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Wall painting in al-Andalus. Precedents and comparative study.

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ENG **Abstract:** Except for some isolated approaches, the origin of the wall painting technique in al-Andalus had not been subject of study until now. In this work, the use of the analysis techniques provided data contributing to its knowledge, origins and influences. These data also helped to clarify, to the extent possible, in what they consisted of, from the point of view of both the constitutive materials and the execution technique. To do so, very significant examples were selected: first, from paintings which can be considered linked to the origins of the technique (Hispano-Roman and Late-Antique paintings, and Umayyad paintings from Qusayr'Amra, Jordania); secondly, from other paintings corresponding to the first period of Muslim occupation in the Iberian Peninsula, specifically, from the Emirate and Caliphate periods (Cordoba, Madīnat Ilbīra, Madīnat al-Zahrā and Arrabales de Poniente). The results obtained led to the conclusion that the influences of the eastern wall painting are evident, as evidenced by the presence of straw in mortars and the use of gum Arabic. Nevertheless, the persistence of the classic tradition is undeniable.
Keywords: Wall painting; al-Andalus, Hispania, mortar, pigment, binder.

ESP Pintura mural; al-Andalus, Hispania, mortero, pigmento, aglutinante..

ES **Resumen:** Salvo algunas aproximaciones aisladas, el origen de la técnica pictórica mural de al-Ándalus no había sido objeto de estudio hasta este momento. En este trabajo el empleo de las técnicas de análisis nos permite aportar datos que contribuyen a su conocimiento, procedencia e influencias y a aclarar, en la medida de lo posible, en qué consisten éstas, tanto en materiales constitutivos como en técnica de ejecución. Para ello se han seleccionado ejemplos muy significativos, en primer lugar de pinturas que pueden considerarse vinculadas con los orígenes de la técnica -pinturas hispano-romanas, tardoantiguas y pinturas omeyas de Qusayr'Amra, Jordania- y, a continuación, otras correspondientes a la primera época de ocupación musulmana en la Península Ibérica, concretamente de época emiral y califal -Córdoba, Madīnat Ilbīra, Madīnat al-Zahrā y Arrabales de Poniente-. Los resultados obtenidos nos permiten concluir que las influencias de la pintura mural oriental son evidentes, como lo demuestran la presencia de paja en los morteros y la utilización de goma arábiga; sin embargo, la pervivencia de la tradición clásica es innegable.

Palabras clave: Pintura mural; al-Andalus, Hispania, mortero, pigmento, aglutinante.

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1. Introduction

The expansion of Islam started after the death of the last orthodox caliph. The Umayyad dynasty changed its capital to Damascus (Syria), former province of the Byzantine Empire, where the Islam Greco-Latin influence increased. The Muslim presence in the Iberian Peninsula lasted for almost eight centuries (from the beginning of the 8th century to the end of the 15th century and had its maximum splendour during the Caliphate (10th century).

Thanks to the Arabic texts, it is known that artisans and architects were brought from Byzantium and Bagdad to execute some of their constructions. For this reason, some renowned authors consider whether the wall painting decoration system is a consequence of the late-Roman art in the national territory or if, on the contrary, it is a disposition imported from the other end of the Mediterranean .[1]

The Department of Painting-Restoration of the Faculty of Fine Arts of the University of Granada has been working for many years now in the identification of the materials used and the evolution of the execution techniques of Hispano-Muslim painting, from its early stages to its last consequences in the Alhambra in Granada. For our line of research, it is essential to establish the possible links between the first pictorial expressions of Muslim art in the Peninsula (Caliphate period) and its possible precedents (Hispano-Roman painting and East Muslim painting). There are few published studies on the materials of this kind of works which might throw some light on this issue, as most of the published studies on Hispano-Roman wall painting correspond to later periods, in particular to the Nasrid period[2] or relate Roman frescoes with Jordan Abbasids[3] which have a later chronology and therefore, despite being of great interest to determine the characteristics and influences of the Roman wall painting in the first East Muslim paintings (both Abbasid or Umayyad), the influence on the al-Andalus Caliphate art would not be direct, as the Abbasids did not arrive to the Iberian Peninsula and however the Umayyad did; therefore, the relation with Qusayr ‘Amra would be more direct.

For this reason, the work presented here starts by referring to the possible origins of the technique, studying different examples of Hispano-Roman wall painting, of greater geographical proximity, as those from Castulo, Cordoba or Guadix. As reference work for the study of the East Muslim painting, corresponding to a first stage of the expansion, wall paintings from Qusayr ‘Amra in Jordania (8th century) were selected, as they are considered one of the most interesting examples of painting not only from the Umayyad period but also from the Islamic art as a whole (declared World Heritage by the UNESCO). Once the technique of the selected artworks was known, we proceeded to study some examples of the first peninsular paintings corresponding to the Emirate and Caliphate periods, so that we could establish their similarities and differences with those being used as reference. Those examples chosen for the study of Hispano-Muslim paintings are Emirate fragments from the excavation in Miraflores, in Cordoba; and Caliphate fragments from Madīnat Ilbīra in Granada (one of the first Muslim settings in the Peninsula), the excavation in Hospital Reina Sofía, Arrabales de Poniente and Madinat al-Zahra, one of the most iconic examples of caliphal art, which has been declared a UNESCO World Heritage site (all three locations are in Córdoba). It is important to emphasize that in cases such as these, sampling must be kept to a minimum, with priority given to preserving the integrity of the artwork. Samples are taken from areas where visibility and authenticity are not compromised, and only for well-justified reasons. Consequently, a small number of samples have been selected, ensuring they are representative, as unaltered as possible, and that their location and quantity do not impact the visual integrity of the artwork.

Therefore, this work aims to achieve the following objectives:

- Characterize the constituent materials and the technique of execution of the various wall coatings mentioned above.
- Compare the results obtained, with special attention to the number of mortar layers and their composition, the pigments used in the pictorial layer, and the technique of execution.
- Assess, as far as possible, the evolution of materials and execution techniques, establishing similarities and parallels between Roman-origin and Hispano-Muslim-origin decorations.

2. Materials and methods

As previously stated, in this work we analysed different wall paintings whose chronology covers from the Roman period to the Caliphate period, and whose origin is delimited in a surrounding geographical area, specifically in

[1] L. Torres Balbás, “Los zócalos pintados en la arquitectura hispanomusulmana”, *Al-Ándalus,* no.2 (1942): 121.
[2] L.F. Capitan Vallvey, E. Manzano, and V.J. Medina Flórez, “A study of the materials in the mural paintings at the Corral del Carbón in Granada, Spain”, *Studies in conservaction,* no. 39 (1994): 87-99; A. Garcia Bueno and V.J. Medina Flórez, “Estudio material y técnica de ejecución de los zócalos pintados del Cuarto Real de Santo Domingo, Granada", *Qurtuba*, no 2 (1997): 87-105; V.J. Medina Flórez and A. García Bueno, “Técnica pictórica empleada en la ejecución de los zócalos de la Alhambra y el Cuarto Real de Santo Domingo de Granada. Estudio Comparado”, *Cuadernos de la Alhambra*, no. 37 (2001): 9-20.
[3] M.C. Corbeil, J.P. Oleson and R. Foote, “Characterization of Pigments Used on Roman and Abbasid Frescoes in Jordan”, *11th Triennial Meeting, ICOM Comitee for Conservation,* no. 1 (1996): 423-429.

the north-eastern area of Andalusia (Table 1). This allowed a more accurate analysis of the evolution of the execution technique, avoiding variations caused by the geographical availability of materials.

