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The age of hand stencils in Maltravieso cave (Extremadura, Spain) established by U-Th dating, and its implications for the early development of art

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A R T I C L E I N F O

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A B S T R A C T

U-Th dating of associated carbonate crusts has been applied to date parietal art in Maltravieso cave, Extremadura, Spain. Known for its large collection of red hand stencils (≥60), one example previously dated to >66.7 ka was taken to suggest Neandertal authorship. Here we present a more detailed U-series study of hand stencils within the cave, and place the results in the context of the chronology of these motifs worldwide. Twenty-two carbonate samples overlying pigment of hand stencils were dated from the cave's Sala de las Pinturas and the Galería de la Serpiente. Minimum ages for the art range from the Holocene to the Middle Palaeolithic. Alongside published dating results from other sites, this demonstrates that Neandertals as well as modern humans could create these motifs.

1. Introduction

Hoffmann et al. (2018a) reported U-Th dates on carbonate deposits from three cave sites in Spain that placed the emergence of cave art prior to 65 ka on the basis of the non-figurative art on the cave surface underlying them. Subsequent publications criticised this study on a variety of points, based on — but not limited to — misconceptions over the sequential nature of speleothem growth; the belief that the accepted chronology of cave art in Europe could not be challenged; the incorrect assumption that the stalactites dated bore no meaningful relationship to the underlying art; and concerns over uranium remobilisation within the dated speleothems that would render their dating incorrect (Aubert et al., 2018a; Pearce and Bonneau, 2018; Slimak et al., 2018; White et al., 2020). We point readers to these papers, and our subsequent rebuttals (Hoffmann et al., 2018b, 2018c, 2019, 2020), for in-depth discussions on these points. Here we report all results for samples dated from one of these caves: Maltravieso. Data were recently published in a Spanish-language monograph about Maltravieso rock art (Standish et al., 2022), but we present them here to allow accessibility for all interested parties, and to enable an in-depth discussion on the potential implications of these results.

Maltravieso Cave, located in the city of Cáceres, Extremadura, Spain, is a key site for Palaeolithic cave art. Rediscovered during quarrying operations in 1951, it consists of several major chambers, successively: the Sala de las Entrada, Sala de las Sumidero, Sala Callejo, Sala de los Huesos, Sala de las Columnas, Sala de la Mesita, Sala de las Pinturas, Sala Alta del Cono, and Sala de las Chimeneas (Fig. 1). Each of these are joined by a series of conduits, or galleries: the Galería de Acceso, Galería

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Central (Fig. 2), Galería Inversa and Galería de la Serpiente. Following the discovery of the art, several chambers were artificially excavated to improve accessibility within the cave by lowering the floor level. Today, Maltravieso is c.135 m long and occupies an area of about 2000 m^2.

Aside from its art, archaeological evidence of Pleistocene human activity in Maltravieso is limited. Archaeological and zoological evidence from the Sala de las Chimeneas indicates that it was visited during the Solutrean. Lithics and animal bones (mainly of rabbit), perforated seashells, and a bovid rib fragment bearing linear incisions, were recovered from a context dated by two charcoal samples to 17,840 ± 90 BP (Poz-30469, 21,563–20,885 cal. BP, IntCal09 at 2σ) and 17,930 ± 100 BP (Poz-30460, 21,758–21,041 cal. BP, IntCal09 at 2σ: Rodríguez-Hidalgo et al., 2013). Quartz tools (Peña et al., 2008), including a core and flake of Middle Palaeolithic form, have been reported from the Sala de los Huesos in association with a large assemblage of animal bones deposited in the main by denning hyaenas. Their context was bracketed by flowstones dated by U-Th to 117 (+17 to –14) ka BP and 183 (+14 to –12) ka BP (Mancha Flores, 2011), and thus demonstrate an earlier human presence.

Maltravieso's art was rediscovered in 1956 (Callejo, 1958), and was subsequently studied by Almagro (1960), Jordá (1970), Ripoll Perelló and Moure Romanillo (1979), and Jordá and Sanchidrián (1992). A general catalogue was published in 1999 (Ripoll López et al., 1999a, see also Ripoll López et al., 1999b), with an updated volume published in 2022 (Collado Giraldo and García Arranz, 2022). It is dominated by hand stencils/prints (generally agreed to number 60). In addition, it contains zoomorphic figures including deer and hinds (3 examples), horses (7), a bovid (2), a goat (1), and a number of geometric symbols (dots, discs, triangles, square motifs, lines, bars and cup marks) as well as a series of indeterminate red pigment spots. The hand motifs are primarily represented as negative stencils, produced by projecting the pigment at the hand with the palm resting against the wall. ATR-FTIR spectroscopy indicates that they were produced using earth pigment containing various mixtures of manganese oxide, hematite, magnetite, and goethite that is naturally present in the cave (Rosina et al., 2023). Numerous examples of these have attenuated (i.e. graphically missing) fingers — typically the little finger — most likely created by flexing the finger towards the interior of the palm rather than reflecting a genuinely missing finger. Both painting and engraving were used to produce the animal figures, whilst the non-figurative elements were made by blowing pigment, engraving, or painting. The relative abundance of hand stencils in the cave makes it one of the most important sites for this iconic Palaeolithic motif.

Despite the importance of Maltravieso's Palaeolithic art, no absolute dating programme had ever been undertaken on the motifs until now. The fact that the majority of examples of the art were either engraved or produced with red mineral pigments (haematite) precluded the use of radiocarbon dating on the pigments themselves, which until recently has been the only chronometric technique applicable to dating cave art. For many years, specialists have regarded European hand motifs to be Mid Upper Palaeolithic (Gravettian *sensu lato*) in age, although this has been based on very few reliable sources of data and almost certainly underestimates their age, as we discuss below. Over the last decade, however, methods permitting the dating of associated carbonate formations by U-Th techniques have been developed, and sample size requirements are now so small as to render its application to dating cave art possible in a way that is non-destructive to the art itself (Hoffmann et al., 2016; Pike et al., 2017). Here, we present data that uses such an approach to investigate the age of Maltravieso's Palaeolithic art. Dating of a hand stencil from panel GS III was published by Hoffmann et al. (2018a), where it was referred to as 'GS3b'. Here we present the full U-Th dataset from this dating programme (see also Standish et al., 2022), and discuss its possible implications for both our understanding of the cave's art and the development of art in general.

