KEYWORDS: ***Palaeolithic maps – Altamira – La Pileta – Estrellas – Palomas***

SPACE AND LAND REPRESENTATION DURING THE UPPER PALAEOLITHIC: SIX ROCK ART CROQUIS IN SPANISH CAVES

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Images have two ways to capture the imagination:
for their beauty and for the ideas they contain.
Leroi-Gourhan, *Préhistoire de l´art occidentale*

Abstract. This article suggests that six complex and enigmatic Palaeolithic drawings in the Spanish caves of Estrellas, Palomas, La Pileta and Altamira could be interpreted as pre-Historic maps. The hypothesis is based on the similarities and correlations between each of the drawings, the corresponding modern maps, and the caves' immediate geographical surroundings from a visual and mathematical standpoint. Some reflect the cave's interiors, while others depict the surrounding territory, and each potential map is supported by at least two drawings, either complementary or sequential. The decoding of at least three Palaeolithic maps suggests that a new approach to interpreting some of the rock art 'signs' and the abstract capabilities of Palaeolithic humans should be considered.

Introduction

Palaeolithic sites provide evidence for the lifeways of Palaeolithic humans. The naturalistic paintings of animals demonstrate that they were exceptional artists capable of representing the world around them as their eyes saw it. They also left enigmatic signs that we have not been able to interpret convincingly after more than a century of study.

Cave paintings can be reductively divided into two categories: those whose interpretation appears straightforward—like zoomorphs—and so-called signs, the interpretation of which is not quite so obvious. The motivations behind the former and the meaning of the latter remain a mystery. Different morphologic classifications and interpretative theories have been proposed in the past, like art for art's sake, totemism, sympathetic magic, sexual dichotomies and shamanism (Mingo 2010; Sanchidrián 2018; David 2017). These proposals have ebbed and flowed over time, facing the difficulties of trying to prove a 'spiritual' and 'collective' interpretation theory and, as a result, the interpretation of signs has been discouraged.

However, science proceeds by investigating new data and accumulating previously ignored facts (Laming-Emperaire 1968). If we switch to a practical and individualised approach (Fig. 1a), it is possible to conclude that rock painting 'A' (the 'sign') and image 'B' (the map) represent the same object 'C' (the cave or the surrounding landscape) and therefore that 'A' is also a map of 'C'. This is possible because the 'signs', the space and the landscape are still today, as and where they were in the past, unlike ideas and culture. From a formal perspective, we present a semiotic analysis of the Palaeolithic' sign' and its correspondence to a modern sign (the map) under the verification that both represent the same physical reality. It is, therefore, not an exercise of interpretation but of decoding. Paradoxically, these specific sets of signs—the most complex in many caves—are the easiest to decode because of the large amount of objective data they contain once we discover that cartography is the 'ordering principle' behind them.

Coincidentally, the six croquis follow a simple 'sign+cave' cartographic pattern: on the one hand, the signs are complex, singular, natural and comprise pairs of dotted or continuous red lines. On the other hand, the caves house singular Palaeolithic rock art assemblages and their interiors or surroundings are topographically complex. Nevertheless, there are also differences: they belong to different Upper Palaeolithic periods and geographies, and different mapping symbols were used.

According to Delano (1987), pre-Historic populations produced surprisingly accurate maps owing to their enhanced sense of orientation, knowledge of the terrain, drawing skills, visual acuteness and 'spatialisation' that may have been the first major feature of human consciousness. She divides pre-Historic topographic representations into landscapes and maps

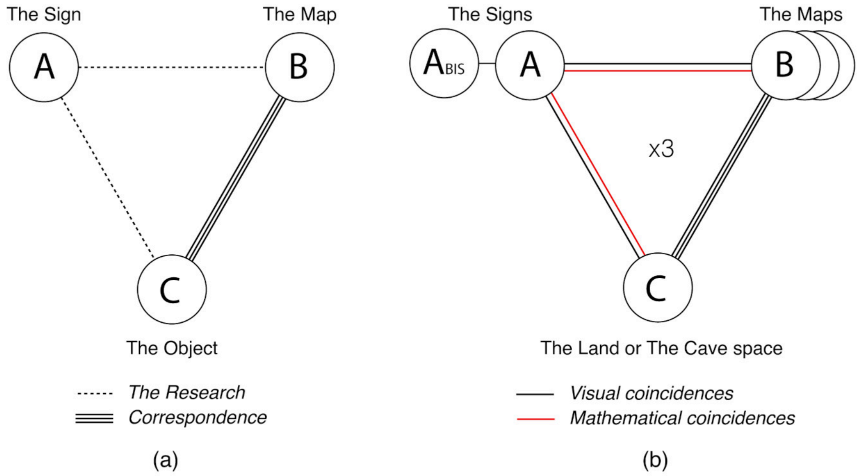


***Figure 1**. Decoding signs as croquis: (a) methodology and (b) customisation to our case.*

(ibid.: 68) and defines the conditions to be regarded as maps: all motifs should be contemporaneous and cartographically correct. First, it needs to be proven that the lines connect with one another neatly, neither overlapping nor lying in isolation; they must be stylistically identical, and they must contain repetitive elements. All these conditions, plus the second one—cartographic correctness—are met by all the croquis we present.

A more recent publication (Utrilla et al. 2021) has defined new criteria to identify pre-Historic maps based on their cartographic credibility and functionality, criteria that our croquis also meet. Utrilla and co-workers emphasised the pebble of Abauntz and the tusk of Mezhirich, both portable art. Concerning rock art, like our paintings, they included the drawings in Fuente del Trucho and Gargas, which could represent passes across the Pyrenees, and Tito Bustillo, which could represent the Sella River. Also, in 2021, Nicolas summarised the issue of pre-Historic maps and took a methodological leap by mathematically demonstrating the topographic nature of the Bronze Age slab of Saint-Bélec (Nicolas et al. 2021).

Methodology and limitations

This paper aims not to present a new interpretive theory but simply to suggest that these six drawings are maps. I recognised the similarities at first sight—in Estrellas and Palomas because I know the region well, and in the other two maps while reading Breuil's books about Altamira (1935) and La Pileta (1915). I developed a methodology (Fig. 1b) to confirm this hypothesis by comparing—for each of the three maps—two signs (main and complementary similar sign) with two non-arbitrary references (modern map and reality) through two non-arbitrary methods (visual and mathematical). Mnemonically, we could express this as 3x(2 x 2 x 2).

The comparisons are based on carbon copies, maps, texts, and photographs and on five mathematical tests for which the reference points have been selected according to objective criteria. The dates of the paintings, including the Aurignacian, Gravettian, Solutrean and Magdalenian periods, are based on published expert assessments.

This paper focuses on answering the factual 'what' question (maps). Outside the scope of the study lie all considerations regarding the conditions of possibility for the creation (the 'how' question), dissemination and use (the 'why' question) of these signs within their social context, which remains unclear.

I shall refer to the various maps or croquis under consideration with the acronym PPM (Possible Palaeolithic Map), followed by a number:

PPM1 refers to Las Estrellas.
PPM1.Bis refers to the 'twin' painting in Palomas.
PPM2 and PPM2.Bis refer to the paintings in La Pileta.
PPM3 and PPM3.Bis refer to the paintings in Altamira.

The following aspects will be examined for each cartogram:
General description of the drawing and the cave
Suggested meaning
Explanation of key similarities
Cartographic test and statistical analysis
Conclusions

PPM1: Estrellas

The first drawing interpreted as a possible Palaeolithic map is the enigmatic Panel 14 in Estrellas (Fig. 2), partially published in Spanish (Moreno García-Mansilla 2022). The panel is a large tree-like figure that comprises multiple bands of red paired dots, surrounded by other drawings.

Estrellas Cave is in Castellar (Cádiz) and was discovered in the 1990s. In 2014, Blanco identified the hand stencils and the large central panel formed by lines of paired dots in the ceiling (Fernández-Sánchez et al. 2020: 148). The paintings have been thoroughly analysed (technique, size, chronology) and are dated to the upper Palaeolithic (ibid.: 2019; Collado et al. 2019), but the meaning of Panel 14—*estrellas* means stars—remains unclear.

The northern shore of the Strait of Gibraltar has been inhabited without interruption since the Palaeolithic, and the region's pre-Historic heritage includes over 250 caves. The people moved seasonally across a rugged terrain, with valleys, hill ranges, rivers and lagoons.

Red dots are a recurrent and enigmatic motif in cave art in Spain. Interpreting their meaning is not a straightforward task, and several tentative proposals have been put forth, including stars, constellations, maps and calendars (Moreno García-Mansilla 2022).

PPM1: Suggested meaning

Our interpretive model is based on the premise that the sequence of paired dots has spatial value: Panel 14 could be a geographical map or croquis of the northern shore of the Strait of Gibraltar, in which the lines of paired dots represent routes that link the main Palaeolithic sites in the region, avoiding geographical barriers such as coastlines, rivers, hills, and lagoons. They could also divide the territory, especially in relation to water courses (Caro Baroja 1946: 99). The hypothesis is based on the visual and statistical coincidences between the Palaeolithic drawing and the geographical features of the region at the time.

As a key reference map, we have used the oldest and most accurate map available for Cadiz (Junta de Andalucía 2010), made by Coello in 1868. This map still features the Lagoon of La Janda, a vital feature of the pre-Historic landscape, which dried out in the 20th century. Figure 3 compares the carbon print of Panel 14 of Estrellas and that of Coello's road map, including geographical features that condition the road network and the main Palaeolithic sites. These sites (red dots) were chronologically and geographically characterised by Breuil and Burkitt (1929: Maps A-G); Ramos et al. (2008: multiple maps); Fernández-Sánchez et al. (2019); Topper (1988) and Solís (2020). Roman roads and cities are cited as references (Sillieres 1990; Thouvenot 1940) as these are the region's earliest known mentions of road networks.

PPM1: Explanation of key similarities

To simplify the argument detailed in the previous paper, we divide the map into three sections. Section 1 covers the northern coast of the strait: Gibraltar, Tarifa, Barbate and Vejer. Although the latter is no longer on the coastline, in the Roman period, before the mouth of the Barbate River silted up, the town was on the seashore. The section includes fifteen Palaeolithic sites, which have been a rich source of fish since antiquity.

Depending on the date of the map, the itinerary would be more or less distant

Figure 2*. Panel 14 in Estrellas Cave, Cádiz (Source: Zephyrus LXXVIII, 2019:25).*

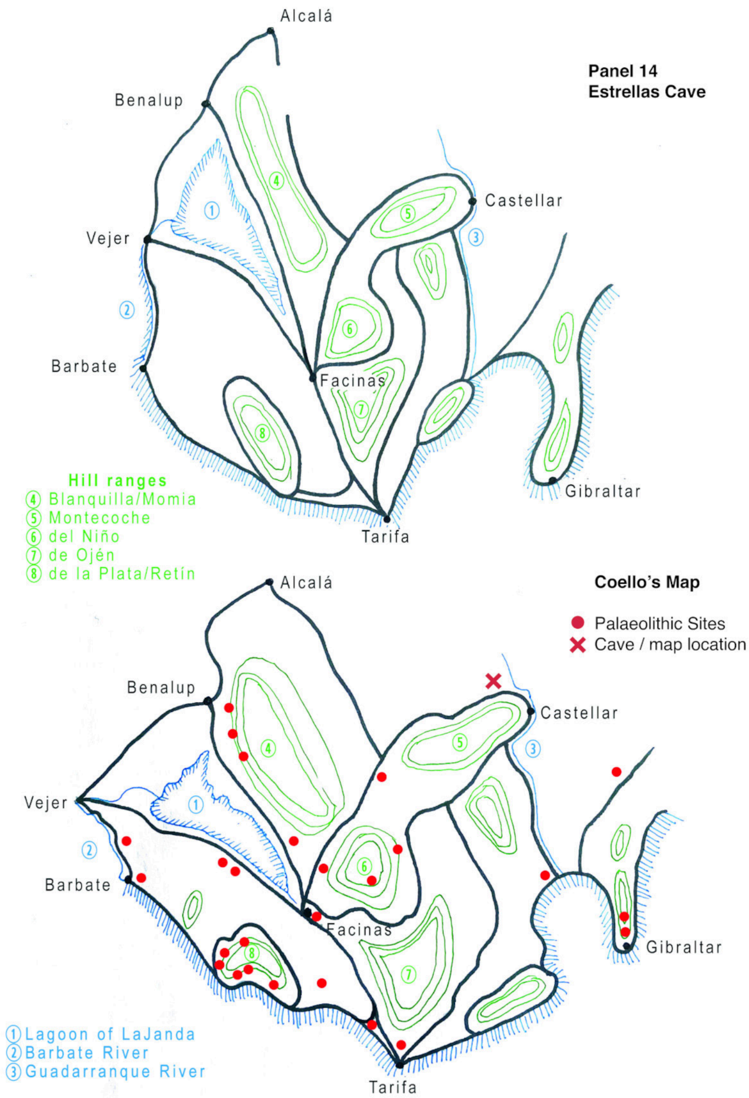


Figure 3*. Panel 14 and Coello's map, including Palaeolithic sites and geographic features.*

from the modern coastline; in c. 9000 BP, sea levels were 30–40 m below the current level (Vanney and Menanteau 2003: 168). Assuming this and the differences in bathymetry, the coastline would be considerably further out around Barbate, somewhat less around Gibraltar, and much less off Tarifa. This route became the Roman *Via Heraclea* during the Christian era, which linked Gades and Malaca, according to the Antonine *Itinerary*, the Anonymous *Ravenna cosmography* and others (Bonsor 1918; Pemán 1954). The cartogram of the cave seems to end at the mouth of the Barbate, without following the coastline to the left bank towards Trafalgar. It can be argued that the Barbate River was a pre-Historic cultural boundary (Jenkins 2009: 270) because no megaliths or rockshelters with wall paintings have been found on its right bank.