Likewise, in order to get to know the wall painting technique used in the East, we studied a piece of wall covering geographically located there, specifically in Jordania, corresponding to the first period of Muslim art.

1st-2nd century (Roman period)	*Castulo*	Jaén
	Parque Infantil de Tráfico	Cordoba
	Guadix	Granada
4th century (Late-Antique period)	*Castulo*	Jaén
8th century (First period of Muslim art)	*Qusayr' Amra*	Jordania
8th century (Emirate period)	Miraflores	Cordoba
8th-10th centuries (Caliphate period)	*Madīnat Ilbīra*	Granada
	Hospital Reina Sofía	Cordoba
	Arrabales de Poniente	Cordoba
	Madinat al-Zahra	Cordoba

Table 1. Summary table of the wall coverings analysed in this work, indicating their chronology and origin.

The following work plan was developed for the characterisation of the constitutive materials and the execution technique of the different wall coverings:

- Visual analysis and photographic documentation: a visual examination of the paintings was carried out, identifying the different mortar strata of the wall coverings, as well as other macroscopic characteristics of the support and the pictorial layer. Additionally, an exhaustive photographic documentation was conducted by means of a Nikon D5300 camera with articulated screen and AF-S Nikkor 18-105 mm lens with VR.

- Sampling: we took samples from the wall coverings being analysed, both of the pictorial layer and the different mortar strata identified. Special attention was put in collecting samples which were representative of the whole artwork being studied, locating those areas with more layers or whose information was more complete. Each sample was studied using several analytic techniques.

- Stereoscopic microscopy: a first approach to all collected samples was carried out using a NIKON SMZ1000 stereoscopic microscope with a DS-U3 Digital Camera incorporated.

- Sample preparation: prepared as thin sections and as polished sections; said preparation was conducted in the Mineral Sample Preparation Laboratory of the Centre for Scientific Instrumentation (CSI) and in the Department of Mineralogy, both from the University of Granada.

- Polarized optical microscopy (POM): using Carl Zeiss-Jena Jenalab and Olympus BX-60 microscopes, the latter equipped with a DP-20 microphotographic system. Colour images were taken and, in some cases, we carried out microchemical tests and tests on selective coloration of layers.

- Scanning electron microscopy (SEM): we used a scanning electron microscope S-510 from HITACHI, equipped with an energy dispersive X-ray spectrometer (EDX), Röntec, M Series, Edwin, Si (Li) using the Edwin microanalysis software from Röntec (CSI, University of Granada); obtaining images of retro-dispersed electrons, as well as specific microanalyses by means of energy dispersion X-ray (EDX).

- X-ray diffraction (XRD): the analyses were carried out with the powder diffraction method using a PANalytical X'Pert Pro diffractometer with X'Celerator solid-state linear detector and a BRUKER D8 ADVANCE diffractometer with BRUKER LINXEYE detector. We used the XPowderX programme for the processing of data. It is important to highlight that the quantification of the aggregate in the samples is approximate.

- Fourier-transform infrared spectroscopy: these analyses were carried out between 4400 cm-1 and 370 cm-1, with KBr pellets or by superficial analysis using the UATR technique (Universal Attenuated Total Reflectance).

- Coupling of gas chromatography with mass spectrometry: for lipophilic substances, the samples were treated with the methylation reagent Meth-prep II; for the carbohydrates and proteins, we carried out a microwave-assisted hydrolysis with HCl 6M and a derivatization with BSTFA in pyridine of the resulting

fatty acids, amino acids and monosaccharides.

3. Results and discussion

The first point to be considered to analyse the evolution of the technique based on the wall coverings studied herein, is the similarity found among the different coetaneous artworks. As discussed below, there are no big differences between those wall paintings corresponding to the same period but located in different places, always considering a close geographical context. Therefore, it is possible to make a first approach on the evolution of the wall painting technique in *al-Andalus* from the Antiquity to the Middle Age based on the wall coverings presented herein.

To undertake the comparative study, the main characteristics of each exemplified period will be presented for their subsequent comparison. In the case of the mortar analyses, even though the total of layers and the characteristics of the same are indicated, we paid special attention to the last 2cm thickness. This implied the analysis of three mortar strata on some occasions, as was the case for the paintings of the Roman period; or just one stratum of mortar, as was the case for the Late-Antique paintings.

3.1. Wall painting of the roman period

We analysed the wall coverings from the *Sala del Mosaico de los Amores* in *Castulo* (Linares, Jaén), the excavation in *Parque Infantil de Tráfico* in Cordoba and the excavation in *Hospital Reina Sofía* in Guadix (Granada). The wall coverings from *Castulo* correspond to a room belonging to a public building with typical tripartite scheme characteristic from the Roman period. [4] In turn, the wall paintings from Cordoba correspond to the wall decoration of the *triclinium* in the so-called "*Domus* of the Satyr", dating from the middle of the 1st century – beginning of the 2nd century A.D., which would belong to the western *vicus* of the city.[5] Finally, the wall coverings from Guadix (Granada) belong to an emergency archaeological excavation in house No.3 of the street *Santa Mª del Buen Aire*; they were found as filling material of a Roman pipeline, together with other construction materials pertaining, presumably, to a domestic structure.[6]

It is important to highlight that in the cases of Cordoba and Guadix, we only had access to decontextualized fragments, something which conditioned, especially, the study of the mortars.

3.1.1.Support

Even though the comparative study paid more attention to the 2 most superficial centimetres of the mortar, as previously stated, it is worth stressing that in the wall paintings from *Castulo* we recognised a backing system with spike-shaped incisions between the first and the second layer.

Analysing that more superficial area we documented, both in the mortars from *Castulo* as in those from Cordoba, three layers of mortar, while in those from Guadix only two strata were identified; these layers reduced their thickness as they became closer to the surface. In the case of the mortars from *Castulo*, the thickness of the first stratum ranged from 4 to 4.5 cm, the second stratum had approximately 1.4 cm thickness whereas the last stratum had a thickness of 1.5 or 2 mm; in some cases, we identified a thin layer of lime between the first and second strata which could be attributed to the carbonation of the mortar. In the case of the mortars from Cordoba, the thickness of the first stratum ranged from 1.5 to 2 cm; the second stratum, between 0.6 and 1 cm; finally, the third stratum had an approximate thickness of 1 mm. In the case of the mortars from Guadix, in the conserved fragments, the first stratum had a thickness of around 2 cm while the second was of around 0.5 cm (Fig. 1).