2. Materials and methods

Eighteen carbonate samples in clear and direct association with red hand stencils in the Sala de las Pinturas (panels P III and P IV) and the Galería de la Serpiente (panels GS I, GS II, GS III, and GS V; Fig. 1) were dated during an initial period of work. One additional sample from GS V was also collected at this time, but failed quality control checks because no direct association with pigment could be demonstrated after the sampling was complete. The majority consisted of >1 sub-sample,

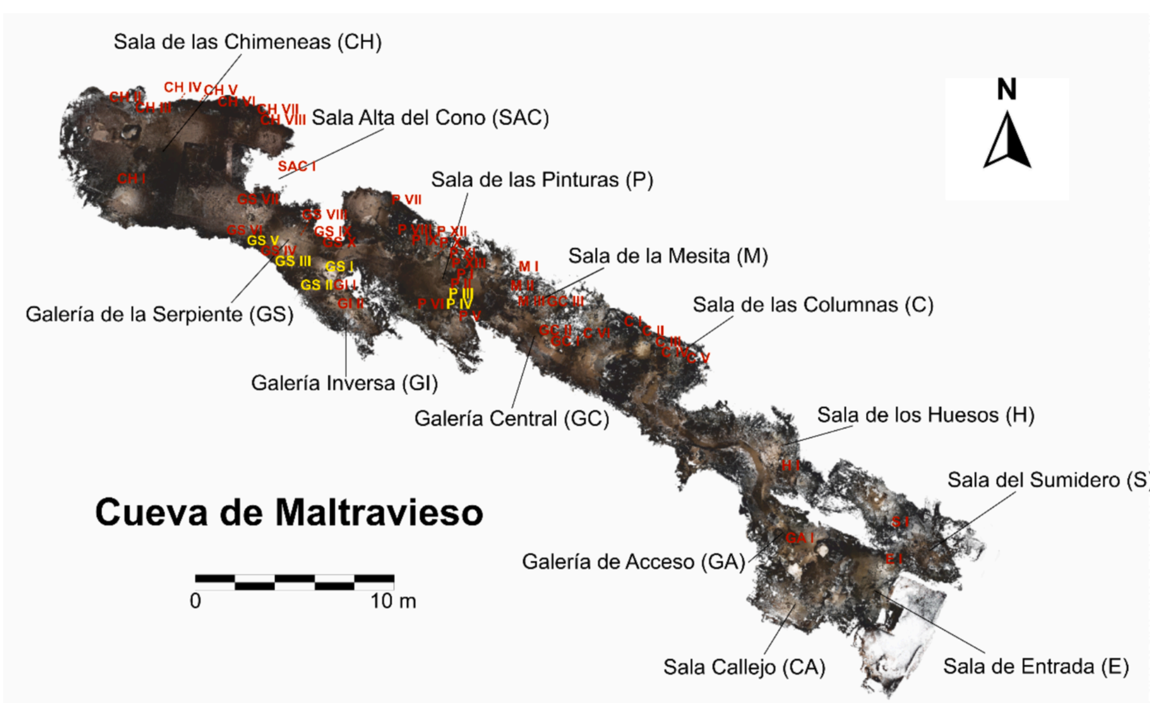

Fig. 1. Map of Maltravieso cave. Art panels sampled in this study are labelled with yellow text; remaining panels are labelled with red text.

Fig. 2. View of Maltravieso's Galería Central, from the Sala de la Mesita.

collected sequentially (i.e. stratigraphically through the carbonate) in order to provide a chronologically consistent sequence that acts as a measure of the internal consistency of the speleothem formation dated. Four further samples were collected at a later date when improving photographic documentation of the initial sampling (specifically, panel GS III). These were not always collected in a stratigraphically consistent fashion, and thus each sub-sample is considered independently rather than as a coherent sequence.

The sampling procedures followed, and the rationale for these, are outlined in Hoffmann et al. (2016). Sample locations were first cleaned to remove surface contamination/alteration prior to sampling. Carbonate removed during the cleaning phase was usually not collected for dating, but when the probability of collecting multiple sub-samples for any locality was low (i.e. the carbonate was too thin), this 'clean' was sometimes retained and analysed as a test of internal consistency. Following cleaning, samples were removed by scraping the carbonate with a scalpel and collecting it directly into pre-cleaned plastic tubes. Additionally, three sediment samples were collected from the cave's floor for characterisation of its detrital Th component, and a fractured stalagmitic column composed of multiple growth layers was sampled to assess the detrital Th correction applied.

U-series dating was performed at the Ocean and Earth Science analytical geochemistry facilities, University of Southampton. Speleothem samples were inspected under a low power microscope and detrital particles were removed where possible, before being weighed into pre-cleaned Savillex PFA vials, dissolved with HNO_3, and spiked with a mixed ^{229}Th/^{236}U spike (Hoffmann et al., 2007). Separation of U and Th from the sample matrix by ion exchange chromatography used 0.6 ml columns and 100–150 μm UTEVA Spec (Eichrom) resin (Horwitz et al., 1992). Procedural chemistry blank values were less than 0.01 ng ^{238}U, 0.1 pg ^{235}U, 0.01 pg ^{234}U, 0.01 ng ^{232}Th and 1 fg ^{230}Th respectively. Sediment samples were dissolved with HNO_3 then the soluble and insoluble fractions were separated by centrifuge. The insoluble fractions were weighed before being dissolved using a combination of HNO_3, HF and HCl. Both fractions were then spiked and processed separately following the same methods used for speleothem samples. The isotopic composition of the total sediment (i.e. combined soluble and insoluble) was calculated using the isotopic composition and mass of both fractions. Full details of sample preparation methods are available in Hoffmann et al. (2018a).

Uranium-series analyses were performed using a Thermo Scientific Neptune Plus MC-ICP-MS equipped with an energy filter (RPQ) on the central ion counter. Samples were introduced using a Cetac Aridus II and Savillex C-flow PFA nebulisers with typical uptake rates of ~ 80 μl/min. Full analytical procedures are outlined in Hoffmann et al. (2018a). Instrumental biases (e.g. mass fractionation) were corrected by sample–standard bracketing; CRM-145 was used for U isotope measurements and an in-house ^{229}Th-^{230}Th-^{232}Th standard solution TEDDii (Hoffmann et al., 2018a) was used for Th isotope measurements. Uraninite URAN 84.5, a secular equilibrium standard, was repeatedly analysed as an indication of accuracy and external reproducibility. Analyses of this gave the following: $(^{230}\mathrm{Th}/^{238}\mathrm{U})_A = 1.0026 \pm 0.0007$ and $(^{234}\mathrm{U}/^{238}\mathrm{U})_A = 1.0001 \pm 0.0002$ (errors 2σ standard errors of the mean, n = 50 over a ~ 1.5 year period). Analyses of a dissolved pristine speleothem sample, which serves as an internal standard, were performed as a further demonstration of external reproducibility. Analyses gave the following: $(^{230}\mathrm{Th}/^{238}\mathrm{U})_A = 0.4335 \pm 0.0082$, $(^{234}\mathrm{U}/^{238}\mathrm{U})_A = 1.0462 \pm 0.0053$, age = 58.15 ± 1.45 ka (errors 2σ standard deviations of the mean, n = 14 over a ~ 1 year period).

