

The Regional Center for Conservation and Restoration of Jerash, Jordan



editors Mario Micheli and Bilal Fawwaz Mohammad Alboreeni



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Contents

Foreword

- 15 **Massimiliano Fiorucci**
Rector of Roma Tre University
- 17 **H.E. Luciano Pezzotti**
Ambassador of Italy to Amman
- 21 **H.E. Emad Hijazeen**
Minister of Tourism and Antiquities of Jordan
- 23 **Marco Riccardo Rusconi**
Director General, Italian Agency for Development Cooperation
- 25 **Fawzi Abu Danneh**
Director General, Department of Antiquities of Jordan

Introduction

- 31 **Alberto Attanasio, Ruben M. Rispoli**
Capacity Building and Multilevel Governance
in International Cooperation: The RCCR Jerash Model

I.

The Regional Center for Conservation and Restoration in Jerash

- 43 **Emilio Cabasino**
The Origins of the Regional Center for Conservation and Restoration
in Jerash, Jordan
- 49 **Daniela Baldoni, Massimo Brizzi, Raffaella Pierobon Benoit**
The Italian Archaeological Mission at Jerash
- 73 **Jomana Baddad, Rami F. Daher**
Continuity, Contrast, and Capacity:
Notes from the designer on Jerash Adaptive Reuse Model for RCCR
- 85 **Mario Micheli, Bilal Fawwaz Mohammad Alboreeni**
Specialist Training in the Field of Restoration
at the Regional Center for Conservation and Restoration in Jerash
- 97 **Qais Azmi Radwan Almomani, Yasmin Fouad Ahmad Al-Moussa Walweel**
The Network of Universities and Research Institutions in Jordan:
Strategic Support for the Regional Center for Conservation
and Restoration (RCCR), Jerash

II.

The training at the RCCR

- 107 **Jacopo Russo**
Digital Documentation Applied to Restoration: Photography,
Stereophotogrammetry and GIS in a Training Programme in Jordan
- 117 **Nicola Pagani, Cristina Passeri**
Methodologies and Practices in Ceramic Restoration
with contributes of **Bilal Fawwaz Mohammad Alboreeni, Qais Azmi Radwan Almomani,**
Mohammad Ali Mustafa Alalawneh, Omaima Ahmed Naser Fodeh,
Rita Sulaiman Yousef Al Dawood, Hussein Mohammad Mahmoud Krashat,
Eman Suleiman Muflih Quran
- 131 **Elisabeth Huber, Manuela Faieta**
Conservation of Archaeological Glass
- 141 **Shen Yijia, Cristina Passeri, Elisabetta Prunas, Alex Sarra**
Conservation Strategies for Jordanian Bronze and Iron Objects:
Addressing Typical Degradation Issues
with contributes of **Bilal Fawwaz Mohammad Alboreeni, Qais Azmi Radwan Almomani,**
Mohammad Ali Mustafa Alalawneh, Eman Suleiman Muflih Quran,
Rita Sulaiman Yousef Al Dawood, Hussein Mohammad Mahmoud Krashat
- 163 **Luciana Festa, Nikolas Vakalis**
Restoration and Conservation of Stone Materials
- 173 **Francesca Mariani, Cristina Caldi, Sara Scioscia, Martina Fagioli**
Training and Methodology in Mosaic Restoration:
The Experience of the Regional Center for Conservation and Restoration in Jerash
- 183 **Laura Bartoli**
Use of Laser in Restoration and the Experience of the Regional Center
for Conservation and Restoration in Jerash

III. The Workshops

- 193 **Sokol Muca, Luciana Festa, Nikolas Vakalis**
The Southern Tetraklion in Jerash: Historical and Technological Analysis,
Diagnosis and On-Site Conservation and Restoration
with contributes of **Najdat Mamoon Abd Alra'oof Hazaimh, Tasneem Aamar
Ahmad Al-Bataineh, Mohammad Ali Mustafa Alalawneh**
- 229 **Florin Cristinel Stan, Martina Bocci, Sara Fares,**
Najdat Mamoon Abd Alra'oof Hazaimh, Tasneem Aamar Ahmad Al-Bataineh,
Marialaura Malena, Pietro Meriggi, Stefano De Santis, Gianmarco de Felice
Structural Aspects of the Perimeter Wall of the Diaconia Mosaic
in the Church of Propylaea in Jerash, Jordan
- 245 **Sokol Muca, Tessa Pirillo**
Restoration of the Diaconia Mosaic, Church of the Propylaea:
On-site Conservation, International Cooperation and Workshop
with contributes of **Tasneem Aamar Ahmad Al-Bataineh, Tamam Khaled
Abedalqader Almjghef, Najdat Mamoon Abd Alra'oof Hazaimh, Baker Yasin
Abdallah Alzawahreh, Mustafa Mahmoud Srou Hawamdeh, Marshwd Alwan
Hussein Ad-Doojan**

IV. Applied sciences in conservation

- 283 **Vasco Fassina**
Methodological Approach to the Implementation of a Diagnostic Plan
for the Conservation of Archaeological Artefacts. Guidelines for Stone Materials
- 302 **Maria Cristina Caggiani, Giancarlo Della Ventura**
Introduction to Archeometric Analysis of Cultural Heritage Materials
with contributes of **Mohammad Hasan Abdul Kareem Albanna, Omaira
Ahmed Naser Fodeh, Edoardo Rossi**
- 321 **Giulia Caneva**
Biodeterioration and Conservation of Jordan Cultural Heritage
- 333 **Carlotta Sacco Perasso**
Biology Applied to the Conservation of Cultural Heritage
with contributes of **Omaira Ahmed Naser Fodeh, Mohammad Hasan Abdul
Kareem Albanna, Tasneem Aamar Ahmad Al-Bataineh**
- 347 **Photo-essay**





Prof. Massimiliano Fiorucci
Rector of Roma Tre University

This volume is the product of scientific and cultural cooperation, clearly reflecting Roma Tre University's commitment towards the wider community. The activities and reflections presented here describe a shared effort founded on high-quality research, advanced training, and the responsible dissemination of knowledge.

The protection and enhancement of cultural heritage emerge as fields in which diverse areas of expertise converge and interact. This space for discussion fosters the development of practices that combine scientific rigour, methodological innovation, and attention to social and territorial contexts. In this way, conservation establishes itself as a living and open process, deeply connected to communities and places.

The journey documented in these pages attests to the strength of an international collaboration nurtured over time, enriched by the contributions of professors, researchers, professionals, managers, as well as students. Within this framework, the university reaffirms its role as a centre of critical thinking and a responsible agent in the development of skills that last over time and are oriented towards cooperation and shared growth.

Roma Tre recognises this project as a tangible expression of its institutional mission and its commitment to both internationalisation and the Third Mission. Here, the production and dissemination of knowledge are closely intertwined with the building of strong relationships, grounded in respect for cultural diversity and guided by a vision of development centred on equity and sustainability.

I would like to extend my heartfelt thanks to all the individuals and institutions that contributed to the creation of this volume. It is my hope that it will accompany the work of scholars, practitioners, and decision-makers, offering tools for reflection and action in the fields of conservation, research, and international cooperation.

H.E. Luciano Pezzotti
Ambassador of Italy to Amman

Cultural cooperation lies at the heart of the relations between Italy and Jordan, thanks to the strong and fruitful collaboration with local authorities and the ongoing commitment of Italian archaeologists and professionals in the sector.

Our cultural diplomacy in Jordan represents a successful example of the ability of the *Sistema Italia* (i.e., Italian System) to move in a coordinated manner towards common objectives, through close coordination across the Italian Embassy – supported by the Italian Agency for Development Cooperation (AICS) in Amman and the local office of the Italian Trade Agency (ICE) –, academia, research institutions and civil society.

This is the background to the initiative described in this volume, dedicated to the establishment of a Regional Center for Conservation and Restoration in Jerash, in northern Jordan. The project has been made possible through the support of Italian Cooperation, in collaboration with an archaeological mission funded by the Italian Ministry of Foreign Affairs and International Cooperation.

Rooted in Italy's recognised excellence in the protection of cultural heritage, the initiative reflects the belief that safeguarding heritage is vital to strengthening the identity of territories and communities. Italy and Jordan, in fact, share a common vision of culture as a strategic driver of development – a means to foster intercultural dialogue, encourage regional reconciliation, promote tourism and enhance historical and artistic heritage.

With this in mind, for many years now, Italy has lent its support to a number of initiatives aimed at strengthening local capacities in the areas of training, conservation and restoration of Jordan's and the wider region's rich cultural heritage. The establishment of the Regional Center for Conservation and Restoration in Jerash has been inspired by this vision, integrating the strengthening of cultural heritage sustainability, the enhancement of cultural identities, and assistance to Jordan in aligning itself with the main international institutions specialising in this field.

Following this approach, the building hosting the Center has been renovated and fully equipped thanks to the collaboration with UNOPS, within the framework of a broad partnership between Jordanian authorities, Italian actors and international organisations.

The current structure is intended not only for operational conservation activities but also for scientific research and specialised training in the field of restoration. The latter has been entrusted to Roma Tre University, which resorted to the collaboration of thirty experts from various fields within the Italian restoration system.

I would particularly like to emphasise that the project is based on a highly participatory and inclusive approach, aiming to actively engaging the local community in cultural promotion and at to ensure access to the archaeological site for visitors at risk of marginalisation, particularly persons with disabilities.

This volume seeks to provide an overview of the complex process that led to the establishment of this new Center – in close coordination with the Department of Antiquities of the Jordanian Ministry of Tourism and Antiquities –, dedicated to the conservation and enhancement of Jordan's and the wider region's cultural heritage. It outlines the Center's design, development and implementation, as well as the future prospects for cooperation and shared growth.

Italy is proud to contribute, through its technical support and capacity-building programmes aimed at the new generations of professionals in the sector, to the promotion of increasingly effective practices for the conservation of artefacts, sites and monuments of historical significance in Jordan, also for the benefit of tourism and local job creation.

H.E. Emad Hijazeen

Minister of Tourism and Antiquities
The Hashemite Kingdom of Jordan

Jordan's cultural heritage is not just a chronology of history; it stands as a living testament to the civilisations that have shaped this land, and a great legacy that compels us to safeguard it with knowledge, responsibility and foresight. Guided by this profound conviction, and under the enlightened leadership of His Majesty King Abdullah II Ibn Al Hussein, the Hashemite Kingdom of Jordan has steadfastly placed the protection, conservation and sustainable stewardship of this heritage at the core of its national vision.

The Regional Center for Conservation and Restoration in Jerash marks a definitive milestone in this enduring endeavour. It is more than a restoration facility; the Centre embodies a progressive vision: to create a permanent regional nexus for advanced training, pioneering research and the exchange of expertise. It signifies Jordan's commitment to fostering national and regional capacities, empowering a new generation of specialists, and supporting scientific methodologies that meet the highest international standards.

This significant achievement is the result of a close and constructive partnership between the Ministry of Tourism and Antiquities and the Italian Agency for Development Cooperation (AICS), enriched by the invaluable academic contributions of Italian universities and specialist institutions.

This volume, documenting this pioneering project, offers an essential reference for all stakeholders. It captures the meticulous technical processes of rehabilitation and presents the vision that frames heritage as a vital driver of cultural identity, social solidarity and sustainable tourism.

Therefore, I wish to express my profound gratitude to all our partners, experts and dedicated teams, whose commitment brought this Centre to fruition and made this publication possible. I am confident that the Regional Center for Conservation and Restoration in Jerash will stand as a beacon of excellence, presenting Jordan's role as a regional hub for heritage and ensuring that our shared legacy endures for generations to come.

Marco Riccardo Rusconi

Director General, Italian Agency for Development Cooperation

The cultural heritage and culture sector has always been a privileged tool for the promotion of Italian excellence, also acting as an effective lever of soft power at the international level, particularly appreciated in partner countries involved in development cooperation.

A key contribution in this regard has also come from the ongoing commitment of the Italian Ministry of Foreign Affairs and International Cooperation in the field of cultural diplomacy, which in recent years has supported almost three hundred Italian archaeological and scientific missions operating in over seventy countries, many of them in the Middle East.

In recent years, alongside the increasing focus on sustainability in development models, the link between culture and development has attracted increasing attention in the international debate. It is well known now that culture plays a fundamental role in human development. Therefore, its promotion is regarded as an essential component of sustainable development, not only from an economic and financial perspective, but also – and above all – because of its social and environmental implications.

Following this approach, since the opening of the AICS Office in Amman in 2016, Italian development cooperation, in close coordination with the competent local authorities and in line with the country's strategic policy documents, has implemented several initiatives – worth over €16 million – focused on tourism development and the conservation and enhancement of the country's important cultural heritage assets. As a matter of fact, cultural heritage plays an essential role in attracting international tourists.

These interventions have focused on the conservation and enhancement of monumental and archaeological sites such as Petra, Wadi Rum, Shobak, Madaba, Jerash, Al Salt and the area of Amman's Roman Theatre, with projects entrusted to agencies of the UN system, such as UNESCO, UN-Habita and UNOPS, as well as to Italian universities of excellence, including the University of Florence – SAGAS Department, the University of Perugia and the Polytechnic University of Milan.

Among these, the project for the creation of the Regional Center for Conservation and Restoration in Jerash – aimed at restoring a monumental building, providing specialist equipment and training officials from the Jordanian Department of Antiquities (DoA) – represents a positive example of partnership with local authorities, combining the outstanding expertise of an international organisation such as UNOPS for the structural component with that of an Italian university such as Roma Tre for the training component.

We consider this project has responded to the need expressed by our Jordanian partners for a suitably equipped structure and a body of trained professionals capable of carrying out conservation and restoration work on the country's cultural heritage. In the years to come, we hope the Center will serve as an actual point of reference for the continuation of the fruitful exchanges between Italian expertise and colleagues working in the Middle East.

Prof. Fawzi Abu Danneh
Director General, Department of Antiquities of Jordan

The Department of Antiquities is one of the oldest institutions of the Jordanian state. It was founded pursuant to the Emirate Decree issued by His late Majesty King Abdullah I bin Al-Hussein, then Emir of Transjordan, on 27 June 1923, to serve as the official authority responsible for safeguarding and preserving the archaeological and cultural heritage of the Hashemite Kingdom of Jordan.

Since its establishment, the Department has assumed a national responsibility to protect, manage, and conserve Jordan's cultural heritage in accordance with the highest scientific and professional standards, and to present it as an integral part of humanity's shared civilisational legacy. The Hashemites have played a foundational and pivotal role in protecting and promoting cultural heritage, recognising its importance in strengthening national identity and fostering historical awareness.

The Department's work aligns with the Economic Modernisation Vision launched by His Majesty King Abdullah II bin Al-Hussein, in which the antiquities sector constitutes a strategic pillar supporting the national economy and advancing sustainable development. Archaeological heritage serves as a driver for empowering local communities, creating employment opportunities, and enhancing cultural tourism.

Guided by this commitment, the Department of Antiquities strives to ensure a sustainable Jordanian archaeological heritage, preserving and showcasing its universal value and significance, while positioning it as a contributor to economic growth and local community development. It also seeks to create an enabling environment and a modern institutional and legislative framework that strengthens the standing of Jordan's archaeological heritage locally, regionally, and internationally, through effective partnerships, adherence to best practices, and the integration of advanced technologies in the protection, documentation, management, and museum presentation.





Capacity Building and Multilevel Governance in International Cooperation: The RCCR Jerash Model

Alberto Attanasio, Ruben M. Rispoli

The project to establish the Regional Centre for Conservation and Restoration (RCCR) in Jerash, promoted by the Italian Agency for Development Cooperation (AICS) and the Department of Antiquities of Jordan (DoA), with Roma Tre University as its scientific implementing partner, represents an exemplary case of how specialised training and multilevel governance can be integrated within international cooperation for the protection of cultural heritage.

Roma Tre University is largely located in areas of industrial archaeology, where former production sites have been transformed into spaces for education and research. This architectural and urban planning choice reflects a founding principle: the built environment and architectural heritage are both expressions of identity and drivers of urban transformation. Their conservation and adaptive reuse ensure durability and continuity over time, embedding the University itself within an ongoing dialogue between history and the urban fabric.

In parallel, Roma Tre has developed recognised scientific expertise in the conservation and restoration of cultural heritage, at both national and international levels. This expertise translates into applied research, innovative methods of analysis and intervention, and the training of new generations of specialists. The same vision underpins the creation of the Regional Centre for Conservation and Restoration in Jerash (Jordan), promoted by AICS and the Department of Antiquities of Jordan.

At the same time, the project's governance – structured around a Steering Committee, a Project Management Unit, a dedicated administrative division, and monitoring instruments established under the MAECI-AICS 2025-2027 Convention – has ensured transparency, coordination, and institutional continuity. The synergy among political, administrative, and scientific dimensions has emerged as a decisive factor in the success and replicability of the initiative.

The Jerash case demonstrates that when training and governance are integrated within a unified framework, they can constitute a sustainable and innovative public–academic model of cultural cooperation, with potential for transferability to other Mediterranean and international contexts.

The establishment of the Regional Centre for Conservation and Restoration (RCCR) in Jerash follows the path set by Law No. 125 of 11 August 2014, which defines development cooperation as «an integral and qualifying part of Italy's foreign policy» (Article 1) and entrusts its management to a range of public and social actors, including universities and research institutions. This law establishes a system of multilevel governance founded on collaboration between the Ministry of Foreign Affairs and International Cooperation (MAECI), the Italian Agency for Development Cooperation (AICS), and implementing partners – both public and academic – within a unified framework for cooperation.

The subsequent MAECI–AICS 2025–2027 Convention makes this institutional framework explicit and up to date, outlining the objectives, management procedures, and monitoring tools of cooperation initiatives. It «defines, for the period from 1 January 2025 to 31 December 2027, the objectives of the Agency and regulates the relationship between the Ministry and the Agency» (Article 2). Among its priorities are the creation of a centralised database allowing «visualisation of all stages of cooperation projects [...] including those entrusted to civil society organisations and public entities» (Article 3, letter b.6), and the development of «a methodology for verifying and monitoring qualitative and quantitative results [...] in accordance with Article 12, paragraph 4, of the founding law» (Article 3, letter b.8).

Within this framework, Roma Tre University assumes a public role in institutional and scientific innovation. It participates as an implementing body and technical partner pursuant to Article 26 of Law 125/2014, contributing to the development of capacity-building models based on specialised training, applied research, and shared management of cultural heritage.

The RCCR Jerash project, promoted by AICS and the Department of Antiquities of Jordan, with Roma Tre University providing scientific coordination, translates these principles into practice. It unites cultural cooperation with scientific diplomacy, consolidating an integrated governance model in which the academic dimension interacts with the political, administrative, and technical levels, following the logic of coordination and transparency established by the Convention.

Roma Tre University has built its institutional identity around a distinctly physical and transformative dimension. The decision to locate in areas of industrial archaeology – from the Testaccio Slaughterhouse to the former San Paolo Glassworks and the Vasca Navale – has given architectural expression to a public vision of education: knowledge as the regeneration of the city and its material heritage. As Attanasio and Rispoli (2024) observe, «Roma Tre has established itself, over its thirty years of existence, as a driver of transformation, capable of inspiring change and contributing to the construction of a more inclusive, dynamic and sustainable city». The redevelopment of university spaces has meant rewriting the urban landscape through culture, returning places of participation and innovation to the community. The repurposed buildings have become factories of knowledge – centres of excellence for teaching, research, and third-mission activities – embodying a principle of continuity between memory, function, and the future.

This physical dimension, conceived as a dialogue between the built environment and knowledge, constitutes the paradigm that Roma Tre also exports to international cooperation. The creation of the Regional Centre for Conservation and Restoration in Jerash represents its symbolic and operational extension: from a university that regenerates urban spaces to a public partner that regenerates cultural heritage. As in the redevelopment projects carried out in Rome, in Jerash

the action goes beyond the physical restoration of sites to focus on building a community of expertise. The training of restorers, technicians, and local officials – developed in collaboration with AICS and the Department of Antiquities of Jordan – transfers Roma Tre’s integrated methodology, in which scientific research, specialised training, and institutional governance operate as components of a single framework, into the Mediterranean context.

The Jerash model thus renews, on an international scale, the principle of *transformative public capacity* that characterises Roma Tre University. In Rome, urban regeneration serves as an instrument of citizenship; in Jordan, cultural regeneration becomes a means of scientific diplomacy and sustainable cooperation. In both contexts, the materiality of space and the quality of restoration express a conception of the university as a form of civic infrastructure, capable of combining academic expertise with public responsibility. Consistency with the MAECI–AICS 2025–2027 Convention, which promotes synergy among institutional, academic, and technical actors in project planning and monitoring, confirms the continuing relevance of this public–academic approach to cooperation.

The Regional Centre for Conservation and Restoration (RCCR) in Jerash was conceived as a platform for training and skills transfer, founded on the principle that cultural cooperation is effective only when it generates autonomous capacities and permanent structures within the partner country. In this sense, the Centre is more than a technical restoration laboratory: it is a place of learning and governance, where training, applied research, and shared administration intersect. The capacity-building pathway promoted by Roma Tre aims to strengthen local expertise through professional courses, diagnostic laboratories, and theoretical–practical modules inspired by European standards and Italian excellence in conservation, adopting an integrated approach across scientific, technological, and humanistic disciplines.

The project’s governance structure reflects the multilevel logic defined by the MAECI–AICS 2025–2027 Convention. A Steering Committee composed of senior representatives – including the Director General of Roma Tre University, counterparts from AICS, and the Department of Antiquities of Jordan – ensures the strategic coherence and political–institutional direction of the initiative. Supporting this body is a Project Management Unit responsible for operational coordination, technical and administrative monitoring, and reporting. Executive management is entrusted to a senior public officer of the University with delegated responsibility for internationalisation and the Third Mission, charged with translating the University’s strategic planning into practical project implementation. This role integrates the various planning levels – the University’s Three-Year Strategic Plan, the Integrated Activity and Organisation Plan (Legislative Decree 80/2021), and AICS cooperation objectives – into a coherent framework of results, indicators, and impacts.

This organisational structure ensures alignment between vision and implementation, preventing fragmentation between political direction and administrative execution. The public manager serves as a bridge between the academic and institutional spheres, ensuring that the knowledge produced in Roma Tre’s laboratories is applied to the restoration sites in Jerash, and that the outcomes achieved abroad inform the University’s internal planning. This model of university public management helps to close the often-visible gap between high-level strategic planning and its operational realisation, integrating the managerial competence of public administration with a culture rooted in research and specialist training.

The RCCR Jerash thus becomes a laboratory of sustainable cooperation, where capacity building translates into the institutionalisation of expertise: training of local personnel, guidelines shared with the beneficiary Department of Antiquities, preventive maintenance protocols, digital archives, and a regional academic partnership network. The Centre's sustainability is ensured not only through material and infrastructural resources but, above all, through a governance model that transfers responsibility and know-how, making local institutions the key agents in safeguarding their own heritage.

From this perspective, the Jerash model represents a synthesis of technical cooperation and scientific diplomacy – a public–academic project demonstrating how specialist training, when guided by multilevel governance, can generate durable and replicable value. Its success points to a strategic direction for international university cooperation: moving from isolated interventions to permanent systems of capacity, in which universities and public administrations operate as a single architecture of knowledge and accountability.

The RCCR Jerash project embodies an exemplary synthesis of the contemporary university's public mission: to produce knowledge, cultivate expertise, and build institutions. Roma Tre has projected its identity as an innovative public university into the international arena, demonstrating its capacity to integrate physical regeneration, civic responsibility, and multilevel governance. The Jerash experience shows that university cooperation, when guided by a coherent strategic vision, becomes an instrument of cultural diplomacy and institutional strengthening. Specialist training, transparent management, and the development of local capacities define a replicable model of cooperation in which culture functions as an infrastructure for shared development. From this perspective, Roma Tre and AICS reaffirm the value of a partnership that unites politics, science, and administration within a single architecture of public responsibility and sustainable progress.

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I.

The Regional Center for Conservation and Restoration in Jerash

The Origins of the Regional Center for Conservation and Restoration in Jerash, Jordan

Emilio Cabasino

Abstract: This paper outlines how the project for the establishment of the Jerash Regional Center for Conservation and Restoration (RCCR) in Jordan was defined and implemented, and it presents it as a model for development cooperation in the field of cultural heritage. The project was carried out in close and ongoing partnership with the local authorities, through the restoration of a historic building, the provision of specialist equipment and an advanced training programme. The activities were carried out by an International Organisation and an Italian public university, with the participation of highly specialised Italian professionals. They were aimed at strengthening local capacities, promoting the sustainability of the established institution and the transfer of knowledge and procedures for the restoration of cultural heritage, not only in Jordan but also throughout the MENA region.

Keywords: Development cooperation; Partnership; Cultural heritage; Restoration; Specialist training; Jordan

The project for the establishment and development of the Regional Center for Conservation and Restoration in Jerash (RCCR), Jordan, as well as the implementation of training activities, can undoubtedly be regarded as one of the possible models for initiatives considering cultural heritage and culture as a priority area for development cooperation.

Given the time frame in which the project was conceived and implemented – from late 2018 to early 2026 – the author of this paper has been able to follow its progress while fulfilling different roles, drawing on thirty years of prior experience working at the former Italian Ministry of Cultural Heritage and Activities (now called Italian Ministry of Culture), as a researcher and consultant on issues relating to cultural economy, as an AICS official (from 2017) and, subsequently, as Director of the Amman Office between 2021 and 2023.

The project was in fact first conceived and designed as part of architect Michele Morana's work. Between 2016 and 2021, not only did he completely reorganise the AICS headquarters in Amman, but he also launched a number of interesting initiatives dedicated to the conservation and promotion of Jordan's rich cultural heritage (in Jerash, Petra, Shobak and Madaba).

The Restoration Center in Jerash, in particular, is of special importance in several respects, both in terms of content and implementation methods.

As a matter of fact, a careful analysis of the needs expressed by the Jordanian Government and by professionals working in the sector led to the identification of a concrete and effective response, aimed at restoring a historic building, providing it with state-of-the-art and advanced equipment essential for restoration activities. The initiative also aimed at delivering training courses for local specialists, primarily for officials from the Department of Antiquities of the Ministry of Tourism and Antiquities of Amman (MoTA).

In the first stage, this was achieved by entrusting the restoration of the building and the equipping of laboratories to the international organisation UNOPS, which specialises in this type of project and was already operating on site. Subsequently, an agreement with Roma Tre University was made, and the University was entrusted to manage the training component, essential for the future sustainability of the project.

In the years that followed, there were also a number of setbacks due to changes in both the Jordanian administrative leadership and the AICS headquarters management, as well as the standstill imposed on the whole world by the COVID-19 pandemic. Moreover, it should also be noted that the process of submitting and signing the documents required to manage AICS projects often needs to be adjusted along the way, which can have a significant impact on timelines.

Therefore, what make this case an example to be followed can be summarised in the elements already mentioned and further detailed below.

1 The identified need

Jordan boasts an extremely rich cultural heritage, with six sites inscribed on the UNESCO World Heritage List and numerous others on the Tentative List, as well as a network of fifteen museums spread across the country. However, despite this wealth, the country suffers from serious structural shortcomings in the field of conservation and restoration.

In fact, the Jordanian education system does not provide for the professional role of the restorer-conservator as defined by international standards and by Italian and European legislation. Universities mainly offer theoretical courses in archaeology and tourism, with a substantial lack of practical and specialist teaching on restoration, as well as poor integration of the sciences applied to the study of materials and degradation processes (i.e., chemistry, physics, biology). Therefore, restoration work is often entrusted to practitioners with a background in craftsmanship or the arts, which is not suited to the complexity of the heritage assets they are working on.

Compounding this situation, the private restoration sector lacks a qualification and certification system due to the DoA's operational monopoly established by the legislation currently in force.

In light of these challenges, the project – designed and constantly updated in collaboration with the relevant Jordanian government authorities – aimed at addressing the issues in a structural manner, through the refurbishment of a space, the creation of a dedicated technical and administrative body, and the implementation of a specialist training programme, primarily aimed at public officials. To this end, a methodology based on the principle of 'training of trainers' was adopted, capable of producing a multiplier effect and ensuring the sustainability of the initiative in the medium to long term.

2 Structural interventions and equipment procurement

In view of its specific expertise in this field and well-established presence in the territory, in 2019 the United Nations Office for Project Services (UNOPS) was entrusted with carrying out the following activities:

- assessment of the structural features and identification of the works required for the rehabilitation and repurposing of the heritage building, formerly occupied by a police station, known as Beit Ali Basha Alkayed, located near the archaeological site of Jerash and selected as the headquarters of the RCCR. Design work included: conceptual design, interior design, structural analysis, geotechnical studies, design of electromechanical infrastructure, design of green elements and landscaping;
- renovation and repurposing work on the premises, characterised by a total surface area of approximately 800 sq. m;
- initial training on health and safety at work, project management, wastewater treatment, maintenance of the photovoltaic system and training handover of the premises to the Ministry of Tourism and Antiquities (MoTA), the project's counterpart and beneficiary.

In this context, in 2019, UNOPS Amman also entrusted an Italian chemist with providing advice for the definition of the technical specifications for the provision of appropriate equipment, which would then be subject to procurement procedures managed by UNOPS Amman itself.

As a matter of fact, in parallel with the design and implementation of the refurbishment works at the headquarters, UNOPS Amman launched tenders for the supply of equipment and materials required for the Center's operation, which were procured within the required timeframe, partly thanks to the advice provided by specialised Italian professionals and the availability on the market of leading Italian companies.

This phase was followed by an interruption of activities due to the lockdowns caused by the COVID-19 pandemic, changes in the leadership of MoTA and AICS-Amman, and the need to identify a suitable Italian institution that could manage the technical training of Jordanian officials and the launch of the Center.

3 Training activities

This institution was identified during the 2022-2023 period,, when Roma Tre University was entrusted with the task. The decision was made considering its significant prior training experience in the field of restoration – including at the international level – and the fact that it boasts excellent partnerships with Italian professionals and public bodies in the sector, such as the *Istituto Centrale per il Restauro* of the Italian Ministry of Culture. The person identified as responsible for this stage was Professor Mario Micheli. Thanks to the expertise gained over many years of work in the fields of restoration and training across a wide range of geographical settings, he has managed to put together a team of officials, who have acquired the essential knowledge required to manage restoration projects and ensure the proper of the operation the Center's equipment.

The two-year project was structured into three main components, namely:

- specialist theoretical and practical courses in the restoration of archaeological materials, such as: metals, ceramics, glass, wood, stone, mosaics, wall paintings and stuccoes;

- in-depth technical and scientific courses on the use of advanced equipment such as: laser cleaning, 3D laser scanners, XRF diagnostics, biological and petrographic microscopy;
- courses dedicated to the prevention, management and enhancement of museums and archaeological areas, to documentation and data management, to conservation science and to the protection of architectural heritage.

The course ended with a two-week study trip to Rome for the students, during which specialist lectures were held at the University and the *Istituto Centrale per il Restauro* of the Italian Ministry of Culture, alongside workshops and visits to archaeological and monumental sites, with a view to learning about how these are managed.

4 Sustainability and potential future developments

Compared with the initial situation, it should be noted that the project has brought about a substantial change in the institutional and organisational structure of the restoration sector within the MoTA, as the Regional Center for Conservation and Restoration (RCCR) has been formally established and placed under the direct authority of the Director-General of the Department of Antiquities.

The courses attended by an initial group of Jordanian officials and conservator-restorers have proved the effectiveness of the ‘training of trainers’ approach, not least with a view to establishing a model for constant professional development. In the future, this could lead to self-managed training activities that would also benefit countries in the MENA (Middle East and North Africa) region, thereby enhancing the sustainability of this initiative.

Furthermore, it is understood that the Memorandum of Understanding, which is due to be signed at the end of the initiative, will include a clause giving priority to the relevant Italian stakeholders in the sector, with a view to carrying out activities and projects in partnership with their Jordanian and Middle Eastern counterparts in the coming years.

In conclusion, and going back to the initial considerations, it can therefore be stated that the project of the Restoration Center in Jerash can be regarded as an example of a successful initiative, with implications for the immediate and medium to long term.

This is in line with what is provided for by Law 125/2014, which sets out the key elements of the Italian development cooperation system (Articles 23 and following) when carrying out a project, as well as the possibility of resorting to services provided by international organisations (Article 5).

In fact, the AICS head office and its overseas branch, the Italian Embassy in Amman, other public administrations such as the *Istituto Centrale per il Restauro* of the Italian Ministry of Culture, a leading public university like Roma Tre University, individual professionals offering their consultancy services, and the Italian companies that supplied the equipment – purchased and installed by an international body like UNOPS – have all worked together and in complete harmony with their Jordanian colleagues. With patience, mutual respect and a spirit of cooperation based on trust, they have achieved very impactful results, which do justice to Italy’s universally recognised leadership in this sector.

Finally, it may be interesting to note that, within the same timeframe, the Culture & Development Team was established at the AICS Headquarters, within Office III. By formalising the thematic sectoral identity of this field, it is gradually

developing proposals for methodologies, tools and indicators for measuring the results of interventions, in order to strengthen awareness of the relevance of such initiatives and to demonstrate how cultural heritage and culture can effectively foster the human and material development of the communities that possess them.

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The Italian Archaeological Mission at Jerash

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Abstract: This paper reviews fifty years of activity of the Italian Archaeological Mission at Gerasa/Jerash, outlining its origins, methodological development, and future perspectives. Established in 1976 at the initiative of Giorgio Gullini and directed by Roberto Parapetti, the mission integrated archaeological research with conservation-oriented restoration, professional training, and the participatory enhancement of archaeological heritage. Among the numerous interventions carried out over the decades, eight projects undertaken within the Sanctuary of Artemis and in the area in front of the Propylaea are presented as particularly representative of the mission's scientific contribution.

Keywords: Gerasa/Jerash; Italian Archaeological Mission; Sanctuary of Artemis; Conservation and Restoration of Archaeological Heritage; Architecture and Urbanism of the Eastern Roman world.

1 The Establishment of the Italian Mission at Gerasa

In the spring of 1976, within the framework of a bilateral agreement on scientific and cultural cooperation between Italy and Jordan, the foundations were laid for the establishment of an Italian Archaeological Mission at Jerash, ancient Gerasa. The initiative was formally confirmed in 1977, when the Jordanian government granted an archaeological research concession for the area of the Sanctuary of Artemis. Administrative and logistical coordination of the expeditions was entrusted to the Centro Ricerche Archeologiche e Scavi di Torino. Its director, Professor Giorgio Gullini, appointed the architect Roberto Parapetti to lead the mission, a position he held until 2022.

An earlier Italian archaeological mission had been active in the area of the Citadel of Amman between 1927 and 1938 under the auspices of the Missioni Scientifiche Italiane in Levante, initially directed by Giacomo Guidi and subsequently by Renato Bartoccini (Parapetti, 2008; Anastasio-Botarelli, 2015). Although this enterprise has often been framed within the paradigm of 'colonial archaeology', the work undertaken by the Italian scholars at Jebel al-Qal'a was distinguished by a methodological approach that was far from conventional for the period. While their research programme was primarily oriented toward the study of the

**Fig. 1**

Giorgio Gullini, Roberto Parapetti, and Guido Fino measuring graffiti positions on the southern side of the Temple of Artemis podium (1977).

classical and earlier phases of the site, Guidi and Bartoccini also investigated the later monuments preserved in the stratigraphy, establishing their chronology with notable precision. The interruption of the project resulted less from the outbreak of war than from Bartoccini's growing commitments within the Italian heritage administration and the chronic shortage of financial resources.

The intellectual programme and motivations underlying the establishment of a new archaeological mission at Jerash were articulated by Giorgio Gullini in the following terms:

«The desire to investigate more thoroughly the remarkable phenomenon represented by the proliferation of colonnades and monumental façades that characterises the townscape of so many cities of the Near East under Roman rule, a phenomenon too often regarded merely as the final expression of a classical architectural tradition still bound to the trabeated system of columns and architraves.

An exceptional opportunity for cooperation between Italian and Jordanian specialists in the protection of archaeological sites, reconciling the needs of urban growth and infrastructural development with the preservation of ancient ruins.

The possibility of directing tourism at historical sites towards programmes in which ruins are not simply relics of the past but also active components of contemporary cultural life» (Gullini, 1983-1984: 7-8).

From its earliest fieldwork activities, the mission sought to implement this programme through the preparation of a new topographic survey of the entire city and the proposal of a master plan aimed at safeguarding the historical landscape of the site and its surrounding territory through the rational management of the rapid expansion of the modern town (fig. 1).

The new survey of Gerasa not only updated the existing plans and improved their metric accuracy but also introduced into the documentation of the city's

architecture the third dimension of elevation at an urban scale. This was achieved through sectional profiles designed to highlight the importance of topography and altimetric relationships in ancient planning strategies¹. The resulting documentation made it possible to develop a new interpretative framework for the urban layout of Gerasa, centred on the concept of ‘visual routes’. These were designed to structure the perception of the urban landscape through a sequence of architectural markers such as colonnaded streets, tetrapyla, triumphal arches, and tetrachionia (Parapetti, 1983-1984; 1995).

During the implementation of the survey, and in keeping with the long-term perspective that has characterised the mission’s operational approach from the outset, the Italian topographers established a dense network of permanent benchmarks across the entire site. This geodetic framework remains in use today and continues to provide a reference system for scholars who need to georeference their documentation in absence of GNSS equipment.

The study carried out by Roberto Parapetti concerning the regulation of the modern city’s expansion within the broader historical landscape, marked by millennia of human occupation, of which the ruins of Gerasa represent only one component, constituted the first management plan ever developed for Jerash. Its failure to be implemented arguably represents one of the most significant missed opportunities in the modern history of the site (Parapetti, 1985a). Promoted by the then Director of the Department of Antiquities, Adnan Hadidi, and inspired by the guidelines of Jordan’s Five-Year Plan for Economic and Social Development (1981-1985), the project sought to enhance the urban centre of Jerash while safeguarding its historical and natural heritage. This objective was to be achieved through measures including the development of alternative road systems, the systematic survey of suburban areas, and the introduction of both direct and indirect planning restrictions on land use and construction within or adjacent to areas of archaeological interest.

Viewed today, the project drawings (fig. 2), with their careful territorial zoning based on primary land uses, the provision of a buffer zone surrounding the archaeological site, and the attempt to mitigate the conflict between the enclosed archaeological area and the modern city, should not merely evoke a sense of regret. Rather, they should serve as a cautionary example for the present condition of many archaeological sites where the balance between the protection of historical landscapes and the development of small urban centres does not appear to constitute a priority, despite the potentially disastrous consequences that such neglect may entail, as the case of Jerash clearly demonstrates.

2 Excavations and Research on the Terraces of the Sanctuary of Artemis

The monumental scale of the Sanctuary of Artemis, its remarkable state of preservation, and the complexity of its architectural layout have attracted the attention of both scholars and the wider public since the modern rediscovery of the site. The sanctuary soon became the focus of numerous studies and field interventions. Among the most significant were the excavations conducted between

¹ The topographic survey was carried out by Domenico Santarsiero and Marina Paris in 1982. Fifteen tables of this work were published in volume XVII-XIX of *Mesopotamia* (1983-1984).

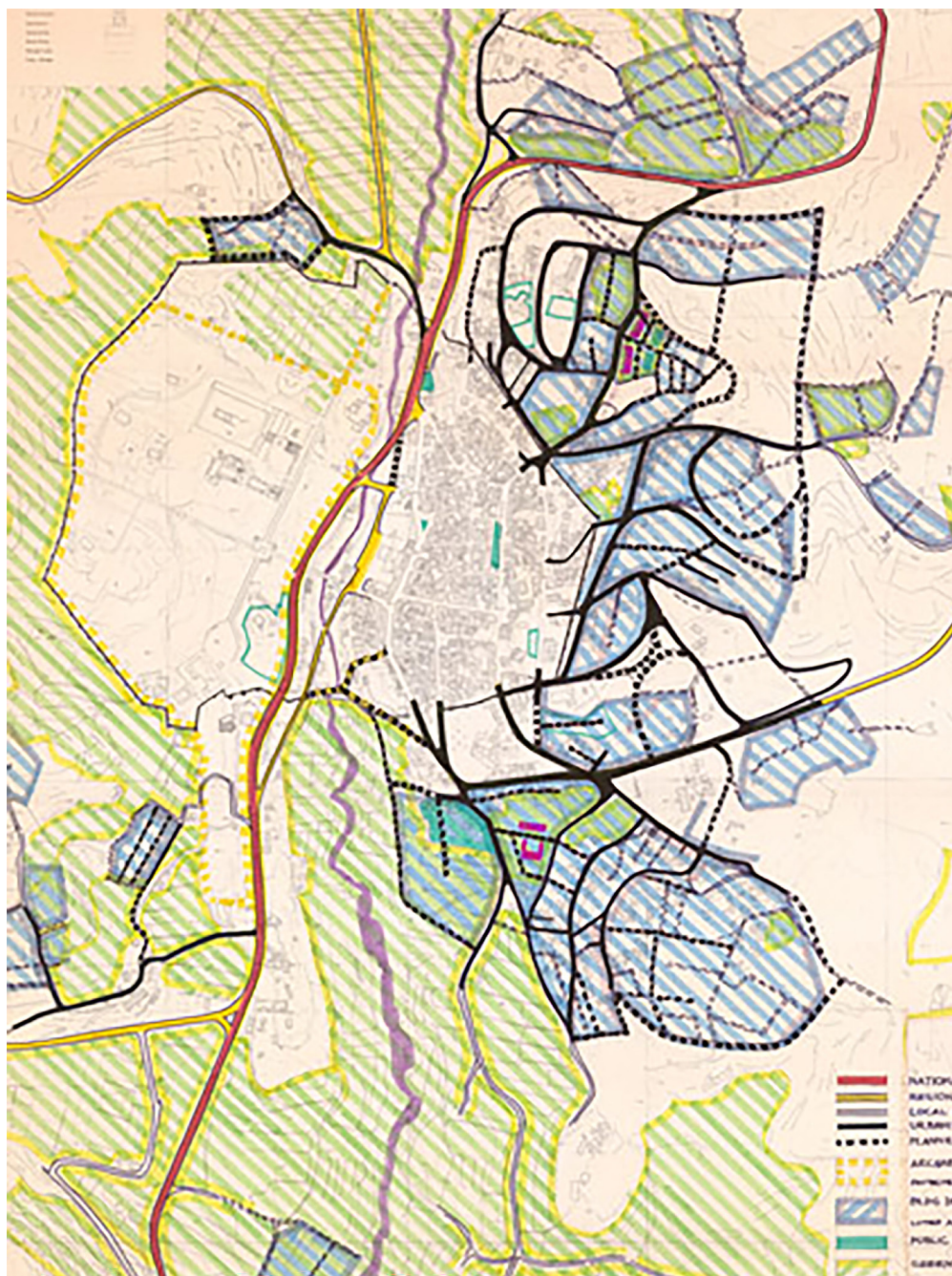
**Fig. 2**

Table of the master plan proposed by Roberto Parapetti for the safeguarding of Jerash's historic landscape, early 1980s.

1928 and 1934 by the archaeologists from Yale University and the British School of Archaeology in Jerusalem. The results of those investigations, promptly published, long fostered the impression that the history of the site and its monuments had been essentially clarified.

As already noted by those scholars themselves, and as was evident to visitors to the site in the 1970s, much work nonetheless remained to be undertaken, both in terms of archaeological investigation and conservation. Although some partial interventions were carried out after the Second World War, these were often poorly coordinated and only inadequately published.

As mentioned above, the Italian mission, as outlined by Giorgio Gullini, focused primarily on establishing a systematic programme of investigation in the Sanctuary of Artemis as a prerequisite for the long-anticipated interpretative reconstruction of the entire complex. The primary objective was the completion of a comprehensive

topographic and architectural survey in preparation for the necessary restoration work. The methodological framework and restoration plans were presented in several publications, some preliminary, which preceded the interventions carried out over the following years.

During the initial stages of work, it soon became clear that the completion of the architectural survey and the reconstruction of the original layout of the sanctuary would require targeted excavations in almost all areas of the complex, including the area in front of the Propylaea.

Priority was therefore given to the analysis of the temple itself, which at that time could only be viewed from the exterior, since the cella was entirely filled with collapsed architectural blocks. A first sounding, opened outside the north-western corner of the podium², revealed four courses of the foundation masonry, together with part of the moulded cornice. The investigation also confirmed, as previously suggested by Clarence Fisher, that the original paving was no longer preserved and that only its preparatory bedding layer remained. The absence of datable material, however, did not resolve the question of possible earlier constructions, whose existence had been tentatively proposed by Kraeling and Fisher. This chronological issue, already identified by earlier scholars, was in turn linked to the broader problem of dating the urban layout of Gerasa, which had originally been attributed to Hellenistic models and chronology³.

In order to address this fundamental question, subsequent research was redirected to the lower terrace of the sanctuary⁴, with the aim of identifying within this extensive area possible architectural remains associated with the earliest phase of the cult of the Goddess, mentioned in inscriptions Welles 28 and 29 (Welles, 1938:389-390). The existence of such a phase appears entirely plausible in view of the goddess's role as the city's tutelary deity.

This area had already been partially investigated by the Anglo-American mission, as described in detail by Clarence Fisher (Fisher, 1938:131-132). Their work concerned primarily the great staircase and the southern sector of the terrace. The northern part, by contrast, had been occupied by an Ottoman military building that later served as the residence of the Director of the Transjordan Department of Antiquities, George Horsfield, and was subsequently converted into the local offices of the Department.

The broad U-shaped terrace extends on either side of the staircase that rises from the inferior level of the Propylaea and terminates at a platform where the foundations of a small altar are preserved. This altar stands directly in front of the monumental staircase that leads to the temple terrace above, part of which had already been exposed. The early excavators also hypothesised the existence of porticoes along the southern side, possibly connected with a gate that provided access between this sector of the sanctuary and the street running north of the complex of St Theodore. They also reported the presence of earlier structures associated with the sanctuary, although unfortunately the plan of these remains was never published.

² The excavation was carried out in 1978 by Gabriella Barbieri.

³ Contra this idea of an earlier Hellenistic grid, although never clearly stated by either Kraeling or Fisher, see Parapetti (1995; 2009).

⁴ The terrace is called 'forecourt' in the publications of the Anglo-American mission and 'intermediate' in the early publications of the Italian Mission.

The exploration of the terrace, begun in 1979, continued until 1983⁵. Noting that the central portion of the southern half of the terrace had remained untouched by previous excavations, a trench was opened in this area with the aim of reaching the level of the small altar across the entire sector and verifying the existence and nature of possible structures delimiting the staircase and retaining the substantial terrace fill visible today.

The results of these investigations proved unexpected. Excavation revealed a substantial fill deposit retained by a massive retaining wall separating it from the rear walls of a row of shops. On the surface created by this levelling operation there stood a rectangular structure with opposing double apses, probably a church. Based on the material recovered from the fill on which it was founded, the building may be attributed to the sixth century. Several phases of modification were identified, involving minor changes to the plan that may indicate a shift in function. The final phase appears to be represented by drainage channels running along the exterior walls and by a basin for water collection. These installations were in turn sealed by a thick fill layer, dated by ceramic evidence to the Umayyad period.

The impossibility of identifying during these investigations remains belonging to the Roman-period arrangement of the terrace was disappointing. At the same time, however, the evidence confirmed earlier observations suggesting the occurrence of events that may have been 'deliberately destructive', previously hypothesised for the temple terrace. The raising of the occupation level to a height roughly corresponding to that of the upper terrace also demonstrates a renewed interest in this sector of the city during the Byzantine period, particularly for the artisanal reuse of the extensive spaces in front of the temple.

These observations provided an initial response to the long-debated question of the scale and consequences of the so-called 'Arab invasion'. This issue, in turn, drew renewed attention to the structures located in front of the temple, among which the best preserved were a circular kiln, against which a rectangular room had later been constructed, and several smaller installations whose function remains uncertain.

Beginning in 1981, several additional soundings were opened in this area. These investigations were made possible by the increased number of archaeologists participating in the project following the incorporation of the Italian mission into the Jerash Project for Excavation and Restoration (fig. 3)⁶.

The soundings focused successively on three areas: first, the zone between the circular kiln A and the two column drums positioned against the northern recess of the temple podium; second, the area of the staircase providing access to the temple; and finally, building B (Parapetti et al., 1986, fig. 8)⁷.

A fortunate discovery contributed significantly to the chronological framework of these contexts: a lamp bearing a Kufic inscription that recorded the year 125 of the Hijra. This find made it possible to date the abandonment of the small kiln

⁵ The investigations on the lower terrace were conducted by Raffaella Pierobon, joined, from the following year, by Gabriella Piazza and, from 1982, by Maria Vittoria Fontana.

⁶ The project was sponsored by the Jordanian Department of Antiquities and funded by UNESCO from 1981 to 1983. In addition to the Italian Mission led by Roberto Parapetti, a French, a Polish, a British-Australian and a Spanish team also joined the project.

⁷ The excavations on the upper terrace in front of the temple were directed by Raffaella Pierobon, Rita Compatangelo and Maria Cristina Bitti.



Fig. 3

The archaeological mission at Jerash, Spring 1982, in front of the Temple of Artemis.

From left: Marina Paris, Domenico Santarsiero, Roberto Parapetti, Cristina Bitti, Raffaella Pierobon, Maria Vittoria Fontana, Mario Letizia.

D to the aftermath of the major earthquake of 749. It also confirmed that the large quantity of ceramic fragments recovered inside the structure was broadly contemporary. Since numerous kiln wasters were present, it seems plausible that this substantial surface deposit resulted from repeated dumping episodes associated with the workshop's activity. The quality and variety of the preserved forms also suggest a lively production system and an active market for these goods.

A comparable assemblage was identified in the upper layers of room B, which had only been partially explored by the American excavations. This space underwent several transformations beginning with the dismantling of the temple altar, one of whose blocks had been incorporated into a roughly constructed wall delimiting the room; a second block was identified during the investigations in the northern stretch of the same wall. These elements likely indicate a phase of spoliation that followed the initial reuse of blocks from the Hadrianic structure. This phase of occupation came to an end with a substantial collapse, which probably prevented further dismantling of the altar.

It has not been possible to establish precisely when kiln A was constructed, although it partially cut into the south-western corner of room B. The material recovered from the layers immediately following the destruction phase can in any case be attributed to the sixth and seventh centuries, thus corresponding to the earliest phase of ceramic production in the area, as already suggested by the earlier excavators. The length of the gap between the two phases remains uncertain, since the materials recovered from the overlying layers and the newly identified kilns D and E appear independent in plan, despite the continuity of the same type of activity.

More directly related to the history of the temple was the sounding opened east of the modern access staircase between the *alae* of the building. This investigation confirmed the existence of activity in the area predating the construction of the

temple, although no associated buildings were identified. Remains of a series of steps that had been levelled during later works were detected; into this surface the mouth of a well and a cistern had been cut. Both were filled with material dating to the first and second centuries AD and were sealed by the construction of the temple. Following the dismantling of the staircase, the area appears to have been reoccupied, possibly in connection with the installation of the earliest kilns in the vicinity, and remained in use until the Umayyad period.

In summary, the results obtained during these first years of research confirmed the limited archaeological evidence for the phases preceding the construction of the large Antonine temple and its associated sanctuary complex. At the same time, they clearly demonstrated that the transition from the Byzantine era to the Arab conquest of the region did not bring urban life to an abrupt end, as the city remained active, at least in terms of artisanal production.

3 The Shops along the Colonnaded Street

Excavations carried out by the Italian Archaeological Mission at Gerasa⁸ as part of the restoration programme in the Sanctuary of Artemis also extended to the rooms facing the western portico of the Great Colonnaded Street, the city's main north-south thoroughfare⁹.

These structures consist of a series of two-storey rooms, interpretable as shops and offices, constructed during the Roman imperial period on either side of the Propylaea and leaning against the retaining wall of the sanctuary's lower terrace. At the two ends of the alignment, staircases inserted within service spaces provided access to the upper storey, where the rooms, covered by barrel vaults, were interconnected. In the façade wall, probably revetted with slabs in the lower part and plastered above, doorways and windows with architraves opened onto the street.

Groups of three or four shops are separated by two large *exedrae*, symmetrically arranged and identical in size. These were roofed with a flat ceiling and articulated on the façade by pairs of columns framed by corner piers, forming a tripartite composition. Their function remains uncertain, as does that of the two adjoining rooms to the north and south, which were originally in direct communication with them. In the southern exedra the original floor, composed of regularly laid stone slabs, is entirely preserved (fig. 4), whereas in the northern one part of a mosaic floor survives. This pavement, apparently contemporary with the construction of the complex, may suggest a different original use of these two halls.

At the beginning of the works in 1984, the archaeological deposits, both inside and outside the rooms, had already been heavily disturbed by repeated clearance operations carried out in previous decades, which had significantly compromised the stratigraphic sequence¹⁰. In the excavations carried out before the restoration

⁸ The archaeological excavation of the shops was conducted by Maria Cristina Bitti from 1984 to 1986, and by Edoardo Pantanella in 1992. The restoration, directed by Roberto Parapetti and supervised by Franco Cardilli, was completed in 1994.

⁹ On the excavation and restoration of the rooms aligned along the western side of the Cardo, see Parapetti (1989). For a preliminary study of the structures and the materials recovered there, see Baldoni (2019).

¹⁰ Between 1928 and 1931, the work carried out by George Horsfield in the two rooms on either side of the Propylaeum had involved the emptying of the southern one and

Fig. 4

Repositioning of the exedra anta capital in the centre of the southern wing of the Cardo workshops, funded by Italian Development Cooperation (1988).



and consolidation of the structures, most of the recorded evidence belongs to the years between the Byzantine and Umayyad eras. This phase of occupation involved the removal of the Roman floors down to the bedrock on which the investigated deposits were stratified. Everything was sealed by the collapse of the vaults, probably caused by the earthquake of 660 CE.

The finds recovered from these deposits include ceramic forms and types produced locally from the sixth to the early seventh century. The excavations also yielded many fragments of lamps belonging to the so-called ‘Jerash lamps’ type¹¹, particularly concentrated in the southern exedra, where the presence of waste materials suggests that this category of objects was manufactured locally. Despite the absence of kiln structures – probably removed during earlier clearance operations – the discovery of vitrified clay slag and, in greater quantity, of deformed glass vessels, fragments, and lumps of raw glass indicates the presence of production

the clearing of the northern one, up to about a meter above the ancient level. Further excavations were carried out in 1980 by Harettin Kalayan, who undertook the reassembly of the columns of the propylaeum and the decorative façade of the room located at the southern end of the complex, along with the partial emptying of the three rooms adjacent to it to the north. On the work of the Anglo-American mission in this area, see a brief note in Stinespring (1938:4-5). The details of these interventions have never been made public.

¹¹ For a typology of Jerash lamps see Kehrberg (2011).

installations in the rooms facing the Colonnaded Street. During this period the structures themselves had undergone only minor modifications: in several rooms the door openings had been narrowed, while in one case a third storey had been created by lowering the first-floor level relative to the imperial-period springing of the vault.

In the room immediately north of the Propylaea numerous artefacts were recovered that can be interpreted as crucibles. These consisted of domestic vessels coated with a layer of refractory clay that shows clear traces of exposure to high temperatures. Most of them are globular, two-handled cooking pots with convex bases and thin ribbed walls, characteristic of the local ceramic production of the sixth century¹². The southern *exedra* also yielded a large quantity of fragments of glass objects, probably intended for remelting, while the excavation of the northern *exedra* produced numerous fragments of basins with glazed internal surfaces and layers of fused glass adhering to the bottom of the vessel. These deposits, which show vacuoles and air bubbles on the surface, display characteristics very similar to those observed in the mosaic tesserae used in the churches of Gerasa. It is therefore likely that this glass was intended to produce mosaic tesserae. In both rooms additional elements associated with workshop activity were also recovered, including part of the perforated circular plate that served as the diaphragm of a small furnace made of refractory clay, fragments of the floor of the firing chamber, and a spacer.

The archaeological evidence thus indicates that by the end of the Byzantine period the complex of imperial-period shops had been transformed into a district devoted primarily to craft production. It appears to have been characterised by manufacturing installations that were probably multifunctional, as suggested by the presence within the same rooms of artefacts associated with the working of glass as well as ceramics and metals. Nevertheless, judging from the quantity of finds, glassworking seems to have been the predominant activity, particularly aimed at the production of mosaic tesserae for the decoration of the walls and ceilings of churches.

It is possible that the workshops of Gerasa operated an autonomous production cycle based on the reuse of fragmented glass objects rather than raw materials for its production. The large quantity of glass debris recovered in one of the rooms along the Colonnaded Street and in other areas of the city suggests that several stages of production were carried out on the site (Baur, 1938: 514-515; Meyer, 1988): the breaking and remelting of glass vessels, the colouring of the molten glass, and the manufacture of glass blocks ready to be cut and set into mosaics.

While excavation in the northern sector of the shops was still in progress, restoration work began in the southern half of the complex. This intervention eventually involved the entire 120-m-long side of the sanctuary facing the Colonnaded Street and continued for approximately ten years (fig. 7). The work first focused on consolidating and partially rebuilding the large retaining wall supporting the lower terrace of the sanctuary, together with the orthogonal walls separating the individual shops. For each room, the corbel supporting the mezzanine and the first course of voussoirs of the barrel vault were reconstructed. In the two *exedrae*, originally covered by a flat roof, the springings of the central arch were reproduced wherever they were no longer preserved, to recreate the central support for the beams of the ceiling.

¹² Uscatescu, 1996:135, fig. 83, 510, group XXXIV, 3D form; Pierobon:1983, fig. E:1; Kehrberg 2009:508-509, fig. 10a.

The restoration of the shops was therefore above all an engineering operation, essential for the preservation of the entire structural complex which, from the lower terrace of the sanctuary, was gradually collapsing toward the *Cardo*. This objective was achieved by restoring the original structural function of the Antonine substructures, while limiting reconstruction strictly to elements preserved in situ or recovered during the excavations.

Today the rooms of the shops are used by the Department of Antiquities mainly for service and storage functions. However, they could potentially be incorporated into a different organisation of the site's visitor facilities. In the southern sector, moreover, it has been proposed to reopen a couple of excavation areas to display the traces of occupation predating the construction of the sanctuary, one of the very few contexts of this type so far documented within the city.

4 Anastylis of the Tetrastyle of the Propylaea of the Sanctuary of Artemis

Within the framework of the same cooperative project that encompassed the restoration of the shops and *exedrae* along the *Cardo*, the anastylis of the four monumental columns of the Propylaea of the Sanctuary of Artemis along the Colonnaded Street was undertaken between 1993 and 1995¹³.

Situated at the terminus of the access route linking the western half of the city with the Sanctuary, the monument had attracted scholarly attention since the earliest systematic investigations at Gerasa at the beginning of the twentieth century¹⁴. Horsfield's interventions between 1925 and 1928 focused primarily on the monumental gateway framed by the shop buildings¹⁵. Of the tetrastyle, only three pedestals and the *imoscopus* of the northernmost column remained in situ. During the reconstruction of the *Cardo* colonnades undertaken by the Department of Antiquities in the 1960s, the missing pedestals were rebuilt and four of the six original drums for each column – recovered from collapse deposits in the street – were repositioned. A subsequent intervention was carried out by the architect Kalayan in 1976, when the four detached-order columns framing the three doorways of the Propylaea were re-erected. Several drums and four capitals used, however, were clearly inappropriate for the monument.

A detailed analytical study of the structure subsequently identified and documented all architectural elements used in previous restorations or remaining on the ground. This study proposed an alternative reconstruction of the tetrastyle and of the Propylaea gates, concluding that only the tetrastyle could be feasibly reconstructed, while intervention on the gates was excluded *a priori* owing to the extensive use of concrete and pre-tensioned iron rods in prior restorations, which passed through the columns and other entablature elements (Parapetti, 1997a).

¹³ The restoration work was directed by Roberto Parapetti, in collaboration with Giannata Rizzi, Dina D'Ayala, Stefano Volta, and Franco Cardilli, all contributing to the project's design and testing of the adopted solutions.

¹⁴ Regarding the study mission of a team led by Otto Puchstein to Jerash in 1902, see Stinespring (1938:2), Mortensen (2018:179), and Lichtenberger-Raja (2020:13-15).

¹⁵ The restoration of the Propylaea was carried out in 1928 with the important contribution of the Italian architect Pierre Ricci, who introduced for the first time in Jerash the methodology of the 'philological restoration' which had established itself in the pioneering activity of the so-called 'Roman School' between the end of the 19th and the beginning of the 20th century (Parapetti, 2013:685).

Given the technical complexity and available budget, it was decided to reconstruct the columns only, postponing the reconstruction of the entablature and of the pedimental triangle to a later phase of the project, which was never implemented. The intervention proceeded in three stages: dismantling of the 1960s restoration, recomposition of partially damaged or missing elements, and re-erection. Dismantling was required due to the incorrect assembly of the drums. Only five of the twenty-three preserved elements could be securely attributed to a specific column and position within the sequence: the northern *imoscapus*, the two drums provided with brackets to receive the architraves of the street colonnades, and the two drums immediately above, which retain the anchoring holes for the architraves.

The remaining eighteen elements were correctly positioned and graphically verified through measurements of diameter and analysis of the *entasis* curvature. Missing portions of many drums were reintegrated to restore their structural and volumetric characteristics. This method replicated the ancient construction technique, avoiding metal dowels between drums and relying on direct contact of bedding surfaces, improved with a thin layer of lime mortar.

For the reintegration of the missing parts, an ‘artificial stone’ mixture was used, composed of white cement, five types of sand, two types of gravel, and polypropylene fibres. After extensive laboratory and on-site testing, this mixture reproduced the physical and mechanical properties of the local *malaki* limestone used for the column shafts.

Each element was cleaned with biocides, consolidated where cracked, and missing portions were reconstructed in clay, modelled to replicate the original surface. A fibreglass and resin mould was applied over the clay additions and part of the block, allowed to harden for forty-eight hours. After removing the mould and the clay, the block was prepared with a stainless-steel reinforcement, then the artificial stone mixture was poured into the cast (Fig. 5). A bush-hammer finish exposed the aggregate matrix. Reintegrated blocks, including two bases and two capitals, were positioned by suspending each element on its centre of gravity axis by three plugs, replacing the ancient dovetailed lewises, whose seatings were mostly compromised, to better manoeuvre the drum during its setting (fig. 6).

The anastylosis of the tetrastyle columns restores the tallest documented order at Gerasa¹⁶ and constitutes an important methodological benchmark among the range of visible restorations and reconstructions. Moving beyond accepted principles of reversibility and recognisability, this intervention respects the structural behaviour of the original elements by balancing their integrity with volumetric reintegration.

5 Excavations in the Temple of Artemis

From nineteenth-century travellers’ accounts, the Temple of Artemis attracted attention both for the excellent preservation of its colonnade and Corinthian

¹⁶ The height of the columns, from base to capital, in the tetrastyle of the Propylaeum is slightly less than that of the columns preserved in the Temple of Artemis. However, because the Propylaeum’s columns rest on pedestals, their overall elevation exceeds that of the temple columns, thus overturning a generally accepted principle in the classical world: namely, that the temple’s order should never be overshadowed by other elements within the sanctuary.

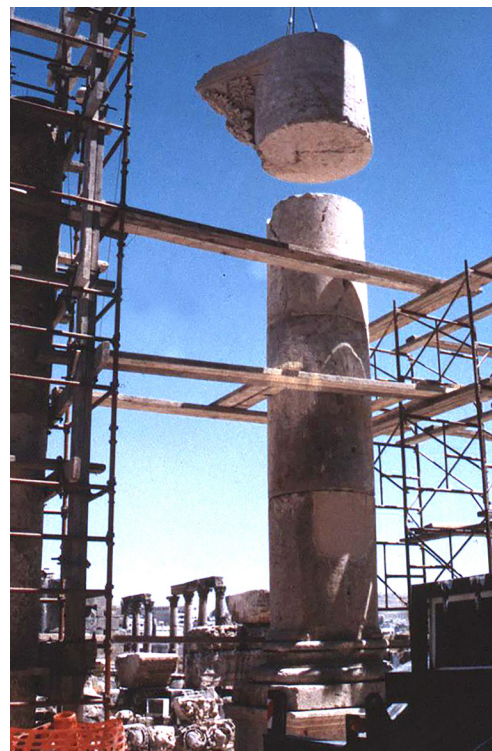
from left

Fig. 5

Integration with artificial stone of a mutilated drum of the Artemis Propylaea tetrastyle. Stefano Volta and Franco Cardilli monitor the fiberglass cast pour (1994).

Fig. 6

Anastylosis of the column element with bracket of the northern Propylaea tetrastyle (1994).



capitals, and for the difficulty of reconstructing the building from its fragmentary remains.

The American mission of the 1930s could not remove the massive collapse deposits filling the cella and thus limited its work to clearing the pronaos and the eastern halves of the ambulatories. In the final publication, Clarence Stanley Fisher expressed the hope for «a rapid completion of the excavations that will give it an acknowledged place beside the temples of Baalbek and Palmyra» (Fisher, 1938:138).

This was achieved in 1994 using the crane acquired by the Italian mission for the Propylaea restorations. Collapse blocks from the cella and western ambulatories were removed sequentially, revealing underlying stratigraphy, investigated over three excavation campaigns until 1995 (fig. 8)¹⁷.

The first major finding concerned the duration of occupation within the cella. The collapse of the upper walls, which rendered the cella, pronaos, and ambulatories permanently unusable, should not be attributed to the 749 CE earthquake, as previously thought, but to the twelfth or thirteenth century, as evidenced by traces of later occupation (Parapetti, 1997b:522-523).

Excavations also documented the pagan temple's profanation in the second half of the fourth century, slightly preceding the Theodosian decrees prohibiting sacrifices. Marble pavements and wall revetments were systematically removed for likely reuse in ecclesiastical buildings, including the moulded doorframe. Unlike the nearby Temple of Zeus, the cella was repaved with a polychrome mosaic, door jambs were restored, and the hall was adapted for public reception, likely connected to provincial or municipal officials.

¹⁷ The excavation was directed and documented by Massimo Brizzi.



The end of the building's public use is documented by a mid-sixth-century earthquake that caused the roof and ceiling to collapse, leaving evident traces on mosaic fragments. This event marks a turning point for both the temple and the sanctuary's urban landscape.

Subsequently, the terrace was occupied by a craft quarter centred on the temple building, transformed into a fortified residential complex. Craft activities, mainly ceramic kilns, were supplied by the Roman aqueduct, which was adapted into new channels and cisterns during this phase.

Following the 749 CE earthquake that irreparably damaged the city's water supply infrastructure (Boyer, 2022:326, 340), while the buildings of the temple and in the upper terrace largely survived, the quarter was abandoned. The temple shifted from residential and storage use to occasional shelter for local shepherds and farmers.

Regarding the temple building, once the excavation was completed, a detailed study of the architecture was undertaken, incorporating the new evidence revealed by the excavation into what was already known from previous studies (Brizzi, 2000; 2018). Although the state of completion of the colonnade remains a matter of debate, it is well established that the upper part of the entablature was never finished. The main contribution of this research lies in the identification and definition of a modification to the original design when the construction was in progress. In particular, the *thalamos* of the cella, the space housing the cult statue of the goddess, and the stairways providing access to the roof terrace were radically altered while work was already underway.