Section 2 covers the triangle Vejer-Benalup-Facinas, which skirts the Lagoon of La Janda, an enormous natural triangular lagoon. The map section includes El Tajo de las Figuras, one of the main settlements in the region (Cabré and Hernández-Pacheco 1914), whose bird paintings registered the stopover of migratory birds to and from Africa over the Strait. The route Vejer-Facinas-Tarifa matches the Roman and modern roads, which run around the lagoon, and is known to have existed during the Palaeolithic (Ripoll et al. 1999; Val-Peon et al. 2023). The section connects at least seven Palaeolithic settlements, including Facinas, which must have been an important crossroads near Palomas Cave.

Section 3 covers the mountains. The route from Facinas to Estrellas must circumvent the hill range of El Niño, forming the characteristic central 'S' found in both 'maps'. Before reaching the cave, at the top end, the route describes another marked curve (inverted 'C'), similarly visible in both 'maps'. This curve followed the course of the Guadarranque River around a mountain and, towards the south, it leads to the Bay of Gibraltar. On reaching it, the Palaeolithic Gorham's and St. Michael's Caves, where Neanderthal skulls have been found, are to the left, while Tarifa lies to the right. To the northwest lies Horadada, on the route followed by the Roman road (Thouvenot 1940; Sillieres 1990).

PPM1: Cartographic test and statistical analysis

Analyses (detailed in Appendix 1.1) were undertaken to test whether the apparent and historical coincidences described are cartographically correct and statistically correlated. Eight objective points were selected for comparison: one at the centre, Facinas—on which five lines converge—and seven in the periphery, where two or more lines cross, the drawing ends in discrete ways, or the cave is located. The analysis examined correlations between these eight key points (matrix analysis) and figures (shape analysis) in painting and map. It was concluded that the likelihood that both elements (painting and map) represent the same reality is 99%.

The positional deviation of the eight key points and the average root mean squared error (RMSE) were calculated using official georeferenced maps and ArcGIS software. The RMSE yielded an error of around 5%, reduced to 3% when two undefined points, currently under the sea, were removed. Additional statistical tests were undertaken to establish concordance based on variables recently used to study the slab of Saint-Bélec (Nicolas et al. 2021). The results of the Mantel Test confirm a strong correlation—over 92%—and rule out the possibility that these coincidences can be attributed to chance, with a level of confidence above 99%. The Jaccard Index confirmed shape concordance. Summing up:

RMSE (eight points): 2870.00 m (5% to 8% error)
Adjusted RMSE (six points): 1499.98 m (2% to 3% error)
Mantel Test (R) Pearson correlation: 0.922 (92%) with p-value = 0.001
Mantel Test (R) Spearman correlation: 0.916 (92%) with p-value = 0.001
Jaccard Index: 81%

These tests were used to prove the mathematical correlation between maps, although it is argued that accuracy was not a necessary characteristic of ancient maps. Their aim was instead to aid orientation, communication and efficient travel.

PPM1: Conclusions

Based on the quantitative and qualitative evidence presented above, it is plausible to conclude that *Panel 14 is, with a very high level of confidence, a pre-Historic map or croquis of the northern shore of the Strait of Gibraltar*. The evidence includes:

Archaeology and chronology: painting dated to the Upper Palaeolithic.

Pre-Historic cartography: the drawing meets Delano's and Utrilla's criteria.

Evolutive geography: high degree of spatial correspondence between Panel 14 and a modern 1:50,000 map of the region from Gibraltar to Vejer (longitude) and from Tarifa to Alcalá de los Gazules (latitude), connecting key Palaeolithic sites (red colour) with footpaths (black) to avoid major geographical obstacles, such as hill ranges (green), seas, rivers and lagoons (blue), once their evolution over time, either natural (silting, rise in sea level) or anthropic, has been accounted for, based on old maps and texts.

Correlation and statistics: there is a high degree of cartographic correlation—in terms of both network and shape analysis—between the cartogram and the georeferenced map, which can hardly be attributed to chance.

Semiology and symbology: pairs of dots are the symbols used by geographic institutes to represent drove-ways and paths in topographic maps.

PPM1.Bis: Cave of Palomas

The Cave of Palomas is 30 km from Estrellas, near Facinas, the central node in the communications network to the north of the Strait of Gibraltar. Breuil explored the cave in the early 20th century. It houses PPM1.Bis, dated to the Solutrean period.

Figure 4 reproduces (above) a recent DStretch picture of the painting (Mira 2022: 60) and (below) the carbon copy made by Breuil (Breuil and Burkitt 1929: Pl. XVII). He described the drawing as: 'On the opposite side of the chamber, there are two figures in brown that only become visible on wetting the rock. The first consists of bands formed of double rows of fine dots, which take the shape of a cross on the left, a branching bough in the middle, and a double arch on the right. The second figure is a horse's head in Palaeolithic style' (ibid.: 53).

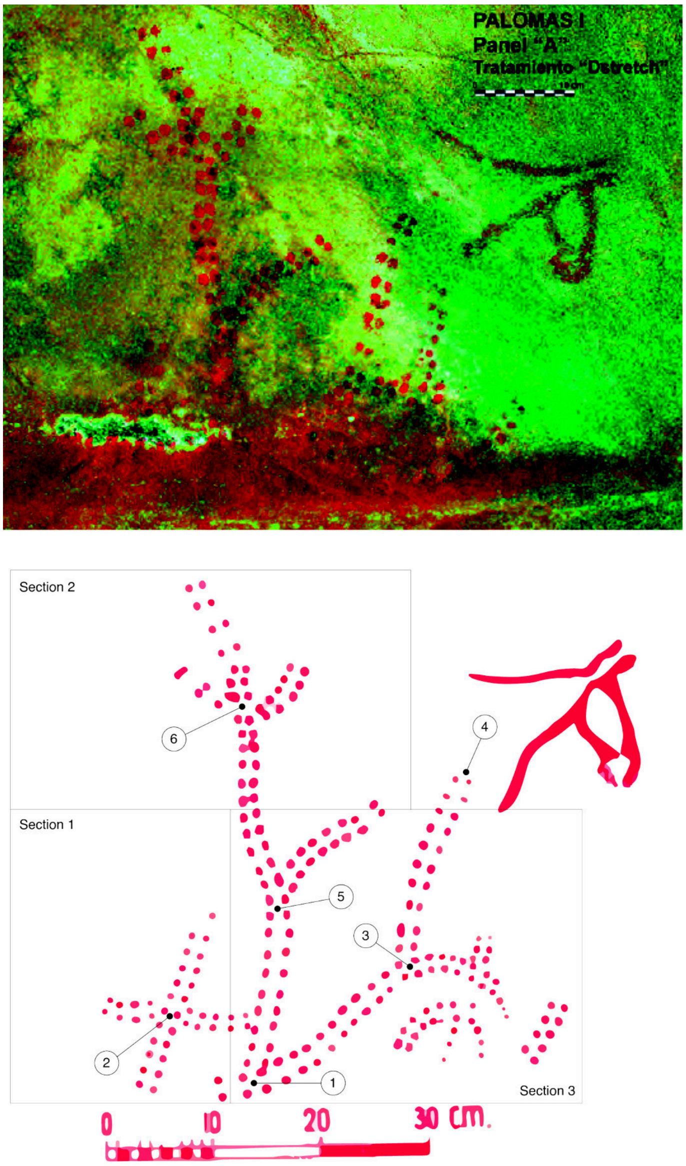


***Figure 4**. Above: a photograph of the cartogram in the cave of Palomas (source: Mira 2022). Below: Breuil's carbon copy with sections and key points indicated.*

PPM1.Bis: Suggested meaning

It is suggested that this tree-shaped figure of paired dots is also a Palaeolithic croquis that could represent the main routes around the cave of Palomas, signalled in the drawing by the horse's head. As such, the map would be a partial representation of PPM1.

PPM1.Bis: Explanation of key similarities

The drawing is divided into three sections, which correspond to the three food-sourcing areas near Facinas/Palomas (Fig. 4). In parallel with PPM1, Section 1 links with the coast; section 2 leads to the lagoon and section 3 links with the nearby hills and the cave in which the map is drawn. The possible pathways have been superimposed upon Coello's map (Fig. 5), where Palomas is marked. These three zones also represent the three westernmost clusters of rockshelters in the hills of Cádiz, divided by fluvial basins (Versaci 2019: 108).

The figure highlights the region's complex orography, caused by the confluence of the Lagoon of La Janda, the Almodóvar River—which needed to be forded to travel between areas—and the ranges of El Niño, which, even today, can only be passed through the valleys. The location of the caves is based on Breuil and Burkitt (2019) and Topper (2022).

Section 1 covers the pathway to the coast. Close to Facinas, there is a cross-shaped junction on the left of the painting (2), which is identical to a cross made of double dotted lines in the most recent official map (IGN n.d.: MTN25 1077-1), indicating the perpendicular intersection of two drove-ways. Three pathways take off from the junction: To the north, a pathway leads to the coast of Vejer/Barbate around the southwestern shore of the Lagoon of La Janda, like in PPM1.To the west, another pathway leads to the coast and the Palaeolithic caves of Atlanterra and El Moro, a path not included in PPM1. To the south, the pathway leads to Tarifa; this matches with the old horse trail in Coello's map, the Roman roads and PPM1.

Section 2 leads to the northern shore of the Lagoon. It sets off from Facinas and runs between the lagoon and the Zanona range, leaving the caves of Pajarito, Culebra and Sauce to the right before forking out again into three different pathways. The last could also indicate access to Mujeres, Tajo de las Figuras and Pretina, where another double dotted line is found (Cabré and Hernández-Pacheco 1914).

Section 3 gave access to the mountains. To the east, the pathway sets off from Facinas in the pronounced 'S' described in PPM1. Immediately to the left, a path branch—marked with red dots in Fig. 5—follows the course of the Toriles River to reach Palomas I, as in Breuil's map of the cave (Breuil and Burkitt 2019: E).

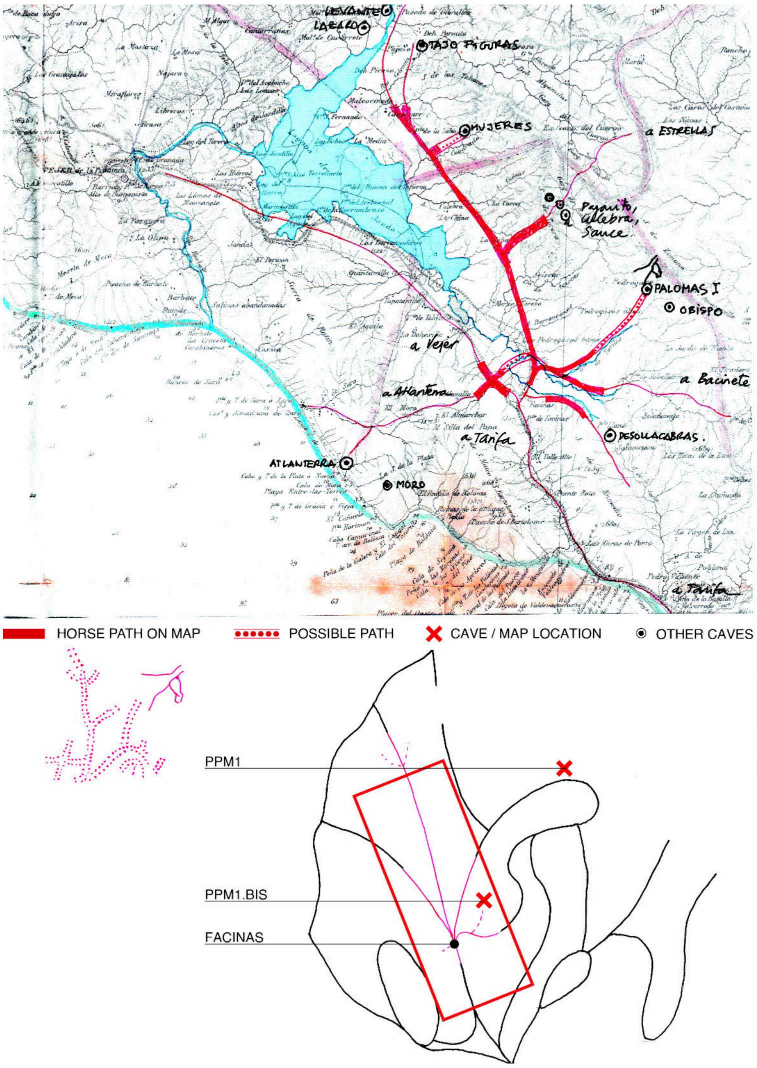


Figure 5*. The suggested pathways superimposed upon Coello's map (above) and correspondence between PPM1.Bis and PPM1 (below).*