Furthermore, according to the analyses conducted with X-ray diffraction (tables 2, 3 and 4), the mortar was in all cases composed of calcite as binding element, accompanied by dolomite and different aggregates of siliceous nature, among which the quartz stood out. With respect to the relation between the binder and the aggregate, the three wall coverings showed an increase of the calcite proportion in the most superficial layers. The percentage of calcite identified in the final render or *intonachino* ranged between 40% and 60%. Regarding the size of the aggregate, its granulometry also decreased as it got closer to the surface, being in the case of the paintings from Cordoba of a slightly smaller size than in the other two wall coverings. Finally, as far as the additives of the mortar are concerned, only in the wall paintings from *Castulo* the use of straw was detected, to provide the mortar with better plasticity.

Mortar stratum and sample	Calcite	Quartz	Dolomite	Potassium feldspar	Plagioclases	Muscovite

[5] T. López Martínez, O. López Cruz, A. García Bueno, A.I. Calero Castillo and V.J. Medina Flórez, "Las pinturas murales de Castulo. Primeras aportaciones a la caracterización de materiales y técnicas de ejecución", *LVCENTVM*, no. 35 (2016): 155-170.

[6] E. Castro del Río, G. Pizarro Berengena and I. Sánchez Ramos, "El conjunto arqueológico del Parque Infantil de Tráfico de Córdoba. La ocupación tardoantigua del suburbium occidental de Colonia Patricia-Corduba", *Anales de Arqueología Cordobesa,* no. 17 (2006): 103-118; E. Castro and A. Cánovas, "La docums del Parque Infantil de Tráfico (Córdoba)", *Anejos de Anales de Arqueología Cordobesa,* no. 2 (2010): 121-140.

[7] A. García Bueno, A. M. Adroher Aroux, M.C. López Pertiñez and V.J. Medina Flórez, "Estudio de materiales y técnica de ejecución de los restos de pintura mural romana hallados en una excavación arqueológica en Guadix (Granada)", *Espacio, Tiempo y Forma, Serie I, Prehistoria y Arqueología,* no. 13 (2000): 253-278.

1st	R47 M	18.07	25.46	-	16.34	29.98	9.52
	R48 M	25.66	30.89	24.66	5.53	4.75	8.51
	R62 M	17.45	30.21	13.30	30.07	2.23	6.74
2nd	R49 M	18.85	44.23	9.27	5.87	5.68	16.10
	R56 M	13.86	22.34	10.31	46.44	2.48	4.56
	R76 M	16.89	42.60	3.25	26.47	3.90	6.88
3rd	R51 M	30.42	2.03	4.54	24.67	6.80	31.53
	R52 M	42.57	16.32	2.22	20.05	13.13	5.71
	R70 M	53.47	8.56	2.66	27.11	2.56	5.63

Table 2. Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars belonging to the wall coverings from the *Sala del Mosaico de los Amores* in *Castulo*.

Mortar stratum and sample		Calcite	Quartz	Dolomite	Potassium feldspar	Plagioclases	Muscovite
1st	PIT 7	43.65	30.36	3.70	10.17	3.39	8.72
	PIT 8	46.99	35.75	4.08	-	1.31	11.87
2nd	PIT 9	21.48	34.99	4.66	12.22	1.92	24.72
	PIT 10	48.50	22.50	9.80	8.15	2.57	8.48
3rd	PIT 11	57.60	27.06	2.59	-	-	12.75

Table 3. Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars belonging to the wall coverings from the excavation in *Parque Infantil de Tráfico* (Cordoba).

Mortar stratum and sample		Calcite	Quartz	Dolomite	Phyllosilicates
1st	G2-M1	33.4%	30.1 %	-	36.2%
	G3-M1	28.5%	38.3 %	-	33.1%
2nd	G2-M2	42.8%	2.5 %	54.6 %	-
	G3-M2	32.4%	-	67.5%	-

Table 4. Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars belonging to the wall coverings from the excavation in *Hospital Reina Sofía* in Guadix (Granada).

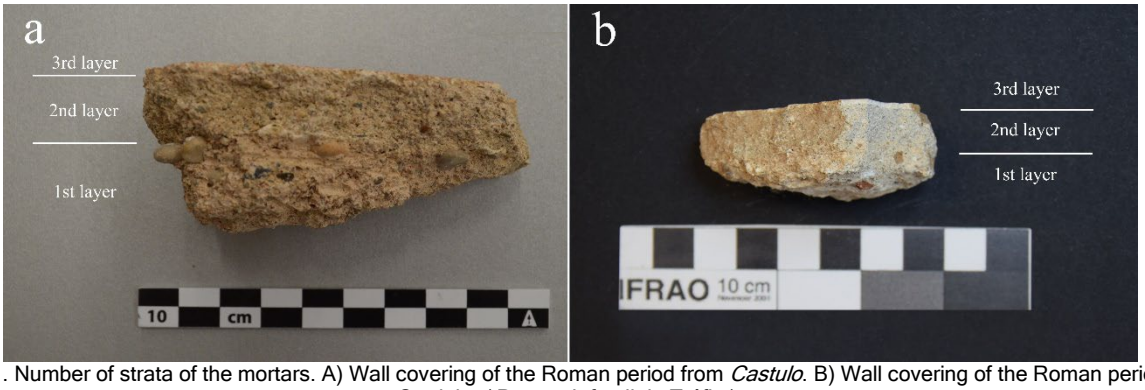

Figure 1. Number of strata of the mortars. A) Wall covering of the Roman period from *Castulo*. B) Wall covering of the Roman period from Cordoba (*Parque Infantil de Tráfico*).

3.1.2.Pictorial layer

The three wall coverings showed the Roman palette indicated by classic authors such as Pliny (*De Arch.,* VII, 7-14) and Vitruvius (*Nat. Hist.,* XXXV, 6-7*)* (Table 5) (Fig. 2). Although in the painting from the excavation in *Parque Infantil de Tráfico* only the red colour samples were analysed, the richness of its palette is referred to in several publications.[7] This palette coincided with that identified in the wall coverings from the *Sala del Mosaico de los Amores* and in the fragments from the excavation in Guadix.

In this respect, the wall paintings from *Castulo* were characterised by a wide variety of pigments: in the red areas of the decorative scheme we identified two different pigments, one composed of hematites, whose characteristic element was Fe, and another one in which we identified Fe and Pb, corresponding to a mixture of hematites and red lead; for the yellow ochre, iron oxide-hydroxides were used; in the blue areas, we identified Egyptian blue mixed, sometimes, with green earth pigments; in the green areas, we detected green earth; for white, both lime white and lead white were used; finally, in the black areas, we identified bone-black and carbon black or lampblack. In the wall paintings from Cordoba two reds were also detected (one composed of pure hematites and the other one in which the latter was mixed with red lead); even though a black pigment was used in all cases to darken the red tone, in most of the samples we could not identify any element characteristic of said colour, so we could consider the use of carbon black, except for one sample in which we identified P, which might indicate the use, also, of bone-black. In the wall paintings from Guadix the pigments already identified in *Castulo* were repeated (hematites, carbon black, Egyptian blue, green earth, lime white and lead white), although the mixture of hematites with red lead was not identified.

