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Methodology to Evaluate the State of Conservation of Historical Plasterwork and Its Polychrome to Promote Its Conservation

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Abstract: This work presents a methodology for the assessment of ancient plasterworks based on traditional inspection techniques, such as organoleptic tests and chemical characterization, and also on digital tools, such as photogrammetric surveys, thermography images, and measurement of ambient conditions with thermohygrometers. This method allows not only defining the alterations detected and establishing the state of conservation but also digitalizing the plasterworks to preserve the heritage and replicate the model if necessary (i.e., replacement of a detachment piece), drawing a hypothesis of the original hidden design of the plasterwork, and conducting a chronological study about the polychromies used over time. In some cases, the assessment has shown that the liming and repolychrome interventions to which plasterworks have been subjected and the powdery state of some areas do not ensure the possibility of the complete polychromy restoration, only its preservation by taking conservation and maintenance measures.

Keywords: gypsum plasterwork; visual inspection; weathering; preservation; architectural heritage; thermography; XRD; polychromies; virtual reconstruction

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1. Introduction

In recent decades, a great effort has been made in the field of preservation and conservation of built heritage. This is important not only for protecting the history of the city but also for improving tourism, one of the main sources of income in European countries. In fact, social networks are a sales display for tourism and play an important role in choosing a travel destination [1]. Thus, destination management organizations (DMOs) together with the governments are promoting preventive conservation and maintenance plans for preserving architectural heritage and restoration interventions. In this sense, methods, policies, and adequate planning for building preservation are being developed to preserve buildings' cultural heritage, slow down their degradation, maintain adequate functionality, and provide information regarding the priority of intervention [2,3].

The literature provides a wide background on the field of ancient plasterworks, which were traditionally used as decorative coatings and are thus a part of cultural and architectural heritage, and their polychromies and anomalies to identify and prevent the causes of alteration and establish a plan of strategies, maintenance, and preservation according to the evaluation.

The Real Alcázar of Seville (RAS) is a palatine complex whose construction began in the 11th century [4], and it is a great sample of a wide variety of plasterwork corresponding to different styles. In 1931, it was declared an Asset of Cultural Interest (RI-51-0001067 according to the Law 16/1985, of 25 June, on Spanish Historical Heritage), and some decades later, in 1987, the UNESCO declared the whole complex of the Cathedral, the RAS, and the Archive of the Indies of Seville as a World Heritage Site (http://whc.unesco.org/en/list/383 (accessed on 1 February 2022)). The RAS is constituted by different buildings, including the noticeable Palace of King Pedro I (1356–1366) due to the compositional richness of its decorations, such as plasterworks [5,6], ceramic tiles [7,8], and carpentry [9,10].

Numerous rehabilitations, repairs, and interventions have been undertaken over time, and the plasterworks are the decorative elements that present the highest level of alteration from these interventions, highlighting especially the liming and repolychrome [6] that implicate the distortion and loss of relief and original color.

The Courtyard of the Maidens, located in the Palace of King Pedro I, is one of the most representative spaces of the RAS, housing approximately 30% of the plasterwork of the ground floor. These plasterworks are located in partially covered outdoor areas, which is why they are subject to more severe conditions that accelerate their deterioration; therefore, they are in the worst state of conservation, having undergone numerous interventions throughout the history of the RAS [11,12].

This work focuses on digitalizing and evaluating the state of conservation of one of the most relevant elements as a representative of the whole, the plasterwork located on the spandrel (a spandrel is a space between two arches or between an arch and a rectangular enclosure) that decorates the entrance door to the Hall of the Ceiling of Carlos V (hereinafter, STCV) [13]. It is worth highlighting the convoluted design of the spandrel (Figure 1) [13,14], with a geometric arrangement and decorative motifs similar to those present in the Hall of Toledans, taking into account that the plasterworks are both contemporary and made by Toledan *alarifes* (bricklayers and other craftsmen working on decorative plasterworks) in the 14th century [14,15].

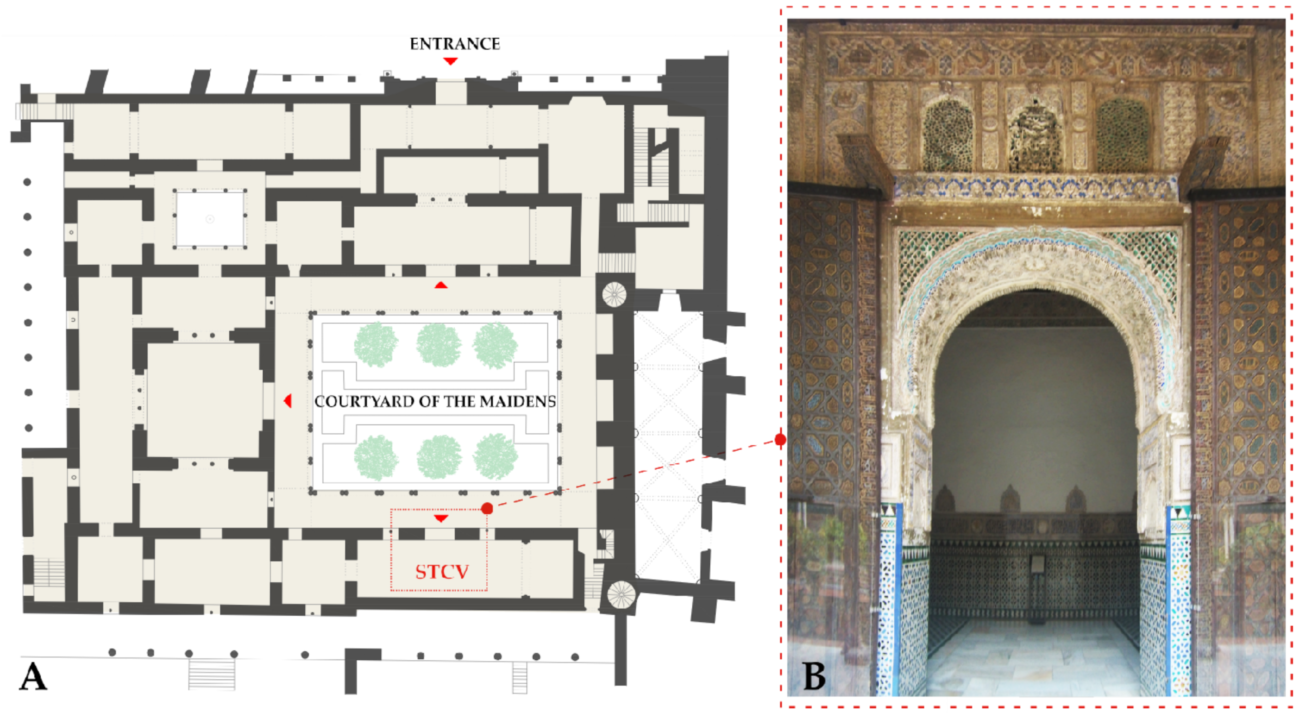


Figure 1. (**A**) Ground floor of the Palace of King Pedro I showing the location of the main courtyard and the entrance to the STCV. (**B**) Current state of the plasterwork of the entrance to the STCV.

The space of the spandrel is quite complex, presenting great geometric and compositional peculiarities, composed of a carved lower plasterwork [16] with vegetal motifs on a background of ataurique to which an exterior lattice is superimposed with a meticulous decoration of thin minisebka and losange, and a deep draft that alludes to the caliphal decoration (Figure 2). To date, it is unknown why the initial carved geometry is almost hidden, and it is also unknown if both plasterworks were executed together or if they are from different eras.

