KEYWORDS: ***Amorphous silica skin – Stratigraphy – Paint composition – Dating – Baja California***

CONSIDERATIONS ON THE DATING OF ROCK ART FROM THE SIERRA DE SAN FRANCISCO, BAJA CALIFORNIA, MEXICO

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Abstract. The current paper focuses on the analysis of the dating of the rock art from the Sierra de San Francisco, a World Heritage site, based on the comparison of existing radiocarbon dating results and on the results from an ongoing research at one site, the Cueva del Ratón. The research includes the use of detailed documentation for the site, which comprised a thorough recording using different complementary techniques, combined with the results from analyses from samples, using polarised light microscopy, SEM-EDS, XRD and IRTF. The use of Harris diagrams to establish the stratigraphy of paintings in specific superimposed areas and the use of analyses to define the paint composition permit to offer an initial sequence for the paintings, with possibly three distinct 'moments', although the results are still too scarce to define the time-span and duration of this painting tradition.

Introduction

This paper presents aspects relating to the painting techniques and age of the rock art at Cueva del Ratón, one of the hundreds of painted rockshelters located in the Sierra de San Francisco, Baja California, an area declared World Heritage in 1993 (Fig. 1), in the north-west of Mexico. The considerations presented here derive from results of the documentation carried out during a joint project between the Getty Conservation Institute (GCI) in collaboration with the Instituto Nacional de Antropología e Historia (INAH), the Government of Baja California Sur, and Amigos de Sudcalifornia (Amisud). The project took place at this site between 1994 and 1996 (Stanley-Price 1996). Subsequent geochemical analyses formed part of a doctoral dissertation, which was in progress at the time of the AURA 2000 congress (Magar 2001).

The painted shelters of the Sierra de San Francisco are widespread in an extensive area of deeply cut canyons, located in a very arid environment. The paintings mostly depict humans and animals, although geometric figures are also present. The animal figures basically represent deer, bighorn sheep and *berrendos*, an endemic species, all shown in profile and in relatively dynamic postures. The human figures instead face the viewer, and are invariably displayed in a static position, with their arms raised. The geometric paintings mainly consist of grid-like figures. The predominant characteristic of these 'Great Murals' (Crosby 1997; Hambleton 1979) are their large dimensions — usually the figures are slightly larger than life size, with human figures having a height of between 1.60 and 2.00 metres. They are located high on the ceilings and back-walls of the shelters, sometimes up to ten metres above the current ground level.

Figure 1. *Location of the Sierra de San Francisco in north-western Mexico.*

Dating of the rock art

For a long time it was impossible to date the rock paintings of the Sierra de San Francisco because of the lack of ethnohistoric and ethnographic data. The groups of Cochimí hunter-gatherers who lived in the area, and were encountered by the Jesuit missionaries in the eighteenth century, denied any relationship with the paintings, claiming that their ancestors also had no link with them (Barco 1973). Tradition says

Figure 2. *The painted figures in the central part of the recorded panel at Cueva del Ratón depicted on the front cover of this issue.*

that the paintings were created by a race of giants, who had disappeared by the time the Cochimís inhabited the area. For the Cochimís, this would have explained the high elevation on the rock faces where most of the paintings are located.

The paintings were therefore thought to be 'very old' by the Spanish missionaries, and this was for a long time the only reference to the age of the paintings. A series of chronicles on Baja California written by the Jesuit missionaries (Baegert 1942; Barco 1973; Clavijero 1970; Vene-gas 1943) provide a detailed description of the region and aspects relating to the life of the hunter-gatherer groups who lived in the peninsula. However, there is little information on their beliefs and traditions, and on the rock art. All the hunter-gatherer groups who had lived in the southern and central part of the peninsula had disappeared by the end of the nineteenth century, mainly due to diseases brought by the Europeans. This left no possibility for retrieving informed ethnographic details about the paintings (Chippindale and Taçon 1998).

At the end of the nineteenth and the beginning of the twentieth century new explorers visited some of the rock art sites, and the nature of the rock was observed with more detail. It was then thought that the paintings were instead 'very young', because the volcanic rocks on which they were found seemed to be eroding rapidly. So, between 'very old' and 'very young', there was no way to locate the paintings precisely in clear archaeological and chronological contexts.