In short, when discussing the architecture of the temple, one must consider that we are dealing with three distinct buildings: the original design, the design as modified during construction, and the building as actually realized, which lacks a large part, if not all, of the entablature and part of the colonnade. As with all ancient buildings, the transformations resulting from the reuse of these spaces and structures must also be considered, as they enrich the history of the monument and

Fig. 7

Eastern front of the Sanctuary of Artemis along the *Cardo* following completion of the restoration of the two workshop wings and the anastylosis of the large Propylaea tetrastyle, all funded by Italian Development Cooperation (2003).

Fig. 8

Commencement of excavation in the Temple of Artemis cella, removing collapsed wall blocks due to a 12th-13th century earthquake (1994).



constitute an additional heritage that deserves to be preserved and documented, even if these are often the most fragile and fragmentary parts of the building. Today, the Temple of Artemis occupies the 'acknowledged place' envisaged by Fisher, as an emblematic monument of the historical and cultural complexity of Gerasa, whose interpretative frameworks remain challenged by ongoing research.

6 Excavations in the Trapezoidal Plaza and the Church of the Viaduct

The route connecting the bridge over the Chrysorhoas (wadi Jerash) with the Propylaea of the Sanctuary of Artemis was conceived and constructed in conjunction with the Propylaea themselves and represents one of the most remarkable architectural innovations in the city. Access to the Propylaea from the bridge comprised a colonnaded approach leading into a trapezoidal plaza, open to the west to the same width as the tetrastyle of the Propylaea on the opposite side of the street. The northern and southern sides of the plaza were defined by two symmetrical 'open-exedra buildings' that is, two façades articulated with niches and preceded by a high podium in the form of a *pulpitum*.

By the mid-sixth century, the entire area had been converted into an ecclesiastical complex: the eastern stretch of the Colonnaded Street was roofed and transformed into a three-aisled basilica, while the trapezoidal plaza was enclosed on the side facing the Cardo and repurposed as the porticoed atrium of the basilica. The

**Fig. 9**

Surveying works during stratigraphic excavation of the southern side of the Trapezoidal Plaza (1999).

two 'open-exedra buildings' were adapted to accommodate a circular hall and a quadrangular room with exedra, both paved with mosaics.

In the first of these, between 1925 and 1926, George Horsfield, architect commissioned by the newly established Department of Antiquities of the British Mandate of Palestine and Transjordan, uncovered an extraordinary polychrome mosaic with geometric decoration and a long inscription identifying the room as the 'Diaconia' and dating the pavement to the month of Artemisius (March-April) 565 CE. Shortly thereafter, the Anglo-American mission of Yale University and the British School of Archaeology in Jerusalem began work at Gerasa. J.W. Crowfoot, director of the British School, studied the Diaconia mosaic but was unable to carry out further investigations within the church; these were only partially completed by American archaeologists in 1934 during the final months of their mission. The decision by the Italian mission to resume and complete these investigations was a natural consequence of earlier interventions during the 1980s and 1990s in the shops along the Cardo and at the tetrastyle of the Propylaea¹⁸.

Between 1994 and 2003, excavations focused on the southern half of the Trapezoidal Plaza, revealing the porticoed building constructed in the sixth century by reusing the structures of the Antonine-period 'open-exedra building' and its extensive foundation platform of blocks (fig. 9) (Brizzi et al., 2001; Brizzi et al., 2010). The Byzantine structure preserves two rooms and a double-ramp staircase connecting the porticoed ambulatory with an upper floor. In the room corresponding to the semicircular exedra, two jambs supporting an arch separate a quadrangular antechamber from an apsidal hall.

The quadrangular room contained substantial collapse deposits, including

¹⁸ The excavation was directed by Massimo Brizzi, with the collaboration of Daniele Sepio, Mariella Mastrogiamoco, and Lieven Loots. The ceramic materials were examined by Daniela Baldoni. Collaborating with the excavation were conservators Giuseppina Bertolotto and Wilma Basilissi, draftsman Raffaele Cestari, and architect Giovanni Ascutto.

fragments of polychrome geometric and naturalistic wall decoration and framed inscriptions. These inscriptions, in Greek and arranged in one or more lines, attest to a religious practice otherwise documented at Gerasa and in the wider region. Although no other liturgical infrastructure was found here, it is likely that this central room, symmetrical to the Diaconia on the other side of the atrium, served a public function within the basilica complex (Del Corso and Mastrogiamco, 2007).

Between 2003 and 2008, excavations were extended to areas of the basilica previously unexcavated by the Anglo-American mission, with deep trenches opened to establish stratigraphic control over the different building phases. In addition to a minor chapel immediately south of the southern nave, these investigations revealed the original stone flooring of the basilica and contexts relating to subsequent reoccupation.

It was thus possible to revise the dating of the complex's religious use, indicating its cessation in the mid-seventh century, with traces of destruction likely due to seismic activity in both the southern chapel and the atrium building. Certain areas of the church and the apsidal space within the atrium preserve evidence of probable domestic occupation continuing until the earthquake of 749 CE, which destroyed the entire northern colonnade of the church and all eight monolithic Aswan granite columns reused at the sides of the basilica presbytery.

Excavations in the atrium and Viaduct Basilica also enabled a reassessment of the architecture and function of the area in the Roman period. Seen as the final stretch of an approach to the Sanctuary of Artemis, a monumental *via sacra*, albeit without direct evidence of ritual activities, by contrast, the Trapezoidal Plaza was distinctive as a public space devoted to the celebration of the emperor and of Roman rule.

The two *exedrae* were not part of nymphaea, as previously interpreted from honorary inscriptions, but belong to a local building typology known as 'open-exedra monuments': podiums intended for the display of votive statuary, facing a central exedra in which statues of emperors, their families, and deities were placed. Within this context, the Egyptian granite columns found near the church presbytery are revealed in their original positions, indicating the imperial patronage of the complex and its role as an architectural expression of imperial authority in close association with the city's patron goddess (Brizzi, 2018:103-108).

With the arrival of Christianity and the transformation of the urban landscape and its symbolism, these valuable granite columns were divided between the basilica built on the site of the eastern Propylaea and a second extramural martyrial basilica to the north of the city, which incorporated numerous *spolia* from the Trapezoidal Plaza.

The result of over a decade of archaeological research in this part of the city, reconstructing the history of building phases and patronage, provides the basis for a broader project aimed at the presentation of the area to the public. In this context, the complexity of structural and cultural stratigraphy has been organised into a narrative that is scientifically rigorous yet accessible to all visitors.

7 The AFCP Project at the Temple of Artemis

Following the archaeological investigation of the Temple of Artemis conducted in 1994-1995, the monument was stabilised and made accessible to visitors through interventions carried out over the subsequent two years.

From 2012 onwards, the temple has been under continuous monitoring by the technical staff of the Italian Mission due to the accelerated rate of decay, most apparent in the vault voussoirs, podium walls, and the walls of the cella. In the latter, superficial fragmentation was evidenced by accumulations of small limestone fragments at the base of the walls. The scale and complexity of the necessary interventions demanded a dedicated budget, which was unavailable at the time from either the Department of Antiquities or the Italian Mission, and highlighted the critical issue, emphasised by the then director of excavations at Jerash, Ali al-Khayyat, of the absence on-site of Department personnel with the technical expertise required to design and implement appropriate conservation measures.

Although the Temple of Artemis is situated within a protected archaeological area and ostensibly not subject to immediate threats, it was clear that its fragility, attributable both to its constructional and usage history and to contemporary climatic changes, required a series of extraordinary interventions designed to restore a sustainable conservation equilibrium manageable through regular maintenance.

In this context, a project was conceived in collaboration with the Department of Antiquities and submitted to the Ambassador's Fund for Cultural Preservation (AFCP), which was awarded to Monumenta Orientalia in 2018¹⁹. The project addressed urgent interventions to safeguard vulnerable parts of the monument, measures intended to mitigate long-term threats to its preservation, training of Department personnel in the conservation of stone-built structures, and a programme of public archaeology within the modern city. The latter was intended to extend beyond the temporal limits of the project, seen as the only effective remedy to the widespread problem of illicit 'treasure hunting' affecting ancient monuments throughout the region, including those within the protected area.

Prior to conservation activities, stratigraphic excavation of deposits overlying the bedrock within the podium rooms was undertaken (fig. 10) (Ghnimat et al., 2022). This was necessary to assess the foundations of the walls supporting the vaults, which had been heavily compromised by the activity of illicit excavators. Once excavation was completed, the monument was thoroughly cleared, and three-dimensional photogrammetric documentation of the entire temple was produced. With updated plans and elevations for every part of the monument, a conservation assessment was carried out, followed by the development of intervention plans.

The primary condition observed was the widespread decay of the limestone elements. Cracking and disintegration of the stonework could be measured by comparing graphic and photographic documentation of the temple over the past twenty-five

¹⁹ The project was developed and co-directed by Roberto Parapetti and Massimo Brizzi, along with Ziad Ghnimat and Mohamed al-Shalabi, directors of the Department of Antiquities in Jerash between 2018 and 2022. Stefano Volta, Valentina Puglisi, and Silvia Simeti were consulted for the conservation program, Giovanni Vercelli for structural calculations, and Anna Paterlini and Mohammad Atoom for the public archaeology program. Conservators Giorgio Arcari, Lorenzo Volta, and Antonio Colella along with the Department technicians Noor al-Deen Marazeeq, Mustafa Ali Mashaykhah, Awni Mashnour al-Rawashdeh, Basil Mohammad Ali al-Sayed, Mohammad Hassan Abu Dlak, and Ibrahim al-Azeh, collaborated on the implementation of the conservation work. Evelyn Hill and Chris Boyd conducted interviews with visitors and local community representatives. Antonio Abate carried out the photogrammetric survey of the temple.

from left

Fig. 10

Stratigraphic excavation in the central podium vault of the Temple of Artemis (2018).

Fig. 11

Consolidation of the podium vaults via injections of natural hydraulic lime mortar and training of specialised workers during the AFCP project (2019).



years, since the excavation of the cella. The principal agent of decay is exposure to rainfall and infiltration, affecting both the walls of the cella and the podium vaults. Subsequent temperature fluctuations induce cycles of wetting and drying that accelerate limestone deterioration. Consequently, rainwater management emerged as the principal priority for mitigating the temple's deterioration.

Given the region's susceptibility to seismic events, all structural vulnerabilities had to be addressed in advance to prevent irreparable damage from the next unpredictable earthquake. The assessment also identified numerous instances of structural instability, subsequently evaluated and prioritised according to threat severity in consultation with a specialist engineer. The urgent interventions identified included:

- The architraves of the cella corner stair towers, weakened by fractures; their collapse would have compromised the upper masonry.
- The blocks associated with the Byzantine hatch in the northern podium vault.
- The jamb of the arched passage between the southern and central podium vaults, where seven blocks had been removed.
- Foundations of the podium walls, undermined by clandestine digging and suspended above the bedrock.
- Most of the blocks within the nine podium vaults beneath the cella and pronaos, affected by surface wear, efflorescence, and missing joint mortar.
- The western wall of the cella, which had been halved in width in antiquity to accommodate the new *thalamos*, significantly weakening the structure and causing recent outward bowing.

Unexpectedly, excavation and clearance of the podium rooms revealed that, despite the temple's location within a protected and monitored area, illicit digging over the past thirty years had been extremely destructive. This activity not only resulted in the loss of stratigraphic information above the bedrock but also severely

damaged the podium's load-bearing structures, triggering processes of progressive damage that posed a significant threat to the monument. Recent plastic artefacts indicate these activities are ongoing, highlighting the necessity of widespread and sustained public engagement with heritage to mitigate further damage.

Conservation activities, distinguished between urgent interventions and long-term mitigation measures, included the following:

- Repair and replacement of northern vault blocks. Five elements of the northern podium vault were replaced with specially cut limestone blocks replicating the original forms and dimensions, including modifications made in the Byzantine period to create a closable hatch.
- Sealing and injection of vault intradoses. Other vault vulnerabilities were addressed individually by injecting fluid mortar into the core of the structure, following prior cleaning with a high-pressure washer (fig. 11).
- Sealing and levelling of the *cella* floor. The extrados of the vaults and the concrete screed supporting the marble floor were treated to ensure waterproofing and a gradual slope towards the north-east, where the north-eastern stairway enables drainage. Lime hydraulic mortar, combined with selected aggregates and sand in sector-specific proportions, was used. This intervention also included the south-west corner, where access to the podium vaults was restored and the original covering slab consolidated.
- Stabilisation of the western *cella* wall. The dangerous outward movement of the western wall was partially mitigated by lifting collapsed blocks lodged between the wall and the exedra structure and stabilising the courses above.
- Laying of a macadam floor over the podium vaults within the *cella*. The impermeable walking surface was protected by a macadam floor composed of sand and gravel of varied granulometry with a minimal proportion of white cement, laid at a consistent thickness while maintaining the north-eastern slope of the underlying cementitious layer.
- Restoration and consolidation of podium masonry. The damaged podium jamb was reconstructed using recovered original blocks, and the foundations of the two central walls were reinforced where undermined by illicit excavations.
- Restoration and consolidation of the *cella* staircase tower architraves. The south-eastern staircase architrave, fractured into three sections, was stabilised by inserting two stainless-steel tension rods passing through the architrave and the upper course, set within a cored bore.

All conservation activities were conducted in collaboration with Department personnel, who provided all machinery available at Jerash. The creation of visitor pathways with informative boards completed the project interventions (fig. 12). Today, the Temple of Artemis is under continuous monitoring and maintenance by trained Department technicians.

8 Ongoing Projects and Future Programmes

Over half a century of archaeological research, restoration work, and educational initiatives has transformed the nature of the Italian Mission, challenging traditional notions of a 'mission'. The relationship with the Jordanian administration has shifted: Italian presence at Jerash is no longer framed as a bounded 'concession' over a site or part thereof but is defined through collaborative projects of varying scope and duration, often co-directed with Department officials, particularly for conservation and restoration activities. Since 2008, project administration and



Fig. 12

Visitors in the Temple of Artemis cella following the conservation and accessibility project funded by the Ambassador Fund for Cultural Preservation, US Embassy in Amman (2022).

logistics have been managed by Monumenta Orientalia, based in Rome, founded by Roberto Parapetti to continue activities at Jerash and subsequently extended to Yemen, Syria, Lebanon, and Iraq.

This framework has allowed for a research agenda encompassing both long-term and short-term objectives. On the one hand, it includes topics related to historical research aimed at identifying and analysing archaeological evidence pertaining to periods or contexts that have so far been poorly defined or only marginally investigated. This is the case, for example, of the ongoing research intended to reconstruct the patterns of use of the area of the Sanctuary of Artemis in the period preceding its construction in the second century CE, as well as the documentation and study of the medieval watermills built along the watercourses of the territory of Gerasa, at a time when the city had already been reduced to a village amid colossal ruins.

A significant component of current activity concerns the maintenance and conservation of previously investigated monuments requiring interventions that were not implemented or were insufficient after the conclusion of earlier excavations. These projects also address the critical need to train local personnel to conduct conservation and basic diagnostic work autonomously and efficiently. The recent interventions at the Temple of Artemis exemplify this approach, combining measures to mitigate long-term degradation with personnel training to enable early detection and remedial action.

Finally, the mission's responsibilities extend to public dissemination, both through scientific publications and, crucially, through architectural restoration and site presentation. These activities, heavily dependent on intermittent funding, are necessarily implemented in phases. Current interventions at the Church of the Viaduct and Trapezoidal Plaza aim to simplify access, improve interpretation, and integrate monuments into frequently visited pathways. A related project at the Roman East Baths seeks to secure the monumental structure within the modern city, near the Ottoman Mosque. The action is intended to create a new focal point

for tourism within the urban area, with the aim of generating economic and social benefits for residents, who have traditionally been excluded from the advantages of archaeological tourism, historically concentrated within the fenced archaeological site. Within this framework, the contemporary significance of the Italian archaeological presence at Jerash lies in serving as a centre of knowledge and expertise, establishing, in collaboration with local authorities, the conditions under which the complex narrative of the monuments can be fully legible, preserved under controlled and shared conservation measures, and safeguarded by a community aware of the historical heritage in its care. The achievement of this balance constitutes the ultimate accomplishment of the mission's objective.

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Continuity, Contrast, and Capacity: Notes from the designer on Jerash Adaptive Reuse Model for RCCR

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Abstract: Continuity and contrast set the design for the adaptive reuse of an *early modern public*¹ building in Jerash into the Regional Center for Conservation and Restoration (RCCR). Rooted in multi-faceted assessment and understanding of its typology and values, the design intervention answers to the Building's central courtyard while introducing contemporary, versatile insertions enhancing the building overall use and performance. The project reframes conservation as an active pedagogical and sustainable framework, linking heritage protection with capacity building and regional knowledge exchange.

Key Words: Adaptive Reuse, Architectural Intervention, Pedagogical Conservation.

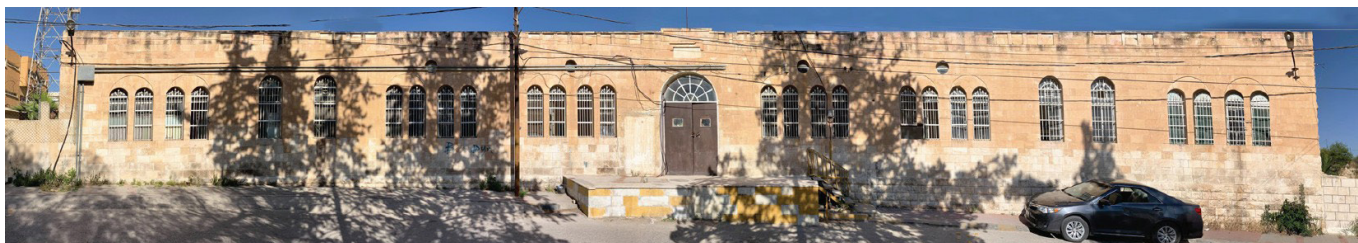
Introduction

The Regional Center for Conservation and Restoration in Jerash is a prominent training center that caters to Jordan and the region around. The Center incorporates theory, technology, and focuses on practical experience within its training goals while addressing conservation, restoration, maintenance, and management of archaeological and heritage sites.

It also treats and studies objects, works of art, and organic and inorganic artifacts within its specialized scientific and conservation laboratories, as well as conservation works conducted in situ. The Center hosts a library, multiple classrooms, and an archives room, in addition to offices and a management section.

Locating the Center within the adaptive reuse of an existing public building in Jerash establishes a powerful pedagogical framework for conservation training. Embedding the institution within a conservation context and interpretation culture enhances the capacity building, allowing restoration and conservation practices to be experienced not as abstract theory but as lived architectural reality. The intervention itself becomes the first lesson: upon arrival, trainees encounter a built example that demonstrates the principles of preservation, rehabilitation, and reuse for contemporary uses and materials. In this way, the architecture operates as both host and teacher opening tangible opportunities for learning, experimentation,

¹ The typology classification presented in this section was developed by Prof. R. Daher.

**Fig. 1**

Main Elevation: Subtle
Monumentality of Early
Modern Public Buildings.
Source: TURATH for
Studies & Design.

and critical engagement in the field of conservation across Jordan and potentially speculating what could have been done better.

The design of this adaptive reuse called for a cohesive design and heritage expertise.. Collaboratively, they have crafted a sensitive intervention, evoking the space potential, translating intended programs and policies into actionable steps. This approach ensures embracing heritage values, and the clear infusion of contemporary spirit into the project.

The project is the fruit of collaboration between the United Nations Office of Project Services (UNOPS), the Ministry of Tourism and Antiquities (MoTA), the Department of Antiquities (DoA) as the operator, and the Italian Agency for Development Cooperation (AICS) as the donor. Thus, the Regional Center for Conservation and Restoration was designed keeping in mind that it will serve as a hub for cooperation and communication in the field regionally. This enhances the level of knowledge exchange and communication by fostering a platform that hosts and indulges the cooperation between governmental bodies, the public heritage sector, private cultural heritage agencies, and universities².

1. Condition Assessment & Significance of the Building

The Center occupies a unique location in the Eastern part of the city of Jarash, where nearby are parts of the ancient City Wall and the ruins of a Byzantine Church, while overlooking the Western archaeological site of Jerash. The Center is the result of an adaptive reuse of a public building that dates to the early 1950s. The original building used to function as a governmental building serving Jerash directorate of security, the Jerash Road Police, and Jerash's Anti-Drugs Enforcement Agency. The Reuse Design kicked off with a full survey & documentation for the building and its surroundings. This included triangulated laser measurements for interior spaces cross-referenced with the total station survey maps. Together with detailed mapping

² RCCR Project Credits:
Conservation & Architectural Intervention Design: Turath for Studies & Design.
Conservation & Adaptive Reuse Advisor: Prof. Rami Daher.
Lead Designer: Jomana Baddad.
Team: Bashar Matar, Zainab Al-Rubaiei, Mazin Al-Khouja, Rasha Abu Shanab, Yassin Al-thbour, Mohammad Hayajneh.
Labs & Equipment Consultant: Dr. Ernesto Borrelli.
Structural Design: Odeh Bureau
Electromechanical Consultant: ACTIVE
Client: UNOPS
Donor: Italian Agency for Development Cooperation.
Key Institution & Operation: Department of Antiquities DOA Jordan.

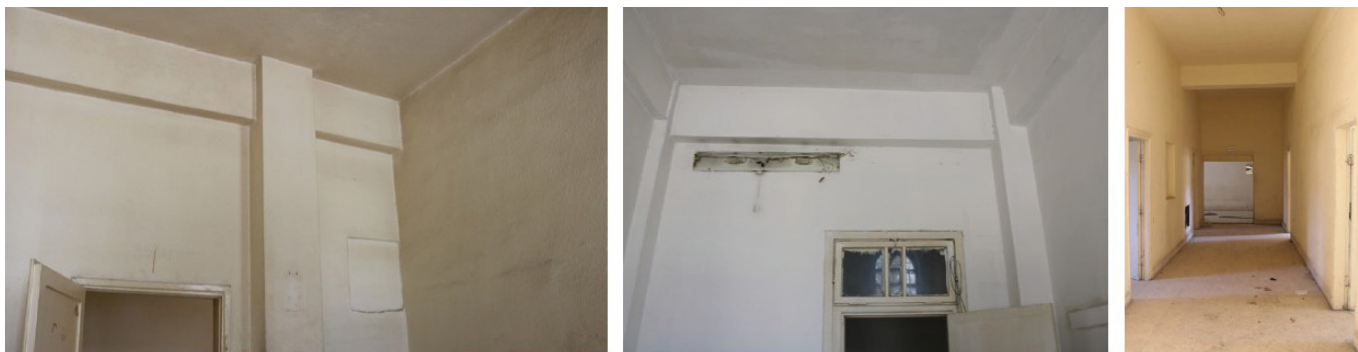


Fig. 2

Figure 2 Building
Existing Post-and-
beam structure. Source:
TURATH for Studies &
Design.

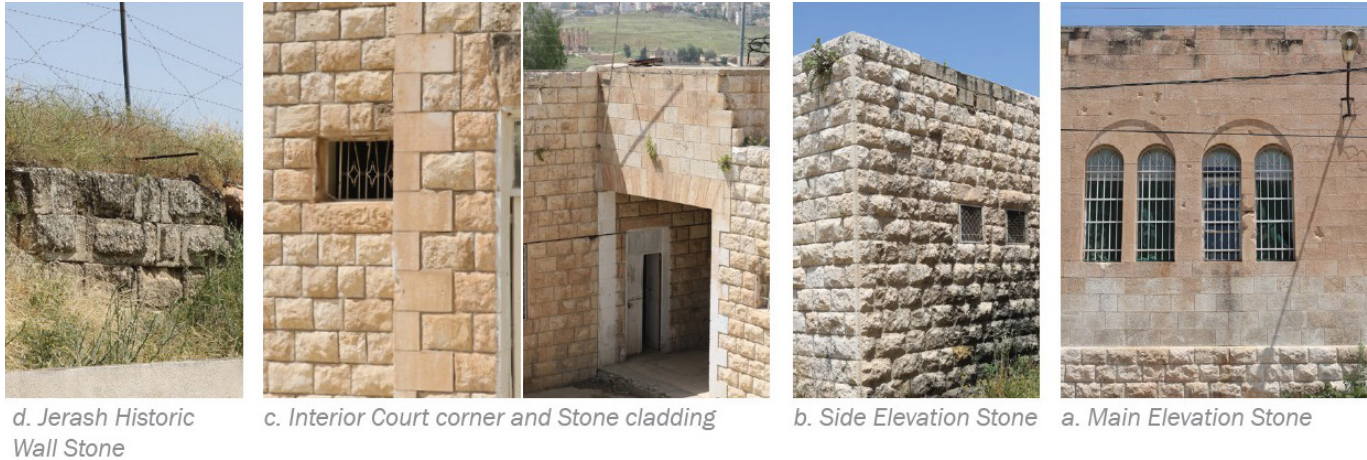
and documentation of openings, beams, interior and exterior features. This was followed by a comprehensive structural and stability assessment. Building electro-mechanical systems assessment for the existing and rehabilitation requirements was also conducted. Afterwards, gap analysis was done between needs identified by the client and stakeholders and standards and operations. This all contributed to concluding the intervention approach.

The building was originally functioning as a Police Office which was later abandoned. This has led to the building being in unsatisfactory condition due to the lack of maintenance but not critically deteriorated. However, access to the building was controlled. Therefore, the building needed no emergency interventions. However, all vulnerabilities and poorly preserved features have been addressed within the assessment phase which was followed by the appropriate levels of interventions. The initial structural assessment was based on visual inspections, core testing and mapping of problems. The outcomes indicated that there are no visible problems or defects in any of the structural elements in the main building. However, concrete samples had been taken for testing to inform the rehabilitation works. For example, the results informed the new addition hosting the multipurpose space and classrooms as the wall that reflected poor stability was demolished, so the space was enlarged and a new steel structure was introduced. The same applies for moments of structural stabilization when needed, i.e. the columns steel jacketing within the interior were designed as a remarkable feature of the interior. The extension building on the back side of the main building exhibited structural issues: visible structural problems in slab because of bad water insulation. Therefore, the extension building was demolished due to its low level of integrity and authenticity and to facilitate an adequate space that hosts the new functions.

The building's typology of a central courtyard, which serves as the focal point for all activities was thoroughly assessed. The court's significant trees dating back to the mid-20th century influenced the design of the open space. The additions to the building were integrated to interact with the courtyard preserving the original typology.

Architecturally, the building represents a particular typology. The RCCR building can be classified within the mid-20th-century Modern Public Architecture genre, a typology common to governmental and institutional buildings of that period. It is characterized by a subtle monumentality expressed in its proportional and symmetrical and rhythmic front elevation often contrasted by asymmetries in plan, massing, and spatial configuration.

Structurally, the building reflects the early transition toward post-and-beam systems using stone and concrete bearing walls combined with reinforced concrete drop beams.



Materially, the façade demonstrates a deliberate hierarchy using finely textured *Msamsam*³ stone on primary elevations and *Tobzeh*⁴ rough stone on secondary façades. Beyond its typological value, the building has architectural and historical significance, having served governmental functions associated with traffic and drug police operations. It also presents potential added value through adaptive reuse.

2. Design Approach

The adaptive reuse for the RCCR answers to the building's character and typological identity, while critically responding to its structural logic, material condition, and performance capacity. The intervention sought to equip the building with a renewed purpose one capable of accommodating a highly pedagogic contemporary program. Together, these considerations informed both nature and the level of intervention, ensuring continuity of heritage value alongside architectural evolution. This philosophy was embodied by gradient interfaces that maintained hierarchy among spaces while emphasizing the importance of the central court. Additions were introduced in distinct and light materials contrasting the existing attributes while having presence and introducing new spatial articulation within the court.

The intervention strategy was guided by two primary considerations: achieving programmatic integration within the existing architectural envelope and positioning the inner courtyard as the principal spatial driver of the design. The courtyard serves as the organizational core around which new insertions are structured. In areas where structural assessment recommended demolition, a new volume was introduced to accommodate multipurpose spaces and classrooms. This addition was carefully designed to preserve the original proportions of the courtyard by replacing opaque walls with transparent, operable glass façades that maintain visual and spatial continuity between indoor and outdoor accommodating larger audience activities.

³ Msamsam stone is characterized by its fine and small grain texture, with a lightly bush-hammered surface finish.

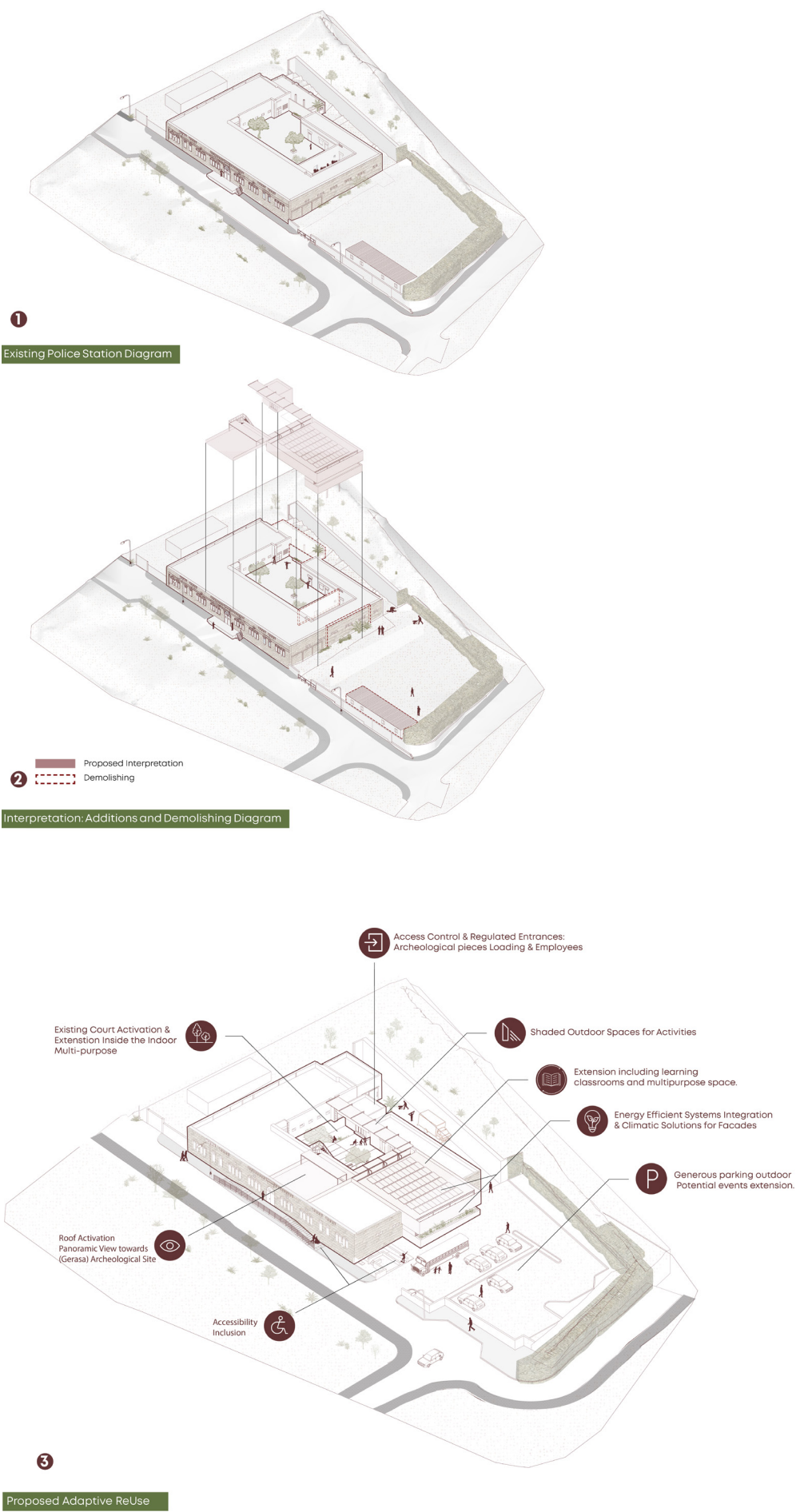
⁴ Tobzeh: Tabza stone features a hand-chiseled finish with a pronounced, rugged, and uneven surface texture.

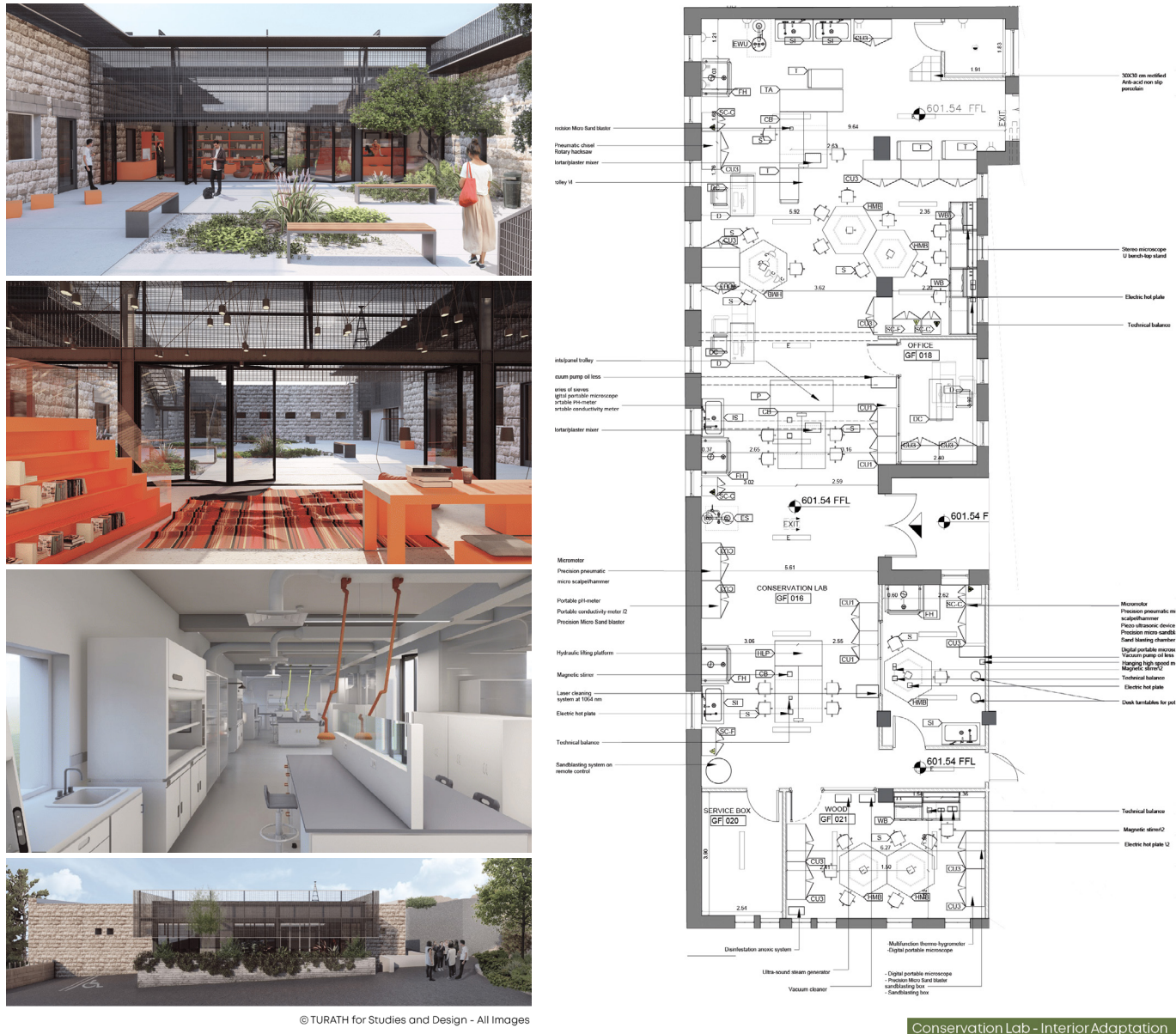
Fig. 3

Different Stone Textures within the Existing Building. Source: TURATH for Studies & Design.

Fig. 4
Intervention & Reuse
Design Diagrams: Source:
TURATH for Studies &
Design.

- 1. Existing Building
(Enforcement Agency).
- 2. Interventions:
Demolishing &
Additions.
- 3. Proposed Adaptive
Reuse.



**Fig. 6**

Design Proposal
Illustrations for the RCCR
(Left) Conservation
Lab Interior Design
& Adaptation, (Right)
Rendered Images for the
Proposed Intervention
Design.

A unified material envelops the courtyard, deployed in multiple configurations and scales. At one moment, it manifests as a cohesive functional mass where needed; at another, as a circulation spine that gently embraces the existing tree and leads upward to the roof terrace, where views extend toward the ancient city of *Gerash*⁵. In yet another articulation, it transforms into a lightweight canopy, casting playful shadows across the courtyard and improving its environmental comfort. Through this consistent yet versatile material strategy, the intervention preserves the identity of the courtyard while amplifying its spatial and environmental performance (Fig. 4). In addition to the specialized conservation and scientific laboratories, classrooms, and administrative facilities, a café was introduced within a room facing the courtyard. Extending toward the roof level, it activates the courtyard as a social interface and broadens the Center's engagement with a wider public. The proposed activities were adapted within the building, fostering high functionality and linkage between indoor and outdoor. This was a challenging

5 Jarash Roman City name.



4

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generator, as the sense of space and functions contradict the functional layout of the original building as an enforcement agency (Fig. 5-6).

The adaptation approach is based on maintaining a clear distinction between the original fabric and the new intervention. Any form of reconstruction resulting in conservation conjecture was avoided. The aim was to harmonize issues of authenticity and future consolidation and stabilization. The removal of the dividing wall within the court expanded the space, creating a generous and transparent multipurpose learning area that extends from the indoor to the outdoor environment.

The new addition generally enjoys a very contrasting body of materiality (metal contrasting stone), color (gray shades vs. yellowish stone and white plaster, grated texture (geometric meshes vs. tobzeh rough stone), open meshes vs. solid walls, exposed structural bracing vs. regular banal walls).

The design of the Regional Center for Conservation and Restoration was conceived as an exemplary model capable of redefining professional practice through the integration of heritage conservation, capacity building, and sustainable development. By situating the Center within the adaptive reuse of an abandoned public building in Jerash, the project positions conservation not merely as preservation, but as an active driver of socio-economic and institutional development. The architectural intervention establishes a living pedagogical environment in which archaeologists, conservators, technicians, and students engage directly with the built fabric, transforming the site into a platform for knowledge exchange at both individual and institutional scales.

Reusing the existing and abandoned building is the first call towards an environmental paradigm. From an environmental perspective, the Project has several positive impacts on the environment in terms of energy and water conservation. The adaptive reuse minimizes material consumption while preserving existing buildings and landscape assets, including mature trees that contribute

Fig. 7

RCCR Before & After
Images for Main Court,
Corridors, Labs & Rooms,
Entrance, Addition Mass.

Source: TURATH for
Studies & Design.



Fig. 8

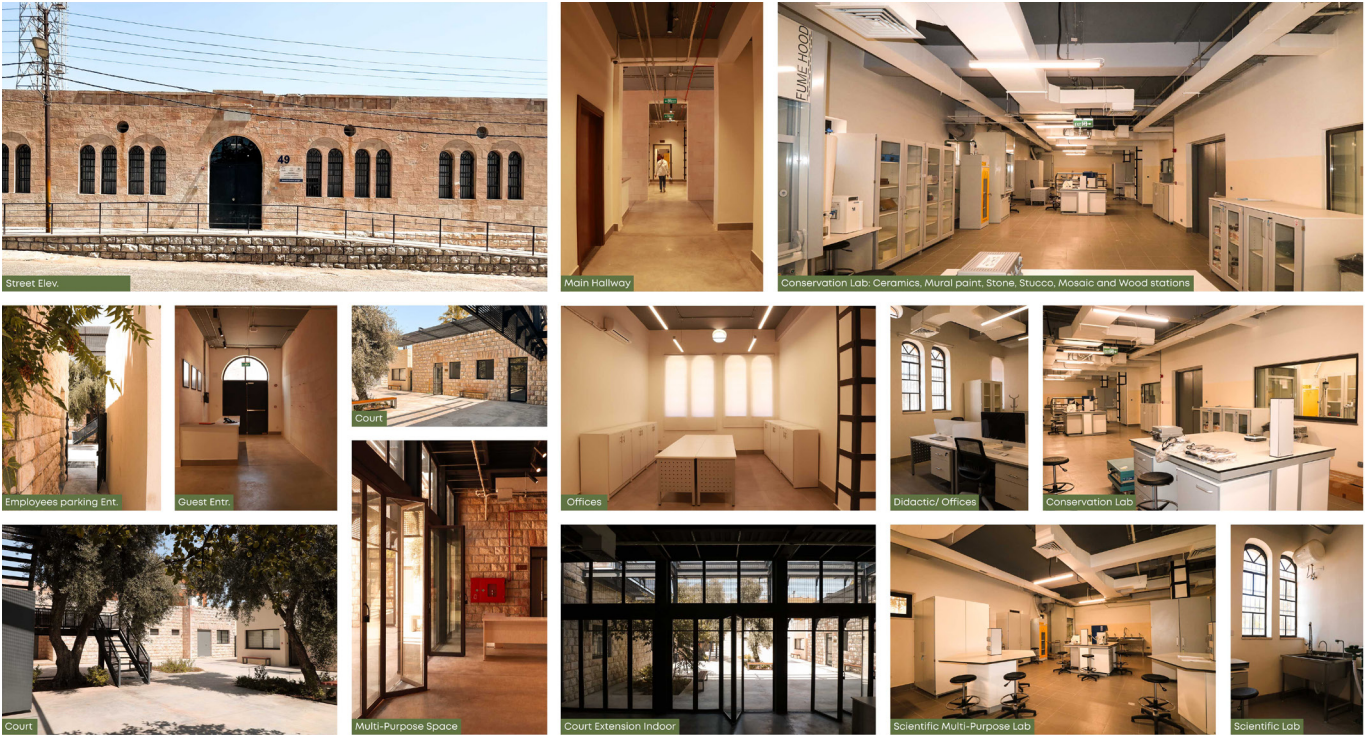
RCCR Adaptive Reuse
Exterior Images after
completion. Source:
TURATH for Studies &
Design.

to the site's ecological identity. Renewable energy systems such as rooftop and parking-shade photovoltaic panels combined with LED lighting, rainwater harvesting for irrigation and domestic reuse, and lightweight shading devices that enhance passive cooling while limiting mechanical loads. Laboratory waste is managed through controlled storage and off-site treatment in coordination with environmental authorities.

This Project highlights the role of heritage in achieving Sustainable Development Goals by utilizing existing assets for development endeavors as an alternative to the establishment of new structures. This adheres to the targets of Goal 11: Sustainable Cities and Communities. Mainly overarching targets 11.4 (Strengthen efforts to protect and safeguard the world's cultural and natural heritage) and 11.6: (By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management)⁶.

Beyond environmental performance, the design advances inclusive and plural practice. The Center integrates universal accessibility, seamless indoor-outdoor connections and is planned for a potential nursery facility that supports women's participation in training and employment. Moreover, universal accessibility was a guiding principle in architectural interventions. The redesigned spaces ensure that individuals with disabilities can access and participate in all Center activities. The connection between indoor and outdoor spaces creates an inclusive, welcoming environment that reflects the project's commitment to pluralism, empowerment, and sustainability at every level.

⁶ United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development* (Goal 11: Sustainable cities and communities). <https://sdgs.un.org/goals/goal11>.



2

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3

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on the previous page,
from top

Fig. 9

RCCR Adaptive Reuse
Exterior Images after
completion. Source:
TURATH for Studies &
Design.

Fig. 10

RCCR Before & After
Images for Main Court,
Exterior Facades. Source:
TURATH for Studies &
Design.

Fig. 11

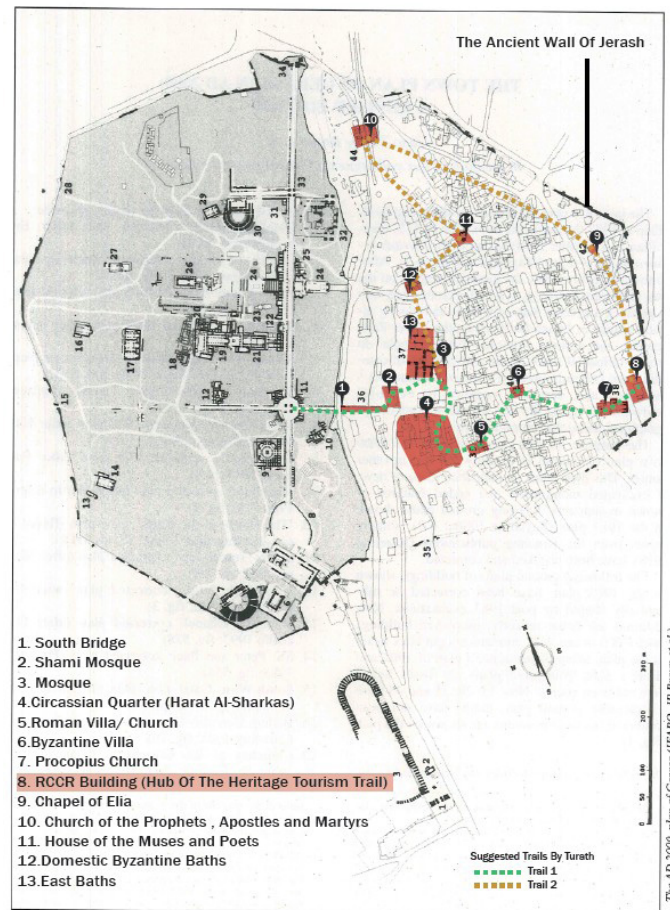
RCCR Design Preserving
Site Existing Trees (Left)
Existing Building, (Right)
Proposed Design after
Completion. Source:
TURATH for Studies &
Design.

in this page, on right,

Fig. 12

Suggested East Side
Gerasa Trail proposed
in RED Diagram
on Historical Map
including RCCR.
Original Map Source:
<https://publication.doa.gov.jo/Publications/ViewChapterPublic/688>.

The proposed design doesn't only preserve but embraces the valuable green cover on site including the evergreen trees and deciduous trees found (*Ailanthus altissima*, *Populus nigra*, *Citrus lemon*, *Cupresses sempervirens* – these trees date to the middle of the 20th century and are significant contributors to the characteristic of the Site – *Olea Europaea* – these olive trees are inside the court and provide shade). The design activation of the site draws a potential avenue to shed light on its context starting with the nearby significant archaeological sites in the Eastern Quarter of the City due to their proximity to the ancient Church and the Ancient Wall as this might provoke future conservation, protection, interpretation and presentation endeavors affecting these two archaeological Sites.



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Specialist Training in the Field of Restoration at the Regional Center for Conservation and Restoration in Jerash

Mario Micheli, Bilal Fawwaz Mohammad Alboreeni

Abstract: This paper traces the development of the previous experiences of the Italian cultural heritage restoration system implemented globally through capacity-building initiatives in the field of restoration. It also includes a report of the training project carried out at the Regional Center for Conservation and Restoration in Jerash (RCCR) within the framework of the project promoted by the Italian Agency for Development Cooperation (AICS) and entrusted to Roma Tre University for the benefit of the Department of Antiquities (DoA) of Jordan. When compared with the initiatives promoted by the Italian Cooperation in the People's Republic of China since the 1990s, the experience in Jerash represents a useful case study to further develop training models that can be replicated in other international cooperation settings.

Keywords: Restoration theory; *Istituto Centrale del Restauro*; *Istituto Italiano per il Medio ed Estremo Oriente*; Sino-Italian Training Center; Training of Trainers.

Introduction

International cooperation in the field of conservation and restoration of cultural heritage is one of the most complex and fruitful areas for comparison among different scientific traditions, theoretical models and cultural contexts. Over the course of the twentieth century, Italy progressively took on a leading role in this field, consolidating a methodological approach grounded in the essential blend of theory and practice, with a combination of historical-critical analysis and technical intervention. Analysing the cooperation between Italy and China – developed from the late 1980s onwards – is a good way to critically examine how this model is transferred, adapted and implemented in non-European contexts. This experience also provides a better understanding of the scope and future prospects of the latest initiative promoted by the Italian Agency for Development Cooperation: the Regional Center for Conservation and Restoration (RCCR) in Jerash, which was established in 2016.

1 The historical roots of Italy's leading role in restoration

The international reputation of Italian restoration is not the result of recent excellence, but rather the outcome of a long historical process. As early as the nineteenth century, the gradual separation of the restorer from the artist laid the foundations for an autonomous profession, based on specific skills and an increasing emphasis on the historical responsibility linked to restoration interventions. In the twentieth century, this process reached a significant turning point with the establishment of the *Istituto Centrale del Restauro* (ICR) in the 1930s in Rome. It was in this context that Cesare Brandi developed his theoretical work, the Theory of Restoration, which was translated into several languages (including Arabic) and is still one of the fundamental references in the current international debate. Rather than being seen as a mere technical operation of material renovation, restoration is defined as a critical act, aimed at recognising both the historical and aesthetic nature of a work of art. This approach, deeply rooted in the Italian philosophical and historical tradition, translates into an interdisciplinary training model, in which humanities and sciences contribute to the development of critical thinking. Adapting this model to different cultural contexts is exactly what characterised Italy's contribution to international cooperation following World War II.

Starting in the 1950s, ICR's international activities, strongly supported by Brandi, became part of a broader framework of cultural diplomacy promoted by international organisations such as UNESCO and, later, ICCROM. Foreign missions, initially focused on monumental and archaeological restoration, gradually expanded to include painting and sculpture, areas in which the 'Institute's method' achieved wide recognition¹.

At the same time, institutions such as the *Istituto Italiano per il Medio ed Estremo Oriente* (IsMEO), under the direction of Giuseppe Tucci, developed their own line of action in Asia and the Near East. In this context, restoration was closely intertwined with archaeological and historical-artistic research and led to the creation in 1954 of the so-called *Squadre di Restauratori Volanti* (Flying Restorers Teams), a special category of experts in the field of restoration. This was a pioneering attempt to implement cooperation projects abroad by properly training the restorers to be sent on site. The 30 experts who collaborated in the training at the RCCR in Jerash in the period 2023-2025 can be considered the direct descendants of the pioneers of the 1950s.

2 The Chinese Case: from Xi'an to Beijing

Starting from the 1980s, and more systematically after the enactment of Law No. 49 of 1987 on development cooperation, Italian intervention abroad in the field of cultural heritage protection and conservation recorded a growing focus on institutional strengthening and specialist capacity building in beneficiary countries through the professional development of restoration and conservation

¹ The international activity of the *Istituto Centrale per il Restauro* following World War II took the form of a genuine cultural strategy, in which restoration became a tool for dialogue and for Italy's scientific presence abroad. The missions of the Institute founded by Brandi in Egypt, Latin America and the Eastern Mediterranean testify the desire to combine direct intervention with the training of local technicians, although this approach only became systematic from the 1980s onwards.

experts. In the following decades, Italian Cooperation launched exemplary initiatives in the field of restoration and conservation of cultural heritage. Even in non-European settings, there was an increasingly strong need for updates in the restoration sector, as its complexity required skills acquired through programmes tailored to the needs of different cultural contexts.

Within this framework, cooperation with the People's Republic of China was developed. The request for collaboration made by the Chinese authorities at the end of the 1980s responded to the need to rapidly modernise a sector still characterised by predominantly empirical practices carried out by operators with uneven and often inadequate prior training. Italy was identified as a privileged partner precisely because of the soundness of its theoretical and educational model. The creation of the Center for the Conservation and Restoration of Historical and Cultural Heritage in Xi'an between 1995 and 1998 represented the first step in this process. Inspired by the ICR model, the Center introduced an interdisciplinary approach to restoration in China, thus enabling the training of the first group of restorers with a modern methodological approach.

The following launch of the Sino-Italian Training Center, inaugurated in 2004 at the China National Institute of Cultural Property in Beijing, marked a further leap in quality. The State Administration of Cultural Heritage (i.e., the central administration responsible for the country's entire cultural heritage sector, equivalent to Jordan's Department of Antiquities) asked for Italy's support to create a national centre for the training of conservators-restorers to be attended by staff already employed in various institutes, centres and laboratories throughout China. The Italian training model was adapted to the specificities of the Chinese context through theoretical courses, labs, workshops and, above all, programmes tailored to the training of trainers (ToT). The balance between Italian and Chinese lecturers and the sharing of methodological choices were among the most innovative elements of that experience².

For the purpose of showing the analogy with the recent case of the RCCR in Jerash, it should be noted that, in 2023, during the start-up phase of the training project entrusted by the Italian Agency for Development Cooperation (AICS) to Roma Tre University, the Department of Antiquities of Jordan requested that the activities necessary for the launch of the RCCR be focused on the training and professional updating of staff in the various units of the institution.

3 Training Project in Jerash: Structure, Methodology and Results

3.1 Institutional Framework and Project Objectives

The project carried out at the RCCR is part of the cultural cooperation policies promoted by AICS, with the objective of strengthening local skills for the

² The comparison between the Italian approach to restoration and the Chinese setting highlighted the significant differences existing between Western and Eastern concepts of authenticity. In particular, these long-term cooperation initiatives encouraged the Chinese tradition, historically oriented towards ongoing functionality and material renovation of works, to deal – with a critical approach – with the Western focus on original materials and their conservation. This dialogue allowed for a non-dogmatic reinterpretation of Brandi's theory, highlighting its methodological rather than normative nature.

protection and conservation of cultural heritage. The project is based on the idea that the conservation of Jordan's archaeological heritage, characterised by very complex material and often critical environmental conditions, requires not only proper infrastructures but, most of all, highly specialised professional skills. Therefore, training is conceived as a strategic tool for the strengthening of institutions, aimed at creating a stable group of conservators capable of operating according to internationally recognised methodological and scientific standards.

3.2. Structure of the Education Programme

The implemented programme had a duration of two years and was structured in two complementary phases. The first year was focused on the intensive specialist training of DoA staff through the simultaneous activation of two main courses, organised according to the categories of materials and types of artefacts most commonly found at Jordanian archaeological sites. The first course focused on the conservation and restoration of movable artefacts, with particular reference to ceramics, metals, glass and organic materials. The second course addressed the conservation of immovable heritage and decorated architectural surfaces, including stone materials and mosaics. This structure reflected criteria of consistency between the training content, the organisation of the RCCR laboratories and the operational needs of the DoA. The second year of the programme was aimed at enhancing the acquired skills and their implementation through two workshops and advanced didactic units, with particular attention to the training of trainers (ToT) model, all with the aim of ensuring continuity in capacity-building activities and the progressive methodological and operational autonomy of the RCCR.

3.3 Teaching Methodology and Operational Approach

The teaching methodology adopted was based on an integrated approach characterised by closely interconnected theoretical and practical components oriented towards laboratory practice on real artefacts, which were treated as case studies used by participants to develop critical analysis and problem-solving skills. The theoretical lectures focused on the methodological, technological and scientific aspects essential to understand constituent materials, degradation processes and possible intervention strategies. Particular emphasis was placed on documentation as a cognitive and decision-making tool, as well as on the use of both invasive and non-invasive diagnostic investigations for the definition of conservation interventions.

Laboratory teaching, which was quantitatively predominant over classroom teaching at the express request of the DoA, enabled participants to master their ability to critically assess the effectiveness of interventions and the compatibility of the materials and methodologies used.

The materials used included original archaeological artefacts from the DoA's deposits, selected on the basis of their state of conservation and educational potential. Intervention methods were defined on the basis of shared protocols inspired by the principles of minimum intervention, reversibility and material compatibility. The procedures included careful visual analysis, photographic documentation, graphic and digital recording of historical and technical information as well as

information regarding the state of conservation, essential diagnostic investigations (optical microscopy and preliminary physical-chemical tests) and monitoring of environmental conditions.

The adopted operational procedures included controlled mechanical and chemical cleaning, consolidation, fragment bonding and surface protection, selected on the basis of the characteristics of the materials and the conditions of deterioration. Particular attention was paid to assessing the short- and medium-term effects of the treatments through comparative observations and systematic recording of the results. All the activities were carried out in the RCCR laboratories using the equipment obtained during the establishment of the RCCR³ and special tools and materials acquired during the implementation of the project entrusted to Roma Tre University.

3.4 Interdisciplinary Didactic Units and Cross-Disciplinarity

The programme therefore included interdisciplinary didactic units common to the two parallel courses, dedicated to conservation science, health and safety in laboratories, non-invasive analytical techniques, graphic and digital documentation, and the use of advanced technologies, such as laser systems for surface cleaning⁴. These units contributed to creating an interdisciplinary training framework in which the conservator operates as a synthesising figure, combining manual skills, scientific knowledge and design skills. The approach adopted reflected a vision of conservation oriented towards prevention, planned maintenance and the sustainability of interventions.

³ See E. Cabasino in the volume; J. Baddad in the volume. The design of RCCR's technical and scientific structures and the technical specifications of the equipment and materials were entrusted by UNOPS and the AICS headquarters in Amman to the Italian expert Dr Ernesto Borrelli. An initial professional development programme had been previously drawn up by architect Donatella Cavezzali.

⁴ The teaching activities covered a wide range of specialist areas, reflecting the complexity of the cultural heritage conservation and restoration sector. The didactic units were as follows:

Course 1: 1.1. Conservation and restoration of ceramics and pottery. 1.2. Advanced techniques for the treatment and conservation of ancient metals. 1.3. Conservation of organic materials, such as wood, textiles and leather. 1.4. Conservation and restoration of historic glass. Course 2: 2.1. Conservation techniques for stone. 2.2. Interventions on decorated architectural surfaces. 2.3. Mosaics: Conservation and restoration of ancient mosaics. Common modules: 3.1 Science in Conservation: Introduction to scientific methodologies applied to conservation. 3.2 Safety and first-aid in restoration sites. 3.3 Non-invasive diagnostic analyses applied to cultural heritage. 3.4 Advanced graphic documentation for restoration. 3.5 Use of laser systems for the restoration of cultural heritage. 3.6 Study and conservation of geological materials. 3.7 Approaches to the management of biodeterioration and the enhancement of cultural heritage. In the second year, new specialisation units were organised: 1.1 3D analysis and documentation of archaeological artefacts and sites. 1.2 Advanced level course on archaeological metals conservation and restoration. 1.3 Advanced level course on glazed ceramics conservation and restoration. 1.4 Launch of the RCCR Scientific Laboratory through training activities on chemistry, geology and biology applied to conservation.

3.5 Selection of Lecturers and Participant Profile

Lecturers were selected on the basis of strict scientific and professional criteria, giving priority to conservator-restorers with proven experience in managing complex interventions and training activities, as well as to specialists in scientific disciplines applied to cultural heritage. The involvement of lecturers from public conservation institutions, universities and research centres contributed to ensuring a high qualitative standard⁵.

Participants were selected by the DoA and included both staff already permanently assigned to the RCCR and staff from other sections of the DoA distributed throughout the country. The aim was to maximise the project's impact on the national conservation system, promoting skills dissemination and the creation of a qualified professional network⁶.

3.6 Training of Trainers and Sustainability of the Model

The second year of the programme was focused on the 'Training of Trainers', which was designed to enable the trained staff to progressively become independent in the planning and implementation of further training activities. This approach aimed at ensuring the sustainability of the project and the continuity of RCCR activities beyond the duration of the project entrusted to Roma Tre University.

3.7 The Workshops

3.7.1 The Stone Conservation Workshop

In 2024, one of the four plinths of the southern *tetrapylon* of Jerash, presumably a *tetrakionion*, became the focus of the first workshop, which dealt with the conservation and restoration of stone materials and was carried out in the autumn of the second year of the project⁷.

⁵ In total, 30 Italian experts – selected from among the best in the country – contributed to the on-site training at the RCCR: Laura Bartoli, Massimo Brizzi, Cristina Caldi, Maria Cristina Caggiani, Giulia Caneva, Marco Cardinali, Gianmarco De Felice, Giancarlo Della Ventura, Martina Fagioli, Manuela Faieta, Vasco Fassina, Luciana Festa, Annamaria Giovagnoli, Elisabeth Huber, Sara Iafrate, Francesca Mariani, Mario Micheli, Sokol Muca, Nicola Pagani, Cristina Passeri, Carlotta Sacco Perasso, Elisabetta Prunas, Jacopo Russo, Alex Sarra, Sofia Schiattone, Sara Scioscia, Tessa Pirillo, Giulia Simonelli, Nikolas Vakalis, Yijia Shen.

⁶ The Jordanian participants in the training activities: Bilal Fawwaz Mohammad Alboreeni, Qais Azmi Radwan Almomani, Tasneem Aamar Ahmad Al-Bataineh, Mohammad Ali Mustafa Alalawneh, Rita Sulaiman Yusef Al Dawood, Marshwd Alwan Hussein Ad-Doojan, Tamam Khaled Abedalqader Almjghef, Mohammad Hasan Abdul Kareem Albanna, Baker Yasin Abdallah Alzawahreh, Wlla Ibrahim Issa Etoom, Oaima Ahmed Naser Fodeh, Ahmad Lorans Melaihan Hammour, Najdat Mamoon Abd Alra'oof Hazaimh, Mustafa Mahmoud Srou Hawamdeh, Hussein Mohammad Mahmoud Krashat, Eman Suleiman Muflih Quran.

⁷ Cfr. S. Muca, L. Festa, N. Vakalis, in the volume.

In the initial phase of the workshop, participants took part in the planning of the intervention that would then be carried out on the monument. They played an active role in the entire sequence of operations, from topographical survey to graphic documentation of the state of conservation, as well as the assessment of biodeterioration, followed by the selective removal of concrete additions, treatment of metal elements, and differentiated cleaning (i.e., mechanical, chemical and laser). The entire process ended with the consolidation of the stone surfaces and the repointing of joints using mortars made of natural hydraulic lime, that allowed to stabilise the surfaces and facilitate their visual interpretation.

This first workshop was intended to foster group work among participants, bringing together different but interdependent skills among the various members, while having a positive effect on each participant's professional growth.

The teaching activities were carried out by lecturers Luciana Festa, Nikolas Vakalis and Sokol Muca. Both groups from Courses 1 and 2 took part in the workshop to ensure the professional development of conservator-restorers through team-based work.

3.7.2 The On-Site Mosaic Conservation Workshop

For the second workshop, intended solely for participants in Course 2, the choice fell on the mosaic of the *Diaconia* of the Church of the Propylaea in the Archaeological Site of Jerash. The mosaic is dated 565 AD and is the only surviving mosaic pavement of the church. The perimeter wall that formed the *diakonia* showed significant structural issues, which were then thoroughly assessed to outline possible intervention proposals⁸. Among the various teaching activities, a thorough reconstruction of the conservation history was carried out, revealing a discontinuous sequence of events from the moment of discovery onwards. This analysis made it possible to distinguish original alterations from subsequent changes and to critically assess the effects of previous restoration interventions, at times carried out using incompatible materials or invasive methodologies. The intervention carried out within the framework of the workshop was therefore structured according to the principles of minimum intervention, material compatibility and reversibility, and consisted in controlled cleaning operations, structural consolidation, removal of inappropriate grouting, filling of gaps and restoration of mosaic cohesion⁹.

The workshop was held during the period September–November 2025 under the guidance of Sokol Muca and Tessa Pirillo, with the collaboration of Sofia Schiattone and Giulia Simonelli. The implementation of temporary measures for structural stabilisation was coordinated by Professor G. de Felice, Roma Tre University.

3.7.3 The Launch of the RCCR Scientific Laboratory

In the second half of 2025, a specific training plan was implemented for the professional development of the two RCCR staff members entrusted with the

⁸ Cfr. F. C. Stan, M. Bocci, S. Fares, Najdat M. Hazaimh, Tasneem Al-Bataineh, Malena, Meriggi, De Santis, de Felice in the volume.

⁹ Cfr. S. Muca, T. Pirillo, in the volume.

Scientific Laboratory of the centre. Three specialised training modules were provided, and they focused on the three areas of applied sciences for restoration and conservation that had already characterised the laboratory's initial set-up project: applied chemistry, applied geology and applied biology¹⁰.

4 Prospects for the RCCR

The core of the RCCR project, conceived by Michele Morana, former Director of the AICS office in Amman in 2016, was creating a centre that would focus not only on the national context but also on the region itself. For the RCCR to be completely independent from an operational standpoint and capable of implementing initiatives that could benefit other countries in the MENA region (i.e., Middle East and North Africa), the Department of Antiquities of Jordan will be required to take further steps forward, including – most importantly – the consolidation of a network of relations between the RCCR and Jordanian universities particularly engaged in the field of cultural heritage, as well as relations with national and international research centres (such as SESAME, Synchrotron-Light for Experimental Science and Applications in the Middle East, in Allan)¹¹. It will also be beneficial to keep collaborating with the extensive network established by Roma Tre University, which also involved the Istituto Centrale per il Restauro. As a matter of fact, such network provided the RCCR with 30 distinguished experts, who conducted activities within the RCCR over a period of two years, thus contributing to its development. A gradual increase in staff numbers, in line with a short-, medium- and long-term development plan, will be crucial to achieving full operational capacity at the RCCR. Finally, it will be necessary to ensure a future phase of technical assistance, to be gradually reduced to achieve the centre's full independence and promote its operations, also for the benefit of the wider regional context.

5 Conclusions

The capacity-building project implemented at the Jerash RCCR represents an important case study for analysing the evolution of teaching models in the field of conservation and restoration within the framework of international cooperation. From a scientific perspective, the RCCR experience offers valuable insights to define strategies that may be replicated in other contexts characterised by rich and vulnerable heritage, confirming the central role of training in the creation of effective and sustainable conservation systems.

The results were achieved thanks to the contribution of an extensive network of

¹⁰ The three modules have been assigned to Prof. Vasco Fassina (Chemistry), Prof. Maria Cristina Caggiani (Geology) and Prof. Carlotta Sacco Perasso (Biology) for the benefit of chemists Dr Oaima Ahmed Nasir Fodeh and Dr Mohammad Hasan Abdul Kareem Albanna. These modules complemented the sciences modules extended to all participants in the training programme delivered between 2023 and 2024 by Profs. Annamaria Giovagnoli, Giulia Caneva, Giancarlo Della Ventura and Marco Cardinali.

¹¹ Cfr. Qais Azmi Radwan Almomani, Yasmin Fouad Ahmad Al-Moussa Walweel, in the volume.

institutions and individuals, to whom we express our deepest gratitude¹².

The comparison between the interventions implemented by Italian Cooperation in the field of restoration in China between 1995 and 2010 and the creation of the RCCR in Jerash, with its launch through the professional qualification plan implemented by Roma Tre University, clearly shows that the transfer of skills cannot be reduced to the mere export of techniques, but shall be based on a deep dialogue between cultural traditions and solid theoretical awareness. The strengthening of local institutions, the creation of professional networks and the enhancement of heritage as a cultural and social resource represent the most enduring outcomes of these two experiences – distant from one another in time and space, yet closely in line in terms of challenges and achievements.