Figure 2. Images of the floral pattern on the background (authors' own images).

The vast majority of studies on ancient gypsum were focused on determining its physical, mechanical, mineralogical, and microstructural characterization by sampling and analyzing [17–23] or on the proposal of methodologies comprising the survey, evaluation, and inspection of the conservation status of a building before the repair, replacement, and rehabilitation of gypsum plasterworks [24–27]. In recent years, the study of plasterwork has been implemented from the approach of the prescription of useful life [28] and the study of the durability of the material.

Detailed knowledge of traditional execution techniques [29], the history of the building [12,30,31], and the characterization of the plasterwork and its polychromies is essential to prevent the causes of alteration and establish maintenance and preventive conservation plans [32]. It is also relevant when addressing any restoration intervention to choose materials that are compatible with the original ones [33] and/or distinguishable [34], as well as to determine the most suitable cleaning, fixing, and replacement techniques [35–37]. Thus, the study of plasterwork has been recently implemented from the approach of the prescription of useful life [28] and the study of the durability of the material.

Sometimes, the scarce and imprecise documentation about the plasterwork execution and the multiple interventions carried out over time makes the evaluation difficult, and in this kind of work, it is necessary to adopt adequate and regular maintenance strategies for plasterwork preservation.

In the specific case of the RAS, characterization work has been carried out on plasterworks [5,38–41] and their polychromies [42–44], restoration work has been performed on the plasterworks [37,45–48], specific study methodologies have been implemented through nondestructive testing (NDT) [49–52], and a model to predict the useful life of the plasterworks was developed [28] to obtain an extensive database that will support future intervention works in the heritage.

2. Research Aim and Novelty

The main objective was to establish a methodology to characterize the plasterwork and polychrome and to determine the state of conservation of historical plasterwork. It is organized in the following stages: (i) elaboration of planimetry, photogrammetry, and 3D modeling, (ii) visual inspection (e.g., fissures, cavities, stains) and diagnosis by NDT (thermography and rebar locator for nails), (iii) mapping of anomalies, (iv) characterization of plasterwork and its polychromies using various instrumental analysis techniques (XRD, stereoscopic and optical microscopies, and electronic SEM-EDAX) to determine their composition and identification of historical and modern pigments to establish a hypothesis of the evolution of polychromy from the 14th century to the present day, and (v) recording the ambient conditions (i.e., relative humidity and temperature) during a long-term period.

In this regard, the novelty of this paper is the combination of all the techniques available to date, namely traditional organoleptic inspection and scientific tests, with new techniques developed for the understanding of the architectural heritage and the assessment of the state of conservation. This work demonstrates the possibilities of a multidisciplinary study and highlights the need to obtain results and contrast them through the application of different techniques promoting information feedback. This fact is relevant for obtaining the best general analysis of the case study to establish a maintenance plan or guidelines for restoration.

An additional objective was to obtain a digital model of the spandrel to study the geometry and the current state of conservation and generate a database linked to this model that contributes to establishing the best conservation and maintenance measures applicable to other similar architectural elements.

3. Material and Methods

According to this case study, the methodology followed in this work comprised these stages: (i) characterization of the plasterwork and its polychromies, (ii) planimetric survey and 3D model, (iii) visual inspection and NDT, (iv) damage mapping, and (v) ambient condition monitoring.

3.1. Characterization of Plasterwork and Its Polychromies

Identifying the mineral phases of the plasterwork allows the determination of its general composition, as well as the presence of impurities and anomalous phases, which will allow obtaining more details about the elaboration process [19]. A PANalytical X 'Pert Pro diffractometer with X 'Celerator solid-state linear detector—whose potential radiation is CuKα 45 Kv and intensity is 40 mA—has been used. The mineralogical characterization by X-ray diffraction (XRD) was performed using a continuous sweep between 3° and 60° of 2θ, 20 s of measurement time in each step, and a sweep speed of 3° of 2θ per minute. Xpowder software was used for the data processing and identification of compounds. For mineralogical characterization, two microsamples of the spandrel were taken from the floral decoration carved in the background and from the external network.

On the other hand, five microsamples of the most representative polychromies were taken by applying the following instrumental techniques:

- Stereoscopic microscopy. It is the first analysis carried out on the samples and serves to select those that can provide more information. It does not require specific preparation, and it allows a preliminary analysis in which the existing strata, as well as their characteristics (grain size of some pigments, insulating layers, metal sheets, or the morphology of the support), can be identified. A Nikon smz 1000 stereoscopic microscope with DS-U3 Digital integrated camera was used.
- Optical microscopy. Thin stratigraphic sections were prepared by impregnation with low-pressure methacrylate resin, then cut with a diamond disc, and finally polished to study stratigraphy under the LEICA DM 750P microscope.
- Scanning electron microscopy (SEM-EDX). A Zeiss SUPRA 40 VP High Resolution Variable Pressure Scanning Electron Microscope (FESEM) equipped with an X-Ray Dispersive Energy (EDX) microanalysis system with an X-Max 50 mm large surface detector was used.

3.2. Planimetric Survey and 3D Model

The methods proposed by Cotrim et al. [24] and Gleeson [25] for the survey and inspection of plasterwork were followed in the first stage due to their quick and low-cost process for establishing the degradation condition of the elements under analysis [53]. A historiographic study was carried out to put the evolution of the plasterwork in context and to find information about the way of execution, restorations, and interventions performed in the spandrels. A thorough visual inspection of the area was carried out, and the necessary graphic and photographic documentation was obtained to obtain a detailed planimetric survey [54].

The photogrammetric model of the spandrel was obtained from the point cloud thanks to the Agisoft METASHAPE Professional software v.1.7.1. Subsequently, 3D modeling and sculpting of the floral geometries were carried out. These processes, along with the final rendering, were performed in Blender v.2.93, while the 3D texturing was performed in Adobe Substance Painter v.7.4.1. The photogrammetry model corresponds to the left spandrel because it is the one that preserves the lower relief visible on most of the surface, which allowed obtaining the information necessary to carry out the planimetry of this area at high resolution. This survey included a hypothetical recreation of the pattern that is currently hidden under the sebka network. Specific software packages were used for this stage: ASRIX for the restitution of the images and AUTOCAD 2020 and PHOTOSHOP CC2015 for the planimetric survey and mapping work.

3.3. Visual Inspection and NDT

A high-performance thermal FLIR T840 camera, with a thermal sensitivity of <30 mK at 30 °C (42° lens) and a resolution of 928 × 696 pixels, and the Flir Tools and ThermaCAM Researcher Pro-2.10 software packages were used to obtain thermographic images, without the help of lamps or luminic perturbation systems, that complement the visually obtained data. This technique allows us to detect discontinuities, possible nonvisible detachments in coatings, and the presence of moisture by representing apparent surface temperatures [55–58].

The detection of cavities was carried out by striking with a rubber hammer and acoustic evaluation to delimit the affected areas [59].

Original iron nails are common in this type of decoration, as they were probably placed during execution or added in later periods to solve fixing problems [60]. A metal detector model ETI-H0385 was used to locate them. This instrument is very useful for detecting the location and depth, which allows one to evaluate possible future damage caused by corrosion, which generates expansive oxides [61] and can trigger the detachment of fragments of plasterwork. In this way, not only the visible oxidations, such as a reddish patina, are studied, but also areas susceptible to future deterioration due to the oxidation of the metal inside the plaster are documented.