A team from the University of Barcelona, co-ordinated by Josep Fullola, carried out the initial radiocarbon dating analyses in 1993 (Fullola, et. al. 1993, 1994). They gave the first four radiocarbon age estimates for rock art in the area, all from samples within the shelter of El Ratón (Fig. 2, see also image on the front cover of this issue):

5290 ± 80 years BP (red 'man', number 39);
4810 ± 60 years BP (black 'mountain lion' – El Ratón, number 1);
1325 + 435 - 360 years BP (small red 'man', number 8);
295 ± 115 years BP (black deer-like figure, number 6).

The samples were collected from figures in the main panel at the Cueva del Ratón, but the publication only gives vague details of the specific locations of the samples, and no reference to their chemical treatment or to the dating method used. These age determinations are all different and wide-ranging, initially indicating a possible long time span for the painting tradition. Care is needed interpreting these measurements for the following series of reasons.

At about the same time as the initial dating was done, between 1992 and 1994, another important archaeological project, co-ordinated by María de la Luz Gutiérrez, obtained two more radiocarbon dates. The samples of black and red paint were collected by Professor Erle Nelson and processed for accelerator mass spectrometry radiocarbon dating (AMS ^{14}C) by Alan Watchman and the Tucson dating facility. They came from two other sites in the Sierra de San Francisco, Cueva San Gregorio II and Cueva de La Palma, and produced the following uncalibrated results: 2985 ± 65 and 3245 ± 65 radiocarbon years BP (Gutiérrez and Hyland 1997).

These two age estimates represent the first reliable approximation for rock paintings in the Sierra de San Francisco. While these isolated results do not allow the defining of a sequence of paintings, they provide important indications of the likely age for the large animal and human figures. (Since this paper was presented in Alice Springs more radiocarbon dating analyses have been carried out by Alan Watchman, María de la Luz Gutiérrez and Marisa-bel Hernandez Llosas, particularly for the Great Murals in the Sierra de Guadalupe, south of the Sierra de San Francisco, with extremely interesting results and ages as old as 5500 radiocarbon years BP; Watchman et al. 2002; National Geographic 2002).

Documentation of El Ratón

The GCI project carried out a thorough documentation at the site of Cueva del Ratón during three seasons of fieldwork (Stanley-Price 1996). The site is located at an altitude of approximately 1100 metres above sea level, which makes it one of the highest known sites within the Sierra de San Francisco. This location is unusual because most of the painting sites are found in shelters near the bottom of the canyons, close to the scarce water sources. The shelter of Cueva del Ratón is situated at the base of a small cliff formed by the faulting and uplift of several thick layers of volcanic rocks, mainly composed of tuffs. One of the softer layers is eroding and undercutting the cliff leading to the formation of the shelter, which is 66 m long, about 13 m deep and up to 6 m high. The paintings were applied both on the ceiling and back-walls of the shelter, as well as on the vertical cliff face. The rock art is found in different areas of the shelter, forming more or less densely superimposed panels.

This paper will only deal with a few relevant aspects of the documentation of the rock art, and in particular with some of the tools used during the recording process, since they had an important influence on the understanding of the rock art (for a complete description of the documentation methods used, see Stanley-Price 1996). Misleading appreciation of the superimpositioning of the figures is apparent when the paintings are seen from a distance, and therefore the use of scaffolding proved essential for obtaining a thorough observation of the paintings. A close inspection also allowed for the discovery of figures, which might have remained unobserved in the densely superimposed sequence. Another interesting tool was the use of artificial light, which was sometimes necessary and extremely useful to discern faded figures and the relative relationships between figures. Many figures were only clearly visible for a very short time early in the morning when natural light conditions were at their optimum. During the rest of the day the lighting conditions emphasised the texture of the rock surface, making the visibility of the figures more difficult. The use of magnifying lenses (×10) also proved valuable for defining and verifying the stratigraphic sequence of the paint layers.

