COMPLETE RESTORATION OF THE ROOFS OF THE HALL OF THE KINGS

RESTAURACIÓN INTEGRAL DE LAS CUBIERTAS DE LA SALA DE LOS REYES

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ABSTRACT A detailed journey is articulated through a wide-ranging intervention and complexity that comprises the entire Hall of the Kings, both the main hall and the bedrooms with paintings. The functional sense of the environment is created by its founder Muhammad V as an essential part of the Court of the Lions is analysed, as well as its space and constructive-structural organization, especially detailing the relationship of the covers with the mocárabe domes and the wooden vaults coated with leather and finished with several layers of plaster that are of assistance to prepare paintings of a great artistic and symbolic value, preserved in critical condition at the end of the nineties of the last century. The intervention carried out over several years is described, including the analysis phase and the response to the serious conservation problems, mainly accumulated since the transformation of the roof covers layout executed by Rafael Contreras in 1855-1857. The measures adopted in an advanced conservation context are also developed: roof covers layout improvement, restoration of structural functions, seismic instability prevention, microclimate control and accessibility for the maintenance both exterior and interior roof covers.

KEY WORDS Hall of the Kings, roof covers, armour, wooden vaults, mocárabe, consolidation, recovery, maintenance, microclimate control.

RESUMEN Se plantea un recorrido minucioso a través de una intervención de gran amplitud y complejidad que abarca la Sala de los Reyes completa, tanto la sala principal como las alcobas con pinturas. Se analiza el sentido funcional del ambiente creado por su fundador Muhammad V como una parte esencial del Palacio de los Leones, así como su organización espacial y constructivo - estructural, detallando especialmente la relación de las cubiertas con las cúpulas de mocárabes y las bóvedas de madera revestidas de piel y terminadas con varias capas de yeso que sirven de preparación a unas pinturas de gran valor artístico y simbólico, conservadas en estado crítico a finales de la década de los noventa del siglo pasado. Se describe la intervención realizada a lo largo de varios años, incluyendo la fase de análisis y la respuesta a los graves problemas de conservación, acumulados fundamentalmente desde la transformación del trazado de cubiertas que lleva a cabo Rafael Contreras en 1855-1857. También se desarrollan las medidas adoptadas en un contexto avanzado de conservación: mejora del trazado de cubiertas, restablecimiento de las funciones estructurales, prevención del riesgo sísmico, control micro climático y accesibilidad para mantenimiento tanto en el exterior como en el interior de las cubiertas.

PALABRAS CLAVE Sala de los Reyes, cubiertas, armaduras, bóvedas de madera, mocárabes, consolidación, recuperación, mantenimiento, control micro climático.

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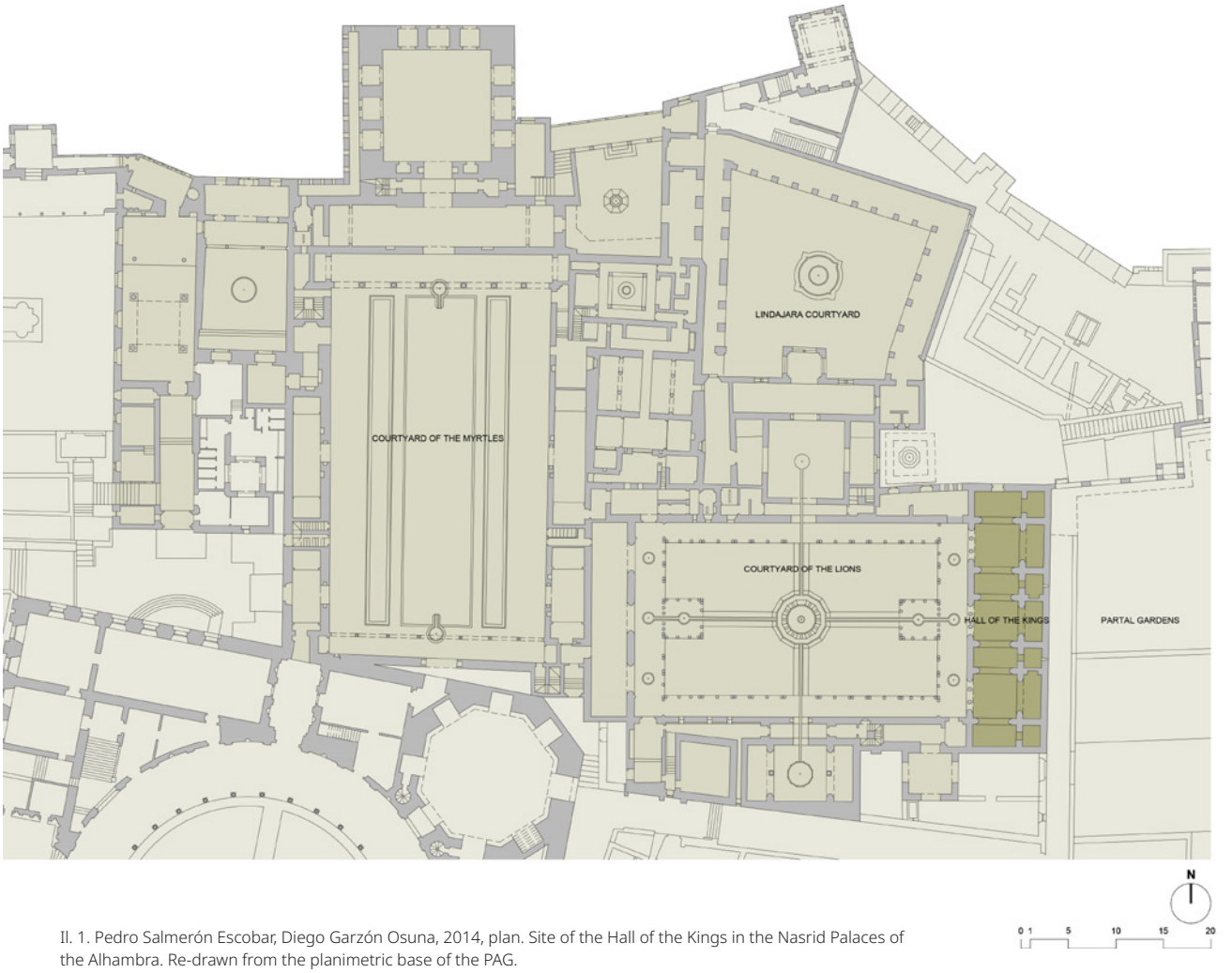


Il. 1. Pedro Salmerón Escobar, Diego Garzón Osuna, 2014, plan. Site of the Hall of the Kings in the Nasrid Palaces of the Alhambra. Re-drawn from the planimetric base of the PAG.

The Palace of the Lions [Palacio de los Leones] has a complex organisation based on a sequence of spaces that follows the rhythm of relationships that make complete sense when the palace is viewed as an inhabited place. The courtyard draws the most attention and acts as an organiser of activities, receiving everyone's gaze: this palace is one of the most closed off buildings in the Alhambra from the outside.

This factor can be understood to be key to the Alhambra's palaces due to the prominence given to their courtyards and an architecture that makes recurring use of this interesting resource, creating intimate, reserved settings with measured, calibrated environments and a masterful play of light. The western flank of the Palace of the Lions is linked to the Palace of Comares [Palacio de Comares], building on the sense of the sultan's power. However, there was no effective communication between the two: existing routes were opened to facilitate public tours.

The south-facing side was also closed to the outside and was connected to Calle Real Baja, an access point for internal relationships within the palatial city and a flank supporting other spaces with a high emotional and religious content: the burial place of the *Rauda* and the main mosque of the Alhambra. It is also no coincidence that, on this side, with the Hall of the Abencerrajes [Sala de los Abencerrajes] as a hub, there was access to the harem rooms on the upper floor, although the activity associated with this use in the Alhambra goes beyond this specific location.

The Hall of the Two Sisters [Sala de las Dos Hermanas] is to the north and ends with the Lindaraja Viewpoint, also known as the Sultan's Eye. It is the most open flank of the palace and has outstanding views of the garden and the city in particular, seen almost flush ahead if you are seated or in a reclining position on the floor of this small room, but currently blocked by the cloister-like development of the courtyard in the Christian period. But it is also the intimate and particularly rich point of connection with the Royal Baths and Comares Palace, becoming a vital node in palatial communications during the Islamic period, which were anchored in an extremely subtle understanding of the private or reserved, and acting as a true architectural filter for public/private activity.

The Hall of the Kings is to the east, which is completely closed off from the outside except for a small north-facing window. The dimensions of the great hall and the way its space expands upwards due to the *muqarnas* domes make it possible to envisage significant resources being used for any recreational activity. But what makes the main space particularly appealing is the contrast between the three rectangular alcoves finished with painted wooden vaults, secluded and at the same time open with large arches leading to the main hall. It is this leap in scale and a clear search for privacy in rooms with links between different spaces, an effect produced by using curtains, lattices or screens[1], that makes it seem the ideal place for the Majlis; the result of a fascinating display of sensuality, pleasure, enjoyment of the senses, and also of artistic, aesthetic and intellectual development.