[8] E. Castro and A. Canovas, "La domus del Parque Infantil de Tráfico (Córdoba)", *Anejos de Anales de Arqueología Cordobesa,* no 2(2010):121-140; E. Castro del Río, G. Pizarro Berengena and M.D. Ruiz Lara, "Actividad arqueológica puntual en el Parque Infantil de Tráfico, Avda. de la Victoria (Córdoba)", *Anuario Arqueología de Andalucía,* no 1 (2009):813-829.

Finally, with respect to the execution technique and the finish of the surface, the three wall coverings were executed with fresco using the technique of the *politiones*, that is, the successive polishing of the surface which facilitates the recarbonation of the same besides providing a bright and waxy finish;[8] in the case of the wall coverings from *Castulo*, there were also some areas of porous and unpolished aspect, corresponding to those points in which the different layers overlapped, what suggest the possible use of binder or lime water for fixing.

In general, we carried out analyses of the binders in the three paintings, but they did not provide conclusive results, as we didn't find organic binders, nitrates or oxalates indicative of the presence of organic materials. In the case of the wall coverings from *Castulo* and Cordoba, we identified rests of fatty acids, in particular palmitic and stearic, whose presence can be linked to the use of egg or saponified oils;[9] these binders might have been added to lime water to facilitate the application. In the paintings from Cordoba, apart from said fatty acids, we also identified phosphate and traces of glycine, leucine and serine, which may proceed from a very biodeteriorated protein, with high phosphate content, therefore, apart from the aforementioned egg and saponified oils, the possible use of an animal glue could not be dismissed.

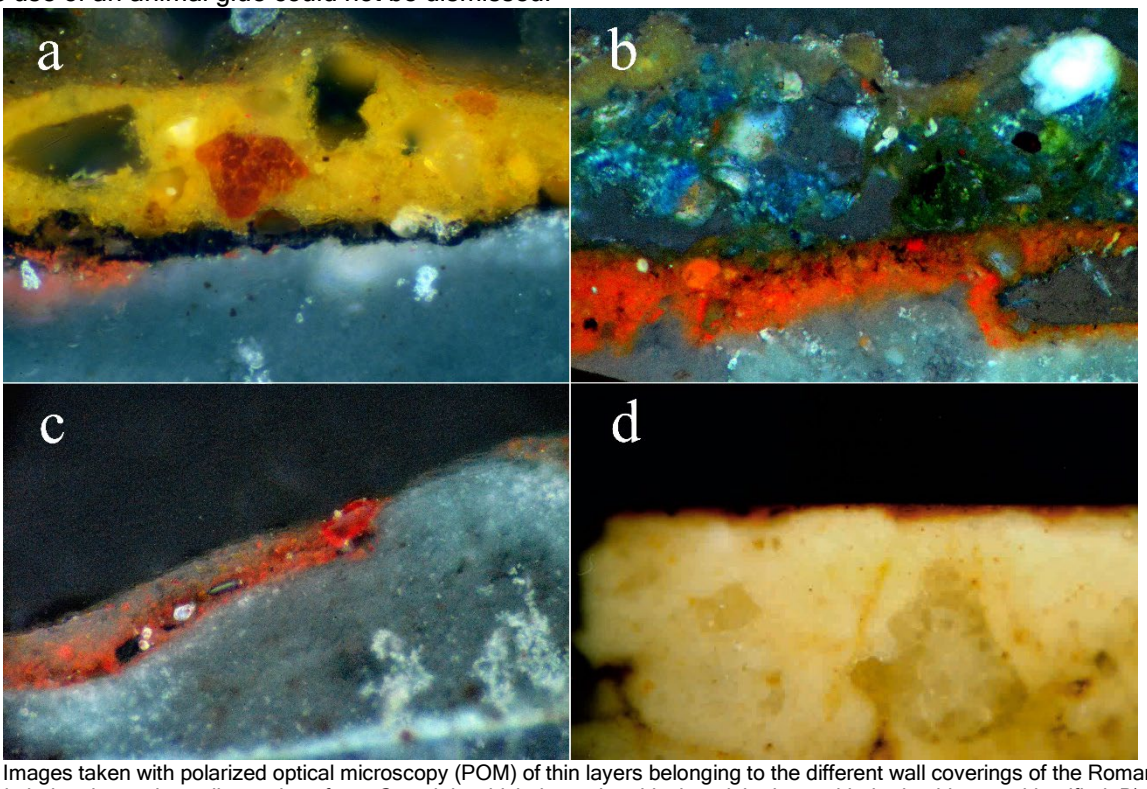

Figure 2: Images taken with polarized optical microscopy (POM) of thin layers belonging to the different wall coverings of the Roman period. A) Sample belonging to the wall coverings from *Castulo* in which the carbon black and the iron oxide-hydroxide were identified. B) Sample belonging to the wall coverings from *Castulo* in which hematites, Egyptian blue and green earth were identified. C) Sample belonging to the wall coverings from Cordoba in which hematites and carbon black were identified. D) Sample belonging to the wall coverings from Guadix in which hematites were identified.

	Mortar	**Pigments**	**Binders and execution technique**
***Castulo* (Roman)**	3 layers of mortar*	Roman palette	Fresco with some secco areas using lime water as binder, and possible addition of egg.
	Composition: C, Q, D, F, P, M		
	Binder-aggregate: increased proportion in more superficial layers. *Intonachino*: approx. 55%.		
	Granulometry: thick aggregate, decreases in more superficial layers.		Polishing of the surface
	Additives: Straw.		
Children's Traffic Playground	3 layers of mortar	Roman palette	Fresco with some secco areas using lime water as binder, and possible addition of egg, animal glue or saponified oil.
	Composition: C, Q, D, F, P, M		
	Binder-aggregate: increased proportion in more external layers. *Intonachino*: approx. 60%.		Polishing of the surface

[9] P. Mora, L. Mora and P. Philippot, *La conservazione delle pitture murali* (Bologna, 2003).
[10] I. Garófano Moreno, "Materiales orgánicos naturales presentes en pinturas y policromías. Naturaleza, usos y composición química", *Revista PH,* no 80 (2011): 56-71; L. Masschelein-Kleiner, *Liants, vernis et adhèsifs anciens* (Istitut Royal du Patrimoine Artistique, 1992).

	Granulometry: intermediate aggregate, decreases in more external layers. Additives: none		
Guadix	2 layers of mortar Composition: C, Q, D, M Binder-aggregate: increased proportion in more external layers. *Intonachino*: approx. 40%. Granulometry: thick aggregate, decreases in more external layers. Additives: none	Roman palette	Fresco with some secco areas using lime water as binder Polishing of the surface

Table 5: Main characteristics of the Roman-period wall coverings studied to analyse the evolution of the wall painting technique. XRD composition: calcite (C), quartz (Q), dolomite (D), potassium feldspar (F), plagioclases (P), muscovite (M).
*Considering only the two most external centimetres, however, up to four layers of mortar were identified.