The detailed observations of all the figures provided an essential basis for the definition of the superimposition sequence of the paintings. In order to visualise such sequence and have a better understanding of each painted panel, one of the team members, Dr Johannes Loubser, suggested the use of Harris diagrams (Harris et al. 1993; Loubser 1997), and these proved invaluable. Figure 3 shows the sequence of paintings for the main panel at Cueva del Ratón. The method consists basically of establishing the relationships between one specific figure and all the other adjacent figures, and then progressing in the same way for every other figure until an entire sequence of overlays is produced. Ultimately it is possible to build up a diagram showing the relative relationships between all the figures. Within the diagram, each number corresponds to a figure, and each line linking two numbers means that those two figures are touching each other directly on the panel. The numbers located in the lower part of the diagram were painted before the ones on the higher part, so there is a progression in time from bottom (older) to top (younger). Such diagrams are extremely useful and practical for intricate panels because they indicate unequivocal visual associations that provide better understanding as to how the panels were created, and reveal the exact relationships between all figures. They are also useful for showing the presence of defined sequences throughout the shelter (Fig. 4), and this was all the more evident when thumbnail representations replaced the use of numbers. For example it is possible to observe that:

1. The lowest part of the sequence, also found at the lowest point on the ceiling and back-walls, is composed of a series of geometric figures, mainly grid-like shapes. These consist of a combination of the full palette of colours found at the Cueva del Ratón, i.e. black, red, white and yellow;
2. The next 'layer' in the painting sequence consists of small animals (rabbit-like or deer-like) located in the same areas or slightly higher than the geometric figures. These figures are always red; and
3. The last or upper sequence comprises the great mural figures, basically painted in red and black, with white used as an outline. These figures start close to the highest point of the grid-like figures, and extend up towards higher parts of the ceiling.

This sequence could possibly indicate the presence of three distinct painting periods, although at this point it is difficult to establish the time difference between the painting of the geometric figures and the great murals. Additional information about the paintings is revealed by the analysis of paint samples retrieved from the Cueva del Ratón.