APPROACH TO THE RESTORATION. STARTING POINTS

One of the most interesting aspects of the restoration work is the unique nature of the painted vaults that have wood covered with leather. Finding out more about this solution was crucial to learning the reasons behind this choice. From a technical point of view, it was logical to use a support such as wood and cover it with a material that could be painted, but there had to be further reasons for such a specific, singular choice.

At certain points during restoration work, initial questions arise that can determine the course of subsequent actions. In the case of the Hall of the Kings, research was performed into the reasons why the paintings had suffered such accelerated and extensive deterioration, its relationship with changes to the roofs and the impact on the delicate materials used to create the vaults.

The description *painting on leather* that stands out in Bermúdez Pareja's work[2] encourages readers to discover in depth the relationships between the different layers: paint, plaster, skin, wood, air chamber and roof, especially as the author of this interesting work links these aspects together and discusses them in reflective terms. The first issue that stands out is the link between the accelerated deterioration and the change made by Rafael Contreras in 1857 when the single roof, which had functioned effectively for a long time, was segmented into independent pavilions. Unfortunately, it was an ill-advised alternative that marked the beginning of a serious process of degradation; analysing and diagnosing this degradation has occupied professionals and organisations until the first decade of the 21st century.

1. MERNISI F. Sueños en el umbral. Memorias de una niña del Harén. Ediciones B, S.A. Barcelona, 2013. This novel and sensitively written work provides a closer insight into the ways in which the spaces of a harem are used.

2. BERMÚDEZ PAREJA J. Pinturas sobre piel en la Alhambra de Granada. Alhambra and Generalife Board of Trustees. Granada, 1987.

Bermúdez Pareja also bases his assessment on the way the leather is attached to the wood, so that the 'outer' side, which has pores and remains of hair, is fixed to the wood, and the vascularised and rough side faces the interior of the room, helping the layers of plaster covering the skin to stick better. However, the decomposition of the gypsum paste preparation and the progressive disintegration of the paint layer into small fragments or particles, which easily became detached, set these valuable testimonies from the medieval period on a critical path towards necessary conservation. The lack of similar examples and knowledge of the wood – leather – plaster – paint relationship is also acknowledged, and he highlights the unfortunate restoration work performed on the paintings to consolidate or fix the leather, and repainting work and other actions carried out on the layer of paint.

Based on these reflections, the situation in the vaults of the Hall of the Kings created the opportunity for a specific consultation on the use of decorative arts applied to leather. This led to a visit to Vic Leather Museum in 1999 by Esther Cruces Blanco, Head of the Research and Dissemination Service of the Board of Trustees of the Alhambra and Generalife, and the author of this article, who was carrying out the initial tasks related to the project of restoring the Hall of the Kings. According to the museum's experts, whether leather is embossed, dyed, painted or treated in any other way, its outer side is worked due to its better qualities. The highly vascularised, irregular and difficult to treat 'flesh side' is left on the hidden side of the piece of art. The museum's specialists suggested an interesting hypothesis: the opposite is true in the paintings in the Hall of the Kings because they were not intended to be simple decoration on leather but instead were specifically used as a type of insulation, like a coat, while also acting as an intermediate support to prevent the plaster preparation on the wood from being directly impacted by the wood's movements.

This hypothesis helps to enrich our view of this space, to understand the unique design of the alcoves' ceiling, the use of imported paintings, the choice of motifs with scenes from court life and the representation of power, the subversion of certain principles displayed by the Palace of the Lions, with its fountain and four porticoed sides, turning its singularity into an advantage. The change from a vaulted ceiling formed by *muqarnas* to sensual, colourful figurative paintings adds a subtlety that accentuates the palace's appeal to privacy, and gives the alcoves the function of a protective, trusted shelter. This facilitates pleasure, making it easier to understand the planning of the Majlis referred to above.

Fatema Mernisi states that majliss comes from the verb jalasa, which in Arabic means to *sit down with the intention of relaxing and doing nothing for a while, for mere enjoyment*[3]. This definition is expanded in the aforementioned work, giving meaning and significance to a form of social relationship in domestic spaces in Islam, which is highly significant in the Palace of the Lions.

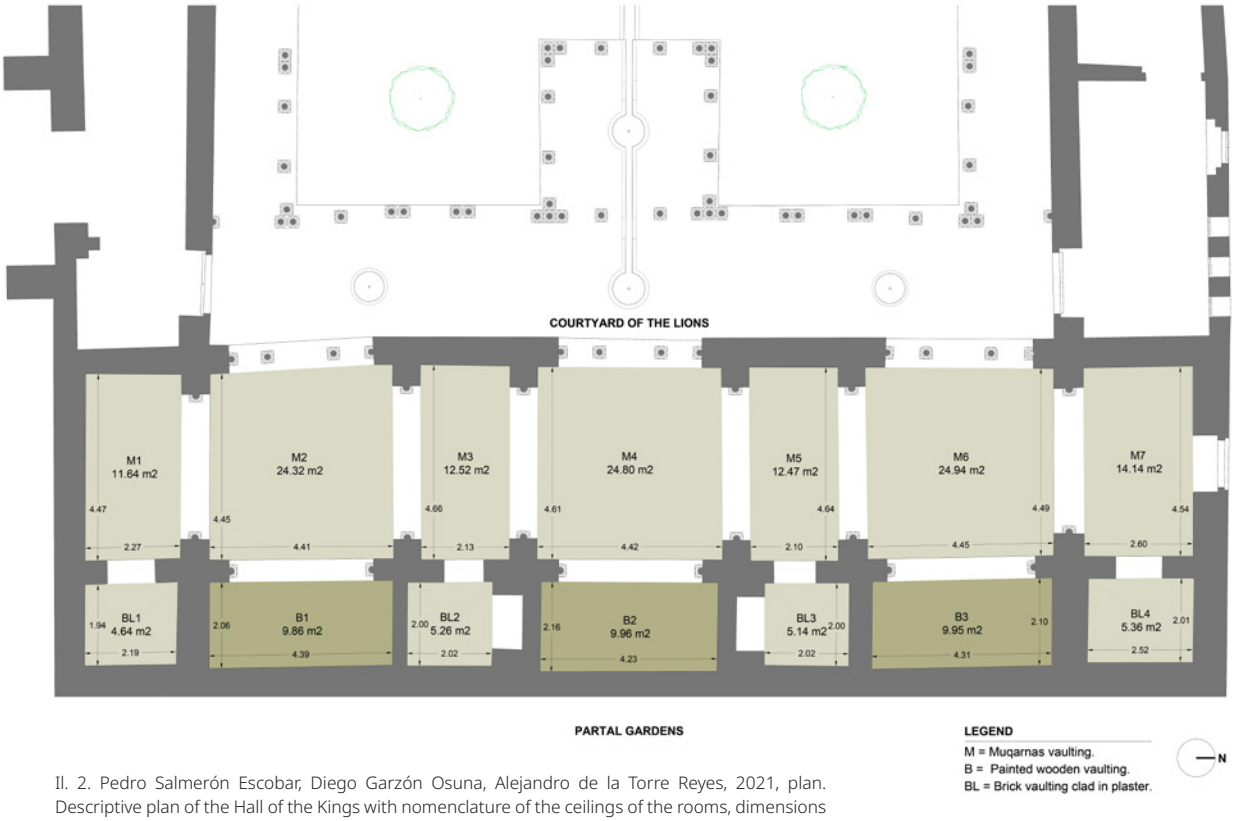
From this point of view and from the way the palace is organised, it is possible to appreciate the idea of living in a space designed to be open that includes the presence of women, whose location was less anchored to a specific place than in other Islamic palaces where there was an exclusive space for the harem and this certainly supports the idea that the Palace of the Lions as a whole played a leading role in private life. Bárbara Boloix's reflections on this aspect are particularly relevant[4]: *in the Palace of the Lions there are today places and corners whose names are a true evocation of the female presence of another time*. As is the allusion to Antonio de Lalaing's text on the Hall of the Kings, in which he stated that in this place *the Moorish King used to lie down to keep cooler and that he had his bed at one end of the Hall and the Queen's bed at the other*. These authors' contributions lead to an important idea in terms of the restoration, which was to ensure the authenticity of a backdrop to private life but also to recover the recreational and creative life of the Alhambra. A real challenge.

THE ROOF MODEL: SINGLE OR SEGMENTED

The single roof that once covered the Hall of the Kings can today be compared with the roof of the opposite wing to the west, which includes the Hall of the Muqarnas adjoining the Palace of Comares. The logic behind such large roofs was that they served to protect a group of areas, regardless of their upper finish (ceiling). An unusual feature of the Hall of the Kings is the diversity of systems that are arranged in a particular way based on the divisions formed by walls and arcades, and following the interesting outline of the structure of the Palace of the Lions, which handles proportions and sequences with great finesse, as seen in the courtyard's porticoes. The spaces can be identified on the attached plan which includes the floor area of each of these ceilings and the main dimensions to give an idea of scale:

3. MERNISI F. El harén en occidente. Barcelona, 2006. p. 153.

4. BOLOIX GALLARDO, B. Las Sultanas de la Alhambra. Las grandes desconocidas del Reino Nazarí de Granada (siglos XIII-XV). Alhambra and Generalife Board of Trustees. Editorial Comares. Granada, 2013, p. 214-215.