3. Results

Table S1 and Fig. 3 present all U-series data for samples from Maltravieso. The U concentrations of speleothem samples range from 41 ng/g to 1311 ng/g, with a mean of 318 ng/g. Samples from the Sala de las Pinturas were generally characterised by lower U concentrations (44–159 ng/g, mean of 90 ng/g) than those from the Galería de la Serpiente (41–1311 ng/g, mean of 380 ng/g). The measured

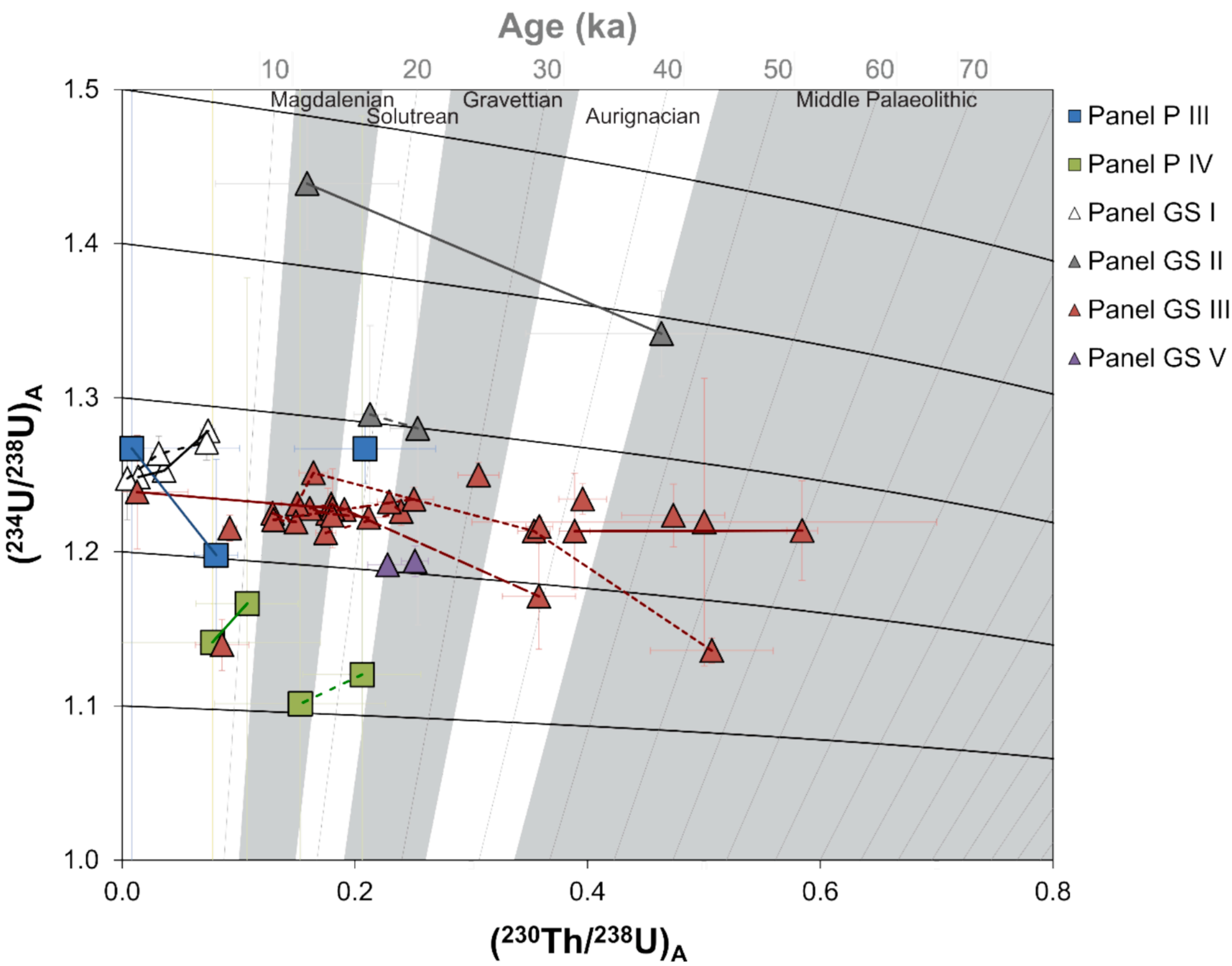

Fig. 3. Detrital Th corrected U-Th data for carbonates associated with Palaeolithic cave art in Maltravieso. Lines joining data symbols indicate sets of sub-samples collected in a stratigraphically consistent fashion. Note that only samples passing quality control checks are plotted. The large errors for samples from the Sala de las Pinturas relate to their high detrital Th content. Figure adapted from Standish et al. (2022).

$(^{234}U/^{238}U)_A$ range from 1.08 to 1.29, with a mean of 1.20. Those from the Sala de las Pinturas are typically lower than those from the Galería de la Serpiente (means of 1.13 compared to 1.22). The degree of detrital ^{230}Th contamination is indicated by the measured $(^{230}Th/^{232}Th)_A$. Lower values indicate increased contamination, and detrital Th corrections have a significant effect on calculated ages when samples are characterised by $(^{230}Th/^{232}Th)_A$ of < 20. The $(^{230}Th/^{232}Th)_A$ of carbonate samples from Maltravieso are variable and often low, ranging from 2.6 to 656.6 (mean of 45.4). Samples from the Sala de las Pinturas typically have lower $(^{230}Th/^{232}Th)_A$ (2.6–120.2, mean of 20.3) than those from the Galería de la Serpiente (3.5–656.6, mean of 52.3). Detrital Th corrections therefore have a significant effect on a number of the samples presented here.