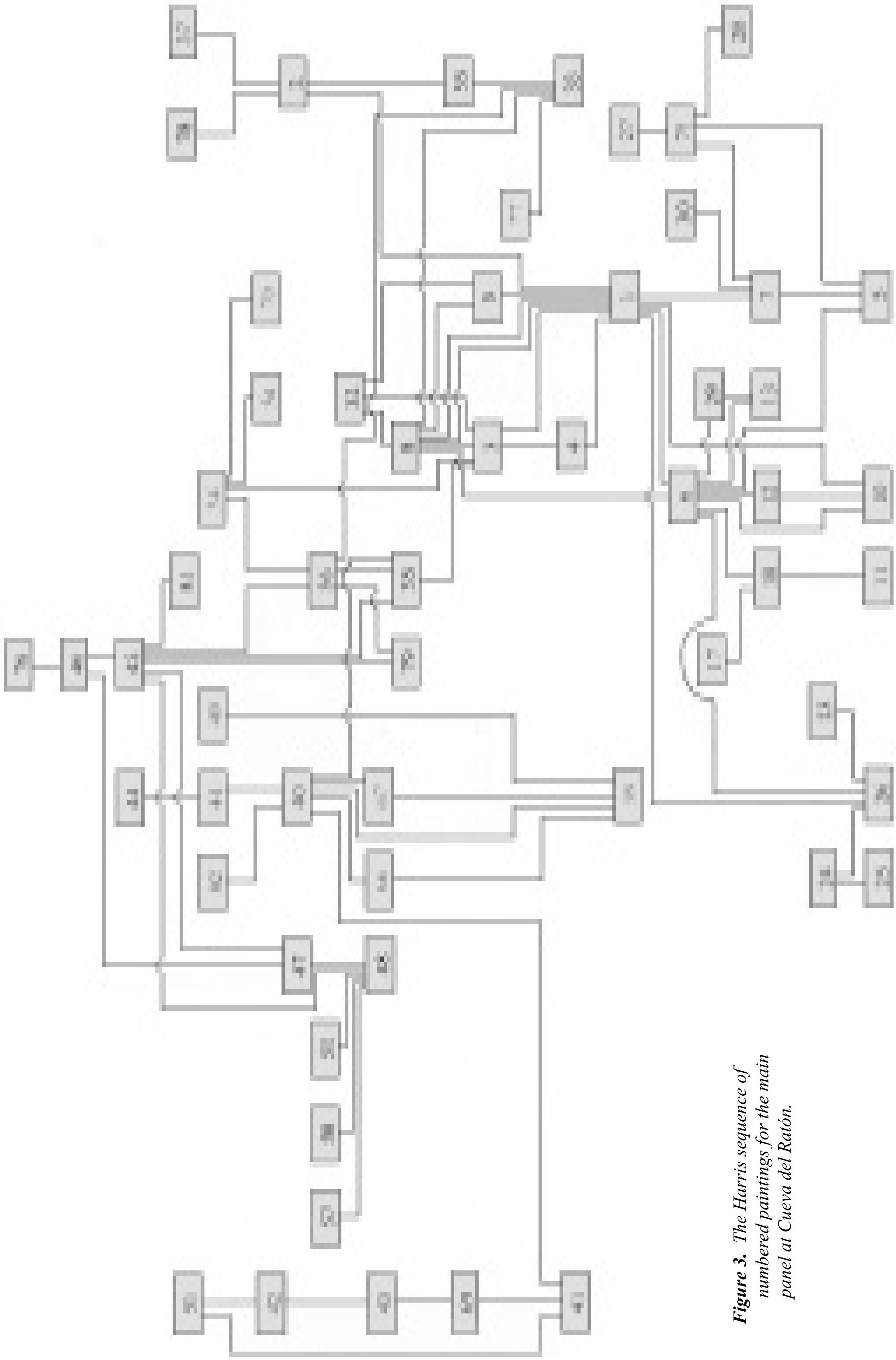

Figure 3. *The Harris sequence of numbered paintings for the main panel at Cueva del Ratón.*