Il. 2. Pedro Salmerón Escobar, Diego Garzón Osuna, Alejandro de la Torre Reyes, 2021, plan. Descriptive plan of the Hall of the Kings with nomenclature of the ceilings of the rooms, dimensions and surfaces.

-A main area with three large *muqarnas* vaults (M2, M4 and M6) with a square floor plan (these can be referred to as domes) and two smaller interspersed rectangular vaults (M3 and M5).

-Alcoves at either end of the main hall with *muqarnas* vaulted ceilings (M1 and M7).

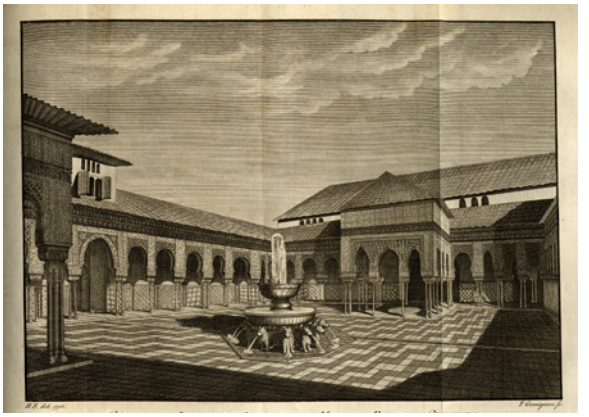
-A series of seven spaces forming the façade facing the Partal gardens, three of which are the alcoves with wooden vaults covered with leather and finished with paintings (B1, B2 and B3) and four smaller areas at the middle and ends of the alcoves with brick vaults covered with plaster mortar (BL1, BL2, BL3 and BL4).

The alcoves that are exquisitely finished with paintings have a surface area of around 10 m2 and the three *muqarnas* domes have a plan of just under 25 m2, indicating a sense of restraint in the rooms while sparing no expense on the richness of their envelopes, an aspect that characterises Nasrid Palaces in general and the Palace of the Lions in particular (Il. 2).

The single roof allowed air to ventilate above these varied and fragile spaces. Water was drained towards the perimeter (Courtyard of the Lions or Partal) without hidden gutters.

There were certain problems at the point where the lattices are found on the perimeter of the three main areas with *muqarnas* domes in the Hall of the Kings (M2, M4 and M6), which play a important role in how the spaces are perceived, and in letting light in and the spaces transpire through their connection to the courtyard. The envelope of these three vaults partially received light through openings in the perimeter, and those facing the Courtyard of the Lions are visible in historical photographs and engravings. The rest of the lattices embedded in the openings were used for ventilation via the roof chamber, establishing a decisive air flow that helped to preserve the interiors, the roof framework and the muqarna and wooden vaults by preventing condensation from generating damp (Il.3) (Il. 4) (Il. 5).

An earlier change had also been made to the Hall of the Kings as a result of modifications made in the Christian period to the upper level of the flank facing the Partal. The perimeter route that was planned along the envelope in some areas of the Nasrid Palaces also reached here in a forced manner; Bermúdez Pareja includes this aspect in his publication with an interpretative diagram of the roofs in Hall of the Kings



Il. 3 Swinburne, H., engraving. Printed by P. Elmsly, London, 1779. Library PAG / A-0546. This image shows a view of the Hall of the Kings with a single roof. The openings in the areas with muquarnas vaults are visible.

Il. 5. Soulier, 1857, photograph. Courtyard of the Lions. Carlos Sánchez GómezCollection. The beginning of Rafael Contreras' restoration work can be seen in the background of the photograph. Once the roof was removed, the back of *muqarnas* vault M6 of the Hall of the Kings emerged.

Il. 4. Pedrosa i Vacarissas, Joaquín, 1857, photograph. Courtyard of the Lions. APAG / Photography Collection / F-005689. The Hall of the Kings still has its single roof and the latticed openings in the areas with *muqarnas* vaulting can be seen.

area and an interesting drawing by Richard Ford that shows an open gallery on this side facing the Partal[5]. Forced passage along this side affected the underlying structures, deforming the upper part of the wooden vault of the south-east alcove (B1), increased this delicate ceiling's problems.

The roofs of the Hall of the Kings had problems in the mid-19th century. Photographs from the period show deformations and there were probably some leaks, which was common in such old roofs, but regrettably transforming it into independent pavilions didn't solve the issues and became the starting point for further problems. In reality, it followed a picturesque vision of this sector and others in the Nasrid Palaces such as the Hall of the Boat [Sala de la Barca] and the front of the south façade facing the Courtyard of the Myrtles [Patio de Arrayanes]. Transforming the roof of the Hall of the Kings involved creating eleven independent and isolated pavilions that enclosed the different areas, with interior channels that didn't evacuate water well and accumulated waste. The pavilions were also not watertight due to the use of flawed waterproofing systems at the time of the intervention. The new system accelerated deterioration due to more regular leaks and a lack of breathability in the spaces under the roof; this caused frequent condensation on the wooden and *muqarnas* vaults.

Problems began to be recorded early on, before the end of the 19th century. In 1892, Gómez Moreno stated that the new roof was the main cause of the poor state of conservation of the paintings, noting repairs due to leaks. Closer to the present day, in the 1970s, the Board of Trustees of the Alhambra and the Ministry of Education and Science were deeply concerned about the condition of the paintings, with a revealing report by Gonzalo Perales[6] (MEC) in 1976, which was the beginning of a new approach to the problems. This approach that saw participation from institutional and professional actors from different agencies and led, albeit slowly, to the comprehensive restoration described in this article.

5. BERMÚDEZ PAREJA J. Ob. cit., p. 64

6. PERALES SORIANO G. Document 15/06/1976. Ministry of Education and Science. Directorate General for Artistic and Cultural Heritage. Institute for the Conservation and Restoration of Works of Art.

Work began in 2006 with the restoration of the roofs of the Hall of the Kings; work was divided into three areas, the first acting as a guide for the others:

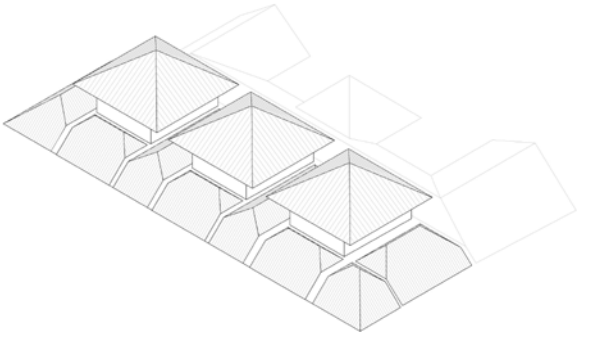
- Restoration of the roofs of the painted vaults[7] (2006-2011).
- "Emergency restoration work on the *muqarnas* domes in the Palace of the Lions in the Alhambra[8] (2007)."
- "Restoration of the reverse sides of the vaults with leather in the Palace of the Lions[9] (2008-2009)."

The long process of preparing for the restoration began in 1999 with work on gathering information and documentation and work on the wooden roofs and reverse sides of the painted vaults ended in 2011. It was agreed that the damp affecting highly complex and fragile supports had to be treated at its source and that this was an essential step before subsequently restoring the visible elements of great aesthetic and historical quality, such as the *muqarnas* domes and paintings (Il. 6) (Il.7) (Il. 8).

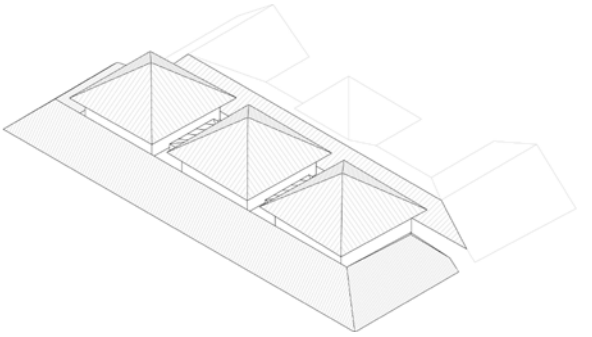
EMERGENCY WORK IN THE MUQARNAS DOMES.

This action is described first because once work had begun on the roofs of the alcove area, deterioration in the others was analysed; emergency measures were taken when serious conservation problems were noted in the main pavilions of the Hall of the Kings. A detailed examination of the *muqarnas* vaults revealed the following deterioration: presence of damp, multiple cracks in the *muqarnas* vaults, deformations in their geometry, the appearance on the underside of circular marks 3 cm in diameter, indicating an inadequate hanging system and a lack of support from the vertical plasterwork cladding caused by fatigue across the entire system[10] [Il. 9] (Il. 10) (Il. 11).

This began to confirm the hypothesis that there was a process in place triggered by the double effect of an ineffective roof and a support system that was too rigid for the *muqarnas*



Il. 6. Pedro Salmerón Escobar, 2012, plan. Perspective diagram of Rafael Contreras' solution for the roofs of the Hall of the Kings in 1857, dividing the single roof into 11 independent pavilions.