NDT applied in other plasterwork studies, such as the measurement of hardness or surface humidity [49] and the realization of readings with the georadar [51], could not be carried out due to the high relief presented by the spandrel and the difficult geometry.

Additionally, an exhaustive visual inspection of the polychromies was carried out to establish the quality of decoration execution and the current state of conservation, for which specific solubility tests were carried out by rotating a swab impregnated with distilled water to verify the stability of the polychromy [62,63].

3.4. Damage Mapping

Before any intervention, it is necessary to list the alterations present in the elements and draw them in a detailed planimetry. This damage mapping consists of indicating the main alterations and visible damage or the data obtained by the NDT on an image or a plan [59]. This will make it possible to characterize the state of conservation and establish the severity of plasterwork degradation, as well as to determine the criteria and priorities to be followed in the maintenance or restoration intervention.

3.5. Ambient Conditions

For the determination of temperature and relative humidity, an EL-USB 2 LCD thermo-hygrometer model with two registration channels was used. In this case, the measurements were carried out over a period of one year, from 20 February 2020 to 20 February 2021, at intervals of one hour uninterrupted with a data logger placed in the southeast gallery of the Courtyard of the Maidens at a height of 3.00 m. For the statistical study and analysis of environmental records, the indications presented by Torres-González et al. (2021) were followed [52].

4. Results and Discussion

4.1. Characterization of Plasterwork and Its Polychromies

4.1.1. Plasterwork

Figure 3 shows the diffractogram of sample (i) of the latticework and sample (ii) belonging to the floral background, whose locations are indicated in Figure 1 [6].

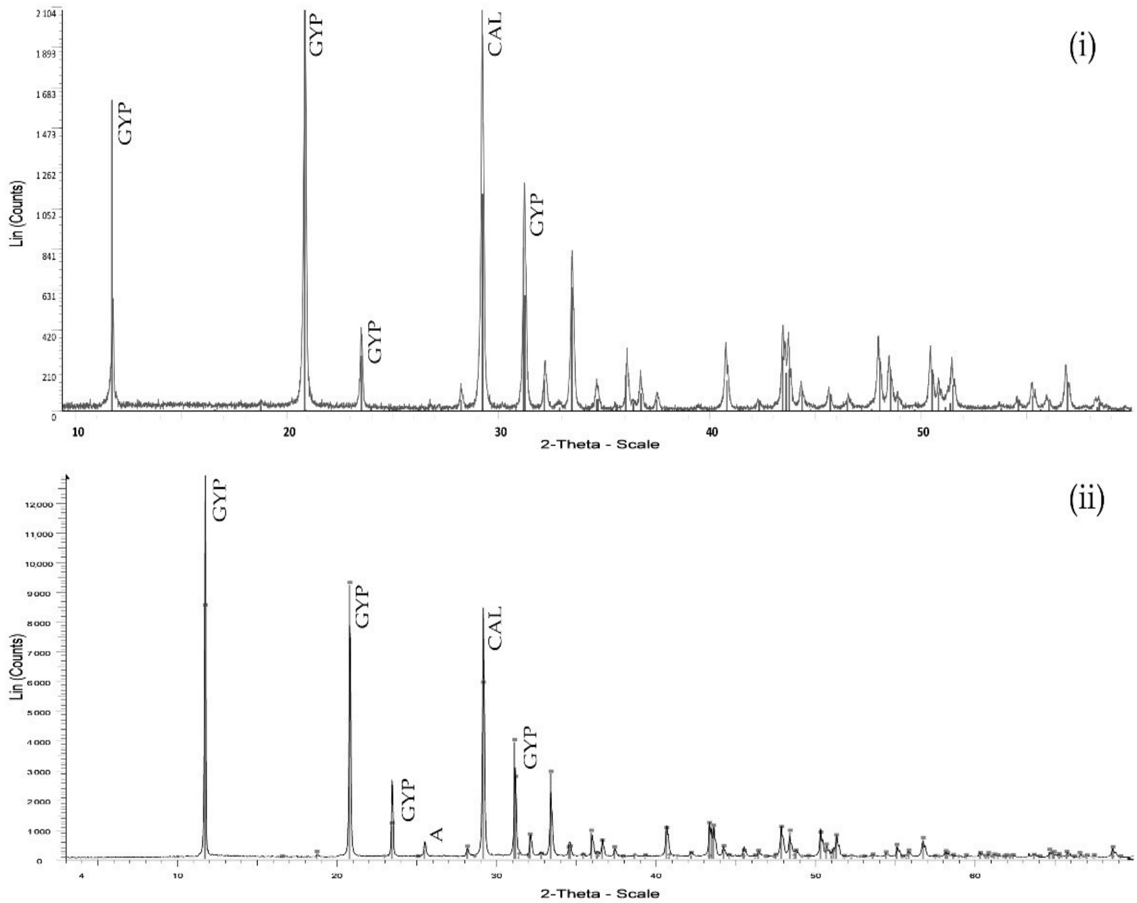


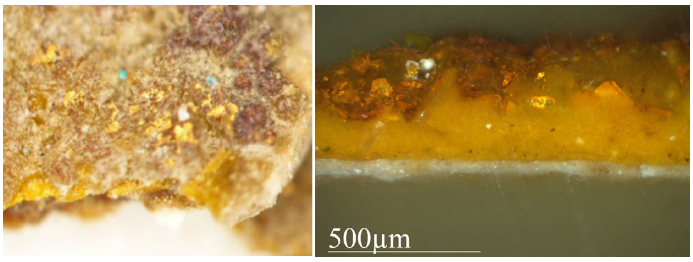
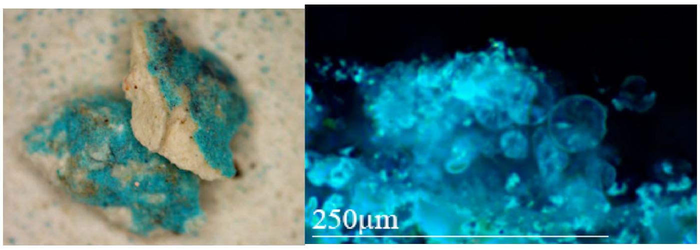
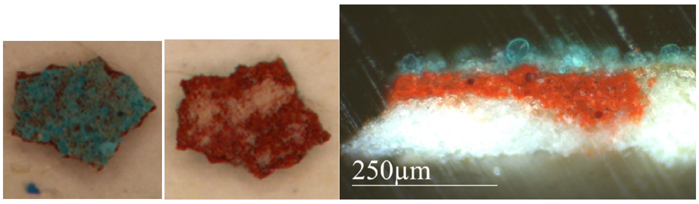
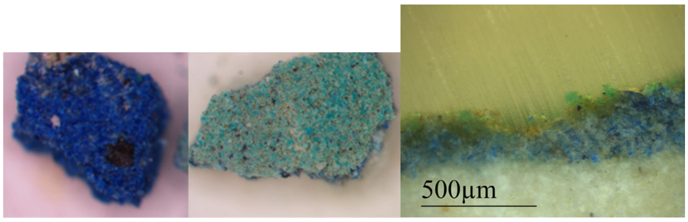
Figure 3. Diffractogram of samples (**i**) and (**ii**): gypsum (GYP); calcite (CAL); quartz (QTZ); anhydrite (A).