Looking ahead, the comparative analysis of the case studies in China and of the RCCR in Jerash, Jordan, offers valuable guidance to reshape the role of cooperation in the field of cultural heritage conservation, confirming the importance of an approach to restoration as a historical-critical act and an ethical practice.

¹² S.E. Emad Hijazeen, Minister of Tourism and Antiquities of Jordan; S.E. Luciano Pezzotti, Italian Ambassador in Amman; Marco Riccardo Rusconi, Director-General, Italian Agency for Development Cooperation; Massimiliano Fiorucci, Rector, Roma Tre University; Fawzi Abu Danneh, Director-General, Department of Antiquities of Jordan; Emilio Fralleone e Giorgio Bassotti, Italian Embassy in Amman; Michele Morana, Emilio Cabasino, Roxane Weber, Michele Romano, Directors of AICS Office in Amman; Luigi Oliva, Director, Istituto Centrale per il Restauro; Bilal Fawwaz Mohammad Alboreeni, Director, Regional Center for Conservation and Restoration of Jerash – RCCR; Qais Azmi Radwan Almomani, Director Assistant, RCCR; Andrea Purgatorio, RAI Teche; Alessandra Blasi, AICS Amman; Paola Abenante, Tiziana De Gennaro, Team Culture & Development, AICS; Raed Hussain, AICS Amman; Alessio Agresta; Jomana Baddad; Martina Bocci; Paola Boncompagni; Ernesto Borrelli; Donatella Cavezzali; Carolina Ceci; Aisha Mahmoud; Franco Sciorilli; Aktham Oweidi Abbadi, Sasha Abzakh, Fadi Balawi, May Hweidy, Yasmin Walweel, Department of Antiquities of Jordan; Rula Al Dweikat, BlueRay Solutions, Amman; Abdelhamid Trabelsi, Abdullah Ali Abdullah Abu Al-Adas, Malek Mahmoud Mohammad Alqaisi, Ihsan Abdul Jabbar Ibrahim Badran, Fuad Hassanat, Mahmoud Bani Mustafa, Ahmad Bani Mustafa e Mahmoud Alzاهر.

The project was carried out thanks to the direct and ongoing commitment in Italy of the Rector, the Director-General and the Director for Internationalisation, Knowledge Valorisation, Orientation and Department Administration at Roma Tre University, as well as 37 administrative staff members: Nicole Biondi, Alberta Cardillo, Giuseppe Colapietro, Luigi Di Carlo, Fabio Lo Casto, Alessandro Peluso, Adina Maria Pop, Giovanni Renzullo, Tomas Sancioni, Gabriella Ali, Rosetta Bellissimo, Chiara Buzzi, Virginia Camera, Lavinia Ciambrone, Monia Czech, Francesca Di Giorgio, Valeria Formaggi, Stefania Giuliano, Fabiana Giustibelli, Franca Iannaccone, Serenella Laforgia, Federica Locarno, Luca Lottini, Roberta Alessandra Mattioni, Daniela Mettimano, Roberta Mettimano, Mirella Parlato, Paolo Pierangeli, Jelka Pibiri, Lucilla Quartararo, Sonia Quarticelli, Daniele Rossi, Valentina Savini, Alessandro Silva, Alessandro Spera, Paola Tedesco, Angela Turchini.

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The Network of Universities and Research Institutions in Jordan: Strategic Support for the Regional Center for Conservation and Restoration (RCCR), Jerash

Qais Azmi Radwan Almomani, Yasmin Fouad Ahmad Al-Moussa Walweel

Abstract: This chapter analyzes the network of universities, research institutions, governmental bodies, scientific infrastructures, and international organizations engaged in cultural heritage conservation in Jordan. It examines the contributions of key academic institutions, national authorities, international research centers, and advanced scientific facilities, including SESAME. The chapter highlights the strategic role of the Regional Center for Conservation and Restoration (RCCR) in Jerash as a coordinating hub that integrates research, training, and applied conservation practice to strengthen national capacity and enhance Jordan's regional leadership in heritage preservation.

Keywords: Cultural heritage conservation; Jordan; Regional Center for Conservation and Restoration (RCCR); Universities and research institutions; Heritage science; Synchrotron-light for Experimental Science and Applications in the Middle East; International cooperation.

Introduction

Jordan occupies a distinguished position in the cultural heritage landscape of the Middle East, preserving an exceptional concentration of archaeological sites, historic cities, religious monuments, vernacular architecture, and cultural landscapes spanning prehistoric, classical, Islamic, and modern periods (Abu-Khafajah, 2014; Adams, 2008; UNESCO, 1972). This richness places Jordan at the center of regional and international heritage research, while simultaneously confronting the country with complex conservation challenges, including environmental stress, climate change, urban expansion, mass tourism, and limited technical and financial resources (De la Torre, 2013; Fatorić & Seekamp, 2017; ICCROM, 2018).

The establishment of the Regional Center for Conservation and Restoration (RCCR) in Jerash represents a strategic national and regional initiative. Conceived as a hub for research, training, and professional exchange, the RCCR aims to advance scientifically grounded conservation practices and foster regional cooperation in cultural heritage preservation. Its long-term effectiveness depends on its integration within Jordan's broader academic, scientific, and institutional ecosystem (ICOMOS, 1964; ICCROM, 2018).

Jordan hosts a dense and diverse network of universities, research institutions, governmental authorities, and international organizations actively engaged in archaeology, conservation, architecture, materials science, and heritage management. This chapter maps that network and examines its potential to provide strategic support to the RCCR, positioning the Center as a coordinating platform linking research, policy, and practice.

1 Universities in Jordan Relevant to Archaeology and Cultural Heritage Conservation

1.1 The University of Jordan

The University of Jordan, the country's oldest and most comprehensive public university, plays a foundational role in heritage scholarship. Its Faculty of Archaeology and Anthropology offers programs in archaeology, conservation, and cultural heritage management, supported by sustained field research and academic publications. Complementary expertise in chemistry, physics, geology, and engineering strengthens its capacity for scientific approaches to conservation (University of Jordan, n.d.). Potential collaboration with the RCCR includes joint postgraduate programs, shared laboratory facilities, co-organized training courses, and collaborative research projects.

1.2 Yarmouk University

Yarmouk University is internationally recognized for its Faculty of Archaeology and Anthropology, which has contributed significantly to archaeological research, heritage documentation, museum studies, and heritage policy development in Jordan and the Levant (Yarmouk University, n.d.). Its extensive fieldwork and methodological rigor provide strong foundations for conservation practice. Cooperation with the RCCR may include joint conservation field schools, development of documentation and site-management standards, and professional training for archaeologists and conservators.

1.3 The Hashemite University

The Hashemite University contributes to heritage conservation through programs in archaeology, earth sciences, environmental science, and information technology. Its strengths in GIS, remote sensing, and environmental monitoring are critical for preventive conservation and landscape-scale heritage management (MoHESR, n.d.). Potential collaboration includes GIS-based heritage risk assessment projects, climate change impact studies, and digital documentation initiatives coordinated with the RCCR.

1.4 Jordan University of Science and Technology (JUST)

JUST provides advanced scientific and technological expertise relevant to conservation science, particularly in analytical chemistry, materials science, nanotechnology, imaging technologies, and environmental engineering (MoHESR, n.d.). Its scientific capacity is essential for diagnostic conservation research, materials characterization, and development/testing of conservation treatments. Collaboration with the RCCR may include joint research projects and training in scientific diagnostic methods.

1.5 Al-Balqa Applied University

Al-Balqa Applied University emphasizes applied sciences and technical education across a nationwide network of colleges. Its vocational orientation aligns closely with the practical needs of heritage conservation, including traditional craftsmanship, site maintenance, and technical conservation skills (MoHESR, n.d.). Cooperation

with the RCCR can involve technician training programs, certification courses, and applied workshops in traditional building materials.

1.6 German Jordanian University

The German Jordanian University integrates applied research with international academic cooperation, particularly in architecture, urban planning, and engineering. Its institutional links with German universities facilitate knowledge transfer and innovation in conservation practice, including adaptive reuse of historic buildings (German Jordanian University, n.d.). Collaboration with the RCCR may include conservation-oriented design studios, research projects, and technical exchange programs aligned with European conservation standards.

1.7 Private Universities

Private universities such as Middle East University, Al-Zaytoonah University of Jordan, Philadelphia University, and Jadara University contribute programs in architecture, interior design, civil engineering, and information technology. These programs provide supporting skills essential for architectural conservation, digital documentation, and heritage-related design projects (MoHESR, n.d.). Collaboration may include student internships, heritage-focused graduation projects, and continuing professional development courses coordinated by the RCCR.

2 National Heritage Institutions and Research Centers

2.1 Department of Antiquities of Jordan (DoA)

The DoA is the primary governmental authority responsible for archaeological heritage protection, excavation permits, site management, conservation, and museums. Cooperation with the RCCR is critical for aligning conservation standards, implementing joint training programs, and coordinating national site interventions (Department of Antiquities of Jordan, n.d.).

2.2 Royal Scientific Society (RSS)

RSS provides laboratory testing, materials analysis, environmental monitoring, and quality assurance across multiple sectors. Its multidisciplinary scientific capacity supports evidence-based conservation, including the analysis of heritage materials and environmental risk assessments (Royal Scientific Society, n.d.).

2.3 Petra Development and Tourism Region Authority (PDTRA)

PDTRA manages the Petra World Heritage Site, addressing conservation, visitor management, risk mitigation, and sustainable tourism (PDTRA, n.d.). Its expertise offers valuable lessons and training opportunities for World Heritage site management in collaboration with the RCCR.

3 International Research Institutes

International research institutes in Jordan significantly enhance the country's heritage research environment. ACOR supports archaeological and architectural research through fellowships, excavations, and publications, integrating Jordanian research into global scholarly networks (ACOR, n.d.). The British Institute in Amman promotes interdisciplinary research in archaeology, history, and cultural landscapes (British

Institute in Amman, n.d.), while the German Protestant Institute of Archaeology conducts long-term architectural and urban research in Jordan. Cooperation with the RCCR includes joint research projects, fieldwork, and academic exchange.

4 Advanced Scientific Infrastructure: SESAME

SESAME provides advanced, non-destructive analytical techniques essential to heritage science, including elemental analysis and high-resolution imaging of archaeological and historic materials (Janssens et al., 2012; SESAME, n.d.). Collaboration with SESAME enables the RCCR to integrate cutting-edge scientific diagnostics into conservation practice, positioning Jordan as a regional hub for heritage science.

5 International Organizations and Development Cooperation

UNESCO, ICCROM, and ICOMOS provide normative frameworks and professional guidance for conservation practice worldwide (ICOMOS, 1964; ICCROM, 2018; UNESCO, n.d.). The Italian Agency for Development Cooperation (AICS) supports cultural heritage projects in Jordan and the Middle East, emphasizing capacity building, site protection, and socio-economic development integration. Collaboration with the RCCR can strengthen applied conservation initiatives and regional programs (AICS, n.d.). JICA also contributes technical assistance, expert exchange, and institutional capacity building (JICA, n.d.).

6 Strategic Role of the RCCR

The RCCR functions as a coordination hub linking universities, research institutions, governmental authorities, and international organizations. By integrating research, training, and applied conservation practice, the RCCR can convert fragmented national capacities into a coherent, sustainable conservation system aligned with international standards.

7 Conclusion

Jordan's universities, research institutions, governmental bodies, advanced scientific infrastructures, and international organizations collectively form a comprehensive ecosystem for heritage conservation. The RCCR in Jerash can serve as the integrative core of this ecosystem, fostering structured cooperation, shared research agendas, and coordinated training programs to enhance national capacity and regional leadership in cultural heritage preservation.

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Digital Documentation Applied to Restoration: Photography, Stereophotogrammetry and GIS in a Training Programme in Jordan

Jacopo Russo

Abstract: This paper describes a training programme on documentation applied to restoration, implemented in Jordan and intended for practitioners with diverse professional backgrounds. The lectures and workshops covered the entire process: controlled photography (light, exposure and colour using a colour checker), projective geometry, direct survey and stereophotogrammetry with Metashape, the production of orthophotos and DEMs, and finally the integrated management, in QGIS, through an application containing raster, vector and alphanumeric data for maps and analyses that are replicable and verifiable.

Keywords: Stereophotogrammetry, Orthophoto, QGIS, GeoPackage.

Introduction

The teaching component on documentation consisted in a course intended for practitioners with different professional backgrounds and aimed to provide a general methodological framework that can be adapted and applied to various contexts. Recognising that documentation as a whole involves tasks entrusted to specific professionals, the aim was to show, through example projects and practical experience, how to compile scientifically reliable and comprehensive documentation starting from physical object. The programme addressed photography, direct and indirect survey with a focus on photogrammetry, the production of orthophotos and the integrated management of raster, vector and alphanumeric data within a GIS.

When it comes to conservation projects, those involved in documentation are sometimes familiar with some of the practical tools used in this work, but often lack an overview of the entire process. In fact, a conservator typically produces thematic vector maps (traditionally using CAD tools) on a scale-corrected orthophoto provided by the survey team, but is not fully aware of how that image was produced. Similarly, the person producing such maps may not be aware of how data can (or cannot) be processed at a later stage, such as in overlay analyses aimed at identifying the co-occurrence of different forms of deterioration, or



Figs. 1, 2

Photographs taken in the laboratory using flash lighting and light modifiers. Colour was calibrated using an absolute reference (ColourChecker).

in the extraction of quantitative data needed to estimate complex conservation interventions based on pilot sites and to support the management of a restoration project accounting. The way in which documentation is produced changes significantly when there is a clear understanding of the intended objectives.

It is not uncommon for those starting out in this field to have some prior experience: most people have taken photographs, and many have used one software programme or another, yet their understanding of these tools is often partial. A sound grasp of how they actually work is essential if they are to be used in an informed way – be it equipment, software or a working method – so as to produce scientifically reliable results.

In anticipation of a future workshop at the archaeological site – which was not yet active at the time of the course – the practical exercises were carried out on small-scale objects: in the laboratory and on a section of an ancient wall on the centre's grounds, in order to simulate, on a small scale, the workflows and typical challenges involved in site survey and documentation. These hands-on activities were accompanied by classroom presentations of highly complex restoration projects in which documentation played a central role. It is worth bearing in mind that “a large project is a series of small projects”: that is, even in a small-scale study and conservation project, nothing should be taken for granted, and it is essential to adopt the best practices typical of more complex interventions.

1 Photographic recording: light, exposure and colour control

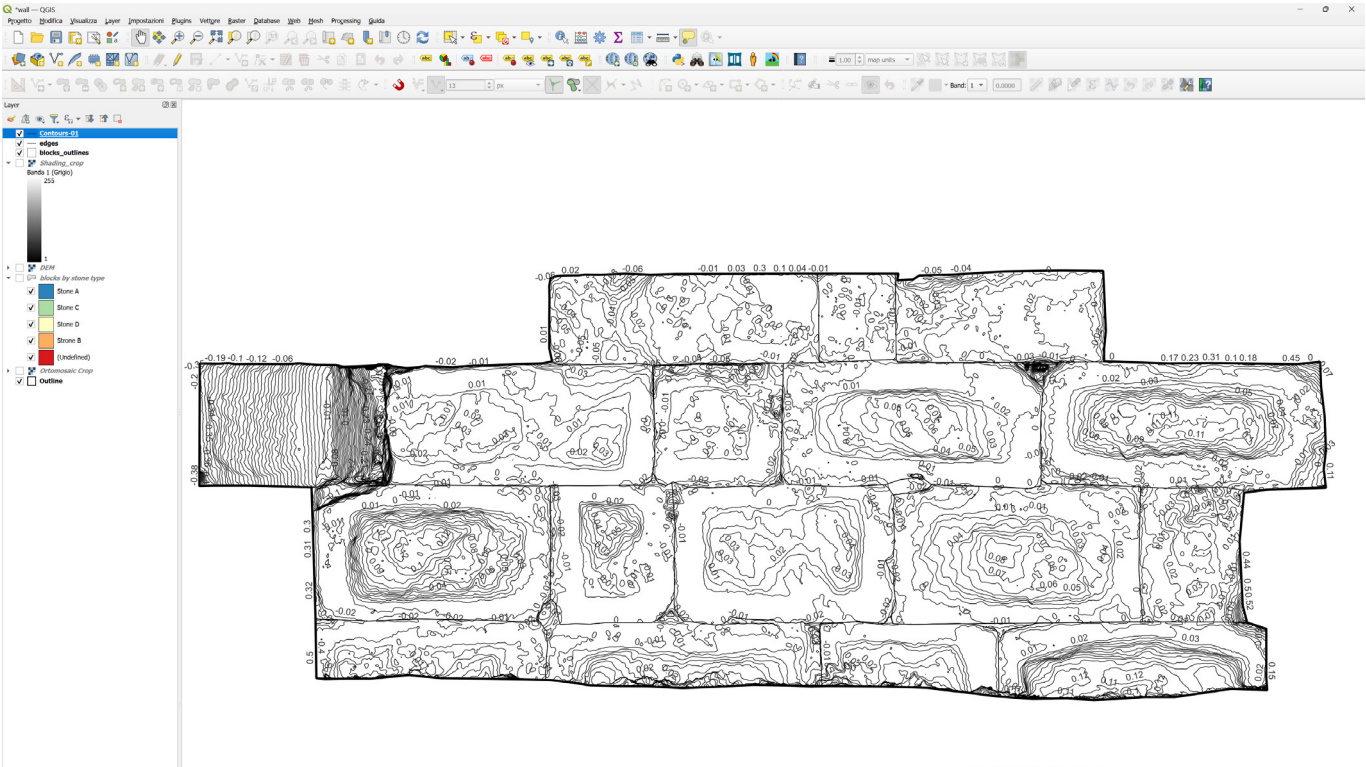
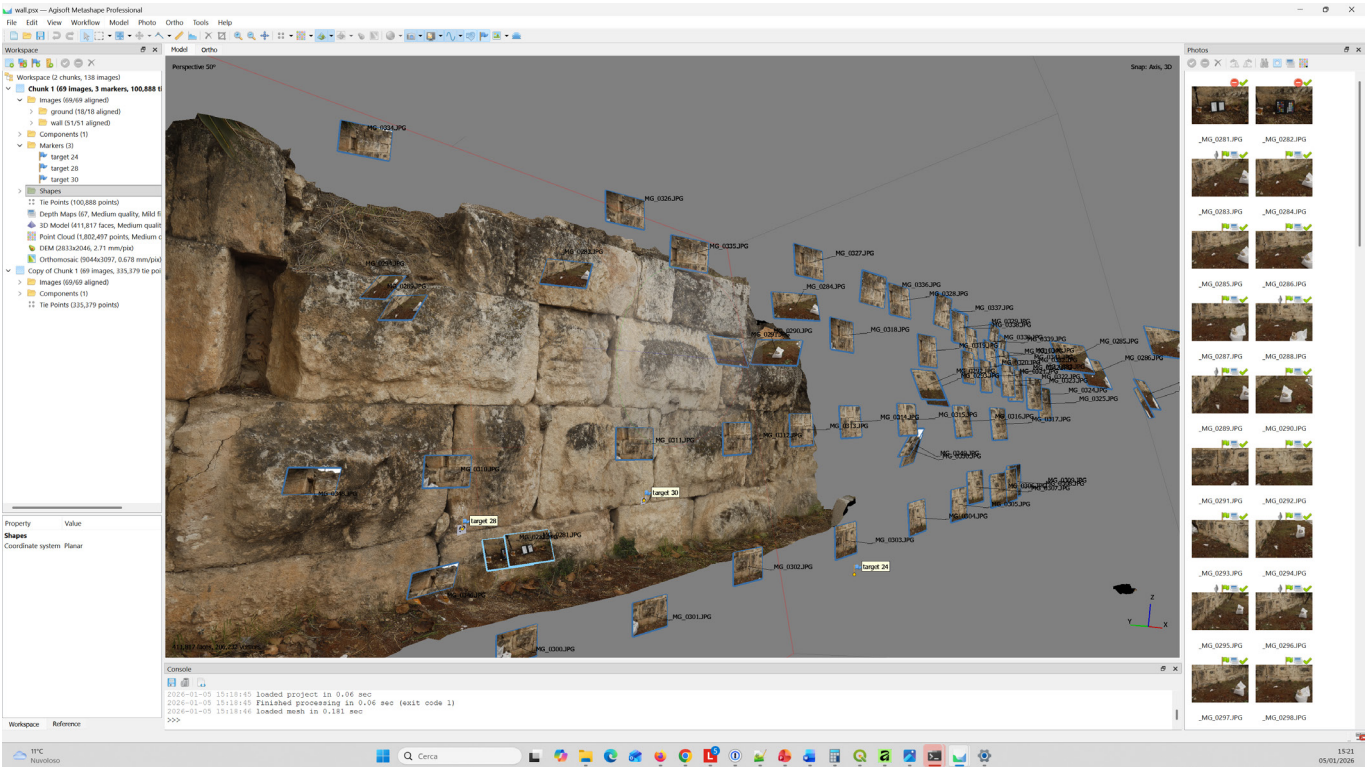
The first part of the course focused on photographic shooting for technical documentation. In the studio, work was carried out on small objects (Figs. 1, 2) using artificial lighting, experimenting with both continuous lights and flash, with and without modifiers (i.e., umbrellas, reflectors, softboxes). The aim of this exercise was to make participants fully aware of the parameters involved in producing a good photograph: exposure control, tonal range management, reduction of unwanted shadows and reflections, and the repeatability of the lighting setup.

The course covered the fundamentals of photographic exposure (i.e., ISO sensitivity, aperture, shutter speed) as tools for controlling noise, depth of field and camera shake, as well as colour rendering in relation to the type of lighting and white balance, both during shooting and in post-production. In this context, the use of a colour checker was introduced as a quality control measure, providing a consistent reference point and reducing colour ambiguity when images are used to support analysis and conservation decision-making.

The exercises were initially carried out using personal equipment (Canon) and subsequently with the centre's camera (Nikon). This was complemented by a brief introduction to RAW workflow and the installation of Nikon's proprietary software on the centre's computers, thus making it possible for procedures to be directly carried out using the centre's own equipment.

2 Projective geometry and survey methodologies

To introduce students to survey and the correct representation of objects, a series of fundamental concepts from projective geometry were covered. At this stage, particular attention was paid to the distinction between parallel and central



On the previous page,
from top

Fig. 3

Photogrammetric model
of a section of wall. The
three photogrammetric
targets were surveyed
directly after being
levelled.

Fig. 4

Arrangement of images
and vector data within
a GIS. Contour lines
and a shaded surface
representation are
derived from the DEM.
The subdivision of the
wall into elements allows
attributes to be assigned
to each block and metric
data to be extracted.

projections, in order to clarify the difference between a photograph and an orthophotograph. This allowed participants to understand when an image can be used as a metric basis and the kind of transformations that may be required to make it suitable for that purpose.

To clarify concepts that are often abstract, specifically designed educational 3D models were used. These made it possible to visualise the geometric behaviour of projections and relate it to the most common forms of architectural representation (i.e., plans, elevations, sections and axonometric views). Once these aspects had been clarified, the methodologies of direct and indirect survey were introduced, highlighting their respective differences, areas of application, limitations and requirements.

Within the section on indirect survey, particular emphasis was placed on stereoscopy and stereophotogrammetry, once again supported by 3D models and an experiment using anaglyph glasses. This helped to illustrate the principles of stereoscopic vision and the relationship between parallax and perception of depth.

3 Exercise on the wall: operational workflow of a stereophotogrammetric survey

Following the theoretical introduction, the course moved on to a practical exercise: a stereophotogrammetric survey of a section of an ancient wall at the rear of the centre. As it was not possible to work on an active site, this approach nevertheless allowed real conditions to be replicated: an uneven surface, irregular texture, and the need for geometric control and a clear, legible output.

The procedure began with the placement of three photogrammetric targets on the ground, levelled using a laser level. Their relative positions were recorded through direct surveying made using trilateration. The data were then processed in the classroom using a CAD tool, providing a reference framework that could subsequently be used to orient and scale the photogrammetric model.

Using the acquired images, the model was then set up in Metashape (Fig. 3), addressing an aspect often overlooked in introductory courses: the optimisation of camera alignment. In particular, attention was paid to filtering tie points with high residual errors, using different parameters and progressively refining orientation accuracy, with the aim of obtaining a point cloud free from significant noise. Then, the focus was placed on orienting and scaling the model based on the markers, and to defining custom projection planes derived from those same markers – an essential step when producing orthographic projections that accurately reproduce surface geometry.

The final outputs of the exercise were an orthophoto of the wall and a DEM on the same projection plane. These outputs were not intended as ends in themselves, but as a basis for constructing an information environment in which drawings and thematic mapping are directly linked to metric data and a stable geometric reference (Fig. 4).

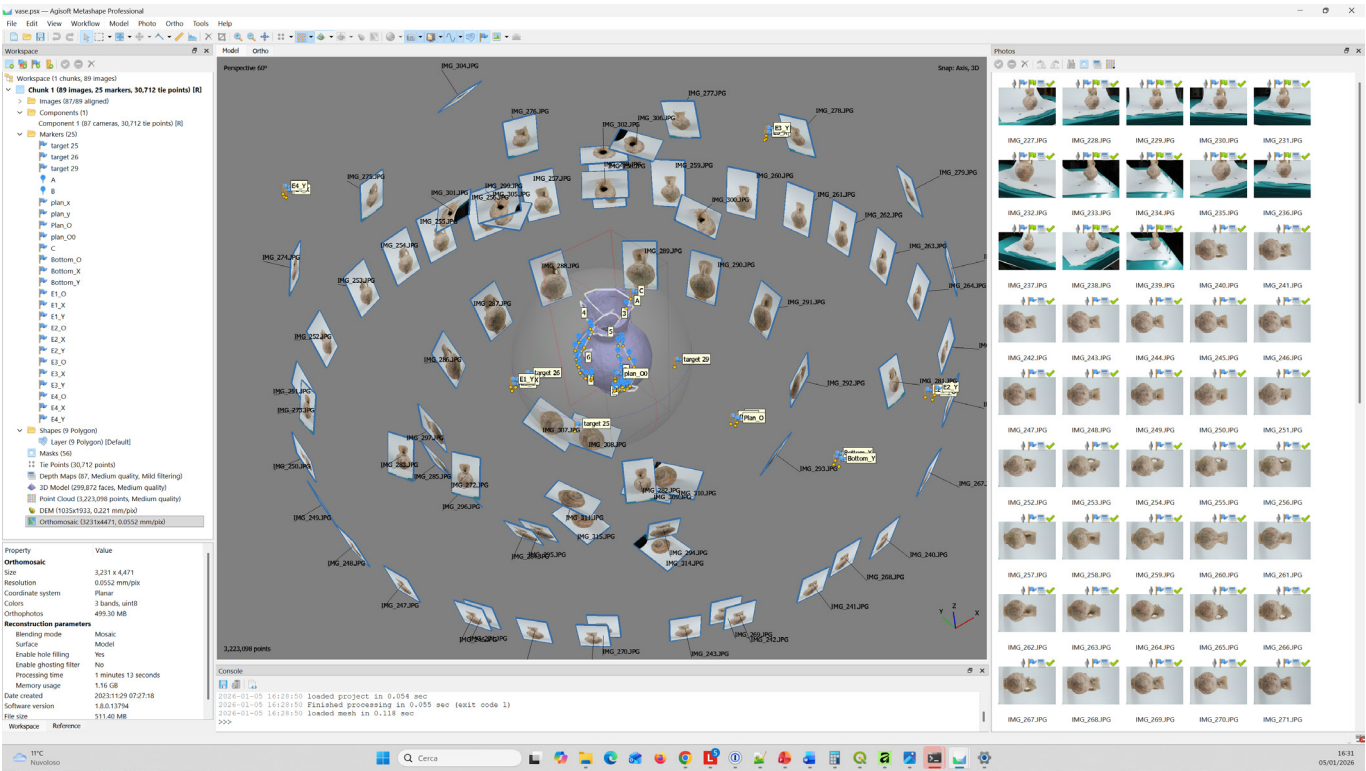


Fig. 5

**4 Laboratory exercises:
archaeological vase and fragment of mosaic**

The exercise carried out on the wall was replicated in the laboratory using an archaeological object (a vase) and fragment of mosaic, with partly different objectives. In the case of the vase (Fig. 6), the aim was to produce a complete 3D model, from which six projections and a cylindrical development could be derived. This provided a useful basis for discussing the relationship between three-dimensional form and the two-dimensional representations employed for the description, diagnostic analysis and communication of restoration work. In the case of the fragment of mosaic (Fig. 7), the practical exercise also encouraged collaborative work. For example, in vector data creation and metadata recording of the tesserae, participants were divided into small working groups, thus highlighting how documentation activities can be effectively organised with a teamwork approach through prior planning and agreement.

Photogrammetric model of a three-dimensional object. The vase was photographed from above and then from below, after being turned over. The use of diffused lighting and a uniform-coloured background facilitated image segmentation prior to alignment.

**5 From metric data to an information system:
why a GIS (and why open source)**

The topic of graphical representation and thematic maps was introduced through case studies drawn from professional experience in both architecture and archaeology (including complex sites such as the Leaning Tower of Pisa and the surfaces of the Colosseum). These examples highlighted how documentation becomes truly effective when it is able to support diachronic comparison, analysis, classification, measurement, and the traceability of decisions.

Fig. 6

Plan representation of a three-dimensional object: projections onto six planes and a cylindrical development were obtained.



Building on this framework, the same methodology was replicated on a smaller scale through the development of GIS projects based on orthophotos and projections derived from photogrammetric models. Preference was given to the use of Quantum GIS, installed on the centre's computers, both for its ability to integrate raster and vector data with descriptive tables, and for the strategic advantage of working with an open-source tool which – based on both teaching and professional experience – proves more than adequate for the typical requirements of graphic documentation in restoration.

During the work in QGIS, several operational procedures were introduced: the extraction of geomorphological analyses from the DEM, the generation of contour lines, the use of alpha channels to mask raster images, and the cropping of images based on vector outlines. Reference systems and map projections were also discussed, particularly to explain the difference between Cartesian and geographic coordinate systems – an essential aspect to properly understand what it means to measure within a digital environment.

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Methodologies and Practices in Ceramic Restoration

Nicola Pagani, Cristina Passeri

Abstract: This paper presents a training programme on ceramic restoration developed within the framework of international cooperation. Using a methodological approach inspired by the Italian school, the course combined theory with practical workshop sessions, fostering critical awareness, intercultural dialogue and ethical reflection on conservation interventions.

Keywords: Cultural heritage conservation; Restoration methodology; Archaeological restoration; Ceramic restoration; Workshop; Colour and material harmonisation; Teamwork.

Introduction

The ceramics restoration course took place as part of a cooperation project focused on the protection and promotion of cultural heritage, with the aim of providing a group of museum professionals and conservators with advanced technical and methodological training. The initiative represented an important opportunity for professional and cultural exchange, in which Italian expertise in the field of conservation engaged with local needs and operational settings.

The training programme was designed for professionals already working in the sector, but with varying levels of experience, and prioritised a workshop-based approach that directly linked methodological reflection with observation and practice. Each stage of the work – from preliminary diagnosis to the selection of materials and aesthetic restoration – was conceived as an opportunity for discussion and for the collective development of skills.

The main objective was to foster an informed approach that integrates knowledge of materials with an understanding of the historical and cultural value of the work, whilst encouraging reflection on the principles that guide restoration.

Because of their complexity in terms of materials as well as the wide variety of types and techniques, ceramics have proved to be an ideal field for practising informed restoration, which requires sensitivity and the ability to maintain a constant balance between intervention and respect for the original material.

1 Methodological approach

The methodological framework of the course was based on an understanding of restoration as a process of knowledge rather than a mere sequence of technical operations. Each intervention was approached through an initial analysis of the object: its constituent materials, the techniques used in its manufacture, and the

**Fig. 1**

Preparation of the equipment required for the photographic documentation of archaeological finds.

transformations it has undergone over time. This established a process of understanding grounded in observation, interpretation and respect for the work.

The teaching introduced participants to the fundamental principles guiding the Italian school of restoration: respect for the original material, the compatibility and reversibility of both materials and interventions, the clear distinction between original and restored elements, and the accurate documentation of every stage of the work. These concepts, illustrated through examples and group discussions, were then put into practice in the workshop, where each operational decision was preceded by a methodological evaluation.

The workshop functioned as a space for exchange. The Italian lecturers encouraged continuous dialogue, and the experience of Jordanian conservators was interwoven with the principles and practices developed within the Italian tradition. This interaction created fertile ground for mutual learning: on the one hand, the transmission of an established methodology; on the other, the exploration of different materials, working conditions and contexts (Fig. 1).

2 Course structure and contents

The course programme combined theoretical lectures, practical demonstrations and workshop activities. Following an initial introductory stage focused on theory applied to ceramic materials (i.e., manufacturing techniques, deterioration patterns and conservation treatments), participants took part in practical sessions working on real artefacts, selected so as to represent a wide range of conservation issues.

The state of conservation of the artefacts was rather diverse: although almost all were fragmentary, each artefact displayed specific characteristics in terms of degree of alteration, type of deposits and constituent material. The surfaces generally showed deposits of excavated soil, as well as carbonate and silicate encrustations of varying thickness and hardness – sometimes considerable in size and particularly

Fig. 2

Assembling fragments of archaeological pottery. Practical laboratory exercise.



stuck to the artefact's original surface. This diversity of conservation conditions provided participants with the opportunity to engage with cases of varying complexity, thus testing intervention methods tailored to the type of deterioration and the nature of material.

In the workshop, each conservator-restorer worked on one or more artefacts, carrying out every stage of the conservation process: from initial visual analysis and photographic documentation to cleaning, consolidation and restoration tests.

Particular attention was paid to the cleaning stage, which served as an opportunity to compare different techniques and materials. Participants were able to try both chemical and mechanical cleaning methods, using surfactants, solvent mixtures, chelating agents such as EDTA, and ion-exchange resins. Tests were also carried out using a micro-sandblaster, vibro-engraver and micro-drill, always under supervision and collective evaluation.

Some larger artefacts were assigned to working groups, with the aim of encouraging communication and collaboration among participants. This approach fostered the development of teamwork skills, an essential component of more complex restoration projects.

Consolidation and surface protection treatments were carried out using low-concentration solutions of Paraloid B72 acrylic resin or Mowital B60HH polyvinyl butyral resin, selected according to the conservation requirements of each individual artefact.

Adhesion and bonding were mainly done using 20% Paraloid B72 solutions in acetone, or 20% Mowital B60HH solutions in ethanol. For large artefacts, which required bonding with greater structural strength, a two-component epoxy resin (UHU PLUS ENDFEST 300 12h) was used, always preceded by the application of a primer¹ coating to ensure the reversibility of the treatment.

¹ Primer coating made using 5-10% Paraloid B72 acrylic resin solutions in acetone.

**Fig. 3**

Jerash, locally produced plate (RCCR temporary inv. nr. 21). Fragments belonging to the artefact following cleaning and bonding.

For almost all of the artefacts, the decision was made to only fill the largest gaps, avoiding any intervention on minor voids, small chips or micro-gaps. This approach, whilst adhering to conservation principles, also served an educational purpose: to reinforce the stability of the most fragmented artefacts while ensuring their correct interpretation. The restorations were carried out using dental gypsum or Polyfilla² coloured with natural earth pigments.

The use of both materials made it possible to highlight their different technical properties and to propose alternative solutions for volumetric restoration. Chromatic restoration was carried out using the stippling technique, applying acrylic paints with brushes and stiff-bristled brushes, in accordance with the principles of recognisability and reversibility.

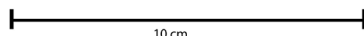
Some artefacts also showed evidence of previous interventions: old deteriorated adhesives, unsuitable fillings or additions no longer compatible with current conservation standards. In these cases, it was necessary to carry out 'de-restoration' work, aimed at removing incompatible or harmful materials and restoring the ability to properly interpret the artefact. This aspect proved particularly significant within the course, as it offered an opportunity to reflect on the ethical dimension of restoration: recognising and correcting inadequate past interventions means upholding the principle of reversibility and reaffirming the central role of the original material as a historical document.

The success of the course was also made possible by the availability of a fully

² Gypsum-based powder stucco with an acrylic binder reinforced with cellulose fibres.

Fig. 4

Jerash, locally produced plate (RCCR TEMPORARY NUMBER 21). Fragments belonging to the artefact following formal restoration using pigmented gesso.

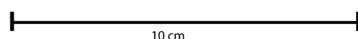


equipped laboratory with professional tools that allowed for safety and precision, in a way that replicated the work conditions of a museum or research environment. A key aspect of the training programme was the documentation of the restoration process, regarded as an integral part of conservation practice. Each stage of the work was accompanied by the completion of conservation records drawn up in accordance with the Italian Ministry's template³, with the aim of ensuring consistency, traceability and completeness of the data collected. These records made it possible to systematically document observations regarding the state of conservation, methodological choices and materials used, providing a valuable tool for monitoring and future reference.

At the same time, a detailed photographic record was kept throughout the entire process. It went from the initial condition of the artefacts, through the main stages of intervention, to the final outcome. The images served not only a descriptive purpose, but also an educational and analytical one, by making sure that the progression of the restoration process be clearly visualised and a collective discussion about the decisions made be held (Fig. 1).

This focus on both graphic and photographic documentation highlighted how proper recording of the work is essential for transparency and professional accountability, as well as a key part of contemporary restoration methodology.

³ Conservation records used by the restoration laboratories of the *Istituto Centrale per il Restauro* in Rome were employed, following their translation into Arabic and English.

**Fig. 5**

Jerash, locally produced plate (RCCR TEMPORARY NUMBER 21) . Fragments belonging to the artefact following formal and chromatic restoration using the stippling technique.

3 Cases and issues addressed

During the workshop, a total of twenty ceramic artefacts were restored, varying in type, origin and state of preservation (Fig. 2). The selection of artefacts had a clear educational purpose: providing participants with as broad an overview as possible of the issues a conservator-restorer may encounter in professional practice, ranging from small fragments to large-scale objects, and from rough earthenware to more complex materials such as glazed or enamelled ceramics (Figs. 3-5).

The two largest artefacts – two large amphorae – proved particularly significant, as they required teamwork (see ‘Conservation and restoration of two fragmented ceramic jars from Jerash’, in this volume). These cases offered an opportunity to explore teamwork dynamics and the shared management of responsibilities, highlighting the importance of communication, planning and constant dialogue among practitioners. The group activity proved to be an effective training tool, combining both the technical and relational aspects of restoration.

The comparison between different artefacts made it possible to apply a flexible methodology, that could be adjusted according to the specific requirements of each object. Some artefacts, particularly fragile or affected by previous restoration interventions, required targeted conservation solutions involving the use of a wide range of materials and techniques. In other cases, surface cleaning raised questions about the balance between effectiveness of the work and safety, encouraging participants to carefully reflect on the relationship between intervention and the preservation of original materials.

The workshop thus took the form of an applied research setting, in which every operation was preceded by observation, discussion and verification. The constant focus on documentation and the evaluation of results ensured that each case study was both a stand-alone experience and part of a broader, collective process of professional development.

4 Concluding remarks

The experience of the course showed how training in ceramic restoration can become an opportunity for shared learning and intercultural dialogue. The exchange between Italian lecturers and Jordanian practitioners brought together different skills and perspectives, fostering the development of a common technical language and a shared sensitivity towards heritage conservation.

The course also highlighted how the sharing of technical knowledge has to go hand in hand with a solid methodological and ethical foundation. Each intervention was a way for participants to be accountable and link precision to the ability to interpret the historical and symbolic value of the work. As a matter of fact, one of the most significant outcomes of the programme was the realisation that restoration is not just about working on the appearance of an object, but it contributes to the understanding and continuity of memory.

A key factor in the success of the activities was the possibility of working in a fully equipped laboratory, which enabled participants to experiment with professional techniques and tools in controlled and safe conditions. This practical dimension made it possible to bridge the gap between theory and practice, giving participants the opportunity to directly test the methodological principles they had previously learnt.

The course thus took the form of an actual training workshop, in which the restoration practice served as a tool for critical reflection and cultural development. At the end of the programme, apart from the visible results achieved through the individual interventions, what stood out the most was the development of a professional attitude based on respect, awareness and the ability to interpret the complexity of ceramic heritage with both a technical and a human perspective.

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Conservation and Restoration of Two Fragmented Ceramic Jars from Jerash

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This chapter presents the conservation and restoration of two fragmented ceramic vessels, which were assigned temporary inventory numbers (Inventory Nos. 5 and 4) upon their entry into the laboratory, and were treated at the Jerash Laboratory of the Regional Center for Conservation and Restoration. Both objects originate from undocumented contexts, most likely related to illegal excavations, and therefore lack precise archaeological information. As a result, their chronological attribution relies exclusively on typological, technological, and macroscopic observations.

Red-Brown Jar (Inventory No. 5)

The first vessel (Inventory No. 5) is a large red-brown terracotta jar without surface coating. It originally featured an oval base, a small neck and rim, and two handles, with horizontal wheel-thrown lines decorating the body. Based on typology and manufacturing technique, the vessel is tentatively dated to the Late Roman or Early Byzantine period, possibly the 2nd century AD.

The jar arrived in the laboratory in numerous fragments, with the base completely missing, partial loss of the rim, several lacunae on the body, and clear evidence of previous restoration attempts. At the time of examination, the surface was covered with dust, calcareous encrustations, greasy deposits, and adhesive residues. Surface damage included abrasions, scratches, stains, and chipping along the rim. Production-related features such as lime inclusions, slight deformation, fingerprints near the handles, and joining lines between manufacturing sections were visible, indicating wheel-thrown production and multi-part assembly.

Light-Colored Jar (Inventory No. 4)

The second vessel (Inventory No. 4) is made of a light-colored ceramic, ranging from white to cream in tone. It originally featured a wide body, a defined neck and rim, and functional handles, with a suggested modeled horizontal band decoration. Based on typology, surface characteristics, and manufacturing technique, the vessel is tentatively dated to the Byzantine period.

This jar arrived in multiple fragments, with missing elements and lacunae affecting the body and rim, as well as traces of previous restoration. At the time of examination, the surface exhibited thick dust layers, calcareous encrustations,

adhesive residues, abrasions, scratches, and localized chipping. Manufacturing features such as wheel-thrown lines, joining seams between sections, and inclusions within the ceramic fabric were observed, confirming wheel-thrown production and multi-part construction.

Conservation Methodology and Treatment

The conservation methodology applied to both vessels followed established principles of documentation, minimal intervention, material compatibility, and reversibility. Treatment began with detailed photographic and written documentation. Mechanical cleaning was carried out using soft brushes, vacuum cleaners, scalpels, micro-drills, and vibrating drills to remove deposits and calcareous encrustations. Chemical cleaning was selectively applied using deionized water, acetone, ethanol, and cationic ion-exchange resin where carbonate accretions or adhesive residues were present, followed by thorough rinsing.

A protective coating of acrylic resin Paraloid B72 (3% in acetone) was applied to the surfaces of both vessels, with higher concentrations along fracture edges. Fragment reassembly was performed after careful matching using Paraloid B72 (20% in acetone). In structurally critical areas, limited use of a bicomponent epoxy resin (UHU PLUS ENDFEST 300 12h) was necessary.

Lacunae were filled with a gypsum-based mixture modified with brick dust, inert fillers, and pigments to ensure chromatic compatibility, then sealed with Paraloid B72. Chromatic integration was carried out using a stippling technique with acrylic colors, ensuring visual coherence while maintaining distinguishability. In some areas, fragments could not be repositioned, and chromatic integration remains ongoing.

Results

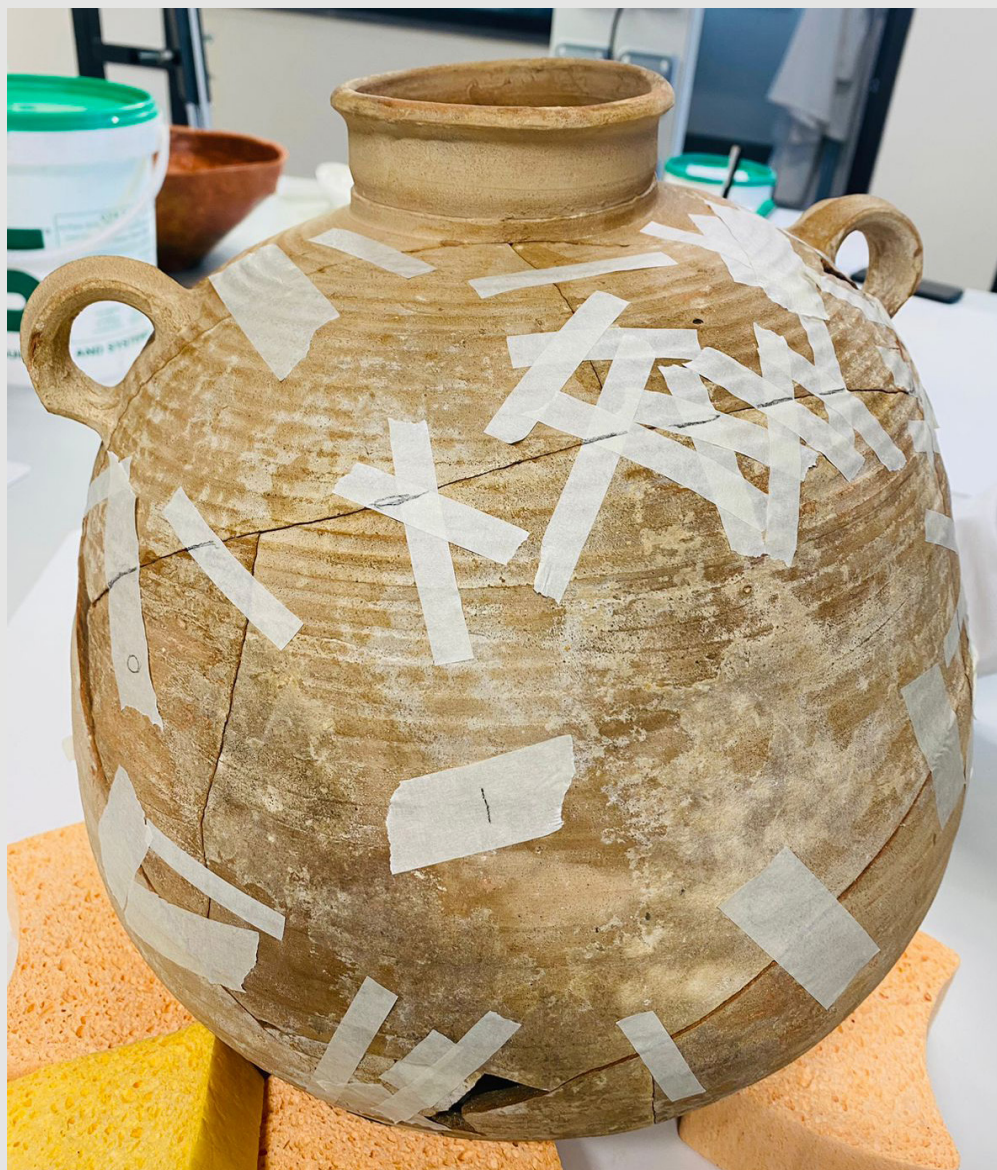
The conservation interventions stabilized both vessels, improved their structural integrity, and restored their overall legibility. The treatments allow for safe handling, storage, and future study of the objects, in accordance with current conservation ethics.

Fig. 1

Light-Colored Jar (RCCR temporary Inv. No. 4)
before conservation,
showing fragmentation
and surface encrustations.

**Fig. 2**

Light-Colored Jar (RCCR temporary Inv. No. 4)
during conservation,
illustrating cleaning,
reassembly, and filling.



**Fig. 3**

Light-Colored Jar (RCCR temporary Inv. No. 4) after conservation, showing the stabilized and restored vessel.

**Fig. 4**

Red-Brown Jar (RCCR temporary Inv. No. 5) before conservation, showing fragmentation and surface encrustations.



from left

Fig. 5

Red-Brown Jar (RCCR temporary Inv. No. 5) during conservation, illustrating cleaning, reassembly, and filling.

Fig. 6

Red-Brown Jar (RCCR temporary Inv. No. 5) after conservation, showing the stabilized and restored vessel.

Conservation of Archaeological Glass

Abstract: This paper examines the main methodological issues associated with the conservation and restoration of archaeological glass, an extremely brittle material susceptible to environmental factors. Following an overview of the material's composition and its process of degradation, the study presents criteria and intervention methodologies with a particular focus on material compatibility and the preservation of original surfaces. The case of Roman-era glass from Jerash serves as a practical example within the context of training in conservation and restoration.

Keywords: Archaeological Glass; Conservative restoration; Methodology; Degradation; Jerash.

Part 1

Restoration and Conservation of Archaeological Glass: Methodological Issues

Elisabeth Huber

1.1 Characteristics and properties of glass

Glass is an amorphous inorganic material produced mainly by melting silicon dioxide (SiO_2) with the addition of alkali oxides such as sodium oxide (Na_2O) or potassium oxide (K_2O), which lower its melting point. Stabilising oxides such as calcium oxide (CaO), magnesium oxide (MgO) and aluminium oxide (Al_2O_3) are also added to enhance chemical stability and water resistance, thereby preventing degradation over time. Unlike crystalline materials, glass has an amorphous structure – meaning it lacks a defined atomic order – resulting in properties such as transparency, surface hardness and mechanical fragility.

Studies about ancient glass have shown that the main raw material consisted of silica-rich sands. In the Roman world, natron¹ was mainly used as a flux, whereas in the medieval period and in northern Europe, ash coming from plants was preferred. Stabilisers, such as calcium, usually came from the limestone residues found in the sand itself. In addition to the main components, the sand could contain metallic

¹ Natron is a natural mineral mainly made of sodium carbonate decahydrate ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$), often mixed with smaller amounts of sodium bicarbonate (NaHCO_3), sodium chloride (NaCl) and sodium sulphate (Na_2SO_4). The natron used by the Romans was sourced mainly from Egypt, specifically from the Wadi Natrun region, a desert area with salt lakes.

impurities such as iron, oxides, which had an impact on the colour of the glass. For example, iron would give greenish hues, while copper could result in shades of blue or green. These natural colours could be altered or enhanced for decorative purposes by adding bleaching agents or colouring oxides.

Despite its apparent stability, glass is sensitive to environmental conditions such as humidity and pH, making it vulnerable to both mechanical and chemical stresses.

1.2 Overview of archaeological glass degradation

Archaeological glass degrades through both chemical and physical processes. Among the chemical reactions involved, the main ones are leaching and corrosion. Leaching occurs when water exchanges H^+ ions with alkali ions (Na^+ , K^+) present in the glass, leading to the formation of a hydrated silica layer on the surface. This results in a loss of shininess and transparency, as well as the development of nacre-like crusts. On the other hand, corrosion occurs in alkaline environments ($pH > 9$), where the solution breaks the $O-Si-O$ bonds within the glass structure, accelerating its disintegration.

From a physical perspective, glass is a brittle material and breaks without undergoing plastic deformation, with rapid fractures caused by the breaking of surface $Si-O-Si$ bonds.

These processes often act in combination, leading to the progressive loss of both the historical information and the aesthetic value of glass objects.

1.3 Conservation issues: challenges and critical aspects

The conservation of archaeological glass presents a number of challenges, due to its fragility and susceptibility to chemical degradation. This makes it necessary to adopt particularly careful treatments in order to prevent further damage. It is essential that the materials and techniques used are compatible with the glass and, wherever possible, reversible, so as to allow for any future interventions. Particular attention must be paid to the conservation of the hydrated silica surface layers, which represent the original surface and contain valuable historical and material information. For this reason, their removal could result in the irreversible loss of fundamental data.

The surrounding environment also plays a crucial role when it comes to conservation: fluctuations in temperature and humidity, as well as the presence of pollutants, can significantly accelerate the degradation process.

1.4 Challenges related glass transparency and the choice of materials

The transparency of archaeological glass represents a major challenge in restoration, as it is one of its defining characteristics and requires the use of materials that do not alter visual perception or compromise the readability of the artefact. The selected materials should have a refractive index close to that of the original glass and ensure long-term transparency, resisting yellowing and clouding caused by ageing, exposure to light or chemical interactions with the surrounding environment. Furthermore, these materials must ensure excellent adhesion without leading to stresses or discontinuities that would undermine the object's mechanical stability.

These requirements make glass restoration particularly complex and highlight the need for ongoing research to identify more suitable materials that also meet visual criteria such as transparency.

1.5 Restoration methodologies

Archaeological glass restoration is based on an integrated approach including several key stages:

Preliminary diagnostic analysis: use of non-invasive diagnostic techniques to determine the chemical composition, state of degradation and physical characteristics of the material.

- Cleaning: this must be carried out with great care to remove deposits and encrustations without damaging the glass surface, while paying particular attention to the hydrated silica layers representing the original surface. It may be mechanical (i.e., using soft brushes or scalpels) or chemical (i.e., using solvents or chelating agents), depending on the nature of the deposits.
- Consolidation: the use of thermoplastic consolidants², such as acrylic or polyvinyl butyral resins, makes it possible to stabilise fragile areas. These materials provide proper adhesion while maintaining transparency and ensuring long-term stability.
- Bonding: among the available options, epoxy resins provide the strongest adhesion, although they have certain limitations, such as irreversibility and a potential tendency to yellow over time. Therefore, adhesive must be chosen depending on the condition of the glass: the use of epoxy resins is not recommended for severely degraded glass, as it may cause further damage. In such cases, thermoplastic resins are generally preferable.
- Filling of gaps: the most complex stage in the restoration of a glass artefact is usually the filling of gaps. Due to its technical difficulty and associated costs, minimum intervention is frequently preferred, in agreement with the owner or responsible institution. However, when filling is required, careful selection of materials is essential. Fluid, transparent epoxy resins are commonly used and may be coloured with specific pigments to achieve the desired shade.

As regards the methods used to carry out the integrations, two main approaches can be distinguished: direct and indirect. The direct method, which is the traditional one and still widely used, involves pouring the resin directly into the gap after creating a double-walled mould, typically using dental wax or silicone rubber. In recent years, however, increasing preference has been given to the indirect method, which is particularly suitable for brittle artefacts that cannot withstand the mechanical stress associated with in-situ casting. This approach allows most of the work to be carried out separately from the object itself, making it more suitable for large, thin or structurally sensitive restorations. It is also relatively quick, which can make it more cost-effective.

Indirect restorations may be carried out either by taking a cast from a plaster model of the missing section or by cutting and shaping sheets of suitably coloured epoxy resin³.

- Environmental control: once the restoration is complete, it is important to ensure stable environmental conditions by monitoring relative humidity and temperature, as well as implementing appropriate measures to protect the object from contaminants.

² A thermoplastic resin is a type of plastic material that becomes soft or liquid when heated and hardens upon cooling, without undergoing any permanent chemical change. This process is reversible and can be repeated multiple times.

³ This method was developed by the Istituto Centrale per il Restauro of Rome about 20 years ago.

Part 2

Restoration work on Jerash glasses

Manuela Faieta

As part of the training course ‘Conservation and Restoration of Ceramics, Metals, Organic Materials and Glass’, a teaching module focused on glass restoration was delivered. Through a combination of theoretical lectures and hands-on activities, participants were introduced to the technical and technological properties of glass, its main forms of degradation, and appropriate conservation and restoration methods. Throughout the course, participants had the opportunity to work on original archaeological material from the Roman period, sourced from the storage facilities at the archaeological site of the ancient city of Jerash.

2.1 State of conservation of glasses

The material examined during the course consisted of a large number of glass fragments, mixed together and originating from hundreds of artefacts. These showed similar types of degradation, as they all came from the same archaeological site and had been subjected to comparable burial conditions, which resulted in largely uniform alteration processes.

The glass fragments still bore traces of their burial setting, including cohesive soil deposits, carbonate concretions, and dark stains likely caused by manganese oxides, which were particularly visually intrusive. The surfaces showed signs of leaching⁴, resulting in a slight but widespread iridescence, alongside localised areas of thicker hydrated silica layers⁵, with a characteristic nacre-like or opaque white look. Some areas showed signs of lifting and detachment of tiny chips, as well as micro-porosity and pitting.

2.2 The restoration work

Before the work began, the fragments were laid out on a large table to allow for an initial sorting based on shape, thickness and, where possible, to determine whether they belonged to the same artefact (Fig. 1). This process enabled participants to gain an overall understanding of the material, identify connections between related fragments, and select the most significant pieces to work on.

The intervention was structured into three main phases: surface cleaning and consolidation; assembly and bonding of fragments; filling of gaps.

Following photographic documentation of the condition of the selected artefacts, the fragments were cleaned by removing residual burial deposits using cotton swabs moistened with solvent solutions⁶ and, where necessary, scalpels and curettes. A microscope was used for the most delicate surfaces (Fig. 2). In cases where hydrated silica layers were present, the removal of deposits was alternated with the consolidation of delaminated or poorly adhering areas at risk of falling off, using a

⁴ See section Overview of archaeological glass degradation.

⁵ See section Overview of archaeological glass degradation.

⁶ Cleaning was carried out using pure ethanol or solutions of demineralised water and ethyl alcohol.

Fig. 1

Series of glass fragments from the archaeological site of the ancient city of Jerash during sorting and classification.



polyvinyl butyral resin⁷.

Glass surfaces showing dark stains were subsequently subjected to a reducing treatment using a neutral aqueous reagent made of ammonium hydroxide and hydrazine hydrate⁸, in order to remove dark manganese stains.

At first, the fragments were provisionally assembled using adhesive tape and cyanoacrylate bridges. Once correctly positioned, permanent bonding was carried out using a low-viscosity two-component epoxy resin⁹ applied by capillary action (Fig. 3), with the exception of a small blue vase (RCCR 11), for which a high-concentration polyvinyl butyral resin¹⁰ was preferred.

The most complex phase was the filling of gaps, undertaken using both direct and indirect methods, the latter involving the use of wax retaining walls applied directly to the artefact. To support training, in addition to the original artefacts, small modern glasses – deliberately broken and with missing sections – were also used to simulate conditions requiring gap filling.

Given the fragility and thin walls typical of Roman glass, most artefacts were restored using an indirect method involving coloured epoxy resin sheets. This technique consists in the production of a sheet matching the thickness and colour of the original glass, which is then sanded to replicate its degree of opacity. Individual elements are cut from the sheet, shaped to fit the gaps, curved as required, and finally bonded in place as if they were original fragments (Fig. 4). The sole exception was the neck of a blue vase (RCCR 4), where the direct restoration method was preferred due to the greater thickness of the glass. In this case, walls of dental wax

⁷ Mowital B60HH (Kuraray), 5% in ethanol.

⁸ The reagent is B.D.G. 86 blue, specifically for glass artefacts with a pH of 5.5 (CTS Srl).

⁹ Araldite 2020 (Huntsman).

¹⁰ Mowital B60HH, 20% in ethanol.

**Fig. 2**

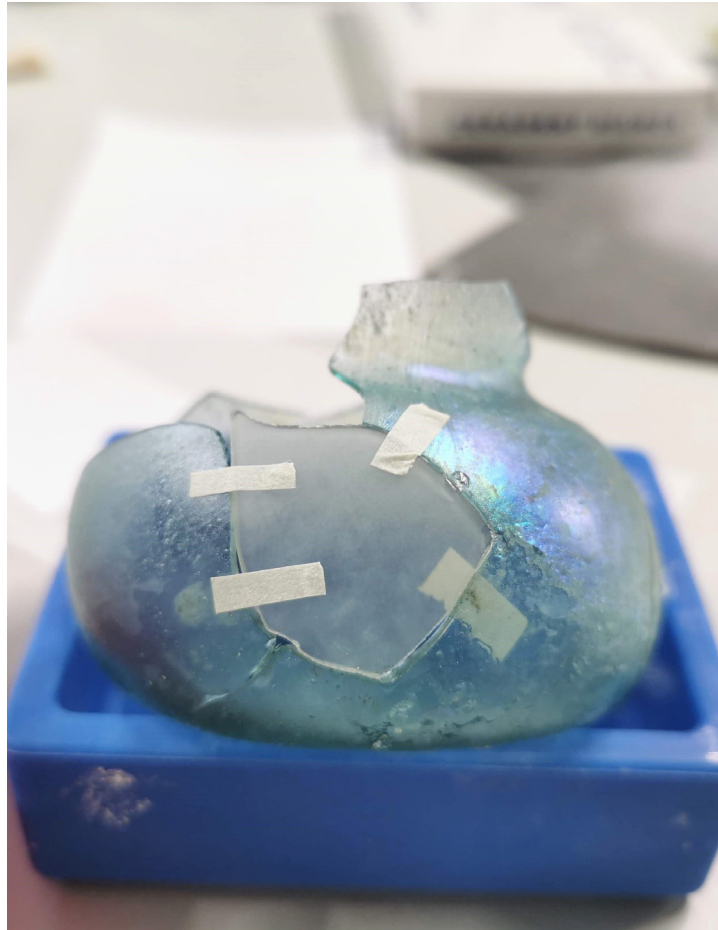
Cleaning operations
carried out using a
stereomicroscope.

**Fig. 3**

Final bonding of a glass
balsamarium using
low-viscosity epoxy resin
applied by percolation.

Fig. 4

Indirect restoration method using an epoxy resin sheet.

**Fig. 5**

Direct restoration method: creation of a counter-mould with walls of wax and plasticine, followed by casting of the epoxy resin.



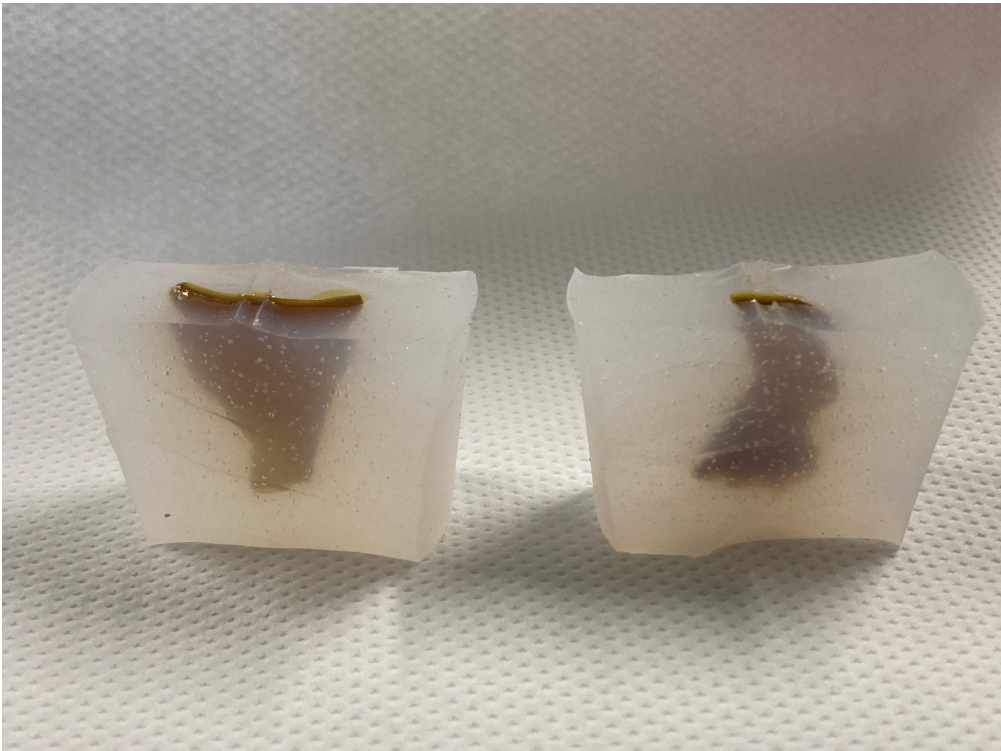


Fig. 6
Two-stage indirect restoration method, detail showing the creation of the resin fragments.



Fig. 7
Restored artefacts at the end of the course.

were created around the gap, and epoxy resin mixed with transparent glass colours¹¹ was poured in it to match the original colours (Fig. 5). The resin surface was then mechanically finished to remove any minor irregularities and make sure it would blend with the surrounding surface.

In both approaches, the final aesthetic finish was achieved by applying the same resin with a cotton swab until it matched the transparency of the original glass.

The two-stage indirect technique – consisting in the production and subsequent removal of plaster fills, which are then used to create silicone moulds for their reproduction using epoxy resin – was tested on modern small glasses due to their greater thickness. The plaster fills were thus converted into resin fragments (Fig. 6), which were then bonded in their respective places using an acrylic resin.

Upon completion of the restoration work (Fig. 7), storing artefacts in suitable microclimatic conditions is essential to ensure proper conservation. In particular, relative humidity must be carefully controlled: levels below 40% should be avoided, as they may lead to the degradation of hydrated layers, while values above 60% can accelerate degradation processes¹².

2.3 Conclusions

Archaeological glass represents a fragile and complex category of cultural heritage that requires particularly careful conservation methods. Its chemical and physical properties, combined with the wide range of degradation processes it can be subject to, require specific and carefully tailored restoration approaches. Ongoing scientific research and the development of non-invasive techniques are a valuable resource for the improvement of conservation practices. Therefore, long-term preservation and transmission of this important testimony to the past can only be ensured through an integrated approach, based on thorough analysis, targeted interventions and constant monitoring.

¹¹ Vitrail (Pébéo) oil-based alkyd paints.

¹² Verità M. 2004, pp.120-130.

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Conservation Strategies for Jordanian Bronze and Iron Objects: Addressing Typical Degradation Issues

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Abstract: Based on the condition of Jordanian bronze and iron artifacts examined in the didactic laboratory of the Italian-Jordanian cooperation program, this study aims to provide a technical reference for heritage conservation professionals in Jordan. It offers guidelines on methods and materials for key conservation steps, including cleaning, reassembly, gap-filling, inhibition of active corrosion, surface protection, and preventive measures, while incorporating the reflections of Jordanian students, offering first-hand insights from the program participants.

Keywords: Metal conservation, Jordan, Italian-Jordanian cooperation program, Bronze, Iron.

1 Introduction

The surviving bronze and iron artifacts in Jordan, though limited in quantity, serve as significant historical testimonies to the spread of ancient Roman and Byzantine cultures in the region. Scholarly publications on metal artifact conservation within Jordan remain limited, with a predominant focus on the treatment of bronze disease using chemical or electrochemical methods by a limited cohort of researchers (Abu-Baker, 2023; Abu-Baker et al., 2021; Al Bawab et al., 2014; Al Saad et al., 2021). Based on the main conservation issues associated with bronze and iron artifacts, and in light of the typical forms of degradation identified in Italian-Jordanian cooperation project *Creation of the Regional Institute for Conservation and Restoration in Jerash*, it is necessary to provide reference methods and approaches for more conservation professionals working in Jordan's cultural heritage institutions.