3.2. Wall painting of the late-antique period

Due to the scarcity of wall painting examples from the Late-Antique period in the geographical context considered, the only wall coverings studied from this period were the wall coverings from the Castulo Archaeological Site. These correspond to the wall decoration of a courtyard belonging to a building located to the north of the *Sala del Mosaico de los Amores*, whose function would be linked to the Christian worship, but not necessarily the Eucharist.[10] The paintings, which can be dated from the second half of the 4th century A.D., have a continuous geometric and vegetal decoration, with a series of discontinuous diagonal stripes with monochromatic squares framing floral motifs.[11]

3.2.1.Support

These wall coverings revealed clear differences with respect to the wall paintings from the Roman period. First of all, we identified a big change in the support: opposite to the three layers identified in the wall paintings of the Roman period from *Castulo*, those from this period only had one layer of mortar with a thickness ranging between 1 and 1.5 cm. The aggregate found in the same had a diameter ranging from 0.25 and 1.25 mm. Given that the surface of these paintings was not spatulated, the aggregate was homogeneously distributed, and it could even be appreciated at a superficial level in the same pictorial layer (Fig. 3).

While the results obtained by means of X-ray diffraction did not show any difference in the mortar composition with respect to the Roman wall coverings, with the identification of calcite as binder; and dolomite, quartz, potassium feldspar, plagioclases and muscovite as aggregate; differences were indeed registered in the percentages of calcite. In this sense, the Late-Antique wall coverings showed a percentage of $CaCO_3$ not exceeding 20%, being those presenting less proportion of calcite of all the wall coverings studied herein (table 6). Another difference in the composition was the absence of straw as additive.

Additionally, as in the Roman wall coverings, in these ones we also documented a backing system fixing the mortar to the wall, done with spike-shaped incisions in the mortar.

Mortar stratum and sample		Calcite	Quartz	Dolomite	Potassium feldspar	Plagioclases	Muscovite
1st	TA 14	22.91	27.21	-	4.52	25.69	19.67
	TA 15	8.51	22.11	-	56.48	8.47	4.45
	TA 16	19.91	41	12.49	8.76	3.76	14.08

Table 6: Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars belonging to the Late-Antique wall coverings from *Castulo.*

[11] B. Ceprián del Castillo, D. Expósito Mangas, M. Soto Civantos and M.P. López Rodriguez, "Hallazgos monetarios para el conocimiento de la secuencia estratigráfica en Cástulo", *XV Congreso Nacional de Numismática,* (2014): 999-1024; D. Expósito Mangas, M. Castro López, F. Arias de Haro, J.M. Pedrosa Luque and B. Ceprián del Castillo, "A large glass dish from Cástulo (Linares-Jaén, Spain) with an engraved representation of Chris in Majesty", *Annales du 20 Congrès de l'Association Internationale pour l'Historie du Verre,* (2015):209-212.
[12] T. López Martínez, V.J. Medina Flórez and A. García Bueno, "Decoración parietal de un edificio paleocristiano en el Conjunto Arqueológico de Cástulo", *I Simposio anual de Patrimonio Natural y Cultural ICOMOS España*, (2021):139-147.

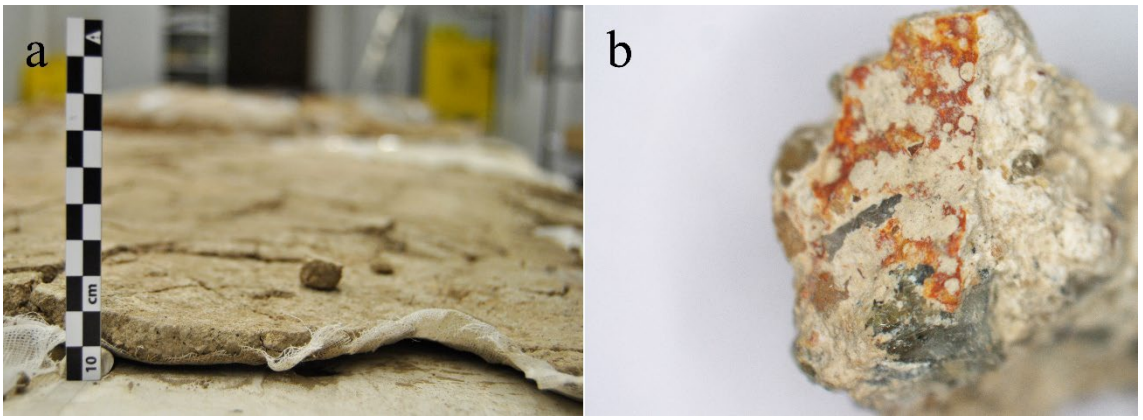

Figure 3: Late-Antique wall paintings from *Castulo*. a) Thickness of the mortar. B) Image taken by means of the stereoscopic microscope in which the aggregate is observed in the surface of the pictorial layer.

3.2.2.Pictorial layer

For its execution, the same palette used in the Roman period was identified, although more reduced in this case, showing less colours and without tone variations of the same, always with plain inks (Table 7). In this sense, it was possible to identify Fe in those areas of red and orange colours corresponding, as in the previous cases, to the use of hematites; in the greens we identified Fe, K, Al and Mg, what is an indicative of the use of green earth. For the white, the background tone was respected; on this point it is possible that a lime milk was extended all over the mortar as a base for the decoration (Fig. 4).

Just like in the Roman wall paintings, the fresco technique was also followed here, with some areas executed in secco using lime water as binder, although without the addition of any organic substance this time. The analyses conducted for the identification of organic materials did not detect any binder in this case, although plenty of components of microbiological systems (fungus, algae, bacteria) were found such as metabolites, fatty acids, glycerol and sugars. The percentage of fatty acids was much lower than in the previous cases which, together with the simplicity of the decorative scheme, ruled out the use of egg or saponified oils.

	Mortar	**Pigment**	**Binders and execution technique**
Castulo **(Late-Antique)**	1 layer of mortar	Reduced Roman palette	Fresco with some secco areas using lime water as binder
	Composition: C, Q, D, F, P, M		
	Binder-aggregate: approx. 25% of calcite.	White characteristic of the mortar, leaving the areas of this colour unpainted.	The surface is not polished
	Granulometry: intermediate aggregate.		
	Additives: none		

Table 7: Main characteristics of the Late-Antique wall paintings. XRD composition: calcite (C), quartz (Q), dolomite (D), potassium feldspar (F), plagioclases (P), muscovite (M).