The presence of gypsum as the major mineral is attributable to the hydration of the hemihydrate used for the execution of the plasterwork. Calcite has its origin in the liming carried out in 1805 and 1816 [64]. The identified quartz and anhydrite at the trace level indicate a careful selection of the raw material, the gypsum stone, and the correct dehydration of it. Thus, it can be concluded that the plasterwork was executed with gypsum pastes with a high degree of purity [65], corroborating the results obtained in other plasterworks previously analyzed from the RAS [5]. These previous works determined that the original pastes of the plasterwork of the Courtyard of the Maidens were composed mainly of gypsum dihydrate, distinguishing other mineral phases in a minority proportion [6,39].

4.1.2. Identification of Pigments

After visual inspection, the polychromies have been classified into two groups: historical polychromies that could be original and modern polychromies that would correspond to repaints executed in the 19th century as indicated by the chronologies of the industrial pigments identified in Table 1 and Figure 4.

Table 1. Summary of the results obtained through microscopy analysis.

Sample Identification	Images Obtained under Optical and Stereoscopic Microscopes	Identified Materials
PD-I		Fine gold on mixtion. Metallic layer of very pure fine gold, appearing in minimal proportions of silver in some spectra on the basis of chromium yellow and lead. This layer of color appears on a 30 µm thick layer of lime.
PD-II		Emerald green polychromy identified by the characteristic spherulitic forms, applied on the whitewashed layer.
PD-III		20 µm thick emerald green polychromy on a 30 µm thick layer of red earth and cinnabar.
PD-IV and PD-V		Artificial ultramarine blue on a layer of natural azurite.

Figures 5 and 6 correspond to the SEM-EDX images of the selected samples PD-I and PD-II. Table 2 shows the results of the elemental chemical composition, and Figures 7 and 8 show the XRD diffractograms of the selected samples PD-III and PD-V.

Modern Polychromies

PD-I. Fine gold in yellow of chromium and lead: Chromium yellow is a synthetic mineral pigment used throughout the 19th century [66], after the construction of the ground floor of the Palace of King Pedro I (RAS), identified in preliminary investigations as executed between the years 1805 and 1816 [64].

PD-II. Emerald green (copper acetoarsenite—$Cu_3As_2O_3Cu(C_2H_3O_2)_2$): The presence of this pigment in the PD-II sample, characteristic both for the spherulitic forms and for the presence of arsenic (As) and copper (Cu) in the composition, also provides a very specific chronology to this study, because in Spain it was used mainly between the last third of the 18th century and the beginning of the 19th century [66–68].

PD-IV. Artificial ultramarine blue: X-ray diffraction analysis of PD-5 and PD-6 samples and optical microscopy of the surface or outer layers verified that the pigment used in both cases was artificial ultramarine due to the presence of Na, Al, Si, O, and S. This pigment also indicates a very specific chronology since it was used since the early 19th century [68].

Below this layer, in both cases a copper carbonate is identified, typical of a natural azurite that probably corresponds to the original polychromy [69].

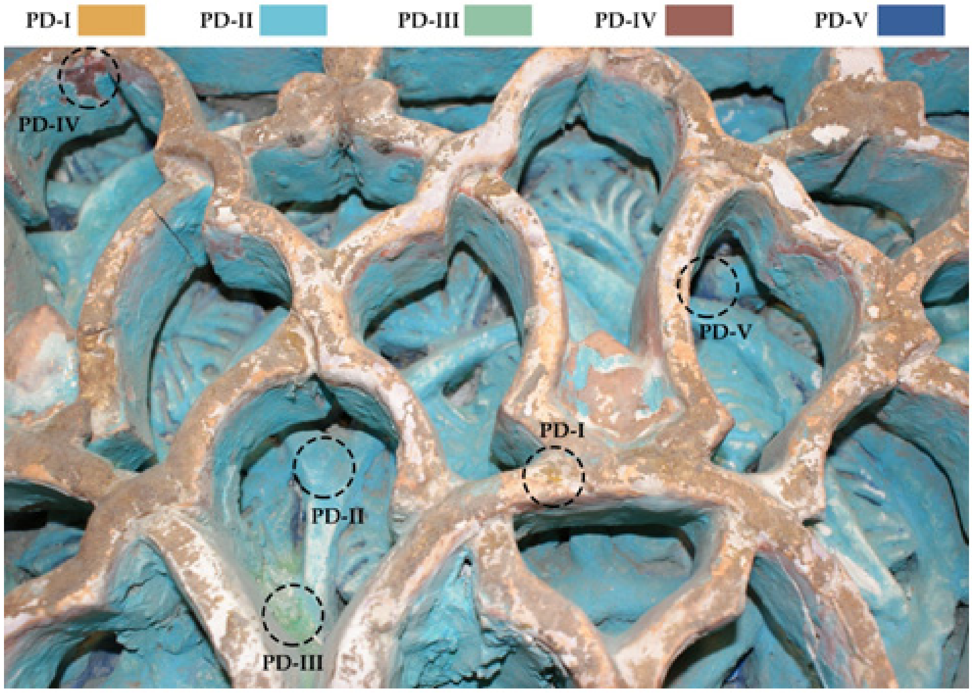


Figure 4. Polychromies present in the spandrel: golden layer (PD-I), emerald green (PD-II), artificial ultramarine blue (PD-III), earth red (PD-IV), and azurite (PD-V).

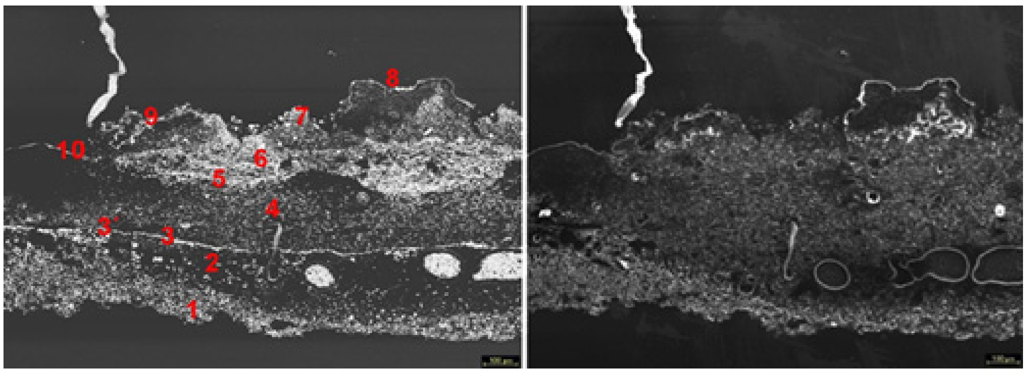


Figure 5. SEM images of PD-I taken in backscattered electron mode (BSE) (left) and secondary electron mode (SE). Numbers 1 to 10 correspond to points analysis whose results are in Table 2.

Historical Polychromies

PD-III. Red earth and cinnabar: The PD-III sample has a red layer composed of a mixture of red earth and cinnabar/vermilion [70].

PD-V. Natural azurite (copper carbonate—$CuCO_3$): This pigment appears in the lower stratum of the samples, a result that coincides with previous research about polychromies on the plasterwork of the RAS [6].