The composition of the detrital components could not be characterised directly through analyses of insoluble fractions because no residues were present after dissolution of the speleothem samples. Furthermore, it was unfeasible to implement isochron methodologies as it was not possible to obtain > 3 samples from the same stratigraphic layer of any distinct speleothem formation. Sediment samples, regarded as a good proxy for the detrital component of the speleothem samples, were instead analysed and their mean $(^{238}U/^{232}Th)_A$ was used for detrital corrections (3.3 ± 0.2). The applicability of this correction was tested through the analysis of six sequential layers from a fractured stalagmitic column (MAL24). When corrections employ an assumed detrital $(^{238}U/^{232}Th)_A$ typical of upper crustal silicates (0.8 ± 0.4; Wedepohl, 1995), sample MAL24F (third from the core) falls out of stratigraphic order. When detrital corrections employ the (sediment) measured detrital $(^{238}U/^{232}Th)_A$, all samples fall in stratigraphic order within error (see Supplementary Text in Hoffmann et al., 2018a). Use of the (sediment) measured $(^{238}U/^{232}Th)_A$ to calculate detrital Th corrected ages is therefore considered appropriate.

Corrected ages of carbonate with a clear association to cave art range from 0.39 ($+0.63$ -0.36) to 70.08 ($+3.82$ -3.37) ka (Fig. 3). Except for MAL21 (GS V) and MAL28E, the dated carbonate always overlies the art, thus the dates discussed are minimum ages for the application of the pigment. Sample subsets are internally consistent in all cases except MAL8, MAL15, and MAL28, whilst a corrected age for MAL23 could not be calculated using the (sediment) measured $(^{238}U/^{232}Th)_A$ value. These will all be discussed in detail below.

4. Discussion

4.1. Sala de las Pinturas

Three samples date the uppermost complete stencil on P III, a panel consisting of three partial or full hand stencils and rows of finger dots (Fig. 4). Minimum ages of 5.87 ka and 13.40 ka were calculated for MAL1 (two sub-samples, internally consistent) and MAL22 (a single sample) respectively. A corrected age for the third, MAL23, could not be calculated using the (sediment) measured $(^{238}U/^{232}Th)_A$, with a value of ≤ 2.5 required to successfully compute an age. When $(^{238}U/^{232}Th)_A =$ 2.5 the corrected age is 1.72 ka, whilst using the bulk earth value of 0.8

Fig. 4. Panel P III and sample locations for MAL1, MAL22, and MAL23. The left picture shows the original photo, the right is the same picture after application of DStretch (correlation LDS 15 %).

Fig. 5. Panel GS I and sample locations for MAL6 and MAL7. The left picture shows the original photo, the right is the same picture after application of DStretch (correlation LDS 15 %).

gives a corrected age of 30.64 ka. The true age of this sample is most likely to fall within this range, however considering the elevated $(^{238}U/^{232}Th)_A$ of the sediment, an age towards the younger end of this range is most likely. Hand stencils from panel P III must therefore be of Magdalenian age or older.

P IV contains five hand stencils superimposed with multiple lines of finger dots, and both figurative and non-figurative engravings. Two samples, both of which consist of pairs of sub-samples internally consistent within error, were dated (Supplementary Figure S8). MAL2 was located overlying pigment above the fingers of hand stencil 2, and returned a minimum age of 6.01 ka. MAL3 was located overlying pigment above the fingers of hand stencil 1, returning a minimum age of 7.39 ka and indicating it is of early Holocene age or older. Samples from both P III and P IV are high in detrital Th, and this is reflected in the large uncertainties of the corrected U-Th ages.

4.2. Galería de la Serpiente

Panel GS I (Fig. 5), a panel of six partial or complete hand stencils, has a Holocene minimum age based on the analysis of two samples: MAL6 overlaid pigment immediately below the wrist of stencil 4, and MAL7 overlaid pigment immediately below the wrist of stencil 6. Both