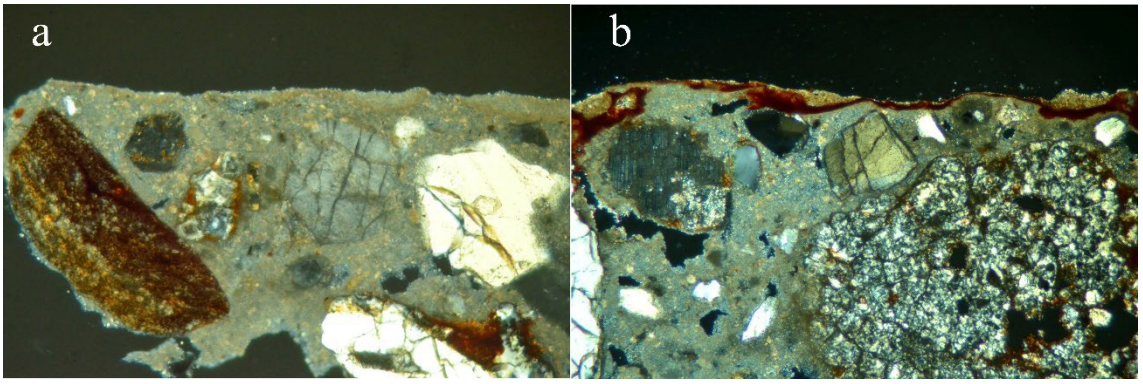

Figure 4: Images taken by means of POM of samples from the Late-Antique wall coverings of *Castulo*. A) Sample TA3 White, in which the lime white is identified. B) Sample TA12 Rojo, in which hematites are identified.

3.3. Wall painting of the first period of muslim art

Following this chronological evolution, although far from the geographical context, we can find the wall paintings from *Qusayr 'Amra,* located in the dessert of Jordania.[12] The residence of *Qusayr' Amra,* built during the rule of

[13] A. García Bueno, "La pintura mural hispanomusulmana. Estudio de los revestimientos del Cuarto Real de Santo Domingo, Granada" (PhD diss., University of Granada, 2000); V.J. Medina Flórez and A. García Bueno, "Técnica pictórica empleada en la ejecución de los zócalos de

the Caliph al-Walid I (705-715), is located at approximately 100 km to the East of Amman, in the middle of a desertic area.[13] Corresponding to an initial period of the Muslim art, they have a clear iconographic influence from the Byzantine art, empire to which they conquered the territories with which they extended the Caliphate. This suggests its possible influence from a technical point of view.

3.3.1.Support

These paintings, dating from the 8th century, generally showed two layers of mortar, the first of them used to level the surface. Two different backing systems were detected: on the one hand, pebbles of homogeneous size and distribution and, on the other hand, spike-shaped incisions like those in the Roman and Late-Antique wall coverings from *Castulo.*

The analyses with X-ray diffraction identified calcite, quartz and feldspar. The proportions of calcite ranged from 75% to 95%, so it was estimated that it was not only used as binder, but also as aggregate (table 8). As well as in the wall coverings from *Castulo*, the mortar from *Qusayr 'Amra* showed, once again, the addition of straw.

Mortar stratum and sample		Calcite	Quartz	Dolomite	Feldspar	Halite
1st	Q1-M1	74.2	20.4	5.27	-	-
2nd	Q1-M2	100	-	-	-	-
	Q2	88.5	7.68	-	-	3.97
	Q3	95.4	1.7	-	-	2.8
	Q6	79.1	-	-	16.1	4.66

Table 8: Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars of the wall coverings from *Qusayr 'Amra.*

3.3.2.Pictorial layer

The palette used in these wall coverings was very varied and very similar to the Roman palette, even though with some variations (Table 9). As is the case in the Roman wall coverings, we identified lime white and lead white, green earth and carbon black. As blue pigment we identified Lapis Lazuli, in opposition to the Egyptian blue found in the Roman wall coverings, and orpiment as yellow pigment. Likewise, we identified different mixtures for the red and orange tonalities in which hematites, iron oxide-hydroxides, red lead, vermilion and realgar were used.

In the study of the binders, we identified the presence of high quantities of arabinose in the pictorial layer, as well as the rest of monosaccharides typical of the gum Arabic, thus indicating its use in the pictorial layer and in the most superficial layer of the mortar. It was estimated that these wall coverings were executed with fresco technique, mixing the pigment with water and gum Arabic to facilitate its application. Likewise, we also detected that the surface might also have been spatulated with a technique equivalent to the *politiones*.

	Mortar	Pigments	Binders and execution technique
Qusayr 'Amra	1 layer of mortar	Roman palette with modifications (Lapis Lazuli, orpiment)	Fresco with addition of gum Arabic
	Composition: C, Q, F		
	Binder-aggregate: 75-95% of calcite*		Polishing of the surface
	Additives: straw		

Table 9: Main characteristics of the paintings from *Qusayr 'Amra*. XRD composition: calcite (C), quartz (Q), potassium feldspar (F). *Said percentage is due both to the binder and to a part of aggregate of carbonic nature.

3.4. Wall painting of the emirate period

The wall coverings from the Emirate period from the excavation in Miraflores, Cordoda, correspond to the same chronology but are located in the geographical context of *al-Andalus*. They belong to an ensemble of edifications distributed around a central courtyard which, according to Casal García et al.,[14] might be interpreted as a *funduq*, a public building linked to trade, in the so-called quarter of *Šaqunda* or *al-rabad*.[15] These paintings represent an intermediate point between the Roman and Late-Antique wall coverings from *Castulo* and those of Eastern tradition like those from *Quasayr 'Amra* and the wall coverings from the Caliphate period which will follow.

la Alhambra y el Cuarto Real de Santo Domingo de Granada. Estudio Comparado", *Cuadernos de la Alhambra*, no. 37 (2001): 9-20.

[14] M. Almagro, L. Caballero, J. Zozaya and A. Almagro, *Qusayr' Amra residencia y baños Omeyas en el desierto de Jordania* (Ministerio de Asuntos exteriores, 1975): 57.

[15] M. T. Casal García, J.M. Bermúdez, A. León, M. González *et al.* , "Informe-memoria de la I.A.U. en el S.G. SS-1 (Parque de Miraflores y Centro de Congresos de Córdoba). Segunda fase", *Anuario Arqueología de Andalucía,* no. 1 (2003):343-356.

[16] M.T. Casal García, "Características generales del urbanismo cordobés de la primera etapa emiral: el arrabal de Saunda", *Anejos de Anales de Arqueología* Cordobesa, no 1 (2008):109-134.

3.4.1.Support

As in the Late-Antique wall coverings, only one layer of mortar was identified in this case, with a thickness which reached 3 cm on some occasions.

The X-ray diffraction analyses identified calcite and quartz as the main elements, while the dolomite and the rest of aggregates identified in the Roman wall paintings appeared in this case in a very small proportion. The calcite proportion went up to 76% although, as was the case of the mortars from *Qusayr 'Amra*, it responded both to the binder used and to a portion of the aggregate (table 10). In the wall coverings of the Emirate period, the granulometry of the aggregate was once again reduced, no aggregates with a diameter bigger than 0.8mm were identified. In contrast to the paintings from *Qusayr 'Amra*, there was no addition of straw in these wall coverings.