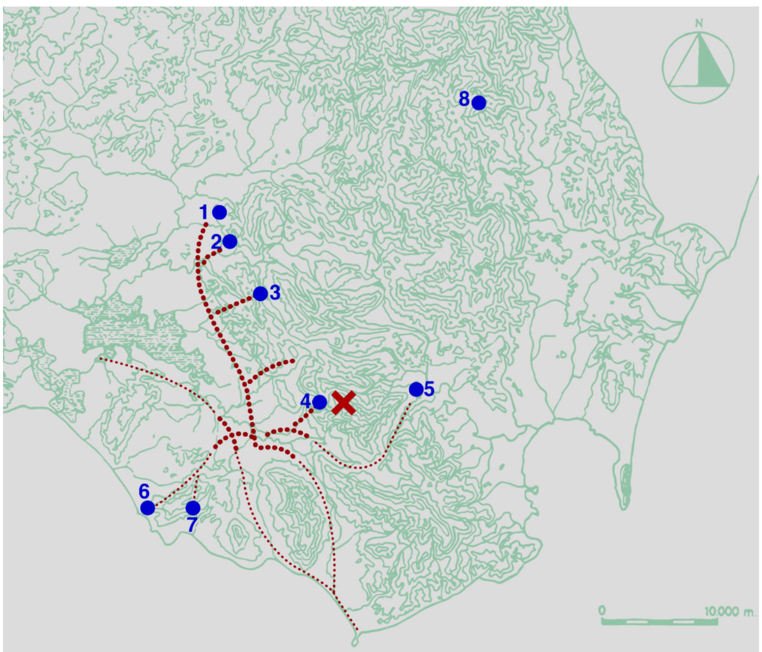


Figure 6*. Map of the main caves in the region (Source: Solís 2020), including Palomas (4), with suggested pathways superimposed in red.*

All this is reflected in PPM1.Bis, where the cave is represented by the horse head forming a composition with the dot lines. If we continue down the bend instead of taking Breuil's path, we reach Estrellas, passing by the Bacinete Cave, where another double line of red dots lies (Breuil and Burkitt 2019; Solís 2020). The curved line (below) corresponds to the pathway that reaches Tarifa after passing Desollacabras Cave. In the Roman period, there were also two roads from Facinas to Tarifa: one skirted the range to the west and the other to the east.

The painting can be compared with a theoretical path connecting all important caves in the area. To show that, we have used Martí Mas's map (Mas 2005; Solis 2020), which combines the main caves and the complex orography of the region. The superimposed dotted red lines (Fig. 6) trace the routes and the match with PPM1. Bis. The caves in Mas's figure are Pretina, Tajo, Mujeres, Palomas (4), Bacinete, Atlanterra, Moro and Laja Alta.

PPM1.Bis: Cartographic test and statistical analysis

The cartographic tests undertaken with the 'main' figure were repeated here. Instead of eight points defined by the intersection of lines, we have only six, including the cave itself, marked by a horse's head. We have only been able to confidently identify the four points situated closest to Palomas (Fig. 4):

1. Facinas (same coordinates as in PPM1).
2. Drove-way intersection (coordinates based on IGN n.d.: MTN25: 1076-1077).
3. Intersection of the Toriles River with the road that skirts the range of El Niño (ibid.).
4. Palomas I. (coordinates in Mira 2022: 45).

The RMSE for these four points is 302.39 m, which results in an error below 6%. Remarkably, the size of PPM1.Bis is approximately 50 × 50 cm, while PPM1 is 120 × 95 cm, so the proportion of the maps is roughly equivalent, if PPM1.Bis is understood as a section of PPM1, as shown in Figure 5.

PPM1.Bis: Conclusions

The drawing matches the area's maps and topography—in geographical and basic statistical terms—representing possible paths around the communication hub in Facinas and the nearby inhabited cave of Palomas. The position—and access to the cave, described by Breuil—would be explicitly expressed in the map with the horse's head, a sort of 'you are here' sign. *PPM1.Bis is, most probably, a croquis of the surroundings of Palomas.*

The similarities between PPM1 and PPM1.Bis, in terms of style, format, colour, date, cartographic rules, accurateness, scale, location within the caves, and areas covered suggest that *PPM1.Bis could be complementary to PPM1, making the hypothesis for both even more plausible.*

PPM2: Cave of La Pileta

La Pileta is situated in Benaoján (Malaga). It was discovered by Bullón in 1905 and has been studied, among others, by Breuil, Obermaier and Verner. The cave houses Palaeolithic and Neolithic paintings, including animals and abstract signs and figures. Our second example is an emblematic Palaeolithic drawing from this cave. Figure 7 presents the carbon copy—extracted from *La Pileta a Benaoján* published by the earliest explorers of the cave (Breuil and Obermaier 1915: Pl. IX)—and a photograph from La Pileta archives.

This sign was regarded as an (evolved) meander by Marshack (1977: 301), who described it as consisting of doubled lines and additions, carefully drawn and with a

***Figure 7**. Photograph of the drawing in La Pileta and Breuil's carbon copy.*

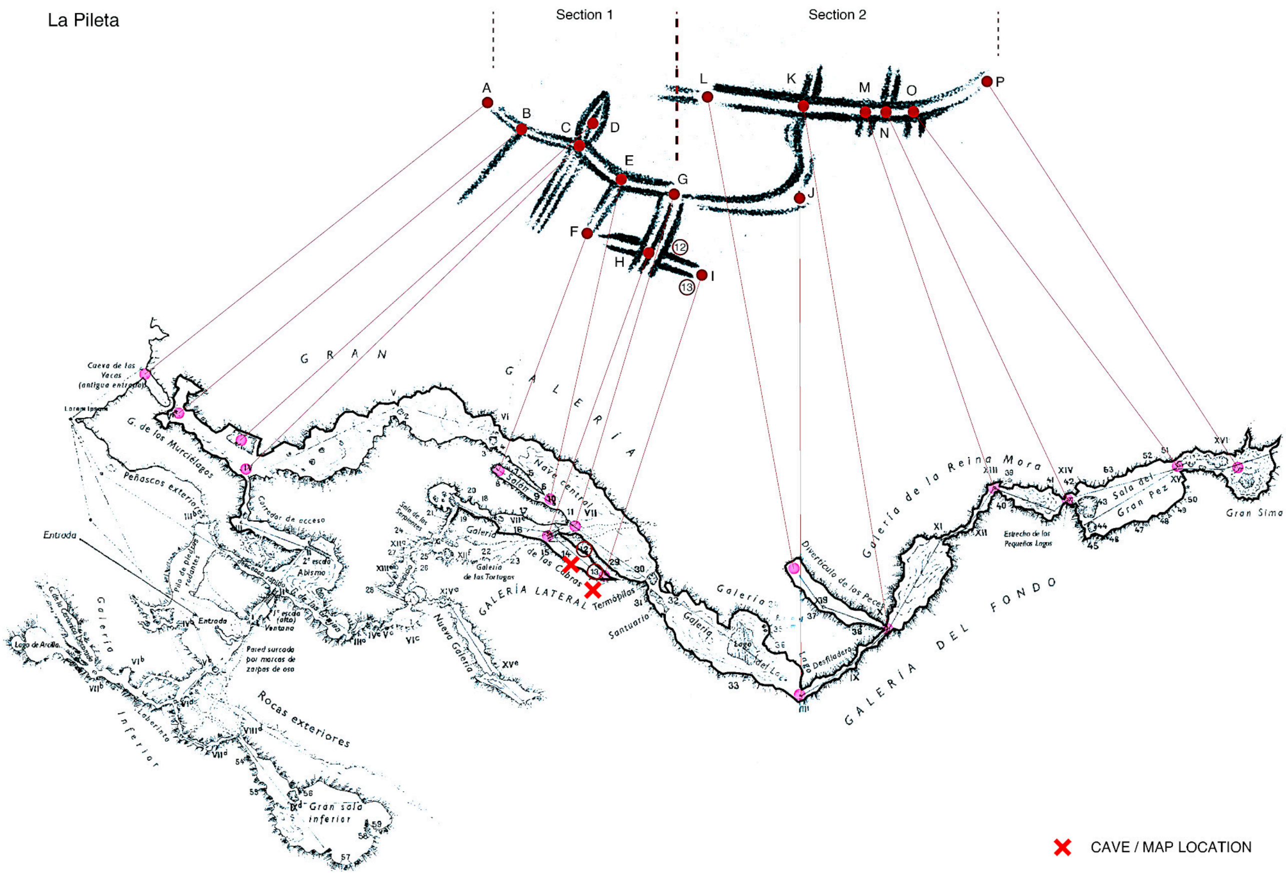


***Figure 8**. Match between the sign at La Pileta and Verner's plan.*

geometric appearance. In his opinion, 'the purpose of meanders was not topographic, but rather iconographic acts of participation in which a water symbolism played a part', with the double line representing a river or stream (ibid.: 315). Fortea (1978: 145) already pointed out the similarities between this sign and the previous one (PPM1.Bis).

PPM2: Suggested meaning

It is suggested that the drawing is a complete plan of the main level of this complex cave; its earliest explorer, Verner, even got lost in it (Cortés et al. 2023). Figure 8 illustrates the coincidences: the top represents the carbon copy, and the bottom is the original plan made by Verner in 1915 (ibid.: 148). He called Obermaier, Breuil and Cabré, who visited the cave in the company of Bullón, whose family have cared for the cave—following Breuil's request—since then. The Bullón family also helped me to confirm, in October 2023, the accuracy of the topographic assumptions for specific points of the cave currently closed to public visitors.

PPM2: Explanation of key similarities

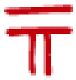
Verner's map contains some inaccuracies, which—if not clarified—could obscure the correspondence between the painting and the cave's layout.

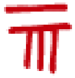
1. Verner's plan did not include the main entrance. He entered the cave through an opening in level -1 and then climbed 20 m to level 0. He never recognised the cave's main entrance, the one used today, which was discovered in 1924. This entrance was walled up during the Bronze Age, when the cave was abandoned (Bullón 2010).
2. Verner's plan begins in an outer cave (Cueva de las Vacas), the bottom end of which is sealed today; he identified this as a possible 'old entrance'. Later studies have shown that this area, which Cabré and Obermaier unsuccessfully tried to open (Cortés et al. 2023), was open in antiquity. It probably closed owing to a cataclysm approximately 4500 years ago and was not used by the Bronze Age (Bullón 2010).
3. Verner exaggerated the curvature of the beginning of the cave, with a nearly 120-degree zigzag, and did the opposite at the end, where he merely reflected a 90º bend. Recent plans have shown that the cave is almost straight—like in the Palaeolithic painting—all the way to the sharp 90º bend in the centre, which is reflected in both plans, ending in a real zigzag.

The proposed decoded meaning of the cartographic symbols used in PPM2 meets the conditions of being simple, pragmatic and unequivocal, as follows:

 Two continuous parallel lines: main passageway.

 One lateral stroke: main entrance/exit.

 Two lateral strokes on one side of continuous parallel lines: lateral gallery.

 Three parallel strokes: descent to the lower level (crossing).

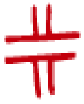
 Two parallel strokes crossing the continuous parallel lines: crossroad (three possible routes).

Figure 8 distinguishes two sections. Section 1 represents the cave from the entrance to the location of the map—situated in a central and discrete location of the cave (Point I)—and section 2 covers the area between the map's location and the cave's back end. The points referred to in the explanation—which will be used later also for statistical calculations—are bi-univocally defined and have been selected according to the following objective criteria:

Endpoints: beginning of cave (A), end of cave (P), and end of galleries (F, I, L).

Crossings, signalling: descents (C, G); lateral galleries (E, H, K), zigzag galleries (M, N, O).

Singular signs: exit (B), central bend (J), and by-passable large column (D).

Section 1: The significant features of this section, represented by letters in Figure 8, are:

A. The beginning of the cave is the ancient entrance, according to Verner.

B. The main access to the cave is represented by a single stroke, corresponding to the current access, as reflected in modern plans (Mayoral 2018).

C. First descent to the level below. This was the point through which the cave's discoverer, following the bats, entered it in the opposite direction, that is, climbing up from level -1, for which reason it features as the entrance in Verner's plan. This level change is represented by a triple line, which, as noted, signalled access to a lower level.

D. This level change is opposite a large by-passable column—the author has confirmed that in situ—which corresponds to the ring drawing opposite the three parallel lines in PPM2.

E-F. On the right side, a little farther, is a gently sloping large lateral gallery known as 'El Salón', 25 m long. The gallery E-F is profusely decorated and is represented in PPM2 by the double lateral stroke between the two level-change paths.