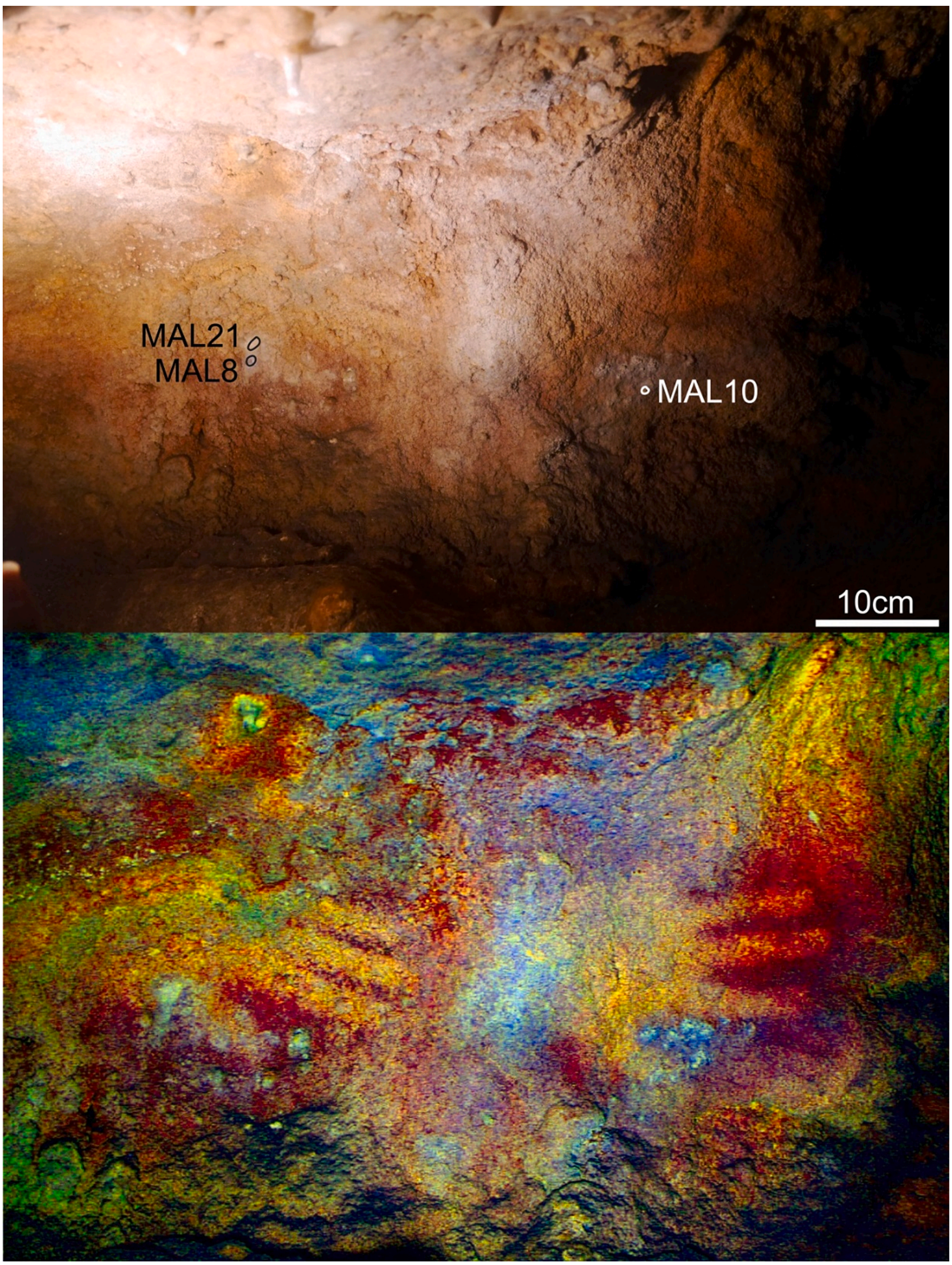

Fig. 6. Panel GS V and location of samples MAL8, 10 and 21. Lower image shows the same panel after application of DStretch (Clogg et al. 2000; correlation LDS 15 %).

consisted of sets of three, stratigraphically consistent, sub-samples, and gave minimum ages of 5.93 and 6.10 ka respectively.

Panel GS V (Fig. 6) can be dated to the Gravettian or earlier. MAL10, a carbonate crust removed as a single piece from Stencil 4 then later divided in half to produce two sub-samples of approximately coeval age provide a minimum age of 24.37 ka. MAL8, which dates Stencil 3, consists of a pair of sub-samples sampled stratigraphically. Sample MAL8A, the uppermost, gives an age of 35.87 (+1.28 −1.26) ka, compared to 30.72 ± 1.03 ka for the lower MAL8B. The stratigraphic inconsistency is most likely due to the complex nature of growth for the cauliflower type deposits sampled in this instance; with multiple potential axis of growth it cannot be established whether the two sub-samples have truly been sampled in stratigraphic order. However, subtle uranium leaching cannot be ruled out in this instance, and these two dates should be treated with caution. MAL21 consists of a series of seven sub-samples, which give a minimum age of 45.56 ka. However, this sample failed quality control checks because no direct association with pigment could be clearly demonstrated after sampling was complete (Supplementary Figure S44). Although visually it looks to be dating the same formation as MAL8, it cannot be used to constrain the age of the art. It does, however, provide an excellent example of a long series of stratigraphically consistent sub-samples providing further evidence that: 1) open-system behaviour is not a significant issue in this cave, 2) the inconsistency between the MAL8 sub-samples is more likely to relate to cauliflower growth patterns, and 3) speleothem crusts were forming in Maltravieso in MIS3, i.e. during the Middle Palaeolithic.

Two samples date the left-most complete stencil of GS II, a panel of four partial or complete hand stencils (Fig. 7). MAL4 and MAL18 were both removed from carbonate formations overlying pigment just beyond the fingertips. MAL4, two stratigraphically consistent sub-samples, gave a minimum age of 20.65 ka, whilst MAL18, also two sub-samples in stratigraphic order but this time including the ‘clean’, gave a minimum age of 32.27 ka. Panel GS II therefore also dates to the Mid Upper Palaeolithic (Early Gravettian) or earlier.

Panel GS III comprises of four hand stencils. Two samples, each dating a different stencil from this panel, returned Holocene minimum ages: 6.20 ka for MAL12 (a single sample) and 8.02 ka for MAL5 (also a single sub-sample). A further hand stencil, newly discovered during one of the sampling trips, was initially dated by five samples (Hoffmann et al., 2018a; referred to as ‘GS3b’), giving the following minimum ages: 14.71 ka (MAL19), 23.12 ka (MAL14), 35.27 ka (MAL15), 55.24 ka (MAL17), and 66.71 (MAL13). MAL15 consists of six sequential sub-samples, all of which are in stratigraphic order except the outer most. This can be explained by the widening of the sample area after MAL15A was taken, which would incorporate a degree of younger carbonate (Hoffmann et al., 2016, 2018a). These samples, despite their close proximity, are from multiple, distinct, cauliflower-type formations, which could have formed at any time and need not, therefore, be coeval. The range of dates indicates that they grew at various times throughout the last ∼ 70 ka. The dating of growth layers within the speleothem column (MAL24) to ∼ 60–70 ka ago provides corroborating evidence that speleothem growth occurred in Maltravieso at the same time as MAL13 and MAL17 were forming. Two of the samples overlying this stencil therefore place its creation in the Middle Palaeolithic.

Four further samples were taken from this stencil during a later fieldwork session that focussed on demonstrating the continuity of the pigment layer at the initial sampling locations (obscured by calcite before sampling) with pigment visible on the cave wall that is unambiguously part of the hand stencil (Hoffmann et al., 2019). Those that collected carbonate from pre-existing sampling locations incorporated material from both within (to sample carbonate nearer to the pigment) and around (to expand the sample area and reveal a continuous pigment layer) the existing sampling void. Sub-samples were therefore not collected in a stratigraphically consistent manner and stratigraphic consistency with the resulting sequence of U-Th ages is not to be expected. MAL25 resampled MAL13, and consisted of four sub-samples which sequentially enlarged the original MAL13 sampling location area (see Supplementary Figures S27 and S29). With each sub-sample treated independently, minimum ages for the underlying pigment ranged from 46.60 ka (MAL25A) to 16.47 (MAL25D). MAL25A, which sampled an area most consistent with MAL13, reinforces the Middle Palaeolithic age for the underlying pigment. MAL27 resampled the MAL17 sample location. It consisted of a single sub-sample, and returned a minimum age of 30.54 ka for the underlying pigment. Both MAL26 and MAL28 sampled new locations on this stencil; below and to the left of MAL13 respectively. MAL26, a single sub-sample, returned a minimum age of 39.07 ka. MAL28 was a series of five sub-samples which sampled a cauliflower-type formation obliquely meaning stratigraphic consistency was not guaranteed (explaining the slight age inversion present between samples MAL28B and MAL28C). Furthermore, the fifth and final sub-sample was found to contain probable pigment during inspection under the microscope. Due to the likelihood that this sub-sample incorporated carbonate that predates the hand stencil, its stratigraphic relationship to the motif is unclear, and the sample – which returned a markedly older U-Th age of ∼202 ka – failed quality control checks. The minimum age for pigment underlying this sample is given by sub-sample MAL28D, and is 22.80 ka.