Metal artifacts begin to deteriorate through interaction with their environment from the moment that they are manufactured, with corrosion being the core form of this irreversible process. In terms of corrosion mechanisms, it can be divided into two fundamental types: first, dry corrosion (chemical corrosion), which refers to the direct reaction of metal with oxygen (or other gases) under dry conditions, forming new compounds on the surface through oxidation; second, wet corrosion (electrochemical corrosion), which occurs in the presence of an electrolyte (such as water) and progresses at a significantly faster rate than dry corrosion. In addition to oxygen and water, the involvement of salts and acidic gases leads to the formation of various corrosion products. Environments with high temperature and humidity, as well as surface acidity, can accelerate the corrosion rate. Corrosion alters the surface color and morphology of metal artifacts and weakens their mechanical properties. However, corrosion is not merely a process of deterioration but also an

element inherent to the historical and, at times, artistic value of metal artifacts. Some stable corrosion products, which can prevent further degradation of the metal substrate and exhibit a uniform, smooth morphology, are referred to as a patina and are retained as part of the metal substrate. In contrast, other corrosion products may continue to develop, leading to severe damage to the metal substrate. Therefore, during the conservation process, it is essential to identify the types of corrosion products and carry out selective removal.

The corrosion products on bronze artifacts consist of oxides, hydroxides, carbonates, sulfides, sulfates, phosphates, chlorides, nitrates, silicates and organic salts of copper (Scott, 2002). Examining the most common types, stable oxides serve as a fundamental and stable products formed on the surface. Owing to its formation from metal-atmosphere reaction, the reddish-brown mineral cuprite (Cu_2O) is nearly always present and provides a protective barrier against corrosive agents when it forms a continuous layer. If the object is initially exposed to air containing even small amounts of hydrogen sulfide or carbonyl sulfide, its corrosion will accelerate, resulting in the formation of covellite (CuS) in black spots or excrescence (Oddy and Meeks, 1982). The development of carbonates is characterized by moist, carbon dioxide-rich conditions, yielding minerals such as the basic carbonate malachite $\text{Cu}_2\text{CO}_3(\text{OH})_2$. This compound forms a green, stable layer that acts as a protective and often aesthetically valued patina. Sulfides originate in sulfur-rich environments. Phosphates are less common and typically develop in burial environments containing animal bones. Libethenite $\text{Cu}_2(\text{PO}_4)(\text{OH})$, for instance, exhibits very low solubility and high thermodynamic stability. In dry conditions, it forms a loose but insoluble layer. Although not strongly protective due to its porosity, it does not actively promote corrosion. Sulfates originate in sulfate-rich contexts such as industrial areas, acid rain regions, or high-sulfate soils. Common examples include chalcantite ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) and brochantite ($\text{Cu}_4(\text{SO}_4)(\text{OH})_6$). These hygroscopic compounds cause spalling and, being non-protective, accelerate substrate loss through a recurring cycle of dissolution, exposure, and re-corrosion.

Chlorides, which form in chloride-rich environments such as coastal sites, saline soils, or through contact with chlorine-containing agents, are the most hazardous corrosion products and are commonly referred to as bronze disease, requiring strict control in conservation. Key examples include nantokite (CuCl) and basic copper chlorides such as atacamite and paratacamite. Nantokite, a highly hygroscopic white powder, rapidly absorbs moisture and converts into light green basic copper chloride at higher relative humidity. The initial form of chlorides is small pitting, which at higher relative humidity or during wet-dry cycles undergoes rapid development and leading to cracking and spalling and eventually covers the surface with green powdery rust. In severe cases, it may penetrate the entire object, causing structural collapse, and can even spread to other artifacts.

The main corrosion products on iron artifacts include oxides, hydroxides, oxyhydroxides, and chloride (Scott and Eggert, 2009). Ferrous hydroxide and iron oxide are fundamental corrosion products. The former is an unstable light green flocculent material that readily oxidizes into red-brown, densely structured hematite (Fe_2O_3). Once a continuous layer forms, it can slow down the corrosion of the underlying iron matrix. Magnetite (Fe_3O_4) is black and dense, typically forming in oxygen-depleted environments. It is relatively stable and offers some protective effect to the substrate. Iron oxyhydroxide is a key intermediate in the transformation from hydroxide to oxide. Among these, goethite ($\alpha\text{-FeOOH}$) is one of the final stable corrosion products of iron, known for its excellent thermodynamic

and electrochemical stability. It often forms a dense layer of nanoparticles that effectively inhibits further corrosion of the substrate. Akageneite (β -FeOOH) has a unique tunnel-like crystal structure that can accommodate and adsorb chloride ions. It is a characteristic corrosion product in chloride-rich environments. Under humid or cyclic wet-dry conditions, it undergoes volumetric expansion, leading to spalling and cracking of the corrosion layer. Acting as a cathodic depolarizer, it accelerates corrosion and is a core factor triggering active corrosion in iron artifacts and represent a core threat to the preservation of iron artifacts. The chloride products, such as ferrous chloride (FeCl_2) and iron oxychloride (FeOCl), are highly hygroscopic and can initiate a vicious cycle of corrosion–moisture absorption, resulting in powdery rust that continuously erodes the iron substrate. An experienced conservator can often assess the potential threat of corrosion products through visual inspection. For instance, bronze disease typically appears as localized, light green spots. When gently probed with a tool, these spots reveal a loose, powdery consistency. On iron artifacts, harmful corrosion often manifests as bright orange spots, indicating the presence of chloride ions within the corrosion products. While precise identification of corrosion products usually requires instruments such as Raman spectrometers or X-ray diffractometers, a silver nitrate spot test can be used in the absence of advanced equipment. The formation of a precipitate in this test confirms the presence of chloride-based corrosion (Selwyn, 2016). Corrosion reduces the elasticity of alloys, making them more prone to plastic deformation and eventual fracture under external forces such as soil pressure or other mechanical stresses. Once mechanical damage occurs, the newly exposed alloy surfaces continue to corrode, initiating a cyclical and progressive deterioration process. Deformation is a particularly critical concern in the conservation of metal artifacts. During the reconstruction of fragmentary metal objects, conservators often find that, unlike with ceramic, glass, or stone artifacts, the pieces cannot be realigned to restore the original form. In the past, heat treatment or mechanical methods were commonly used to attempt reshaping (Fagg et al., 1964). However, these approaches carry significant risks, especially for heavily mineralized objects. Today, it is common practice to avoid reshaping intervention or apply only limited mechanical pressure. Conservators are required to adopt a flexible approach during reconstruction, taking into account factors such as the object's craftsmanship, condition, technical risks, and interpretive presentation to the visitors. In summary, the conservation and restoration of bronze and iron artifacts involve the following key tasks:

- Removal of surface deposits;
- Evaluation of corrosion products based on their nature, morphology, and distribution;
- Partial removal of stable corrosion only where it affects the legibility of the object, while active and hazardous corrosions should be removed as thoroughly as possible and affected areas should be treated with inhibitors;
- Restoration of structural integrity through rejoining fragments and filling gaps, aiming to recover the object's original form and stability;
- Application of appropriate protective product to isolate the surface from environment, considering the potential for ongoing corrosion;
- Implementation of, or recommendation to the collecting institution, preventive conservation measures tailored to the artifact's microclimate, in order to stabilize its condition over the long term.



2 Some typical degradation issues of the Jordan bronze and iron artifacts

The ancient bronze and iron artifacts entrusted to the Regional Centre for Conservation and Restoration in Jerash are from the storage facilities of the Jerash Archaeological Site and the Jerash Archaeological Museum. X-ray fluorescence analysis has revealed that the bronze objects contain over 90% copper, with small amounts of tin and lead.

While the local climate in Jerash is generally dry, the collecting institutions often lack adequate environmental controls. Exhibition cases in the museum galleries are typically not airtight, and the air-conditioning systems are primarily designed for visitor comfort. As a result, daily fluctuations in temperature and humidity, driven by HVAC operation and visitor numbers, can be significant, potentially accelerating the development of corrosion products.

The main types of degradation observed are as follows:

- Surface deposits:
All objects exhibit varying amounts of soil-based deposits, which not only impair the legibility of the artifacts but can also retain harmful substances and moisture, and should therefore be removed.
- Corrosion products:
Some bronze objects are highly mineralized, with surfaces showing signs

from top,
Fig. 1

Bronze objects exhibiting active chloride corrosion.

Fig. 2

Iron objects showing different conditions.



from left,

Fig. 3

The dark areas on the iron cleaver blade indicate the locations of previous fills.



Fig. 4

Thick resin layer applied to the reverse of the lion-face handle.

of exfoliation. The localized chloride corrosion commonly observed on the objects likely originated from their burial environment and has been exacerbated by inadequate post-excavation storage conditions (Fig.1). The condition of iron artifacts varies significantly (Fig.2). Some excavated pieces from storage are severely mineralized, displaying active corrosion in typical form of orange spot and delaminating in irregular layers. Two objects from museum showcases had been previously polished, resulting in stable and lustrous external surfaces. However, ongoing internal corrosion led to expansion, generating stress between the corroded areas and sound metal, and causing cracks and disintegration. Loose, powdery orange corrosion products are visible within these cracks.

- Previous improper treatments:

Evidence of earlier interventions, such as adhesion, fillings, and coating, is present on some objects, though no corresponding documentation exists (Fig.3). A protective was applied to some artifacts without proper cleaning or desalination. Latent hazardous corrosion continued to develop in uncontrolled environment and form localized chlorides on bronze. On the lion-face handle, the inventory photo of unknown date showed that the active corrosion was once confined to a small area, by contrast, extensive symptoms of bronze disease are observed now. A thick resin layer on the reverse trapped the corrosion, leading to an explosive outward growth of chlorides, severely damaging the object's structure and the appearance of front side (Fig.4). On a roman bronze jar, stable corrosion and soil deposits were consolidated by protective agent, becoming more firmly adhered and difficult to remove.

- Cracks and breaks:

Such degradations are observed on both bronze and iron objects, as aforementioned, the cracks of the iron objects may occur in a secondary moment during the storage or display.

- Deformation:

In addition to deformation caused by natural deterioration, some objects exhibit distortion resulting from human-induced damage at a certain point in time. For instance, the roman bronze jar formerly used for storing coins was violently smashed, leading to particularly severe deformation around the broken areas (Fig.5).



Fig. 5
Close-up of the damaged
base of a Roman bronze
jar.

- **Losses:**
Losses of varying extents were found on almost all the objects. Past efforts to mitigate this problem are also observed on some objects (see Fig.2). On the iron cleaver from the museum, the blade was filled in an imitative way in the past, while the handle retains only adhesive residues. The loss of lion-face handle has been filled with a fibrous material, with highly mimetic inpainting on the front side (see Fig.4).

For conservation professionals in Jordan, identifying the presence of active harmful corrosion and previous restoration interventions is crucial in developing treatment strategies for bronze and iron artifacts. When selecting conservation methods and materials, it is essential to consider the intended storage environment and display conditions of the artifacts, as well as the available resources, in order to determine the most feasible approach. Given that many collecting institutions lack sufficient analytical equipment and well-equipped laboratory facilities, the methods and materials recommended in this study are environmentally friendly, relatively simple, and practical to implement. Readers should be aware that a wider range of conservation interventions is available in practice, and the approaches presented here are not exhaustive (Pedeli and Pulga, 2013; Rodgers, 2004, Selwyn, 2004).

3 Conservation strategies for bronze artifacts

3.1 Cleaning

The cleaning of metal artifacts primarily targets surface deposits and non-chloride corrosion that compromises their legibility, typically involving both mechanical and chemical methods. Mechanical cleaning employs handheld tools such as brushes, bamboo sticks, scalpels, dental probes, and fiberglass rods, as well as equipment like electric rotary grinding bits, ultrasonic scalers, and sandblasters. Due to the high copper content and resultant susceptibility to scratching in Jordanian bronze artifacts, mechanical cleaning must be carried out with extreme care. Handheld tools are generally preferred; powered tools such as rotary grinder with silicon carbide or corundum bits, or ultrasonic scalers, should only be considered for thick and hard encrustations. It is important to note that the use of metal brushes and sandblaster is generally not recommended for bronze objects.

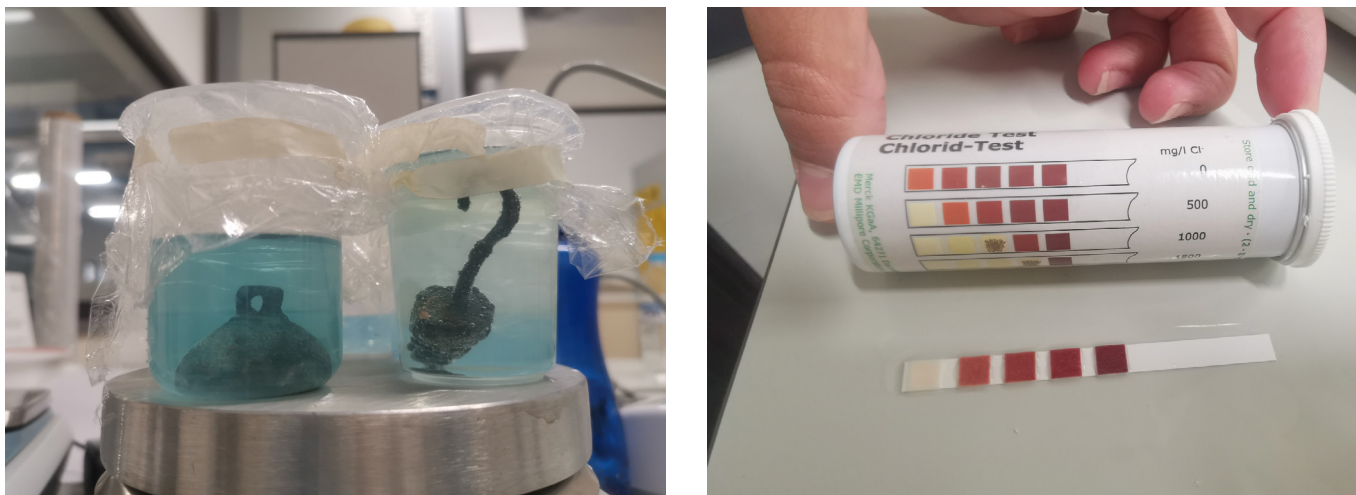


Fig. 6

A localized area on the rim of the roman bronze jar, before and after cleaning.

Chemical cleaning involves the use of low-toxicity organic solvents to remove greasy substances or aged restoration materials, as well as chelating agents such as EDTA trisodium, citric acid, and ion-exchange resins to eliminate corrosion products. While inorganic acids were employed in the past, they are now largely avoided due to their high risks. The concentration, application method, and contact time should be adjusted according to the area and the condition of the treated region. Primary application methods include swabbing, localized compressing, and immersion, which are listed in ascending order of intensity and invasiveness. During compressing and immersion, the surface condition must be monitored regularly to prevent over-cleaning. Another frequently overlooked issue is the redeposition of dissolved residues as the chemical solution dries. To avoid this, residues should be gently removed with a clean swab while the surface is still moist, after the reagent has sufficiently acted on the corrosion. For this reason, it is not advisable to treat excessively large areas at once, as this may hinder timely residue removal and compromise cleaning effectiveness. Furthermore, when chelating agents are used, thorough rinsing with deionized water is indispensable to eliminate any residual reagents.

The two cleaning approaches can also be combined. For instance, when chemical cleaning has loosened corrosion products, the process may be halted to prevent damage to the protective patina, followed by the use of mechanical tools for removal. This requires the conservator's professional judgment and flexibility in application. During the didactic program of the project, most of the Jordanian bronze artifacts were cleaned mechanically. For the removal of aged protective found on the Roman jar and the lion-face handle, tests with organic solvents revealed that acetone could affect the protective, which is probably a polyacrylic resin. Due to acetone's high volatility, neither swab rubbing nor the application of cotton pads soaked with acetone was sufficient for adequate removal of the bulky protective from the bronze jar. A method using Carbopol Ultrez gel loaded with acetone or methyl ethyl ketone was employed. This approach allowed for the controlled, sustained release of the solvent over a longer period, which proved highly effective and facilitated the subsequent mechanical removal of corrosion and soil (Fig. 6). However, the gel was found to be somehow sticky. For the fragile surface of lion-face handle, only compress with cotton loaded with acetone was used on the areas where very small pitting was found to occur, in order to allow a better evaluation of the condition and following mechanical removal.

**Fig. 7**

Immersion of small Roman bronze artifact in sodium sesquicarbonate solution and chloride monitoring with test strips.

3.2 Treatment of chlorides and inhibition

Chlorides usually penetrate deep into the metal core. It is necessary to first remove all visible loose powders until a relatively smooth and continuous cuprous oxide surface is exposed. If a discontinuous cuprous oxide surface is revealed, it is required to continue using sharp tools to remove the underlying cuprous chloride as much as possible. This corrosion product often appears as a greyish-white, waxy substance.

Mechanical removal alone cannot completely eliminate chlorides, necessitating further intervention with chemical methods for conversion and/or inhibition. This has been a subject of ongoing research interest, with a wide variety of materials employed. The specific choice of treatment must be determined by a comprehensive consideration of factors such as the artifact's size, the overall condition and the extent of chloride contamination. The potential for discoloration from the chemical reagents involved makes the original patina's condition and color an important consideration, as well. Different treatment strategies were adopted during the didactic program to tackle the case-specific situation.

A group of small Roman-era bronze artifacts exhibited dark surfaces with multiple spots of active corrosion. Besides, there was a high probability of latent chloride corrosion within the metal. After initial removal of the pitting visible on the surface, the long-established method of immersion in 5% sodium sesquicarbonate was employed (Fig. 7). The principle of this treatment is the substitution of chloride ions with carbonate ions, forming stable corrosion products in the form of basic copper carbonate (Oddy and Hughes, 1970). The chloride ion concentration in the solution was measured regularly, and the solution was replaced until the concentration stabilized at a low level. Subsequently, the objects were immersed in distilled water to remove any residual sodium sesquicarbonate. The ion exchange process can be accelerated by applying heat during immersion. There is no universally standard target for chloride ion concentration; values cited in different literature range from 50 ppm to 100 ppm (Cheng, 2024). Stabilization of the concentration must be observed concurrently. The frequency of solution changes is also determined by the conservator. Generally, it is changed weekly initially and can be changed bi-weekly later. The entire treatment process typically takes about



Fig. 8

Slight discoloration on the muzzle of the lion-face handle after localized application of L-Cysteine; humidity chamber test of small fragments detached from the border after immersion in L-Cysteine.

three months. Prolonged immersion in sodium sesquicarbonate may cause a color shift towards bluish-green due to the formation of chalconatronite. Nevertheless, for these bronzes, such a discoloration risk was considered acceptable.

In the case of the bronze jar, chlorides have been found as localized spots. The surface is covered by a thin, dark patina, with some areas exhibiting a shimmering copper-red color. Therefore, a localized treatment approach was clearly the more appropriate strategy: after mechanically removing the powdery part of the chlorides, a 0.15M L-Cysteine solution was applied by brush for inhibition (Gravgaard and Van Lanschot, 2012). Over the past decade, this inhibitor has been widely adopted in Italy, largely replacing benzotriazole due to its high efficacy and its safety for both humans and the environment. Additionally, it is reported to be effective in inhibiting copper corrosion in other aggressive acidic environment (Barouni et al., 2010). Areas treated with L-Cysteine turn grey; however, as the treatment was confined to small spots, it does not cause significant visual disruption.

Despite the extensive development of bronze disease, on the intact areas of the lion-face handle, a distinctive and aesthetically significant silver-colored patina remains. Therefore, a thorough treatment such as complete immersion was not feasible. Instead, handheld tools were used to carefully remove loose powdery corrosion from areas where a metallic core still survived beneath, followed by localized application of L-Cysteine. For some detached and severely corroded fragments, an attempt was made to immerse them entirely in L-Cysteine for approximately 24 hours without prior removal of the surface consolidant applied in the past. After drying, they underwent a 72-hour humidity chamber test, and



Fig. 9
The lion-face handle after
gap filling.

no new chloride activity has been observed so far (Fig.8). Following an extended observation period (approximately one month) in room temperature and relative humidity, the fragments are scheduled to be consolidated by drop-wise application of Paraloid B72 at 1.5–3% concentration and then re-attached to their original positions. While active corrosion issue may re-emerge in the long term, this approach represents a necessary compromise to avoid excessive material loss.

Jordan scholars have achieved satisfactory results using electrochemical desalination for bronze artifact treatment (Abu-Baker, 2023; Al Saad et al., 2021). This method, however, requires specific equipment, poses challenges in process control, and is unsuitable for extensively erupted corrosion products. A simpler alternative based on the same electrochemical principle is the zinc powder reduction method (Sharma et al. 1995). This approach involves applying a paste of zinc powder mixed with ethanol or an ethanol-deionized water mixture locally onto powdery corrosion spots to facilitate galvanic replacement, which demonstrates considerable practical utility.

3.3 Reassembly and gap filling

The conventional materials and procedures for reassembly and gap filling are as follows: a layer of Paraloid B72 around 3% is first applied to the fracture, which improves the following adhesion and the reversibility of the intervention. The fragments are then bonded using a two-part, solvent-free epoxy resin, UHU Plus Endfest 300, ensuring the adhesive is applied in appropriate quantity to avoid excess. The same epoxy resin is used for gap filling, mixed with mineral fillers and mineral pigment powders to achieve a suitable consistency and color. Common mineral fillers include calcium carbonate powder and talc powder. The particle size should not be too fine, as this can compromise the strength of the cured resin. The epoxy requires approximately 24 hours to cure fully. Once hardened, the filled areas are carefully sanded to eliminate any undesirable gloss. If necessary, the surface can subsequently be toned to match the surrounding original patina using alkyd paint or resin-based acrylic paint.

An alternative strategy is required for areas with limited bonding surface and where gap filling is impractical. The base of the bronze jar is severely deformed; however, further intervention has not been authorized by the custodial institution. Therefore, for the fragile and lifting sections of the base, a method combining epoxy resin adhesion with internal lining reinforcement was employed. The lining material selected was silk, applied from the inside using a 20% Paraloid resin, which offers greater reversibility.

The lion-face handle exhibits partial losses along its edges and on some part of the facial areas. Given the object's highly fragile state, the conventional approach of filling losses with epoxy resin was deemed too risky, as it would require subsequent sanding which is accompanied with further stress. Instead, it was decided to trim the lining material to an appropriate size and apply reinforcement from the reverse. The plan is to subsequently carry out inpainting on this lining. This strategy mitigates the visual disruption caused by the losses while avoiding more invasive and risky procedures, and it adheres to the conservation philosophy of recognizability (Fig.9). The product of adhesion in this case should also be a reversible and more elastic resin such as Paraloid B72.

3.4 Surface protection

The surface must be thoroughly dried and dusted. Polyacrylic resins are typically used for surface protection. During the application, the resin is usually applied in two coats, brushed in perpendicular directions to minimize brush mark visibility. Among the commonly used Paraloid resins, B44 has a higher glass transition temperature and is less bulky than B72, making it more frequently chosen for metal artifacts. However, the selection also depends on the visual effect on the surface. Excessively volatile solvents like acetone may cause blooming (whitening), while applying the resin too thickly can leave an overly glossy finish.



Fig. 10

Inpainting over the fill of the handle to create a visually homogeneous surface.

4 Conservation strategies for iron artifacts

4.1 Cleaning

The working logic for iron cleaning is similar to that for bronze objects. The most common method for archaeological iron is mechanical cleaning, with sandblasting also being frequently employed. Chemical agents such as citric acid, ammonium citrate, oxalic acid, phosphoric acid, and disodium EDTA are sometimes used. However, these chemicals require thorough rinsing with deionized water to remove residues, which poses a potential risk. Within the didactic program, mechanical cleaning was almost exclusively adopted.

4.2 Inhibition

The most commonly used inhibitors for iron artifacts are rust converters and tannic acid (Binnie et al., 1995; Logan, 2014). The standard practice of applying tannic acid involves preparing a 2.5% solution using a water-ethanol mixture or pure water; a 5% concentration can also be used sometimes. During application, the solution should be brushed in unidirectional strokes. A second coat is applied after a 24-hour interval, brushed in a direction perpendicular to the first layer. Controlled, firm pressure should be applied during brushing to ensure sufficient reaction between the solution and the surface. Tannic acid tends to darken the surface towards a purplish-black hue, so it is crucial to monitor whether the color change exceeds the visually acceptable level.

4.3 Reassembly and gap filling

The materials and methods are similar to those used for bronzes. On severely degraded iron objects, fragmented sections often cannot be fully reintegrated, and fillers do not need to be sanded perfectly flush with the surrounding surface. As seen in the treatment of the iron cleaver, the gap-filling is primarily for the fixing of the fragments, some fissures are just consolidated without bulky filling, allowing the object to bear witness to its past. The choice of inpainting is based on both the aspect of the extant historical filling, which is conserved for its good condition, and the color of the surrounding original surface. A dark tone was selected to subdue the visual impact while ensuring the recognizability of the filling (Fig.10).

4.4 Surface protection

The methods and materials for surface protection of iron artifacts are also similar to those used for bronzes. Conventionally, a layer of microcrystalline wax is applied over the polyacrylic resin to provide extra protection for this more reactive metal. This must be done after the complete evaporation of the solvent in the acrylic resin (Molina, 2023). After applying the microcrystalline wax, it should be left to set overnight. Then, use a chamois or a soft, lint-free cloth to burnish the surface. This process removes brush marks from the wax application and adjusts the surface sheen to a soft, natural aspect. If the surface is highly coarse, care must be taken during application to prevent wax from accumulating in the pores. Wax compensates for the susceptibility of polyacrylic resins to scratching and acts as a sacrificial layer. Solvents for the eventual removal of aged wax coatings have already been reported in relevant literature (Biribicchi et al., 2023).

Fig. 11

Alignment of the joints during reassembly.

**Fig. 12**

Bonding of the fragments of the sleeve from the later-damaged side (left) and the initially damaged side (right).



5 Interpretation of the conservation principles in practice

Principles derived from Cesare Brandi's theory, such as minimum intervention, reversibility, and recognizability, have become the prevailing ethical guidelines in today's cultural heritage conservation field. However, their practical interpretation largely depends on the specific condition of each artifact and the conservator's understanding, as previously illustrated.

During the conservation treatment of objects in this project, aged coatings that hindered cleaning were removed, while structurally sound historical adhesives and fills were retained, as demonstrated in the case of the iron cleaver. Sometimes, this preservation is a reluctant choice and a temporary compromise. For instance, the restoration materials on the reverse of the lion-face handle, whether judged by the appearance, material composition, or the craftsmanship of the application, could not be considered qualified work. However, given the extreme fragility of the artifact itself, it was temporarily decided to leave them in place.

Different strategies have been adopted for the issue of deformation. In the case of the iron cleaver, the development of internal corrosion and inadequate previous adhesion had caused the components of the handle to detach, and only the core remained connecting to the blade. During the restoration, doubts were raised regarding the adhesion of a fragment at the end of the handle. It was observed that, based on the alignment of the joints, one end of a fragment was slightly raised and detached from the underneath fragment (Fig. 11). This actually touches upon the need to balance historical information from different periods of the artifact.

The deformation was more severe in the sleeve of an iron spade. Based on the fracture morphology on both sides where it connected to the blade, it could be determined that destructive external force, focused compressive pressure on one side of the sleeve, had caused severe compressive deformation in the arched middle section of the sleeve. The compression at the opening measured nearly 1 cm, making it impossible to realign through minor adjustments at the joints. The adopted reassembly strategy involved seamlessly rejoining the central fractures of the sleeve. The alignment of the sleeve with the later-damaged side of the blade closely followed the original fracture, but was slightly adjusted to improve its fit with the initially damaged side. The latter subsequently received a thicker adhesive filling to close the inevitable gap (Fig. 12). For display, it is suggested that the artifact be shown in profile, accompanied by an acrylic mount extending from the sleeve to suggest the original form of the missing handle. This approach minimizes the visual disruption caused by the misaligned side, while still allowing viewers to understand the object's original appearance and function.

6 Measures for preventive conservation

The recommended relative humidity (RH) for storing metal artifacts is below 40%, with fluctuations not exceeding $\pm 5\%$. Although some regional institutions have developed straightforward conservation guidelines (Marri and Dissi, 2020), improvements in physical infrastructure and facilities of Jordanian custodial institutions cannot be achieved overnight. A more feasible measure at present is to create sealed microclimates with low humidity for high-risk artifacts. Since display cases are generally not airtight, and active humidity control is costly, it is recommended to create a suitable microclimate for individual objects. One of the simplest methods is to place the artifact in a sealed bag along with sheet-type Artsorb moisture-absorbent material. This is particularly suitable for relatively flat

objects with lower display requirements and can remain effective for an extended period.

For the lion-head handle, the preliminary plan involves designing a display case with a passively controlled microclimate. The case of transparent acrylic material should be divided into upper and lower sections by a perforated panel. The upper section houses the artifact for display, along with a small electronic temperature and humidity data logger. The lower compartment is reserved for moisture-absorbent material such as silica gel, designed with a flip-top or drawer mechanism for regular replacement. A silicone gasket will be installed around the edges to enhance airtightness, and the entire lower section should be shielded using adhesive film or opaque panels. Regarding the quantity of silica gel, based on experience in high-humidity environments, placing 1 kg of silica gel per cubic meter of space can maintain a relative humidity (RH) of 40% for up to three months, provided the display case is well-sealed. For the discussed case, it is recommended to keep the RH below 30%. Assuming the total volume of the display case is 0.03 m³, the calculated amount of silica gel would be 30 grams, though a higher quantity is advisable. Before placing the artifact, it is recommended to position the silica gel inside first and conduct a period of humidity monitoring to test the case's seal and determine the appropriate amount of silica gel required.

Regardless of whether a humidity-controlled microclimate is established, regular condition assessments of the artifact are essential. If any deterioration is detected, immediate isolation and treatment measures should be taken. As research on the long-term performance of protectives remains limited, collecting institutions should establish inspection frequencies based on their specific storage environments and the condition of the artifacts.

In addition to humidity, volatile pollutants in the environment are also critical for the preservation of metal artifacts. One long-established, economical, and straightforward method is the Oddy test, developed by the British Museum (Korenberg et al., 2018). This test involves placing display or storage materials together with copper, silver, and lead coupons in a high-temperature and high-humidity environment for a set period. The corrosion status of the metal coupons is then assessed to determine whether the material is unsuitable, suitable for short-term use or long-term use.

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Conservation of an Iron Cleaver

Qais Azmi Radwan Almomani, Mohammad Ali Mustafa Alalawneh

In conserving the iron cleaver, we balanced factors such as available time, object safety, and visual outcome, selectively preserving or removing previous restorations. The final result retains both the archaeological profile and the 'vicissitudes' of the object. The condition of this object is quite typical, making the experience a valuable reference for future work.

The sodium sesquicarbonate immersion treatment revealed a notable level of chlorides within the small bronze objects, which would have been difficult to anticipate. This method allows for a more thorough treatment of bronze disease. During the treatment, we gently heated the solution to accelerate it. As light-colored products from the reaction were found to accumulate on the objects' surfaces, we periodically removed them by mechanical means.

Fig. 1

Mohammed and Qais
filling the gaps of the iron
cleaver.



Conservation of a Roman Bronze Jar

Eman Suleiman Muflih Quran, Rita Sulaiman Yousef Al Dawood

The surface condition of the Roman bronze jar was highly inhomogeneous. Our challenge was to remove the corrosion products and hard encrustations without damaging the thin patina of the surrounding areas. Experimenting various chemical and mechanical methods gave us deeper insight into each approach's suitable applications, advantages, and limitations. We will certainly retain the gel-loaded organic solvent method in our toolkit and expect to use it again in the future.

The iron spade illustrates the frustrating issue of metal deformation. While it was neither ethically permissible nor technically feasible to restore its original shape, deducing the point of force application at the time of damage based on the fracture morphology and deformation pattern was a truly exciting process. We hope that our final choices in the conservation and presentation of this artifact will help viewers understand both its original form and its history.

Fig. 1

Emman and Rita
cleaning the roman
bronze jar.



Conservation of a Bronze Lion-face Handle

Bilal Fawwaz Mohammad Alboreeni, Hussein Mohammad Mahmoud Krashat

The lion-face handle proved to be a rare and valuable challenge for conservators. It is regrettable that the past improper restoration and substandard preservation conditions have led to the object's current highly deteriorated state. Based on its preservation condition and original craft characteristics, after careful consideration, we selected L-Cysteine as the corrosion inhibitor and applied it flexibly in different delivery methods according to the varying local conditions. We also employed new technologies such as 3D scanning and printing to document the object and to enhance the safety of the object during intervention. The effectiveness of the intervention will require long-term verification – we look forward to observing the results.

Fig. 1

Bilal and Hussein removing the corrosion from the lion-face handle.



Fig. 2

Support of the lion-face handle realized through 3D techniques.



Restoration and Conservation of Stone Materials

Luciana Festa, Nikolas Vakalis

Abstract: This paper examines the methodologies involved in the restoration and conservation of stone materials, highlighting the importance of diagnostic surveys, careful planning, and the need for compatible and reversible interventions. It also presents the training experience carried out at the RCCR in Jerash, based on an interdisciplinary approach integrating theory, laboratory practice and innovative technologies for the protection of cultural heritage.

Keywords: Stone materials; Documentation; Diagnosis; Conservative intervention; Maintenance.

Introduction

Stone restoration is a complex and delicate process that requires not only technical expertise but also a thorough understanding of materials and historical construction techniques. Over time, stone – widely used in historic buildings, monuments and sculpture – can undergo various forms of degradation caused by environmental factors, pollution, wear and tear, and, in some cases, inappropriate past interventions. Therefore, restoration must be approached with scientific rigour and respect for cultural heritage.

The fundamental principles guiding conservation are minimum intervention, reversibility – wherever possible – and respect for the original material. Every intervention should be preceded by a comprehensive diagnostic study, which is essential to understand the nature of the material, its state of preservation and the causes of its degradation.

1 Methodological aspects of stone materials conservation

1.1 Preliminary surveys and documentation

The first stage of the project involves the collection and analysis of all available information relating to the monument:

- historical research;
- high-resolution graphic and photographic documentation;
- identification of the stone type, its mineralogical composition and the original construction technique;

- identification of any previous treatments and their effects on the surfaces;
- macroscopic analysis and mapping of degradation phenomena (such as black crusts, disintegration, erosion, biological colonisation, etc.);
- targeted diagnostic investigations (including petrography, SEM-EDS, XRD, salt analysis, moisture measurements);
- assessment of the environmental context, including thermo-hygrometric cycles and active causes of degradation.

This phase provides a comprehensive understanding of the object and forms the basis for designing a conservation project tailored to its specific needs.

1.2 Intervention planning

The intervention plan must comply with conservation principles. Careful consideration should be given to the selection of materials, which must be compatible with the original materials, both chemically and visually. Consolidants, mortars and resins must be selected with particular care, avoiding aggressive chemicals that could accelerate over time.

1.3 Restoration work implementation

The practical approach may vary considerably depending on the specific condition of the artefact. Interventions may include cleaning, crack repair, surface protection, or, where appropriate, the reconstruction of missing elements. All procedures must be carried out with caution, using minimally invasive mechanical methods and avoiding abrasives that could damage the original surface.

Cleaning

The cleaning process aims to remove deposits and degraded layers without damaging the original surface.

Techniques are selected according to the nature of the stone and the type of present deposit:

- mechanical cleaning (soft brushes, micro-chisels, controlled micro-sandblasting);
- chemical cleaning using compresses with low-concentration chelating agents or surfactants;
- cleaning using innovative physical systems (low-intensity laser systems, controlled water misting).

Each intervention must be preceded by preliminary tests to assess the effectiveness and safety of the selected method.

Pest control and biological treatment

In the presence of biological growth, including algae, lichens or bacteria, the following steps shall be undertaken:

- application of broad-spectrum biocides, selected according to compatibility criteria;
- careful mechanical removal of dead organisms;
- follow-up monitoring to check for any potential regrowth.

Consolidation

Consolidation aims at restoring cohesion in degraded stone, particularly in cases of disintegration or loss of structural integrity.

Commonly used materials include:

- ethyl silicates, suitable for siliceous and calcareous stones;
- nano-calcium and nano-magnesium, suitable for calcareous substrates;
- specific inorganic hybrid systems for specific situations.

The consolidant should penetrate deeply, remain stable over time and preserve the stone's colour and permeability.

Filling of gaps

The filling of gaps should be:

- recognisable yet visually harmonious;
- compatible in terms of composition and physical behaviour.

These are typically carried out using traditional lime-based mortars, stone powders, or specially formulated mixtures with additives, depending on the specific context. The degree of formal restoration depends on the conservation approach adopted (recognisability, controlled camouflage, neutral restoration).

Surface protection

Where stone is exposed to severe environmental or weather-related degradation, a final protective coating may be applied such as:

- low-viscosity siloxane water-repellents;
- specific treatments against erosion or salt crystallisation.

In cases of particular exposure to vandalism, anti-graffiti treatments may be used. These involve the application of surface coatings that may be either permanent (i.e., allowing cleaning without removal) or sacrificial (i.e., removed together with the graffiti).

In all cases, protective treatments must allow the material to breathe, must not alter the original appearance of the stone, and should not form impermeable surface films.

Follow-up monitoring and maintenance

Once the restoration is complete, a follow-up monitoring plan must be put in place to assess the effectiveness of the interventions over time. This involves regular inspections to detect any new signs of degradation, as well as a preventive maintenance programme to ensure the long-term performance of the applied solutions.

Final documentation

Finally, comprehensive documentation of the entire restoration process is essential – from the initial diagnostic phase through to the interventions carried out and the final results. This documentation serves not only as a historical record but also as a fundamental resource for any future conservation work.

Conclusions

In summary, the restoration of stone materials requires a multidisciplinary approach that combines scientific, technical and historical perspectives. Only through carefully planned interventions carried out with expertise can the long-term preservation of significant cultural heritage be ensured for future generations.

2 Training at the RCCR in Jerash

2.1 Introduction

The didactic unit on the conservation and restoration of stone materials was designed to provide a structured and in-depth understanding of current methodologies and advanced techniques in the field.

The training enabled participants to develop highly specialised skills in an area that play a crucial role in the protection and enhancement of cultural and artistic heritage, both locally and across the wider Middle Eastern region.

Combining theoretical lectures with practical fieldwork, the course offered a comprehensive and multidisciplinary specialist programme, designed to train professionals capable of addressing the complex challenges characterising the conservation and restoration sector today.

A key strength of the training programme laid in its interdisciplinary approach and focus on practical application. Alongside the acquisition of technical and scientific knowledge, participants were encouraged to critically reflect on the broader issues regarding the conservation and protection of stone artefacts. The aim was to promote a deeper and more informed awareness of the importance of safeguarding historical and artistic heritage, going beyond purely technical work. This methodological approach aimed to equip participants with the ability to balance the technical requirements of restoration with respect for the symbolic, cultural and historical value of the objects and sites they will encounter in their future professional practice.

The training programme was designed to cover all stages of the conservation and restoration process, from diagnostic survey and project planning to the implementation of interventions.

Particular attention was paid to the use of advanced technologies in conservation. Traditional methods were combined with innovative solutions, promoting effective and sustainable approaches designed to reduce the environmental impact of interventions. These included laser cleaning techniques for precise and delicate operations, as well as the use of eco-friendly products. Furthermore, the course examined recent advances in nanomaterials, highlighting their transformative potential due to their chemical and physical properties and their ability to ensure long-lasting and sustainable results over time.

Practical laboratory sessions formed an integral part of the programme, providing hands-on experience with real case studies. These activities enabled participants to engage with complex conservation issues, work with peers and develop teamwork skills, which are essential in professional practice. Through guided discussions and critical analysis, participants were encouraged to examine different approaches and identify the most appropriate solutions for each specific project.

In summary, this course provided a comprehensive and high-quality training opportunity for those who have a conscious and careful approach to the conservation and restoration of stone materials. Participants not only acquired practical conservation techniques but also developed an integrated, interdisciplinary understanding of conservation work, encompassing technical, aesthetic, ethical and cultural dimensions. This kind of training has equipped them with the cutting-edge skills, knowledge and critical awareness required to pursue a professional career in a field that plays a vital role in the protection of cultural heritage.

2.2 Theoretical lectures

The course included a theoretical component designed to provide participants with a solid foundation of interdisciplinary knowledge, essential for navigating the complex world of restoration and conservation with confidence.

The introductory topics addressed general themes, including the fundamentals of mineralogy, the identification of stone materials and working techniques employed in the past, as well as the criteria used to assess the state of conservation of historical artefacts. These initial sessions prepared participants to explore in greater depth the conservation methodologies, structured according to the different stages of the restoration process.

All the main processes involved in the conservation of stone materials were examined, from cleaning techniques – chemical, physical and mechanical – to consolidation procedures using both organic and inorganic materials. Particular emphasis was placed on methods for reassembling artefacts – both with and without supports –, as well as on restoration techniques using air-setting and hydraulic mortars, and on preventive protection against environmental and anthropogenic degradation. Through interactive lectures and practical demonstrations, participants had the opportunity to become familiar with the materials and the most appropriate intervention strategies to ensure effective conservation.

A specific section of the course focused on preventive conservation and on the importance of ongoing maintenance, both in museums and at archaeological sites. This theoretical knowledge was supplemented by case studies illustrating the application of the methodologies discussed.

One of the most innovative aspects of the programme was its focus on cutting-edge techniques, including the use of nanomaterials and laser cleaning. A three-day intensive seminar was devoted to the latter, during which participants were able not only to have a practical demonstration of the technology itself but also to put it into practice. They were also given a certificate confirming their ability to use it.

Equally important was a preparatory module focused on the technical documentation required in restoration work. Participants were trained to fill in, with precision and methodological rigour, photographic and graphic documentation for every single artefact, recording essential information such as constituent materials, manufacturing techniques, state of conservation, previous interventions and treatments carried out during the course. This component, which started and accompanied the restoration work, served the dual purpose of providing technical skills and emphasising the importance of traceability and scientific rigour in contemporary conservation and restoration practice.

Overall, the course did not simply provide a strong theoretical foundation. It fostered a modern, interdisciplinary approach to conservation, combining tradition and innovation, sensitivity to cultural heritage, and adherence to the highest ethical and professional standards.

2.3 Laboratory training

The practical component of the course took place in the laboratories of the Regional Centre for Conservation and Restoration, state-of-the-art facilities fully equipped with cutting-edge equipment. The laboratories included: a diagnostics department, essential for the in-depth analysis of the artefacts to be restored; a storeroom containing a wide range of materials required for interventions; a

**Fig. 1**

Discussion on the conservation aspects of the artefacts.

shielded environment designed for the safe use of laser technology; and a room equipped with protective devices for potentially hazardous procedures. For detailed and microscopic observation, both optical and digital microscopes were available, which proved indispensable to examine the conditions of surfaces and materials. The artifacts selected for restoration were provided by the Management of the Jerash archaeological site, with the attempt to expose participants to a wide range of typical damage and issues. This selection ensured a comprehensive and varied learning experience, providing opportunities for discussion and the application of diverse restoration techniques.

The materials addressed during the restoration work consisted mainly of limestone, marble and sandstone – the most common stone types found in the Jerash area and, more broadly, across Jordan. These were primarily architectural elements from the nearby archaeological site, often showing signs of degradation caused by weathering, as well as, in many cases, human intervention.

Following careful initial graphic and photographic documentation, participants engaged with all stages of the restoration process: from cleaning – carried out using chemical, mechanical and laser methods (Fig. 2) – to the consolidation of structures through the application of advanced chemical treatments. The restoration of missing parts using specific mortars (Fig. 3) was also addressed, as was the reassembly of fragments using appropriate adhesives (Fig. 4). Finally, a final protective layer was applied to ensure the long-term preservation of the restored works, in accordance with safety and sustainability criteria.

Thanks to this hands-on experience, participants were able to explore a wide range of techniques and materials, acquiring valuable practical skills that can directly be applied to professional practice in conservation and restoration.



Fig. 2

Surface cleaning as a key stage in the conservation work.

2.4 Concluding remarks

As is often the case with international projects, the experience proved to be both professionally enriching and personally rewarding.

The ancient city of Jerash provided an extraordinary setting that significantly enhanced the practical components of the course. The site's historical significance and charm not only served as a source of inspiration, but also highlighted the importance of preserving this heritage for future generations.

The architectural elements, primarily in limestone, marble and sandstone, offered a wide range of materials for study and practical work, thereby broadening the scope of the restoration techniques covered during the course.

One of the the most significant aspects of the experience was the exchange of knowledge and ideas between the trainers and participants. Working alongside Jordanian colleagues from diverse cultural and professional backgrounds fostered a dynamic and collaborative environment. It was particularly rewarding to see how this dialogue enriched the learning process for all involved, creating a space in which different perspectives contributed to the development of innovative solutions.

The laboratory activities, supported by advanced equipment such as microscopes and laser systems, enabled participants to engage fully with every stage of the conservation process, from documentation to final protection. Guiding participants through these stages—from cleaning and consolidation to reintegration and long-term preservation strategies—was particularly rewarding from an educational perspective.

The three-day seminar on laser cleaning was particularly engaging (see L. Bartoli



above,

Fig. 3

Experimental preparation
of material mixtures for
the filling of gaps.



on left,

Fig. 4

Testing of fragment as-
sembly methods.

in this volume). Showing how to use this cutting-edge technology and enabling participants to obtain certification was a particularly significant moment, as it confirmed the course's commitment to integrating innovation with established practice. Sharing knowledge on such advanced techniques highlighted the importance of modern tools in addressing conservation challenges in an effective and responsible manner.

Overall, participation in this project represented a highly valuable professional experience. It highlighted not only the technical aspects of conservation but also the importance of collaboration, knowledge exchange, and education in safeguarding cultural heritage and training future professionals in the field.

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Training and Methodology in Mosaic Restoration: The Experience of the Regional Center for Conservation and Restoration in Jerash

Francesca Mariani, Cristina Caldi, Sara Scioscia, Martina Fagioli

Abstract: This paper presents the training programme carried out in 2024 at the Regional Center for Conservation and Restoration in Jerash, focusing on the conservation and restoration of detached mosaics. The course combined theory with practical work through the study of a floor mosaic preserved at Ajloun Castle in the form of panels. The analysis of these sections enabled the definition of different strategies for restoration and preventive maintenance, while proposing a replicable educational and operational model for the sustainable management of detached mosaics.

Keywords: Mosaics restoration; Detached mosaics; Training on conservation; Preventive conservation; Reversible backings; Museum exhibition; Microclimate control.

Introduction: training programme framework in Jerash

The establishment of the Regional Center for Conservation and Restoration (RCCR) in Jerash forms part of a broader framework of scientific and cultural cooperation aimed at safeguarding Jordan's archaeological heritage, with a particular focus on floor mosaics from the Roman, Byzantine and Umayyad periods, which can be found all over northern Jordan.

The training programme for the course 'Conservation and Restoration of Detached Mosaics – Didactic Unit No. 2-03' was structured into both theoretical and practical didactic units, held between March and June 2024 at the RCCR laboratories in Jerash and at Ajloun Castle, where a pilot restoration and documentation project was launched.

The course, delivered by the authors of this paper, comprised 36 hours of lectures and over three months of practical training. The teaching pursued a dual objective: on the one hand, to train officials from the Department of Antiquities (DoA) in up-to-date conservation techniques in line with the principles of minimum intervention; on the other, to define an integrated operational model based on a combination of different multidisciplinary skills.



Fig. 1
Exhibition hall and display
panels.

1 The Ajloun mosaic case study: reconstruction, restoration and prospective exhibition

As part of the project, the working group examined a floor mosaic from a private residence at the Umm al-Yanābī site, from which it had been removed to protect it from the works due to be carried out at its original location.

The mosaic had been detached by cutting it into thirteen sections. It is not known whether the bedding mortar had also been removed during this process. However, the back of the sections was subsequently thinned down to the tiles. These reduced sections are now preserved at the Ajloun Castle Museum.

Set on a white fibre-reinforced concrete backing strengthened with a metal mesh, the sections form independent panels supported by a metal frame. Ten of these panels are on display in a large room with windows, arranged at an angle on wooden display stands specifically constructed to facilitate viewing, as shown in Fig. 1.

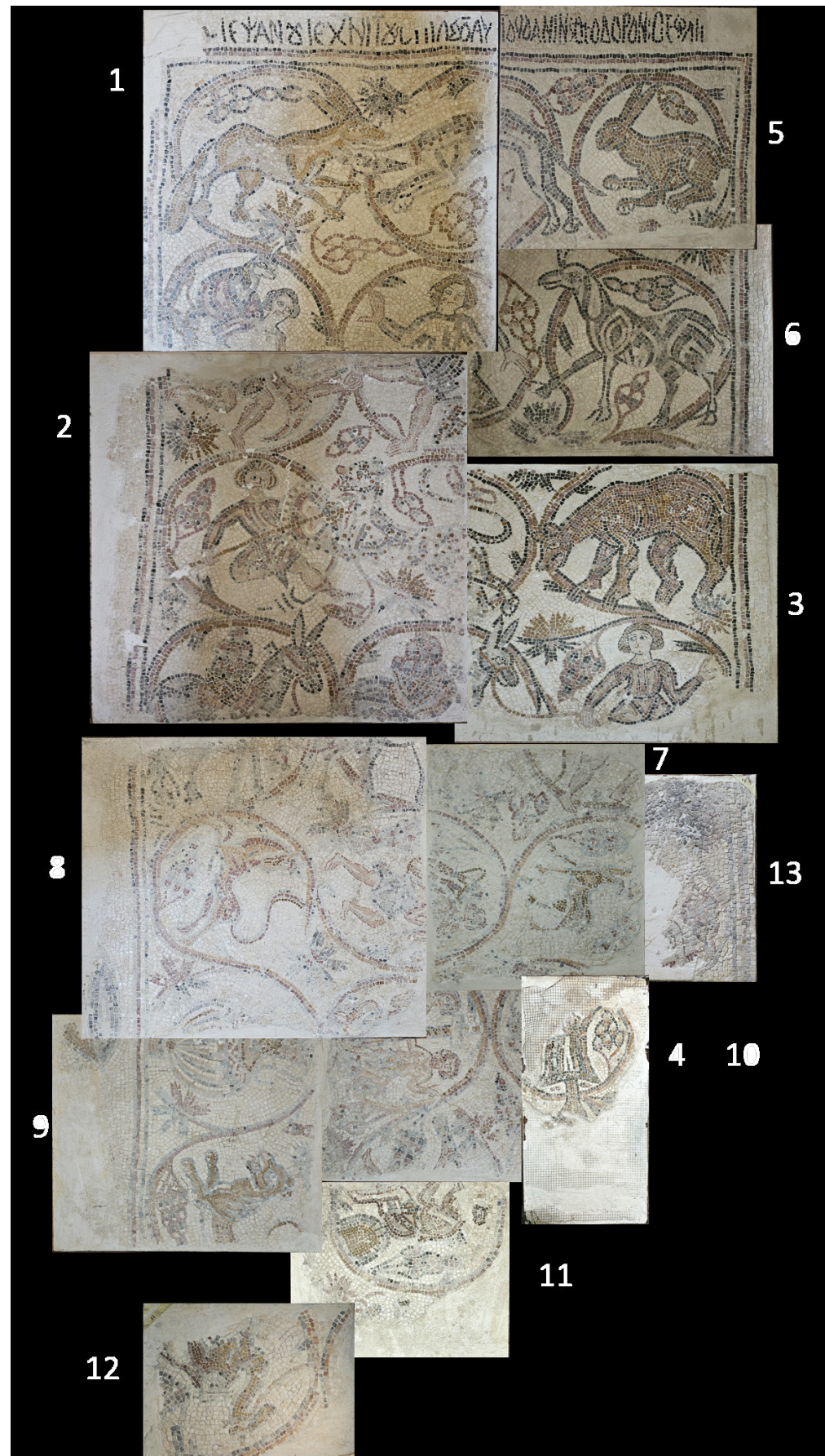
A report on the intervention, together with photographic documentation of the removal stage, is held in the Castle offices. While these documents have been made available for consultation, it was not possible to reproduce photographs of the mosaic on site.

The cuts made to remove the mosaic floor have abruptly disrupted its narrative, dividing it into isolated episodes, which – although numbered – are now arranged randomly. As a result, it has lost much of its unique historical, artistic and material significance. A possible reconstruction of the scenes, as well as the panels size, are shown in Fig. 2, which retains the numbering found on the back of each section.

The proposed reconstruction allows part of the mosaic to be appreciated as a whole. At the top, a dedicatory inscription in Greek characters can be read. Within a double frame, the field presents allegorical and agricultural scenes, as well as

Fig. 2

The proposed reconstruction allows part of the mosaic to be appreciated as a whole.



**Fig. 3**

Panels found in the museum's storerooms and an example of the condition of the state of conservation of the

backing.

a. Panel 13;

b. Panel 12;

c. Panel 10;

d. Panel 10: oxidation and damage to the backing.

lively representations of courtly life and hunting. The various scenes, set among vine branches bearing bunches of grapes and date palms, are interwoven in a continuous sequence of visual references and transitions. These compositions draw on Alexandrian iconographic traditions later passed on to the proto-Islamic period.

Similar representations can be found in other significant examples of mosaic decoration in Jordan [Piccirillo, 1991; Nassar and Turahan, 2012], although the composition here less structured and more dynamic.

The mosaic features both domestic and wild animals, including large mammals such as the bear and the oryx, now extinct.

The background, made of limestone tiles laid using the *opus tessellatum* technique, is light in colour, just like the vegetal elements and the animals. The human figures, by contrast, are particularly refined, with faces and limbs executed using the *opus vermiculatum* technique. In addition to red and black stone tiles, there

are rare examples of green and turquoise glass paste tiles – materials widely used in Byzantine and Umayyad eras [3] –, which are thought to have been reused here. Of the sections removed during the previous conservation work, ten (No. 1-9 and 11) are currently on public display, while three (No. 10, 12 and 13) were kept in storage and were found to be in a state of advanced degradation. Figs. 3a, b and c show the panels prior to the intervention, while Fig. 3d shows details of the condition of the backing. During the course, observations made through direct examination of the artefact made it possible to distinguish between two types of conservation requirements: in the case of panels on display, it was found that proper scheduled maintenance combined with microclimate control would be enough to ensure their long-term stability; on the contrary, for the panels in storage, considering the widespread oxidation of the metal mesh and the partial loss of tiles, a full restoration intervention as well as the replacement of the backing were deemed to be essential.

A comparative analysis of the sections was thoroughly carried out using 1:1 scale drawings and systematic photographic documentation. These activities, which required course participants to work in close contact with the artefacts over an extended period of time – as shown in Figs. 4a, 4b and 4c – highlighted the real possibility of reassembling the mosaic in its entirety, thereby restoring iconographic continuity and giving back narrative clarity to the scenes.

The resulting prospective way in which it could be exhibited envisages a new arrangement based on principles of historical coherence and clarity. It combines the restored panels with those already in good condition through an integrated and reversible display system. This proposal, discussed with the management of the Ajloun Museum, outlines a future programme of enhancement and virtual reconstruction to be developed using 3D laser scanning and digital graphic reconstruction.

2 Teaching methodology and interdisciplinary approach

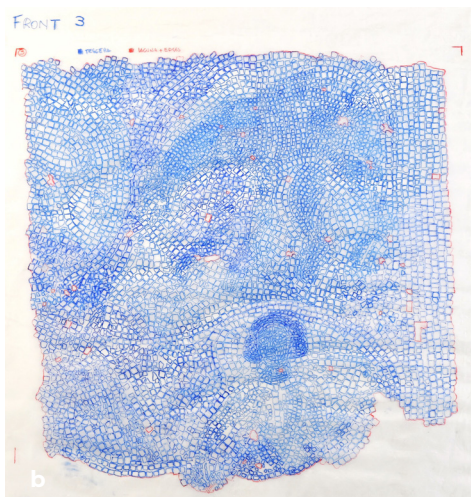
The course's methodological framework combined lectures, practical demonstrations and workshop activities, organised into progressive didactic units. The first didactic unit focused on the study of the constituent materials and construction techniques of the Umm al-Yanābī mosaic at Ajloun Castle. This included the production of 1:1 scale drawings of all the panels and the observation of the main forms of degradation affecting both the mosaic fragments and their modern backing.

The second didactic unit addressed the lime cycle and mortar testing. As a practical exercise, participants were required to reproduce an ancient model using the *opus tessellatum* technique (Fig. 5).

During the third and fourth didactic units, participants were guided through the processes of facing, removal of cement-based backings, and preparation and laying of sections 10, 12 and 13 onto new panels.

Finally, the fifth didactic unit focused on the filling of gaps and the final presentation of the artefacts.

Throughout the course, strong emphasis was placed on the relationship between theory and practice, with the aim of strengthening participants' ability to diagnose the causes of degradation and to choose appropriate and reversible technical solutions.

**Fig. 4**

- a. Course participants during the survey, examining the mosaic;
- b. Bear, detail from panel No. 3;
- c. 1:1 scale drawings of the bear. Note the pattern, the density of tiles and the missing sections (shown in red).

Fig. 5

Participants involved in the creation of a model using the *opus tessellatum* technique.



Active learning methods were employed, including the discussion of case studies, comparison with historical examples of Italian restoration, and simulations of drafting intervention plans and condition reports. The intercultural nature of the group fostered collective reflection on the ethical principles of conservation, as well as on the need to adapt techniques to the local context, giving priority to materials that are available locally and compatible with the original substrates.

3 Diagnostics, microclimate control and scheduled maintenance

The entire project was based on the principle of preventive conservation. In the case of the Ajloun panels, it was decided to limit direct intervention where conservation conditions were stable, and instead to implement a programme of continuous environmental control.

The use of data loggers to record temperature and relative humidity over a period of four seasons would make it possible to correlate environmental conditions with the state of conservation of both the substrates and the mosaic as a whole.

In parallel, microscopic and petrographic analyses of tiles made of different materials (i.e., stone and glass), together with a microanalysis of the original and restored bedding mortars, would enable the identification of degradation products and the formulation of appropriate mitigation measures. At the same time, the stability of the backings could be monitored using non-destructive vibro-acoustic techniques.

This methodological approach proved particularly significant in the teaching context. Participants came to understand that the study of the techniques used to make the artefact in question, together with the analysis of deterioration processes through observation and diagnostic surveys, does not represent a separate stage from restoration, but rather an integral part of the broader process of knowledge acquisition and decision-making.

Looking ahead, the systematic application of environmental control protocols and scheduled maintenance programmes could reduce the need for more invasive and costly interventions, thereby ensuring the long-term preservation of this valuable detached mosaic.

5 Conclusions

The experience of the Jerash course has shown the effectiveness of a model of technical and scientific cooperation based on training, experimentation and the sharing of results. By means of the training focused on the case study of Umm al-Yanābī in Ajloun, participants were able to acquire not only practical skills but also a critical understanding of the conservation process and its ethical implications.

The course also represents an initial step towards the establishment of a permanent local training and professional development programme for DoA staff and regional museums. The work carried out at the RCCR in Jerash in 2024 yielded significant results, both in operational and methodological terms.

The restoration of sections 10, 12 and 13 found in storage at Ajloun Castle made it possible to recover important portions of the mosaic and to experiment with the use of reversible and lightweight backings, in line with the principles of contemporary restoration.

At the same time, the analysis of how the mosaic was made and the condition of the ten panels on display led to recommendations for routine maintenance and microclimate control protocols, showing that effective preventive care can often reduce the need for more invasive interventions.

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Use of Laser in Restoration and the Experience of the Regional Institute for Conservation and Restoration in Jerash

Laura Bartoli
El. En. S.p.A.

Abstract: Laser cleaning is a selective and controllable technique used in cultural heritage conservation, which can be applied to stone, metal and painted materials. This paper presents the development of laser technology in restoration and examines the experience of the Laser Operator Course held in November 2023 at the Regional Center for Conservation and Restoration in Jerash. The course combined theoretical lectures on physical principles, laser-material interaction and safety with practical activities on archaeological artefacts, stressing the importance of correct parameter calibration and specialist training.

Keywords: Laser cleaning, Cultural heritage conservation, Laser operator, innovative technologies.

Laser ablation is one of the most significant radiation effects that can be induced in optically absorbing materials. Laser cleaning is a specific application of this process, in which unwanted surface layers are removed in order to reveal the underlying substrate of interest.

The application of laser cleaning in the field of cultural heritage conservation was first proposed in the early 1970s, following a series of experimental tests conducted in Venice on stone artefacts affected by black crusts. However, this innovative approach remained largely experimental for several years, primarily due to the technological limitations of the pulsed laser sources available at the time. In the 1980s, the performance of laser systems improved significantly, although their high cost continued to limit systematic use within the restoration sector.

From the second half of the 1980s onwards, laser cleaning found widespread application in the restoration of stone artefacts across Italy, France, England, Portugal, Austria and other countries. It was mainly used for the removal of black crusts caused by environmental pollution, but also to eliminate dark layers purposely applied in earlier periods. The technique was widely used for the restoration of stone reliefs, historic façades and archaeological finds – including the western frieze of the Parthenon – as well as for renowned Renaissance works such as the ‘Prophet Habakkuk’, ‘St. Mark’ and Donatello’s ‘Pulpit’, the panels of Giotto’s bell tower at Florence Cathedral by Andrea Pisano, and the Leaning Tower’s and Pisa Cathedral’s capitals.

From the mid-1990s onwards, this widespread use of laser cleaning was accompanied by extensive research on radiation effects and the physical modelling

of the processes involved. These studies made it possible to define operational ranges of energy density (fluence) capable of effectively distinguishing the crusts to be removed from the substrate to be preserved.

In particular, the effectiveness of pulsed Nd:YAG lasers with a wavelength of 1064 nm was shown. These systems allow both the energy and pulse duration to be adjusted, enabling the selective removal of black crusts, layers of atmospheric particulate matter or organic residues, while leaving the underlying material largely unaffected. The body of scientific evidence supporting these results led to the recognition of laser technology as one of the most promising tools in restoration, in some cases replacing more traditional chemical and mechanical cleaning methods.

Thanks to its gradual and controllable action, self-limiting behaviour, high degree of selectivity, reduced environmental impact and its ability to preserve the so-called 'patina of time', laser cleaning offers several advantages over conventional techniques.

Although laser cleaning is mainly used for the removal of black crusts from stone materials, the technique has – over time and through careful experimentation – been successfully extended to a wide range of other materials such as metals, murals, wood, and paintings on canvas and panel.

In the conservation of murals, laser cleaning can be used to remove overpaint, adhesives and biological deposits.

In such cases, it is essential to precisely calibrate both the energy density and the duration of the laser pulse to prevent damage to the original pigments. Studies have shown that, through the use of pulses with a controlled duration, unwanted layers can be removed without affecting the underlying paint film. Notable examples of this application include the frescoes in the Villa of the Mysteries and the House of the Ceii in Pompeii, as well as murals in the Catacombs of Santa Tecla and Domitilla in Rome.

The application of laser technology to metals – particularly to gilded or silver-plated bronzes – also represents a field of considerable interest.

When properly calibrated, laser cleaning makes it possible to take advantage of the differences in absorption and ablation thresholds existing between oxides and noble metals. One notable case in which this technology was applied is the cleaning of the three gilded bronze doors of the Florence Baptistery, outstanding examples of Renaissance craftsmanship by artists such as Lorenzo Ghiberti and Andrea Pisano.

A more recent application concerns the removal of aged varnish from paintings on canvas and panel using the Er:YAG laser, operating at a wavelength of 2940 nm. This wavelength gets absorbed by varnish layers, allowing for their gradual removal. One notable case study is the treatment of Tintoretto's painting 'Saint Martial in Gloria with Saints Peter and Paul', where a crystallised and yellowed varnish was successfully removed using this technique.

In recent years, technological advances have led to the introduction on the market of active fibre lasers sources, which are gradually replacing traditional Nd:YAG systems. Active fibre are highly efficient, generate more stable beams and offer greater flexibility in pulse duration modulation.

Active fibre lasers are scanning laser systems capable of covering areas of up to 10–15 cm, making them particularly suitable for the cleaning of large surfaces such as entire façades of historic buildings.

Regardless of the material being treated, one of the most critical aspects of laser application is the careful optimisation of operating parameters. Each surface – and

Figs. 1

a, b Practical session on the use of lasers.



indeed each area of the same object – may respond differently to laser radiation.

The main parameters to be adjusted include:

- Wavelength, which influences differential absorption by the various layers.
- Pulse duration (nanoseconds, microseconds), which determines the mode of interaction with the material (photothermal, photomechanical).
- Energy per pulse and energy density (fluence), which establish the cleaning threshold and the damage threshold.

Preliminary testing, carried out on selected test areas, is therefore essential to correctly calibrate the treatment and avoid any side effects such as smearing, micro-cracking or loss of surface detail.

To make effective use of laser cleaning and fully unlock its potential, operators require in-depth training enabling them to become familiar with laser systems characteristics and operating procedures, as well as with the safe handling of the equipment.

These were precisely the topics explored during the laser training sessions held at the Regional Centre for Conservation and Restoration in Jerash. The course, held in November 2023, was structured in two parts: an initial theoretical component followed by a practical stage.

During the theoretical lectures, participants gained a solid understanding of the fundamental principles of laser technology and laser-material interaction. They became familiar with systems operation, the physical processes involved in beam generation, and the main components of a laser system. The key properties of a laser beam (i.e., coherence, monochromaticity and directionality) were also examined in detail, along with their implications in different applications. Particular emphasis was placed on the understanding of emission parameters such as energy, pulse duration and repetition rate, in order to provide participants with the skills necessary for the independent and informed use of the tool.

Particular attention was given to laser safety, with comprehensive training on the risks associated with the use of Class 4 lasers and on the essential protective and preventive measures to be adopted during operation. Finally, several real case studies relating to the cleaning of stone, metal, murals and other substrates were presented, enabling participants to identify the most appropriate operational strategies for each material and to understand the importance of selecting both the right laser system and the most suitable operating parameters depending on the substrate and the type of encrustation to be treated.

Following the theoretical component, the course moved on to the practical stage, which proved to be one of the most engaging and stimulating parts of the training (Figs. 1 a, b). Participants were given the opportunity to use the El.En. S.p.A. EOS COMBO laser, housed at the Center, to clean a range of archaeological materials, thus applying the knowledge gained in the theoretical sessions to real case studies. This practical session allowed participants to observe laser-material interaction in real time and highlight the different responses of various substrates. The practical session was also a key opportunity to apply safety procedures and operational guidelines regarding the safe use of a laser system in a controlled environment. Participants showed particular curiosity and enthusiasm for the practical use of the laser system.

Finally, the laser operator course held in Jerash provided an important opportunity for training and international exchange on conservation methodologies in the field of cultural heritage (Fig. 2). The course allowed participants to explore both the theoretical principles and practical applications of laser cleaning, showing its effectiveness and selectivity in comparison with more traditional methods. As a lecturer, I hope that the skills acquired during the course will contribute to the development of informed and sustainable conservation practices on local artefacts, and will encourage the wider adoption of advanced technologies for the protection and enhancement of Jordan's remarkable artistic heritage.

Fig. 2

At the end of the course on the use of lasers in conservation, each participant was given a certificate attesting to their knowledge of safety procedures.