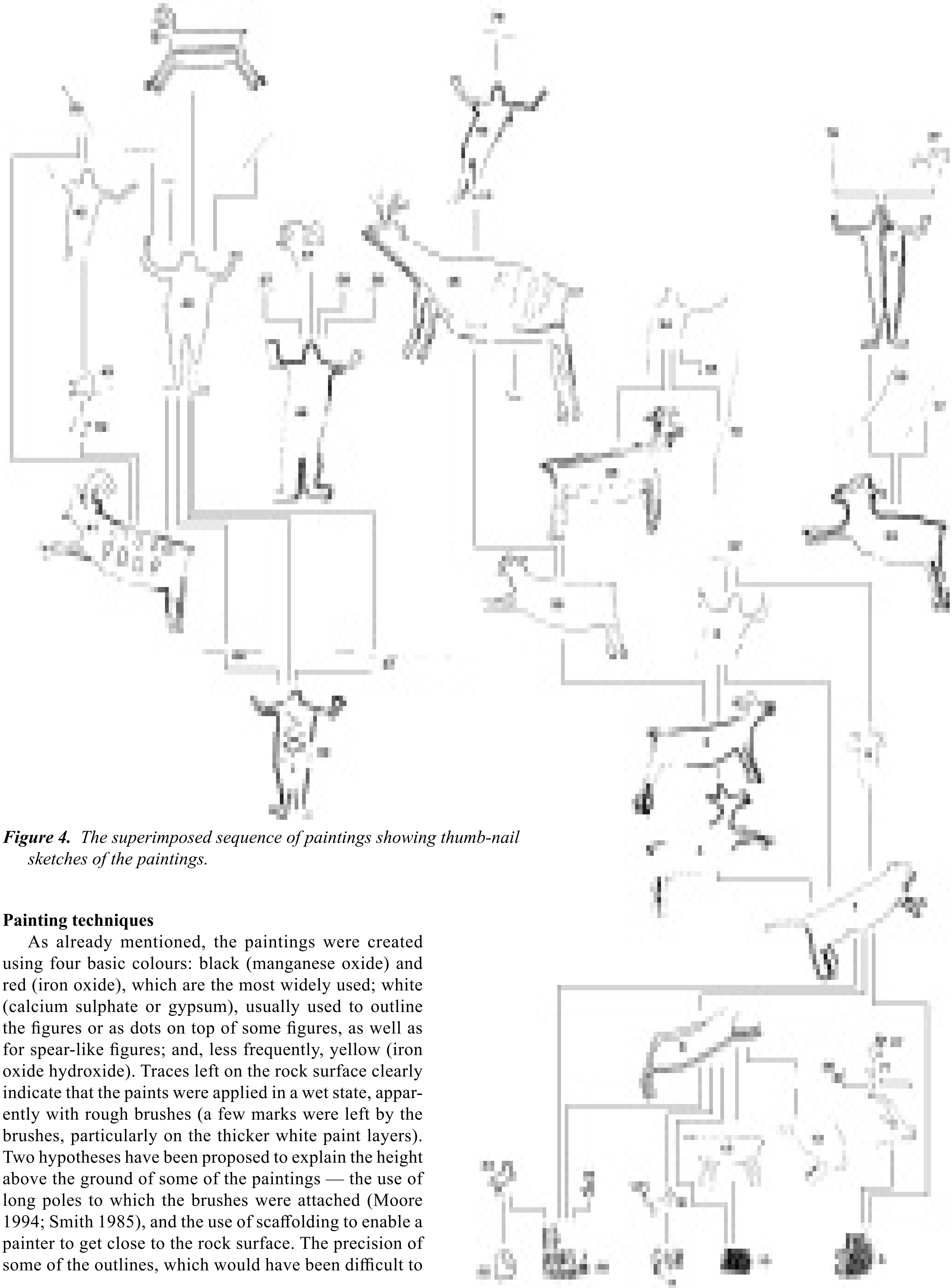

Figure 4. *The superimposed sequence of paintings showing thumb-nail sketches of the paintings.*

Painting techniques

As already mentioned, the paintings were created using four basic colours: black (manganese oxide) and red (iron oxide), which are the most widely used; white (calcium sulphate or gypsum), usually used to outline the figures or as dots on top of some figures, as well as for spear-like figures; and, less frequently, yellow (iron oxide hydroxide). Traces left on the rock surface clearly indicate that the paints were applied in a wet state, apparently with rough brushes (a few marks were left by the brushes, particularly on the thicker white paint layers). Two hypotheses have been proposed to explain the height above the ground of some of the paintings — the use of long poles to which the brushes were attached (Moore 1994; Smith 1985), and the use of scaffolding to enable a painter to get close to the rock surface. The precision of some of the outlines, which would have been difficult to achieve from a long distance using a brush at the end of a long pole, tends to favour the second theory.

Considering the painting sequence, it has always been thought that the white outline was placed first, as a sort of sketch that would then allow an easy infill of the figure (Gutiérrez and García Uranga 1990; Van Tilburg 1990). However, a different order of the application of the paints was established through the detailed close examination made possible by using the scaffold. The actual sequence consistently found was:

1. That the painter did start with an outline of the figure, but it was made with the same colour as the infill. This outline is usually the area with the densest amount of paint, corresponding to the head, the arms and the legs of both humans and animals;
2. Then the rest of the figure was filled in with an uneven layer of paint; and
3. Finally the white outline was painted. At some locations the white pigment tended to be slightly pink or grey, as if the brush used for the infill had not been properly washed, or as if the white paint had been applied while the infill colour was still partially wet and the two paints mixed.

In the areas with several superimpositions it was also observed that application of new paint layers was not done, but instead the existing paint of an underlying figure was 'reused', perhaps in an attempt to save some pigment, or as a sign of respect for that particular area of the underlying figure.

These are all fundamental observations, which become extremely relevant when decisions are made concerning the sampling of figures for dating. They enable one to foresee potential problems and estimate what the samples might look like in cross-section analysis of paint samples.