4.3. *The hand stencils of Maltravieso cave and their significance*

There is clear archaeological evidence for human presence in the Sala de las Chimeneas, the deepest part of the cave, during the Solutrean.

Fig. 7. Panel GS II and location of samples MAL4 and 18. Lower image shows the same panel after application of DStretch (Clogg et al. 2000; correlation LDS 15 %).

Hand stencils are, however, absent from this section of the cave, and are instead focussed in its central portions, with only one panel comprised of six hand stencils located near the present day entrance (the original entrance, destroyed by quarrying, was nearby). Ten carbonate samples (MAL10, 13, 14, 15, 17, 18, 25, 26, 27, 28), overlying four hand stencils on three separate artistic panels (GS II, GS III and GS V), provide minimum ages that securely pre-date the Solutrean, and therefore clearly demonstrate human activity within Maltravieso at a date earlier than the Late Upper Palaeolithic.

All of the panels dated to pre-Solutrean times are located in the Galería de la Serpiente. Dating of two sample sequences on one of the hand stencils on panel GS III suggests that Maltravieso's hand stencil tradition began as early as the Middle Palaeolithic (here we consider MAL13 and MAL25 together because they sample the same area), an estimate consistent with archaeological evidence for the presence of humans (Neandertals) in or around the cave during this period, i.e. the Middle Palaeolithic quartz tools of the Sala de los Huesos (Peña et al., 2008) dated to ~180–120 ka ago (Mancha Flores 2011). Carbonate overlying pigment in the Sala de las Pinturas, by contrast, formed at a much younger time, and thus our results here can only confirm a Palaeolithic date for the hand stencils in this region of the cave (i.e. Magdalenian or older). There are two basic implications of our results. If we consider the hand stencils to have been created in one phase, i.e. that they are contemporary, this implies they are all > 66.7 ka in age. If, however, we assume a much longer, periodic, accumulation of stencils, perhaps by subsequent imitation (either by later Neandertals or modern humans), then the origin of the tradition of creating hand stencils lies within the Middle Palaeolithic, whether or not similar forms were created later during the Aurignacian, Gravettian, Solutrean and/or Magdalenian. Either way, the data presented here suggest that hand stencils were a Neandertal innovation. Whilst future programmes of scientific dating will be able to critically test this hypothesis, the significance of it warrants further discussion here.

Rosina et al. (2023) performed ATR-FTIR spectroscopy on eight figures, including four hand stencils, in Maltravieso cave. The two stencils analysed from the Galería de la Serpiente were made with the same pigmental composition (hematite), and it was argued that these stencils were created as part of the same artistic phase. This pigment composition contrasts with that of the two other stencils studied; one located in the Sala de las Pinturas and the other located in the Sala de las Columnas (a mixture of hematite, magnetite, geothite and in one case manganese oxide); evidence of a different phase of application. At face value, this supports the notion that Maltravieso's hand stencils were not created in a single phase, thus favouring a longer tradition of stencil making in the cave. It is worth noting that this finding is consistent with the minimum ages presented here: hand stencils from the Galería de la Serpiente have older minimum ages going back to the Middle Palaeolithic compared to the Sala de las Pinturas which have minimum ages from Magdalenian or younger.

A further argument in favour of an extensive diachronic sequence for Maltravieso's hand stencils is provided by the differences in the range of visibility that these motifs offer to the viewer who contemplated them. Stencils in the Galería de la Serpiente, including those associated with the oldest minimum ages, include examples created in locations that would not have been obvious to visitors to the cave. This contrasts with those located in the Sala de las Entrada, Sala de las Columnas, and Sala de las Pinturas, which are depicted on open panels that are easily perceptible to the individuals wandering through the cavity.

Collado Giraldo and García Arranz (2022) devised a relative chronology of the different artistic styles present in Maltravieso, placing the hand stencils in their Phase 1 and 2. The only motifs predating the stencils, based on superimposition, are an engraved ibex and triangles on Panel P IV. Our sample MAL3, which returned a minimum age of 7.39 ka, was located overlying pigment above the fingers of Stencil 1