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The Southern Tetrakionion in Jerash: Historical and Technological Analysis, Diagnosis and On-Site Conservation and Restoration

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with contributes of Najdat Mamoon Abd Alra'oof Hazaimh,
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Abstract: This paper presents the conservation and restoration work carried out on the Southern Tetrakionion in Jerash, a Roman monument located at the intersection of the Cardo Maximus and the Southern Decumanus, examined here as a case study of the conservation issues typically associated with on-site archaeological stone heritage. The study combines historical research, technological analysis of materials, preliminary diagnostic surveys and targeted interventions, including cleaning, the removal of incompatible materials, consolidation, and grouting with use of natural hydraulic lime mortars. Particular attention was paid to material compatibility, the treatment of modern additions, and the mitigation of biodegradation. The work was conducted in the form of a training workshop as part of the project to establish the Regional Center for Conservation and Restoration in Jerash (RCCR).

Keywords: Stone materials restoration; Training courses; Roman monument; Onsite conservation.

Introduction

The conservation and restoration work on the Southern Tetrakionion forms part of a broader programme of conservation and training activities carried out at the archaeological site of Jerash as part of the project to establish the Jerash Regional Center for Conservation and Restoration (RCCR).

For the training workshop scheduled in the second year of the project – specifically, in spring 2024 – the stone monument located at the intersection of the Cardo Maximus and the Southern Decumanus was selected as a case study. This choice made it possible to systematically address the main conservation issues affecting on-site archaeological stone heritage, which are subject to physical, chemical and biological degradation processes, as well as to the impact of incompatible interventions previously carried out (Ashurst and Ashurst, 1988-1998; Winkler, 1997; Price, 1996; Torraca, 2009; Warscheid and Braams, 2000).

The restoration of the Tetrakionion was organised as a training site over a period of approximately two months, between October and November 2024. The mon-

**Fig. 1**

Archaeological plan of Jerash. The tetrakionion is highlighted in red. Image in: Lichtenberger, Rubina Raja: Mosaicists at work: the organisation of mosaic production in Early Islamic Jerash

ument served as a practical training site for for developing of skills in archaeological stone conservation, integrating diagnostic observation, technological material analysis and the application of compatible restoration methods (Price, 1996; Torraca, 2009).

The working group consisted of lead conservators responsible for scientific and educational coordination, conservators providing operational and training support, Jordanian officials from the Department of Antiquities who had participated in the first-year training courses and were involved in all stages of the work, and technical support staff. The project was conceived not only with the aim of ensuring the safety and conservation of the monument, but also as a structured programme of international cooperation focused on the specialist training of Jordanian officials and the strengthening of local expertise in the field of archaeological heritage conservation. The training site was conceived as a space for exchange and mutual learning, where technical and scientific knowledge on restoration, developed in different contexts, could be shared, discussed and adapted to the specific material and environmental conditions of the Jerash site. To this end, the project fostered not only the transfer of operational methodologies, but also the development of a shared technical language and an international professional network committed to the long-term sustainability of conservation interventions.

1 Historical and architectural context of the monument

The Southern Tetrakionion dates to the period of greatest urban and monumental development of the Roman city, between the late 2nd and the 3rd century AD, when Jerash established itself as one of the principal centres of the province of Arabia (Kraeling, 1938; Ball, 2000; Butcher, 2003). The urban layout, organised according to the characteristic Roman orthogonal grid, was structured around the *Cardo Maximus*, the principal north–south axis, flanked by continuous colonnades, while the Southern *Decumanus* regulated east–west traffic and connected the city’s major public and religious complexes (Seigne, 2002; Ball, Bowsher, Kehrberg, Walmsley, and Watson, 1986). At the intersection of these two axes stood the Tetrakionion, an architectural type widely attested in Roman cities of the eastern Mediterranean and designed to lend monumental emphasis to key urban junctions (Kennedy, 1996; Ball, 2000). In Jerash, the monument takes the form of an open tetrakionion, consisting of four independent bases positioned at the corners of the crossroads without a central superstructure. This arrangement enhanced the perspective effect along the two main road axes and created a powerful scenographic accent within the urban fabric (Madain Project, n.d.; Ball, Bowsher, Kehrberg, Walmsley, and Watson, 1986).

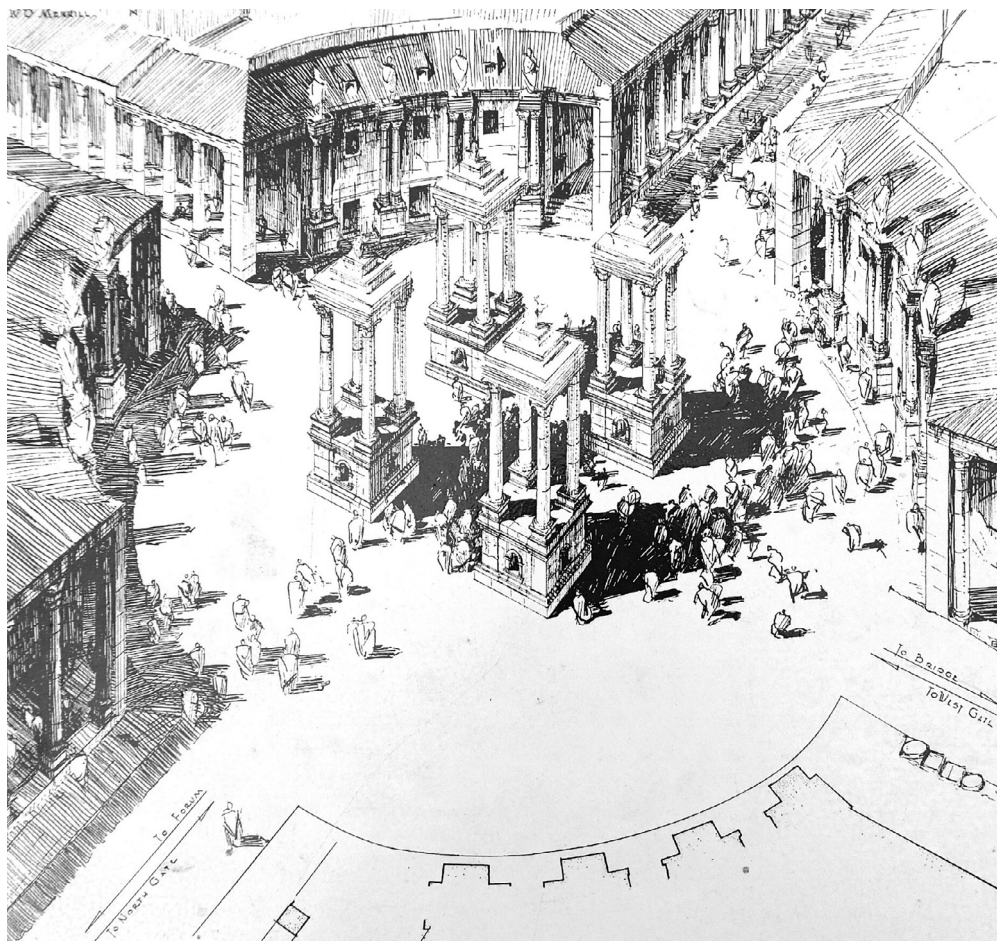
At the intersection of these two axes stood the Tetrakionion, an architectural type widely attested in Roman cities of the eastern Mediterranean, designed to mark key urban junctions (Kennedy, 1996; Ball, 2000). In Jerash, the monument takes the form of an open tetrakionion, consisting of four independent bases arranged at the corners of the intersection, without a central superstructure. This configuration enhances the perspective effect along the two road axes and produce a striking visual effect in the urban space Fig. 1 (Madain Project, n.d.; Ball, Bowsher, Kehrberg, Walmsley, and Watson, 1986).

Each plinth is decorated with carved semicircular niches, often surmounted by shell motifs, a recurring feature in Roman-Eastern monumental architecture. These niches likely served a commemorative function, housing statues of emperors, deities or civic personifications, thereby contributing to the symbolic layout of the urban crossroads (Lichtenberger and Raja, 2015; Madain Project, n.d.). The shell motif, widely attested in Decapolis settings, is traditionally associated with themes of regeneration, divine protection and fertility, reinforcing the commemorative value of the monument.

The Tetrakionion was therefore understood not merely as a traffic management device, but as the true hub of the city, marking monumental routes and providing a setting for ceremonies and processions. At such strategic intersections, architecture served as an instrument for projecting Roman power and structure the urban landscape according to imperial ideals (Kraeling, 1938; Seigne, 2002).

Of particular importance for understanding the monument’s long history is the inscription preserved on the southern façade, dedicated to Emperor Constantine I. This inscription attests to a phase of renewed prominence for the Tetrakionion in late antiquity, likely associated with restoration and repurposing works carried out by the provincial administration of Arabia during the 4th century AD (Kraeling, 1938; Lepelley, 1996; Madain Project, n.d.). The inscription confirms the monument’s political role as a vehicle of imperial propaganda and as a core element in the visual representation of power within the civic space.

The continuity and symbolic revitalisation of Roman urban architecture in the Constantinian period is well documented in the Near East, where pre-existing

**Fig. 2**

Graphic reconstruction of the monument's volume

monumental buildings – rather than being abandoned – were maintained, restored and integrated into evolving urban layouts (Ward-Perkins, 1984; Lepelley, 1996). The Tetrakionion of Jerash fully fits within this long-term process, bearing witness to the persistence of the classical building style in shaping late antique urban identity.

Taken as a whole, the monument exemplifies Roman-Eastern urban architecture, in which functional, scenic and political dimensions converge within a single spatial arrangement (Ball, 2000; Butcher, 2003). Its conservation is therefore essential not only for preserving the structure itself, but also for a deeper understanding of the urban and symbolic dynamics of the cities of the Roman Decapolis.

2 Formal description of the monument

The Tetrakionion is a monumental complex made up of four independent architectural units, located at the centre of the circular square formed by the intersection of the *Cardo Maximus* and the *Southern Decumanus*. Each unit consists of a squared parallelepiped stone base, measuring approximately 3.0×3.0 m and with a preserved height of about 3.0 m, constructed from large square limestone blocks and set upon a continuous plinth (Fig. 2). Each base originally supported a group of four columns, in accordance with a popular style in Roman-Eastern urban architecture between the 2nd and 3rd centuries AD (Kraeling,

1938; Ball, 2000; Seigne, 2002). These columns were very likely surmounted by capitals and an architrave. The parallelepiped studied and undergoing conservation is the only one that retains all four column bases – the columns themselves no longer exist. Such bases are carved from a single block of limestone similar to that used in the parallelepiped.

The arrangement with four separate cores represents a variant of the open tetrakionion, designed to keep the road clear while simultaneously making the crossroads visible through a striking structure without a central superstructure.

At the centre of each façade of the parallelepipeds is a semicircular niche, making a total of four niches for each architectural element, each topped by shell-shaped apse-like basins.

Taken together, the four architectural units formed a coherent yet open system, in which the firmness of the bases, the depth of the apsidal niches and the vertical colonnades blended to create a highly dynamic three-dimensional urban composition, designed give a specific visual and symbolic look to the city's main crossroads.

In the upper part of the southern façade of the plinth under study and restoration, there is an engraved Latin inscription, the subject of research, which documents a phase of repurposing and imperial celebration of the monument during the Constantinian era. The epigraphic text reads:

On the upper part of the southern façade of the plinth under study and restoration, there is an engraved Latin inscription. This epigraph, the subject of ongoing research, documents a phase of repurposing and imperial celebration of the monument during the Constantinian period. The text reads:

Transcription: «Imp(eratori) Caes(ari) Fl(avio) Val(erio) Constantio nobilissimo Caes(ari) Aurel(ius) Felicianus v(ir) p(erfectissimus) praeses provinciae Arabiae numini maiestatique eius dicatissimus.»

«To the Emperor Caesar Flavius Valerius Constantine the Noble.
Dedicated to His Majesty by Caesar Aurelius Felicianus, governor of
the province of Arabia, for his perfect sympathy.»

3 Materials and construction techniques

The Southern Tetrakionion in Jerash was constructed from a compact, pinkish limestone of local origin, sourced from quarries at Asfur, Al Shawahid, Wadi Suf and Majar. This material was widely used in ancient monumental architecture owing to its good workability and mechanical strength (Winkler, 1997; Price, 1996; Torraca, 2009; Abu-Jaber, Al Saad and Smadi, 2009). The lithotype belongs to the group of fossiliferous micritic limestone typical of the region, characterised by a fine carbonate matrix that gives the stone a homogeneous texture and generally low porosity – properties well suited to the production of moulded architectural elements and carved decorative features.

Mineralogical and microscopic studies conducted on comparable lithotypes from other monuments in Jerash – particularly from the colonnade of the Temple of Artemis – have revealed the presence of slightly marly biomicritic limestone of Jurassic age. These are characterised by a calcitic micritic matrix with fossiliferous elements and widespread iron oxides, responsible for the pink and yellowish hues. Although these findings relate to different settings, they provide a useful reference for understanding the physical and structural properties of the stone materials



used in the city's major monumental construction sites, suggesting a deliberate selection of compact stones with low primary porosity and good mechanical performance.

Examination of the architectural surfaces of the Tetraklion has allowed the main stone-working techniques employed during construction to be clearly identified. The flat surfaces of the plinths bear regular marks left by a toothed point chisel (Fig. 3), used for rough-hewing the blocks, which were subsequently finished with a flat chisel to achieve smooth surfaces. In the curved areas of the apsidal niches and in the shell-shaped basins, clear traces of a round chisel are visible, a tool particularly suited for shaping concave surfaces and structure outlines.

In certain areas, the use of a drill (Fig. 4) can also be observed. It was likely used to carve the floral motifs along the sides of the niche. This combination of tools is widely documented on monumental construction sites from the Roman era and reflects a highly specialised construction practice, capable of combining speed of work and efficiency.

Bedding mortar residues were found between the blocks, attesting to a traditional technique based on limestone binders, compatible with the stone substrate and suited to ensuring the proper distribution of structural loads. Further residues of the original mortar have been identified on the surface of several blocks, particularly along the northern and western elevations. Above these mortars and in a few other places applied directly onto the stone, traces of red and yellow ochre have been detected.

Further traces of original mortar were observed on the surface of several blocks, particularly along the northern and western elevations. Over these mortars – and in some cases directly on the stone – traces of red and yellow ochre were also detected.

above, from left,

Fig. 3

Marks left by the toothed
point chisel.

Fig. 4

Drill marks.



above, clockwise,

Fig. 5

Previous interventions,
cement grouting.

Fig. 6

Insertion of new stone
elements.

Fig. 7

Metal bars and
reinforcement plates
embedded in the
cement.

Fig. 8

Stone flaking.

4 Conservation history and previous interventions

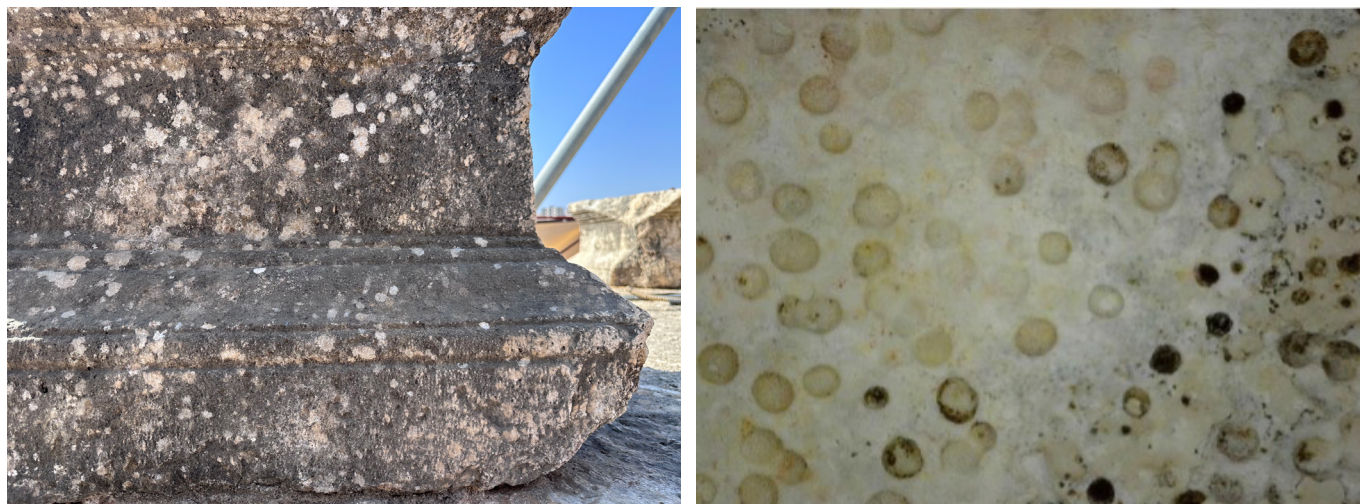
During the course of the 20th century, the monument underwent a number of interventions, including anastylosis and restoration works reflecting an archaeological restoration approach primarily focused on structural stabilisation. In particular, the following interventions have been documented:

- extensive filling of gags between the stone blocks using cement mortar (Fig. 5);
- insertion of new stone elements in several sections (Fig. 6);
- use of metal bars and reinforcement plates embedded in the concrete installation of a security camera fixed directly to the top using cement mortar (Fig. 7).

These interventions created significant physical and chemical discontinuities between the original materials and the modern additions, thus accelerating degradation processes due to differences in thermal expansion rates and the greater rigidity of the cement mortars.

5 State of conservation

At the beginning of the intervention, the monument was in a moderately degraded conservation condition, typical of stone heritage in open-air archaeological



above, from left,

Fig. 9

Biological colonisation.

Fig. 10

Biological colonisation
observed under a
portable microscope.

settings, where natural weathering processes interact with the damaging effects of previous restoration campaigns carried out using incompatible materials.

This condition results from the interaction between natural degradation processes inherent to exposed stone materials and the impact of previous restoration works carried out using incompatible materials.

In some areas, the stone surfaces showed moderate wear of the architectural features, with rounded edges and a partial loss of definition in the mouldings. Here, the combined effects of rainwater runoff, thermal and hygrometric cycles, and salt crystallisation had compromised the legibility of the decorative elements in several places. In these same areas, flaking and surface exfoliation were observed (Fig. 8), with the detachment of thin stone flakes and a gradual increase in surface porosity.

These alterations were localised and cannot be interpreted as a generalised process of surface erosion, but rather as forms of differential alteration linked to environmental exposure and to the microstructural characteristics of the lithotype. Closer observation and portable digital microscopy revealed the presence of surface micro-cracks and internal mineralogical discontinuities within the stone, which constitute areas of greater vulnerability to moisture penetration and biological growth. Only limited instances of limestone matrix decohesion and surface micro-flaking were found in these areas.

Biological colonisation represented a further significant degradation factor, developing primarily in areas with limited sun exposure and at the joints between stone blocks (Caneva, Nugari, and Salvadori, 1991; Warscheid and Braams, 2000). Portable microscopy revealed the presence of crustose lichens, algae and mosses, locally accompanied by higher vegetation. Beyond their visual impact, these organisms pose a significant conservation risk. As extensively documented in the literature, they can trigger chemical and physical degradation of the carbonate matrix through the production of organic acids, increased surface water retention, and the mechanical action of their biological structures.

Within the apsidal niches and in more sheltered areas, black crusts and cohesive deposits, attributable to the accumulation of atmospheric particulate matter and organic residues (Fig. 11), were observed. Although not harmful from a structural point of view, these deposits compromised the legibility of decorative elements and contributed to the formation of localised humid microenvironments.

from left,

Fig. 11

Black crusts in the
niches.

Fig. 12

Cracking of the blocks.



The most significant impact on the monument's structural integrity was associated with the presence of cement-based mortar fillings (Fig. 5), introduced in previous interventions to seal joints and fill gaps. Close to the areas where these materials had been used, localised cracking of adjacent blocks (Fig. 12) and moisture accumulation, caused by the mechanical incompatibility and low vapour permeability of modern mortars, were observed.

Metal inserts, introduced during previous stabilisation works, were also identified between the blocks (Fig. 7). These elements had undergone oxidation, resulting in the formation of brownish stains that had penetrated the porous structure of the surrounding stone, without, in any case, compromising its overall structural stability.

From a structural perspective, the monument did not present any major concerns: the large blocks forming the bases were stable and well supported, indicating good overall structural integrity.

Overall, the Southern Tetrakionion was not in a severe state of conservation, but rather exhibited localised surface degradation and isolated issues, primarily related to incompatible materials introduced during previous interventions. The preliminary assessment made it possible to clearly distinguish between natural alteration processes and those induced by human activity, thereby providing a sound basis for a targeted conservation intervention proportionate to the actual level of degradation found.

6 Preliminary diagnostics

Preliminary diagnostic surveys included microscopic observations using a Dino-Lite, aimed at characterising biological colonisation, black crusts, original mortars and residual traces of colour.

Samples were also collected for the analysis of surface deposits, historic mortars and stone materials, with the aim of guiding conservation decisions. These observations confirmed the predominantly carbonate nature of the substrates and the significant presence of biodeteriogens in damp and shaded areas.



7 Conservation and restoration work

The conservation and restoration work of the southern Tetrakionion was guided by the framework established through preliminary diagnostic surveys, in accordance with the principles of minimum intervention, chemical and physical compatibility of materials, and reversibility of treatments.

Prior to the operational phases, all proposed methods were tested through a systematic programme of preliminary on-site trials, aimed at assessing the effectiveness, selectivity and potential impact of different products and concentrations on the stone surfaces. The results made it possible to define intervention protocols tailored to the specific response of the historic materials, thereby minimising the risk of undesirable alterations.

7.1 Cleaning and assessment of biological degradation

The first stage addressed the widespread biological colonisation, responsible for both chemical alteration of the limestone surface and localised micro-displacement of the blocks. Repeated applications of a 3% Biotin T-based biocide were applied followed by controlled rinsing with deionised water. This treatment successfully, eliminated colonies of algae, lichens and mosses and significant reduction in surface moisture retention (Fig. 13). Subsequently, loose deposits were removed through gentle mechanical action using soft-bristled brushes, with the aim of eliminating particulate matter accumulated in the surface pores without compromising the stable historic patina.

7.2 Removal of cementitious/cement-based additions and treatment of metal elements

Modern repairs and cement-based grout - recognised as contributing to degradation due to their rigidity and low vapour permeability – were progressively removed by controlled manual work with hammer and chisel. This restored joint permeability and reduced moisture accumulation, which had been generating stress and micro-

above, from left,
Fig. 13
Biocide application.

Fig. 14
Previous grouting
removal.

Fig. 15

Cleaning test.



cracking in adjacent stone blocks.

Where oxidised metal elements were found, they were treated through fine mechanical cleaning using scalpels and the application of organic solvents (acetone) to remove corrosion products. A subsequent passivation treatment was carried out using a 5% alcoholic solution of tannic acid. Final protection was achieved through the application of Paraloid B72 acrylic resin at 10% in acetone, ensuring stabilisation of the metal components and preventing further oxidative processes detrimental to the surrounding stone material.

7.3 Chemical and laser cleaning of encrustations

Cleaning of the stone surfaces was completed using a non-ionic surfactant (3% Tween 20) to remove adhering deposits. In areas affected by more compact encrustations – particularly within the apsidal niches – localised cellulose pulp compresses containing 10% ammonium carbonate and 5% EDTA were applied. These were selected on the basis of preliminary tests for their ability to solubilise alteration products without compromising the limestone matrix Figg. 15, 16, 17. Finally, the particularly resistant black crusts found on the shell-shaped basins were treated using Nd: YAG laser cleaning, carried out with an EOS 1000 El.En system in LQS mode. This technique enabled the selective removal of carbonaceous deposits without mechanical contact, thus preserving the micro-morphology of the carved surfaces and significantly improving the legibility of decorative elements.

7.4 Consolidation of weakened surfaces

Areas affected by flaking and exfoliation – caused by a loss of cohesion in the stone matrix and the presence of micro-cracks – were subjected to localised consolidation through capillary impregnation with a 10% solution of ACRIL 33 acrylic resin (Fig. 18). This treatment restored cohesion in weakened zones and reduced the risk of further detachment.



Unstable or accidentally detached stone fragments were reattached using a two-component structural epoxy resin, thereby restoring the material and functional continuity of the architectural elements.

7.5 Compatible grouting and joint rebalancing

Deep gaps and open joints were filled using compatible mortars made of natural hydraulic lime, namely: NHL 5 with limestone aggregates in a 1:3 ratio for structural fills, and NHL 3 in a 1:2 ratio for surface levelling layers (Figs. 19-20). This choice made it possible to obtain materials that are mechanically suitable for an exposed environment, while remaining compatible with the original stone in terms of porosity, vapour permeability and hygrometric behaviour.

Finishing was carried out using a calibrated mix of hard and soft limestone, travertine powder and fine silica sand as aggregates. This allowed for effective chromatic integration of the restorations while ensuring the recognisability of the conservation work Fig. 21.

7.6 Conservation outcomes

Overall, the works have made it possible to:
 significantly reduce active biodegradation;
 eliminate the main causes of moisture accumulation;
 stabilise detached surfaces;
 restore the permeability of the joints;
 restore the architectural and decorative legibility of the monument.

The intervention did not aim at formal reconstruction, but rather at the conservation of the historic material. Its primary objective was to slow down ongoing degradation processes and to establish the conditions for sustainable long-term maintenance.

above, from left,
Fig. 16
 Surfaces cleaning.

Fig. 17
 Cleaning results.



above, from left,
Fig. 18
 Re-adhesion of flakes.

Fig. 19
 Preliminary test for
 mortar selection.

Fig. 20
 Selection of the most
 suitable mortar

Fig. 21
 Final grouting.

8 Conclusions

The conservation and restoration work on the southern Tetrakionion successfully addressed the main conservation issues affecting in-situ stone heritage. These included the presence of incompatible modern materials, widespread biological colonisation, cohesive deposits accumulation in sheltered areas, and localised surface delamination. The selective removal of cement-based mortars, the treatment of oxidised metal inserts, and differentiated cleaning – mechanical, chemical and, where necessary, laser – based combined with consolidation and repointing using compatible mortars made of natural hydraulic lime, have re-established more balanced conservation conditions. Surface stability has been improved and the legibility of the architectural elements recovered, without resorting to invasive solutions.

The approach, tailored to the monument's actual state of conservation, ensured a proportionate intervention, mitigating active risk factors and preparing



the structure for more effective long-term maintenance. In this respect, the Tetrakionion served as a representative case study of the typical issues affecting exposed archaeological stone heritage, offering practical guidance that can be applied to other monumental contexts within the site.

The decision to structure the project as a training site facilitated the direct transfer of technical and methodological skills to staff from the Department of Antiquities of Jordan, through their continuous involvement in all the stages of the work: from diagnosis and cleaning to the removal of modern additions, consolidation and restoration. The monument thus functioned not only as an artefact to be restored, but also as an active training platform, where the exchange of diverse professional experiences contributed to refining procedures and consolidating a shared technical language.

Within the broader training programme promoted by Roma Tre University at the RCCR in Jerash, the Tetrakionion site has contributed to further establish an approach to conservation based on interdisciplinary collaboration, the progressive strengthening of local expertise, and the long- and medium-term sustainability of conservation works. From this perspective, the experience confirms that conservation work on archaeological monuments carries significance beyond the mere preservation of fabric, extending to the development of lasting operational expertise within the communities and institutions responsible for such heritage.

above, from left,
Fig. 22 a
South elevation of the
monument before
restoration.

Fig. 22 b
South elevation of
the monument after
restoration.



above, from left,

Fig. 23 a

East elevation of the monument before restoration.



Fig. 23 b

East elevation of the monument after restoration.

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The documentation of the Southern Tetrapylon, Archeological Site of Jerash

Najdat Mamoon Abd Alra'oof Hazaimh,
Tasneem Aamar Ahmad Al-Bataineh,
Mohammad Ali Mustafa Alalawneh

A Total Station was used to record coordinates around the monument. In parallel, the Global Positioning System (GPS) was employed to establish five reference control points surrounding the monument, starting from the georeferenced origin point (0,0,0).

More than 500 high-resolution, overlapping digital photographs were captured and processed using Agisoft Metashape to create a detailed 3D model as much as possible. From this model, orthomosaics were produced for the four elevations and the top surface. These outputs were then imported into Quantum Geographic Information System (QGIS) to prepare accurate two-dimensional (2D) drawings. At this stage, the drawings were ready for systematic documentation, including material characterization, tool marks, previous interventions, condition assessment, proposed treatments, and sampling locations.

The documentation of the monument investigated within the teaching workshop was carried out by adopting data recording protocols already established in archaeological practice for the in situ documentation of stone-built architecture¹. This approach was selected in order to ensure methodological consistency, data comparability, and the integration of metric survey, material analysis, and the recording of conservation interventions. Following the photogrammetric survey and the generation of the three-dimensional model, the 3D model was used as the primary metric reference for both graphic restitution and the systematic mapping of material evidence and of the operations undertaken during the workshop².

The documentation produced during the intervention was organized into five thematic plates, each addressing a specific analytical domain:

- constituent materials;
- working and manufacturing techniques;

¹ Cfr. S. Muca, L. Festa, N. Vakalis, *he Southern Tetrakionion in Jerash: Historical and Technological Analysis, Diagnosis and On-Site Conservation and Restoration*, in the volume.

² We would like to thank: Professors Luciana Festa, Sokol Muca and Nikolas Vakalis for their extraordinary teachings and for coordinating the didactic worksite and the entire process of documenting the state of conservation of the monument, Professor Jacopo Russo for his valuable teachings on documentation applied to conservation and Professor Massimo Brizzi for his fundamental contribution to the topographical survey of the monument.

- previous interventions;
- state of conservation;
- interventions carried out during the teaching workshop;
- localization of sampling points for diagnostic analyses.

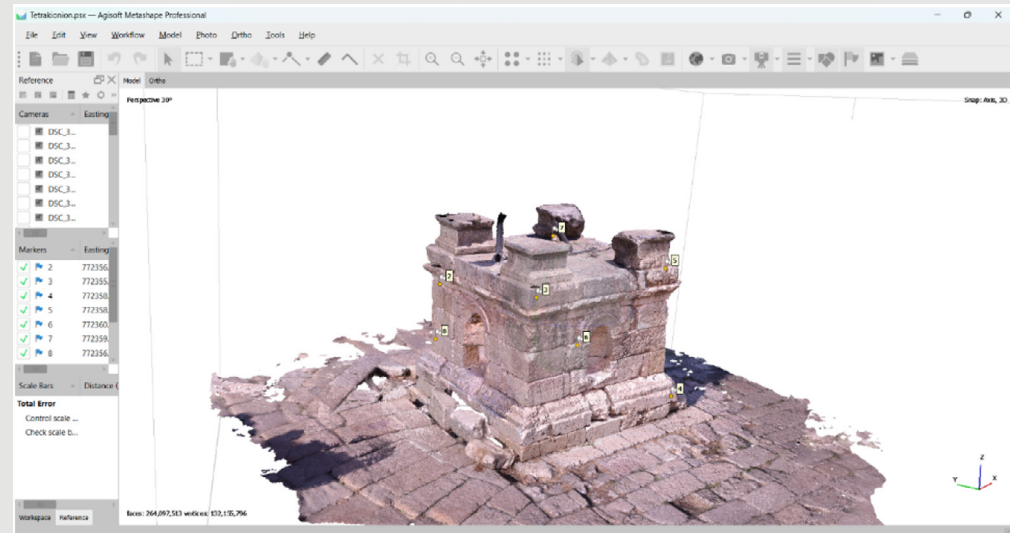
The organization of documentation into thematic plates constitutes an operational tool for the planned monitoring of the monument, enabling diachronic comparison between the condition recorded at the end of the intervention and any subsequent changes. The georeferenced mapping of alteration phenomena and of the interventions performed provides an objective framework for identifying new degradation processes, assessing the effectiveness of applied treatments, and updating maintenance strategies. At the same time, the body of documentation assumes the role of a primary technical source, accurately recording the material condition of the artifact and the operational decisions adopted during this specific phase of its conservation history.

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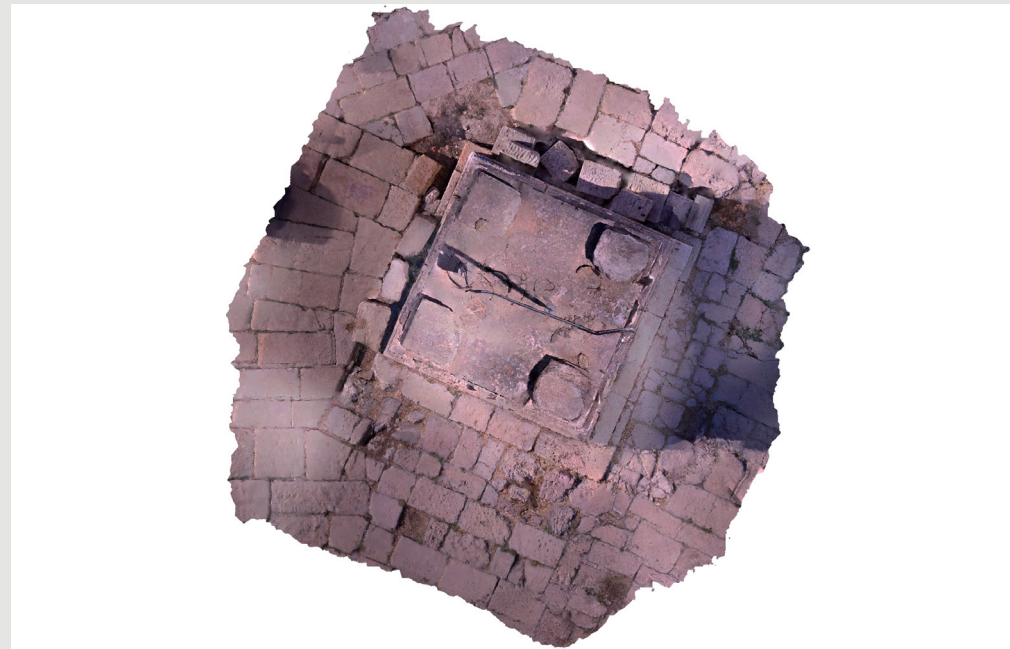
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Fig. 4

Agisoft Metashape software to create 3d model.

**Fig. 5**

Orthomosaic of the top view.

**Fig. 6**

Orthomosaic of the north elevation.





Fig. 7
Orthomosaic of the south
elevation.

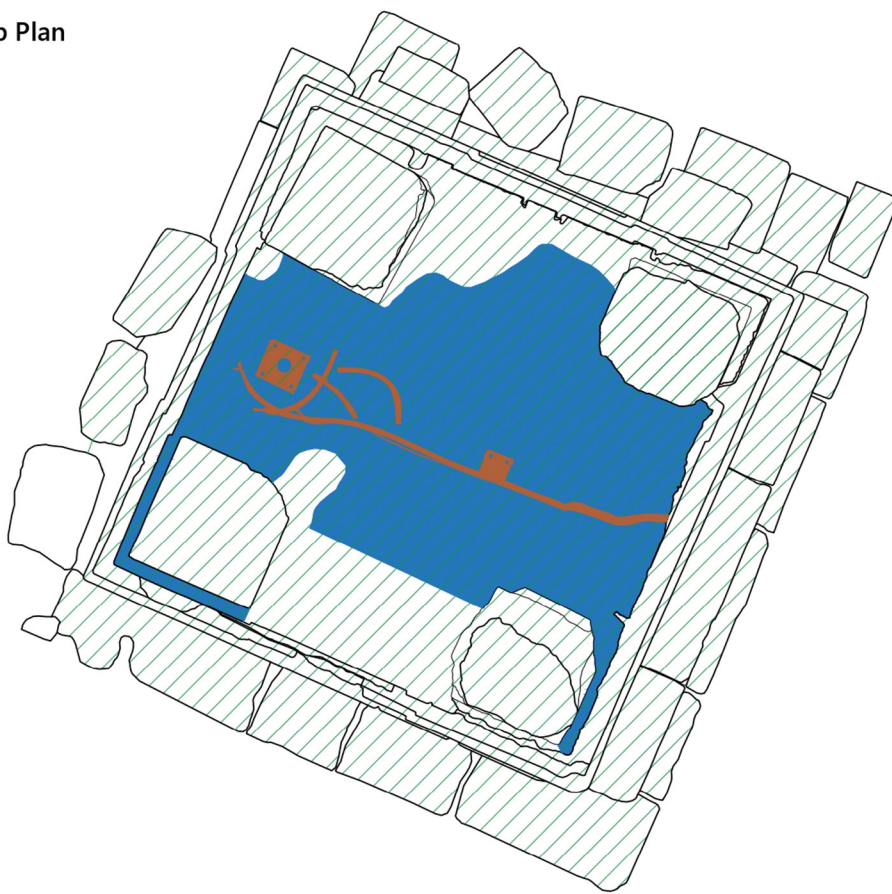


Fig. 8
Orthomosaic of the west
elevation.



Fig. 9
Orthomosaic of the east
elevation.

Top Plan



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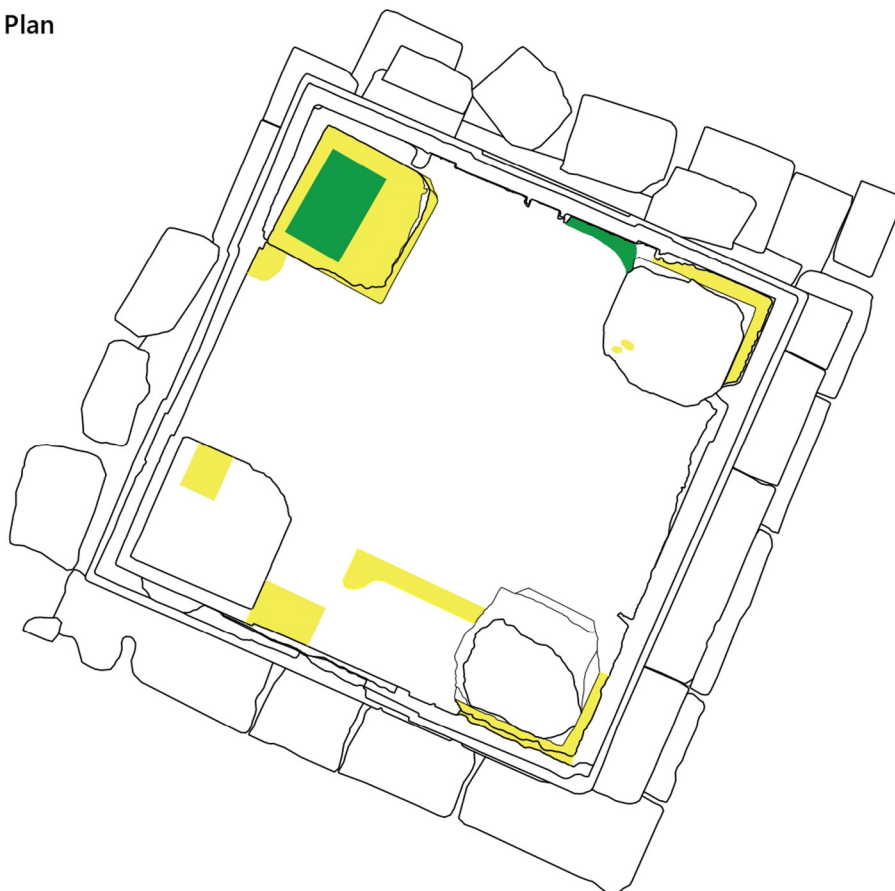
Table 1 - Materials

-  Calcareous Limestone
-  Metal
-  Cover Protection

Drawn By :

Eng. Najdat Hazaymeh

Top Plan



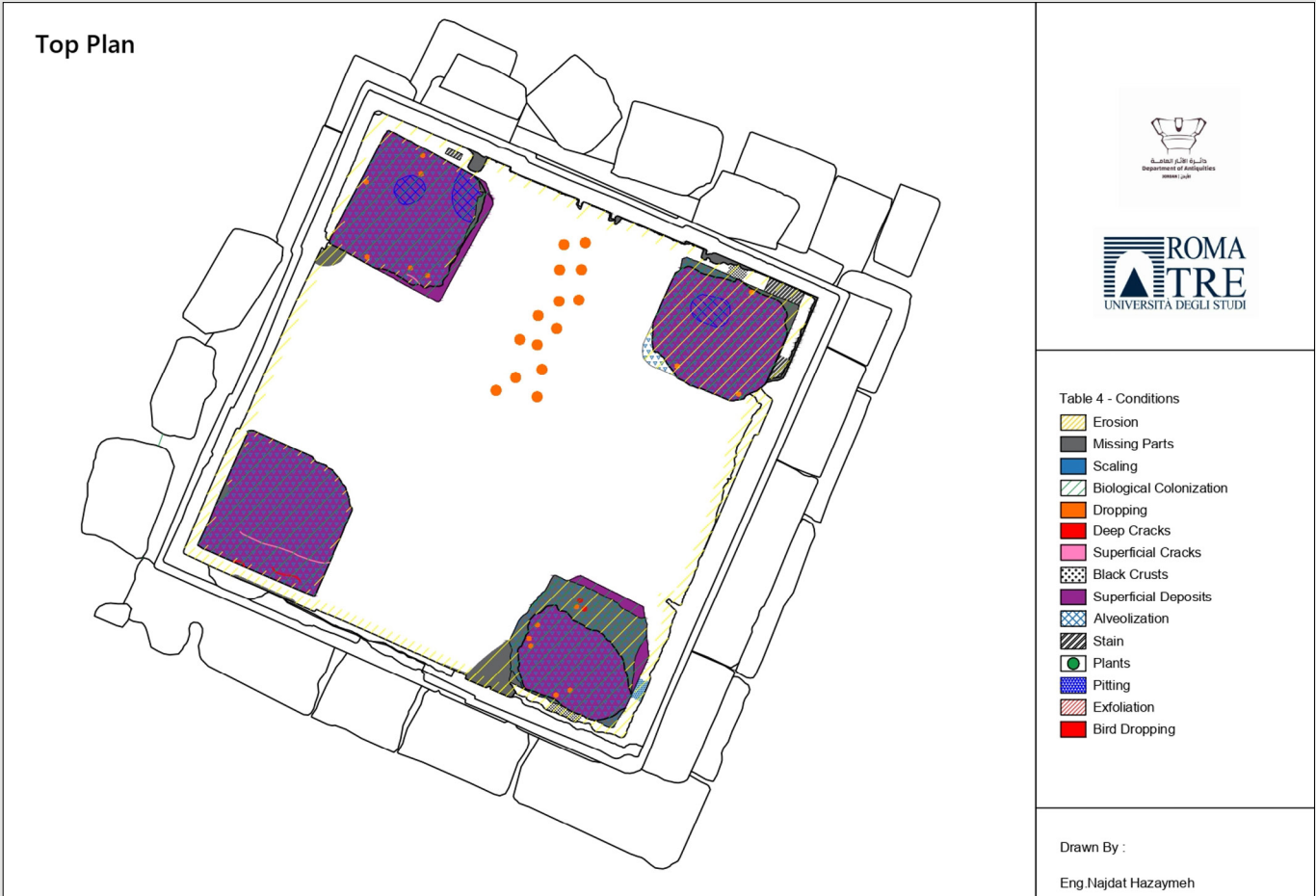
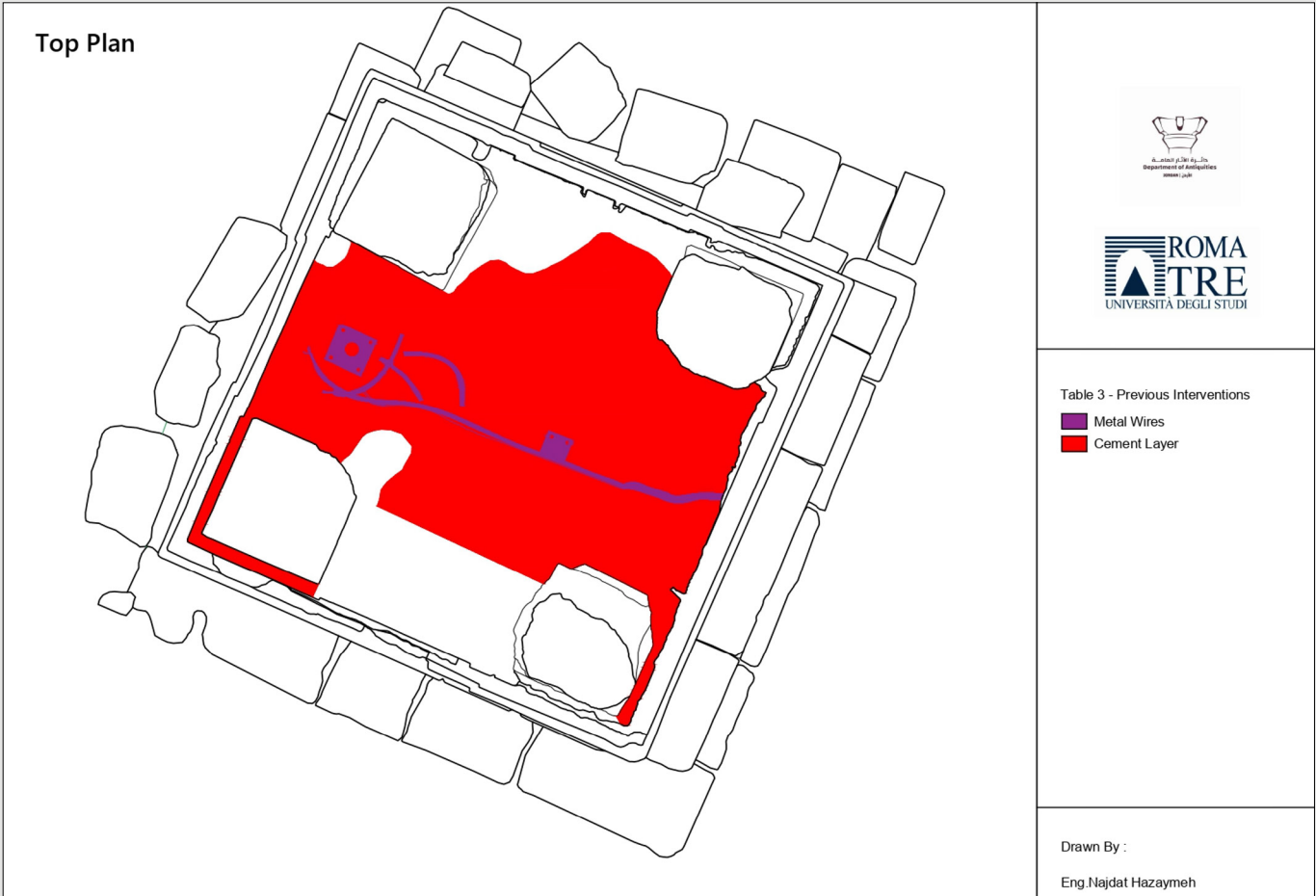
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Table 2 - Tool traces

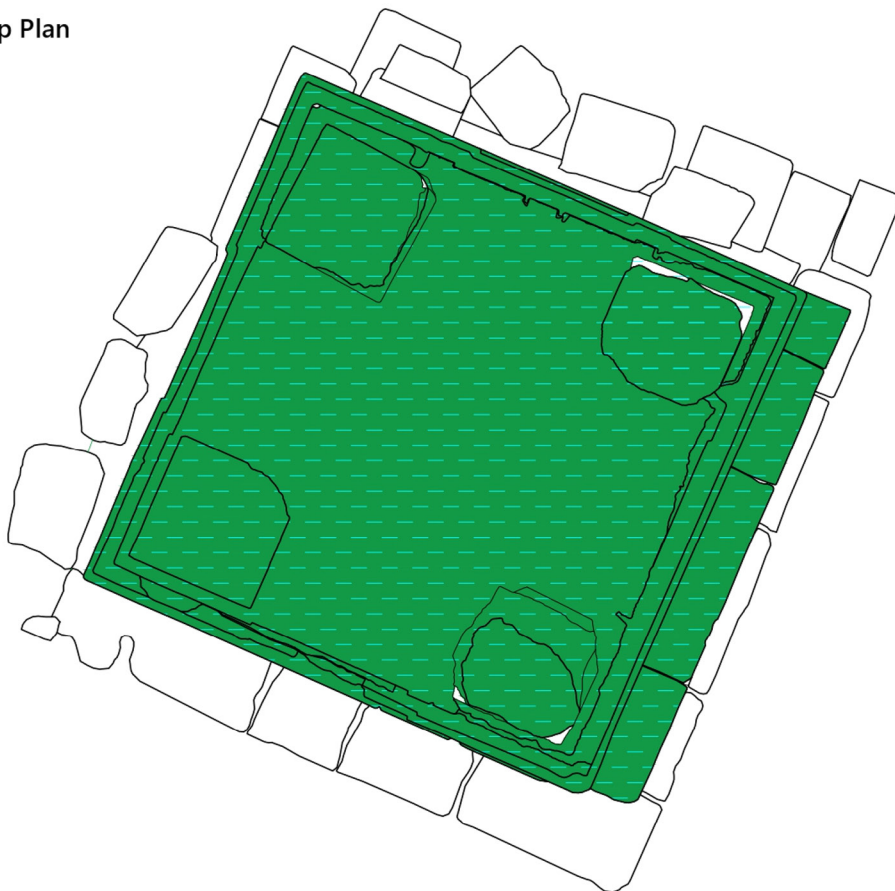
-  Point Chisel
-  Tooth Chisel

Drawn By :

Eng. Najdat Hazaymeh



Top Plan



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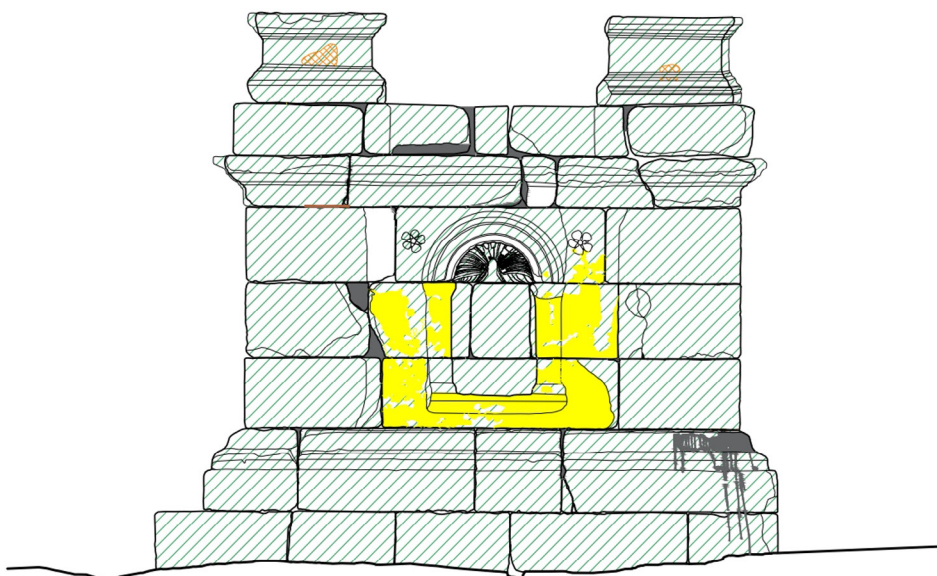
Table 5 - Interventions

- Biocide Treatment
- Cleaning with Water

Drawn By :

Eng. Najdat Hazaymeh

North Elevation



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Table 1 - Materials

- Calcareous Limestone
- Cement Mortar
- Metal
- Original Mortar
- Traces of Original color

Drawn By :

Eng. Najdat Hazaymeh

North Elevation

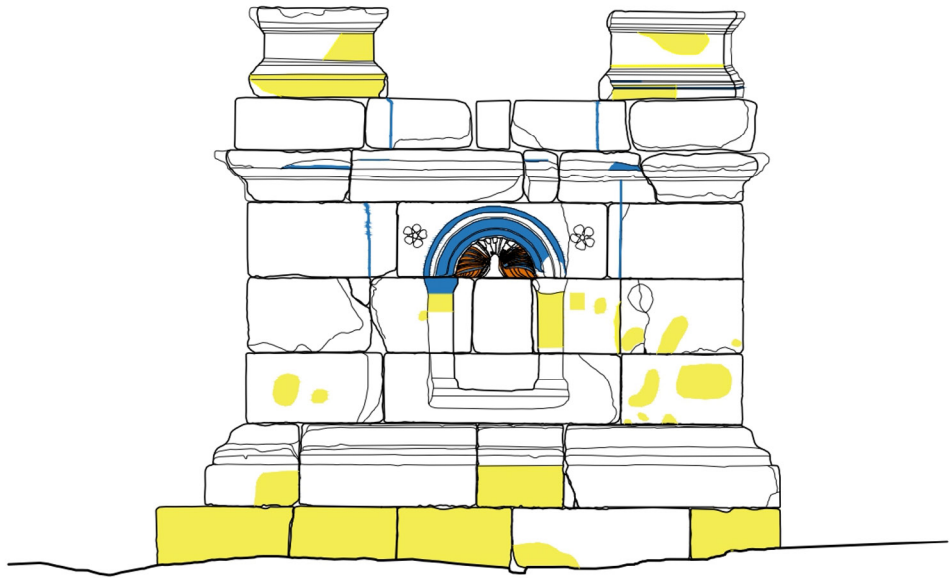


Table 2 - Tool traces

- Flat Chisel
- Tooth Chisel
- Round Chisel

Drawn By :

Eng.Najdat Hazaymeh

North Elevation

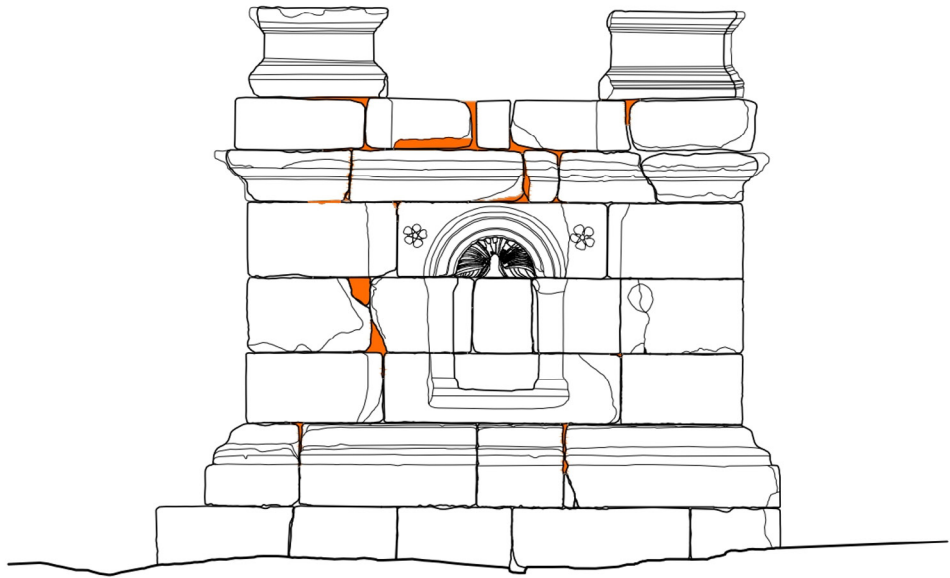


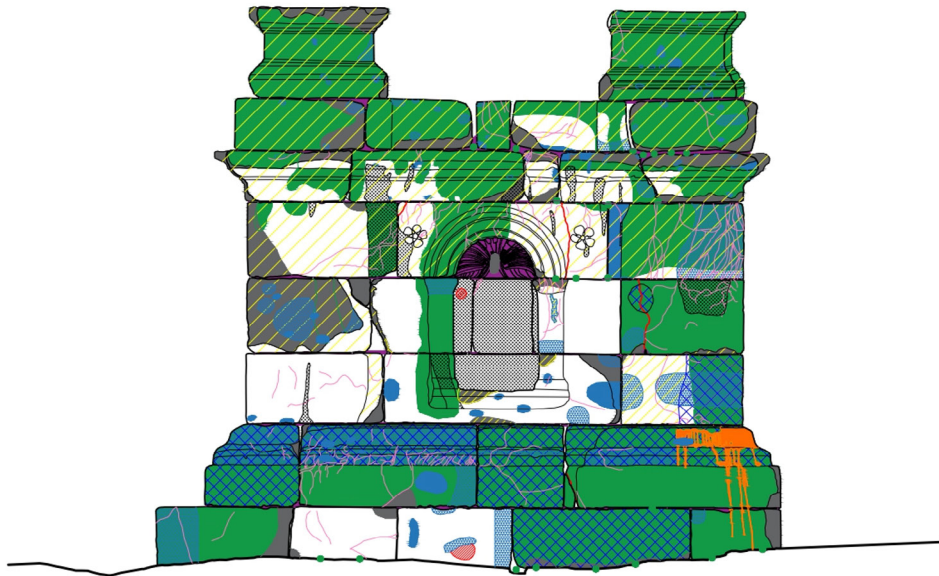
Table 3 - Previous Interventions

- Fillings

Drawn By :

Eng.Najdat Hazaymeh

North Elevation



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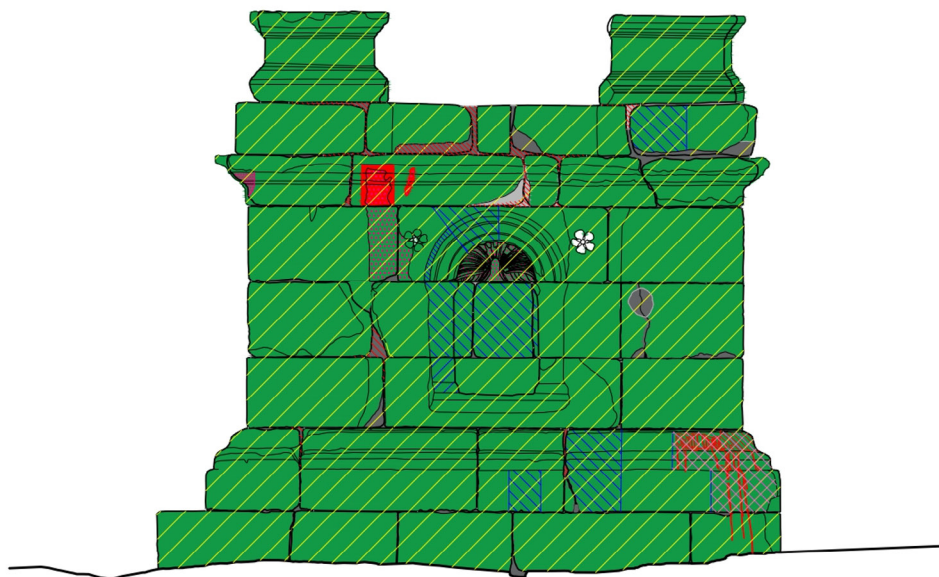
Table 4 - Conditions

	Erosion
	Missing Parts
	Scaling
	Biological Colonization
	Dropping
	Deep Cracks
	Superficial Cracks
	Black Crusts
	Superficial Deposits
	Alveolization
	Stain
	Plants
	Pitting
	Exfoliation

Drawn By :

Eng.Najdat Hazaymeh

North Elevation



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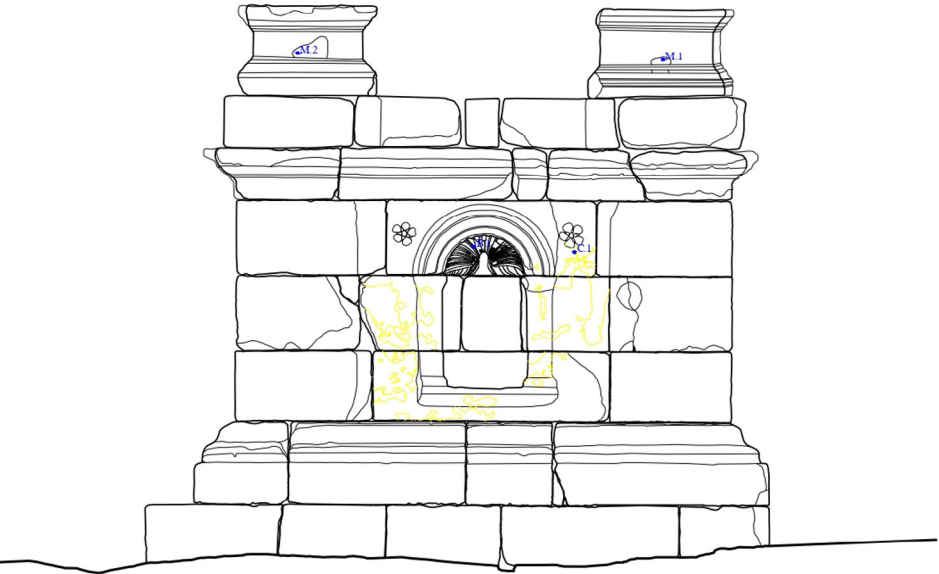
Table 5 - Interventions

	Biocide Treatment
	Cleaning with Tween 20
	Cleaning with Ammonium Carbonate
	Mechanical Cleaning
	Adhesion with resins (Injection with Acril 33)
	Fillings
	Cleaning with Laser
	Cleaning with EDTA
	Cleaning with Acetone

Drawn By :

Eng.Najdat Hazaymeh

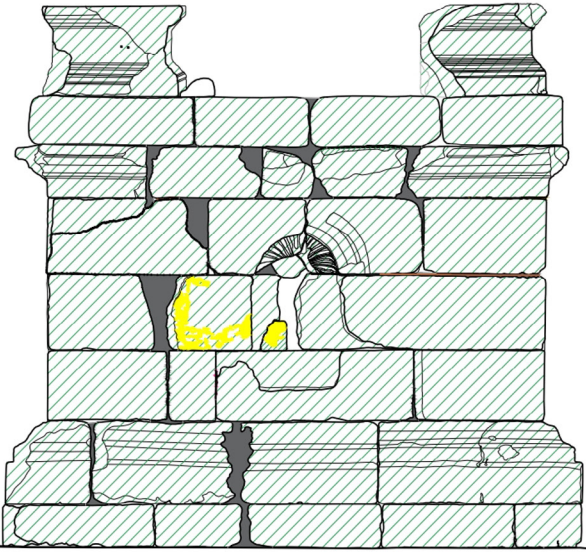
North Elevation



- Table 6 - Samples
- M.1 Original Mortar Sample
 - M.2 Original Mortar Sample
 - C.1 Original Color Sample
 - B.1 Black Crust Sample

Drawn By :
Eng.Najdat Hazaymeh

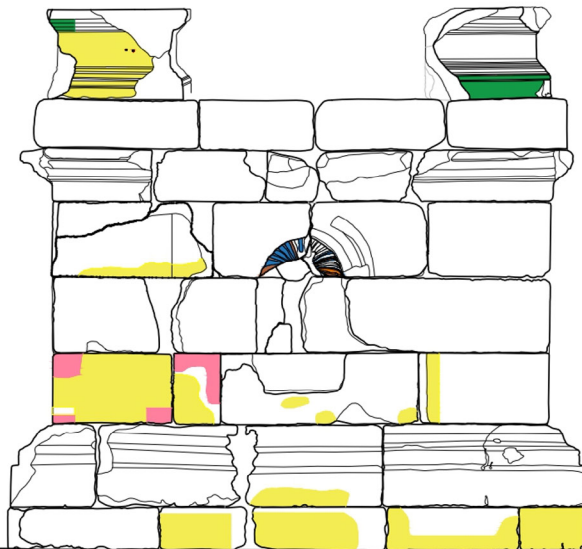
East Elevation



- Table 1 - Materials
- Calcareous Limestone
 - Cement Mortar
 - Metal
 - Original Mortar
 - Traces of Original color

Drawn By :
Eng.Najdat Hazaymeh

East Elevation



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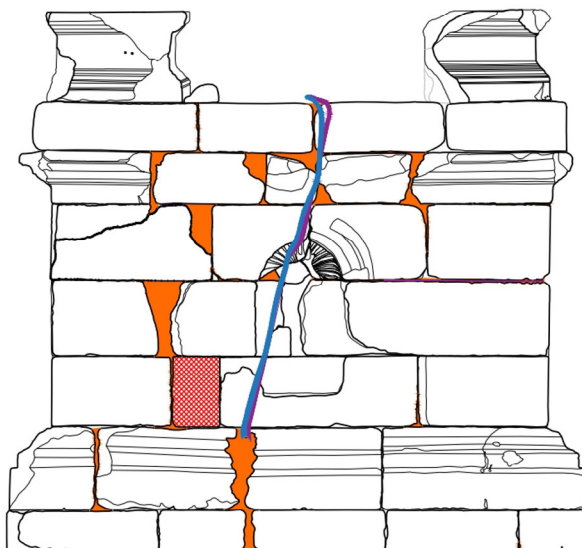
Table 2 - Tool traces

- Flat Chisel
- Point Chisel
- Tooth Chisel
- Drill
- Round Chisel
- Push Hammer

Drawn By :

Eng. Najdat Hazaymeh

East Elevation



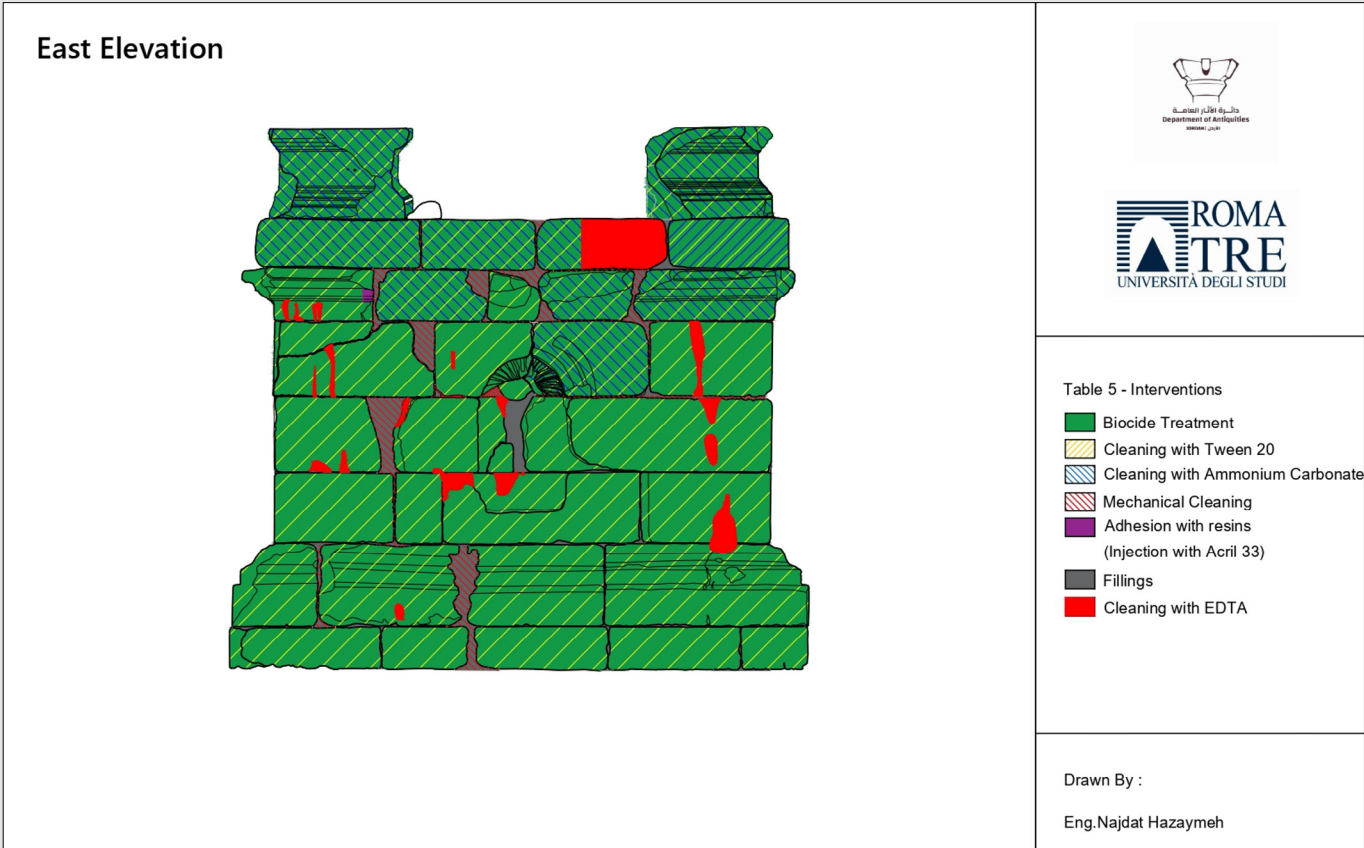
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Table 3 - Previous Interventions