G. Second level change. The cave has two level changes, exactly matching the two triple strokes in the drawing. Today, this second level change is a near-vertical 4-m drop in which a metal ladder has been installed.

H. The bottom opens to two galleries to the left and right, accurately reflected in PPM2 and the plan.
I. The cartogram is painted halfway up the wall of the lower left gallery, known as Gallery of the Goats. The sign depicts the exit of this gallery and the way to the main level above; once there, the bottom of the cave (Section 2) is to the right of this, and the entrance is to the left (Section 1). Point 12 in Breuil's plan, marked in both maps, is the location of PPM2.

Section 2: It goes from the location of the sign and the level change (G) to the back end of the cave, which is the most difficult and darkest area, with narrow and twisting passageways that can only be negotiated walking sideways (Bullón 2010):

J. It represents a sharp 90° left turn, faithfully depicted in Verner's plan and the painting.
K. Immediately after the bend is a crossroad, leading to a diverticulum to the left, marked again by two confronted double strokes, transversal to the main passageway.
L. In PPM2, it looks like the diverticulum K-L had a false ending before continuing. In Verner's plan, this passageway ends abruptly, although it was later discovered that it continued farther, as duly represented in modern plans.
M-N-O. Farther in, the following section presents three sets of perpendicular double lines, pointing right, left and right, respectively; this represents the three last galleries described by Giménez Reyna (1963: 14) and the zigzagging turns found in this final section: at the end of the first hall (Organs) there is a 90° bend to the right (M); after the second hall (Dosel) there is another 90° turn but to the left (N)—better represented in modern maps—and at the end of the third one (Gallery of the Fish) we found on the right the access to the chasm.
P. This is followed by a 72 m deep chasm where the cave ended; this section was not explored until 1935 (Bullón 1977).

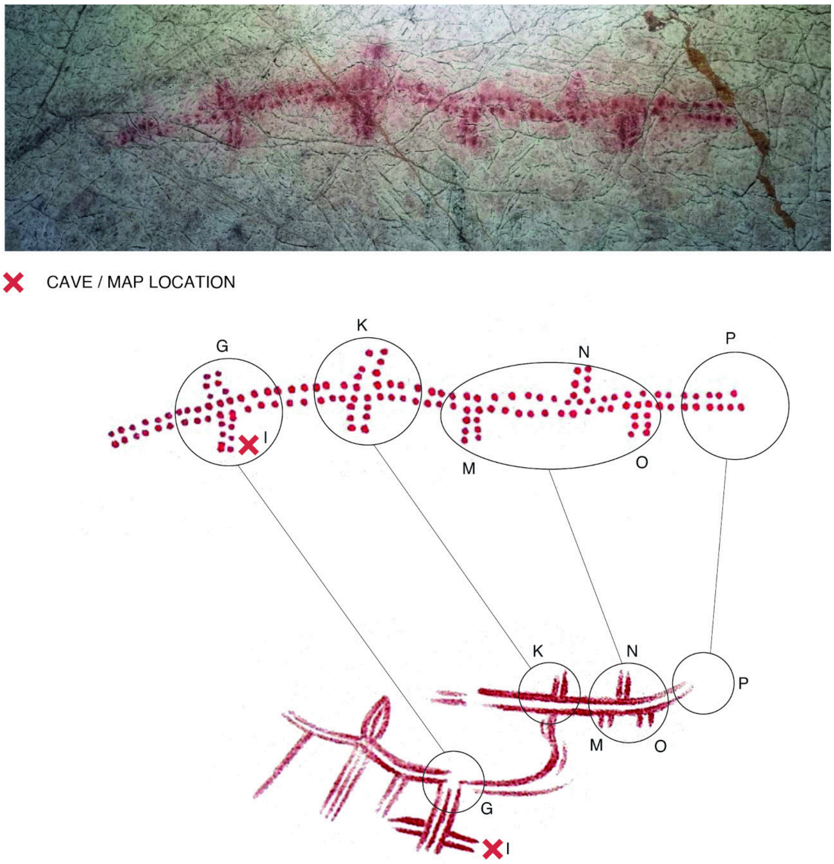


Figure 9. *Above: picture of PPM2.Bis (Source: La Pileta Archive). Below: correspondence between PPM2 and PPM2.Bis.*

PPM2: Cartographic test and statistical analysis

If this cartogram represents the inside of a cave instead of a wide landscape, it prevents us from using georeferenced maps to test connections between a point matrix in the drawing and the official maps. However, we can still establish cartographic correlations between the sign and the map in terms of distances and shapes using the previous bi-univocally defined sixteen nodes (Fig. 8), which cover the whole visitable level of the cave.

To assess statistical evidence of the topological similarities between the graphs and their nodes, we used Mantel's test and Levenshtein's distance. The results, presented in detail in Appendix 1.2, are as follows:

Mantel Test (R) Pearson correlation: 0.9403 (94%) with p-value < 0.001
Mantel Test (R) Spearman correlation: 0.9433 (94%) with p-value < 0.001
Levenshtein Distance: Lower than 10,000 alternative graphs

Mantel Test: the two graphs are highly correlated, with a confidence level of over 99%.
Levenshtein distance: the two drawings are, with a confidence level close to 99%, the most similar graphs among 10,000 equivalent—but restricted by similarity conditions—alternative character sequences.

Therefore, it can be concluded that the graphs represent, with a very high level of confidence, the same object.

PPM2.Bis: A twin painting in La Pileta

Additionally, right opposite PPM2, at Point 13 in Breuil's plan (Fig. 8), there is a second drawing (Fig. 9, above), which consists of parallel double dotted lines

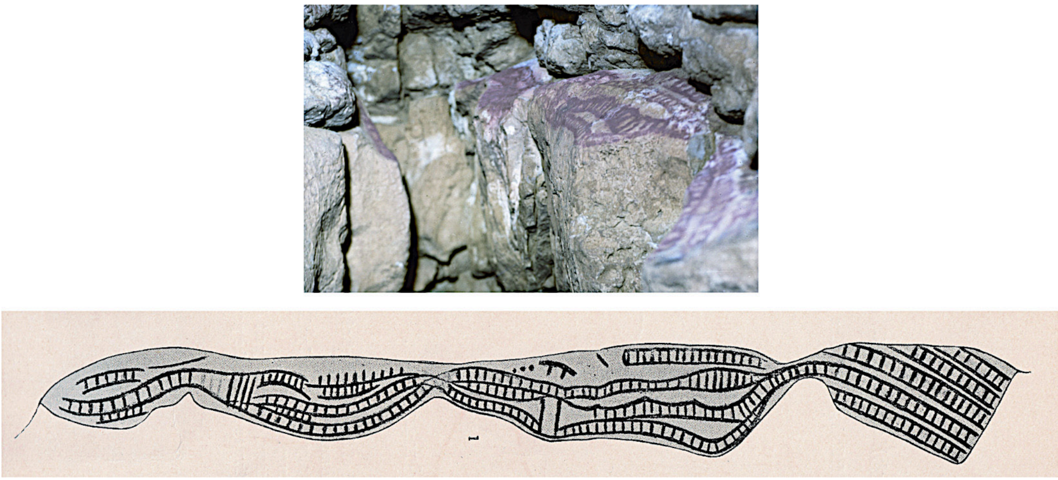


***Figure 10**. Photograph (source: Deutsches Archäologisches Institut) and Breuil's carbon copy of Altamira's ladder-like figure.*

and could be interpreted as a partial preliminary version of PPM2. Another photograph and the carbon copy can be found in *La Pileta a Benaoján* (Cortés et al. 2023). Breuil described it as 'a horizontal axis, with two dotted lines with short transversal appendixes like a double smudge: on the left side these appendices alternate, on the right, opposing each other' (ibid.: 175). Giménez Reyna (1963) interpreted it as a drove-way framed by hedges. They are quite similar in size: PPM2 is c. 35 cm and PPM2.Bis c. 50 cm.

If both are compared (Fig. 9), the right-hand sides appear very similar, with three alternating pairs of strokes (right, left and right, corresponding with points M, N, and O), perpendicular to the main line, and the same ending (P). Comparing also the left side, PPM2.Bis could be a more basic version of PPM2, representing only section 2, with a double straight line (no bends, no descents) meaning: 'when you leave the map position (I) and go up to junction (G), on your way to the back of the cave, you will find another junction (K) and then three zigzagging halls (M, N and O), and then the end of the cave (P)'. It is very likely that analyses would show that PPM2.Bis is older than PPM2.

PPM2 Conclusions

The multiple visual matches between PPM2 and modern maps of the cave—in addition to the cave itself—alongside the statistical and bi-univocal similarity results, support the notion that *PPM2 represents the main level of the cave of La Pileta with an extremely high level of confidence.* The correspondence between PPM2 and PPM2.Bis further reinforces the hypothesis.

All objectively relevant elements in the cave's layout (entrance, exit, descents, curves, lateral galleries) are represented in the painting by a unique biunivocal symbol situated in the right place, not only longitudinally but also in terms of right/left orientation. Similarly, not a single symbol in the drawing does not correspond to a relevant feature of the cave. The statistical results (Mantel and Levenshtein) confirm that these elements represent the same object, the main level of the cave, with a 99% confidence level.

At any rate, the cartogram of La Pileta is a masterpiece of abstraction, synthesis, signalling, and accuracy worthy of the best modern artist. It beautifully and simply reflects the cave's complexity, using internally consistent symbols that effectively represent the relevant orographic features of the cave.

PPM3: Cave of Altamira

The cave of Altamira (Cantabria) was discovered in 1868. Universally known for its beautiful naturalistic paintings, they were the first of their kind to be discovered. Saenz de Sautuola, whose daughter noticed the ceiling paintings in 1879, was an amateur who suggested, in 1880, against all expert opinion, that they may be Palaeolithic in date. He died in 1888 before his inspired theory was accepted. Years later, the famous archaeologist Cartailhac, who had played a leading role in the choir of voices that dismissed Sautuola's idea, recognised his mistake. To make up for his error, he wrote one of his most famous articles, 'La grotte d'Altamira: mea culpa de un sceptique' (Cartailhac 1902), in which he recognised his unjustified scepticism, and fully endorsed Sautuola's daring theory. The cave has been declared a World Heritage Site by UNESCO.

Our third example is a singular Palaeolithic painting from this cave. Figure 10 presents a photograph and the carbon print made by Breuil (Breuil and Obermaier 1935: 46). However, the first recording of this drawing appeared in '*Breves apuntes sobre algunos objetos prehistóricos de la provincia de Santander*' (Sautuola 1880: Pl. IV).

The drawing is located between halls III and IV (Point 14) of the cave plan undertaken by engineer Corral (Breuil and Obermaier 1935). In Breuil's opinion, the drawing is likely dated to the Aurignacian period (Breuil and Obermaier 1984: 69), although, according to the Museum of Altamira catalogue (Inv.

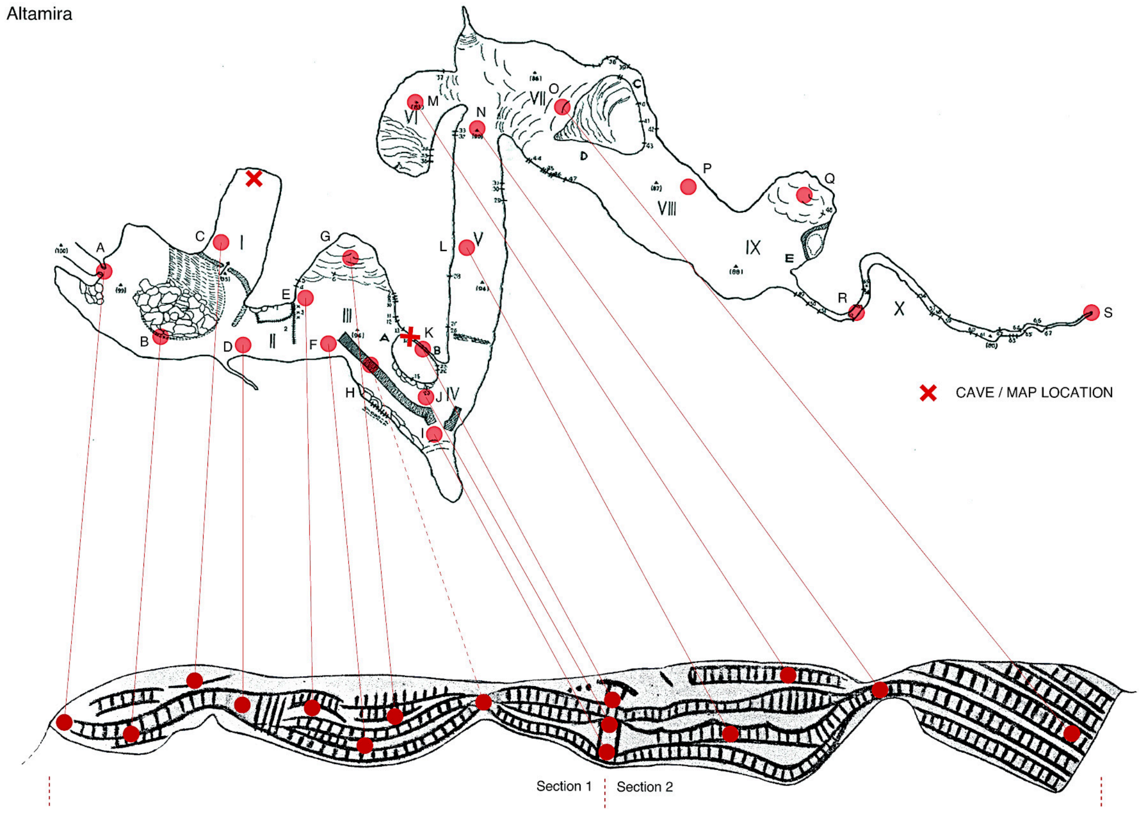


Figure 11. *Correspondence between the ladder-like figure and the plan of Altamira.*

No. CE58155), it could also be dated to the early Magdalenian.

