2016. La fauna cazada, consumida y representada en la cueva del Buxu. In: Menéndez Fernández, M. (Ed.), La Cueva del Buxu (Cangas de Onís, Asturias) en el centenario de su descubrimiento. Excavaciones arqueológicas en Asturias. Monografías IV. Consejería de Educación y GEA, Oviedo, pp. 53–58.

Ruiz López, J.F., Sebastián López, M., Quesada Martínez, E., Pereira Uzal, J.M., Fernández Ortiz de Vallurejo, S., Pitarch Martí, Á., Maguregui, M., Giakoumaki, A., Martínez, I., Madariaga, J.M., Lorente, J.C., Dólera, A., 2016. 4D· arte rupestre. Monitorización del Abrigo del Buen Aire I (Jumilla), Cueva del Mediodia (Yecla), Cañaica del Calar II (Moratalla), Abrigo Grande de Minateda (Hellín) y Solana de las Covachas (Nerpio). Monografías Centro de Estudios de Prehistoria y Arte Rupestre (CEPAR) 3. Murcia.

Ruiz López, J.F., Quesada Martínez, E., Pereira Uzal, J.M., 2019. Diagnosis and monitorif of rock art sites in "4D arte rupestre" projects. Les Nouveles de l'Archeologie 154, 1–6.

Rull, F., Gázquez, F., Medina, J., Sanz, A., las Heras, C. de; Prada, A., Lasheras, J.A., Calaforra, J.M., 2014. Caracterización de pigmentos utilizados en el arte rupestre de la Cueva de Altamira. In: Morales Ruano, S., Gervilla Linares, F., Torres Ruiz, J. (Eds.), Comunicaciones del Congreso SEM 2014. XXXIV Reunión científica de la Sociedad Española de Mineralogía (Granada, 2 a 7 de julio de 2014). Revista de la Sociedad Española de Mineralogía, Macla19. Madrid.

Samaniego Bordiu, B., 2016. Lenguaje visual prehistórico. Una propuesta metodológica. La Ergastula Ediciones, Madrid.

Santamaría Santamaría, S., Montes Barquín, R., Morlote Ex-pósito, J.M., Muñoz Fernández, E., 2010. Arte rupestre paleolítico en la Cueva de Cordoveganes I (Puertas de Vidiago, concejo de Llanes, Asturias). Hallazgo y primera documentación de un nuevo conjunto parietal en la región. Zephyrus 66, 57–78.

Sarmiento, A., Pérez-Alonso, M., Olivares, M., Castro, K., Martínez-Arkarazo, I., Fernández, L.A., Madariaga, J.M., 2011. Classification and identification of organic binding media in artworks by means of Fourier transform infrared spectroscopy and principal component analysis. Anal. Bioanal. Chem. 399 (10), 3601–3611. https://doi.org/10.1007/s00216-011-4677-0.

Sauvet, G., 2015. Una nueva figura roja en la cueva de El Buxu (Cangas de Onís, Asturias). Zephyrus 75, 165–172. https://doi.org/10.14201/zephyrus201575165172.

Sauvet, G., Fortea, J., Fritz, C., Tosello, G., 2008. Crónica de los intercambios entre los grupos humanos paleolíticos. La contribución del arte para el periodo 20.000-12.000 años BP. Zephyrus 61, 35–59.

Sauvet, G., Bourrillon, R., Garate, D., Petrognani, S., Rivero, O., Robert, E., Tosello, G., 2017. The function of graphic signs in prehistoric societies: The case of Cantabrian quadrilateral signs. Quat. Int. 491, 99–109. https://doi.org/10.1016/j.quaint.2017.01.039.