Il.7. Pedro Salmerón Escobar, 2012, plan. Perspective diagram of the solution of the restoration project to recover the paintings in the Hall of the Kings, unifying the ceiling of the surrounding areas with a U-shaped enveloping roof.

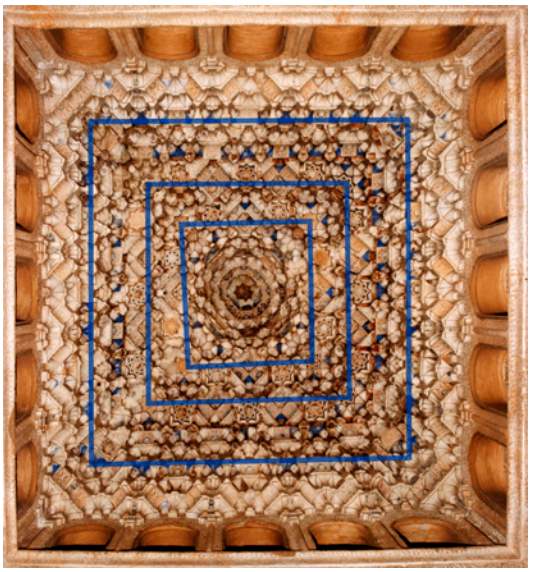
Il. 8. Pedro Salmerón Escobar, 2007, photography. View of the back of *muqarnas* vault M2. Restoration work protected by the cover placed over the entire area of the Hall of the Kings.

7. This extensive restoration work is outlined in Pedro Salmerón's project "Restauración de las pinturas sobre piel de la Sala de los Reyes del Palacio de los Leones" (2005).

8. In 2007, architect Pedro Salmerón was responsible for drafting the Emergency Restoration project for the *muqarnas* domes and managing the corresponding work. Work was supervised by the Conservation and Protection Service of the Board of Trustees of the Alhambra and Generalife, with direct assistance from restorer Ramón Rubio Domene, the author of another article in this issue of Cuadernos de la Alhambra. For this reason, detailed aspects concerning the restoration of the *muqarnas* domes are not included here, and instead this article focuses on construction and structural aspects of the restoration.

9. Architect Pedro Salmerón was responsible for the project (2008) and project management (2008-2009) of this restoration work. Restorers Benjamín Domínguez Gómez and Juan Carlos Bermejo Cejudo were the main collaborators on the project and were in charge of performing the work. This work is described by Benjamín Domínguez Gómez in another article in this issue of Cuadernos de la Alhambra.

10. SALMERÓN ESCOBAR, P. Informe previo. Intervención de emergencia en las cúpulas de mocárabes en el Palacio de los Leones en la Alhambra. Granada, febrero 2007.

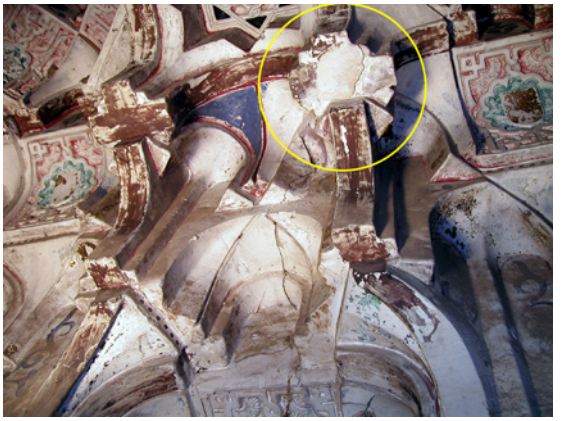


Il. 9. Pedro Salmerón Escobar, 2007, photography. General view of *muqarnas* vault M2 with the shoring lines (blue) at the beginning of the emergency intervention.

Il. 10. Pedro Salmerón Escobar, 2007, photography. Cracking typical to the accumulated deterioration of the *muqarnas* vaults.

domes. These symptoms were serious enough to warrant immediate action. Work was possible thanks to a covering that was installed over the entire area and that proved to be very effective for all the delicate work involved.

Before dismantling the roof, the first measure was to thoroughly shore the three main *muqarnas* domes due to the pathologies that had been detected. Support rings with wooden planks were used that were left 2 to 3 cm above the irregular *muqarnas* level and then wooden and high-density extruded polystyrene wedges of varying thicknesses were inserted. Once levelling had been achieved, the ring was raised using the



Il. 11. Pedro Salmerón Escobar, 2007, photography. Cracks in the *muqarnas* vaults and a spreading perforation towards the interior due to the fasteners installed in 1857 (marked with a yellow circle).

spindles on the modular scaffolding to ensure correct support. Shoring up meant that all subsequent dismantling operations could be carried out in complete safety.

Not all the actions that were undertaken will be detailed here; the article will highlight the most important processes in terms of the structure and the behaviour of the complex in the event of earthquakes. The effect of roof movement on the *muqarnas* vaults was of particular concern, so once the tile and the roof boarding had been removed, a analysis was performed to determine the causes of the mechanical damage. It was found that the 3 cm holes in the plasterwork mass of the vaults had been used to insert black elm wood and twill rods, priming the joint with plaster. The drilling was extremely deep in places and reached the interior level of the domes, which was detected in the previous report. The *muqarnas* vault was actually working with such rigid suspension that the roof framework was directly transmitting movement to the vault. Movement was mainly due to deformations in the wooden framework and the frequent earthquakes in Granada. This last aspect explained why there was such widespread and severe cracking, making it advisable to review the basis of the hanging system itself. The Board of Trustees of the Alhambra and Generalife's interest in controlling this process in the future was demonstrated on the roof of dome M2 where a copper sheet was used to access the interior and equipment was installed in the chamber that monitors deformations and displacements due to earthquakes and other factors. This procedure makes it possible to experiment with testing and monitoring the effects of earthquakes on heritage structures, and is very useful in the medium and long term to

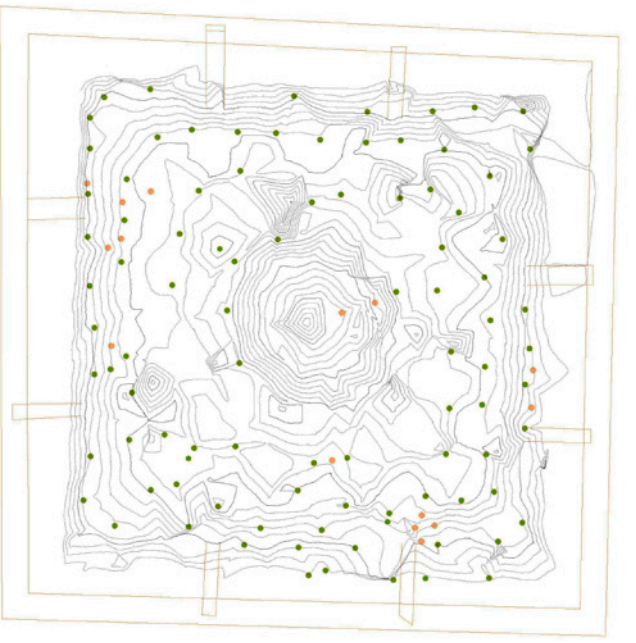
assess the effects of prolonged seismic activity such as events that occurred much later in 2021.

The framework was then completely dismantled in order to carry out all the necessary repairs and replace its various elements. Once the visual obstacles had been cleared to allow precise action to be taken, a topographical survey was carried out.[11] This made it possible to define the irregular geometry of the spaces and the morphology of the upper face of all the *muqarnas* vaults. This detailed topography could be used to locate the position of the old suspensions on the three domes and to plan where to place the new ones so that work could be performed with the utmost rigour. The results were very interesting and made it possible to reformulate and plan such complex restoration work. The accompanying graphs show the topographical survey with a plan of the contour lines and the position of the drill holes in the existing suspensions (Il. 12).

The innovative new hanging system consisted of cushioning direct actions by using a suspension system with braided stainless steel cables fitted with corresponding tensioners. A bulb at the end of the cable, consisting of a stainless steel nut and washer, helped to resist pull-out. This bulb was made to be embedded in the existing bore with the help of tow and plaster to create a bridge that is compatible with the medieval plasterwork.

In terms of the framework, the brackets and angle braces were in relatively good condition and could mostly be recovered, while the rafters were mainly replaced with new ones made of selected red pine sawn timber. The eaves were restored to good working condition, maintaining the materials and design of the previous restoration. Once the wooden framework had been remounted with a new kingpost and the supports perfectly organised in the brackets, the next stage of installing the new suspension system could begin. It was installed after first redesigning the upper fixings and anchoring the cables to the new rafters. Finally, the bulb was placed in each hole of the dome and gradually loaded by tensioning each cable. At the same time, all the perimeter supports were revised, and large-section wooden pieces originally located at different points along the outline were restored to their original function. Re-establishing a more balanced load distribution also helped reduce pressure from the domes on the original plasterwork slabs at the crown of each space. To evaluate these stresses and carefully respond to their mechanical needs,

11. The topographical survey of the back of the *muqarnas* vaults and masonry spaces in the different areas was carried out in 2007 by surveyor Dámaso Chávez González.