Breuil describes the painting in the context of the crack in which it is located: 'To the left, there is nothing particular to be seen at first, but in stooping we perceive that the underpart of a rocky shelf, 20 to 30 cm wide, is decorated for a length of 2 m. Parallel ladder-like red bands, which merge when the surface is narrow, spreading out and multiplying at the wider parts, cover the whole surface of the projecting ledge. The general appearance and the location of the signs combine to impress the modern visitor trying to discover something of the life and customs of the men of the past; here everything points to a holy place' (Breuil and Obermaier 1935: 48). The place was described earlier by Cartailhac: 'This narrow corner attracted the attention of troglodytes, who made some strangely arranged drawings. The largest, despite its excessive length, forms like a ladder, and is one of the most curious motifs of Palaeolithic art' (Cartailhac and Breuil 1906: 230).

Different interpretations have been offered for this 'scalarifom' (in IFRAO's terminology). For Breuil and Obermaier, it was a ladder-like figure resulting from the degeneration of five tectiforms, with two supporting pillars in the centre (1935: 46, 50). Carballo thought they might represent huts (1970), and Ángel de los Ríos simply admitted not understanding the arrangement (Madariaga 1976). Züchner thought that the drawing could represent a meandering river or the routes followed by migratory animals (1996: 331), and Madariaga saw a waterway with separating and merging branches (2014: 34); Alcalde del Rio described it as pure fantasy, an ornament based on geometrical figures (1906: 27) and later on, together with Breuil, he identified the drawing, 'without any doubt', as palisades attached to houses (1911: 187). The museum catalogue reads that 'it seems to express one or several complex ideas'. One of the earliest local descriptions argued that 'these signs are important for the light they could shed on research, and it is a pity for them to go unnoticed to most visitors' (Madariaga 1976: 241). For Giedion, the meaning of this '*grande signe*' still awaits explanation (1991).

PPM3: Suggested meaning

It is argued that the drawing is a pre-Historic cartogram that faithfully represents the cave's interior of Altamira. The cartographic correspondence between the painting and the cave is illustrated in Figure 11, which represents the plan of the cave (Breuil and Obermaier 1935: Fig. 1) and below Breuil's carbon print of the red scalariform.

PPM3: Explanation of key similarities

To better understand the cave space, readers may consult the ground plan of the cave (De las Heras and Lasheras 2014: 615). As the cave is not open to visitors, the correlation analysis was based on cave plans, descriptions and 89 detailed section plans of the cave prepared by GimGeomatics and made available by the Museum of Altamira. The longitudinal

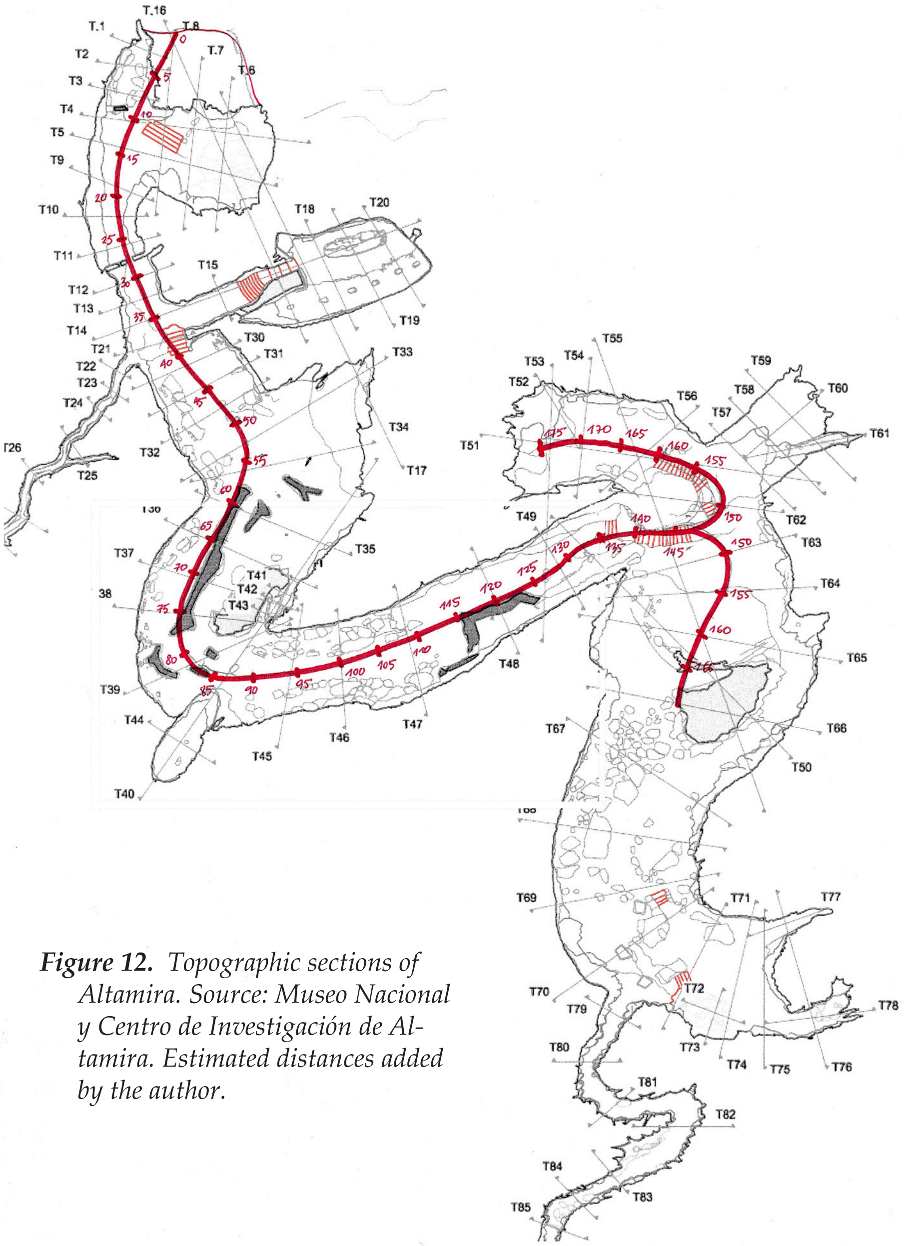


Figure 12. *Topographic sections of Altamira. Source: Museo Nacional y Centro de Investigación de Altamira. Estimated distances added by the author.*

correspondence of the sections with the cave layout (de Guichen 2014: 36) is presented in Figure 12. A visit and a meeting in November 2023 helped confirm other assumptions about the cave's interior.

It is argued that the drawing was constructed by combining the following concepts and symbols:

1. Scalariform shapes represent possible pathways inside the cave.
2. The number of parallel scalariforms represents the width of the cave.
3. The number of parallel strokes in the scalariform represents the length of pathways.
4. The painting is adapted to the painting surface available: long, straight and narrow.

The first concept identifies ladder-like bands with pathways. This should not be too surprising, as a 1921 Altamira map from Corral (Bernaldo de Quirós et al. 1979) represents the paths inside the cave with bands and strokes that diverge, run parallel and join again. Also, the museum uses red ladder-like drawings on the current map representing the recently built stairs (De las Heras and Lasheras 2014).

The second concept builds on the first one: the number and trajectory (merging and diverging) of basic units (ladder-like bands with a regular width) is used to represent the variable breadth inside the cave. In Figure 10, a single band would mean that the pass was very narrow, while five, like on the right, corresponds to the widest area of the cave.

The third concept builds on the second and views the separation between parallel strokes subdividing the bands transversally—which are remarkably uniform—as an indication of the relative length of each section, like a scale (which would lead to the figures being referred to as 'scale-like' or 'scaleforms', rather than 'ladder-like' or 'scalariforms').

Finally, the fourth concept is related to the limitations posed by the medium on which the figure is drawn: a 2.5 m long ledge, straight and flat, with variable width. As the artists could not represent the cave's zigzag profile in a straight ledge, they did so by 'flattening' the drawing. This should be no surprise because the early modern plans of the cave—which we could link to 'how' the cave was perceived before it was measured—were also almost straight.

The suggested meaning of 'other' signs is referred to the band as follows:

When the ladder-like band is missing one of the lateral strokes, this could mean that the passageway is not practicable on that side. The Cartographic Institute uses this symbol to indicate an embankment, and Breuil interprets it as a barrier.

A single line—no band, no strokes—could mean a non-transit area.

Two parallel large vertical lines interrupting

bands mean an obstacle interrupting transit. Breuil interpreted these as pillars.

 A lintel or door-like figure means an entrance.

It must be pointed out that Breuil's plan, despite its accuracy, does not record the cave entrance as it was when the sign was painted. The entrance collapsed approximately 13,000 years ago, keeping the cave undisturbed until the 19th century. It was originally higher and wider (Lasheras et al. 2005: 154), with a much larger hall that gave direct access to the Gallery of Paintings, situated to the left; before the collapse, these two areas formed a single space (García Guinea 1975). This differs from Breuil's plan and the modern entrance, which is to the right of the hall instead of the left.

Figure 11 distinguishes two sections: section 1 goes from the entrance to the plan's location—like in La Pileta, in a central and sheltered cave area—and section 2 from the plan to the end of the sign. The explanation relies on 19 topological discrete points connected in both graphs. As they will be used later in calculations, they were selected according to the following objective criteria:

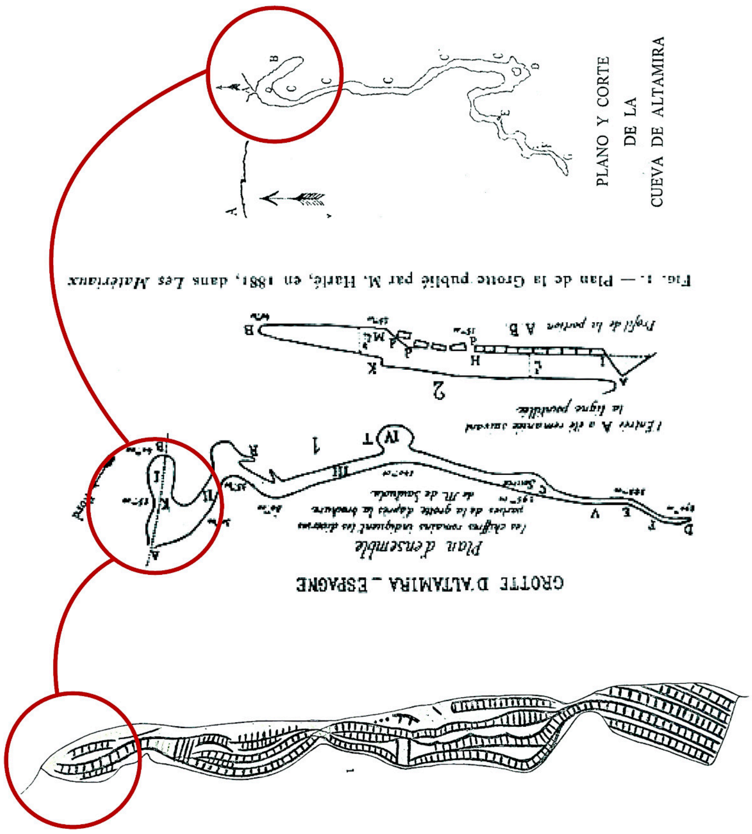


***Figure 13**. Correspondence between the beginning of the ladder-like symbol and the cave entrance in early plans.*

Endpoints: beginning of cave (A), end of painting (O) and end of cave (S).
Single band points: (D, H, J, N).
Lateral galleries: (C, M, Q).
Singular symbols (in sign): single line (C), pectiform (G), 'pillars' (I) and 'lintel' (K).
Singular symbols (in Breuil's plan): crossed line (E), pile of rubble (B).
Breuil's galleries not previously covered: III, V (F, L), and at the end of the cave, VIII, X (P, R).

Section 1

A. The entrance of the cave. Originally, it was wider and farther out. The main scalariform running continuously along the cave begins on the lower side. At the same time, the upper section gave direct access to the gallery of the paintings, which Sautuola saw as part of the first gallery (Sautuola 1880: 14). As noted, access was from the left, as in the NeoCave. In the first plans drawn by Argumosa in 1880 (Madariaga 1976: 232) and by Harlé in 1881 (Cartailhac and Breuil 1906: 3), the entrance directly leads to a short upper section and a long lower one, whose shape and angle are like those depicted in PPM3 (Fig. 13).