The modern polychromies were probably made after 1816 and perhaps between the years 1843 and 1858, a period of time in which an attempt to clean the liming carried out in the years 1805 and 1816 was carried out by intervening in the four galleries that surround the Courtyard of the Maidens [64,71]; however, when they did not achieve a uniform finish, they were repainted with emerald green pigments giving a general color finish to the plasterwork. This fact can also be seen in the low delicacy of the intervention, without following the lines or contours of the plasterwork and painting the background in all its extension, in this case, using emerald green. On the other hand, the golden layers were probably created between 1854 and 1857 [72–74].

Taking into account the results obtained, a hypothesis of the chromatic evolution has been made, and the levels of intervention established are shown in Figure 9.

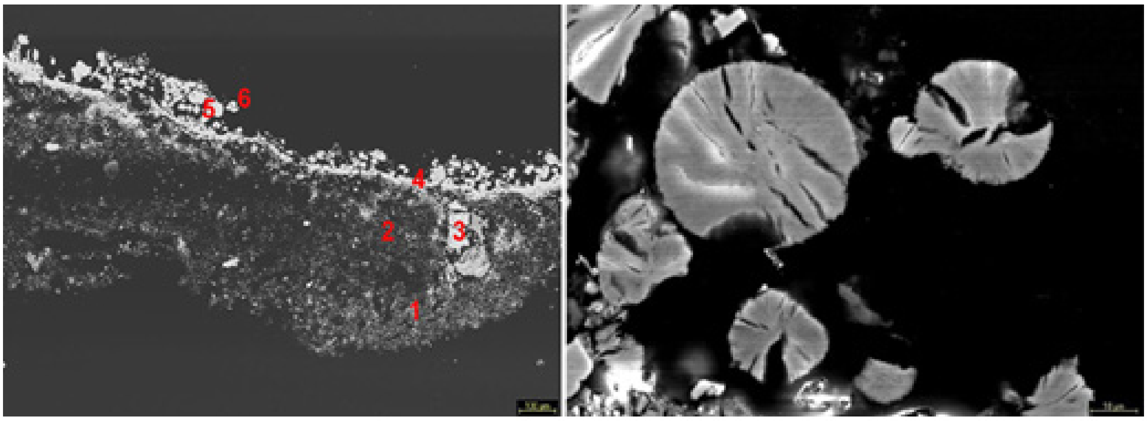


Figure 6. SEM images of PD-II taken in backscattered electron mode (BSE) (left) and emerald green polychromy identified by the characteristic spherulitic forms. Numbers 1 to 6 correspond to points analysis whose results are in Table 2.

Table 2. Chemical composition of PD-I and PD-II determined by SEM-EDX.

Sample	Strata	Elements
PD-I	Whitewash	Sp.1—Al, Si, S, Ca Sp.2—Al, Ca Sp.2′—Al, Si, K, Ca Sp.3—Al, Si, S, Cl, K, Ca Sp.3′—Mg, Al, Si, S, Cl, K, Ca, Ti, Fe Sp.4—Al, Si, S, Ca
	Gold base. Chrome and lead yellow	Sp.5—Mg, Al, Si, S, Pb, Ca, Cr Sp.6—Mg, Al, Si, S, Pb, Ca, Cr Sp.7—Mg, Al, Si, S, Pb Sp.10—Mg, Al, Si, P, Pb, K, Ca, Fe
	Gold leaf	Sp.8—Au, Ag, Ca Sp. 9—Au, Ca
PD-II	Whitewash	Sp.1—Al, S, Ca Sp. 2—Mg, Al, S, Ca Sp.3—Fe, Mg, Al, Si, P, S, K, Ca
	Emerald green	Sp.4—Ba, Fe, As, Al, Si, P, S, Cl, Ca, Cu Sp.5—Cu, As, Cl, Ca Sp.6—Cu, As, Cl, Ca

4.2. Planimetric Survey and 3D Model

The graphic survey has made it possible to distinguish the elements incorporated in the background decoration, in spite of the overlapping latticework that draws rhombuses such as sebka and horseshoe arches, respecting the law of the bow and maintaining a similar thickness in the whole [76]. The complexity of the latticework, the low thickness of its partitions, and the depth of the same can be indicative of a plasterwork executed by carving [16] (Figure 10).

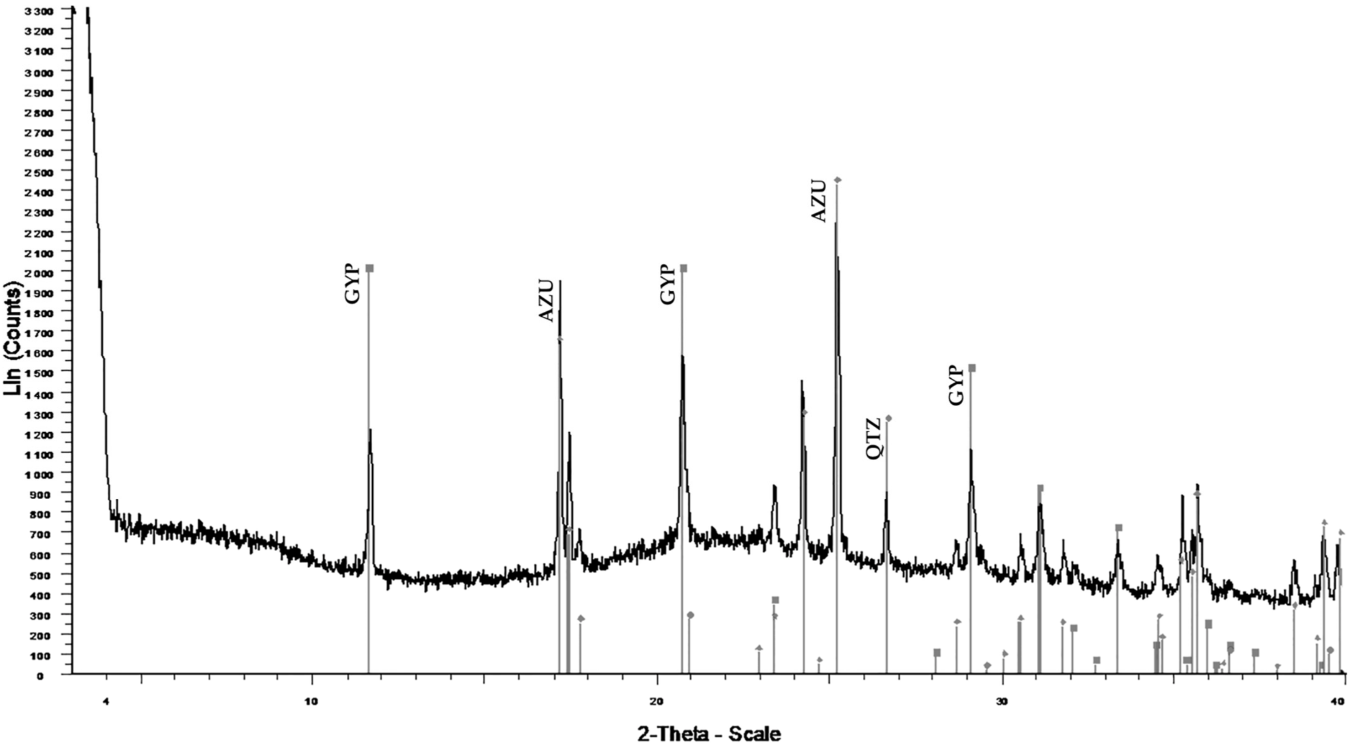


Figure 7. PD-V diffractogram showing azurite (AZU), gypsum (GYP), and quartz (QTZ) minerals.