Dating considerations

After the three-year project, we obtained a thorough recording of the painted sequences, and found that three of the Spanish radiocarbon dates initially seemed to be consistent with the Harris diagram that had been developed in the Getty project. Only one date seemed discordant (Fig. 3). In the publication of these dates, there was no reference to the methodology used to recover or process the samples and no mention of the stratigraphy of the sampled areas. (During the session at Alice Springs, Marvin Rowe, who had carried out the analyses of two of the samples for the team from the University of Barcelona, declared that the dating results had no value. He never received a sample of bare rock from the shelter of Cueva del Ratón, and he therefore had no reference to validate the dates. Furthermore, he considered that none of the dates should be used because he could not verify the precise locations from where the samples had been collected from the figures. This important comment is significant because Fullola and his team have not specified these details, and yet those published dates are considered the first ones for the Sierra de San Francisco. New dating analyses will have to be done in order to know the possible time span shown by the figures at the extremes of the Harris diagrams).

In spite of this lack of information, and the possible problems this has created, the age determinations have shown that some of the figures in the Harris diagram, especially the ones located at the end of vertical sequences, had positions that needed to be very flexible in time. The ones located in the lower parts *could* be extremely old, while the ones high up *could* be extremely recent. The Harris matrix gives an approximation of the sequence, especially when several figures are involved, but as mentioned earlier, there is no way to know how long it took to paint a figure on top of another one. There could be a time difference of a few minutes, days, years, decades or even hundreds of years.

Analyses of samples from Cueva del Ratón

A total of twenty paint samples were collected at the Cueva del Ratón, from different figures, including two of the figures dated by the team from the University of Barcelona (see front and back covers of this issue, Fig. 5). All the analyses were carried out at the Institute of Geology and the Institute of Materials Research at the Universidad Nacional Autónoma de México (UNAM) in Mexico City. These included polarised light microscopy, scanning electron microscopy (SEM-EDX) and powder x-ray diffraction analyses. The results obtained using these analytical techniques provide relevant information for the dating of the rock art.

The analyses of the different paint samples from Cueva del Ratón offered little surprises in terms of the pigments, which had the expected composition often found at rock art sites: goethite for yellow, haematite for red, gypsum for white and pyrolusite for black. It was interesting to discover that although the main pigment composition does not vary between figures, the quality of the grinding changes in the red pigment. A coarse preparation for the small red animals is noticeably different from the fine red paint in the large figures. This tends to reinforce the idea that the three painting types were produced by different groups of people using different techniques at different times.

This initial analysis of the paint composition of all the colours used in the rock art also showed the presence of an organic component. The SEM-EDX analyses carried out on thin-sections of cross-sections of the samples (coated with gold) showed consistent peaks of carbon, in the pigment area, which indicates the possible presence of an organic binder. Figure 6 (back cover, this issue) shows the analysis for the black paint. The nature of the binder still has to be determined through other analyses (Fourier transform infrared analyses were carried out after the presentation of this paper, and they confirmed the presence of compounds consistent with a natural gum).

The petrographic analyses also showed the presence of an amorphous mineral layer under the painted layers, whose existence had been detected with the aid of magnifying lenses during the direct observation of the paintings. The paintings were applied over this white mineral layer, which usually appears internally laminated at a microscopic level (Fig. 6; back cover). Frequently, interlaminations are coloured in white and black.

In some areas of the shelter, the process causing the formation of these layers was still active after the paintings were made, and some are therefore partly covered by new laminations. This had initially provided an exciting perspective to have an additional possible means to determine the age of the rock art, if the rate of formation of these laminations could be established.

The analysis (SEM-EDX and XRD) of the same thin sections containing this white material showed that it is rich in silica, although calcium and sulphur are also usually present, as well as other minerals. It is a naturally formed amorphous silica skin. The presence of similar silica-rich layers on the surface of rocks has been documented at other sites in Australia, Norway and Canada (Dolanski 1978; Wainwright and Taylor 1978; Watchman 1990, 1992), but this is the first occurrence reported in Mexico.

From the analysis of the thin-sections with polarised light microscopy we were able to document that the main process for silica precipitation is the migration from within the rock (Fig. 7, back cover), and it is being deposited on the surface. This movement is necessarily linked with water, possibly from rainwater percolating very slowly through cracks in the rock. The phenomenon was therefore quite surprising at the Cueva del Ratón, due to the extremely dry environment of this area, which has less than 100 mm of rain per year. The explanation of their widespread presence throughout the shelter needs to be correlated with other possible sources of humidity, such as high relative humidity of air, fog, or with the combination of the scarce water with specific elements, which would make chemical dissolution more aggressive and increase the solubility of the silica.