- Fillings
- Camera
- Metal Wires
- Added Stone

Drawn By :

Eng. Najdat Hazaymeh



East Elevation

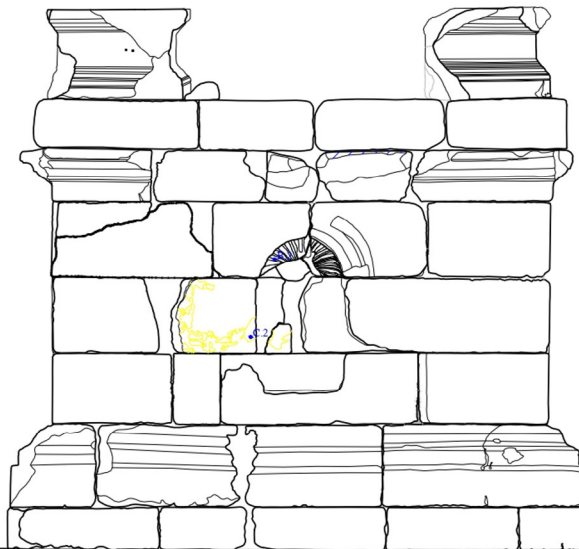


Table 6 - Samples

- C.2 Original Color Sample
- B.2 Black Crust Sample

Drawn By :

Eng.Najdat Hazaymeh

South Elevation

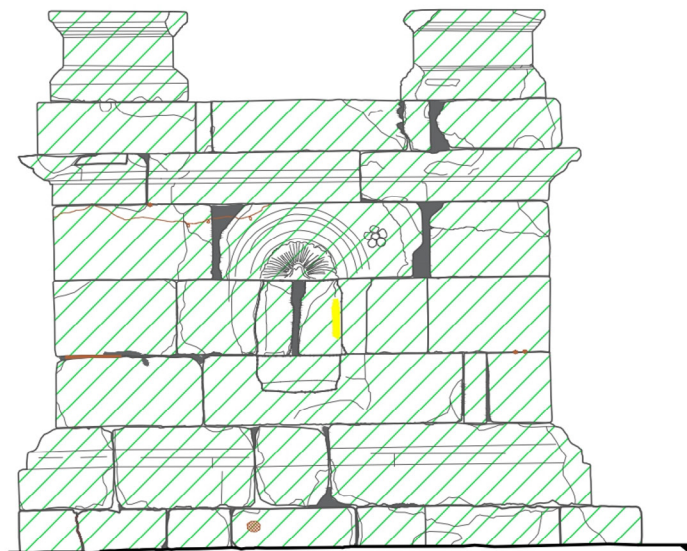


Table 1 - Materials

- ▨ Calcareous Limestone
- Cement Mortar
- Metal
- ▨ Original Mortar
- Traces of Original color

Drawn By :

Eng.Tasneem Al-Bataineh

South Elevation

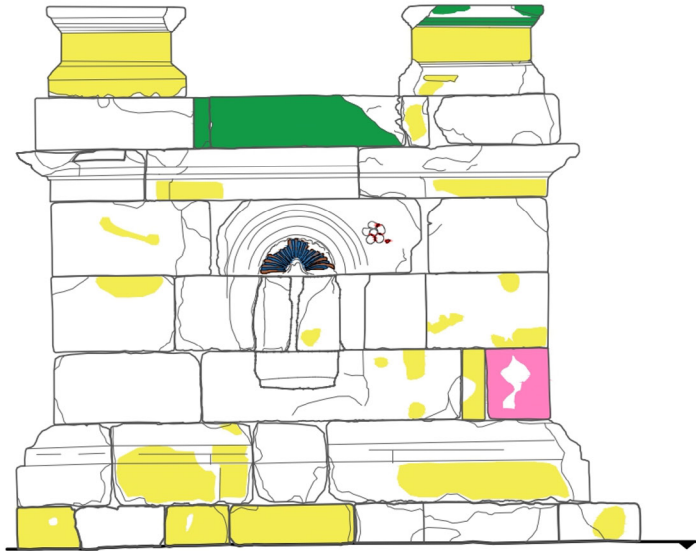


Table 2 - Tool traces

- Flat Chisel
- Point Chisel
- Tooth Chisel
- Drill
- Round Chisel
- Push Hammer

Drawn By :

Eng. Tasneem Al-Bataineh



South Elevation

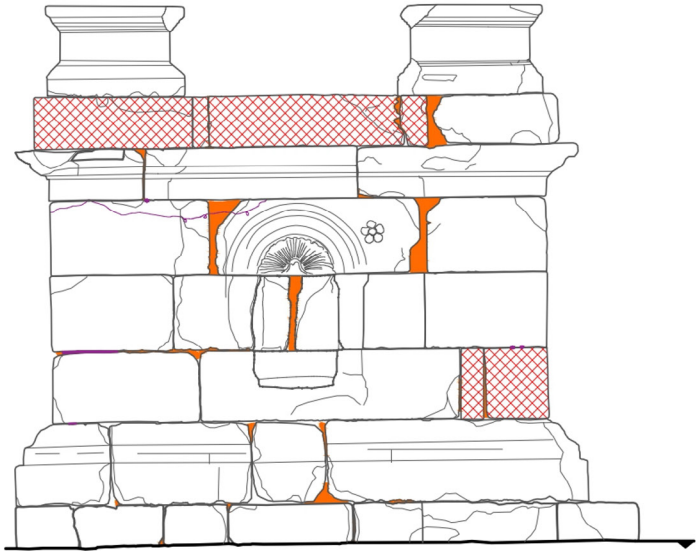


Table 3 - Previous Interventions

- Fillings
- Metal Wires
- Added Stone

Drawn By :

Eng. Tasneem Al-Bataineh



South Elevation

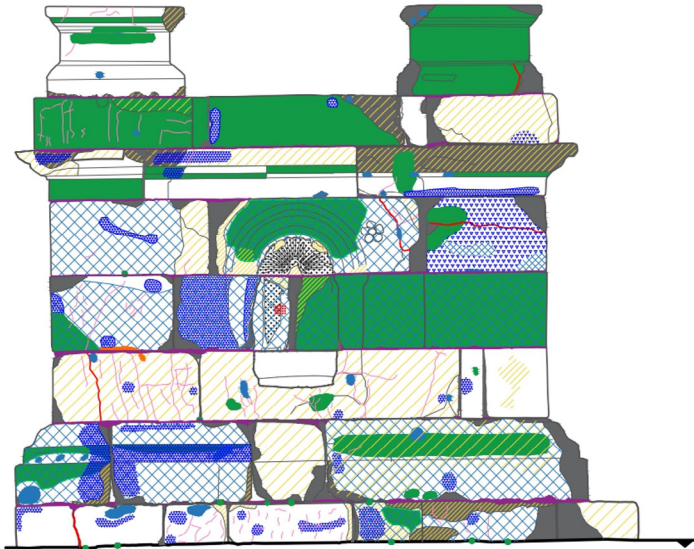


Table 4 - Conditions

- Erosion
- Missing Parts
- Scaling
- Biological Colonization
- Dropping / Cement
- Deep Cracks
- Superficial Cracks
- Black Crusts
- Superficial Deposits
- Alveolization
- Stain
- Plants
- Pitting
- Graffiti

Drawn By :
Eng.Tasneem Al-Bataineh

South Elevation

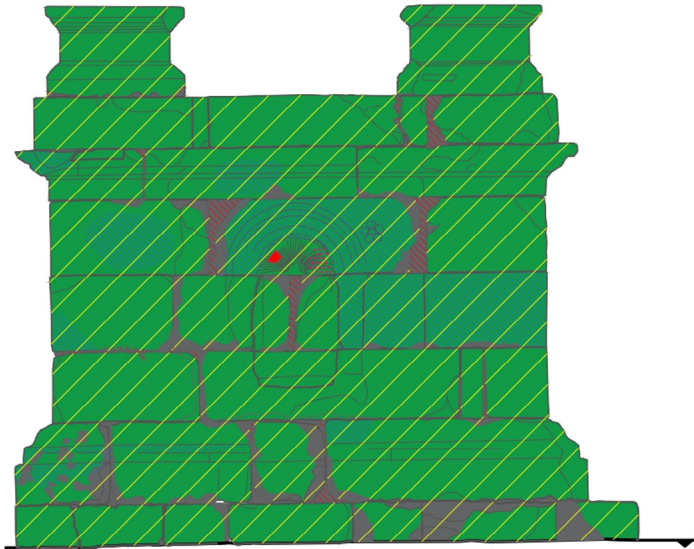


Table 5 - Interventions

- Biocide Treatment
- Cleaning with Tween 20
- Cleaning with Ammonium Carbonate
- Mechanical Cleaning
- Adhesion with resins
(Injection with Acril 33)
- Fillings
- Cleaning with Laser
- Cleaning with EDTA

Drawn By :
Eng.Tasneem Al-Bataineh

South Elevation

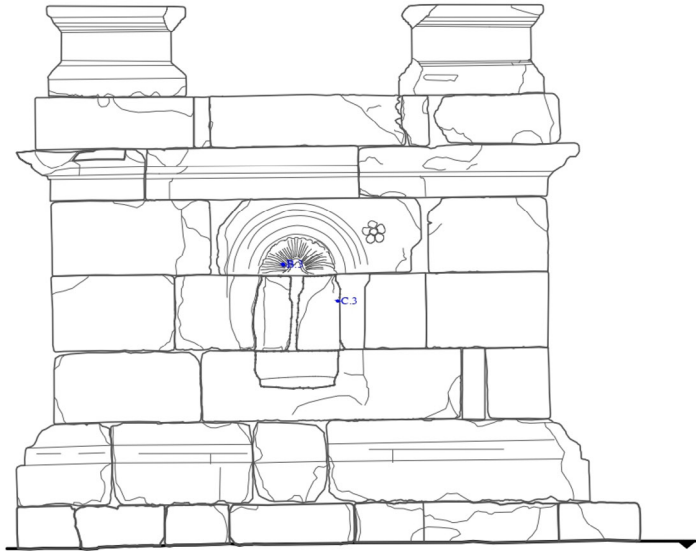


Table 6 - Samples

- C.3 Original Color Sample
- B.3 Black Crust Sample

Drawn By :

Eng. Tasneem Al-Bataineh

West Elevation

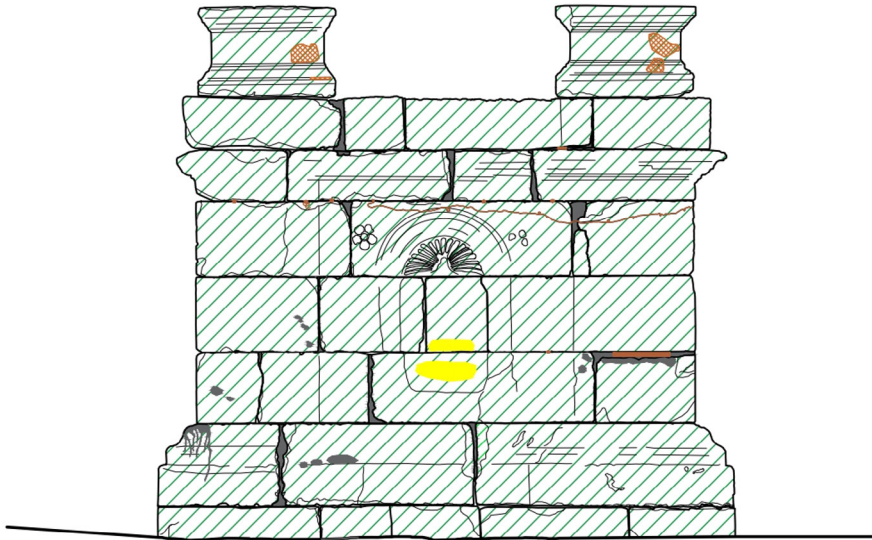


Table 1 - Materials

- ▨ Calcareous Limestone
- Cement Mortar
- Metal
- ▨ Original Mortar
- Traces of Original color

Drawn By :

Eng. Tasneem Al-Bataineh

West Elevation



Table 2 - Tool traces

- Flat Chisel
- Tooth Chisel
- Drill
- Round Chisel

Drawn By :
Eng. Tasneem Al-Bataineh

West Elevation

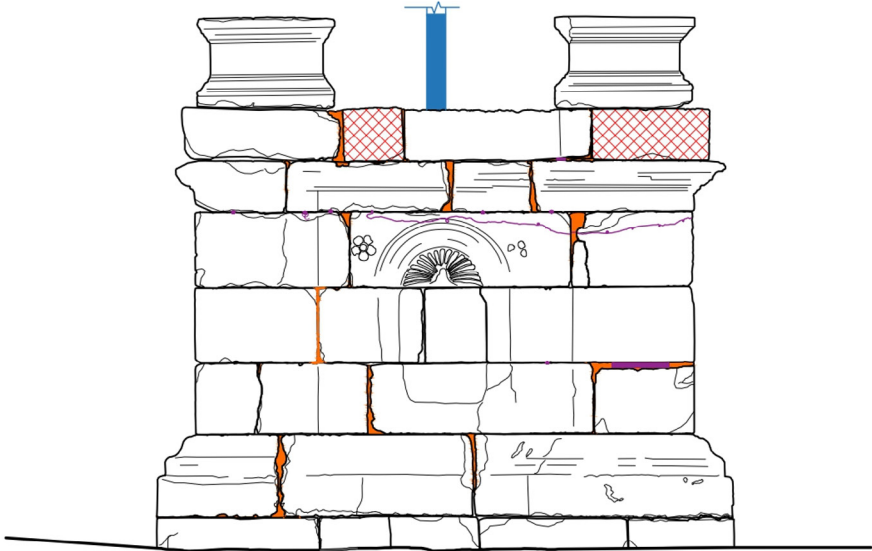


Table 3 - Previous Interventions

- Fillings
- Camera
- Metal Wires
- Added Stone

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West Elevation

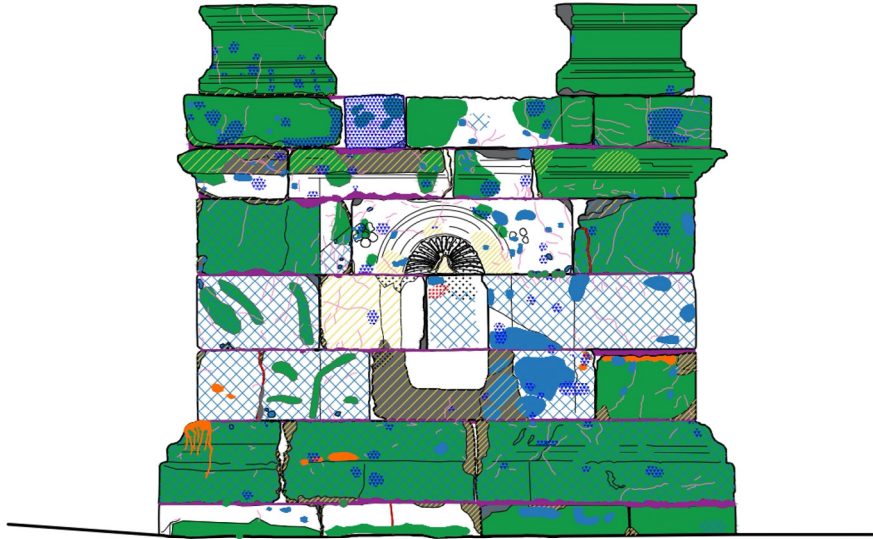


Table 4 - Conditions

	Erosion
	Missing Parts
	Scaling
	Biological Colonization
	Dropping
	Deep Cracks
	Superficial Cracks
	Black Crusts
	Superficial Deposits
	Alveolization
	Stain
	Plants
	Pitting
	Graffiti

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Eng. Tasneem Al-Bataineh

West Elevation

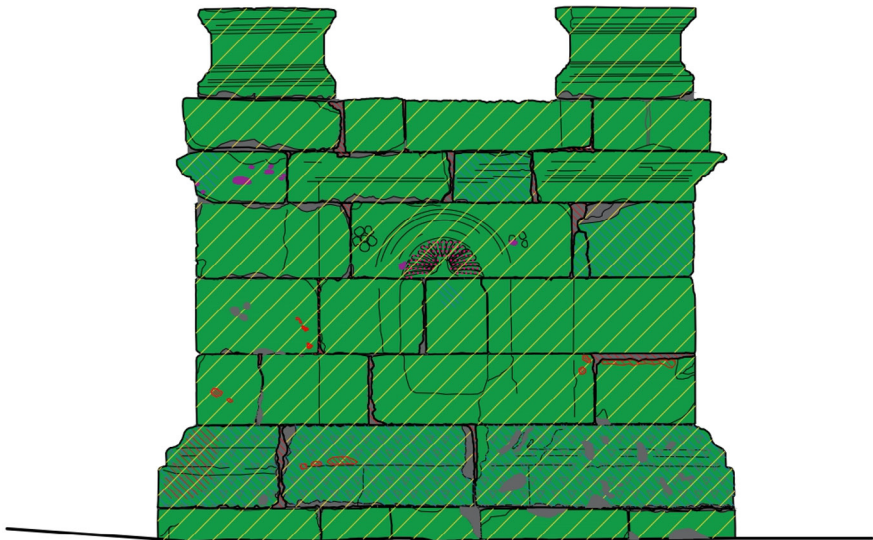


Table 5 - Interventions

	Biocide Treatment
	Cleaning with Tween 20
	Cleaning with Ammonium Carbonate
	Mechanical Cleaning
	Adhesion with resins (Injection with Acril 33)
	Fillings
	Cleaning with Laser
	Cleaning with Hydrogen Peroxide

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Eng. Tasneem Al-Bataineh

West Elevation

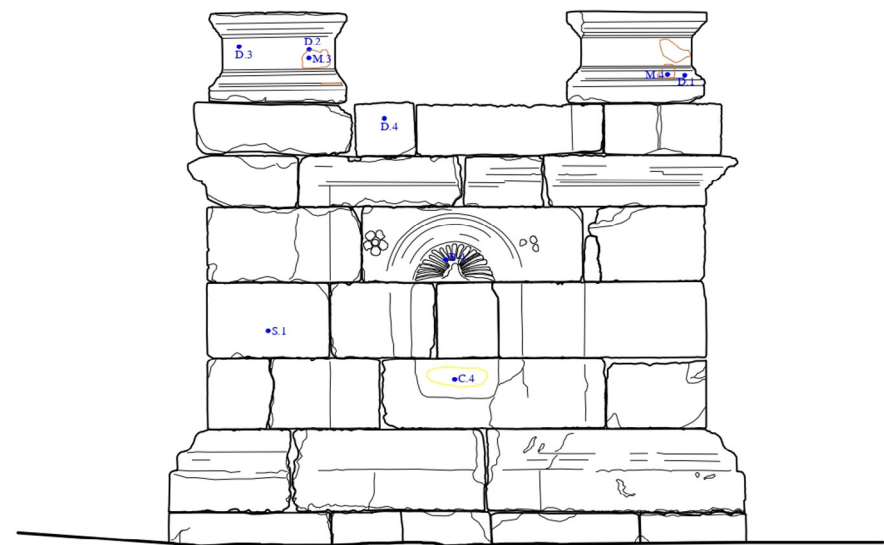


Table 6 - Samples

- S.1 Lime Stone Sample
- C.4 Original Color Sample
- M.4 Original Mortar Sample
- B.4 Black Crust Sample
- M.3 Original Mortar Sample
- D.1 Dino-Light Sample
- D.2 Dino-Light Sample
- D.3 Dino-Light Sample
- D.4 Dino-Light Sample

Drawn By :
Eng. Tasneem Al-Bataineh

Structural Aspects of the Perimeter Wall of the Diaconia Mosaic in the Church of Propylaea in Jerash, Jordan

Florin Cristinel Stan, Martina Bocci, Sara Fares,
Najadt Mamoon AbdAlra'oof Hazaimh, Tasneem Aamar Ahmad Al-Bataineh,
Marialaura Malena, Pietro Meriggi, Stefano De Santis, Gianmarco de Felice

Abstract: The study concerns the stability of the remaining wall of the diaconicon of the Propylaea Church in Jerash, a Byzantine building constructed in the 6th century AD on top of the remains of a previous Roman building. The geometric model of the structure is derived from a high-density point cloud obtained through photogrammetric surveying and integrated into a Distinct Element code. Static and dynamic analyses are performed to simulate gravity and seismic load conditions. The stability of the wall is then assessed and restoration strategies are devised, together with the necessary temporary scaffolding, which is designed and installed.

Keywords: Masonry, Stability, Block structure, Distinct element method, Photogrammetric survey, Structural analysis, Restoration.

Introduction

The archaeological site of ancient Gerasa features a series of large structural systems made of stone blocks that have suffered severe damage due to earthquakes and lack of maintenance (Fig.1). The beauty of the archaeological site and the great structural challenge presented by many of the archaeological remains pose structural problems that cannot be addressed with traditional finite element analysis. In most cases, the structures consist of blocks that have undergone finite displacement, and the equilibrium condition is controlled primarily by the shape and position of the blocks and their displacement capacity, rather than by the stress state, as compared to the material strength. In this context, digital surveying of the stone skeleton and its reproduction in the structural analysis code, become the key factor for a reliable assessment of the safety level.

**Fig. 1**

The geometries of some stone structures and the severe damage conditions they have suffered.

This approach was followed in the present study in order to assess the stability of the remaining wall of the diaconicon of the Church of Propylaea in Jerash, a Byzantine building constructed in the 6th century AD on top of the remains of an earlier Roman building. The geometric model of the structure is derived from a high-density point cloud obtained through photogrammetric survey, allowing an accurate reconstruction of the three-dimensional configuration and block arrangement. The digital survey data are integrated into the numerical framework of a Distinct Element code to ensure a faithful representation of the actual geometric conditions, which is crucial for reliable structural assessment. Mechanical properties are adopted from existing literature and calibrated to reflect the specific characteristics of the structure under study. Following an initial quasi-static phase under dead loads, dynamic analyses are performed to simulate seismic loading conditions. The study allowed to assess the stability of the wall under both static vertical load and expected seismic action. Accordingly, the temporary scaffolding was designed and installed, and the restoration strategies were presented in order to ensure the conservation of the wall remains.

1 Seismic Hazard

The seismic hazard assessment was carried out using the web platform of the European Facilities for Earthquake Hazard and Risk (EFEHR) to determine the Peak Ground

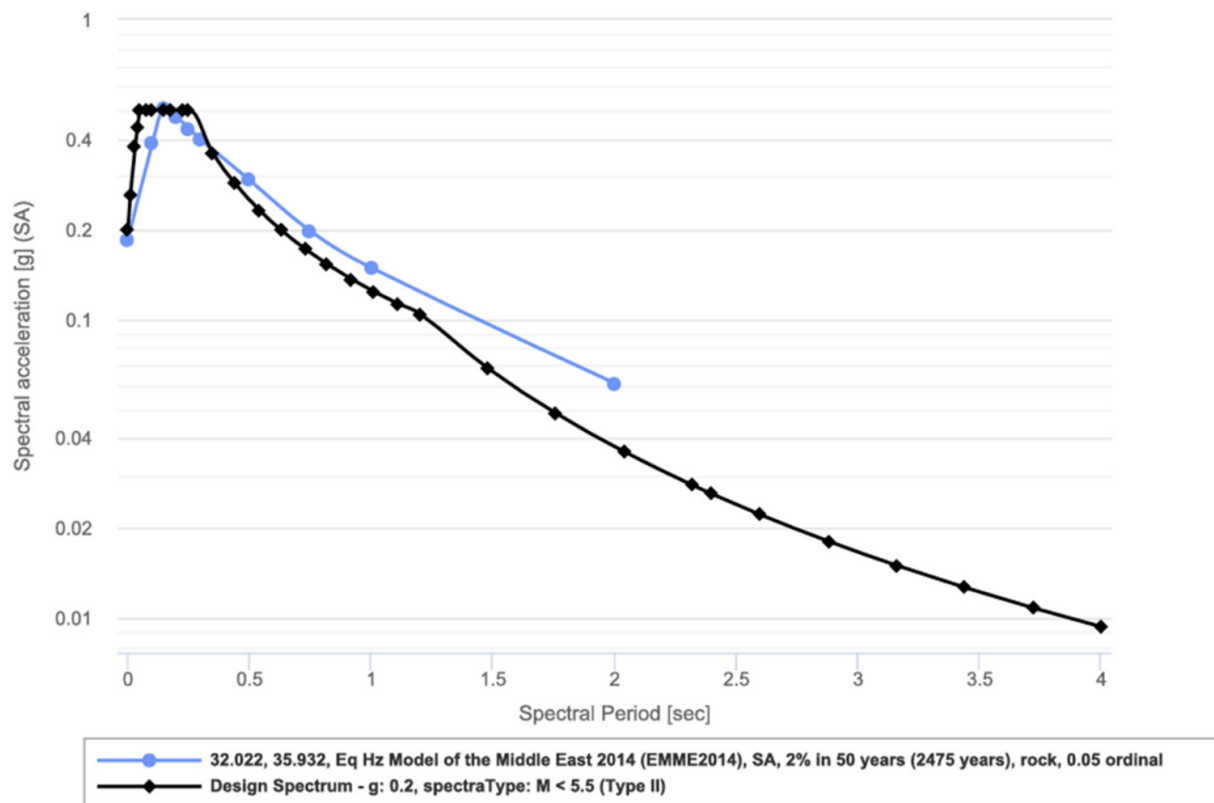
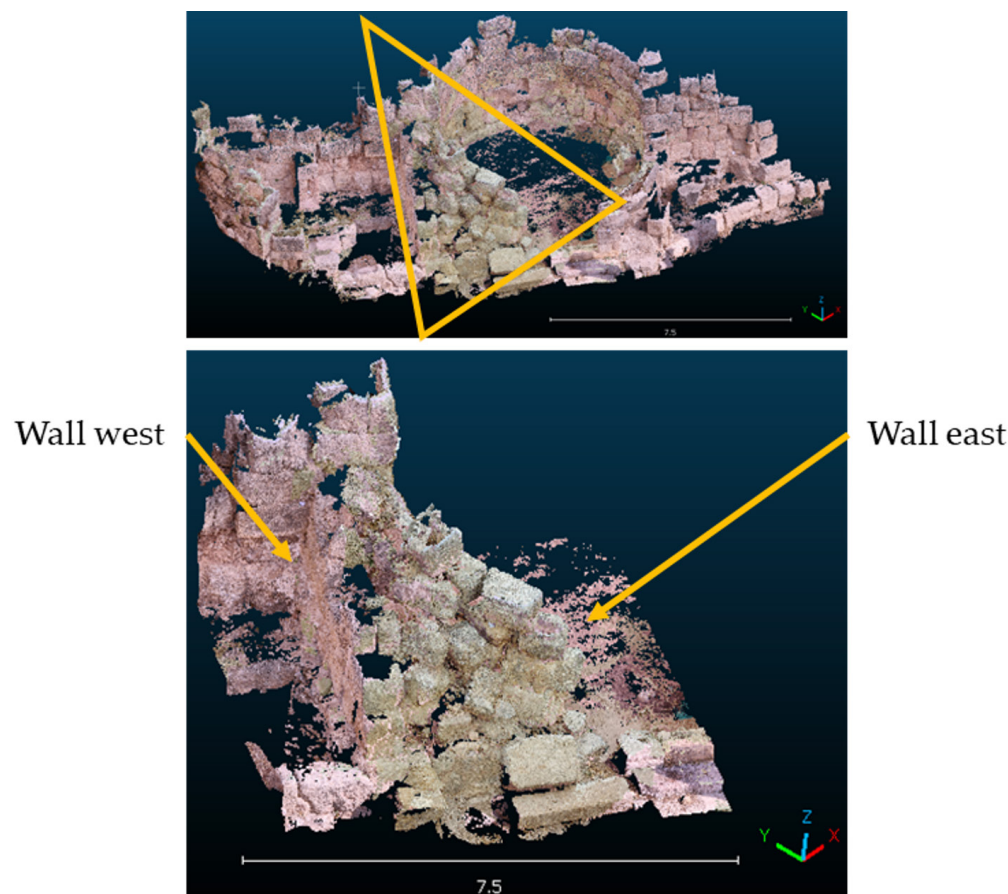


Fig. 2
Hazard Spectra.

Acceleration (PGA) related to the geographical coordinates of the study area (latitude 32.283, longitude 35.893) and selecting the appropriate parameters for the risk model. This latter was defined according to the 2014 Earthquake Model of the Middle East (EMME). Considering the archaeological importance of the building under study, a probability of exceedance of 2% was adopted, corresponding to a return period of 2475 years. The corresponding design spectrum (2% exceedance probability in 50 years) is shown in Figure 2.

2 Modelling of the block structure

The assessment of the dynamic behaviour of discontinuous structural systems, such as assemblies of stone blocks or masonry elements, poses a major challenge in structural engineering, especially in the context of historic constructions. These systems exhibit a highly complex mechanical response, governed by the inherently non-linear interactions at joints, the presence of cracks and discontinuities, and the pronounced variability in the mechanical properties of materials and interfaces. When subjected to dynamic actions, their behaviour is largely controlled by contact phenomena including opening and closure of joints, sliding, and rolling, which are difficult to capture efficiently through conventional modelling approaches. The seismic response of historic masonry structures has traditionally been investigated using finite element models (FEM), which can provide accurate representations of structural behaviour under dynamic loading. However, FEM formulations are fundamentally based on continuum assumptions, which limits their ability to effectively reproduce the highly localised non-linear mechanisms and finite displacements, which characterise discontinuous systems, particularly at

**Fig. 3**

Point cloud processing:
from the initial (top) to the
final (bottom) cloud.

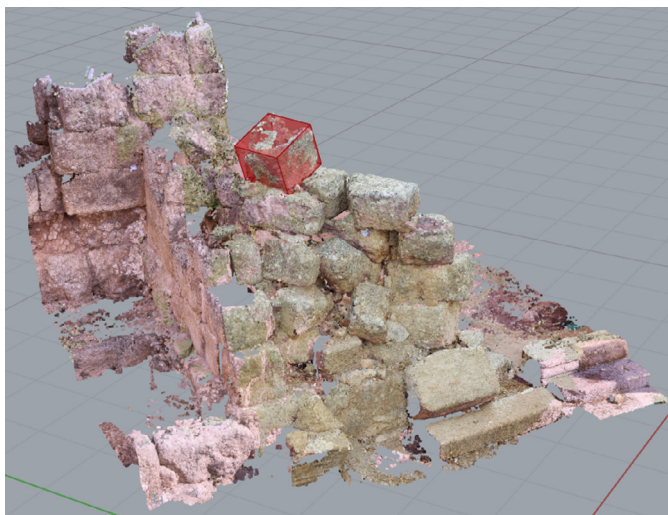
joints and cracks. For such structures, numerical approaches based on the discrete element method (DEM) offer a particularly suitable alternative. By modelling each block as an individual rigid or deformable body and explicitly simulating contact interactions in terms of friction and cohesion, DEM enables a reliable representation of historic masonry and dry-stone constructions. This approach is especially effective for analysing damage evolution, collapse mechanisms, and the influence of geometric and mechanical parameters on the global structural response, with advanced geometric modelling techniques providing essential support for accurate numerical representation.

2.1 Data pre-processing

The geometric modelling was supported by the acquisition of a point cloud, the availability of which represented an important resource for defining the geometry of the archaeological site.

The photogrammetric survey was managed and coordinated by prof. Massimo Brizzi, Monumenta Orientalia, with the collaboration of Dr. Najadt Mamoon Abd Al Ra'ooof Hazaimh and Dr. Tasneem Aamar Ahmad Al-Bataineh.

A preliminary phase of processing and optimisation of the cloud was necessary in order to obtain a model suitable for structural analyses. In particular, the initial cloud, containing about 690.5 million points and weighing 10.5 GB, was subjected to subsampling and the number of points reduced to improve processing times (Fig.3). The subsampling was performed by imposing a distance between the points of the cloud equal to 1 mm, thus obtaining a final cloud composed of 48.7 million



from left,
Fig. 4
 3D modelling of the structure by defining regular blocks.

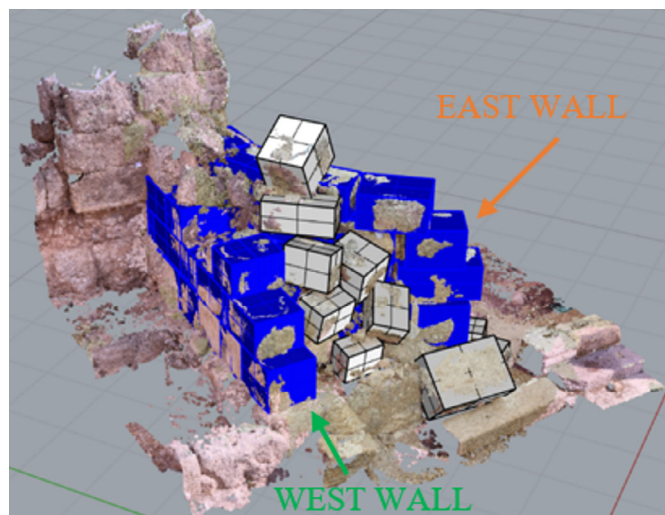


Fig. 5
 Subdivision of the modelled blocks into structural elements (in blue) and blocks excluded from the analyses (in white).

points with a weight of 700 KB. These operations were performed using Cloud Compare, an open-source software dedicated to the management and processing of 3D point clouds.

2.2 Three-dimensional geometric modelling

The optimized point cloud was imported into Rhino for the generation of the three-dimensional model. A parametric script developed in Grasshopper was used to generate regular blocks based on the dimensions of individual building elements (Fig.4). For the structural analysis, only the well-preserved blocks from the East and West Walls of the ancient structure were modelled, as the blocks in the intermediate area were in a state of significant deterioration and lacked sufficient definition for inclusion (Fig.5). To improve the accuracy of the model, the geometry was further refined to better reflect the actual shape of the blocks, incorporating details such as geometric irregularities, degradation, and crack patterns that play a crucial role in the structural behaviour.

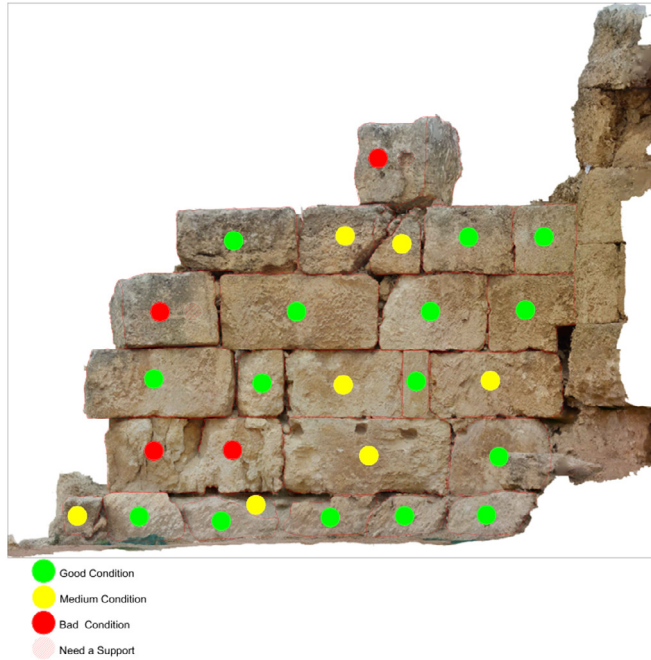
3 State of deterioration

The survey of the state of deterioration of the remaining walls of Propylaea church have been carried out by Dr. Tasneem Aamar Ahmad Al-Bataineh, Dr. Najadt Mamoon Abd Al Ra'oof Hazaimh and Dr. Qais Azmi Radwan Al Momani, with the general coordination of Dr. Bilal Fawwaz Mohammad Alboreeni, as shown in Figures 6-7.

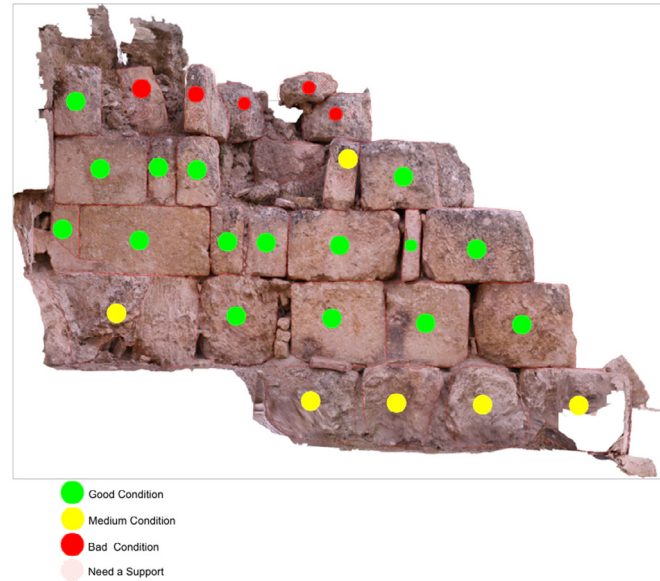
The survey shows that most of the blocks are in a good or medium state of conservation. However, there are a number of blocks that are severely degraded and in a poor state of conservation, some of which require support to ensure stability. The East Wall, in particular, is the most critical due to a deteriorated ashlar at the base, which destabilizes the blocks above it. In contrast, the West Wall appears generally stable, except for the uppermost row of ashlars, which are also in poor condition.

The refinement process focused mainly on the East Wall, involving modifications such as cutting blocks, shifting faces, and adding discontinuities to reflect the damage

Wall-East



Wall-West



more accurately. Additionally, the positions of the vertices of the damaged blocks were adjusted to enhance the geometric representation (Fig.8). These adjustments allowed for a more realistic depiction of the blocks and the joints.

4 Structural analysis

The structural analysis was conducted using 3DEC calculation software. Originally developed by Cundall in 1983, 3DEC is a three-dimensional numerical program designed to simulate the behaviour of rock masses. Subsequently, the code was extended to the study of masonry structures viewed as an assembly of blocks. This software is based on the distinct element method (DEM), a numerical approach that represents the mechanical behaviour of systems made up of separate blocks, which interact through contacts located on their interface surfaces (joints) (Hart et al., 1988). The method has been adopted in the scientific literature to simulate the structural behaviour of historical masonry structures, including walls (Lourenço et al., 2005; de Felice, 2011; Pulatsu et al., 2016; Meriggi et al., 2019), arches (Lemos, 2007; Dimitri et al., 2011), and archaeological sites (Oliveira et al., 2012; Mordanova and de Felice, 2020; De Santis, 2024).

DEM allows to simulate finite displacements, including the complete detachment between the blocks, and to automatically update the geometry of the model, identifying new contacts that form during the analysis. The integration of the equations of motion takes place in the time domain using an explicit central difference method, guaranteeing efficient integration, accounting for the non-linear behaviour of discontinuities and for large relative displacements between the blocks.

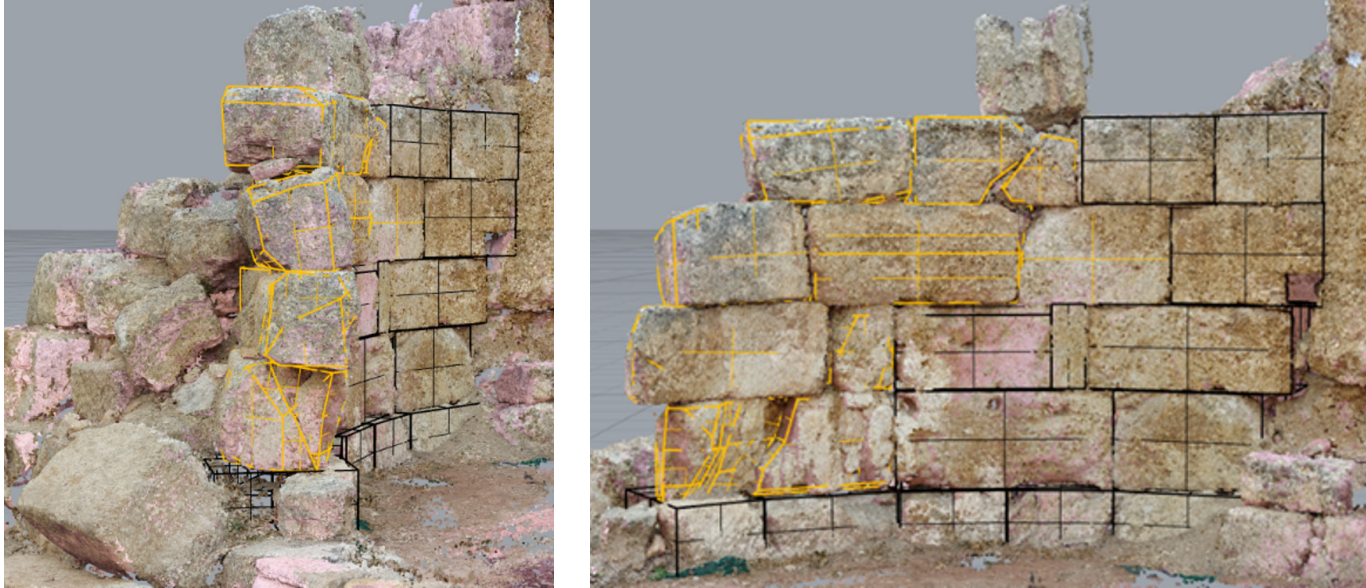
from left,

Fig. 6

Survey of the state of deterioration of the East wall.

Fig. 7

Survey of the state of deterioration of the West wall.

**Fig. 8**

Geometric refinement of the 3D model for greater accuracy in geometry representation.

4.1 Geometry

Once the model was finalized in Rhino, it was exported in *.wrl format and subsequently imported into 3DEC for numerical analysis (Lemos, 2016). The 3DEC model (Fig.9) consisted of 47 blocks, including those from the East Wall, which were geometrically refined during the previous step. To ensure a proper simulation of the structural behaviour and to prevent the blocks from moving freely under gravity, a constraining block was introduced at the base, acting as a one-sided constraint to prevent any blocks from falling. The model is shown in Figure 9.

4.2 Mechanical parameters

In the numerical model, the blocks were modelled as rigid elements, assuming that their internal deformation is negligible compared to rigid body motion. In order to improve the representation of the interactions between blocks, the contact surfaces were discretized by triangulation, introducing a central node on each face. This choice allows for a more realistic distribution of interface forces thanks to a refined representation of the surfaces compared to the default approach, in which the contacts are described simply through vertices and edges.

For the blocks, a mass density of 2200 kg/m³ was assumed as representative of soft calcarenite. For the mechanical characterisation of the joints, an infinitely resistant model in compression was adopted, while in traction and shear an elastic-plastic behaviour with perfect yielding was considered. The normal stiffness of the joint was determined by assimilating the dry-stone wall to a system of springs arranged in series, which allows its value to be expressed through the following relationship:

$$k_n = \frac{E_b E_w}{(E_b + E_w)h}$$

where E_b , E_w represent the elastic modulus of the block and the wall, respectively, while h indicates the height of the block. Moreover, thanks to the relationship $G = E/[2(1+\nu)]$, the shear stiffness of the spring k_s can be expressed as a function

of the normal stiffness k_n as follows:

$$k_s = \frac{k_n}{2(1 + \nu)}$$

For rigid blocks, assuming $\nu = 0$, the previous equation becomes $k_s = k_n/2$. The friction angle is assumed equal to 30° , in accordance with the values reported in the scientific literature for dry masonry structures. The mechanical properties were suitably reduced to consider the surveyed state of degradation, which can compromise the structural performance. This choice allows for a more realistic representation of the behaviour of the material under current conditions. The physical-mechanical properties of the model are summarised in Table 1.

Density	$\rho=2200 \text{ kg/m}^3$
Elastic modulus of the block	$E_b=2000 \text{ MPa}$
Elastic modulus of the wall	$E_w=100 \text{ MPa}$
Normal stiffness	$j_{kn}=105 \text{ MPa}$
Shear stiffness	$j_{ks}=53 \text{ MPa}$
Friction angle	$\phi=30^\circ$

Tab. 1
Mechanical properties.

4.3 Structural analyses

A preliminary gravity load analysis was carried out to determine the equilibrium configuration of the structure under its self-weight, based on the assigned physical and mechanical properties of the blocks and joints. This quasi-static analysis incorporated a viscous damping coefficient of 0.8 to reduce numerical oscillations and facilitate the achievement of a stable equilibrium state. This initial step is crucial for establishing a static reference configuration, from which further analysis can proceed. The results confirmed that the model reached a stable condition, validating the assumptions regarding material properties and boundary conditions.

Following this, seismic action was applied to the base block of the model, prescribing the three components of a seismic signal corresponding to an event located 17.6 km from the site. The signal featured a 20-second strong-motion duration, with peak ground accelerations (PGA) of 0.15 g in the East-West direction, 0.13 g in the North-South direction, and 0.08 g vertically. The velocity time histories of the seismic event are presented in Figure 10. For this dynamic analysis, the viscous damping coefficient was omitted, as energy dissipation primarily occurred through friction between the blocks. The seismic input was applied to the model to evaluate the dynamic response of the wall and assess its stability under the ground motion. To focus on the most significant effects of the earthquake, the seismic signal was applied starting from the tenth second, excluding the initial low-velocity phase.

4.4 Results of structural analyses

The results revealed a progressive damage pattern, with localized collapse mechanisms activated in specific areas. Notably, the top blocks of the East Wall underwent displacements and rotations that destabilized their equilibrium, resulting in partial

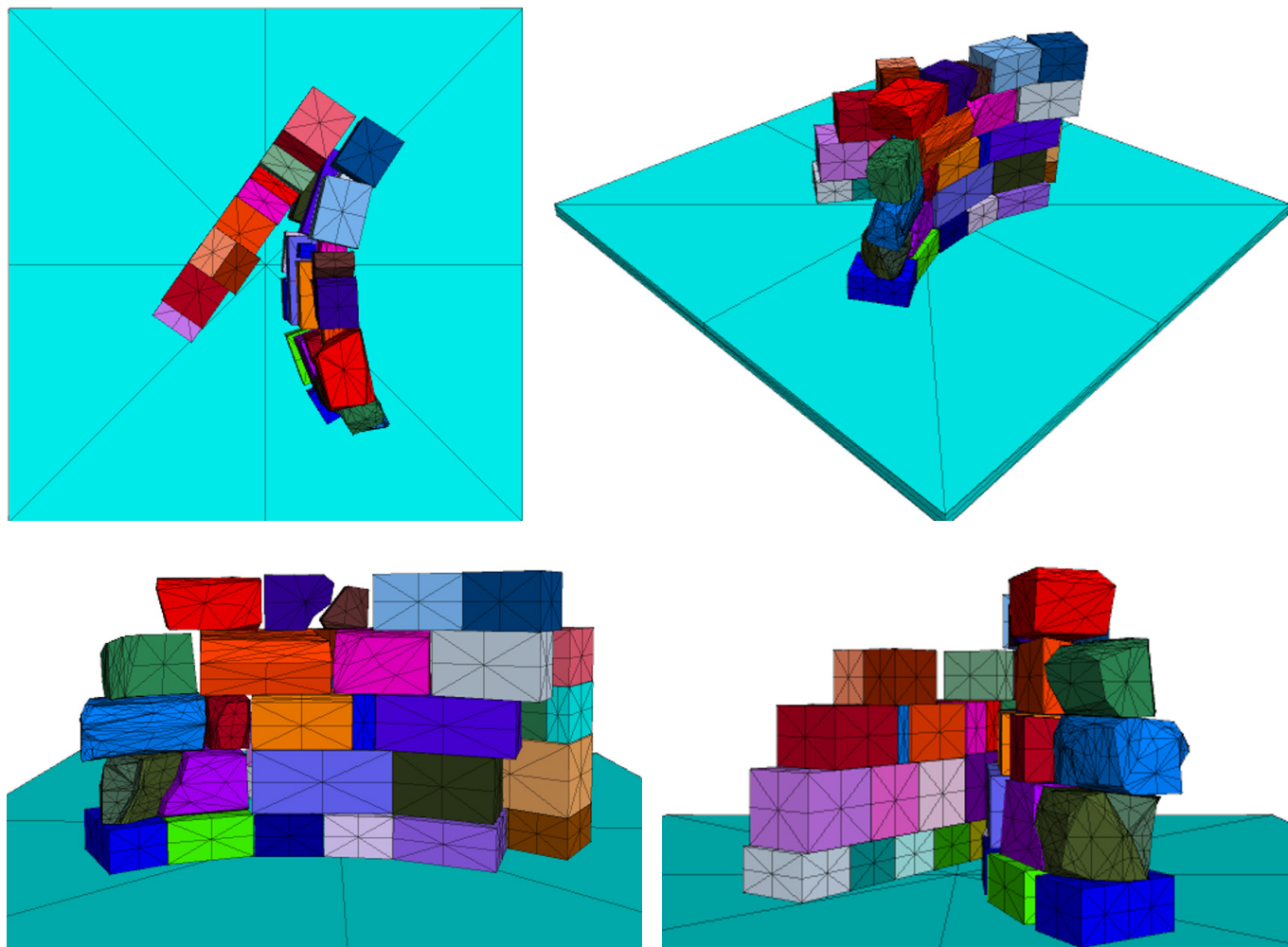


Fig. 9
Structural model in 3DEC.

collapse (Fig.11). Four blocks detached and fell at an angle, while other blocks experienced relative sliding. This analysis provided insights into the progressive damage evolution, identified the most vulnerable sections of the structure, and offered valuable information for assessing structural safety and considering potential reinforcement measures.

5 Temporary scaffolding

In order to plan the restoration design and stabilization measures, the results of the structural analyses were combined with the actual conditions of deterioration found during the on-site inspection. It emerged that some of the stone blocks were so deteriorated and/or fractured that they were no longer able to carry out their load-bearing function under static load. In addition, some blocks had shifted, slipped, or rotated, to the extent that their actual condition posed a risk of collapse even under their self-weight.

Consequently, it was decided to carry out temporary works to ensure the safety of the archaeological artefacts during the time needed to organize the restoration work and to allow the cooperation activities for the restoration of the mosaics to be carried out in a safe condition.

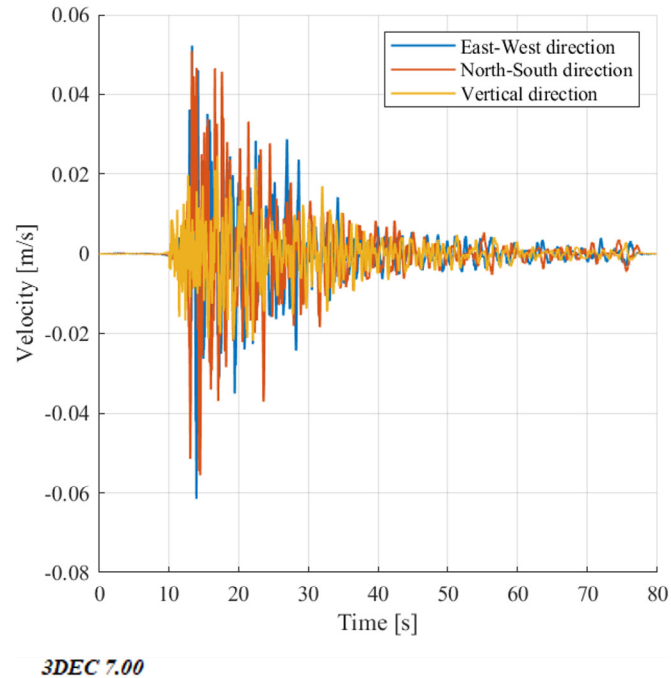


Fig. 10
Velocity time histories
used in dynamic analyses.

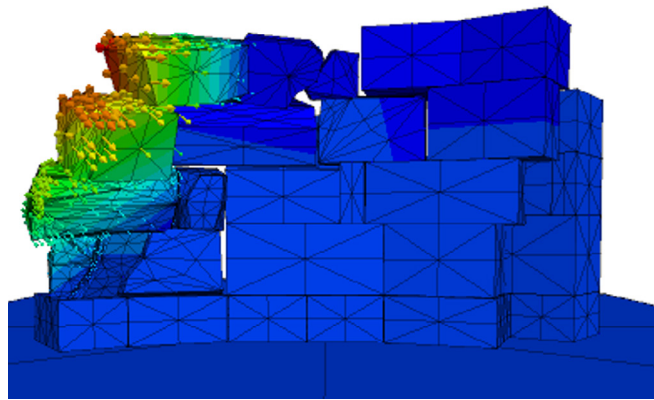


Fig. 11
Collapse configuration
of the East Wall under
earthquake base motion.

The temporary shoring measures did not include dismantling and/or repositioning the unstable blocks, as there were insufficient facilities available for this purpose. It was necessary to work with temporary scaffolding and with the help of local workers. The choice fell on hardwood elements, which had already been used in other parts of the archaeological site (Fig.12), due to their simplicity, reversibility, and undoubted effectiveness as a temporary measure.

Four wooden struts were therefore installed to support two blocks that were in the most precarious condition. The beech wood props were connected by transverse wooden elements to stabilize the shoring system (Fig.13).

The fact remains that the shoring carried out was able to allow the mosaic restoration to take place, but under no circumstances can it be considered a sufficient measure to guarantee the safety and stability of the block wall, for which restoration work deems necessary.

6 Restoration measures

The project stems from the survey of the state of deterioration and the result of the stability analysis to guarantee the safety of the walls and preserve their actual state.

Fig. 12

Examples of wooden props placed in different parts of the archaeological site.

**Fig. 13**

Temporary stabilization measures for stone blocks using wooden trusses.



This involves restoring a number of stone blocks that are essential for ensuring the stability of the wall, which were severely degraded and/or fractured and are therefore no longer able to perform their load-bearing function. It is also necessary to restore the position and stability of those ashlar blocks that have shifted, slipped or rotated, which, according to analyses, are in danger of falling.

The restoration work will require the removal of the stone elements that have accumulated between the east and west walls of the church, presumably the result of previous collapses. Subsequently, the portions that were severely degraded or unstable due to displacement have to be dismantled and then reassembled in their original position, after replacing some degraded ashlar blocks that can no longer be recovered. The possibility to preserve the original fractured ashlar blocks by bolting together the fractured parts is also considered, through the possible use of carbon bars, in order to restore the original continuity of the block interlocking.

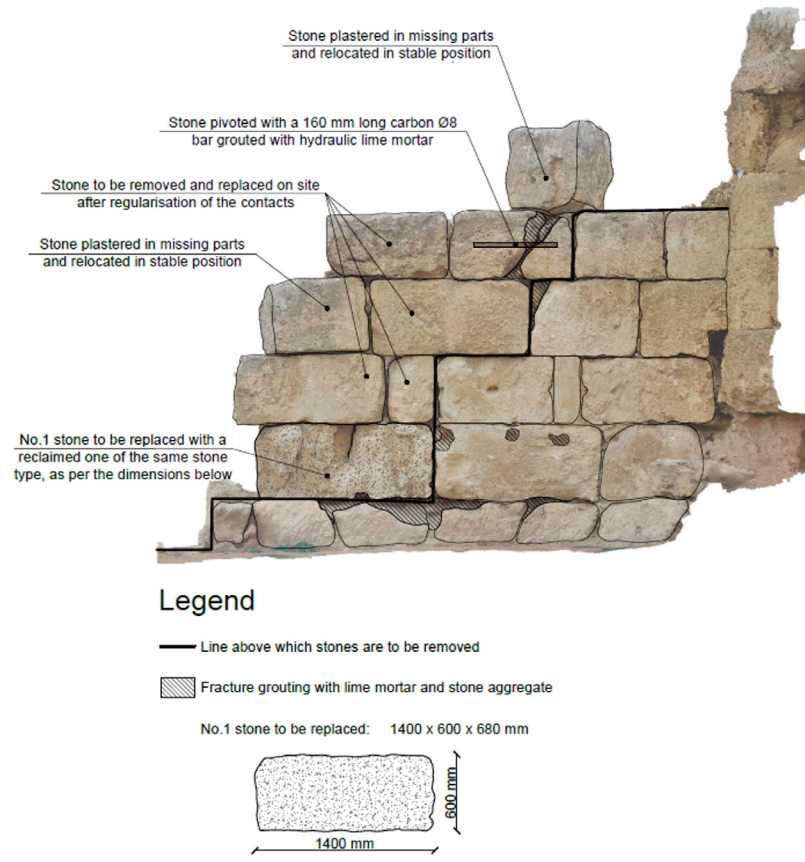


Fig. 14
East wall restoration.

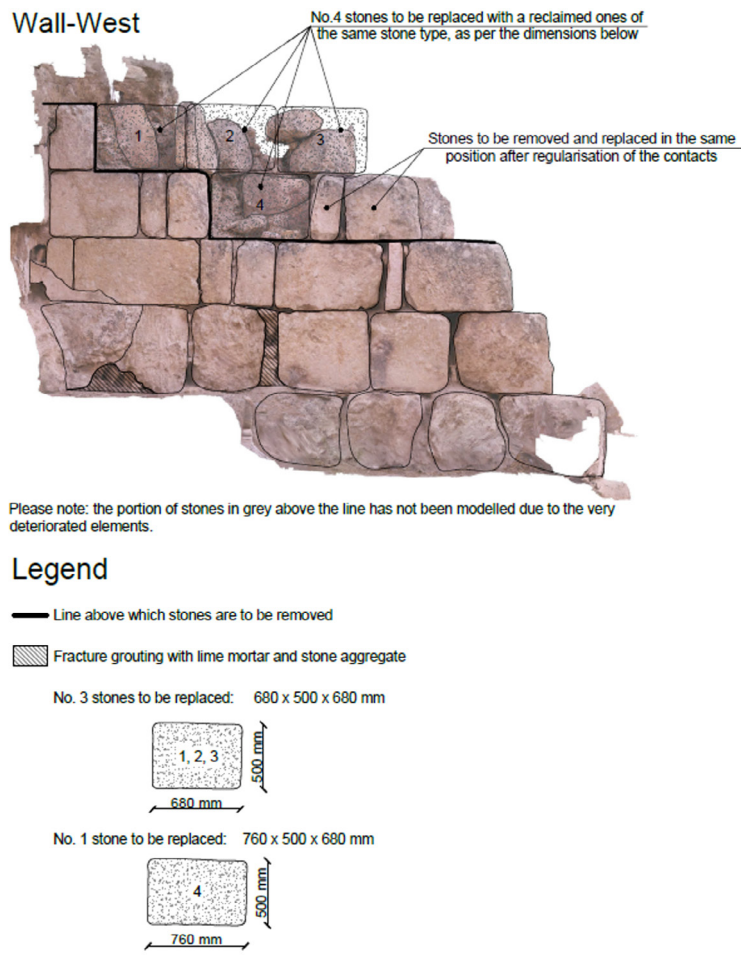


Fig. 15
West wall restoration.

In Figures 14-15, the portion to be dismantled and reassembled is indicated, the blocks that require replacement with stone elements similar in size and characteristics to the original ashlar are highlighted, as are the elements that require restoration of the missing portions and defects.

Particular attention should be paid to the reassembly of the parts that have been dismantled, to guarantee the perfect stability of the wall. To this end, the contact among the joints, if necessary, should be enforced with wooden wedge and lime-based mortar. Those ashlars that, although degraded, do not compromise the stability of the wall can be preserved and possibly filled with natural hydraulic lime mortar mixed with the powder of the same stone, to protect the stone element, guarantee its durability and ensure the stability of the wall.

7 Conclusions

This study explored the seismic behaviour of the archaeological remains of the wall of the Church of the Propylaea in Jerash, Jordan, a historic masonry structure composed of dry-stone assemblies. Using a numerical approach based on the discrete element method (DEM) implemented in the 3DEC software, the research effectively modelled the discontinuous nature of the structure, where block-to-block interactions are crucial to the overall mechanical response. The geometric model was developed from a high-density point cloud obtained through photogrammetric surveying, allowing for a highly accurate representation of the three-dimensional layout of the diaconia, including the irregularity of the blocks and their spatial arrangement. The integration of digital survey data with numerical simulations was pivotal for providing a realistic understanding of the geometry and assessing the structure's response to seismic forces. After conducting a quasi-static analysis under gravity loads, dynamic simulations were performed, revealing how the mechanical properties of the joints and the geometric configuration influence the overall response, particularly in terms of opening, sliding, and rotation mechanisms that can lead to localised failures or progressive collapse.

This work provides a contribution on the integration of advanced surveying techniques with numerical simulations for evaluating the seismic safety of archaeological structures. It also lays the groundwork for future research, which may involve refining the model through experimental data calibration and simulating potential reinforcement strategies to assess their impact on the structure's stability. Finally, thanks to a scientific framework and a simulation of structural behaviour, this work made it possible to develop both temporary measures to shore up the most unstable parts of the wall and to plan the necessary preservation works in line with the principle of minimal intervention, ensuring the compatibility with the historical and architectural value of the site.

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Restoration of the Diaconia Mosaic, Church of the Propylaea: On-site Conservation, International Cooperation and Workshop

Sokol Muca, Tessa Pirillo

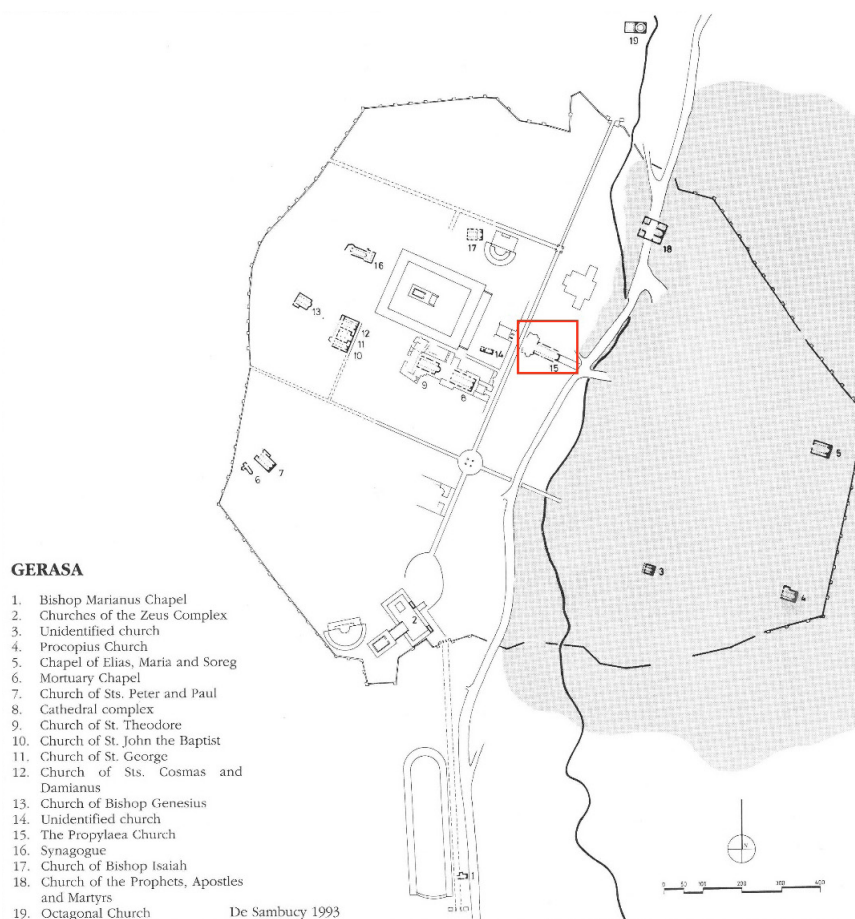
Abstract: This paper presents the conservation and restoration of the Diaconia mosaic of the Church of the Propylaea in Jerash (AD 565) as a case study for examining the challenges typically associated with archaeological mosaic floors preserved on site. The work combined technical surveys, the study of materials and execution techniques, an analysis of its conservation history, and targeted interventions of stabilisation, cleaning, consolidation and mortar repairs, in accordance with the principles of compatibility, reversibility and minimum intervention. The project was carried out as a training workshop, with a strong educational and collaborative approach. Particular attention was paid to preventive conservation, through the design and construction of a temporary protective covering system intended for future interventions on the structures and for the enhancement of the complex as a whole.

Keywords: Floor mosaic; On-site conservation; Workshop; International cooperation; Archaeological restoration; Temporary covering.

Introduction

The conservation and restoration of the Diaconia mosaic is part of the broader project to establish the Regional Center for Conservation and Restoration in Jerash, funded by Italian international cooperation and supported by the Department of Antiquities of the Hashemite Kingdom of Jordan.

Within this framework, the Diaconia mosaic – the only floor mosaic still preserved in situ in the Propylaea Church – was selected as a case study addressing the typical challenges of archaeological mosaics conserved on site (Silkatcheva, 2013; Viaduct Church Project Team, 2008). The project was organised as a two-month workshop, running from late September to late November 2025.

**Fig. 1**

Location of the Church of the Propylaea (No. 15) in the northern sector of the archaeological site of Jerash.

© De Sambucy, 1993.

The operational team consisted of two lead conservators-restorers responsible for scientific and educational coordination; two assistant conservators-restorers providing operational and training support; six Jordanian trainees involved in all phases of the work; and a skilled worker assisting with conservation activities. The project's objectives extended beyond the conservation and restoration of the mosaic itself. It was designed to strengthen local expertise through a model of international cooperation that brought together professionals from different national backgrounds, including conservators, archaeologists, engineers, architects and conservation scientists.

1 Mosaic description

The mosaic undergoing conservation and restoration is located in the northern section of the archaeological site of Jerash, inside the so-called Propylaea Church (Fig. 1). As a result of alterations dated AD 565, the Propylaea, which connected the eastern quarter of the Decapolis city to the Temple of Artemis, were converted into a religious building (Crowfoot, 1935; Piccirillo, 1993; 2003). In this context, one of the exedras was turned into a diaconia and decorated with a circular mosaic featuring a complex geometric pattern and two inscriptions, one of which dates the room and the mosaic floor to AD 565 (Piccirillo, 1993; 2003) (Fig. 2).