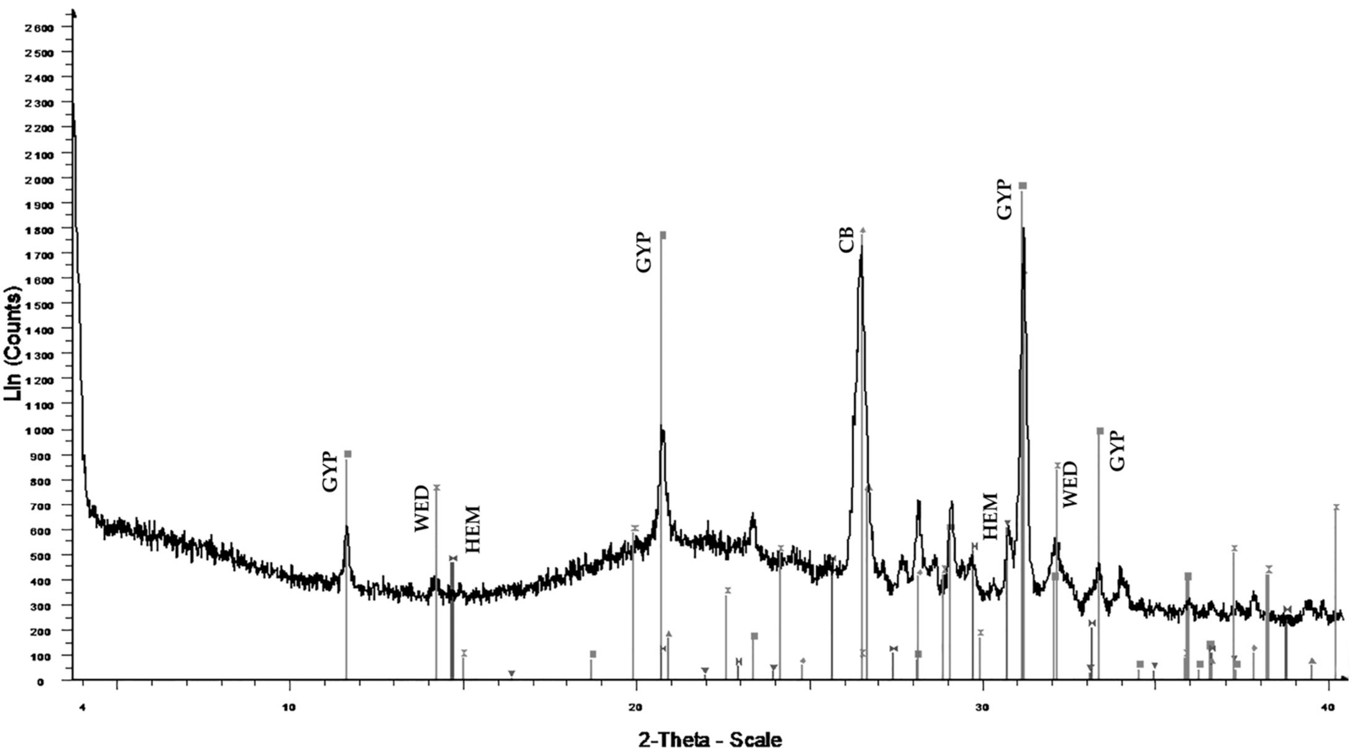


Figure 8. PD-III diffractogram showing gypsum (GYP), hemihydrate, dolomite (DOL), weddellite (WED), and cinnabar (CB) minerals.

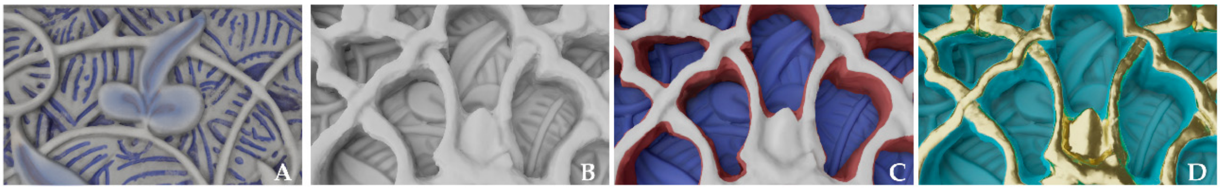


Figure 9. Hypothesis of the evolution of color with veracity scale 9 according to Resco and Figueiredo (2017) [75]: (**A**) mid-14th century; (**B**) early 19th century; (**C**) mid-19th century; (**D**) late 19th century.