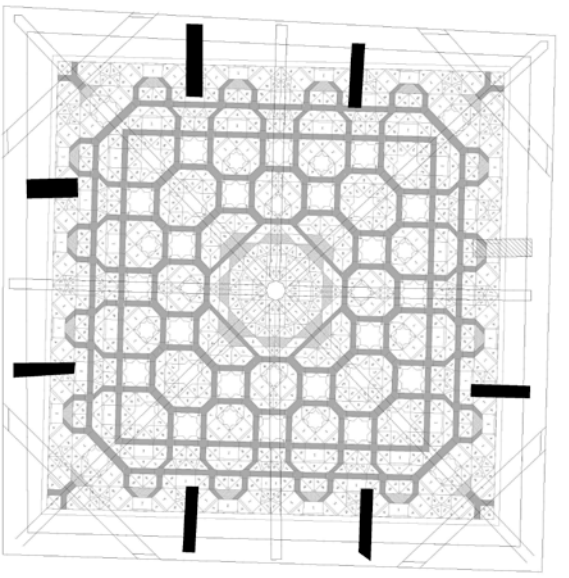


Il. 12. Pedro Salmerón Escobar, Dámaso Chávez González, 2007, plan. Plan of the back of *muqarnas* vault M2 with the topography and the position of the fastenings of 1857 in black elm wood (show in green) and purple willow (show in orange).

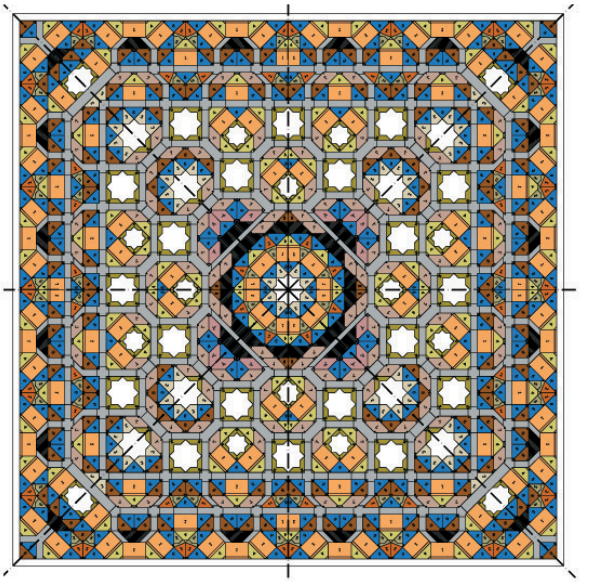
studies were carried out on the load transmission of the *muqarnas* domes based on their own weight, and synthetic graphs are included here (Il. 13) (Il. 14).

The new suspension is designed to withstand tensile stress but is very elastic when earthquake movements push or try to push the *muqarnas* dome towards the roof or when deformations in the roof act on the *muqarnas* dome. To carry out this work precisely and to check the effectiveness of the proposed system, a test was planned in the laboratory of the School of Technical Architecture of Granada (2007), which made it possible to define the effectiveness of the solution. Several plaster blocks were made and drilled with a 3 cm diameter hole, where the bulb attached to the stainless steel cable was anchored with plaster and tow. Once the plaster had set and dried, the results of the tensile test were satisfactory, proving that pull-out was produced at tensions far higher than the real stress found at each support point (Il. 15) (Il. 16).

Once these tasks were completed, a multi-layer finish was placed on the framework consisting of: 3 cm thick red pine boarding, 3 cm wooden slats at distances modulated to 60 cm where extruded polystyrene insulation was placed to cushion thermal oscillation, waterproof chipboard, a galvanised steel



Il. 13. Pedro Salmerón Escobar, Blanca Espigares Rooney, 2007, plan. Plan of the intrados of *muqarnas* vault M2 with interpretation of the main lines of stress transmission (grey) and original wooden fastenings to the walls (black).



Il. 14. Pedro Salmerón Escobar, Blanca Espigares Rooney, 2007, plan. Plan of the intrados of vault M2 with showing the different types of *muqarnas*.

mesh and finally the tile set in a rough mortar, using new tiles in the channels and the old restored tiles in the ridges. The channel tiles were perforated at the upper end so a bolted anchor could be used to prevent slipping due to the steep slope of the roof panels, as was also done in the 1857 project. The emergency intervention, which was part of the process of recovering watertight roofs that were sensitive to having underlying elements of great historical and aesthetic value, was completed in 2007 when the covering material was put in place.

RESTORATION OF THE ROOFS OF THE PAINTED VAULTS.

As stated in section 3, the choice of a sectioned roof model with independent pavilions in the 1857 restoration led to the issues caused by damp and condensation in the Hall of the Kings until the beginning of the 21st century. When the first meetings were held in 1999 between the Board of Trustees of the Alhambra and Generalife and the author of the future project, it was considered advisable to prepare specific studies that would provide information on the state of conservation and that could be used as a working tool by the whole team. The strategy had the following basic lines:

- Carry out a photogrammetric survey, with special detail of the alcoves with painted vaults (B1, B2 and B3), including an orthophoto of the alcoves.

Il. 15. Pedro Salmerón Escobar, 2007, photography. Testing of the tensioner and anchoring of the suspension system used in *muqarnas* domes M2, M4 and M6. Test carried out by Juan de Mata Vico Rodríguez in the laboratories of the Granada School of Architectural Technology laboratories (now ETS Building Engineering).

Il. 16. Pedro Salmerón Escobar, 2007, photography. Tensioners placed in the new wooden framework for the elastic support of *muqarnas* vault M2.

- Use this survey for all the tasks that would be performed when restoring the Hall of the Kings.
- Expand information on techniques for applying paint to leather in order to guide the restoration, from recovering the stable condition of the roofs to the later restoration of the paintings in the alcoves, the Gordian knot of this work.
- Initiate micro-climate analyses in the Hall of the Kings to establish comparative studies over the long period of planned work.
- Study the layout of the roofs to propose a solution that would improve ventilation without altering the consolidated view of the main pavilions from the Courtyard of the Lions as seen since 1857.

The photogrammetric survey[12] was carried out in 1999, so that a decisive instrument for comparative studies and performing specialised tasks with sufficient precision was available at an early date. The tracings that had been made to distinguish between original work and repainting were also scanned at the same time. Thanks to both works it was possible to overlap these information sources so they could be specifically used to restore the paintings. Initial research into decorative techniques applied to leather was supported by the 1999 visit to Vic Leather Museum referred to above. This revealed the double function of the prepared painted vaults as protection and also a support for the plaster and final painting. In terms of the micro-climate study, the micro-climate point installed by the Andalusian Historical Heritage Institute (IAPH) in the Royal Chapel to monitor the new museography of the Sacristy-Museum was moved to the Hall of the Kings in 2003 because its verification measurements ended around this time. Studying the climate of the museum had been carried out in collaboration between the IAPH and the Italian ICR[13] and therefore the same expert, physicist Carlo Cacace, was in charge of micro-climate monitoring in the Hall of the Kings. These measures consisted of applying a methodology of technical scientific support to a heritage space in need of a new, more expert and research-ba-

12. The photogrammetric survey was carried out in 1999 by CONSULTING TOPOGRÁFICO S.L. of Madrid, under the direction of Saturio Estebaranz.

13. The IAPH and the Istituto Centrale per il Restauro (ICR) renewed this collaboration for the study and monitoring of climate conditions in the Hall of the Kings.

sed direction, as has been demonstrated by constant contributions from various disciplines and specialists who belong to different areas of expertise related to this complex work, an example of applying analysis techniques. (Il. 17) (Il. 18)

Finally, a decisive aspect of this initial phase of the project concerned the layout of the roofs. The Board of Trustees of the Alhambra and Generalife established that it was necessary to maintain the image that had been consolidated since 1857 and therefore the idea of a single roof for the Hall of the Kings was abandoned. Instead, the project author proposed joining the pavilions on the perimeter using a U-shaped roof that would allow ventilation to be shared by all the spaces, reducing conservation problems and making it easier to access the interior for maintenance and installing the monitoring devices, particularly those related to climate control. The accompanying perspective diagrams provide a comparison between the 1857 solution and the one that was finally approved and implemented. Once this clear starting point was in place, project drafting was finalised; work began in 2006 and was completed in 2012. (Il. 19)