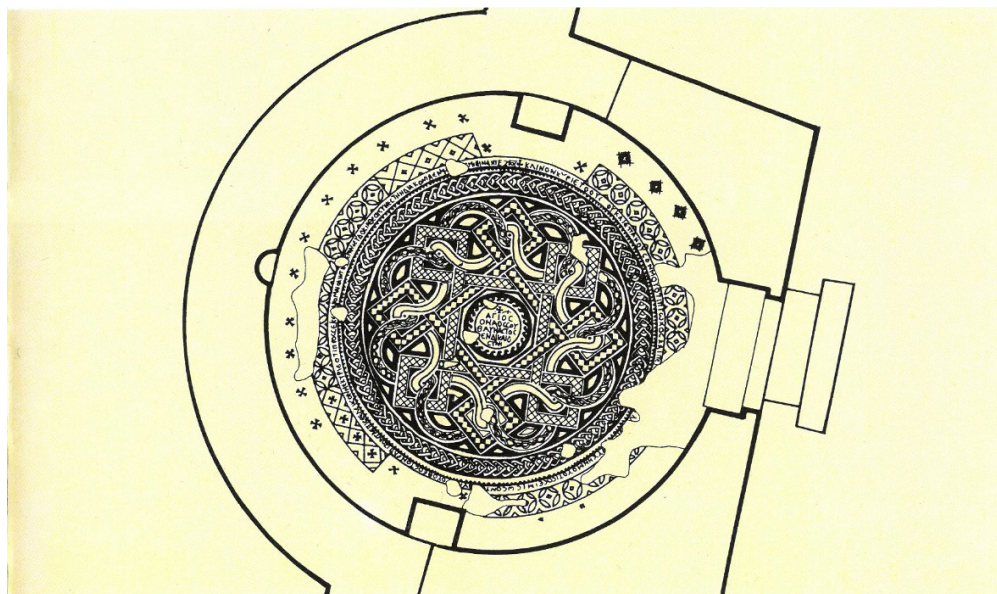
The diaconia has a circular plan, enclosed by a perimeter wall made of large stone blocks. The wall, preserved to a height of approximately 5m, is notably thick. At

Fig. 2

General view of the Diaconia in 2003, showing the perimeter walls and circular mosaic floor preserved on site. © Brizzi et al., 2021.

**Fig. 3**

Graphic survey of the Diaconia mosaic floor, illustrating the concentric arrangement of the pattern and the main gaps. © Piccirillo, 1993.



the entrance threshold, two slabs of pink limestone are set flush with the mosaic floor.

The floor consists of a circular mosaic, 6.5m in diameter, arranged in a strict geometric pattern based on radial symmetry and the alternation of borders and decorated fields, in accordance with the compositional principles of Late Antique geometric mosaics (Piccirillo, 1993; Dauphin, 1998) (Fig. 3).

Moving from the outer edge inwards, the mosaic floor is first framed by a marginal band of white *tesserae*, decorated with stylised floral motifs arranged along the perimeter of the masonry. This is followed by a decorative band forming a lattice of lozenges, within which repeated dot motifs are regularly distributed around the entire circumference. Beyond this lies a continuous annular epigraphic band bearing a Greek inscription, oriented towards the centre and intended to be read from the perimeter (see M. Mahmoud Hawamdeh, B. Alzawahreh, M. Ad-Doojan,

**Fig. 4**

Detail of the mosaic surface, showing the range of stone types and colours used in the decoration.

‘The Inscriptions of the Mosaic of Diaconia, Propylaea Church’, in this volume). Within the borders runs a continuous frame of multiple braids, formed by the regular interlacing of bands of *tesserae* in alternating light and dark colours, which defines the central field. The field is organised around a circular medallion at the centre, enclosed by a ring-shaped frame of continuous waves and containing a second Greek inscription. From this medallion extends a radial pattern based on a system of intersecting circles combined with curvilinear interlace, generating a series of symmetrically arranged compartments. These are filled with interlaced motifs – braids, meanders and infill patterns – organised within a continuous geometric scheme (Piccirillo, 1993; 2003).

2 Techniques and materials

The technique used in the Diaconia mosaic of the Church of the Propylaea in Jerash is fully in line with the Byzantine mosaic tradition of Transjordan and Palestine. This tradition is extensively documented in major floor complexes at Madaba, Umm al-Rasas (Kastron Mefa’a) and Mount Nebo (Piccirillo, 1993; 2003; Dauphin, 1998). Stratigraphic and material observations carried out during the conservation and restoration work confirm the use of Greco-Roman construction techniques, reflecting the continuity of technical knowledge within regional mosaic workshops between the 5th and 6th centuries AD (Balty, 1981; Piccirillo, 1993). The mosaic is mainly made of local limestone *tesserae*, in accordance with a practice widely attested in the Jerash area and across the Madaba plateau. As noted by Michele Piccirillo, most Byzantine mosaics in Jordan make use of locally available stone, both for economic reasons and because of the widespread



from left,
Fig. 5a
 view of the largest gap
 located at the entrance to
 the room.

Fig. 5b
 Stratigraphic detail of
 the gap showing the
 sequence of layers
 constituting the mosaic
 floor (tesserae, bedding
 mortar, preparatory layers).

availability of compact, easily workable limestone, combined with basalt to enhance colour contrast (Piccirillo, 1993; 2003). Similar stone combinations can be observed in the floors of the Church of Saints Lot and Procopius in Madaba, the Church of Saint Stephen at Umm al-Rasas, and the monastic complexes of Mount Nebo (Piccirillo, 1993; 2003).

The *tesserae* in the Diaconia mosaic measure on average between 8 and 12mm, in line with regional *standards* for high-quality geometric mosaics of the 6th century AD (Piccirillo, 1993). Only the outer border features larger *tesserae*, approximately 2cm per side—a characteristic of Late Antique practice, in which framing bands tend to use larger modules and less refined decorations (Dauphin, 1998). As highlighted by Claudine Dauphin, Byzantine floors in Palestine and Transjordan display greater dimensional regularity in the *tesserae* than in earlier periods, reflecting a growing specialisation in this type of craftsmanship and a more standardised production of stone elements (Dauphin, 1998). All *tesserae* are made from local limestone, with no evidence of glass or imported stone materials (Piccirillo, 1993). Although all the stone belongs to the same lithological family, colour variations allowed for a nuanced palette, used with considerable elegance – particularly in curvilinear motifs and braided patterns (Piccirillo, 1993; Dauphin, 1998). The mosaic examined during the restoration work revealed a varied colour palette, comprising *tesserae* of different lithological types (Fig. 4). The white *tesserae*, tending towards cream and forming the predominant colour of the mosaic floor, are made of a fairly compact limestone and show no significant signs of disintegration or exfoliation. The black *tesserae*, used to define geometric patterns and create contrast, are structurally less compact and were more susceptible to disintegration, although this process now appears stabilised. The red *tesserae*, found in three different shades (i.e. deep red, pinkish red and very pale pink), are made of naturally pigmented limestone and serve to outline decorations and introduce chromatic variation. They appear resistant and show no advanced deterioration. The yellow *tesserae*, found in both saturated and lighter shades, are in comparable condition and show similar stability. Completing the palette are grey *tesserae* with slight greenish tones, used as transitional colours within the decorative pattern. This limited but carefully selected colour palette, achieved exclusively with naturally pigmented local limestone, enabled the mosaicists to produce refined effects of depth, visual rhythm and formal articulation – evidence of a high level of craftsmanship (Piccirillo, 1993; 2003).

**Fig. 6**

Graphic reconstruction of the mosaic floor,
produced in 1928–1929 by Dorothy Crowfoot
Hodgkin.
© Yale University Art Gallery.

From a stratigraphic perspective, the mosaic consists of the following layers: *tessellatum*, *sovrannucleus*, *nucleus*, *rudus* and *statumen* (Figs. 5 a, b). The sequence identified in the Diaconia mosaic corresponds to the canonical structure of Roman and Byzantine mosaic floors described both in ancient sources and in archaeological documentation from the Levant (Balty, 1981; Piccirillo, 1993). Janine Balty has noted that in Near Eastern mosaics this stratigraphy is maintained with remarkable consistency into Late Antiquity. Particular attention was paid to the compactness of the *rudus* and the fineness of the *nucleus*, the latter often enriched with limestone powder to improve adhesion of the *tesserae* (Balty, 1981). Comparable thicknesses are documented by Piccirillo in the complexes of Madaba and Mount Nebo, where the *rudus* ranges between 7 and 12cm and the *nucleus* between 2 and 4cm, with a very thin laying layer rich in air lime (Piccirillo, 1993). The measurements recorded in the Diaconia mosaic in Jerash fall within these parameters, confirming the adoption of a standardised construction system at a regional level (Piccirillo, 1993; Balty, 1981).

No clearly identifiable daily working sections were observed. This absence is also documented in many Byzantine geometric mosaics from Transjordan, particularly in the circular and radial patterns of Umm al-Rasas and Madaba, where the continuity of design suggests that they were laid in large, coordinated sections rather than strictly segmented daily units. Dauphin sees this as an indication of well-managed workshops with teams of mosaicists capable of maintaining geometric coherence across extensive surfaces (Dauphin, 1998).

The stratigraphic relationship between the mosaic floor and the perimeter walls provides further insight into the environment and the decorative phases. The



Fig. 7a

State of conservation of the mosaic prior to full uncovering: the surface is partially covered by an inadequate protective system consisting of a synthetic fibre sheet and a layer of sand. Vegetation growing through the covering is visible.

Fig. 7b

Detail of the previous covering system: fine-mesh synthetic netting and uneven sand deposits, with the tessellatum visible in places..

presence of wall painting overlapping the mosaic *tessellatum* – observed in the Diaconia in Jerash – is also attested in ecclesiastical complexes of Madaba and Mount Nebo, where plaster was systematically applied after completion of the mosaic floors.

During restoration, no traces of preparatory drawings or incisions were found on the preparatory layers. However, given the limited areas in which the substrate is visible, it is not possible to determine with certainty whether they were originally present or not. The absence of material evidence could instead reflect the use of ephemeral design-transfer methods, such as strings, central nails or handmade compasses, as attested in Late Antique mosaic practice. As Balty and Dauphin have shown, many complex geometric patterns in the Byzantine East were made by laying *tesserae* directly on geometric grids, rather than through permanent preparatory incisions (Balty, 1981; Dauphin, 1998).

Together, these technical data place the Diaconia mosaic within the major tradition of Byzantine mosaic production in Transjordan, which between the 5th and 6th centuries AD developed a strongly geometric decorative language supported by highly consistent, standardised construction techniques.

3 Conservation history

The conservation history of the mosaic unfolds through a sequence of discoveries, coverings, interventions and inspections. This sequence is closely linked both to the excavation history of the ecclesiastical complex and to the evolving methodologies applied at the Jerash archaeological site throughout the 20th and early 21st centuries (Crowfoot, 1935; Piccirillo, 1993; 2003).



The mosaic was first identified in the 1920s during the initial campaigns conducted by the British School of Archaeology in Jerusalem (Crowfoot, 1935; Piccirillo, 1993). From the outset, the Diaconia floor attracted particular attention due to the complexity of its geometric pattern and, above all, the presence of the inscription, which proved fundamental for dating the transformation of the Propylaea into a Christian building. Archaeological investigations continued in the 1930s under the direction of John Winter Crowfoot, within a context of still partial excavation, characterised by selective exposure of structures and the frequent use of temporary protective or functional coverings (Crowfoot, 1935).

An exceptionally important document for reconstructing the material history of the mosaic dates to this initial discovery: the graphic reconstruction made in 1928 by Dorothy Crowfoot Hodgkin (Fig. 6). The drawing, now preserved at the Yale University Art Gallery, depicts every single *tessera* at scale, reproducing with remarkable precision not only the pattern and colour scheme of the floor, but also the gaps already present at the time of discovery (Crowfoot Hodgkin, 1929-1930). This record may be regarded as a precursor to modern photogrammetry and represents the main reference for diachronic analysis of the mosaic's state of conservation (Crowfoot Hodgkin, 1929-1930). Comparison between Hodgkin's drawing and the mosaic's current state of conservation allows at least two major phases of restoration work to be distinguished. The gaps already visible in the 1920s-1930s correspond to areas now filled with grey cement-based grouting attributable to early 20th-century restoration works. These rigid, poorly compatible mortars were primarily aimed at restoring the physical continuity of the mosaic surface. By contrast, the more brittle, reddish fills observed in several areas are not documented in historical records and must therefore be attributed to later damage, likely resulting from prolonged exposure, repeated cycles of uncovering and covering, and the lack of systematic maintenance.

Following this initial phase of investigation and targeted interventions, the mosaic became part of the broader research programme carried out by Italian missions at the Sanctuary of Artemis between 1978 and 2003. During this period, numerous Late Antique and Byzantine mosaic contexts were progressively identified and documented, including the Church of the Propylaea. This long phase of study laid the foundations for more structured on-site management of the floors and for subsequent conservation initiatives (Piccirillo, 1993; 2003).

In 2004, the Diaconia mosaic was rediscovered by the Italian mission and

from left,

Fig. 8a

Detail of localised damage to the *tessellatum* caused by plant roots, with detached and dislodged *tesserae*.

Fig. 8b

Area showing detached and dislodged *tesserae* due to the presence of roots.



from left,

Fig. 9a

Image acquired using a Dino-Lite® digital microscope of a white limestone tesserae showing clear signs of surface erosion, likely attributable to acidic action. © C. Caggiani, 2025.

Fig. 9b

Detail of the mosaic surface showing the near-total absence of interstitial mortar.

underwent restoration work carried out by a conservator-restorer from the Madaba School, now known as the Madaba Institute for Mosaic Art & Restoration. In 2005, further minor consolidation and safety measures were implemented, after which the mosaic was covered with a protective layer of sand due to the absence of permanent coverings. A new phase in the conservation history began with a campaign carried out in November 2021, aimed at assessing the state of conservation of the mosaics inside the Sanctuary of Artemis (Brizzi et al., 2021; Sciorilli, 2021). The operations followed a standardised procedure including the removal of protective coverings, cleaning, assessment of the state of conservation, minor localised interventions, photographic and georeferenced photogrammetric documentation, biocidal and herbicidal treatments, and subsequent protective covering (Brizzi et al., 2021). On this occasion, only the southern half of the Diaconia mosaic was uncovered, as the documentation produced in 2004 was considered sufficiently comprehensive.

Comparison with earlier records revealed that the recent interventions had generally performed well, with no significant new gaps identified. However, it also highlighted major conservation issues, specifically localised bulging and widespread detachment of *tesserae* from the bedding layer (Sciorilli, 2021). Targeted consolidation work was carried out in detached areas, and edges were secured using mortars based on hydraulic lime and marble dust. However, more extensive consolidation of the floor was postponed to a later phase. Prior to covering, the mosaic was treated with a biocide – benzalkonium chloride – and a herbicide was applied to the sand covering to limit biological recolonisation.

One aspect that remains unclear, due to a lack of historical and archival data, concerns a probable cleaning intervention carried out using highly corrosive substances, most likely acidic in nature. Although limited to a relatively small area of the mosaic floor, this treatment caused significant corrosion of the limestone *tesserae*. In the absence of direct documentation, it is tentatively attributed to the early 20th century, a period when aggressive chemicals were commonly used for cleaning mosaics. However, there is no definitive evidence available to precisely date the intervention.

This case demonstrates how critical analysis of historical documentation extends beyond its value as an archaeological record, becoming an essential tool for interpreting deterioration processes, assessing past interventions and designing effective conservation strategies.



from left,

Fig. 10a

Detail of a restoration area dating to the 1930s, executed using cement-based mortar.

Fig. 10b

Detail of cement-based mortar used as interstitial filling in the same restoration area: *tesserae* embedded in a rigid cement matrix, with edge alterations and consequent loss of legibility of the design.

4 State of conservation

The Diaconia mosaic floor presents a state of conservation typical of mosaics preserved on site. The structure in which it is located, the Diaconia, had long remained uncovered and therefore directly exposed to environmental agents, without any form of protective measures or controlled access (Silkatcheva, 2013; Viaduct Church Project Team, 2008). The absence of a structured programme of monitoring and periodic maintenance has contributed over time to the progressive deterioration of the surface (Silkatcheva, 2013). This was further compounded by earlier interventions from the first half of the 20th century, carried out with materials and techniques incompatible with those of the mosaic floor. The recently adopted covering system also proved inadequate, as it was made using incompatible materials. Specifically, it consisted of a fine synthetic fibre mesh laid directly onto the mosaic surface and covered with a layer of sand, without appropriate separation or drainage layers. Over time, this system lost both uniformity and continuity, thereby compromising its protective function (Brizzi et al., 2021; Sciorilli, 2021). During the preliminary assessment phase, prior to the mosaic's uncovering, the Diaconia's floor was affected by widespread vegetation growth, which had developed through the protective covering. This was accompanied by visible damage to the covering system, partly attributable to the activity of stray animals (Figs. 7a, b). Following complete uncovering, a detailed assessment of the mosaic's state of conservation revealed a range of critical issues affecting both the structural integrity of the floor (i.e. its constituent layers and mosaic surface) and the *tesserae* themselves. From a structural perspective, localised detachment between the *tesserae* and the bedding layers was identified, primarily due to roots penetrating between the *tesserae* and the *sovrannucleus*. In most cases, however, these phenomena remained limited in extent and did not result in a significant loss of adhesion, as the *tesserae* generally retained a reasonable degree of mutual stability. Localised deterioration was further exacerbated by active ant nests: their tunnels extended through the constituent layers of the floor and contributed to the detachment of *tesserae*. However, the most significant structural issues were caused by roots above



from left,

Fig. 11

Detail of a gap filled with a reddish edge-preserving mortar, attributable to interventions carried out in the early 2000s.



Fig. 12

Workshop set-up: wooden access platform and temporary covering installed to protect the mosaic and improve working conditions.

ground, which in certain areas led to the lifting, displacement and fragmentation of the mosaic surface, as well as the formation of gaps exposing the underlying layers (Figs. 8 a, b).

The mosaic surface itself was, overall, in a reasonably good state of conservation. However, at the time of uncovering, it was covered by a widespread deposit of loose material accumulated on the mosaic as a result of the inadequate protection system. The interstitial mortar was also almost entirely absent, most likely because of the mosaic's conservation history in particular, previous cleaning operations carried out using excessively aggressive methods (Fig. 9a). Subsequent cleaning revealed further conservation issues affecting the newly exposed *tesserae*. In the northern section of the floor, an area characterised by irregular and poorly defined boundaries exhibited severe bleaching, marked colour alteration and surface erosion (Fig. 9b). This evidence supports the hypothesis of a previous chemical cleaning treatment, likely involving acidic agents, as already discussed in the conservation history. Microscopic observations and analyses carried out on the *tesserae* by the Interdepartmental Laboratory of Electron Microscopy at Roma Tre University appear to confirm this hypothesis (see also E. Rossi, M. C. Caggiani, 'Application of SEM-EDS to the analysis of a mosaic *tessera* and a glazed ceramic from Jerash', in this volume). Particularly problematic were the grouting works associated with earlier restoration campaigns. Those dating to the first half of the 20th century were executed using cement-based mortars, characterised by high rigidity and marked physical and chemical incompatibility with the original materials. These additions were visually intrusive and, in some areas – especially along the edges of gaps – protruded onto the surface of the *tesserae*. In other cases, they had even been used as interstitial mortar (Figs. 10 a, b). Later restoration works, likely carried out in the early 21st century, employed fewer rigid materials than cement-based mortars. However, these too had undergone degradation and alteration, both in aesthetic terms and from a conservation perspective (Fig. 11).

**Fig. 13**

General view of the mosaic within the apse prior to restoration, with part of the protective covering still in place and accumulations of surface deposits.

5 Restoration work

Given the state of conservation, the work carried out in autumn 2025 followed the principles of minimum intervention, material compatibility, reversibility and recognisability. The methodology was defined through preliminary consultation within the working group and was continuously updated during the work. This allowed the project to be progressively adapted to emerging conditions and to adopt procedures tailored to the specific case, rather than the adoption of standardised solutions. The initial phase focused on the organisation of the work area, which required specific measures in terms of both site safety and logistics. Therefore, a custom-made wooden access platform with steps was built to facilitate the movement of staff and the delivery of materials. At the same time, temporary protection was provided by installing a large tarpaulin covering the entire Diaconia, shielding it from direct sunlight and providing more even natural lighting for photographic documentation (Fig. 12).

In parallel, safety measures were implemented on the perimeter masonry of the Diaconia, which was in a highly unstable condition and posed a potential risk to the operators. The most critical structural elements were therefore secured using wooden supports, ensuring safe working conditions for the conservation activities on the mosaic floor (see F. Cristinel Stan, M. Bocci, S. Fares, Najadt Mamoon Hazaim, Tasneem Al-Bataineh, S. De Santis, G.de Felice, 'Structural aspects of the perimeter wall of the Diaconia mosaic in the Church of Propylaea in Jerash, Jordan', in this volume).

A systematic campaign of photographic and graphic documentation was carried out before, during and after the restoration work. Its aim was to record the state of conservation, document previous interventions and ensure full traceability of all the operational phases of the current restoration (see Tasneem Albataineeh, Tamam Almjghef, Nadjdat Hazai, 'The Documentation', in this volume). Once

Fig. 14

Controlled removal of the covering and loose deposits using manual tools (brushes and trowels), aimed at recovering dislodged tesserae and securing the surface.



the preliminary operations had been completed, conservation work began with the controlled removal of the protective covering, consisting of – as stated above – a sand layer and a tightly woven synthetic fibre mesh. Vegetation emerging through the mesh was first cut back, and then the overlying sand was gradually removed (Fig. 13). This operation was carried out systematically, with the sand being collected and sieved to recover any loose *tesserae*. During the documentation phase, the mosaic surface had been divided into functional areas to allow for precise localisation of the detached *tesserae*. The recovered *tesserae* were therefore collected, catalogued and stored in bags labelled according to the division scheme. Following the removal of the covering layers, residual sandy deposits beneath the mesh were carefully removed manually using soft-bristled brushes, with particular attention paid to avoiding mechanical stress on the mosaic surface (Fig. 14). The removed material was again systematically sieved, allowing for the complete recovery of detached *tesserae*, which were subsequently arranged according to their area of origin. This phase revealed a critical state of conservation of the white perimeter band, characterised by numerous dislodged *tesserae* and the formation of new gaps. Temporary edge and gaps protection was therefore applied using a mortar made from local sand and air lime, ensuring the stability of the mosaic during subsequent stages.

The removal of roots followed, as cutting the above-ground vegetation had not allowed for the removal of the roots embedded within the mosaic layers. These were first treated with localised injections of a herbicide (Glyphogan Top CL®), left to act for a few days, and then carefully removed mechanically. Where possible, displaced *tesserae* were re-bedded using a mortar based on air lime and sieved local aggregates. In cases where this was not possible, temporary grouting was applied to stabilise the edges of gaps.

An initial surface cleaning phase was then carried out to remove loose deposits, using brushes and water (Figs. 15a, b, c). Where necessary, this was supplemented



by localised deep consolidation aimed at re-establishing adhesion between the *tessellatum* and the underlying layers, through injections of a suitable mortar (Ledan ITAL TB2®) (Fig. 16).

Once cleaning was complete, grouting from previous restoration work was removed. The additions dating to the early 2000s were removed mechanically using a fixed-blade scalpel and, where necessary, chisels and a hammer. The earlier cement-based mortar grouting, characterised by greater hardness, required a more controlled approach: prior to mechanical removal, the edges of the gaps were protected with cotton gauze fixed with acrylic resin (Paraloid B72®) at 15% in acetone, to safeguard the surrounding *tesserae* (Figs. 17a, b). The grouting was then removed mechanically using chisels and a hammer, taking particular care to avoid transmitting stress to the original *tesserae*.

To prevent prolonged exposure of the *lacunae* and the consequent risk of detachment of adjacent *tesserae*, temporary layered grouting was applied during the removal work. It consisted of two layers: a roughcast of air lime and coarsely sieved local aggregates (ratio 1:3), followed by a finer layer of air lime and more finely sieved aggregates (ratio 1:2) (Fig. 18). At the same time, after removing the protective facing from the edges using acetone compresses, excess cement protruding onto the *tesserae* was mechanically removed using ultrasonic devices and rotary micro-tools (Fig. 19).

In the small gaps where the bedding layer was still preserved, targeted consolidation of the *sovrannucleus* was carried out by brush application of a stable colloidal lime

above, clockwise,

Fig. 15a

Detail from the initial cleaning phase, showing the contrast between treated and untreated areas.

Fig. 15b

Detail from the initial cleaning phase, showing the contrast between treated and untreated areas.

Fig. 15c

Detail of the central medallion with Greek inscription before and after initial cleaning.

Fig. 16

Localised consolidation carried out by injecting a consolidant using a syringe.



hydroxide dispersed in ethanol (Calosil E25®) (Fig. 20). The large gap near the entrance, extending through the entire stratigraphy down to the subsoil, required preliminary consolidation of the earthen substrate. This was achieved by applying an injection mortar highly diluted in water (Ledan ITAL TB2®) using a brush, to ensure the stability of the subsequent layers of roughcast and grouting.

In the final stages of the restoration work, the treatment of gaps was guided by a critical assessment of grouting depth and extent. For reasons of conservation and visual consistency, all gaps were filled using the same method, maintaining a slight recess of approximately 1mm below the surface of the mosaic. This solution makes it easier to remove surface deposits and facilitates future maintenance, particularly in view of the mosaic's public display. An exception was made for a small gap near the entrance, which was intentionally left open to expose the *sovranucleus*, which preserves the imprints of the original *tesserae*. For similar conservation reasons and again to facilitate future maintenance of the mosaic, an interstitial mortar – which the diagnostic phase had shown to be almost absent – was also applied across the entire surface to restore cohesion of the mosaic surface.

The final grouting was therefore carried out in two layers. The first, a roughcast layer, was based on hydraulic lime and coarsely sieved aggregates (ratio 1:3). The second, a thin surface layer, was based on air lime and selected aggregates (ratio 1:2): one part lime putty to two parts aggregates, the latter being a mixture of local sieved sand and sieved travertine in a 2:1 ratio. The mortar pattern was defined through preliminary testing (Figs. 21a, b). At the same time, the interstitial mortar was applied using the same mortar based on air lime as that used for the final layer, ensuring consistency in terms of material properties, colour and overall work execution.



6 Temporary covering

Upon completion of the conservation and restoration work on the mosaic, a temporary protective covering was installed as a precautionary measure pending further work on the building's walls and the construction of a permanent roof system, in preparation for the mosaic's future public display. The aim was to provide effective, yet temporary, protection of the mosaic surface, preventing mechanical stress and accidental accumulation of deposits, while also allowing the safe movement of workers involved in the subsequent phases of the project. Following technical assessment and group discussion, a reversible, modular and non-invasive covering system was chosen, capable of protecting the mosaic without interfering with planned works on the masonry and architectural roof system. The system has a layered structure. A first geotextile layer (DuPont™) was laid directly on the mosaic surface, chosen for its breathability: it offers mechanical protection without hindering moisture exchange. This was overlain by a second, waterproof geotextile layer (Delta XX Plus®), acting as a barrier against rainwater infiltration. The system is completed by forty-eight custom-made containment cushions, made using the same geotextile as the lower layer, calibrated in size and weight and filled with pre-washed expanded clay aggregate (Fig. 22). The cushions serve two purposes: they stabilise the geotextile layers and provide a support base for a suspended wooden flooring system. The wooden structure (Figs. 23a, b) was designed and custom-made to fit the irregular geometry of the Diaconia precisely. The load-bearing frame, consisting of wooden cross-beams arranged in a regular grid, rests exclusively on the expanded clay aggregate cushions placed on the geotextile layers, thereby avoiding any direct contact with the mosaic surface (Fig. 24). Floorboards were subsequently fixed to the frame using screws, creating a continuous and stable surface. The whole structure follows the internal perimeter of the room while maintaining a slight gap from the walls, visible along the edges,

from left,

Fig. 17a

Detail of a gap following removal of previous grouting, with protective gauze applied to the edges.

Fig. 17b

Detail of a gap during the removal of cement-based fills.

Fig. 18

Gap stabilised with a temporary mortar to secure tesserae during subsequent intervention phases.

**Fig. 19**

Before-and-after detail showing the removal of cement-based residues from the surface of the tesserae.



to prevent interference with the vertical structures and ensure proper ventilation. Although not visible in the photographic documentation, a PVC drain was also installed beneath the threshold to allow for water runoff.

7 Conclusions

The conservation and restoration work carried out on the Diaconia mosaic of the Church of the Propylaea pursued two aims. First, it systematically addressed the main challenges typically associated with mosaics preserved on site: localised instability of the mosaic surface, loss of interstitial mortar, biological colonisation



Fig. 20
Large gap characterised
by the loss of *tesserae*,
where the bedding
layer and imprints of
the original *tesserae* are
visible.



Figs. 21a-b
Before and after the
application of the final
mortar on the gaps.

Fig. 22

Temporary covering system: first layer of DuPont™ geotextile placed directly over the mosaic surface.



and the impact of earlier incompatible interventions. Second, it defined an operational protocol tailored to the context of Jerash, in accordance with the principles of compatibility, minimum intervention, reversibility and recognisability. The integrated approach adopted – combining controlled cleaning, targeted consolidation, selective removal of cement-based grouting and the homogeneous treatment of gaps – has restored both structural stability and visual legibility to the mosaic surface, preparing it for future enhancement.

The decision to structure the project as a training site also enabled the effective transfer of practical skills, through constant support provided to the Jordanian trainees across all phases of the work, including assessment, safety measures, intervention techniques, documentation and quality control. In this context, the mosaic served not only as a case study but also as a learning tool, where daily interaction between professionals from different backgrounds enabled critical discussion of operational choices and the development of a shared technical language. Moreover, the training site forms part of the broader framework of international cooperation linked to the establishment of the Regional Center for Conservation and Restoration in Jerash. It contributes to the consolidation of an intervention model based on interdisciplinary collaboration, the progressive strengthening of local expertise and long-term sustainability.

Fig. 24 Stratigraphic section of the protective covering system.



Fig. 23a
Installation of the
suspended wooden
flooring system.



Fig. 23b
Completed wooden
walkway. Reversible
modular structure
designed to protect
the mosaic and allow
controlled access.



Fig. 23b
Stratigraphic section of
the protective covering
system.

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The Documentation

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Preliminary Documentation

The initial documentation phase was based on a rectified image produced during previous conservation seasons 2005 (Fig. 1). This image served as the primary reference for defining the boundaries and geometric configuration of the decorative elements forming the mosaic. At this stage, the mosaic surface remained covered, which necessitated reliance on pre-existing visual data. AutoCAD software was employed to trace and record the detailed outlines of the mosaic in a digital way (Fig. 2).

Exposure and Initial Condition Assessment

Following the exposure of the mosaic, a series of overlapping photos were taken before starting the work to document the mosaic floor after remove the cover (Fig. 3) a systematic documentation and condition assessment process was undertaken. This assessment was structured through five dedicated documentation tables (Fig. 4) addressing: Table 1 (Materials), Table 2 (Previous Interventions), Table 3 (Conditions), and Table 4 (Treatment), and Table 5 (Samples). All observations were recorded in a Condition assessment map (Fig. 5) in accordance with a standardized Legend to ensure clarity, consistency, and methodological coherence (deterioration, plants intrusion, tesserae loss, lacunae, detachment, depression and rise).

Photogrammetric Documentation during the Conservation Works

A continuous photographic documentation (Fig. 6) program accompanied all phases of cleaning and restoration. Multiple high-resolution photographs were taken for each treated area. The exposure of original stratigraphic layers was carefully documented (Fig. 7,8). The stratigraphic layers and construction details were digitally recorded using AutoCAD in a plan and section drawing (Fig. 9, 10).

Photogrammetric Documentation

A series of overlapping photos were taken before starting the work to document the mosaic floor after remove the cover, photogrammetric techniques rectified orthophoto for the mosaic floor after the conservation and restoration work in two ways; dry (Fig. 11) and wet (Fig. 12). The floor has been sprayed with water then documented.



Fig. 1

Diaconia Mosaic, Church of the Propylaea. Rectified photograph, 2004. After M. Brizzi, 2021.

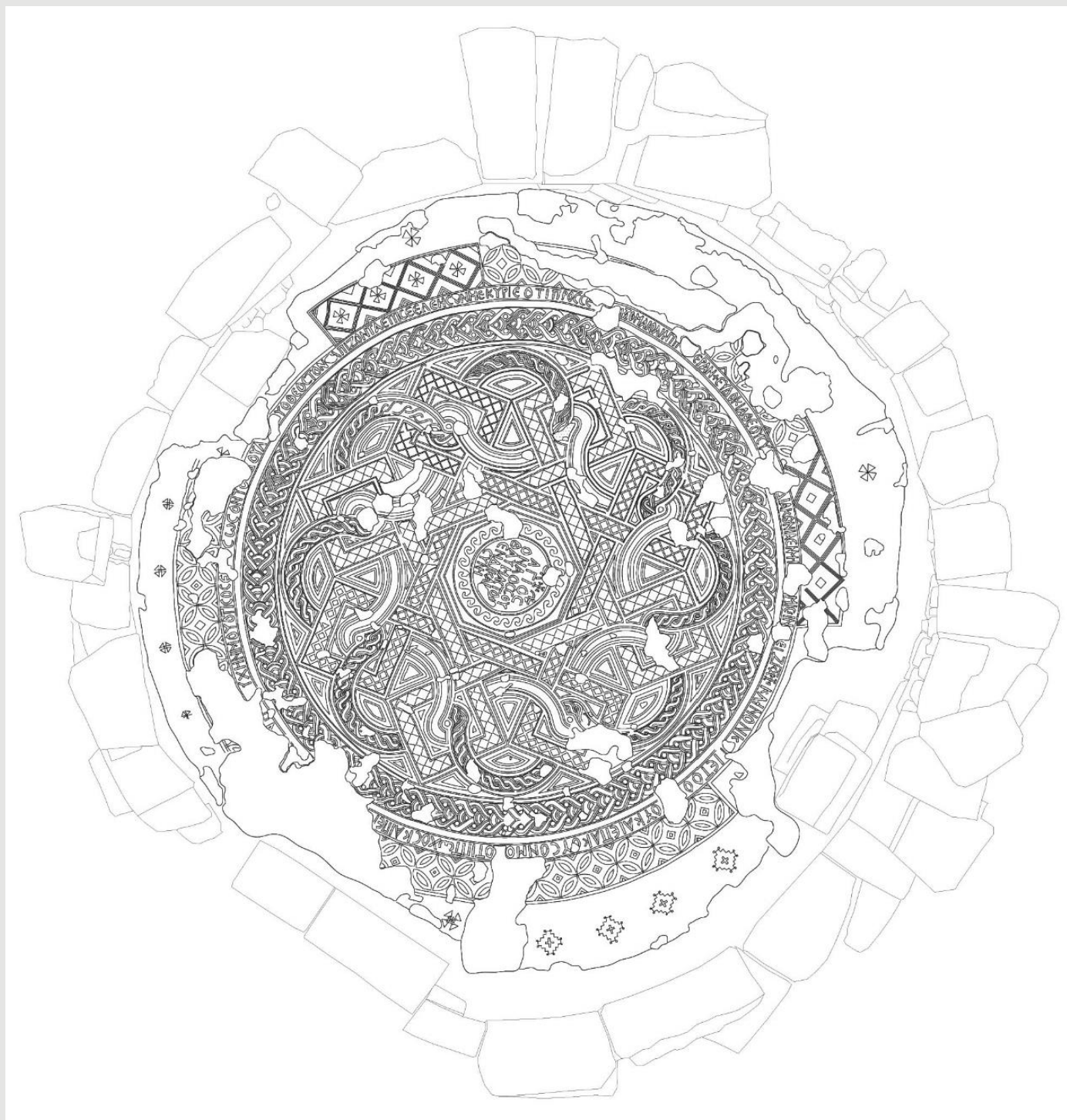


Fig. 2
Graphic documentation, 2025



Fig. 3
Rectified orthophoto (before the conservation treatment), 2025.

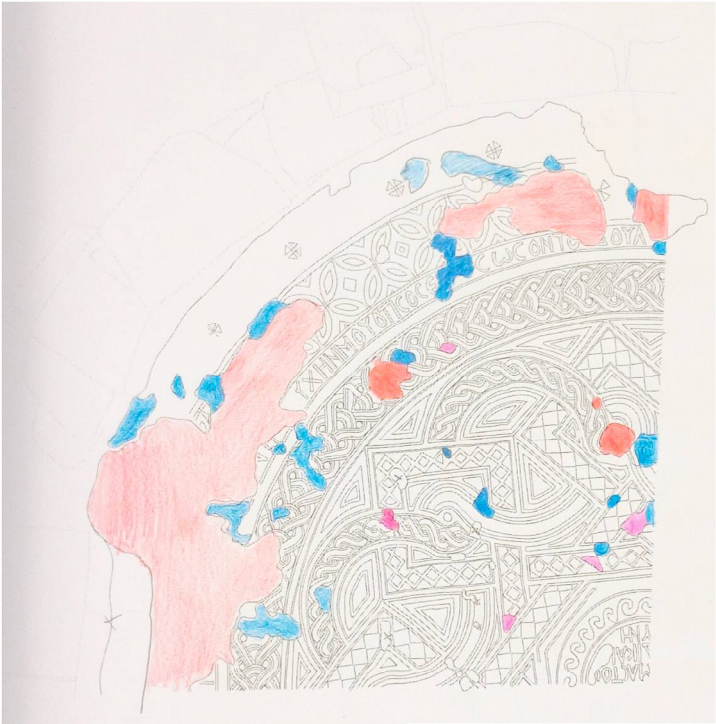


TABLE 2 : PREVIOUS INTERVENTION

- Filling (Lacuna)
- Edging Repair
- Filling (Between Tesserae)
- Treated Surface



TABLE 3 : CONDITIONS

- Lacuna
- Crack
- Cavity
- Detached Tesserae
- Detachment between Mosaic Layers
- Depression
- Plant Intrusion
- Deteriorated repair mortar
- Deteriorated Tesserae
- Fractured Tesserae
- Stain
- Deposit
- Incrustation
- Rise (Bulge)
- Treated Surface

Fig. 4
Hand-rendered deterioration mapping, 2025.



Fig. 5
Photographic documentation.



Fig. 6

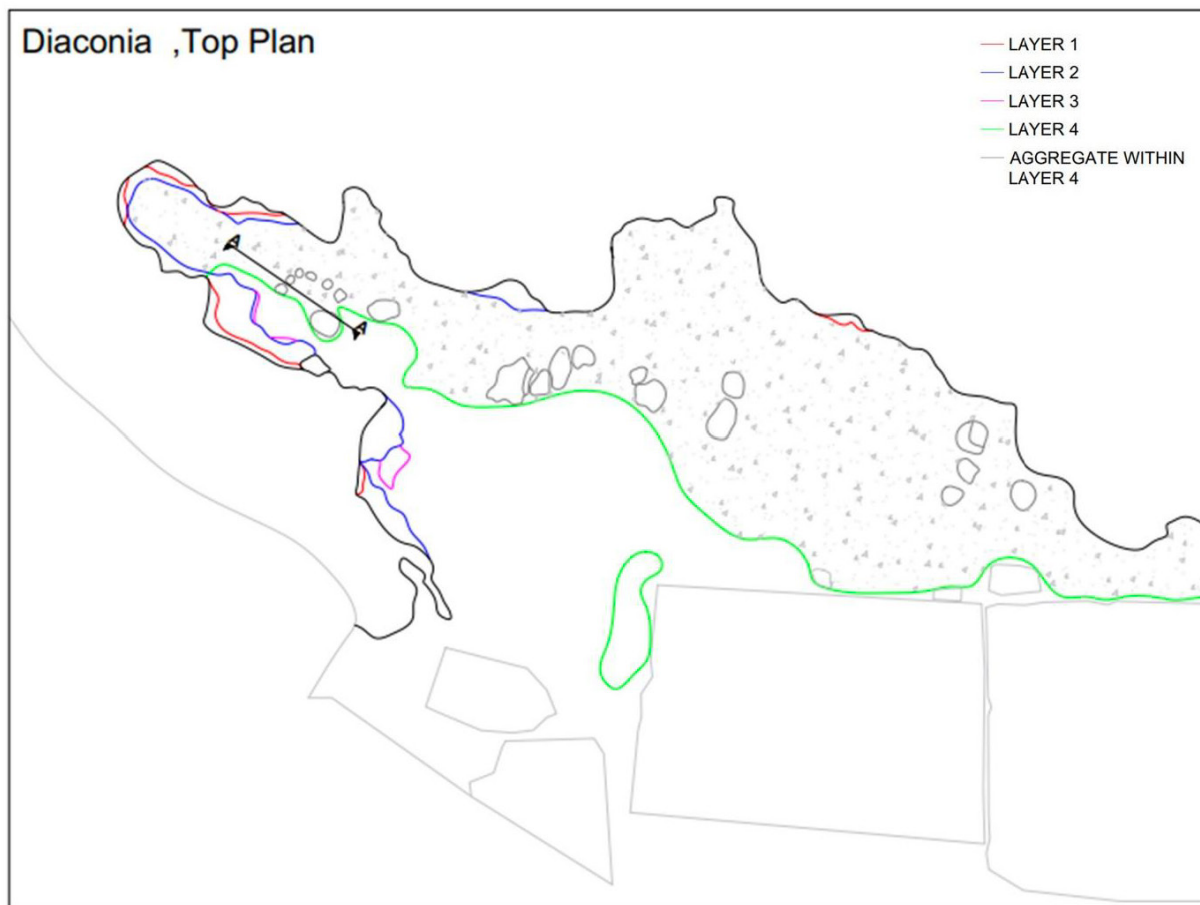
Top view of the original stratigraphic layers.

**Fig. 7**

Section A-A of the original stratigraphic layers.

MOSAIC STRATIGRAPHY

Diaconia ,Top Plan

**Fig. 8**

Top plan of the original stratigraphic layers

MOSAIC STRATIGRAPHY

Diaconia , Section A-A

- LAYER 1
- LAYER 2
- LAYER 3
- LAYER 4
- AGGREGATE WITHIN LAYER 4

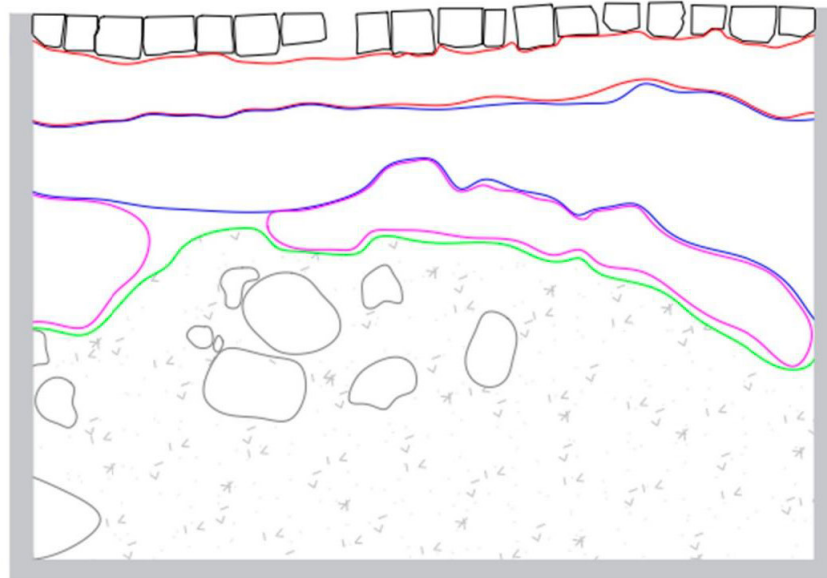


Fig. 9

Section A-A of the original stratigraphic layers



Fig. 10
Rectified orthophoto after conservation treatment (dry surface), 2025.



Fig. 11

Rectified orthophoto after conservation treatment (wet surface), 2025.

The Inscriptions of the Mosaic of Diakonia, Propylaea Church

Mustafa Mahmoud Srour Hawamdeh, Baker Yasin Abdallah Alzawahreh,
Marshwd Alwan Hussein Ad-Doojan

First inscription

The inscription located in the center of the mosaic floor

Inscription in capital letters:

ΑΓΙΟC
ΟΝΑΟCCOY
ΘΑΥΜΑCΤΟC
ΕΝΔΙΚΑΙΟ
CΥΝΗ

Inscription in small letters:

Ἅγιος ὁ ναὸς Σου, θαυμαστὸς ἐν δικαιοσύνῃ

Translation:

“Holy is Your Temple, Marvelous in Justice”

Second inscription

The large inscription found in the circular frame of the mosaic floor

Inscription in capital letters:

ΚΛΙΝΟΝ ΚΥΡΙΕ ΤΟ ΟΥΣ [Σ]ΟΥ ΚΑΙ ΕΠΑΚΟΥΣΟΝ ΜΟΥ ΟΤΙ ΠΤΩΧΟC
ΚΑΙ ΠΕΝ[ΗC ΕΙΜΙ [Φ]ΛΥΛΑ[Ξ]ΟΝ ΤΗΝ
ΨΥΧΗΝ ΜΟΥ ΟΤΙ CΟC ΕΙΜΙ CΩCΟΝ ΤΟΝ ΔΟΥΛΟΝ CΟΥ Ο ΘΕΟC ΤΟΝ
ΕΛΠΙΖΟΝΤΑ ΕΠΙ CΕ ΕΛΕΗCΟΝ ΜΕ
ΚΥΡΙΕ ΟΤΙ ΠΡΟC CΕ ΚΕ[ΚΡ]ΑΞΟΜΑΙ ΟΛΗΝ ΤΗΝ [Η]ΜΕΡΑΝ +
ΕΥΔΟΚΙΑ ΘΕΟΥ CΥΝΕCΤΗ Η ΔΙΑΚΟΝΙΑ
ΕΝ ΜΗ ΑΡΤΕΜΙC ΙΝΔ[ιγ] ΕΤ[ζκχ]

Inscription in small letters:

Κλίνον, Κύριε, τὸ οὗς [Σ]ου, καὶ ἐπάκουσόν μου ὅτι πτωχὸς καὶ πένης εἰμί.
Φλύλα[Ξ]ον τὴν ψυχὴν μου ὅτι Σός εἰμι. Σῶσον τὸν δοῦλόν Σου, ὁ Θεός,
τὸν ἐλπίζοντα ἐπὶ Σέ. Ελέησόν με, Κύριε, ὅτι πρὸς Σε κε[κ]- [ρ]άξομαι ὅλην
τὴν [ἡμέραν. + Εὐδοκία Θεοῦ συνέστη ἡ διακονία, ἐν μῆ[(νὶ) Ἀρτεμισ(ίῳ),
ἰνδ(ικτιῶνος) ιγ', ἔτ(ει) ζκχ

Translation:

Turn to me, Lord, and answer; I am downtrodden and poor. Guard me, for I am constant and true; save Your servant who puts his trust in You. O Lord my God, show me favor; I call to You all day long [Psalm 86:1-3]. By the will of God, the diakonia was built in the month of Artemisius in the thirteenth indiction of the year 627 [May of A.D. 565]

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Methodological Approach to the implementation of a Diagnostic Plan for the Conservation of Archaeological Artefacts: Guidelines for Stone Materials

Vasco Fassina

Abstract: The application of scientific principles and analytical methods to the study of material behaviour is fundamental for understanding the degradation processes affecting archaeological artefacts.

Diagnostics—defined as the investigation of the causes of deterioration—is based on these principles and plays a crucial role in the characterisation, quantification, interpretation, and assessment of damage affecting stone materials.

The state of conservation is initially documented through visual inspection and subsequently investigated through laboratory analyses. This paper outlines the principal analytical methods established by European technical standards, which enable the evaluation of material behaviour in relation to environmental conditions and deterioration processes..

Keyword: degradation, stone materials, efflorescence, exfoliation, deterioration, X-ray fluorescence, scanning electron microscopy.

1 General considerations

Stone artefacts at archaeological sites are affected by both anthropogenic and natural factors. Human activities have introduced various alterations over time, while natural processes have progressively modified the physical and chemical properties of materials. In recent centuries, industrialisation and urbanisation have further accelerated the deterioration through the emission of aggressive atmospheric pollutants.

The earliest recorded observations concerning the the degradation of archaeological artefacts exposed to the atmosphere date back to at least 3,000 years ago. The earliest account is that of Herodotus of Halicarnassus, from the 5th century BC, who attributed the degradation of the Pyramids of Cheops in Egypt to the corrosive action of saline solutions rising through the stone blocks of the pyramids. He also observed that the sandstones and limestones used in their construction naturally contained soluble salts, derived from their formation. As a matter of fact, according to him, they contained salt precisely because they were sedimentary rocks formed by the deposition of solid materials in salt-rich seawater. Vitruvius

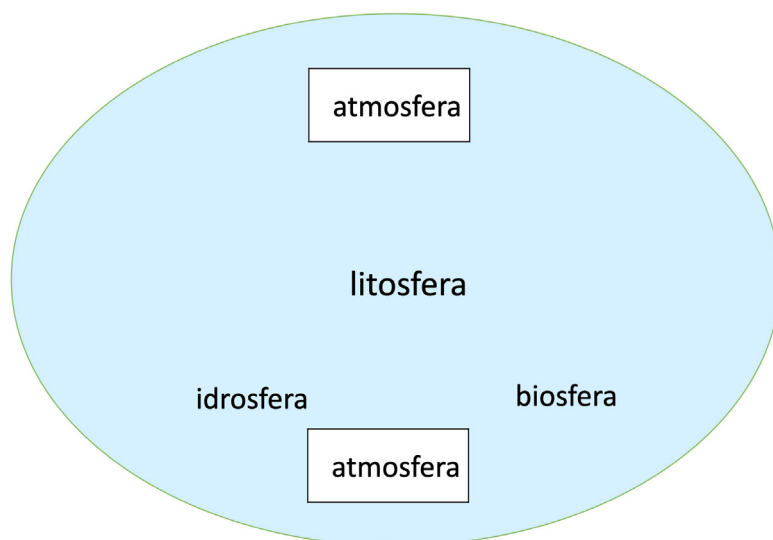


Fig. 1
Interactions between
lithosphere, hydrosphere,
biosphere and
atmosphere.

later provided a more precise understanding of the physical and chemical processes affecting building stones, along with practical repair strategies.

In natural environments, materials are subject to continuous transformation driven by physical, chemical, mechanical, and biological processes. These transformations arise from the disequilibrium between the conditions under which rocks originally formed and those of the environments to which they are subsequently exposed within the lithosphere.

The complex set of interactions between the lithosphere (rocks on the Earth's surface), the atmosphere (air on the Earth's surface), the hydrosphere (water on the Earth's surface) and the biosphere (living organisms on the Earth's surface) collectively defines the process of alteration in its broadest sense (Fig. 1).

Weathering is controlled by both external agents—such as temperature variations, water, erosion, and biological activity—and intrinsic material properties, including mineralogical composition, texture, and structure. These processes are governed by thermodynamic principles and often involve mineral decomposition and the migration of chemical elements.

When these considerations are applied to natural stone blocks used to make artefacts, the following conclusions could be drawn. Prior to extraction from a mountain, a stone block is in a state of equilibrium with the surrounding geological environment. Once extracted, this equilibrium is disrupted by exposure to new environmental conditions, initiating a series of interactions that lead to progressive alteration of the material. Thermodynamic principles provide a environment framework for understanding the phenomena observed in artefacts. According to the second law of thermodynamics, such changes proceed irreversibly, resulting in gradual degradation. However, the extreme outcome predicted by thermodynamics is unlikely to occur within human timescales.

Degradation encompasses all processes that alter the appearance, structure, and chemical behaviour of materials. These processes are complex, as multiple factors typically act simultaneously or sequentially. Moreover, the effect of each agent is influenced by the presence of others, making it difficult to isolate individual causes.

Weathering of stone materials primarily depends on their intrinsic properties – such as mineralogical composition, texture and structure (i.e., so-called internal

or passive factors) – and on external environmental conditions, which may be marine, desert, rural, urban, industrial, tropical or glacial.

The nature of the materials influences both the morphology (i.e., forms) and the extent of degradation. A deep understanding of chemical-mineralogical composition, structural characteristics and texture of a specific material is therefore essential for predicting how and in what form degradation will occur, regardless of the environment in which it is located.

As already mentioned, the environment, as an external factor, plays a fundamental role in deterioration processes. Today, environmental conditions are influenced not only by natural atmospheric agents but also, particularly in industrialised contexts, by pollutants of human origin.

The interdependence of the abovementioned factors highlights the complexity of degradation phenomena occurring outdoor and underscores the difficulty when trying to distinguish between the various causes and, above all, to quantify their individual contributions.

Finally, the degree of degradation depends on both the susceptibility of the materials' constituent components and the uniformity of the surfaces exposed to degrading agents.

As already noted, the atmospheric agents responsible for degradation – classified here as physical, chemical and biological – act either in combination or in succession. As a consequence, when observing and analysing a given form (i.e., morphology) of alteration, it is often difficult to attribute it to a single cause. Nevertheless, for the purpose of understanding the mechanisms underlying degradation, it is useful to consider these agents separately. Such an approach may also allow for the identification of a predominant agent, or even a triggering one. Physical or mechanical weathering agents cause damage through direct interaction with atmospheric factors such as heat, water, ice and pressure.

Chemical weathering results from the action of atmospheric chemicals, whether of natural origin or produced by biological activity (also known as biological atmospheric agents), on the surfaces of materials.

Biological weathering, in turn, refers to the degradation caused by the chemical and physical activity of vegetation and microorganisms.

The influence of any weathering agent varies according to location. Climatic and atmospheric conditions therefore play a significant role in determining the extent of deterioration of any material. The study of this issue is made even more complex by the difficulty of isolating the effects of each individual weathering agent. No weathering agent acts independently: the relative importance of each is influenced by the simultaneous or sequential action of others, and exposure to one process may increase susceptibility to the subsequent action of another. While certain agents may play a dominant role in the degradation of specific materials, they may have little or no effect on others. In many cases, the effect observed on a structure result from the combined action of multiple factors.

Every degradation process – being it physical, chemical or biological, acting independently or in combination – is, at least in its initial stages, determined by physical factors that can largely be interpreted through the laws of thermodynamics. From this perspective, the thermodynamic model suggests that degradation could be prevented if a state of perfect thermodynamic equilibrium between the artefact to be preserved and its conservation environment were achieved. Practically speaking, this model provides a general conservation principle: degradation may be slowed down by reducing the degree of imbalance between an artefact and the surrounding environment.

As previously discussed, the classification of degradation into physical, chemical and biological causes remains a useful interpretative framework, facilitating both the understanding of transformation processes and the identification of the interactions existing among different deterioration mechanisms. It also allows these processes to be related both to the intrinsic properties of the material and to the characteristics and properties of the conservation environment.

The main mechanisms responsible of degradation include the following:

- chemical weathering, which manifested through the dissolution and erosion of alkaline substrates (such as carbonate stones and frescoes) by acidic substances of both natural origin (e.g., atmospheric CO₂, volcanic gases, rainwater) and artificial origin (e.g., SO₂ from the combustion of fossil fuels emitted by industrial and urban emissions), as well as through the dissolution of constituent minerals through the action of water or acidic solutions;
- physical-mechanical deterioration caused by expansive forces generated within the pores and capillaries of porous materials, as a consequence of the migration and crystallisation of salts originating from the soil or the atmosphere;
- abrasion caused by the action of dust particles transported by the wind impacting surfaces (i.e., wind erosion due to the combined action of wind and dust);
- aesthetic degradation (i.e., rust or copper-based compounds stains) caused by the migration of coloured substances from adjacent areas into the porous substrate, as well as changes in the colour of the surface due to selective leaching of one of its components from the porous substrate, surface abrasion or erosion;
- aesthetic damage caused by chemical and mechanical action resulting from the biological activity of microorganisms, fungi, algae, mosses and other organisms, including – among others – pigeons;
- chemical and mechanical damage (anthropogenic factors), associated with previous restoration work carried out using materials that are unstable when exposed to polluted environments or have physical properties that are incompatible with the materials an object or structure is made of (e.g., differing thermal expansion coefficients).

2 Artefact history

A conservation project begins with the reconstruction of the artefact's history. This preliminary phase involves collecting, analysing, and critically evaluating all available documentation, including historical records, previous interventions, and environmental data.

Such information is essential for understanding past degradation processes and provides the contextual framework necessary for subsequent diagnostic investigations.

3 Diagnostics and scientific investigations

The application of scientific principles and related analytical methods to the study of material behaviour is essential for understanding the processes of degradation that have affected the artefact over time and that may still be active when conservation work is being planned.

In the past, preliminary studies aimed at identifying the causes of degradation resulting from interactions with the environment were rarely undertaken.

Diagnostics builds upon the information derived from the historical analysis and provides the basis for the selection and implementation of appropriate conservation measures. Its primary objective is the characterisation, quantification, interpretation and assessment of damage affecting the material of an artefact.

The methodological approach to diagnostics combines on-site surveys with laboratory analyses and can be divided into two main stages: a) the first one implies visual observation and consists in the description of the state of conservation of any alteration form; b) the second one involves a series of in-depth analytical investigations aimed at determining the causes of degradation. This second stage is fundamental to the development of a conservation project.

The state of conservation may be described in accordance with European standards: specifically, EN 16096 for immovable heritage and EN 16095 for movable heritage. In the case of large-scale artefacts found at archaeological sites, the diagnostic process must also take into account the different scales at which surface degradation occurs.

3.1 Documentation of the state of conservation over time

Archival records, where available, may provide valuable information on the condition of the material and on past degradation processes, thereby enabling their characterisation and quantification over time. However, in most cases, such records are lacking. It then becomes necessary to trace the progression of degradation by taking into account the current state of conservation.

The alteration progression curves established for most lithotypes indicate a continuous acceleration in the deterioration rate, typically showing a linear trend in the initial phase followed by exponential increase over time.

3.2 Lithological mapping of stone materials at an archaeological site

A preliminary mapping may be carried out through macroscopic observation based on the professional's experience and knowledge of local quarries from which the construction materials were presumably extracted.

A more accurate and detailed lithological mapping requires laboratory-based scientific investigation and includes the survey, identification, petrographic characterisation and systematic recording of all types of stone present (see below). This process is essential for assessing degradation in relation to specific types of stone. Well-established petrographic classification systems should be employed for the description of the types of stone.

Lithotype identification is typically carried out using thin sections, which allow for petrographic characterisation. The reason for sampling from an artefact must be clearly explained, by providing the purpose of the analysis as well as details of the location, the type of materials and the size of the samples.

3.3 Mapping of forms of alteration

Mapping is carried out in accordance with the UNI 11182 standard or the ICOMOS glossary drawn up by the ISCS (International Scientific Committee for Stone).

Once the lithological mapping has been completed, it is necessary to proceed with the mapping of the various forms of alterations observable on the surfaces of artefacts

at archaeological sites. For this purpose, reference may be made to commonly used terminology, including European standard CEN/TS 17135, Italian standard UNI 11182, the ICOMOS–ISCS glossary, and the glossary proposed by Fitzner.

3.4 Guidelines for the characterisation of stone materials EN 16515

These guidelines aim to provide professionals working in the field of cultural heritage with a shared methodological framework for the characterisation of both unaltered stone and the various stages of alteration, through the application of the most appropriate analytical techniques to samples taken from an artefact.

The proposed methods are intended to determine the mineralogical, textural, physical and mechanical properties of the natural stone used in archaeological artefacts. This information is essential to define the lithotype, assess the state of conservation and understand the degradation processes affecting natural stone.

The characterisation of both the nature of the material and its state of conservation is fundamental for the development of a conservation plan, as it enables the selection of the most appropriate intervention strategies in terms of methods and technologies.

The methods employed are, in most cases, minimally or entirely destructive. However, non-destructive methods should always be preferred whenever possible.

The methods used for the analysis of stones may vary according on the objectives of the investigation. All studies and analyses must be proportionate to the cultural significance of the artefact, its condition and the expected extent of the interventions. The selection of any analytical methodology should be preceded by a preliminary assessment of the environmental context and a description of the state of conservation, in accordance with standards EN 16095 (movable heritage) and EN 16096 (immovable heritage).

This preliminary assessment should include the type of stone and its macroscopic characteristics, such as colour, texture and structural features.

Sampling must be carried out in accordance with standard EN 16085. In all cases, the location, orientation, number, quantity, size and morphology of the samples used must be fully documented in the analytical report. It should also be specified whether the samples have been taken from sound or deteriorated areas, as defined during the preliminary survey.

The characterisation of sound and deteriorated materials is typically carried out through the following analytical stages:

- visual examination of samples using stereomicroscope;
- petrographic analysis of thin sections under an optical microscope (OM);
- mineralogical analysis by X-ray diffraction (XRD);
- microstructural analysis using a scanning electron microscope (SEM);
- *chemical analyses*: SEM (scanning electron microscopy), EDS (energy-dispersive spectrometry), AAS (atomic absorption spectroscopy), FTIR (Fourier transform infrared spectroscopy), IC (ion chromatography);
- *physical analyses*: density, porosity and pore size distribution (EN 1936); water absorption by capillarity (EN 15801) or by the pipe method (EN 16302); water vapour permeability (EN 15803); colour measurement (EN 15886);
- *mechanical parameters*: compressive strength (EN 1926), flexural strength (EN 12372), static modulus of elasticity (EN 14580) and dynamic modulus of elasticity (EN 14146).

These abovementioned analyses allow for a comprehensive characterisation of the material an artefact is made of. In many cases, the most essential investigations

are those detailed in points a), b) and d), as well as scanning electron microscopy (SEM) coupled with EDS.

Mineralogical quantification may be further refined by adding XRD and/or FTIR, while ion chromatography is especially useful for the identification of soluble salts. Where the presence of previous treatments involving organic materials is suspected, FTIR analysis is also recommended.

Particular attention shall be given to petrographic analysis under an optical microscope (OM) and to microstructural analysis using a scanning electron microscope (SEM).

The petrographic description of a stone material by examining thin sections under an optical microscope in transmitted polarised light must be carried out in accordance with standard EN 12407. The petrographic analysis of thin and polished sections provides detailed information on mineralogical composition, grain size, type and quantity of minerals, structural features, shape and orientation, microstructures, discontinuities, veining, porosity, etc. It also allows for the identification of altered minerals and the assessment of the extent of alteration.

The following information should also be included:

- the stratigraphy of any surface layers, where present;
- the thickness of atmospheric pollutants deposits;
- the degree of adhesion and cohesion between altered layers and the underlying sound stone;
- the presence of any forms of biodegradation;
- the nature of atmospheric pollutants to better understand deterioration processes;
- a preliminary hypothesis concerning the mechanisms of degradation and the agents involved;
- the characterisation of surface deposits (i.e., nature, degree of adhesion, and whether they contribute to deterioration or they are merely unsightly).

During the preparation of thin or polished sections, particular care must be taken to avoid altering the original characteristics of the sample. In particular, excessive heating (temperatures above 45°C) must be avoided and contact with water should be minimised to prevent secondary hydration processes and the loss of water-soluble compounds.

3.4.1 Microstructural analysis using a scanning electron microscope

A scanning electron microscope (SEM) equipped with energy-dispersive or wavelength-dispersive spectroscopy (EDS or WDS) enables morphological, microstructural and morphometric examination of the surface of sample sections, together with qualitative and quantitative elemental analysis, as well as elemental mapping. In addition to elemental mapping, SEM enables the identification and mapping of the distribution of soluble salt crystals.

Further information may be obtained by combining SEM and petrographic analysis of thin and polished sections with image analysis across a range of areas. For example, see *Chimica applicata alla Conservazione e restauro del patrimonio culturale, vol. I, degrado dei materiali* ['Chemistry Applied to the Conservation and Restoration of Cultural Heritage, Vol. I, Degradation of Materials'] (Nardini, 2022).

3.5 Methodology for sampling materials from archaeological artefacts

Sampling of an artefact becomes necessary when non-invasive analyses are not enough to identify the causes of degradation or to achieve a more precise characterisation of the constituent materials.

Since sampling is an invasive procedure affecting the integrity of an artefact, it may cause damage – however minimal. Consequently, it should be carried out only when strictly necessary for understanding the deterioration processes. Moreover, it requires close coordination between those responsible for the care of the artefact and the professionals conducting the analyses.

With reference to the integrity of an object, analytical approaches may be classified as non-invasive, micro-invasive or invasive. Non-invasive techniques involve no physical contact between the artefact's surface and the tool used (e.g., portable XRF). Micro-invasive techniques involve the removal of very small quantities of material that are not visible to the naked eye. Invasive techniques involve the removal of larger samples (i.e., millimetric), which are therefore visible.

The analyses performed on samples may be non-destructive – when the sample can undergo multiple tests without alteration – or destructive, where the analytical procedure irreversibly modifies the sample, preventing further analysis.

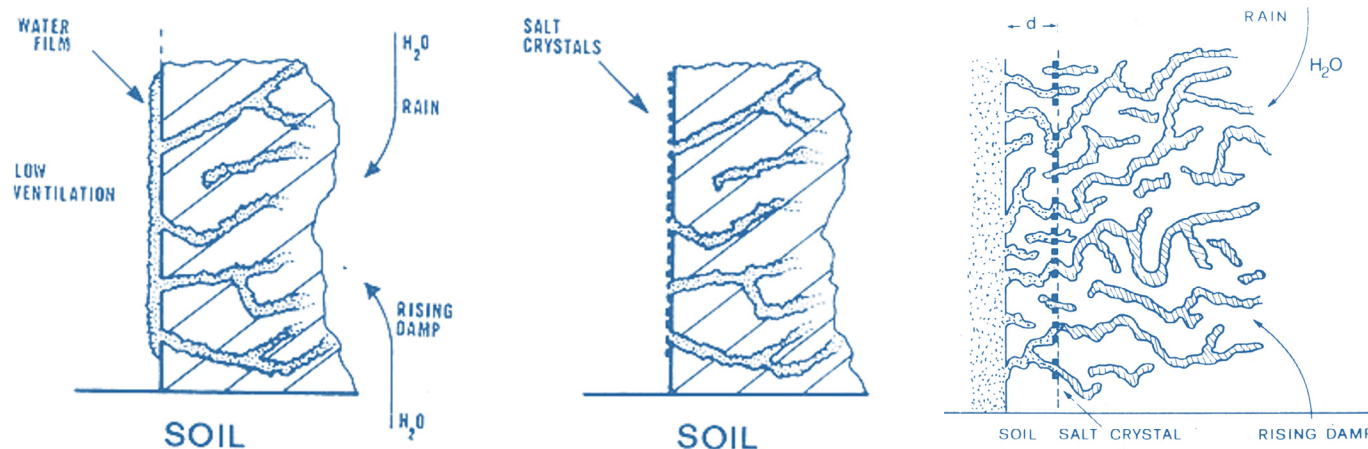
The sampling procedure depends on several factors, including the type of material, the condition and cultural significance of an artefact, and the analytical methods subsequently to be applied. For example, mineralogical and petrographic analyses typically require samples measuring a few millimetres, which may not be feasible in the case of small artefacts.