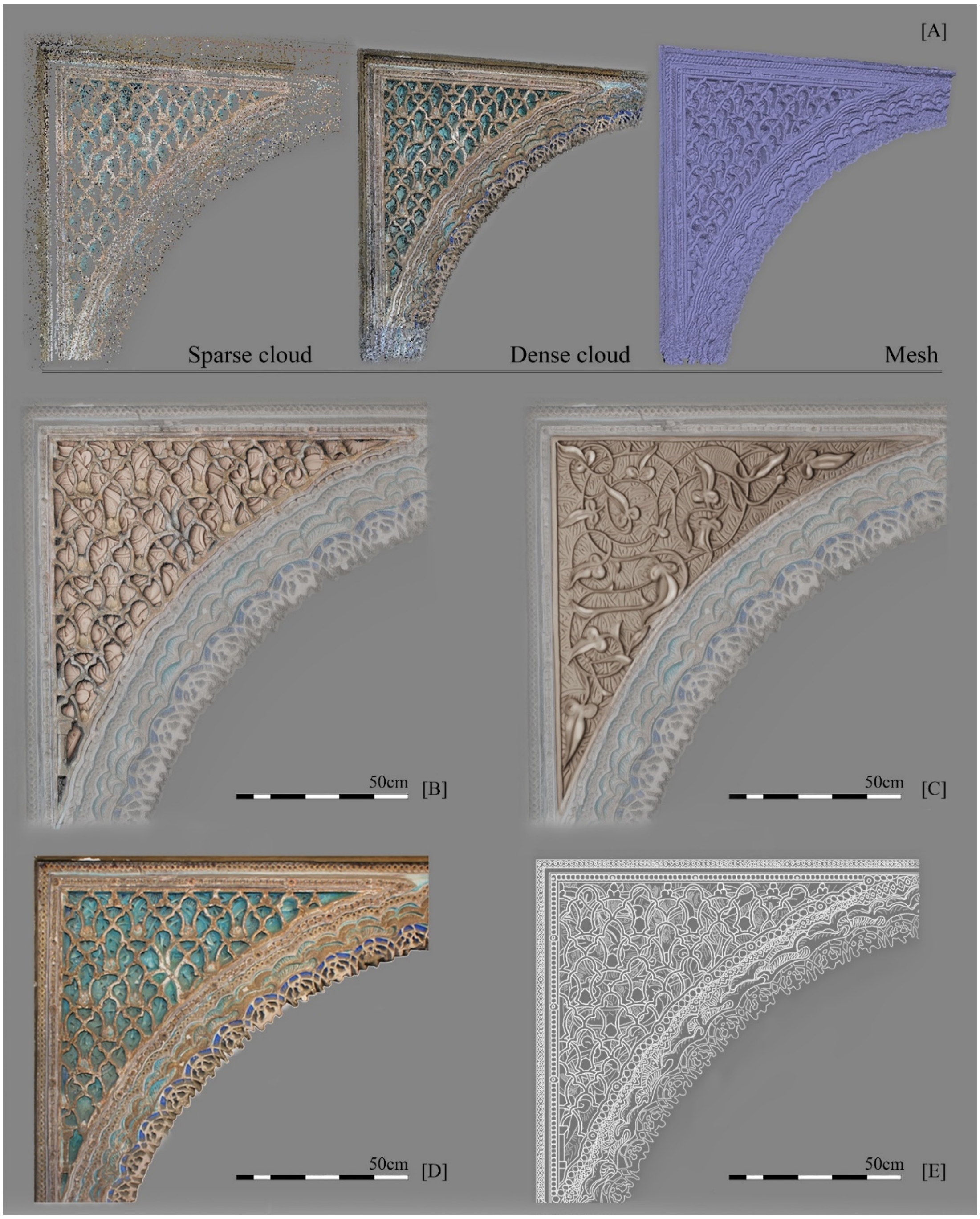


Figure 10. Data processing in Metashape software (**A**); results after the process of 3D modeling of the spandrel (**B**). Hypothesis of the hidden layout made by the authors based on the previous photogrammetric survey (**C**). Planimetric survey of the spandrel: photograph (**D**) and planimetric map drawn by the authors (**E**) (authors' own images).

The 3D modeling carried out (Figure 11) has allowed corroborating that the geometries in drawn in the latticework present similar proportions and dimensions, but they are not exactly the same, reinforcing the hypothesis of carving as the execution technique used. Furthermore, at some points, traces made with the knife during the carving process were identified.

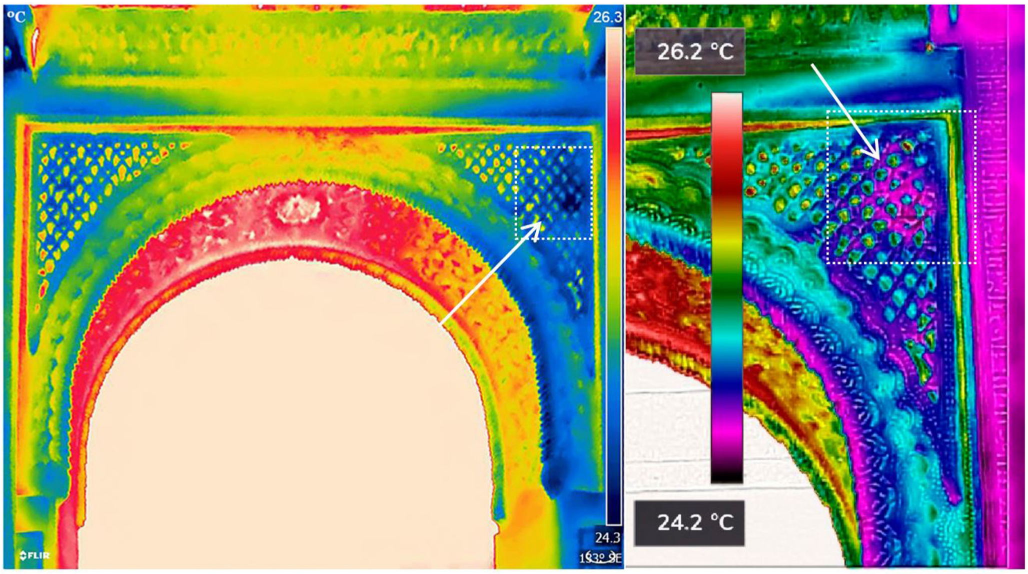


Figure 11. Thermography of the case study under ambient conditions of 23.5 °C and 61% relative humidity (images taken by the author on 27 June 2020 at 11 am).

4.3. Visual Inspection and NDT

The thermography images do not show significant temperature jumps (Figure 11). Thus, the carved surface in the background does not present problems of fixation or cavities according to the initial surveys and organoleptic analysis [49]. However, the overlapping lattice is unstable at some points due to the delicacy of the geometry and the degradation presented due to the passage of time. Regarding the metal fasteners, no hidden fixings were detected; only seven visible fixings were identified, used as reinforcement fixation—iron nails—to avoid the collapse of the latticework.

The visual analysis has allowed corroborating that the polychromies of the spandrel show alterations detected in works of similar typology, as well as in other areas of the Courtyard of the Maidens [77]. Thus, the pulverulence, repolychromies, and cracks stand out [6]. The accumulated dirt and dust, especially in the inner areas of the relief decorations, constitute a significant aesthetic deterioration that hides the relief and color of the decorative coating, also contributing to the production of the habitat necessary for the nesting of different species or microbiological development [54,78]. The way in which the floral background is polychromed nowadays does not coincide with the traditional method; usually, polychromies follow the contours and maintain the relief of the decoration, but, in this case, the background is completely painted in one single color, highlighting the latticework [79].

The solubility tests carried out confirm that the current polychromies present in this area are quite unstable, demonstrating a high degree of decomposition, pulverulence, and little adhesion to the surfaces. This instability is evident even when cleaning the surface dirt with a very soft bristle brush [43]. This problem is detected in all the colors studied except for the golden zones of the latticework, where the layers are cracked but relatively well adhered, probably as a result of their adhesion with oils and varnishes [6].

4.4. Damage Mapping

The observed alterations, namely metallic elements, cracks and fissures, detachments, and replacement of material, are identified in Figure 12. Dirt (aesthetic deterioration) and consequent biological development have not been included in this mapping, as they are extended throughout the whole surface of the spandrel.