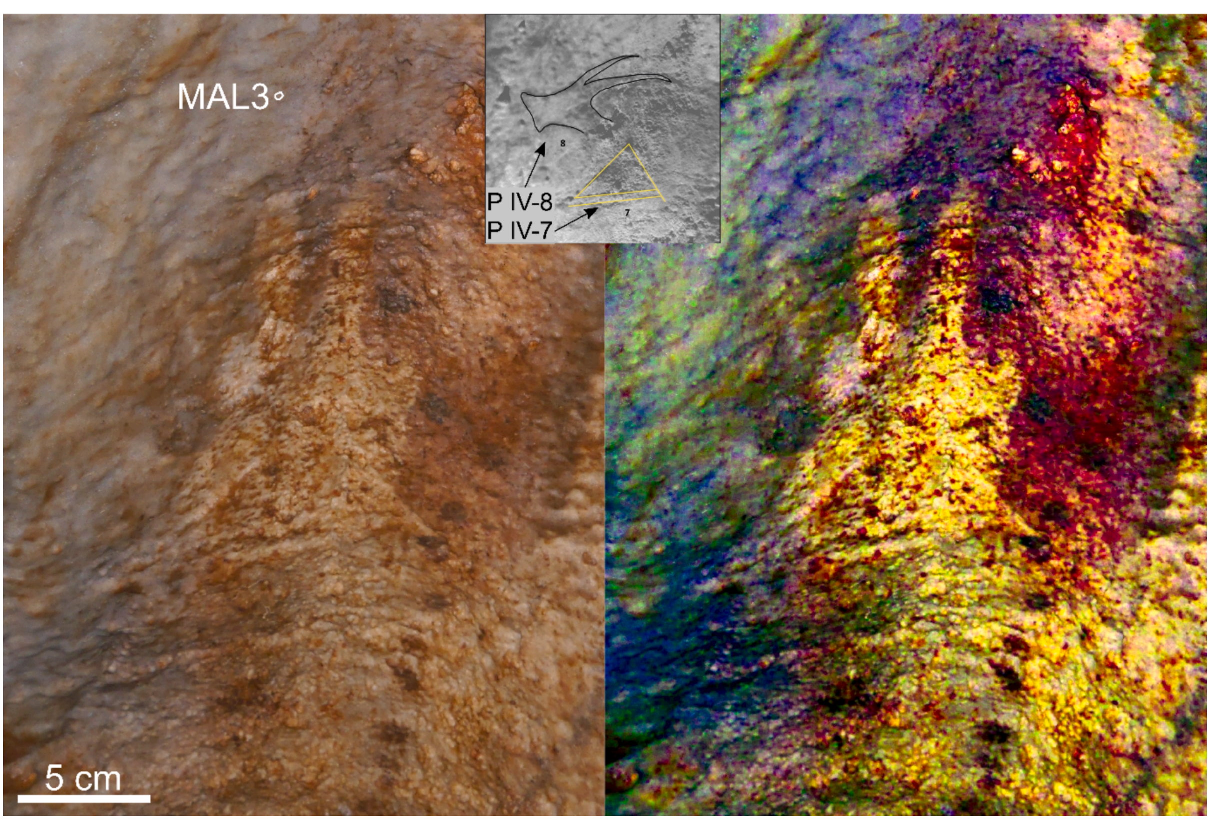

Fig. 8. Superimposition of engraved 'ibex' and triangles with hand stencil 1 on Panel P IV, and location of sample MAL3. The left picture shows the original photo, the right is the same picture after application of DStretch (correlation LDS 15 %). Inset shows position of engravings as identified in Collado Giraldo and García Arranz (2022).

which Collado Giraldo and García Arranz (2022) describe as overlying and therefore post-dating this ibex and triangles (Fig. 8). Considering the evidence presented for multi-phase application of hand stencils, and the Holocene minimum ages reported for Panel P IV, all of the aforementioned engravings could realistically date to the Upper Palaeolithic. Parsimoniously, this is where they must be placed for now.

Due to the absence of suitable sample material it was not possible to directly date any of the other forms of art present in Maltravieso, such as the painted triangles, finger dots, or figurative engravings that constitute the later phases of Collado Giraldo and García Arranz (2022). The cave's relative sequence of artistic traditions cannot, therefore, be tied to a wider absolute chronology, and although an earlier age cannot as yet be ruled out for the cave's relatively few figurative motifs, i.e. those in the Sala de las Chimeneas, it is perhaps parsimonious to view them as associated with the Solutrean activity. The key implication of our results, however, is that the motifs with the earliest minimum ages in the cave are the hand stencils; a number of these stencils pre-date the Solutrean activity in the cave; and, in some cases at least, were created prior to 66.7 ka ago.

These new results are consistent with recent critical evaluations of the existing chronological data for European Palaeolithic hand stencils in Spain, France and Italy, on which are based the oft-cited dogma that they are of Mid Upper Palaeolithic age. These concluded that the existing (i.e. radiocarbon) chronologies must be regarded as minimum ages, and that at face value they should be regarded as early Gravettian and earlier (García-Diez et al., 2015; Pettitt et al., 2015). Hence we see no inconsistencies between the results we present here and the existing minimum age for hand stencils and prints.

Following the current dating evidence, the age of the Maltravieso stencils is highly significant to our understanding of the origins of art and the emergence of human visual culture. Given that there is no convincing evidence for modern humans in Iberia prior to 40 or 45 ka ago (Zilhão and d'Errico, 1999; Mellars, 2011; Higham et al., 2014, Alcaraz-Castaño, 2023), more than 20,000 years later than our *minimum* ages, it follows that at least some of the Maltravieso hand stencils were created by human groups in Europe long before modern humans. While it is, strictly speaking, an open question as to which human group they represent – as they are minimum ages – their age is consistent with an authorship by Neandertals, present at a number of Iberian sites until ~40–37 ka ago (Higham et al., 2014; Zilhão, 2021), including to ~38 ka ago at Foz do Enxarrique in western central Iberia (Cunha et al., 2008). As some of the Maltravieso stencils significantly pre-date the presence of modern humans, we therefore regard it as a parsimonious interpretation that Neandertals (rather than earlier, archaic humans) created them. Whether or not this was during the period 120–180 ka BP indicated by the cave's Middle Palaeolithic archaeology remains unclear.

The location of these earliest examples deep within the cave, in chambers far away from the natural light, is not surprising considering evidence from elsewhere of Neandertal activities deep underground, e.g. the stalagmite structure at Bruniquel, France (Jaubert et al., 2016), minimum ages for cave art in La Pasiega and Ardales, Spain (Hoffmann et al., 2018a), and engravings (finger tracings) at La Roche-Cotard (Marquet et al., 2023). While the specific reasons for being underground, and the specific meaning of hand stencils is, of course, unclear, such trips underground into potentially dangerous environments where there were no quotidian reasons to be, presumably indicates that there was some deliberate reason behind the creation of this early visual culture, whether or not this was psychological in nature (e.g. Hodgson and Pettitt, 2018).

Some of the stencils in Maltravieso were created on easily visible and accessible sections of cave wall, such as those in the Sala de las Columnas, and Sala de las Pinturas, implying a collective character, a participatory role, and an active style where the hand becomes a figure that provides information to the observer. In contrast, others — including the oldest hands in the Galería de la Serpiente — are located on hidden panels beyond the perception of visitors. For example, GS III consists of a series of stencils located underneath an overhang c.1 m above the present-day floor surface (Fig. 9). Even taking into account the relatively lower floor level at the time of their creation, they would not have been obvious to visitors to the cave, and their positioning suggests that they were more than simple graffiti. Instead, these are representations in which a communicative desire is not discernible, but rather a passive style of private, intimate, and individual nature, linking the creative process with realms closer to ritual or cultic aspects than to the inherent functional and communicative sense.

Furthermore, several the cave's stencils seem to be placed deliberately within concavities or on convexities, observations also made the stencils of El Castillo and La Garma caves in Cantabria (Pettitt et al., 2014). These associations are too repetitive to be coincidental; rather, they suggest the 'exploration' of cave walls by palpation and the 'fitting' of stencils onto certain features. Asking whether the exploration of deep caves away from any provisioning or other affordances, the creation of stencils of the human hand, and their fitting to specific areas of the cave wall was 'symbolic' is misleading; whatever the case, this is the creation of an obvious visual culture, meaningfully placed at specific points, well away from a quotidian environment.