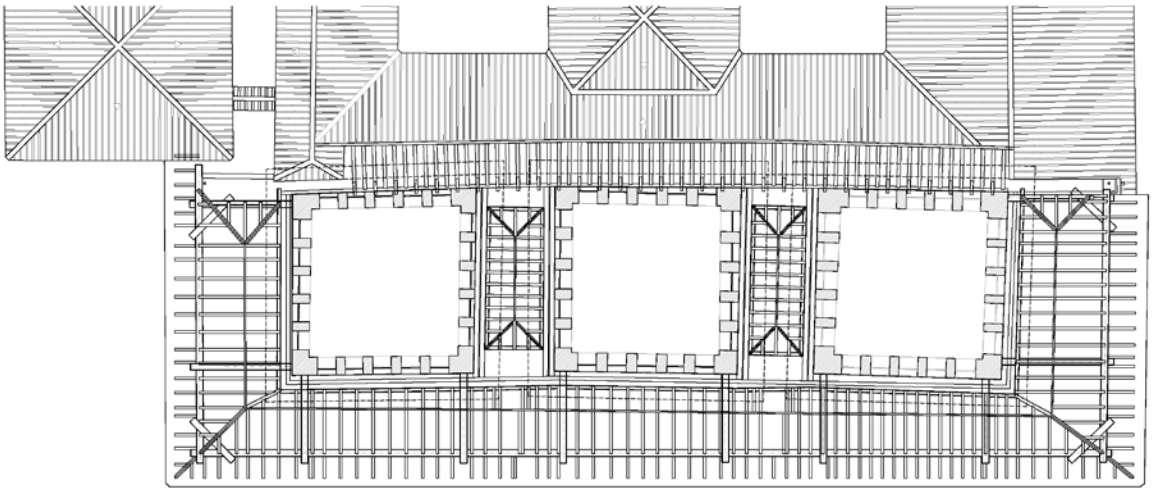
This long period, which included work on the *muqarnas* domes (2007) and the reverse sides of the painted vaults (2008-2009), began with construction of a covering as an initial protective measure. It covered the entire area of the Hall of the Kings and made it possible to work without being troubled by inclement weather, which would have had a huge impact on the existing sensitive materials. The covering had a tubular structure finished with a galvanised steel sheet and was surrounded by awnings and protections so that views were acceptable from other areas of the monument.

Another significant area of prevention work was safely shoring up the painted vaults so that the paintings wouldn't be affected by knocks or unexpected movements during work on the reverse side, and all the work on the roofs. The project was based on the idea of *counterforms* or moulds precisely fitted to the interior surface of the vaults thanks to information provided by the photogrammetric survey, and were planned with plywood and wooden ribs. It was very difficult to make moulds out of curved sheet metal that could be adapted to the specific deformations of each vault, so it was finally decided to make the *counterforms* with high-density extruded polystyrene in a laser carving workshop using the 3D photogrammetric resource from 1999. As the moulds were large when whole, the workshop was commissioned to cut them into 11 pieces as shown in the illustrations[14]. The parts were covered with a 20 mm thick polyethylene foam sheet to achieve a snug and

Il. 17. Saturio Estebaranz, CONSULTING TOPOGRÁFICO S.L., drawing, 1999. Photogrammetric survey. 3D display of vault B2. Tracing of the important figures in the painting of this vault that gives it the of the Hall of the Kings.

Il. 18. Pedro Salmerón Escobar, 2003, photography. Micro-climate point installed in the Hall of the Kings for initial environmental monitoring (agreement with the IAPH).

14. TRAGACANTO S.L. of Alcalá de Henares (Madrid) was commissioned to do the carving in 2007 because it specialises in 3D sculptures. Each counterform had an average overall dimension of 4.10 m (longitudinal axis), 1.75 m (transverse axis) and 1.25 m (height).



Il. 19. Pedro Salmerón Escobar, 2012, plan. Plan of the framework of the new roof with the new U-shaped envelope at the Hall of the Kings, tiled with Arabic tiles. Framework with individual closures of *muqarnas* vaults M3 and M5 clad with copper sheet.

sensitive fit[15]. To complete the shoring, the *counterforms* had to be supported on a board, with the logical condition that the moulds could be removed to work from the inside. Finally, the board was made accessible. Part number 10 was chosen to be a key part and was used as an access 'porthole' to be able to remove the moulds. (Il. 20)

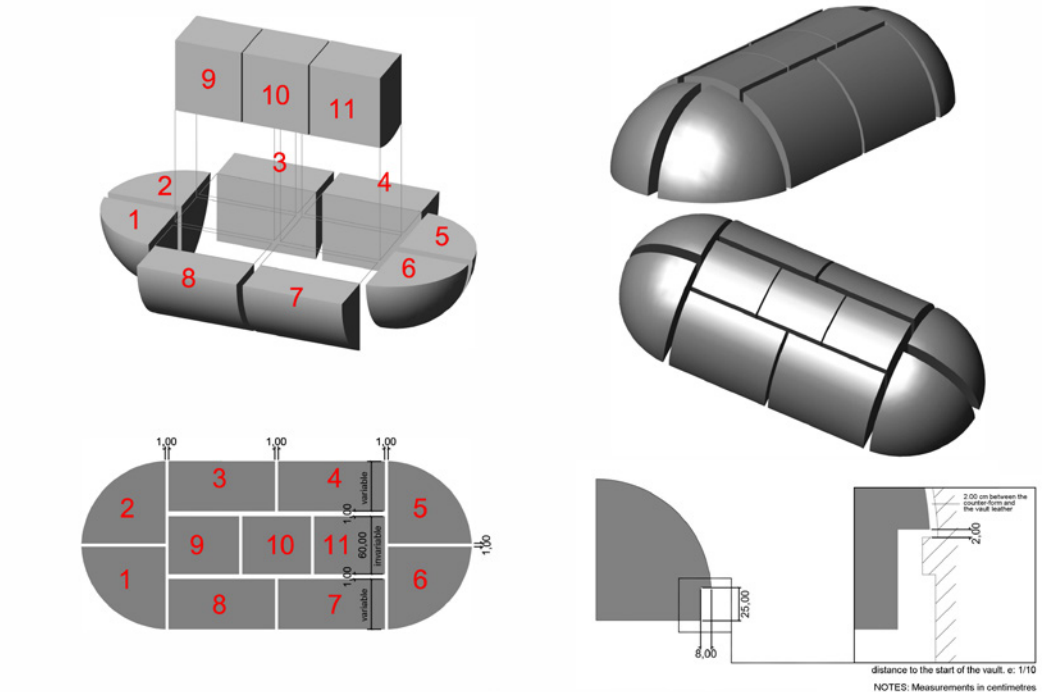
The roof of the perimeter pavilions then began to be dismantled, and simultaneous measures were taken to protect the upper face of the wooden vaults so that the surface wouldn't be damaged. The frameworks were going to be arranged in a very different way, so the existing timber wasn't used.

Assembly used brick screeds and two 20 x 20 cm parallel pieces of glued laminated timber, leaving a free space in the centre to house the parts of the water drainage system of the channel that was installed on this double beam. This framing played a fundamental role in distributing load and the construction elements of the roof. All the frameworks were organised on this basis and raised above the main channel to achieve the correct evacuation capacity and slope. The couple roof framework in glued laminated timber formed a hip roof and a U-shaped envelope following the outline of the entire perimeter of the Hall of the Kings. This roof covered spaces M1, BL1, B1, BL2, B2, BL3, B3, BL4 and M7. The entire roof was designed to be tiled with Arabic tiles, except for *muqarnas* vaults M3 and M5 between the main pavilions, which were made with a small wooden hipped roof truss without eaves, leaving space for the interior channels, and the surface was finished with a board and copper sheet cladding. The inner edge channels were constructed independently to the framework to improve their performance and provide the greatest possible width for maintenance.

Water drainage was fundamental to the project and a large part of the route was laid out in the interior space defined by the different roof bodies. The first measure to prevent water from accumulating at higher levels was to wrap the high roofs of the three main pavilions (M2, M4 and M6) with copper channels with a very narrow section so that they were visually integrated into the eaves and did not draw attention in views from the Courtyard of the Lions. This simple measure prevented water from running over the lower level, an issue that had caused so many problems with the roofs of the alcoves and other pavilions since 1857. The overall system has three main evacuation channels:

- *Main master channel*: U-shaped to adapt to the main outline of the lower roofs. Evacuation is connected to the façade of the Hall of the Kings towards the Partal.
- *Secondary master canal*: located on the west flank of the main pavilions M2, M5 and M6, facing the Courtyard of the Lions. It flows to the south (*Rauda*) and to the north (area where the Lindaraja Courtyard and Partal Houses are accessed).
- *External channel*: attached to the eaves of the façade towards the Partal. It collects water from the north, east and south gables and receives water from the main canal.

15. The polyethylene film lining the counterforms came into contact with the paintings, but these had previously been protected by a facing put in place by the specialist restoration and monitoring team. This meant that there was no friction with the fragile and deteriorated painted layer during the initial stages of the works.



Il. 20. Pedro Salmerón Escobar, 2007, plan. Plan, detail of exploded views and perspective of the high density extruded polystyrene counterforms.