In addition, the space between this upper band and the main passageway could signal different paths bypassing the ceiling collapse between them, which appears to have been in place when the cave was inhabited.

B. Opposite the Gallery of the Paintings, to the right as we move inwards, the drawing expands with an additional third band. This matches the width and height of the area, as illustrated in the modern plans and section T5 (Museo de Altamira 2013).

C. The isolated, singular, left-curving single line following the upper short band may represent the singular Gallery of the Paintings, a non-transit particular area.

D. This element is highlighted because it is the only point where the band widens, rather than representing the increase in width by adding bands. In any case, this widening coincides with that of the cave and with an increase in height (sec. T30, T31). This topographic coincidence, despite the graphic divergence, is explained in H.

E. This section of the cave is wide enough to accommodate four bands. Further on, they become just two. This could mark a particular area where the roof is decorated with 'macaroni', signalled by a transversal line (Breuil and Obermaier 1935: 59) just before the cascade (Saura 1998: 98). It seems that both Breuil and the ancient inhabitants found a reason to highlight this zone.

F. Bypassing the barrier described in E, as we progress from the right, we meet an ample and high passageway with two bands (three at the beginning), also recorded by modern plans and old

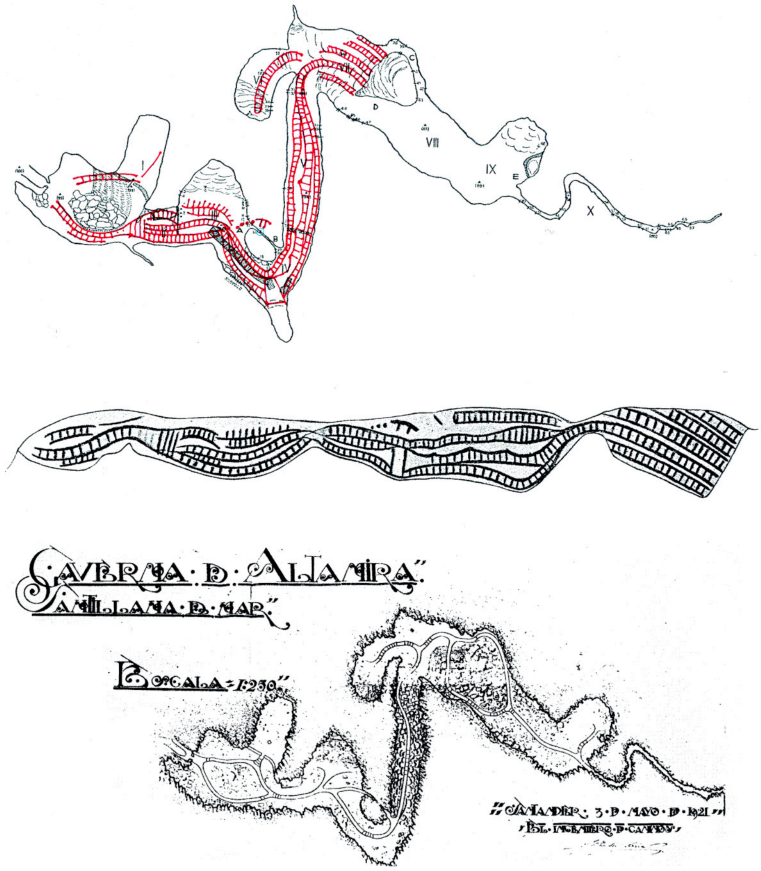


Figure 14*. Superimposition of the ladder-like bands and the plan of the cave.*

descriptions: 'The right-hand side is high and spacious, and the ceiling is solid' (Cartailhac and Breuil 1906: 40), as illustrated by section T33.

G. This zone represents the 'big cascade of earthly stalagmite' (Breuil and Obermaier 1935: 70). The symbol used—a ladder-like band missing a side—could indicate an impracticable passage on that side as illustrated by the elevation plans and section T34.

H. This is a peculiar point because it does not seem to match the topography, and the bands appear diluted and seem to cross. There are two plausible explanations for this: recently, the application of hyperspectral techniques has led to the conclusion that sections 1 and 2 of the painting, which meet exactly here, were made with very different techniques and qualities (Bayarri et al. 2015) and likely by different authors. This could also explain why point D represents the increase in breadth differently. In addition to this, the rock shelf narrows precisely at that point: the drawing cannot be wider at H because the available space does not allow it. As we shall see later, this point is still one of the effectively narrowest passable areas of the cave.

Section 2

I. The 'triad' I-J-K is critical to understanding the topographic correspondences. The singular blank space (I) between particularly long vertical strokes—which Breuil viewed as pillars of the central tectiform—cutting the passageways to left and right represents the large upsloping outcrop, a narrow bottleneck as seen in modern maps which forces the walker to stick to the centre of the passageway (Section T40).

J. The central band, the only one that runs through the whole cave, here becomes extremely narrow on the upper part of Breuil's 'pillars', just to open again to the left and right with two additional 'lanes' farther on. Just in front of the outcrop, another pillar invades the central area and reduces the space to a single 'lane' (section T38).

K. This point is also crucial to understand the correspondence. Like in Palomas, it points precisely to the map's location ('you are here'), which is slightly off the main passageway, as signalled by the dotted line, in the crack at the back of the outcrop, Breuil's plan point 14. The symbol used resembles a door or lintel, which can be recognised in a drawing of the entrance to this lateral passageway, crowned by a beautiful globular stalagmite (Cartailhac and Breuil 1906: 40). Sections T41, T42, and T43 show the profile of the crack in detail.

L. Gallery V in Breuil's plan—long, flat, and relatively wide—is represented by three bands, starting at J and ending at N, where they merge again on the left. At the beginning of the long gallery, the central band is slightly different, with serrated instead of smooth edges. Perhaps this is because the central sector is full of collapsed rocks, which makes circulation difficult and compels the walker to advance skirting the wall (ibid.) (Sections T45 to T50).

M. This section contains a ladder-like band unconnected to the main circuit. This could represent the second lateral gallery, marked as VI in Breuil's plan. This gallery sets off beyond the end of the passageway (N). It takes a wide 180° turn, running parallel to the main passageway but in the opposite direction, as reflected in both drawings of Figure 11.

N. At this point—the narrowest of the cave—the three scalariforms or 'lanes' merge to the left, signalling a significant narrowing of the passageway caused by a sharp rise of the floor to the right, as reflected in section T50. In the museum's plan, this area is also represented with a similar ladder-like symbol, representing real stairs.

O. Right beyond the bottleneck (N) and turning to the right—a large bend only partially reflected because of the limitations of drawing space—the passageway leads to the cave's widest and highest area, as reflected in modern plans. Sections T63 and T64 reflect the amplitude of this Great Hall, which is expressed in the drawing using five bands, after which the drawing abruptly ends.

P. Afterwards, collapse debris in halls VII and VIII makes progress very difficult (Lasheras 2002). The central column separates the passageway into two, although according to Cartailhac, only the one on the left was passable and with difficulty.

The scalariform ends here, but the plan continues further:

Q. Gallery number IX, on the left, including a well.

R. Final gallery, number X, known as the 'horsetail', including black paintings.

S. End of cave.

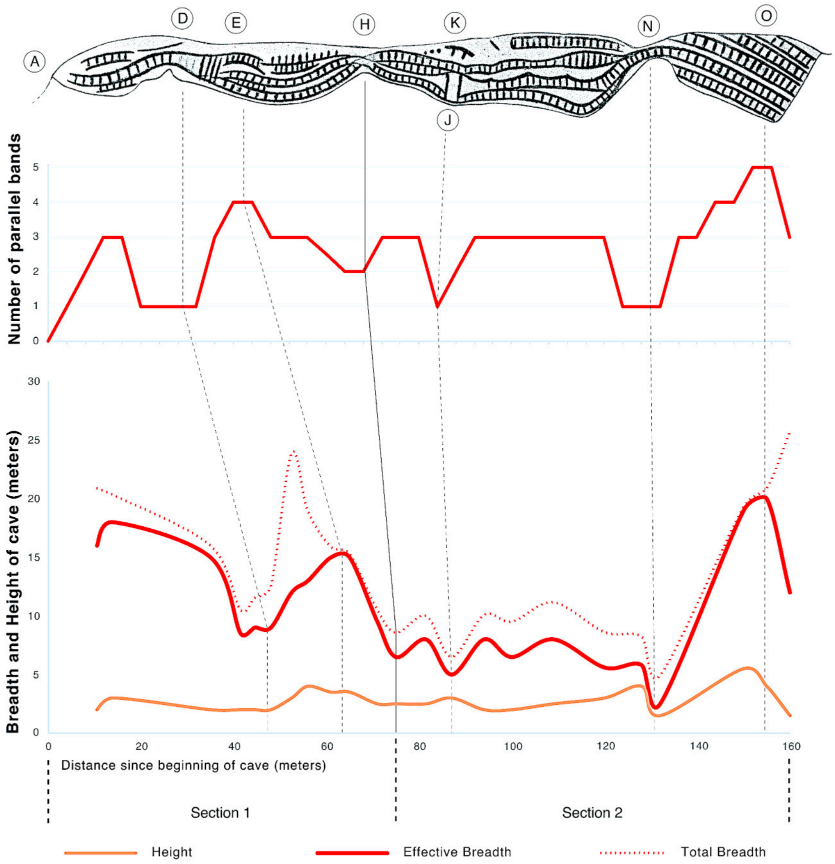


Figure 15. Visual correlation of width profiles of sections 1 and 2 of the cave, according to the Palaeolithic painting (above) and the Museum sections (below).

Figure 14 synthesises the explanation and the hypothesis. It superimposes the ladder-like sign on the cave's plan. It also shows the 1921 Corral map of the cave (below), on which merging and separating bands with strokes have been used to represent paths inside the cave (Bernaldo de Quirós et al. 1979).

Intriguingly, PPM3 ends where it does, as the cave continues further (galleries VIII, IX, and X in Breuil's plan). It is argued that the sign ends there because the 'drawable' surface ends abruptly or because, for practical purposes, the cave ended there for the inhabitants at the time, which agrees with the absence of red paintings in the halls beyond (Lasheras 2002). A possible explanation of this anomaly is presented later.

PPM3: Cartographic test (I): correlation of widths and lengths

As the hypothesis holds that not only is PPM3 a plan of the cave of Altamira, but that, directionally, the number of parallel bands refers to the width of passageways and the number of transversal lines to their length, we shall use visual graphics and basic numbers, followed by statistical test, to show the correlations for sections 1 and 2. To do this, the five most significant points in Figure 11 that have enough recognisable features to be bi-univocally identified in both the cartogram and modern maps, were selected:

Point A: beginning of cave.

Points J and N: where bands converge into a single pristine band.

Point K: position of the scalariform.

Point O: end of the drawing, maximum number of bands.

Points D and H, where bands seem to converge into a single band, will also be used. The correlations will be based on the sections marked in Figure 12, provided by the Altamira Museum. Once the 23 most representative sections were selected, a figure with estimates of maximum width, effective width (i.e. passages that allow a person to pass walking upright) and heights for the first 160 m of the cave was generated. The lower part of Figure 15 represents in the longitudinal axis the approximate distance in metres from the beginning of the cave, while the vertical axis represents, using different colours and scales:

The maximum breadth of each section (pink dotted line).

The effective breadth of each section, discounting areas of difficult passage (red line).

The average estimated height of each section (orange line).