It may well be of significance that Aubert et al. (2014) have provided a minimum age of 39.9 ka BP for a hand stencil at Leang Timpuseng, Sulawesi, and of 37.2 ka BP for another two in Borneo (Aubert et al., 2018b). In fact, where they are found, hand stencils are regularly thought to be part of the earliest artistic phase in their respective regions (Taçon et al., 2014; Standish et al., 2020, García-Diez et al. 2021). The data we present here, indicating that hand stencils were part of the Middle Palaeolithic artistic repertoire, consolidates the emerging picture that stencils and prints of the human hand were some of the earliest forms of deliberately created human visual culture for both Neandertals and modern humans. It is interesting that the other aspects of this earliest artistic tradition so far identified, were also created with red pigment and were non-figurative in nature (Hoffmann et al., 2018a).

Does this emerging picture help us understand the origins of figurative art? Hand stencils pose an interesting dichotomy, being both 'depictions' of real objects but created, in a graphic sense, non-figuratively (Pettitt et al., 2015). In a sense, then, they are both figurative and non-figurative, and constitute a potential link between both forms of visual culture (Hodgson and Pettitt, 2018). Our null hypothesis is that Neandertal art was non-figurative, and figurative art was exclusively produced by modern humans. However, given the contextual associations of the Neandertal visual culture in Maltravieso it may be naïve to suggest that this hypothetical difference implies any 'cognitive' difference between the 'symbolling' activities of the two groups; why should it?

5. Conclusions

U-Th dating of carbonate crusts overlying painted rock art in Maltravieso cave indicates that the tradition of making hand stencils in Europe began prior to the Aurignacian; a conclusion that is consistent with wider chronological information for examples elsewhere. In Maltravieso, two samples from one stencil, including one sequence of four sub-samples that demonstrates closed-system behaviour of the carbonate and therefore reliability of the dates, gave minimum ages well within the range of the Middle Palaeolithic and long before the Initial Upper Palaeolithic; the oldest of these being 66.7 ka. Together with published dating evidence from sites elsewhere in the world, this suggests that Neandertals as well as modern humans created these enigmatic motifs.

CRediT authorship contribution statement

Christopher D. Standish: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis. **Paul Pettitt:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Hipolito Collado:**

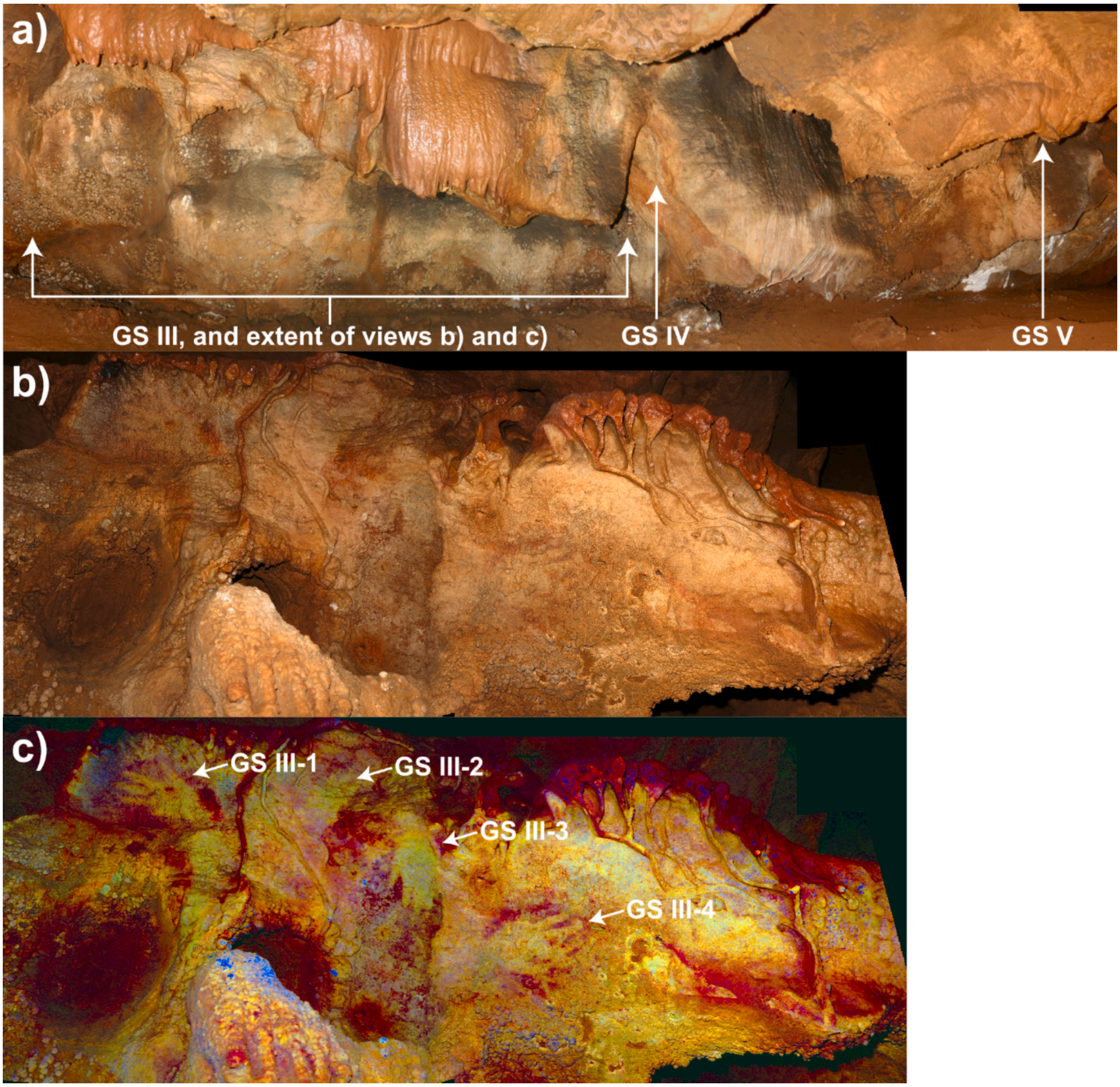

Fig. 9. Location of panel GS III from the centre of the Galería de la Serpiente (a), and view of the GS III stencils from the cave floor before (b) and after (c) application of DStretch (correlation LDS 15 %).

Writing – review & editing, Resources, Methodology, Investigation, Formal analysis. **Juan Carlos Aguilar:** Writing – review & editing, Resources, Methodology, Investigation. **J. Andy Milton:** Resources, Methodology, Investigation, Funding acquisition, Formal analysis. **Marcos García-Diez:** Writing – review & editing, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Dirk L. Hoffmann:** Methodology, Funding acquisition, Conceptualization. **João Zilhão:** Writing – review & editing, Funding acquisition. **Alistair W.G. Pike:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2024.104891.

Data availability

Research data included with publication

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