The system was designed to have sufficient capacity to handle rainwater and snow and to provide an easily accessible route for maintenance workers, with widened areas at the entrances to the embrasures. This type of element has to be regularly checked to keep it clear, especially in a place like the Alhambra where there are a large number of trees, especially the cypress trees that line the façade of the Partal and produce a huge amount of pine needle waste that can clog drainpipes. This type of common risk to roofs has been minimised with spillways at the ends of the secondary main channel so that, if there is a blockage, water can spill out before it flows into the interior through any other openings. (Il. 21) (Il. 22) (Il. 23) (Il. 24) (Il. 25)

One particular difficulty with a roof that covered such valuable and fragile elements was its small size, as it had 2.5 m spans that were reduced to a clear width of less than 2 m due to the thickness of the construction elements. However, enough space to access to the interior was achieved by installing a sliding platform that maintenance staff, restorers and installation technicians can use to move. This ensured a close-up view of wooden vaults B1, B2 and B3, the most fragile ones from a conservation perspective, but also brick vaults BL1, BL2, BL3 and BL4 and *muqarnas* vaults M1 and M7 could be seen at close proximity. As the future conservation of these elements, especially the painted vaults, depends on how the space under the roof responds to changes to Granada's climate and whether condensation is produced, a climate control point was installed to accurately measure any changes to the environment that could cause unforeseen dampness, which had already been the cause of deterioration in the long period since 1857. This new approach, developed under a specific project independent to the architectural one, used fairly comprehensive devices in 2008–2009 consisting of the following equipment[16]:

- Weather station placed outdoors in a location with minimal visual impact.
- Outdoor sensors: solar irradiation, temperature and relative humidity and anemometer.
- Sensors in the space under the roof:
  - Temperature and relative humidity of the air positioned on the back of vaults B1 and B3.
  - Surface temperature in contact with the wood on the backs of vaults B1, B2 and B3.

16. This equipment was also connected to other sensors in the Courtyard of the Lions to control climate-related variables in the fountain and the courtyard.

- Anemometers located near the access/ventilation embrasures and the centre of the space under the roof, as there was concern about possible air stagnation inside.

To solve any possible problems related to air not flowing through the roof chamber properly, six passive ventilation elements were designed consisting of 55 mm diameter copper ducts topped with a cap, also made of copper sheet, to help suction air through by the Venturi effect. They were placed on the inner flank of the main line of the roof so that they were not visible from the outside. The interior was also equipped with a small aeration device to improve air movement on an ad-hoc basis.

Work was complemented by restoring the reverse sides of the painted vaults and the muqarnas domes, as all the processes were linked and coordinated. It was time to focus on the situation in the small space of the Hall of the Kings, which housed elements of unquestionable value from the Hispano-Muslim past and rarities such as the painted vaults, emulating other unique features of the Palace of the Lions.

Il. 21. Pedro Salmerón Escobar, 2010, photography. Double glued laminated timber beam supporting the main channel and the structure. Positioning of PVC drains. The back of *muqarnas* vault M5 can be seen between the main pavilions M4 and M6.

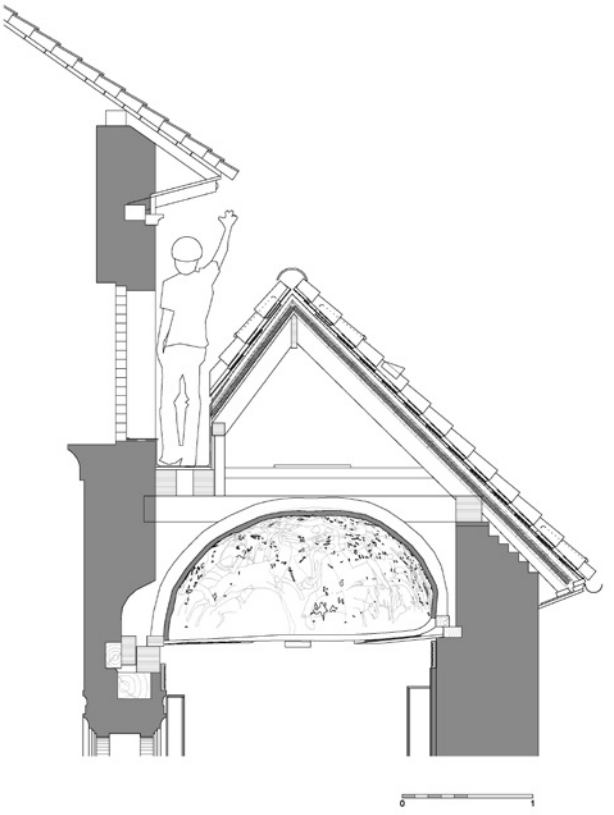
Il. 22. Pedro Salmerón Escobar, 2011, photography. Copper plate finishes on main channels and embrasure for access to roof for maintenance. A static hoover in sheet copper can be seen in the background.

Il. 23. Pedro Salmerón Escobar, 2010, photography. New wooden roof frame over the painted wooden vaults. Vault B3 in the foreground where the ribs and curved and assembled boards can be seen.

RESTORATION OF THE REVERSE SIDES OF THE DOMES WITH LEATHER IN THE PALACE OF THE LIONS

This restoration work was carried out in 2008–2009 and specifically focused on vaults B1, B2 and B3[17]. Fully detailed in another article, it was closely connected to the architectural restoration of the roofs and therefore this section will cover this interaction, especially structural aspects and the protection and control measures designed to make this delicate work possible, without going into the details of how the reverse si-

17. SALMERÓN ESCOBAR, P. Informe de seguimiento de obra. Restauración de los reversos de las bóvedas de cuero del Palacio de los Leones. Granada, June 2012.



Il. 24. Pedro Salmerón Escobar, 2012, plan. Section of painted wooden vault. The main channel, which can be used by maintenance workers, and the wooden vault B1 are shown with its existing deformations.

Il. 25. Pedro Salmerón Escobar, 2010, photography. New wooden roof framework over the wooden vaults with exposed installations and laterally sliding support platform to aid inspection during maintenance.

des were restored. The starting point was having protection in place thanks to the covering that had been used since 2006. This made it possible to work in a protected environment and have a platform ready for use by the workshop from the day the specialised team of restorers arrived. The painted vaults were also protected by *counter-forms* as described in the previous section.

The three vaults have a layout composed of a semi-cylindrical central body with two half-spherical caps at the ends, made of curved and assembled wooden boards, and ribs gathered at the base with a perimeter ring that structures the support in the spaces with enclosing masonry. The poor way in which the vaults had been supported on this resistant perimeter had produced significant deformations that could not be properly improved without further damaging the paintings. Changes to the shape of vault B1 had been created by using the crown at this level of vaulting as a passageway during the Christian period. Localised crushing of the vault was noticeable, raising fears for its stability. It also leaned considerably, which can be seen in the accompanying section. Therefore, repairs were carried out in 1976–1983 by installing wooden cross beams, fastening the ribs of the vault to these beams with bolted fixings.

The idea of the project was to make the vaults self-supporting again by repairing or restoring the main resistant elements of the vault itself, especially the ribs and perimeter base, and by restoring and replacing all the supports around the vault. When comprehensively restoring the reverse sides, including all their components, curved boards and ribs, a initial difficulty arose: it was impossible to access the support areas to carry out in-depth work, which sometimes required the partial replacement of areas lost due to rotten wood. To solve this problem and leave the area completely free to work, a vault-to-vault hanging system was designed, consisting of an auxiliary scaffolding stretched over the vaults for suspension using braided stainless steel cable with flanges at the ends and equipped with a tensor to make the adjustments. Temporary fixings were made to the cross ribs with through bolts, choosing a suitable position that wouldn't damage the structure. The system, which can be seen in the attached pictures, involved literally hanging each vault and freeing up the lower area of the shoring board and polystyrene *counter-forms*, allowing the entire structure to be safely repaired. (Il. 26) (Il. 27)

Vault B1, which had a permanent shoring system based on wooden beams with fastenings bolted to the ribs (1976–1983), was treated in a different way, taking advantage of the fact that

its use as a support had been effective for many years, although the vault structure itself and its supports weren't fully restored. The beams were used to hang the vault with the same type of braided steel cables and tensors used in the others. To check the effectiveness of this alternative suspension system, any possible deformations were monitored with an extensometer when the lower supports were released. The results were positive, and therefore the scaffolding used in vaults B2 and B3 was unnecessary. In agreement with the Conservation and Protection Service of the Board of Trustees of the Alhambra and Generalife, a decision was made not to correct the turning or twisting of the vault as this was considered a high-risk action.(Il. 28)

An example of how the original working conditions were recovered can be seen in the work on vault B1, which had serious conservation problems as mentioned above. Once the structure of the vault itself had been consolidated and suspended by the method described above, the lower perimeter was freed and the work detailed below was carried out, which can be seen in the accompanying images. It exemplifies the decisive link between restoring the material qualities of the reverse sides and recovering their construction purpose and structural function:

- Replacement of angle braces with pine wood pieces (140 x 70 mm) fitted with L-shaped 60.60.5 mm stainless steel metal supports, 550 mm long, screwed to the edge to receive the perimeter ring, which had been completely renovated due to the almost complete loss of the original one.
- Metal reinforcement with a length of 195 mm on the south and north sides and at its midpoint. It was inlaid as there are no beams in the walls located on these sides. The reinforcements were used when necessary and helped to transmit loads in a balanced way, avoiding future deformations.
-Complete replacement of the beam located on the west side due to severe damp from higher levels. The new piece consists of two 100 x 200 mm selected pine planks assembled on site as there was not enough room to manoeuvre to use a whole piece.
- A new wooden beam was placed on the east side, over the arcade of the alcove that opens onto the main hall, to consolidate the ceiling of the whole space.(Il. 29) (Il. 30)