The top part of Figure 15 represents the ladder-like figure and, beneath it, the number (1 to 5) of parallel scalariforms or bands in the sign (upper red line). The scalariform has been divided into 40 equal parts, and the number of bands has been calculated

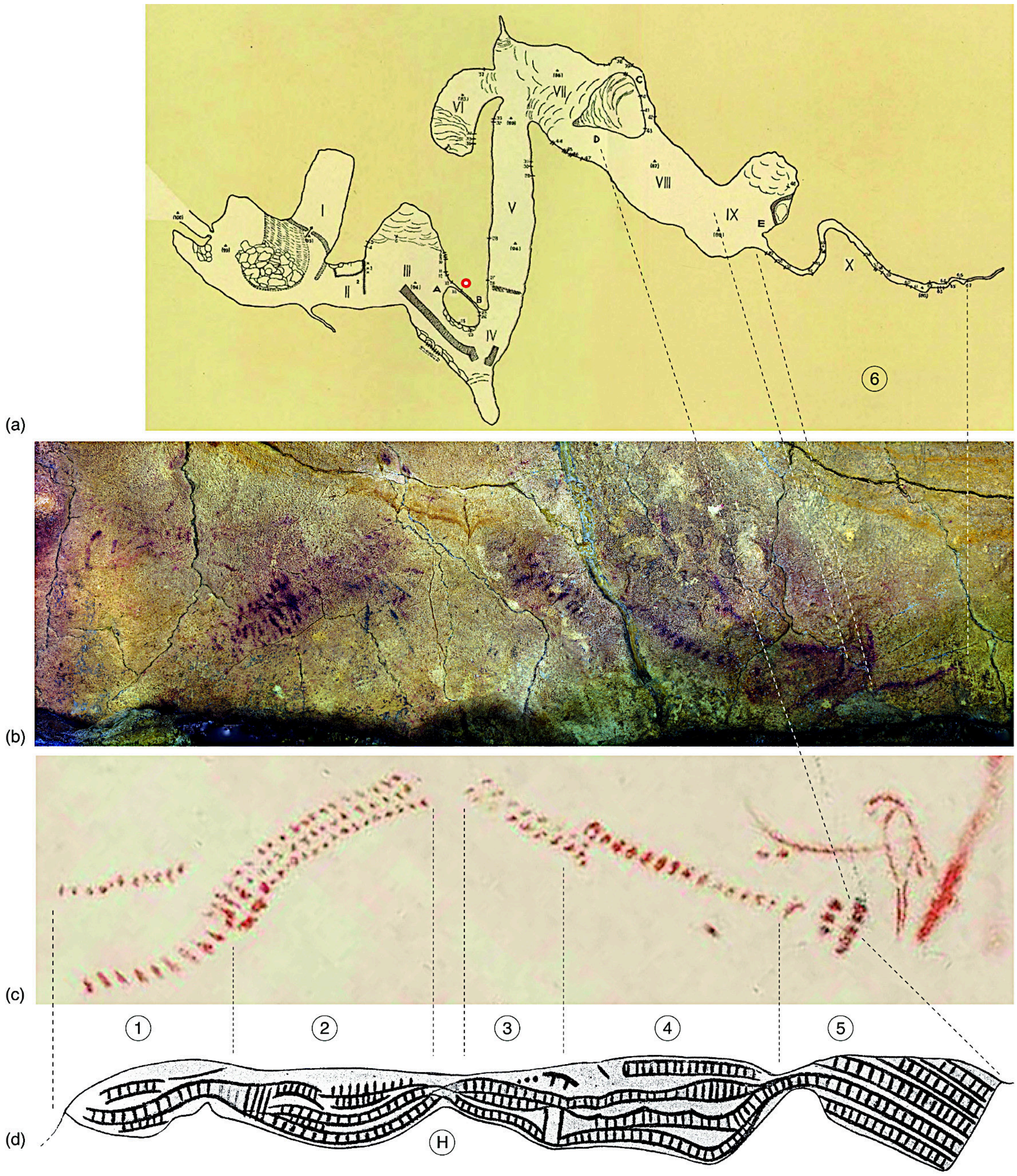


***Figure 16**. Correspondence between PPM3 and PPM3.Bis (picture source: José Latova).*

and represented for each section.

By representing the different widths of the cave along a linear distance from the beginning, as if we were just recording them while we walk through the cave, we have generated a graph that allows a more accurate comparison of correlations between real cave breadths (below) and the number of parallel bands in the scalariform (above) because, as noted, the painting was also carried out with the same flattening criteria, owing to the limitations of the painting surface.

At first glance, section 2 represents breadth changes quite accurately, while section 1 is also somewhat correlated but displaced. The visual analysis of the data confirms that:

1. The two narrowest passageways (minimum values of the lower red curve), located in the cave at the end of corridor V and near the 310° bend connecting Gallery III with Corridor IV, correspond exactly with points N and J in the cartogram. These are the only two places where the main band—going through the whole cave—is clearly represented by just one band.
2. In addition to this breadth correlation, the length is also correlated, as the relative distance between the beginning of the cave and the two previous points in the lower red curve (85 m for J and 135 m for N) is roughly proportional to the number of steps in the cartogram or upper red curve, along the main path: 46 steps for J, and 75 steps for N.

For point J, this implies an average distance of 1.84 m per step and 1.80 m for point N. That is, there is graphic and numerical confirmation that the only two parts of the cartogram limited to a clear single band correspond bi-univocally and simultaneously to the two narrowest passageways in the cave, in terms of both breadth and length. It is fair to say that the scalariform shows two other 'special' places with a single band. The third narrowest point is located around 75 m from the entrance and could represent point H, where two bands cross. The fourth is point D, which represents the widening of the cave at the entrance of Gallery II, approximately 40 m from the old entrance; this is the fourth narrowest point in the cave. In terms of breadth correlation, the fourth narrowest sections of the cave correspond with the fourth place in the cartogram, where there is only one band.

3. Furthermore, the widest and highest section of the cave, located around 160 m in gallery VII, close to section T65, corresponds to point O, where we find the most bands in the drawing, up to five.
4. Furthermore, the second widest area of this part of the cave, located in gallery III, between 50 and 60 m from the beginning of the cave, just before the cascade, coincides with point E, the place with the second-most bands—four.

PPM3: Cartographic test (II): statistical analysis

Statistical evidence has been sought to confirm the visual and numerical coincidences: the Mantel test and Fisher-Snedecor's test (Analysis of Variance, ANOVA), as well as a distance metric, DTW (Dynamic Time Warping), were used. These methods, presented in detail in Appendix 1.3, enable us to analyse topological similarities between the graphs. The summary of the results and conclusions is:

Mantel Test (R) Pearson correlation: 0.9444 (94%) with p-value < 0.001
Mantel Test (R) Spearman correlation: 0.9437 (94%) with p-value < 0.001
Fisher-Snedecor Test p-value = 0.001622
DTW Distance: 0.0775

According to the Mantel Test, we can conclude, with a level of confidence of 99%, that the two graphs are highly correlated and that the correlation is linear. According to the Fisher-Snedecor Test, we can conclude, with a confidence level of 99%, that there is a strong dependence between the representations of width in the cartogram (parallel scalariform bands) and the actual width measurements of the cave. According to Dynamic Time Warping (DTW), the Mean Squared Error is less than 8%, allowing us to conclude again that the graphs are very similar.

PPM3.Bis: A twin painting in Altamira

Like in La Pileta, where we located a preliminary version of the map drawn with parallel bands of red dots, in Altamira, there may also be a draft of the main map, which is again made with red dots. The unstudied sign is located at the far end of the ceiling of the Gallery of the Paintings (Cartailhac and Breuil 1906: 67). By visual comparison with the nearby hind, it is estimated to measure 2 m. Alcalde del Rio and Breuil also recorded this 'sign' (1911: 200).

This painting, which we shall call PPM3.Bis, is divided into six sections. Figure 16, which will be used for the comparisons with PPM3, shows (a) Breuil's map of the cave; (b) a photograph of the enigmatic rows of points from José Latova; (c) a carbon copy of the ceiling 'sign' (ibid.: Pl. V); (d) Breuil's carbon copy of the scalariform.

Section 1 consists of two rows of points, which are much more widely spaced than the rest. It corresponds to the initial part of PPM3, the entrance to the cave, indicating two paths: a higher one leading to the Gallery of the Paintings—where this drawing is located—and a lower one that gives access to the rest of the cave, as represented in the scalariform.

Three parallel lines of dots represent Section 2. It corresponds to the expansion of the cave that follows the hall, reaching point H, past the waterfall. This is the second-widest area of the cave, represented in the scalariform by four bands. The curvature and size resemble the actual shape of the Cave.

Interestingly, in the continuation of this section—matching our point H—there is a gap in the ceiling sign followed by a turn, which exists in the cave but cannot be captured in PPM3 because the ledge on which it is drawn is too straight and narrow to allow it. In the scalariform, H is also a singular point where the drawing seems to blur. All of this could bring another explanation for point H: it is not impossible that water accumulated in this area in front of the waterfall, which is lower than the surrounding areas (Saura 1998: 99), blocking the passage. This could be represented by the dots' interruption on PPM3.Bis and the blurring of bands in PPM3. In Cantabria, the Gravettian period was 'a cold climatic period, with increased humidity, activated hypogeal circulation, and flooded cavities' (De la Rasilla and Guy 2004: 215). The Solutrean period also underwent a very humid intermediate period.

Section 3 is represented by two parallel lines of dots, narrower and shorter than the previous one. It would represent from point H to 'Breuil's pillars', where a significant narrowing and a left turn at the end are found.

A single straight line of dots represents Section 4. Figure 15 shows a relatively narrow passage (J–N) of the cave, long and straight, equivalent to Gallery V.

This simple line of dots abruptly expands at its end, section 5, first into three perpendicular dots and then into five. This represents the expansion of the cave, and it is also represented in PPM3 by an increase in the number of bands to five.

During the review of correlations between PPM3 and the cave (Fig. 11), an anomaly was detected: the painting ended in (O), but the cave goes on to (P) and (S). In the author's opinion, however, this missing last part of the cave is represented to the right of the drawing PPM3.Bis in Section 6. It is visible in the Latova photograph but not in the carbon copy.

This section begins at the top with a dotted line and could represent the passage around the large column described in (P). Further in, now with a solid line, the drawing represents Gallery VIII—framed by lines above and below like in the plan—and then gallery IX, which opens to the left (Q) in both places. Finally, the long and narrow 'Horsetail' or gallery X is represented by the single line that projects perpendicularly from point Q or gallery IX, moving in that direction—like in the real cave—all the way to the end of the cave (S).

In other words, the map in the Gallery of the Paintings (PPM3.bis), made of dots, has a solid-line addendum that completes the cave's map, while PPM3 only covers, with scalariform bands, the dotted part of PPM3.bis. Dating and hyperspectral analysis of both paintings could confirm that they were made at different times and by different hands, as suggested by their different styles, places and scopes.

According to the Museum's catalogue, these 'signs' (FD00653) belong to the Gravettian period. Their location, at the deep end of the Gallery of the Paintings, could suggest that the inhabitants of Altamira painted an early plan of the cave in the Gravettian period (PPM3.Bis) in a hidden area near the entrance, using firstly the number of parallel dots to represent lengths and widths up to point (O), and at some uncertain point in time, using a solid line (a stylistic departure) for the representation of the final section of the cave, which is missing in PPM3.

The cave map was painted again later (PPM3) with solid lines and scalariforms on a ledge inside a crack—making it straighter and narrower, although it was still divided into two sections—and with a better expression of dimensions. Width and distance are more accurately represented with bands and strokes, respectively. The new painting also adopted a unique artistic style that turned the painting not only into a functional tool but also an enduring work of art.

PPM3: Conclusions

The multiple matches between the ladder-like figure, the cave, and the maps—including 23 recent sections of the cave—alongside the graphic and statistical similarity support the notion that *PPM3 represents the cave of Altamira with a very high level of confidence. The correspondence between PPM3, located in a crack in the middle of the cave, and PPM3.Bis, located in the Gallery of the Paintings, further reinforces this hypothesis.*

With the flexible use of ladder-like bands, this complex painting also signals two key interior circulation concepts: the variable width expressed by parallel bands and the relative distance expressed by transversal strokes. Particularly important from this perspective are the two main bottlenecks in the cave, which are faithfully represented—in terms of width and length—in the cartogram. These correlations are also found in less critical junctures—like the third and the fourth-narrowest points and the widest and second-widest points—and generally in all fifteen points (A to O) of Figure 11 (below). This is confirmed not only visually and numerically in Figure 15 but also by the Mantel Test, the Fisher-Snedecor Test and DTW metrics. Finally, all the other signs beyond the ladder-like bands (like semi-bands, lintels or single lines) accurately signal unique and significant features that curtail circulation: the Cascade, the Gallery of the Paintings and the entrance to the crack where the map is found.

Only one point, point H, potentially diverges from visual correspondence, but there are strong arguments to explain this exception. At this point, the rock face becomes so narrow that there is only room for a single band. Moreover, this point separates two drawings undertaken with different techniques and, very likely, by different hands. Last, but not least, in PPM3.Bis, the drawing is abruptly interrupted to continue a little further.

It is also true that the scalariform does not accurately represent significant changes in direction and the total length of the cave. However, considering the limited length and straight shape of the ledge, representing bends is impossible in most sections, and the 19th-century plans of the cave are equally inaccurate in this regard (Fig. 13). While PPM3 matches the 'dotted' sections of PPM3.bis, this one has an addendum that represents the final part of the cave. There was no room to do likewise in PPM3. That is, only two potential and partial discrepancies exist, and both can be convincingly explained.

Relationship between cartograms

Various authors have wondered about potential similarities between drawings: Züchner (1996: 326) pointed out affinities between PPM2, PPM2.Bis and PPM3 (La Pileta and Altamira); Fortea (1978: 145) between PPM1.Bis and PPM2 (Palomas and Pileta); and Moreno García-Mansilla (2022) between PPM1 and PPM1.Bis (Estrellas and Palomas).

Conclusions and implications

The six Palaeolithic paintings in Estrellas, Palomas, La Pileta and Altamira—all of which are based on red, multi-branching, dotted or continuous double lines—reflect their surrounding topography and are interpreted as Palaeolithic maps or croquis.

In Estrellas (PPM1) and Palomas (PPM1.Bis), the croquis represent the region north of the Strait of Gibraltar, where the caves are located. The Estrellas sign represents a vast region with various Palaeolithic sites and includes the area covered by the 'sign' in Palomas. Both match in style, scale, date, colour and region. The topographic coincidences have been proven and confirmed by the RMSE, Mantel's and Jaccard's tests, which rule out these matches being the result of random factors.