Mortar stratum and sample		Calcite	Quartz	Dolomite	Potassium feldspar	Plagioclases	Muscovite
1st	MIR 7	76.51	3.85	3.59	3.66	-	12.39
	MIR 8	61.88	15.32	8.57	5.36	1.90	6.97
	MIR 9	43.37	25.59	3.52	15.37	0.97	11.19

Table 10: Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars belonging to the wall coverings from the Emirate period in Cordoba.

3.4.2.Pictorial layer

Pigments typical from the Roman palette were identified, even though the chromatic range was reduced to three tones, anticipating the two-colour scheme which will be common in the following periods (Table 11). The pigments identified were lime white, and earth rich in oxides and in iron oxide-hydroxides.

Additionally, the finish of the surface reminded a lot to that of the Late-Antique wall paintings from *Castulo*, a non-spatulated surface in which the aggregate was homogeneously distributed, being distinguishable in the pictorial layer.

Finally, it must be highlighted that the conservation state of these wall coverings, with very scarce rests of preserved polychromy, did not allow to carry out a study of the binders with reliable results, therefore it was impossible to determine whether it was a very deteriorated fresco painting or, on the contrary, a secco in which the binder was equally completely deteriorated.

	Mortar	Pigments	Binders and execution technique
Miraflores	1 layer of mortar	Three pigments from the Roman palette	Fresco
	Composition: C, Q (D, F, P, M in smaller proportion)		
	Binder-aggregate: 85% of calcite*		The surface is not polished
	Granulometry: thin aggregate		
	Additives: none		

Table 11: Main characteristics of the paintings from the Emirate period from the excavation in Miraflores, Cordoba. XRD composition: calcite (C), quartz (Q), dolomite (D), potassium feldspar (F), plagioclases (P), muscovite (M).
*Said percentage is due both to the binder and to a part of aggregate of carbonic nature.

3.5. Wall painting of the caliphate period

Finally, the last period analysed was the Caliphate period, for which we studied the wall paintings from *Madīnat Ilbīra* (Granada), as well as the paintings from the excavations in *Hospital Reina Sofía*,[16] *Arrabales de Poniente* and *Madīnat al-Zahrā* (Cordoba).[17]

3.5.1.Support

The wall coverings analysed did not present a fixed rule as far as the number of layers of the mortar is concerned, although the outer stratum was always of a considerable thickness. Nevertheless, there were similarities in their composition, with the calcite as predominant element, reaching a proportion of 96% (tables 12-15). Said proportion of calcite is once again attributed to its use both as binder and aggregate. Together with the calcite, we found quartz and, sometimes, dolomite and phyllosilicates, although always in a very low proportion, as had already been documented in the wall coverings from the Emirate period. This gave as a result a very white mortar in which the aggregate was almost imperceptible, same as in the last mortar stratum of the paintings from *Qusayr 'Amra* (Fig. 5). The presence of straw was also documented in all of them, once again repeating the location of *Qusayr 'Amra* and that of the wall paintings from the Roman period in *Castulo*.

[17] F.J. Murillo Redondo, M.T. Casal García, A. Cánovas Ubera, B. García Matamala and E. Salinas Plegazuelo, *Informe-preliminar de la actividad arqueológica preventiva para la ampliación del Hospital Universitario Reina Sofía y la construcción del Centro de Investigación Biomédica de la UCO* (Córdoba: Gerencia de Urbanismo, 2009).
[18] A. García Bueno, "La pintura mural hispanomusulmana. Estudio de los revestimientos del Cuarto Real de Santo Domingo, Granada" (PhD diss., University of Granada, 2000).

Mortar stratum and sample		Calcite	Quartz
1st	ME2-M1	96	3.96
2nd	ME2-M2	96.98	3
	ME3-M1	90.4	9.5
3rd	ME2-M3	100	-
	ME3-M2	100	-
	ME5	100	-

Table 12. Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars belonging to the wall coverings from *Madīnat Ilbīra.*

Mortar stratum and sample		Calcite	Quartz
1st	HRS 10	93.88	6.12
	HRS 11	93.63	6.37

Table 13. Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars belonging to the wall coverings from *Hospital Reina Sofía*.

Mortar stratum and sample		Calcite	Quartz	Dolomite
1st	CP1	96	4	
	CP2	85	11	3

Table 14. Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars belonging to the wall coverings from *Arrabales de Poniente.*

Mortar stratum and sample		Calcite	Quartz	Phyllosilicates
1st	CZ-M1	28.3	4.7	67
2nd	CZ-M2	91.9	8	-

Table 15. Results of the XRD analyses and approximate quantification of the different crystalline phases identified in the mortars belonging to the wall coverings from *Madīnat al-Zahrā.*