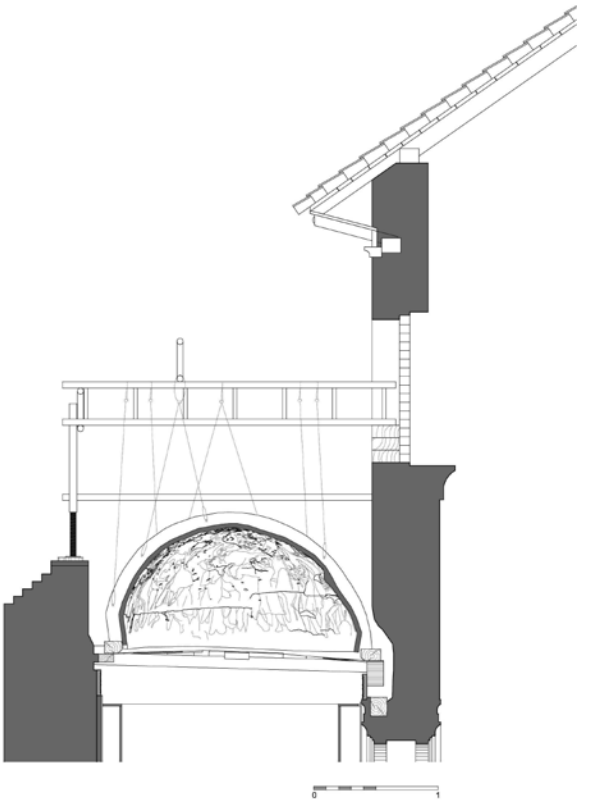
The actions described here presented the challenge inherent to exceptional cases such as this, since resistance had to be reintegrated into each vault without altering its intrinsic qualities; this meant adapting the support system of these wooden shells to deformations in their perimeter and base. The attached plans and diagrams faithfully reflect the real situation of each vault with its alterations and how it was re-adapted to the frame formed by the perimeter walls, which in turn have been altered by changes to the masonry over several centuries of existence. The strategy followed during the construction work consisted of reinforcing the outlining elements such as angle braces and main beams and using individual support segments with stainless steel profiles that could be freely positioned at the level required according to the deformation in the support. Successfully implementing these repairs consisted of adapting to the object, whose actual situation required a sensitive and flexible response to to its various distortions, continuous changes of contour, partial losses and curved geometric elements in a significant part of the materials present: wood and brick masonry.

Contouring work on vaults B2 and B3 were similar and followed the same pattern of adapting how the supports were consolidated without forcing the vaults' geometry, which had been deformed with the passage of time. The three vaults regained their status as self-supporting elements, making additional permanent fixings unnecessary. When the backs and support structure of each vault was finished, the polystyrene *counterforms* and shoring boards were put in place again, this time for protection purposes as restoration work would continue on the roof until it was completed in 2012. The approach to restoring the reverse side, including the condition of the outlines and freeing the vaults from negative forces from the masonry, meant it was possible to provide a flexible, adaptive response to movements typical of masonry structures with poor cohesion, action by the wooden roof structures and, in the case of Granada, to a situation where earthquakes represent a continuous stress on buildings of all types, especially those from the medieval period.

CONCLUSION

The actions described above made it possible to safely tackle the primary objective: restoring the painted wooden vaults. This main aim served as a driving force for other important processes such as treating the muqarnas vaults and the vertical cladding throughout the Hall of the Kings. During the long preparatory phase described in this article, work on the layout of the roofs and their structures found a balance between the material history of the Palace of the Lions and construction logic. A decisive part was also played by connections to the most notable heritage features, with flexibility at the joins, respect for the changes imposed by time and the decision to provide an artistic response that is compatible with the delicate nature of the Palace of the Lions building, trying not to introduce

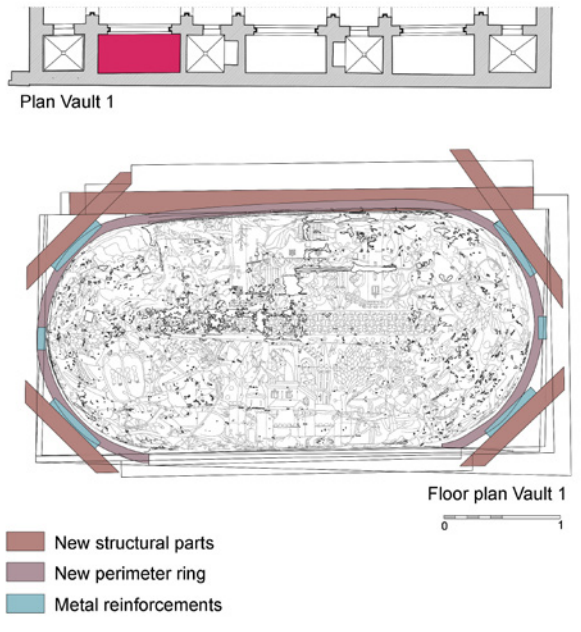
rigid structures in a space as vital as the Hall of the Kings. This approach had the advantage of maintaining the original sense of balance and adjusting the response used in one part to that used across the area as a whole, the main directive followed when working to protect the heritage of the site (Il. 31).



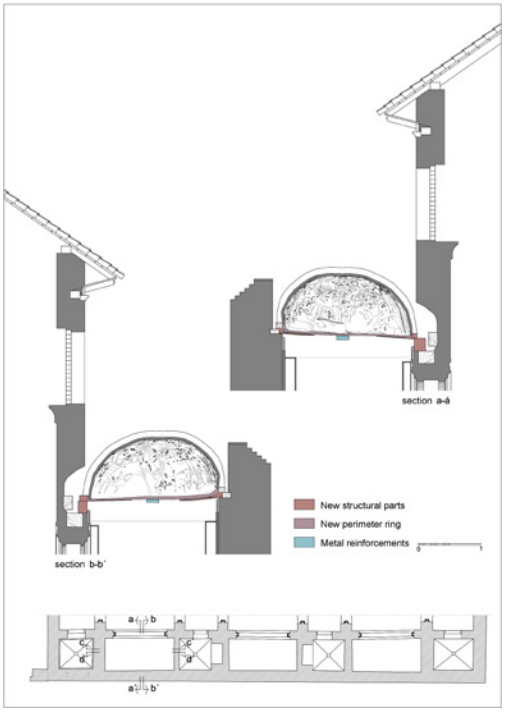
Il. 26. Pedro Salmerón Escobar, 2011, plan. Section of the suspension system used in vaults B2 and B3 to restore the support system in the walls.

Il. 27. Pedro Salmerón Escobar, 2009, photography. View of the suspension system used in vault B3 using auxiliary scaffolding.

Il. 28. Pedro Salmerón Escobar, 2008, photography. View of the suspension system used in vault B1, reusing the wooden beams installed in the 1976–1983 restoration. Extensometers used in the load test can be seen.



Il. 29. Pedro Salmerón Escobar, 2011, plan. Plan depicting the consolidation of vault B1 for restoring the support system in the walls.



Il. 30. Pedro Salmerón Escobar, 2011, plan. Sections detailing the consolidation of vault B1 for restoring the support system in the walls.

Il. 31. José Marín, 2014. The Courtyard of the Lions today. View of the main pavilions of the Hall of Kings in the background.

TECHNICAL DETAILS OF THE WORKS

This section details the professionals and companies that participated in the work described in this article. Other specialists in specific fields of restoration or analytical studies are not mentioned because they will be referenced in the various articles in this issue of Cuadernos de la Alhambra.

Restoration works

- Restoration of the roofs of the painted vaults (2006-2011)
- Emergency intervention in the muqarnas domes (2007)
- Restoration of the reverse side of the domes with leather vaulting (2008-2009)

Project and senior manager of the works

- Pedro Salmerón Escobar. Architect

Additional management of works

- María Cullell Muro. Technical architect

Contractor awarded the works

- Bados Navarro S.L.

Collaborators in drafting projects and reports in all restoration works

- Néstor Cruz Ruiz. Architect
- Blanca Espigares Rooney. Architect
- Laura Martínez García. Technical Architect
- Palma Pajarón Bermúdez Cañete. Architect
- Ignacio Pascual Martínez. Architect
- Paloma Vázquez del Rey Hervás. Architect

Collaborated on the following restoration works

- Emergency restoration of the muqarnas domes
  - Dámaso Chávez González. Surveyor
- Restoration of the reverse sides of the domes with leather
  - Benjamín Domínguez Gómez. Restorer and conservator.
  -Juan Carlos Bermejo Cejudo. Restorer and conservator.

Technical consultants on the restoration process

- Preventive conservation
  - Raniero Baglioni. Restorer of movable property (IAPH)
- Intervention criteria (painted vaults)
  - Mª José González López (Lecturer, University of Seville)
- Treatment of wooden substrates
  - Jean Albert Glatigny (Institute for Cultural Heritage IRPA KIK)

Other collaborators

- Posterior planimetry for the Hall of the Kings
  - Diego Garzón Osuna. Architect
  - Alejo de la Torre Reyes. Architect

Overall direction and supervision of the restoration process by the PAG Protection and Conservation Service

- Francisco Lamolda Álvarez. Architect
- Elena Correa Gómez. Conservator of Movable Property
- Ramón Rubio Domene. Restorer. (Plaster and ceramic workshop)