In La Pileta, the sign PPM2 represents the complex internal layout of the main level of the cave. The topographic match between the drawing and the cave is complete: all the relevant elements in the drawing match with a real topographic feature, and all relevant topographic features of the cave are reflected in the drawing. The bi-univocality between both figures was mathematically tested by Levenshtein distances and the correlation between painting and plans by the Mantel Test. Additionally, the two cartograms identified inside the cave are interrelated. One of them (PPM2.Bis) covers only the section of the cave that lies between the location of the map and the back end and is probably the earliest, being but a straight double dotted line, whereas PPM2 represents bends and level changes of the whole cave and was drawn with continuous lines.

In Altamira, PPM3 not only artistically depicts the cave's layout like in La Pileta but also introduces an ingenious system to represent the length (number of strokes) and the width (number of bands) of different sections. The topographic correspondence between the painting and the cave plans has been demonstrated and statistically confirmed by the Mantel Test. The correlation between number of bands and cave width has been proven visually and with the support of DTW metrics and the Fisher-Snedecor Test. Additionally, the comparison of PPM3 and PPM3.Bis—a ceiling painting composed of rows of red dots at the back end of the Gallery of the Paintings—leads to the conclusion that PPM3.Bis is likely an earlier—and complete—version of the map.

La Pileta and Altamira's croquis have additional common patterns: they are painted in the interior of the caves, in a concealed place, halfway into the cave, and represent the inside of the cave. Both are drawn with solid lines but have a potential early dotted 'draft'.

It is recognised that we shall never be able to be certain about the nature of these croquis; the only ones in a position to confirm or deny the hypothesis—the authors of the drawings—are no longer among us. However, the match between drawings, real plans and topography; the mathematical confirmations; the number of examples presented; the similarities among them; and the fact that all of them are supported at least by two matching drawings confirms that the hypothesis is highly plausible and likely correct. As such, it may be concluded that:

The Palaeolithic painting in Estrellas (PPM1) is, in all probability, a croquis of the region to the north of the Strait of Gibraltar;
The Palaeolithic painting in La Pileta (PPM2) is, in all probability, a croquis of level 0 of the cave;
The Palaeolithic painting in Altamira (PPM3) is, in all probability, a croquis of the cave;
The secondary Palaeolithic paintings in Palomas (PPM1.Bis), La Pileta (PPM2.Bis) and Altamira (PPM3.Bis) are likely complementary or earlier versions.

Subject to further research, these conclusions open the door to redefining some of the existing paradigms:

Some Palaeolithic signs can be deciphered. Recognising these six Palaeolithic signs as maps implies that, for the first time, we know the real meaning of some of them. As such, they cease to be ideoform signs—or any other word with the suffix -form—to become CROQUIS, a new category of signs including decoded maps. Once this is accepted, the new challenge will be—in addition to decoding other examples around the world—trying to understand how Palaeolithic humans could execute them and what use they made of them: perhaps they were simply a means to improve their chances of survival, a tool for better orientation, organisation and communication that met collective functional needs. If this is the case, more will surely be identified in the future.

Palaeolithic humans had conceptualisation and cartographic skills, which means that they had the power of abstraction required to represent maps. This places a new milestone, much earlier than 12,000 years ago, that signals an evolved human intelligence and 'scientific' thought for which there was no evidence to date. As such, these 'information tools' should perhaps redefine new periods (Altamirensis) in our pre-History, in the same way 'lithic tools' define stages in the Palaeolithic. The fact that some 'signs' are dated as early as the Aurignacian or Gravettian period raises the stakes of testing this hypothesis.

Epilogue

Many theories have been put forth in the past to interpret Palaeolithic' signs', but none of them are convincing. Perhaps, one day, 'The next big theory' will come. However, it is legitimate to wonder if any is possible or even necessary, as it would have to cover an extraordinarily wide range of millennia, categories and contexts (Bahn 1994). Trying to push the complex hermeneutics of cave art iconography forward, I have followed a different approach, and, not surprisingly, I have reached different conclusions. Reductively put, instead of a 'theory without solid cases', this author pursues 'solid cases without a theory', and instead of supporting an interpretation with classifications and intellectual arguments, he deciphered the 'signs' using geographical tools and mathematical tests. This is key because the signs, the space and the landscape are still as they were and where they were, but ideas and culture are long gone. These signs are not a language but a form of communication that still works today. We have finally deciphered the message, and the key to their decoding was not inside the mind of Palaeolithic humans but outside, in the surrounding space.

Ortega and Gasset rightly emphasised the importance of the pre-Historic invention of the 'line, something that does not exist in reality', without which these maps would not have been possible. According to him, what is most satisfying about these primitive works of art is their pristine nature, the absence of a tradition, as well as their mysterious resilience; when the painting is not only the artistic charm that it contains but the reality that the image reflects, enabling comparisons (Ortega and Gasset 2004, Vol. I and III, and 2006, Vol. V).

Zweig, in the 'Mystery of the artistic creation', reminds us that no work of art shows its depth and greatness at first glance. They are not only to be admired but also understood. And even if we have not seen when it was made, we can reconstruct its genesis because the greatest virtue of the human spirit is to understand what at first seems incomprehensible.

Finally, as an amateur researcher, I cannot but humbly admire and undersign Sautuola's words in his book on Altamira (1880), at least about the meaning of the proposed maps: 'Leave it to more learned people to interpret the data that I lightly mention, as the author of these inconsequential lines is happy enough with having collected objects [in our case, only signs and ideas] of such interest for the country's history so that men of science put their eyes in this province [in our case, in these 'signs'] more than it has been to date'.

Altamira profoundly changed existing perspectives on pre-Historic humanity. Perhaps now, alongside the other caves, it will do it again.

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Appendix 1.1 (PPM1)

The tests were performed using the Phyton language and the following libraries: scikt-bio (Mantel), dtaidistance (DTW), scipy.stats (Pearson & Sperman), pingouin (ANOVA / Fisher), levenshtein (Levenshtein) and networkx (Djikstra). To compare PPM1 and the georeferenced map, eight key line intersections were selected: 1. Tarifa; 2. Facinas; 3. Barbate; 4. Vejer; 5. Benalup; 6. Alcalá de los Gazules; 7. Castellar; 8. Gibraltar.

The georeferenced map used was MTN200_2015_ZONA30E_ETRS89_UTM30.ecw, allowing UTM points to use over Datum ETRS89. The fitting algorithm used was 'first order polynomial (Affine)'. The positional deviation of the eight key points and the average root mean squared error (RMSE) were calculated using the software ArcGIS. Figures illustrating the result of the cartographic study representing the connections between points, positional deviations, and fit of cartogram and georeferenced map, together with the ARCGIS-generated table with coordinates and residuals for both maps, are available in previous publications (Moreno García-Mansilla 2022: 30).

The tests yield an RMSE of 2870 m, which implies a deviation of approximately 5%. The two largest residuals correspond to two coastal points, Barbate (3) and Gibraltar (8). Considering that c. 9000 years ago, the sea was approximately 35 m lower than today (Onrubia 1988: 152), these points could well correspond to points that are currently under the sea. Especially in Barbate, the continental platform descends gently, and the river mouth was farther out. The distance roughly coincides with the -40 m sea level difference. Something similar applies to Gibraltar. Based on this, rather than trying to reposition points 3 and 8 out at sea, we undertake a complementary RMSE analysis, owing to the uncertainty factor introduced by the differences in coastal profiles between the Palaeolithic and now. Considering only points with minor changes, the RMSE drops to 1499.98 m, an error of 3%.

In addition to RMSE, the Mantel Test (network analysis) was used to compare the distance matrix between the eight points in the georeferenced map and the cartogram, yielding values of 0.9 and a p-value of 0.001. These results confirm a strong correlation with a level of confidence above 99% and rule out that these coincidences can be attributed to chance. To determine shape correspondence between the drawing and equivalent routes in Coello's map, Jaccard's index (81%) was calculated to establish the level of correspondence between 23 points in both maps (Moreno García-Mansilla, 2022: 33) based on connections and angles.

Appendix 1.2 (PPM2)

The Mantel Test was used to compare distance matrices using all existing node pairs in Figure 8. Since connecting different points within cave galleries and the drawing was impossible, distances between two nodes were calculated based on the graph's definition. When a pair of nodes is not contiguous, the shortest paths were calculated using Dijkstra's algorithm. The Mantel Test was used to test the following null and alternative hypotheses:

H0: There is no linear dependence between the distance matrices of the cartogram and plan.

H1: There is a linear dependence between the distance matrices of the cartogram and plan.

A p-value close to zero ($p\text{-value} < 0.001$) suggests the null hypothesis is false, indicating a linear dependence between the two metrics. The Mantel Test yielded the following results:

Mantel Test (Pearson correlation): $p < 0.001$ and correlation equal to 0.9403

Mantel Test (Spearman correlation): $p < 0.001$ and correlation equal to 0.9433

Therefore, we can conclude that the matrices are not independent and that the two graphs are highly correlated, rejecting the null hypothesis with a confidence level of over 99%.

The second test aimed to evaluate the level of bi-univocality between both figures. The Levenshtein distance allows us to measure the similarity between two strings of characters. By constructing a sequence that represents the characteristics of each node in both the cartogram and the cave plan in Figure 8, we can calculate the distance between these two sequences and compare it with distances yielded by similar sequences randomly generated. To do this, we labelled each of the 16 nodes with three symbols and then formed a left-centre-right sequence of 48 characters. The symbols used and the topographic characteristics they represent are as follows:

'x' for NO continuity in a specific direction; 'E' for beginning or end; 'I' for continuity; 'O' for circular path; 'T' for a sharp curve.

Numbers 1, 2 and 3 indicate the sides allowing departure from the main path: '1' for entrance, '2' for gallery, '3' for descent. The labels for each node in Figure 8 and the character strings are as follows (N=Node, C=Cave, P=Painting):

N	C	P	N	C	P	N	C	P
A	xEx	xEx	G	xI3	xI3	L	2xx	x2x
B	xI1	xI1	H	2xI	2xI	M	xIT	xI2
C	OI3	OI3	I	xxx	xxx	N	TIx	2Ix
D	III	III	J	TIx	TIx	O	xIx	xI2
E	xI2	xI2	K	2Ix	I2I	P	xEx	xEx
F	xxx	xxx						

Cave: xExxI1OI3IIIxI2xxxxI32xIxxxTIx2Ix2xxxITTIxxIxxEx
Cartogram: xExxI1OI3IIIxI2xxxxI32xIxxxTIxI2Ix2xxI22Ixx-I2xEx

The Levenshtein distances between these two strings were compared with those resulting from 10,000 equivalent alternative representations randomly generated with the following restrictions: a set number of nodes; the first and last nodes are identical; and all intermediate nodes have the same probability of featuring a symbol on the left, centre and right, as in the representation of the real map.

Monte Carlo-generated labels, keeping the graph structure, indicate that none of the simulations result in a Levenshtein distance below that yielded by the drawing. In other words, our drawing is the most similar graph among the 10,000 models used, and a one-to-one correspondence can be established with a confidence level close to 99%.

Appendix 1.3 (PPM3)

Like in PPM2, the Mantel Test was used to compare distance matrices and test the null (H0) and alternative (H1) hypotheses, using all pairs of nodes in Figure 11, yielding the results:

Mantel Test (Pearson correlation): $p < 0.001$ and correlation equal to 0.9444

Mantel Test (Spearman correlation): $p < 0.001$ and correlation equal to 0.9437

Therefore, it can be concluded that the matrices are not independent, and the two graphs are highly correlated, rejecting the null hypothesis, with a confidence level above 99%.

The similarity between the number of parallel scalariform bands in the drawing and the effective width of different sections of the cave was calculated by performing an analysis of variance using Fisher-Snedecor's Test, aimed to establish whether the presence of different bands in the cartogram matched with significantly different widths in the cave passage. The Fisher-Snedecor's Test is used to study associations between two qualitative variables.

The p-value yielded by Fisher-Snedecor's test for the 'effective width' variable was 0.001622**.** Since the sample is sufficiently representative to be regarded as significant, it can be rejected, with a confidence level above 99%, that these drawings are independent**.** In other words, as our hypothesis holds, there is a strong dependence between the representation of width in the cartogram and the actual width of the cave.

A third way to measure differences between both metrics is DTW, or 'dynamic time warping.' In Time Series analysis, Dynamic Time Warping (DTW) is an algorithm that measures similarity between two temporal sequences. However, any data that can be turned into a one-dimensional sequence can be analysed by DTW, such as signature recognition and partial shape matching. We used it to test the correlation between cave width and bands. The mean squared error (relative) was calculated after normalising and interpolating both curves to the same length using a series of one hundred equidistant values. The mean squared error for the Euclidean distance was also calculated. The results were:

MSE concerning effective width (after normalising both series):

DTW distance: 0.0775. Euclidean distance: 0.1075.

In other words, the Mean Squared Error of this comparison is less than 8%, leading again to the conclusion that the graphs are very similar.

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