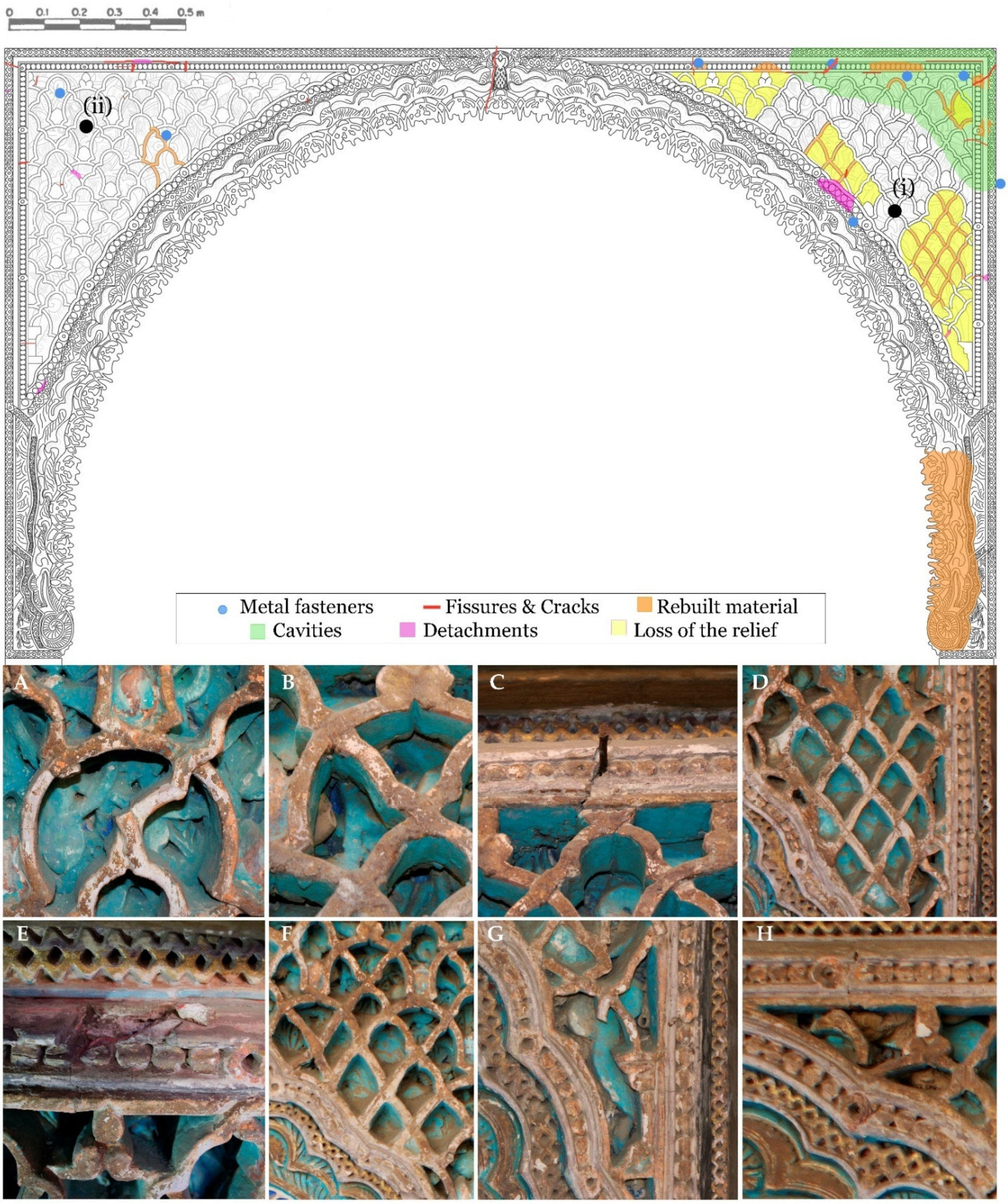


Figure 12. Mapping of alterations present in the spandrels of the arc of access to the STCV. (**A**) Types of deterioration present in the spandrels: (**A**) detachment and lack of repolychrome due to successive interventions, (**B**) presence of hornets, (**C**) presence of oxidized metal elements, (**D**) loss of the lower relief due to fillings with plaster/lime mortar, (**E**) detachment of part of the frame, (**F**) dirt, (**G**) detachment and hornet's nest, and (**H**) fissure and presence of hornets (**B**).

Regarding the metallic elements, reddish spots identified around the nails are a result of the oxidation of the metal. The loss of adhesion that makes it necessary to incorporate these metal elements is usually due to mechanical stresses that occur over time.

From a conservative point of view, the right spandrel presents greater conservation problems than the left one. In fact, important deformations are visible in the central and upper right areas, and the latticework in some areas presents a collapse of 2 cm. To prevent this situation from going further and even resulting in the detachment of the latticework, the latticework was fixed to the support by means of plaster sinks in previous interventions.

4.5. Ambient Conditions

Plasterworks from this case study are exposed to external ambient conditions but are protected by a gallery that prevents direct contact with rainwater and protects them from the prevailing winds of the city, i.e., southwest winds, favoring their preservation.

The presence of moisture (filtration moisture, capillary moisture, humidity by direct contact with rainwater, etc.) is the main source of the most significant damage to plasterwork and its polychromies, promoting the oxidation of the metal fixing elements; causing detachments, the appearance of surface stains of humidity, and stability problems in the internal structure of the material; and reducing C-Shore surface hardness, compressive strength, and adhesion to the support [80–84]. Environments with a relative humidity (RH) close to or greater than 90% weaken the structure of the plasterwork and involve the proliferation of microorganisms and biological agents.

Above 40 °C, calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) begins to dehydrate in dry environments [85], so the plasterwork can initiate internal destabilization. However, situations of high temperatures combined with high RH do not alter the mineral phases of gypsum [86]. In this regard, Winkler and Wilhelm (1970) indicate the relationship that must occur between ambient temperature and RH for gypsum to be transformed into basanite ($CaSO_4 \cdot 0.5H_2O$); the material is likely to lose stability only if unfavorable conditions are maintained over time [86,87].

In the case of polychromies in plasterwork—usually tempera—the presence of moisture implies the alteration of binders, and it could also impede the transpiration of the layers—mainly in those cases in which there are repolychromed layers with oils and waxes or golds of later times [40]—accelerating the degradation processes.

Measurements taken in the Courtyard of the Maidens reveal that the temperature never exceeds 40 °C, and the RH measurements indicate that the RH was close to 90% only during the month of January; thus, the hygroscopic adsorption is very low and the risk of deterioration due to the action of hygroscopic water is eliminated under these ambient conditions [81,82]. Nevertheless, even in the case of the RH being below 90% and the T exceeding 40 °C in the summer months, there would not be a problem with gypsum dehydration, as it is a reversible internal phenomenon, requiring a long period of time under these ambient conditions to avoid the irreversibility [52,85].

5. Conclusions

The proposed methodology combines traditional inspection techniques (organoleptic tests) and material characterization with the use of digital tools (photogrammetric survey, thermographic imaging, and record measuring with thermohygrometers) that unequivocally complement and refine the analysis and evaluation of the state of preservation. This complete collection of various types of data provides adequate information for the cataloging of the elements and appropriate decision-making for their protection.

The three-dimensional model obtained allows us to theorize about the original elements and the modifications made over time. Through this study, a hypothesis has been made regarding the floral background that is semi-hidden by the latticework, making it possible to corroborate that the geometries used match those from other areas of the Palace of King Pedro I.

The characterization of the pigments has confirmed that the polychromies hidden under the current emerald green hue also correspond to the repolychrome present in the plasterwork of other elements of the palace. It has been possible to establish a chronological hypothesis of color. The analysis carried out has not allowed dating the latticework in minisebka, and so it remains undetermined whether it was executed in the 14th century—at the same time as the carved background—or if its placement took place later. The logical explanation would be that the *alarifes* who carved the bottom of the spandrel executed a meticulous work for it to be seen, and not to hide it later. The latticework possibly dates from the 14th century as well, but from years after the initial plasterwork was carved, and the reason for its execution is unknown to date.

The whitewash and repolychrome interventions to which this plasterwork has been subjected, together with the powdery state of the currently existing polychromies, make it unfeasible to recover the original polychromy. Attempting this recovery would require meticulous and precise work that would incur high costs, but there is no guarantee that a full restoration would be possible. Some parts of the polychromy have been completely lost due to deterioration over time. In this situation, a consensus must be reached to decide whether to undertake restoration work or simple conservation.

After evaluating the alterations present in the spandrels, it is concluded that periodic maintenance is necessary to address the cleaning of superficial dirt through aspiration. It is also recommended to monitor fissures and cracks and to seal them with mortar or a suitable adhesive if there is a risk of detachment. The complete study of plasterworks and their polychromies provides detailed information that can be used to digitalize and divulgate this type of decoration. It also provides data that allow establishing different degrees of degradation to prioritize interventions, establish effective conservation and maintenance plans, and ensure the suitability of the materials employed in future restoration projects. This methodology would be applicable to any of the plasterworks found in the Real Alcázar of Seville and to any building with this type of plaster coating, regardless of the execution system used, the style, and the chronology of the plasterwork.

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