The fact that the amorphous silica skins in this rock-shelter are laminated also suggests the presence of a cyclical phenomenon, where the silica is probably deposited during or just after the rainy season and the much thinner black layers form during the dry season. Oxalate minerals were identified through x-ray diffraction of the rock surface coatings, but their precise location in the samples has not been determined. This is an important aspect to consider because it could seriously impact on the results of an isotopic dating analysis.

Another very important aspect in the study of the thin-sections was that it allowed us to see that the formation of the amorphous silica skin is not homogeneous throughout the shelter. It seems to correspond with small cracks and fissures, through which the solutions flow from the inside of the rock. This was quite unfortunate because, unlike other areas outside of Mexico where silica skins have been analysed, and a rate of formation has been estimated, it will not allow us to do any relative dating for Cueva del Ratón. A painting covered by a thick skin is not necessarily older than a painting covered by a thin layer; it could just mean that the first figure is closer to a crack and deposition is more frequent.

Another kind of surface deposit was also visible in the shelter and it covers an extensive zone in the most protected parts. This layer is black and is essentially composed of manganese, although calcium and sulphur (presumably as gypsum) are again usually present (Fig. 8, see back cover, this issue). Unlike the white amorphous silica layers, this black coating does not seem to come from material emanating from inside the rock. It could therefore be an accretionary deposit, although the nature of its formation is still not understood.

Finally, the SEM-EDX of one sample from the main panel contains a carbon-rich layer at the surface. This sample comes from the black animal which was dated by the Spanish team as 295 ± 115 years BP. The presence of this carbon-rich layer indicates that the ^{14}C age determination of that sample may have been affected so that the result does not reflect the age of the painting. The origin of this carbon-rich layer is still unknown, but its presence has important dating implications and further investigations are warranted.

Conclusions

With the current state of knowledge of the paintings and rock surface coatings at Cueva del Ratón it is only possible to offer a few general final remarks. The combined use of careful documentation of the site and preliminary chemical analyses allow for the proposition that there were three specific 'moments' in the painting tradition, as evidenced by the Harris diagrams. The time that has elapsed between these three different kinds of figures has yet to be determined, but the results supplied by the painting techniques tend to reinforce the idea of these three distinctly separate moments. Yellow was an important pigment only in the initial geometric figures, a coarse red pigment was used for the small animal figures of the second moment, and red, black and white in the last 'moment' of the Great Murals themselves.

The preliminary radiocarbon dating analyses are too limited in number and extent to offer a good overview of the entire sequence of paintings, but the first approximation of c. 3000 years BP (uncalibrated) for the Great Mural figures is extremely interesting.

Other results from the chemical analyses are also very encouraging for future radiocarbon dating analyses, particularly with the existence of several carbon-bearing substances that can be used for radiocarbon dating. The presence of an organic binder provides the most interesting and direct method. The occurrence of oxalates, the carbon-rich surface layer and the possible presence of carbon within the amorphous silica skins offer potential sources which should be considered in future dating analyses.

Due to the presence of carbon on the surface of some samples, a careful analysis needs to be done on each sample before carrying out any ^{14}C dating. A full understanding of all the layers is necessary to ensure a complete vision of the geochemical and microbiological processes that are taking place in the shelter.

An unfortunate result was that the amorphous silica skins found under and over the paint layers cannot be used to provide relative age estimates for the rock art at El Ratón. The system of fractures within the shelter release different amounts of silica depending on various localised physical, geological and hydrological parameters, and therefore no direct correlation exists between the thickness of an amorphous silica skin covering a painting and the age of those samples. The silica could only be used at specific points in order to retrieve the carbon embedded in its black layers, to specifically date one figure. In the future, a better understanding of the amorphous silica formation will undoubtedly allow its use to make deeper inferences related to the rock art at Cueva del Ratón

With this new knowledge we are now in a much better situation to carry out more direct dating analyses in order to define the time span of this still mysterious painting tradition. This research opens the way for the dating of the grid-like designs, the small animals and the last great figures from the sequence.

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