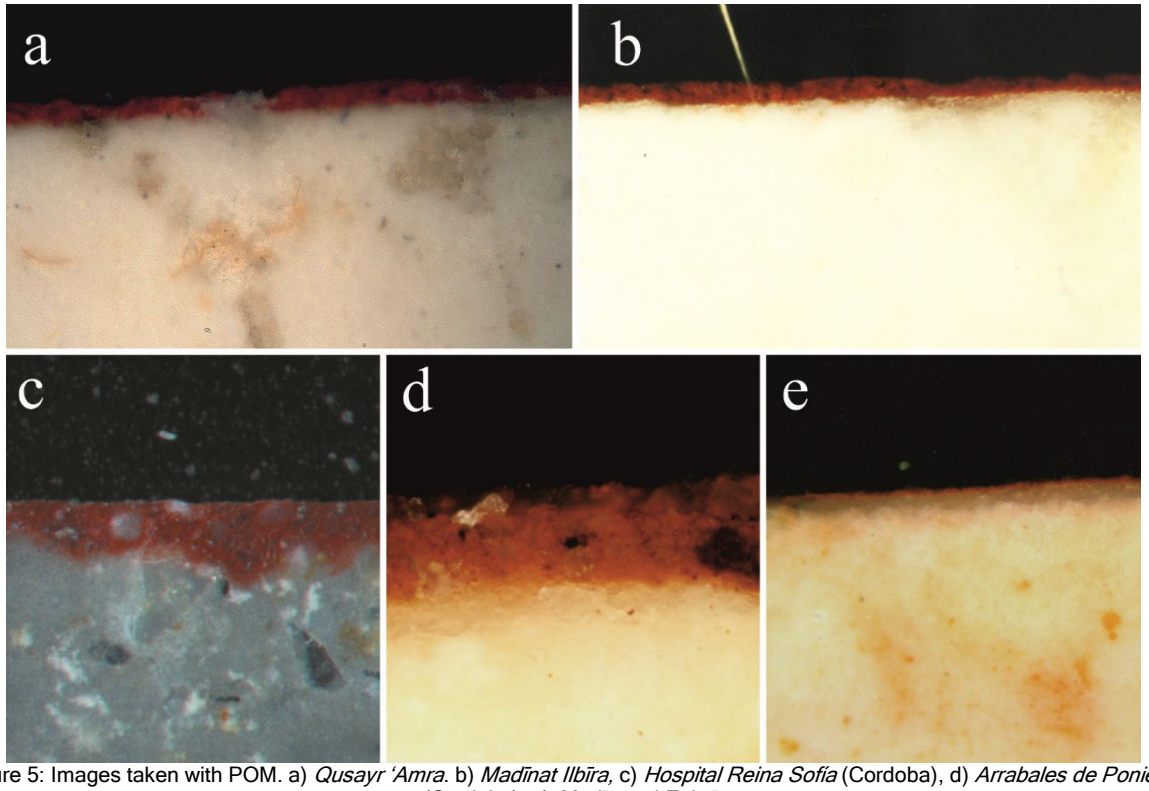

Figure 5: Images taken with POM. a) *Qusayr ʿAmra*. b) *Madīnat Ilbīra,* c) *Hospital Reina Sofía* (Cordoba), d) *Arrabales de Poniente* (Cordoba), e) *Madīnat al-Zahrā.*

3.5.2.Pictorial layer

With respect to the polychromy, the paintings from this period generally showed a bichrome scheme composed of almagre and white, being the later the mortar itself. In the case of *Madīnat al-Zahrā*, yellow ochre was also documented in some parts of the decorative scheme, characterised by the use of iron oxide-hydroxides (table 16). In the wall paintings from *Madīnat Ilbīra*, a red-coloured layer was extended on all the mortar and was later removed in those areas in which white was desired, while in the rest of the wall coverings the white colour was obtained by leaving those areas unpainted, same as in the Late-Antique paintings from *Castulo*.

Lastly, as far as the execution technique is concerned, there was diversity among the different wall coverings. Although the action of the recarbonation in the surface contributed to fixing the pigment in all of them, while gum Arabic was identified in *Madīnat Ilbīra, Arrabales de Poniente* and *Madīnat al-Zahrā* as binder of the pigment, it was not the case of the wall coverings from the excavation in *Hospital Reina Sofía*, although we cannot fully

dismiss its use or the use of secco with lime water. Besides, except from the paintings from *Arrabales de Poniente*, the rest presented a polished surface as was the case in the wall coverings from the Roman period and in the wall paintings from *Qusayr' Amra*.

	Mortar	Pigments	Binders and execution technique
Madīnat Ilbīra	2 layers of mortar Composition: C (Q in little proportion) Binder-aggregate: 90-96% calcite* Granulometry: very thin aggregate, decreases in the most external stratum Additives: straw	Bichrome scheme White of the mortar by elimination of the red-coloured layer	Fresco with addition of gum Arabic. Animal glue in the red polychromy** Polishing of the surface
Hospital Reina Sofía	1 layer of mortar Composition: C (Q in little proportion) Binder-aggregate: approx. 90% of calcite* Granulometry: thin aggregate Additives: straw	Bichrome scheme White preserving the area to be painted	Fresco o secco with lime water Polishing of the surface
Arrabales de Poniente	1 layer of mortar Composition: C, Q (D, in a very low proportion) Binder-aggregate: approx. 90%* Granulometry: very thin aggregate Additives: straw	Bichrome scheme White preserving the area to be painted	Gum Arabic reinforced by recarbonation The surface is not polished
Madīnat al-Zahrā	2 layers of mortar Composition: C, Q, M Binder-aggregate: approx. 90%* in the last stratum Granulometry: very thin aggregate Additives: straw	Bichrome scheme and ochre White preserving the area to be painted	Fresco with addition of gum Arabic. Polishing of the surface

Table 16: Main characteristics of the wall paintings from the Caliphate period studied to analyse the evolution of the wall painting technique.
XRD composition: calcite (C), quartz (Q), dolomite (D), muscovite (M).
*Said percentage is due both to the binder and to a part of aggregate of carbonic nature.
** The animal glue might be due to a subsequent restoration.

4. Conclusions

After the analysis carried out, a certain trend in the evolution of wall painting was observed, corresponding both to a local tradition and to an importation from the East.

Firstly, we detected a reduction in the number of mortar strata which constituted the support of the painting. Opposite to the four layers identified in the wall paintings from the Roman period in *Castulo*, in most of the paintings from the Caliphate period only one layer was identified. Therefore, the thickness of the last stratum increased, and in the wall coverings from the Caliphate period we didn't find a coating of millimetres thickness, as was the case in the Roman *intonachino*, boosting and extending the drying process and, therefore, the carbonation.

Furthermore, the percentage of calcite increased, being used both as binder and aggregate. The use of aggregate of siliceous nature was, therefore, reduced. This, together with the reduction of the granulometry of the aggregate used, resulted in a much whiter mortar, like the one observed in the wall paintings from *Qusayr 'Amra* which will later be the common proceeding in Hispano-Roman wall coverings, and which could be attributed to an influence from the Eastern technique.

As far as the chromatic palette is concerned, there was a great similarity between that used in the Roman world and the one used in the Eastern world, exemplified by *Qusayr 'Amra*, although we registered some pigments such as the Lapis Lazuli and the orpiment, which had not been identified in the paintings from the Roman period studied

herein. Likewise, a reduction of the chromatic range used was documented as the chronology advanced: the Late-Antique paintings already showed less diversity of tonalities than the Roman palettes, and the palette was even more reduced in the Emirate wall coverings, ending in the bichrome scheme of the Caliphate period (with isolated cases of ochre), where we documented the use of unpainted mortar as white colour, as in the Late-Antique paintings studied herein.

At the same time, a higher use of organic binders was perceived in later periods. In all the periods the pigment was fixed, primarily, by means of lime carbonation, and the use of organic substances is estimated to facilitate the application of the pigment and make a first fixing. Nevertheless, while in the Roman period the fresco was the main execution technique and the organic substances, of difficult identification due to their deterioration, would be added along with lime water; in the Caliphate period sometimes, like in *Arrabales de Poniente*, it was the organic binder the one fixing the pigment, having its action reinforced by the recarbonation of the surface.

Finally, both the addition of straw to the mortar and the polishing of the surface did not follow a fixed pattern in their application, appearing, or not, in paintings from the same period and from the same geographical context. In the first case, the analysis of the paintings studied herein evinced that the use of straw as additive was not registered only in Hispano-Roman paintings, therefore it cannot be considered an Eastern influence, as was previously thought.[18] In the second case, the polishing of the surface seems to be lost in the Iberian Peninsula after the Roman period, as it was not found in the Late-Antique nor in the Emirate periods, but appeared in some isolated cases of Caliphate painting and those corresponding to the last periods of the Hispano-Muslim art. Given that in the paintings from *Qusayr 'Amra* the polishing of the surface is registered, the hypothesis proposed is that said aspect of the technique was lost in the Peninsula after the Roman period and, therefore, its use during the Hispano-Muslim period might be a consequence of the Eastern influence.

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