Sampling criteria:

- The first requirement is that the objective of the sampling be clearly defined and that a detailed sampling plan be prepared. This involves identifying the sampling points and the corresponding analyses to be carried out in the laboratory.
- The second requirement is that sampling must be carried out in accordance with the legislation in force in the relevant country, in consultation with the authorities responsible for the protection of cultural heritage and in line with the owner's conservation policy. For example, in Italy, sampling must be authorised by the Italian Ministry of Culture (MiC), acting through its regional offices (Superintendencies).
- The third requirement is that sampling must be preceded by a condition assessment to be carried out in accordance with standards EN 16095 and EN 16096, for movable and immovable heritage respectively.
- The fourth requirement is that sampling must be carried out in such a way as to minimise visual impact, by selecting locations that are concealed as possible while still remaining representative of the phenomena under investigation.

Sampling must also be conducted in accordance with the objectives to be achieved through subsequent laboratory analyses.

Last but not least, sampling must be carried out by suitably qualified professionals with appropriate manual skills and a thorough understanding of the artefacts under investigation. For this reason, within the Italian context, only trained conservators-restorers and conservation scientists with appropriate qualifications and professional experience are eligible to carry out this kind of task. The role of the conservator-restorer is defined by the Italian Ministerial Decree No. 86 of May 26th, 2009 (Articles 1-3 and Annex A), while the professional profiles of diagnostic experts and specialists in science and technology applied to cultural



above, from left

Fig. 2a

Migration from the interior towards the surface.

Fig. 2b

Migration to the exterior.

heritage are outlined in Article 4 of the same decree and further specified in the Italian Ministerial Decree of May 20th, 2019 (Rep. 244).

Standard EN 16085 provides detailed guidance for preparation of the sampling plan, which must clearly specify the sampling locations, the analytical objectives associated with each sample and the methods to be used in order to address the preliminary questions. The plan should therefore be accompanied by diagrams or photographs indicating the proposed sampling locations. Minor adjustments may be made during the sampling process where necessary.

Moreover, according to the abovementioned standard, each sample shall be assigned a unique identification code linked it to its container. These identification codes shall be recorded on a document which also specifies the analyses to be carried out for each sample. During sampling, photographic documentation must be produced, including both general views of the sampling area and detailed images of each sampling location.

Samples must be placed in appropriate containers to ensure safe handling and, where immediate analysis is not possible, must be stored under conditions that prevent alteration of their original characteristics.

3.6 Soluble salts according to the standard EN 16455

Soluble salts are ubiquitous in the masonry of historic buildings. They can migrate through porous materials and may crystallise under specific climatic conditions. Crystallisation may occur at different points within capillary networks and depends on both the solubility of the salts and the rate of water evaporation, which in turn is influenced by the amount of water circulating within the porous structure and surface ventilation.

Two different scenarios may therefore arise:

- if the rate of water evaporation is lower than the rate of migration from the interior towards the surface, the saline solution migrates to the exterior (Fig. 2a) and, as the water evaporates, it is deposited crystals on the surface (Fig. 2b). This phenomenon, known as efflorescence, generally causes limited damage. A typical example of it is shown in Fig. 3 a;
- if the rate of evaporation exceeds the rate of migration from the interior, salt crystallisation occurs beneath the surface, resulting in crypto-efflorescence or sub-efflorescence (Fig. 3 b). In this case, crystallisation begins within larger capillaries and the resulting increase of internal pressure – caused by the



above, from left

Fig. 3 a

Salt efflorescence on the surface.

Fig. 3b

Crystallization under the surface (Sub-efflorescence)

greater volume occupied by crystallised salts and residual water compared with the original saline solution – may exceed the cohesive strength of the porous material, progressively affects the smaller ones, leading to exfoliation of the surface layers. Subsequent flaking exposes the underlying sound surface to the abovementioned phenomena, resulting in progressive material loss.

Salts may originate either from the surrounding environment or from building materials themselves. Salts may derive from: a) the soil, which may release sodium, potassium and ammonium nitrates and sulphates; b) the atmosphere, which can release gaseous pollutants such as CO_2 , SO_2 , and NO_x , which are easily soluble in water.

With regards to building materials, it should be noted that:

- clays contain calcium, sodium, potassium and magnesium sulphates;
- cement mortars contain calcium, sodium and potassium hydroxides which, when reacting with atmospheric CO_2 in the air, form carbonates which are in turn transformed into sulphates through interaction with atmospheric SO_2 .

Consequently, the salts most commonly encountered in porous materials are calcium, sodium, potassium and magnesium carbonates, sulphates, nitrates and chlorides. Carbonates generally originate from the material themselves. Sulphates may come from the material itself, but also from the soil – together with nitrates and phosphates – or from atmospheric pollution. Chlorides are mainly environments associated with in coastal areas.

The solubility of salts varies: calcium salts are generally less soluble than those of sodium and potassium.

As already mentioned previously, soluble salts are often present in aqueous solutions generated by capillary rise, rainwater infiltration or water vapour condensation. Each salt possesses a specific solubility and may therefore repeatedly dissolve and recrystallise in response to changes in environmental conditions (i.e. particularly fluctuations in relative humidity and evaporation rates). Each cycle involves a change in volume, generating mechanical stress within capillary network. The frequency of these solubilisation-crystallisation cycles depends both on the solubility of the salt species and the equilibrium relative humidity of its saturated solution. The most harmful salts are those that undergo a greater number of solubilisation-crystallisation cycles under the prevailing environmental conditions. In addition to the cycles, it must also be considered that each salt species exerts its own crystallisation pressure. In some cases, may occur in different hydration

states. Consequently, another factor must be taken into: the hydration pressure manifesting itself during the transition from the anhydrous to the hydrated form. Sodium sulphate is a particularly significant example, as it can both absorb moisture and crystallise, thereby exerting both types of pressure. It may originate from the leaching of cement mortars or from past cleaning operations using sodium-based compounds, such as sodium bicarbonate or sodium carbonate, whose long-term effects were not fully understood at the time.

The introduction to standard EN 16455 states that:

«Soluble salts are often present in stones and other porous inorganic building materials as alteration products of chemical or biological origin. They can originate from surface deposition of environmental pollutants or from water capillary transport from other external sources and also from materials themselves or from conservation interventions».

«Soluble salts present in porous inorganic materials can, (depending on material properties, environmental conditions or possible treatments the surrounding conditions), initiate physical-chemical degradation processes».

The extraction of soluble salts from porous materials is carried out by adding a known quantity of distilled water to a previously weighed sample.

Several analytical methods may be employed for salt analysis, including:

- identification of salt crystals by microscopy;
- qualitative chemical reactions. These make it possible to identify the type of anions and cations present in a solution, after dissolution of salts in water (i.e., sulphates, nitrates, chlorides);
- semiquantitative tests. These are mostly based on colorimetric reactions that lead to the formation of colored compounds formed by each anion and its specific reagent;
- X-ray diffraction, which provides information on the nature of a salt (in crystalline form) identifying the mineralogical composition of the compounds;
- spectroscopic techniques like flame photometry, AAS (Atomic Absorption Spectrometry), ICP-AES (Inductively Coupled Plasma - Atomic Emission Spectrometry) for cations;
- ion chromatography which makes it possible to identify and quantify separately anions and cations.

Among these methods, ion chromatography is generally considered the most comprehensive and rapid technique for determining both the nature and concentration of ionic species.

The principal ions are: chlorides, nitrites, nitrates, sulphates, and the cations sodium, potassium, calcium, magnesium and ammonium.

4 Jerash archaeological site. State of conservation of the masonry surrounding the Diakonia mosaic

The state of conservation of the masonry surrounding the mosaic is precarious. In particular, the second and third rows of stone blocks show marked deterioration forms, resulting in the loss of extensive surface areas (Fig. 4). The main deterioration forms observed include: erosion, flaking, disintegration and pulverisation. Surface erosion affects all the blocks to varying degrees, primarily due to the action of water combined with the deposition of atmospheric dust.

The limestone displays a reddish colour attributable to the presence of iron oxides (estimated at approximately 6-7%). However, a distinction must be made



between the intrinsic component contained in the blocks and the yellow-reddish atmospheric dust principal from the ground and deposited on the surfaces. A more advanced stage of degradation is represented by exfoliation/flaking (Figs. 5, 6), caused by sub-surface crystallisation of salts, which are often visible beneath detached flakes. In some areas, white salt efflorescence is also on the surface. An even more severe stage of deterioration is characterised by the disintegration and pulverisation of the stone material (Fig. 7), resulting in the formation of

Fig. 4
General view of the masonry, showing various deterioration forms.



from left
Fig. 5
Exfoliation.

Fig. 6
Flaking.

incoherent stone fragments that progressively turn into dust (Fig.8). The second row of blocks is the most severely affected, although the first and third courses also exhibit deterioration phenomena to a lesser extent.

Several contributing factors acting simultaneously may be identified. Firstly, salt ions originating from the soil rise by capillary action and, during evaporation, form

from left

Fig. 7

Disintegration/
Pulverisation.

Fig. 8

Formation of incoherent
stone fragments and
significant loss of material.



salts with different solubilities that crystallise within the capillary network. Sub-surface crystallisation generally occurs at the evaporation front, corresponding to the second row of blocks. However, in some cases, the area may expand to affect parts of the blocks in the first and third rows. Exfoliation and pulverisation are primarily associated with this process. More generally, the erosive action of water fairly uniformly affects all rows at different heights.

With regards to salts, the measurements carried out indicate the presence – listed in decreasing order – of chlorides, sulphates and nitrates. Salt efflorescence at the beneath the surface has been observed in areas where the superficial stone layers have detached (Fig. 9 e 10).

from left,

Fig. 9

White salt efflorescences

Fig. 10

White salt efflorescence



Sampling location



Fig. 11
General view.



Fig. 12
Sample 2. WAC.



Fig. 13
Sample 3.



Fig. 14
Sample 2. Detail.



Fig. 15
Sample 4. Stone fragments.



Fig. 16
Sample 4. Detail.



Fig. 17
Sample 5. White powder from the cavity.



Fig. 18
Sample 5. Detail.



Fig. 19
Sample 6. General view, right side.

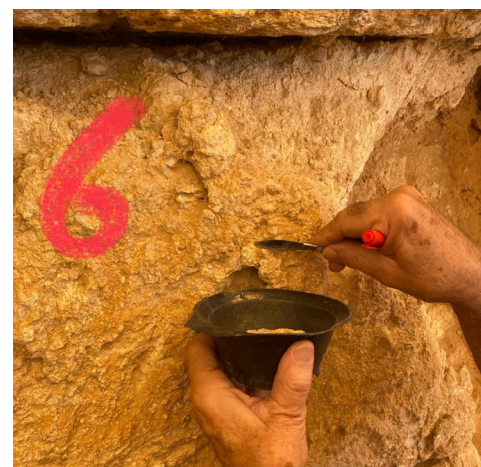


Fig. 20
Sample 6. For WA-porosity 9.2%.



Fig. 21
Sample 6. WA for porosity 9.2 %.



Fig. 22
Sample 6 a.



Fig. 23
Sample 9. General view, in the middle of the wall.

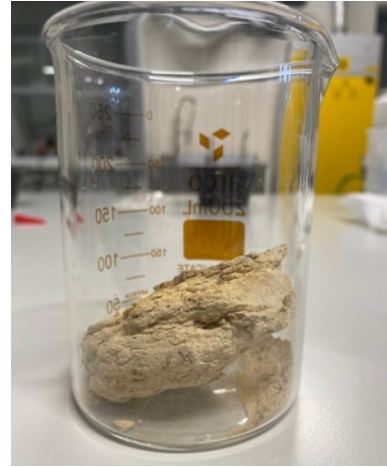


Fig. 24
Sample 9. WA for porosity 11.2 %.



Fig. 25
Sample 7. Red powder.



Fig. 26
Sample 7. Red powder.



Fig. 27
Sample 8. General view.



Fig. 28
Sample 8. White mortar.



Fig. 29
Sample 10. White mortar powder.



Fig. 30
Sample 11- Plaster.

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CEN/TS 17135: 2020, Conservation of cultural heritage - General terms for describing the alterations of objects.

Introduction to Archeometric Analysis of Cultural Heritage Materials

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Abstract: Archeometric analysis of cultural heritage materials of geological origin constitutes a fundamental approach for achieving a comprehensive understanding of artefacts. It serves as a starting point not only for archaeological and historical investigations, but also for their proper conservation. The analytical methods commonly used for this purpose are summarised in a series of boxes throughout this chapter and include microscopic, spectroscopic and diffractometric techniques. A section also focuses on the training experience at the Regional Center for Conservation and Restoration of Jerash (Jordan).

Keywords: Archaeometry, Geomaterials, Marble, Ceramics, Microscopy, Spectroscopy, Diffraction.

The scientific analysis of cultural heritage artefacts (i.e., archaeometry) encompasses a range of chemical and physical techniques that are essential for characterising the materials used in the creation of works of art. Indeed, it represents a vital link between the humanities (i.e., art history and archaeology) and the material sciences (i.e., biology, chemistry, physics and geology). Every object of archaeological or artistic significance contains information relating to its creation and history that cannot be obtained through visual examination alone. The task of archaeometry is to bring this information to light and make it available for further study, while also supporting conservation and restoration works on artistic objects. More recently, diagnostic techniques have increasingly been applied in case of issues related to the forgery of works of art, thereby contributing to the protection of cultural heritage.

The data obtained through diagnostic surveys can provide detailed information regarding an artefact's age, manufacturing techniques, mineralogical and chemical composition, and any changes these characteristics may have undergone over the course of their history. They may also reveal the presence or absence of specific substances indicative of the presumed period of manufacture or the place of discovery. Taken together, this body of information allows archaeologists and art historians to place artefacts within a far richer interpretative framework.

A key consideration in the application of diagnostic techniques used in archaeometry is the distinction between destructive and non-destructive methods, the quantity and type of samples required (e.g., powder, fragment, solid or liquid, etc.) and the feasibility of sampling procedures that can be more or less invasive. Equally important is the definition of the research objectives – whether historical-artistic, archaeological, museological, restoration-related or linked to authenticity assessment – as these could have a significant impact on the selection of analytical methods. These methods may require either relatively low-cost tools, which would cost about a hundred euros (e.g., a Dino-Lite) or highly specialised and expensive ones, which would cost hundreds of thousands of euros (e.g., electron microscope), as well as differing levels of technical expertise for their use.

A vast body of manuals and literature exists on chemical and physical diagnostic techniques, to which the reader is referred for detailed discussions of advanced methods and specific applications (D'Amico and Venuti, 2022; Quinn, 2022). In the present chapter, rather than providing a review of methods, a particularly interesting case study will be used to show how several methodologies have been applied. The rationale behind the choice of each method will be discussed step by step, while the corresponding procedures are presented in dedicated information boxes. The case study focuses on the analysis of particular materials known as “casting cores” extracted from a group of bronze portraits of Michelangelo attributed to Daniele da Volterra; these bronze portraits, are currently held in various museums, and both the artist who made them and the workshop they came from remain uncertain. Their analysis was thus undertaken to shed light on their origin. The study has been published by Della Ventura et al. (2022), to which the reader is referred for further details.

To follow the discussion, it is worth clarifying that the most common Renaissance technique for producing bronze artefacts was the ‘lost-wax method’. This process involved the creation of a wax model around a refractory core, typically made using common geological materials, such as clay mixed with fine and coarse sands to reduce shrinkage on the inner mould and ensure good workability. Organic fibres of plant or animal origin were also added to the clay, along with binders such as mortar or plaster. These materials were subjected to extremely different firing temperatures depending on their position within the mould. As a consequence, their characterisation is important for reconstructing historical casting techniques and, where possible, identifying specific workshops based on the origin of the raw material used. This work represents a complex analytical challenge that requires a multidisciplinary approach.

Very small amounts (100-200 mg, or slightly more) of core materials were available for the study. The first analysis carried out was a preliminary observation, which showed that the samples consisted of highly heterogeneous material in terms of grain size, colour and the presence of mineral fragments within a fine-grained paste (see Fig. 1 in Della Ventura et al., 2022). Thin sections were then prepared from all the samples for examination under a polarised light petrographic microscope (1). This type of analysis is an essential step in the characterisation of materials such as ceramics, rocks and mortars. However, it is a destructive method, as it involves cutting a sample fragment. The examination of a thin section (see Fig. 2 in Della Ventura et al., 2022) nevertheless allows for direct observation of the material’s internal structure, including porosity and its spatial distribution. Generally speaking, in cultural heritage studies optical microscopy is a prerequisite to address features like precipitation phenomena occurring after the artefact’s production (e.g., during burial), the quantitative ratio between matrix

and aggregates (in the case of ceramics and mortars), and the type of rock (e.g., for ornamental stones, whether sedimentary, metamorphic or igneous). X-ray diffraction was then used to determine the mineralogical composition of the cores (2). This method is destructive as it requires the sample to be pulverised in order to be examined. However, it offers several advantages: (1) the amount of material required for sampling is minimal, often less than 10 mg, and this can be obtained, for example, by scraping the base of a vase or cut out a hidden part of the artefact using a scalpel; (2) the analysis is quick, typically requiring only a few tens of minutes with modern instrumentation; (3) it allows for the reliable characterisation of the mineralogical phases and, by means of modern procedures (i.e., the Rietveld method), it is also possible to obtain a quantitative composition of the main phases. Instead, its limitations are: (1) the identification of trace minerals (below approximately 1-2%) is difficult, if not impossible; (2) amorphous phases, such as glass, organic binders, resins, etc., which are sometimes important for the study of an artefact, cannot be identified. It should also be noted that X-ray diffraction makes it possible to identify the mineral phase rather than its chemical content, because natural minerals often exhibit highly variable compositions. Therefore, the identification of minerals such as pyroxenes or micas using X-rays does not, in itself, provide detailed information on the chemistry. In the present case study, X-ray diffraction made it possible to group the samples into three main categories with distinct mineralogical characteristics (see Fig. 3 in Della Ventura et al., 2022).

In the field of cultural heritage, the question of chemical composition is addressed using two main techniques: X-ray fluorescence spectrometry (XRF) (3) or a scanning electron microscope (SEM) equipped with an EDS detector (4). These two techniques are based on the same physical principle, namely the emission of X-ray fluorescence by atoms in response to electronic excitation. However, while the first method (XRF spectrometry) is a bulk method – providing the average composition of the entire sample (e.g., a ceramic fragment, a corrosion layer or mortar) –, the second allows for chemical analysis at the micrometre scale, that is of a single mineral within the sample. Both methods are generally destructive, as they require the sample to be pulverised or manipulated. However, in the case of XRF, portable instruments that can be used directly on an object without causing any damage (e.g., a vase, a fresco, a corroded metal surface, etc.) are also available. In contrast, SEM analysis may be performed on a small object (a few centimetres in size, such as a piece of jewellery or a small statuette) without manipulation, provided that it can be placed inside the analysis chamber. A major advantage of SEM is that it allows observation at very high magnifications (up to 1,000,000 times), which cannot be achieved with other techniques, and enables the mapping of chemical elements (see M. C. Caggiani, E. Rossi, ‘Application of SEM-EDS to the analysis of a mosaic tessera and a glazed ceramic from Jerash’, in this volume). In the specific case studied by Della Ventura et al. (2022), SEM-EDS proved fundamental for the investigation of microporosity, the chemical composition of the clay matrix as well as the identification of accessory minerals in the samples (see Figs. 4-5 in Della Ventura et al., 2022).

Two complementary spectroscopic techniques widely used in archaeometry are FTIR (5) and Raman (6). Both are based on the interaction of radiation – infrared radiation in the case of FTIR and UV, visible to IR light in the case of Raman spectroscopy – with the chemical bonds of a material. For this reason, these techniques are essential for the characterisation of amorphous and organic materials (such as organic binders, resins, carbonaceous compounds, glass, etc.),

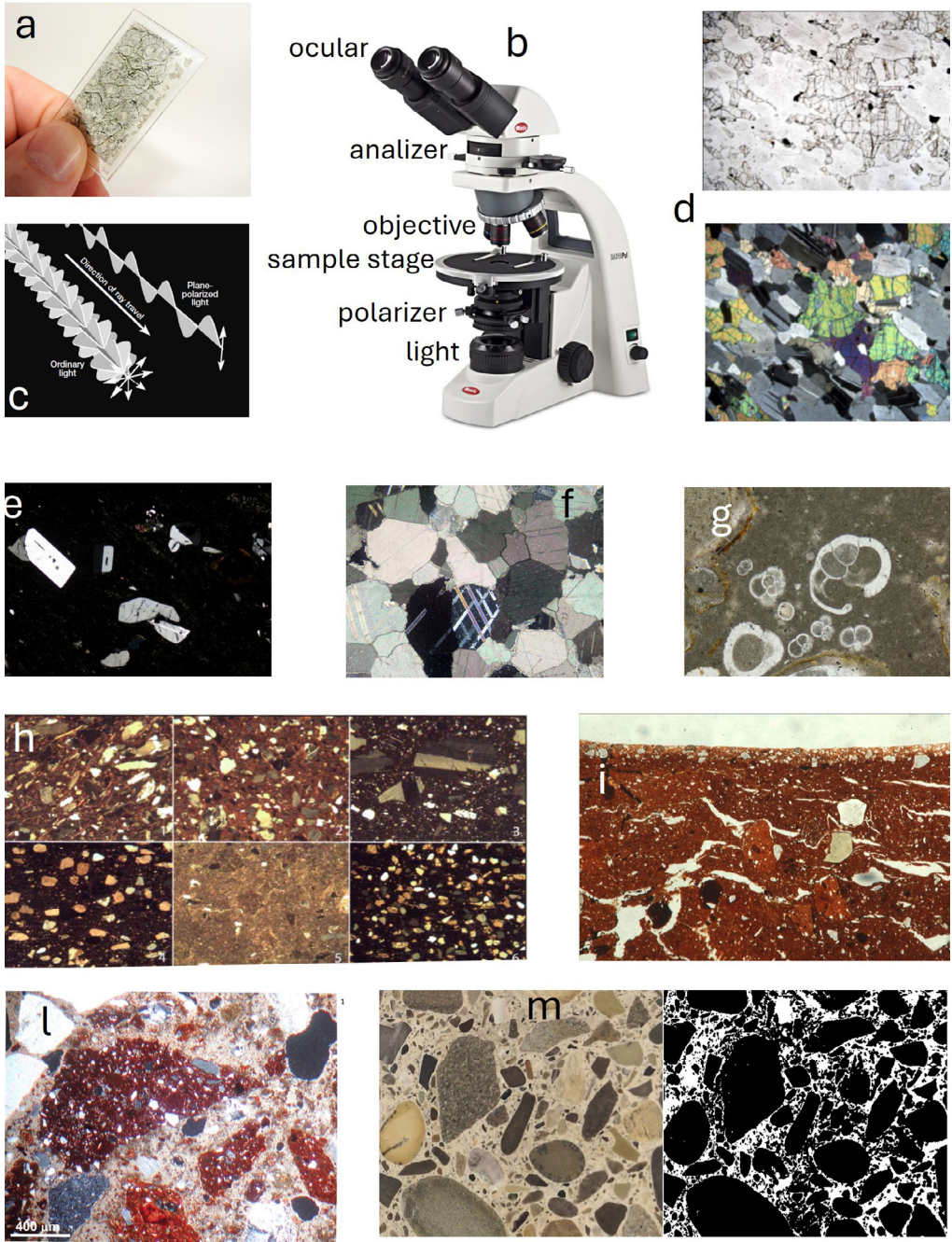
which are often important components of artistic artefacts (see Figs. 4-6 in Della Ventura et al., 2022), as well as crystalline compounds. Raman spectroscopy is a non-destructive technique that can be combined with an optical microscope and allows for very high spatial resolution (i.e., about one micron). For this reason, it has become widely used, for example, in the study of archaeological ceramics (Caggiani et al., 2021). Portable Raman spectrometers are also now widely employed in archaeometry. FTIR spectroscopy is generally destructive and typically carried out on powder samples (<1 mg), but it allows very efficient identification of organic compounds. It can also be coupled with optical microscopes, although its spatial resolution rarely falls below 50 microns.

The Conservation Scientist training programme at the RCCR in Jerash

The training programme at the Regional Center for Restoration and Conservation in Jerash included a theoretical introduction to basic concepts relating to minerals and rocks, the operation of the optical microscope, and the main analytical techniques mentioned above. Subsequently, samples were prepared for the production of thin and polished sections of stone mosaic tiles, mortars from the same mosaic, and glazed ceramics (7). A selection of these samples was also subjected to SEM-EDS analysis (8).

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in the previous page

Fig. 1

(a) Thin section; (b) polarised light petrographic microscope; (c) schematic diagram of light polarisation; (d) a thin section observed under parallel polarisers (PPL), at the top, and crossed polarisers (XPL), at the bottom: note the appearance of interference colours. (e-l) Thin sections of rocks and materials observed in XPL: (e) obsidian, note the quartz and feldspar crystals in grey and the extinct (black) glass; (f) marble; (g) fossiliferous limestone; (h) ceramics with varying clast content; (i) ceramic observed in PPL, note the porosity in white; (l) mortar observed in XPL, note the fragments of *cocciopesto* (red). (m) example of binarisation of an optical image for image analysis.

Polarizing Optical Microscopy

The sample to be examined using this technique must be prepared as a thin section, mounted on a glass slide, conventionally 30 micrometres thick (Fig. 1a); therefore, this is a destructive technique.

In a petrographic microscope (Fig. 1b), the light emitted by a bulb is polarised (the electric field of the light vibrates in a single plane, Fig. 1c), then passes through the thin section and proceeds towards the eye, passing through an objective lens and an eyepiece, which magnify the image.

A second polariser (analyser), oriented at 90 degrees to the first, can be inserted into or removed from the light path after the light has passed through the sample. In the first case (observations with parallel polarisers), the colours of the minerals – where applicable – can be observed, along with a range of features such as relief and cleavage (Fig. 1d, top). In the second case (observations with crossed polarisers), all crystalline materials take on colours, known as interference colours (Fig. 1d, bottom), which are created by the interference of the waves passing through the sample and interacting in the analyser after passing through the mineral slab. Interference colours depend on the physical characteristics of the mineral (ultimately on variations in refractive index within the mineral) and, with a certain degree of experience, allow for the identification of the various substances observed in the section. Amorphous substances always appear black ('extinct') and can therefore be easily recognised. This type of analysis makes it possible to observe porosity and the presence of clasts, as well as their type and size, within the material.

When used with appropriate software, modern image analysis techniques make it possible to quantify porosity and matrix-to-clast ratios – all of which constitutes highly valuable information in the study of archaeological artefacts (Quinn, 2022).

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Powder X-ray Diffraction (PXRD)

X-ray diffraction in crystals occurs when X-rays interact with the atoms arranged in a regular pattern within the mineral's structure.

When a beam of X-rays strikes the planes of the crystal lattice at an angle θ , constructive interference occurs if the path difference between the incident ray and the reflected ray is equal to an integer multiple of the wavelength. This condition is described by Bragg's law:

$$2d \sin \theta = n\lambda,$$

where d is the distance between the lattice planes, θ is the angle of incidence, and λ is the wavelength of the X-rays.

By measuring the angle θ , it is therefore possible to determine d and identify the type of crystal being analysed (Jenkins & Snyder, 1996).

Powder diffraction studies samples reduced to a fine, homogeneous powder. Proper sample preparation is essential for obtaining reliable results: the powder is spread in a thin layer on a substrate, and the diffracted rays are recorded by a detector. The analysis can also be quantitative, thanks to methods such as the internal standard or the Rietveld ones (Cappelletti et al., 2019).

There are several different ways in which this technique can be applied to the study of geomaterials constituting cultural heritage and they regard both natural and artificial stone materials (such as mortars, ceramics, glass, etc.). These range from determining the provenance of materials such as marbles (Antonelli & Nestola, 2021) or raw materials used in the manufacture of artefacts, to investigating production technologies, including the firing temperature of archaeological ceramics (Mangueira et al., 2011), and identifying forms of existing degradation (Brai et al., 2010).

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X-ray Fluorescence Spectroscopy (XRF)

X-ray fluorescence spectroscopy (XRF) involves irradiating a sample with primary X-rays and analysing the secondary X-rays emitted. When the radiation strikes the atoms in the sample, it causes a vacancy to form in the inner orbitals; the subsequent rearrangement of energy generates characteristic X-ray radiation. The wavelength of this radiation depends on the type of electronic transition and the chemical element involved, thus allowing the identification of the elemental composition of the sample (Beckhoff et al., 2007). Furthermore, the intensity of each characteristic X-ray peak is related to the quantity of the corresponding element in the sample, allowing for measurements ranging from 1 ppm up to 100% (Fitton, 1997).

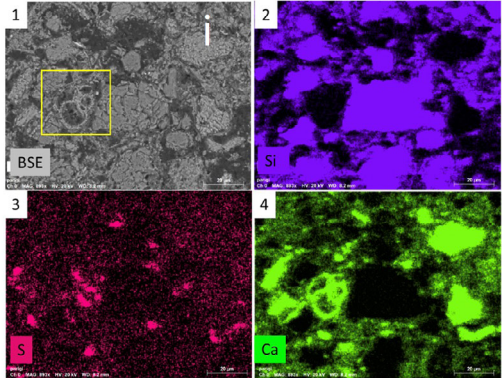
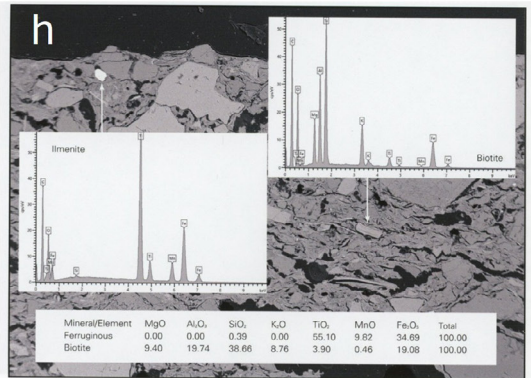
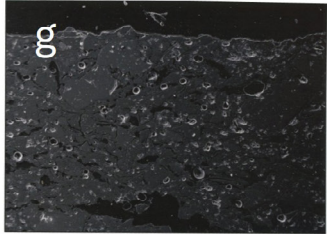
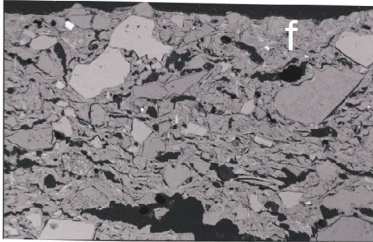
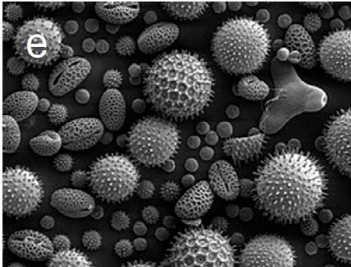
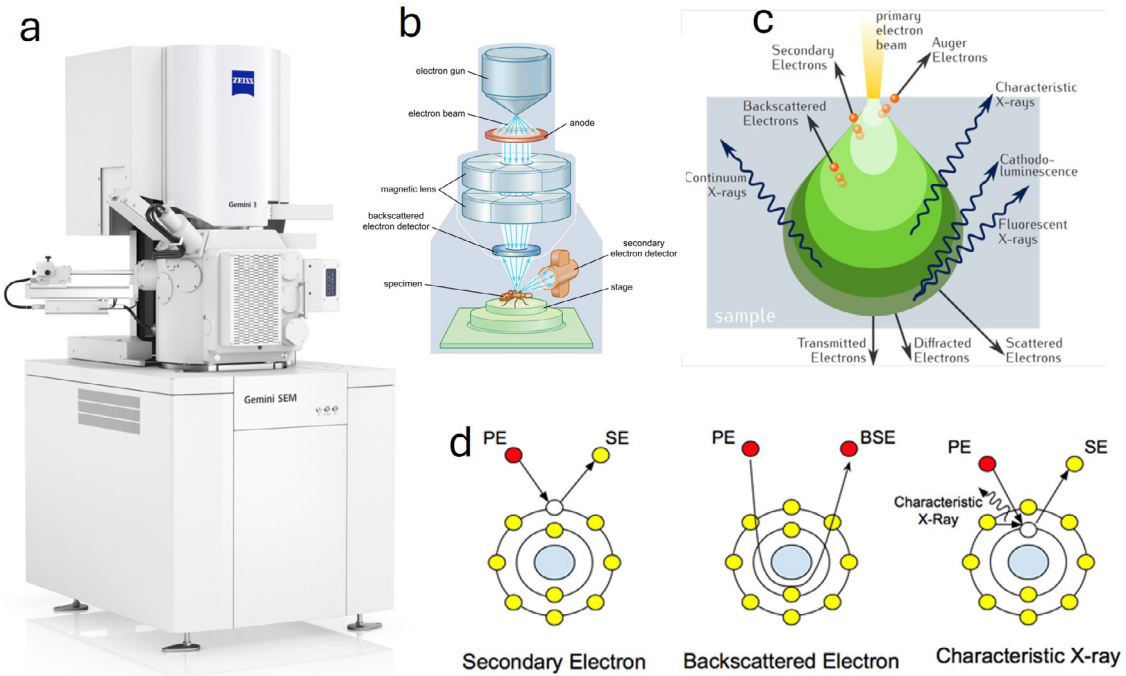
The traditional equipment used is bench-top instrumentation that requires sample preparation. A common technique for preparing geological materials involves producing powders and pellets following crushing and grinding processes. Additives are sometimes introduced – typically 2-10% by weight – to facilitate the grinding, mixing and compaction stages, resulting in a flat disc (Beckhoff et al., 2007).

On the other hand, the use of portable systems is regarded as a valuable way to gather information on the elemental composition of ancient artefacts in a completely non-destructive and non-invasive manner, thereby meeting the requirement of avoiding damage to an artefact. This type of characterisation allows for the formulation of preliminary hypotheses, which can subsequently be verified through other types of analysis – where possible of a destructive nature (Ridolfi, 2012). As a matter of fact, portable XRF spectroscopy (pXRF) does not achieve the same level of accuracy and detection limits as traditional laboratory-based elemental analysis techniques. In particular, difficulties may arise in detecting light elements due to the presence of air between the sample and the detector. To overcome this issue, a flow of helium gas at atmospheric pressure can be released through this space (Gianoncelli et al., 2006).

In the field of cultural heritage, the elemental composition of both natural and man-made materials – such as ceramics, glazes, glass, obsidian, pigments and metal artefacts (the latter being among the most suitable for this type of application) – can be analysed in order to determine provenance, investigate technological and production aspects, conduct comparative studies, and spread knowledge in the field.

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Fig. 2

(a) Modern SEM and (b) schematic diagram of the electron column; (c) interaction between the electron beam and the sample, and types of emitted radiations; (d) interaction between electrons and atoms: emission of electrons used for imaging – secondary (SE), backscattered (BSE) – and X-ray fluorescence (XRF) for chemical analysis; (e) typical SE image of spores (size approximately 20 microns), note the depth of field; comparison between images of a ceramic section in BSE (f) and SE (g); (h) example of point analysis on two crystals from the section in (f): the EDS spectra and oxide quantification are shown.

4

Scanning electron microscopy coupled with microanalysis (SEM-EDS)

The scanning electron microscope (SEM, see Fig. 2a) is an essential tool in a modern diagnostic laboratory. It consists of a column containing an electron source and a system of electromagnetic lenses that focus the electron beam onto the sample (see the diagram in Fig. 2b). The SEM allows for the observation of an object at magnifications up to two orders of magnitude greater than those of an optical system (i.e., a few nm versus 0.5 micrometres) and also provides images with higher depth of field.

The interaction of the electron beam with the sample is highly complex and results in the emission of various types of radiation from the material bombarded by the electron beam (Fig. 2c). Of these, secondary electrons (SE) and backscattered electrons (BSE) are collected by two detectors and used to generate images. Images obtained using secondary electrons are used to study the details of the sample's surface, while those obtained using backscattered electrons are used to visualise the different minerals according to their chemical composition, via the different shades of grey that the material takes on (Fig. 2d). On the other hand, X-ray fluorescence (XRF) is collected by an EDS detector (Fig. 2e), with which almost all SEMs are equipped, and allows for point or area microchemical analysis (Fig. 2f). If the sample fits the analysis chamber (Fig. 2a), there is no need to manipulate it (i.e. reduce the size).

However, the sample must be conductive in order to be analysed with a SEM. If it is not metallic (e.g., gold or silver jewellery, copper objects, etc.) but insulating (i.e., consisting of silicates such as ceramics or mortars, or carbonates such as marble), it is coated with a thin layer of graphite, which can subsequently be removed.

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Fourier transform infrared spectroscopy (FTIR)

In FTIR analysis, the absorption of infrared radiation raises the molecule to a higher energy state, causing bonds vibrations (such as stretching, bending or torsional vibrations). These vibrations occur at different wavelengths in the infrared region, and each absorption peak is linked to the molecule's characteristics, thereby providing information about its functional groups. A detailed description of the fundamental mechanism of this technique is available in Griffiths and Haseth (2007) and Smit (2011).

The most traditional mode of operation for FTIR spectroscopy is transmission, in which infrared radiation passes through the sample and the transmitted portion is subsequently detected. Among the reflection acquisition modes, however, is ATR (Attenuated Total Reflectance), in which the sample is placed in close contact with an internal reflection element with a high refractive index. When infrared radiation strikes this element, a small portion of it penetrates slightly into the sample. The sample absorbs energy in specific spectral ranges and the resulting attenuated beam is collected by the detector (Rosi et al., 2019). On the other hand, diffuse reflectance infrared spectroscopy can be used for non-invasive on-site measurements if the instrument is equipped with a measurement head that does not require contact with the sample. Consequently, in recent decades, this technique has been increasingly employed in archaeometric studies.

Generally speaking, infrared spectroscopy is widely used in the field of cultural heritage to address archaeometric questions concerning the molecular composition of pigments, binders, varnishes, clays, ceramics, fossil resins, etc., often combining the spectral data obtained with chemometric analysis aimed at interpreting the data and classifying the samples (e.g. De Benedetto et al., 2005).

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Raman scattering is a phenomenon in which monochromatic light interacts with matter and is scattered inelastically, that is, with a change in energy. The phenomenon is named after Chandrashekhara Venkata Raman, who was awarded the Nobel Prize in Physics in 1930 for this discovery, although similar results had already been obtained by other Russian, French and German researchers (Krishnan & Shankar, 1981). In the Raman effect, incident light temporarily excites the molecule into a virtual state, and when it returns to a more stable state, transitions occur between its vibrational levels (Long, 1977). The molecule may return to a vibrational state higher or lower than the initial one. Vibrational transitions can proceed from the ground state ('Stokes' spectrum) or from the excited state ('anti-Stokes' spectrum, less likely) (Fig. 3a). A Raman spectrum shows a symmetrical pattern relative to the elastic scattered signal, or Rayleigh scattering, at the same energy as the incident laser. In the spectrum, the scale in cm^{-1} is measured relative to the excitation energy, which is set to zero. This is why the result is defined as the 'Raman shift' (Pasteris & Beyssac, 2020).

Raman instrumentation consists of three main components: a source of excitation (laser), a diffraction lattice that disperses the different wavelengths, and a detector. Over the last 15 years, the miniaturisation of laser sources, CCD detectors and optical filters has spurred the development and use of the method in fields such as cultural heritage, with the widespread adoption of portable instruments that allow for in situ analysis without the need for sampling (Caggiani & Colomban, 2018) (Fig.3b).

The analysis of a Raman spectrum consists in the identification of the vibrations involved. A thorough and comprehensive description of this approach can be found in Nakamoto (2009), while a more specific description for minerals and rocks in Karr (1975). Mineral identification is a process supported by well-established scientific literature and extensive spectral comparison databases (e.g., Colomban et al., 2001; Bersani & Lottici, 2016; www.ruff.info). Among the materials for which good and rapid identification can be most easily obtained are, for example, gemstones, thanks to their well-polished surfaces and the well-established knowledge of their Raman spectra. Raman spectroscopy is also highly effective in detecting patinas and corrosion layers, as these consist of compounds characterised by covalent bonds (i.e., sulphides, sulphates, oxides, carbonates and nitrates).

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7

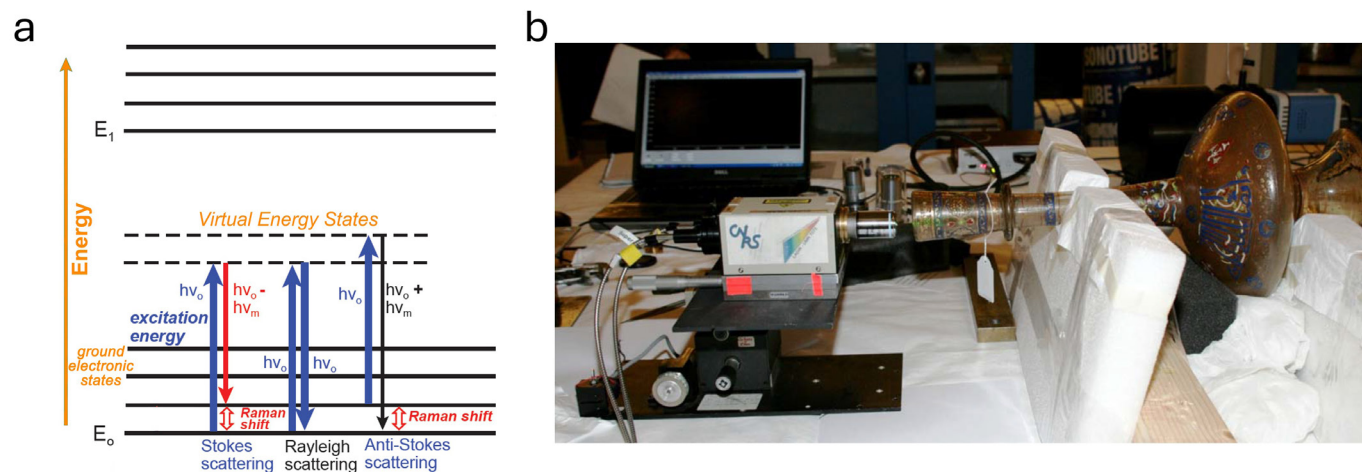


Fig. 3

(a) Schematic representation of the physical principle underlying Raman spectroscopy (after Pasteris et al., 2020, modified). (b) Example of on-site Raman analysis using portable instrumentation (from Colomban et al., 2012, modified).

The Jerash Experience – by Mohammed Albanna and Omaima Fodeh

Sampling of tesserae, mortars and glazed pottery

Erratic tesserae samples were taken from diaconia mosaic at Jerash site (Figure 4a). Mortar samples were taken from the same mosaic (4 layers) (Figure 4b). Glazed pottery samples were taken from fragmented objects in RCCR coming from Aqaba (Figure 4c).

Thin Sections Preparation Procedure



Fig. 4

Sampling of tesserae (a), mortars (b) and glazed pottery (c).

First of all, since the archeological materials (mortars and pottery) were incoherent we needed to impregnate them with epoxy resin (Fig.5a). On the other hand, stone tesserae could be directly cut.

The epoxy resin was prepared and put in vacuum to avoid bubbles formation, then poured until the sample was covered. After that, the samples were left for 24 hours at room temperature. After the resin became hard and dried, the samples were cut by cutting machine (around 0.3 cm thick) (Fig.5b).

The cut samples were polished carefully on the lapping wheel (120grit / 240/320/600) (Fig. 5c) and then by hand on 1000 grit until the surface was perfectly flat and polished. Finally, the samples were cleaned with water to remove the dust.

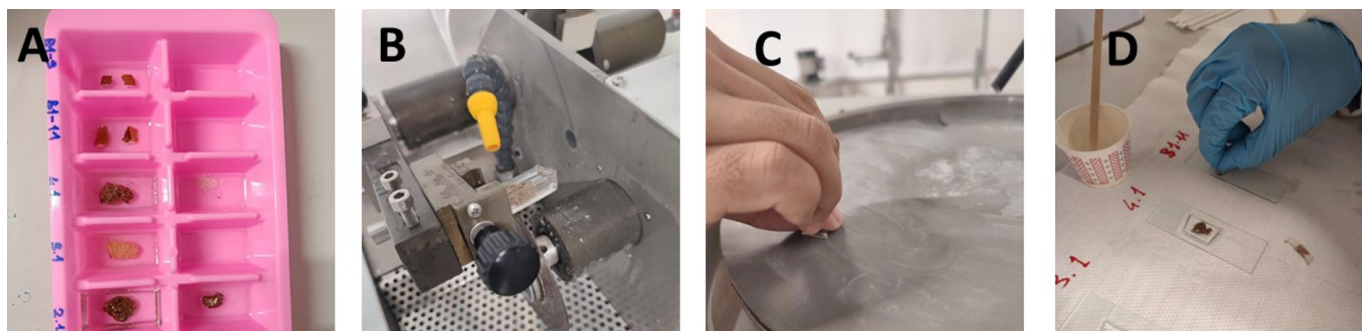
Before the samples were glued with epoxy resin on glass slides (Fig.5d), with epoxy resin these were cleaned with ethanol. The epoxy was allowed to dry completely (24h). The mounted samples were polished using progressively finer abrasives: 120, 320, 600, 1000 grit (by hand).

The final step was checking the thickness of samples until the quartz reached its characteristic white to grey interference color at 30, or, if quartz was not present, until the sample constituents were visible at the microscope.

Optical microscopy results

Fig. 5

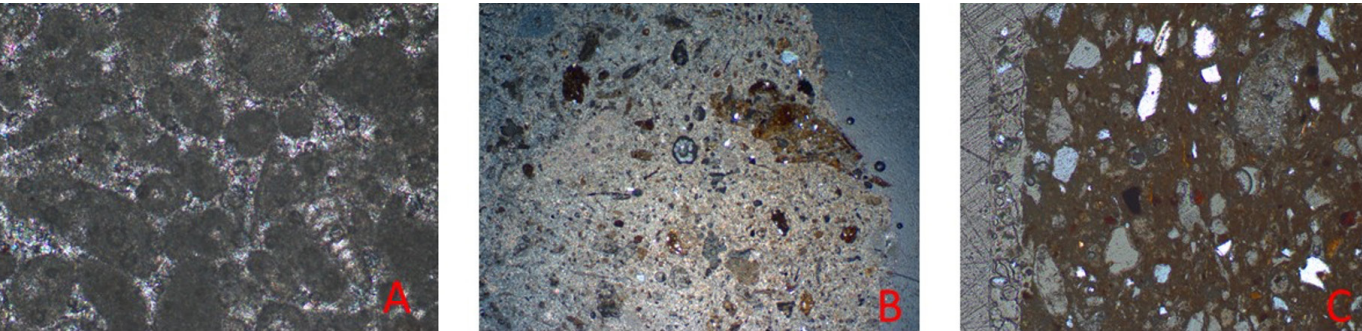
(a) impregnation process, (b) cutting, (c) polishing, (d) glueing sample on glass slides.



Optical microscopy allowed us to observe the prepared thin sections. In the stone tesserae we could distinguish the material according to Folk (1959) and Dunham (1962) limestone classification; in mortars we could observe the porosity, the binder and the aggregates; in ceramics, we could observe groundmass, non-plastic inclusions and porosity (Figure 6). The observation results of limestone tesserae are reported in Table 1.

Fig. 6

Optical microscope images of (a) stone tessera, (b) mosaic mortar, (c) glazed pottery.



Sample	Color / name	Peloids	Fossils	Mud supported	Grain supported	Intracrysts	Folk classification	Dunham classification	Hypothesized formation	Notes
1	White	-	+	+	-	-	bio-micrite	wackestone	Naur Formation	
2	Pink	+	+	-	+	-	pelbiospary-micrite	grainstone	Naur Formation	
3	corroded 1	+	+	-	+	-	pelbiospary-micrite	grainstone	Naur Formation	
4	corroded 2	+	+	-	+	-	pelbiospary-micrite	grainstone	Naur Formation	
5	grey	+	+	-	+	+	biopelmicrite	packstone	Fuheis formation	
6	light yellow	-	+	+	-	-	bio-micrite	wackestone	Shuayb or Fuheis formation	Iron oxide
7	yellow	-	-	+	-	+	Intra-micrite	wackestone	Not identified	Iron oxide and quartz
8	brown	-	+	+	-	-	bio-micrite	wackestone	Naur formation	Iron oxide
9	black	-	+	+	-	-	bio-micrite	wackestone-pack-stone	Shuayb formation	Carbon
10	red	-	+	+	-	-	bio-micrite	packstone	Hummar formation	

Table 1

Summary of the characteristics of the limestones constituting the mosaic tesserae from Jerash site. (+ = found; - = not found).

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Application of SEM-EDS to the analysis of a mosaic tessera a glazed ceramic from Jerash - by Edoardo Rossi and Maria Cristina Caggiani

Materials and aims

A cross section of a corroded stone mosaic *tessera* (see Box 7) was selected to be analyzed with the aim of comparing the chemical compositions of the bulk body with that of the corroded edge. An acid attack, such as due to hydrochloric or sulfuric acid has been hypothesized as agent of the surface corrosion.

Furthermore, a thin section of a glazed pottery coming from Aqaba (B1.9), prepared as described in Box 7, was also analyzed with the aim of investigating the composition and morphology of the interface between the ceramic body and the glaze.

Experimental Methods

SEM–EDS analyses were carried out using a Thermo Fisher Helios FIB-SEM 5CX equipped with an integrated Thermo Fisher EDS detector. Observations were performed in secondary electron mode under high-vacuum conditions, with a working distance of 10 mm and zero stage tilt. For the mosaic *tessera*, EDS spectra from a small rectangular scan area two distinct regions of the same tile were acquired: an internal region (Sample Center) and a chemically altered boundary (Corroded Edge). The glazed ceramic sample B1.9 a was analysed at the glaze interface using combined point spectroscopy and elemental mapping.

Results and discussion

Mosaic tessera: internal region vs. chemically altered boundary

Figure 7 compares normalized EDS spectra acquired from the internal region of the mosaic *tessera* (Sample Center) and from the altered boundary (Corroded Edge). The two spectra exhibit clear differences that cannot be explained by local heterogeneity in the stone alone.

The Sample Center spectrum is dominated by Ca–O–C signals, with only minor contributions from Mg, Al, Si and Ti (Figure 7b, top; Table 2). No transition metals are detected beyond trace Ti, and no phosphorus-bearing species are observed. This composition defines a chemically stable reference for the bulk material.

Element	wt.%	at.%
C	14.8	21.5
O	62.8	68.7
Mg	0.1	0.1
Al	0.1	0.1
Si	0.1	0.1
Ca	21.3	9.3
Ti	0.7	0.3
Total	100	100

Table 2
Sample Center –
semi-quantitative EDS
composition.

In contrast, the Corroded Edge spectrum (Figure 7b, bottom) shows the emergence of a Ni-dominated chemistry, accompanied by measurable phosphorus and a strong depletion of calcium relative to the internal region (Table 3).

Element	wt.%	at.%
C	8.3	23.7
O	6.1	12.9
Al	13.4	16.9
P	3.9	4.3
Ca	9.3	7.9
Ni	59	34.3
Total	100	100

Table 3
Corroded Edge –
semi-quantitative EDS
composition.

From a comparative standpoint, two features are diagnostically relevant. First, the Ca-rich matrix characteristic of the Sample Center is not preserved at the boundary, indicating partial removal or masking of the original ceramic chemistry. Second, the strong enrichment in Ni and the concurrent presence of P cannot be produced by simple leaching of the rock and require an external chemical source. The absence of chlorine or sulfur rules out hydrochloric or sulfuric acids involvement in the corrosion of the stone; on the other hand, the Ni–P association at the altered edge points to exposure to a phosphoric acid attack, capable of mobilizing or depositing transition-metal species.

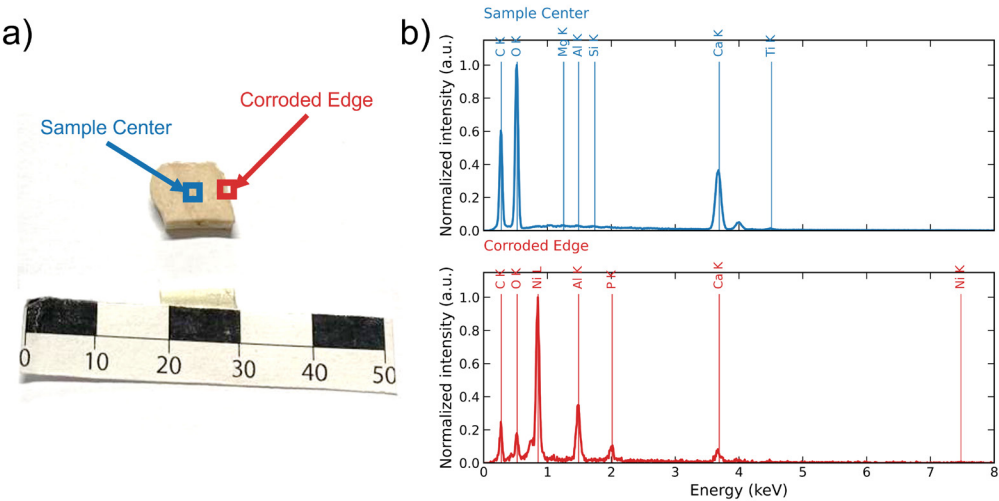


Fig. 7
(a) Photograph of the ceramic mosaic tile showing the locations selected for EDS analysis in the internal region (Sample Center) and at the chemically altered boundary (Corroded Edge). (b) Normalized EDS spectra acquired from the two regions, highlighting a Ca–O–C–dominated composition in the Sample Center and a Ni-enriched, Ca-depleted chemistry with the appearance of P at the Corroded Edge.

Glazed ceramic B1.9 a: glaze interface

The elemental maps and the associated EDS spectrum (Figure 8–9) indicate that the glaze interface exhibits a chemically heterogeneous composition. Silicon creates a continuous background across the mapped area, while alkali and alkaline-earth elements (Na, K, Ca, Mg) show spatial distributions that are not strictly linked to Si, indicating local variation at the interface. Aluminium and iron are detected at minor but significant levels, presenting dispersed, low-intensity signals that suggest their presence as subordinate components rather than primary matrix elements. Titanium appears at trace levels and exhibits localized signal intensity, consistent with a spatially confined distribution rather than uniform incorporation within the glaze. Conversely, alkali elements have broader spatial

Fig. 8
EDS elemental maps (atomic %) acquired at the glaze interface of the glazed ceramic B1.9 a, showing a continuous Si background with spatially heterogeneous distributions of alkali, alkaline-earth, halogen, and Ti signals.

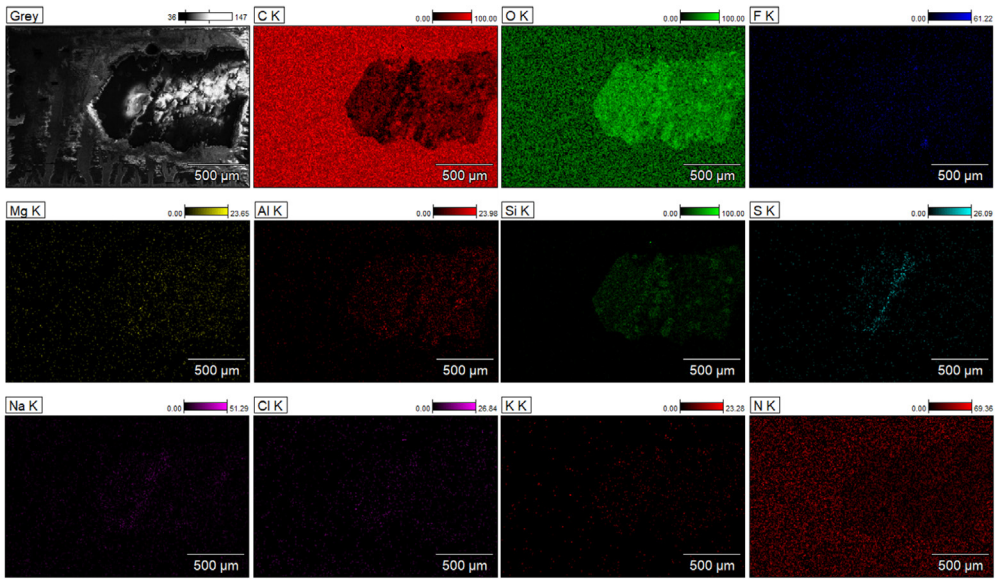
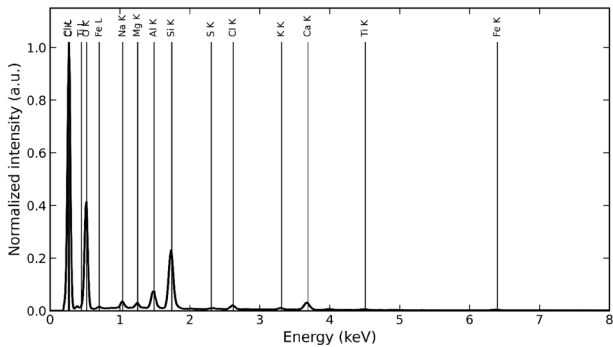


Fig. 9
Normalized EDS spectrum extracted from the glaze interface of the glazed ceramic B1.9 a. The spectrum confirms a Si-bearing glaze matrix with minor contributions from alkali, alkaline-earth, halogen, sulfur, and transition metals, consistent with the spatially heterogeneous elemental distributions observed in the associated EDS maps.



spread, indicating greater chemical mobility compared to Ti at the interface. Overall, the glaze interface features a Si-rich matrix with minor, spatially variable contributions from alkali, alkaline-earth, halogen, sulfur, and transition metals. Within the limits of EDS analysis, these features suggest a chemically complex interface rather than a single, well-mixed composition.

Table 4
Glaze interface (B1.9 a) – semi-quantitative EDS composition.

Element	Line	Intensity	Net counts	wt.%	at.%
C	K	4289.2	189121	46	56.9
O	K	1792	79013	37.7	35.1
Na	K	148	6527	1	0.7
Mg	K	107.1	4721	0.6	0.4
Al	K	440.7	19430	2.1	1.2
Si	K	1602.2	70646	7.7	4.1
S	K	47.3	2085	0.2	0.1
Cl	K	124.9	5507	0.8	0.3
K	K	58.2	2568	0.4	0.2
Ca	K	270.1	11909	2.2	0.8
Ti	K	27.3	1205	0.3	0.1
Fe	K	35.4	1563	0.9	0.2
			Total	100	100

Biodeterioration and Conservation of Jordan Cultural Heritage

Giulia Caneva, Dep. Science, Roma Tre University

Abstract: Biodeterioration of cultural heritage can be a major risk to conservation of cultural heritage when the nature of materials and their bioreceptivity can sustain a biological colonization and when environmental conditions become favourable for the growth of microorganisms. Through different physical or chemical processes, the growth of microorganisms, lichens, mosses and higher plants can damage the materials, and the knowledge of this risk or of the process in act is fundamental to slow down its adverse effect. The ecological assessment of biological communities, usually recognizable through different biodeterioration patterns (BP), i.e. typical phenomenology of alteration, can support the intervention plans of conservator's through preventive strategies (indirect control methods). In addition, as direct intervention, different biocidal methods and/or products have been used, and increasing research has been dedicated to green solutions. An overview of such general principle was carried out during the Jordan training course to strength the ability of restorers and conservation scientists in a longer preservation of the monuments in the archaeological site of Jerash and of the wide Jordan cultural heritage.

Keywords: biodeterioration, ecology, archaeological sites, preventive conservation, biocides.

Introduction

A worldwide literature enhances as the maintenance of archaeological sites and monuments should include management plans to reduce biodeterioration. As in the medical field, to perform the best conservative strategy, a precise diagnosis of the causes of biodeterioration should be acquired on a case-by-case analysis, taking into consideration organisms, materials, environmental factors, and artworks (Favero-Longo and Viles 2020).

In fact, a complex system of inter-relationships links organisms, materials, and the environment. Interacting elements and biogeochemical cycles provide for the establishment of complex communities, forming more or less complex trophic chains (Villa, et al. 2016).

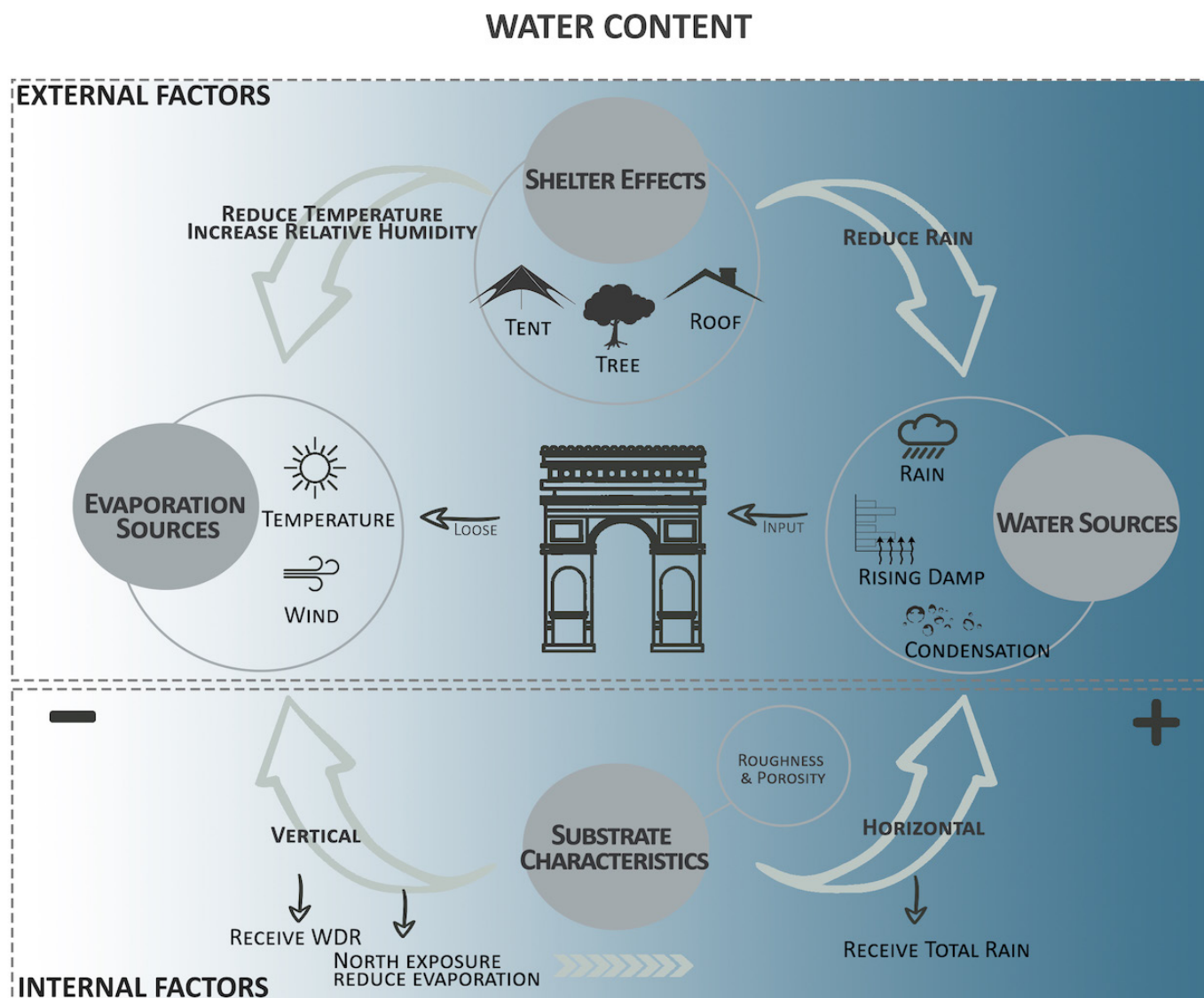
**Fig. 1**

Visit at the archaeological site of Jerash with the class of restorers and observation of phenomenology of stone biodeterioration.

In the dry and sunny conditions of the Jordan country, and in case of stone monuments, photosynthesizing organisms, such as cyanobacteria, green algae, and lichens, are usually the pioneer taxa able to start a colonization. In particular, cyanobacteria and lichens, which are poikilohydric organisms, have tolerance for low levels of water. To be protected by aridity, such stress tolerant organisms may also assume an endolithic habitus, that is not always easily detected from a direct visual observation (Danin and Garty, 1983, Viles and Culter 2012, Lombardozzi et al. 2012). In such conditions, dark-blackish phenomenology's, also prevail, and these biopatinas are also not always recognized as biological phenomena and they are often confused with chemical weathering processes (e.g. black crusts due to pollution). When water content increases, these pioneer communities are substituted by different algal and less xero-tolerant lichens communities, and then by mosses and higher plants associations (Rindi, 2007, Caneva et al., 2008). Furthermore, the produced or deposited organic matters can support further ecological successions made by heterotrophic organisms, such as some bacteria and meristematic fungi (black yeasts) (Sterflinger 2010)..

The growths and succession of such microbial communities produce specific physical and chemical alterations, that can be detectable as typical biodeterioration patterns (BP) (Caneva et al. 2015).

Few studies have been carried out today on the Jordan cultural heritage (Elserogy 2016, Al-Jokhadar et al. 2024, Elgohary et al. 2024), and this contribution is aimed to summarize the topic of the short course, partially theoretic and in the field (Fig. 1) that I carried out in 2024 at Jerash for the improvement of the knowledges and the skills of restorers and of conservator scientists.

**Fig. 2**

External and internal factors that affect water content of stone monuments in archaeological sites, giving rise to favorable or negative effects for the biological growths (WDR: Wind-driven rain) (Elaboration by the Author).

1 Ecology of biodeterioration

As stated by the two main laws of ecology- the Liebig's law of minimum and the Shelford's law of tolerance (Odum et al. 1971)- the growth of an organism depends on the values of the ecological factor, which is present in limited or excessive quantities in relation to the organism's requirement (Caneva et al. 2008).

Many ecological factors may influence the life of an organism, and each of them can become a limiting factor when its values don't fit with the survival conditions of the analyzed taxon.

Usually, for monuments in archaeological sites, the most relevant limiting factor is water, because it is the most frequently factor present in the lower value, when considering the microbial needs for growth. Raising damp, rainfall, humid winds, low solar radiation and low ventilation can give rise to favorable conditions for the biological growths, whereas sheltering, high solar radiation, and high ventilation exert limiting conditions (Fig. 2).

The role of water as a limiting factor for biodeterioration processes, and in defining the successional stages among different microbial communities, was also enhanced when analyzing several archaeological sites, such as Copán (Honduras), Angkor

**Fig. 3**

Different Biodeterioration patterns due to lichens (epilithic crusts of various color) and cyanobacteria (blackish biofilm) in the archaeological site of Jerash.

(Cambodia) (Bartoli et al. 2014; Caneva et al. 2015, 2016), Pompei (Traversetti et al. 2018). Confirming such observations, Liu et al. (2018) stressed that the relevance of water is also due to the accumulation of solutes in water and their transport into sandstone as a result of capillary action.

When looking at the archeological site of Jerash, the stone biodeterioration seems highly influenced by the growth of epilithic and endolithic lichens and cyanobacteria (Fig. 3), which can form different biodeterioration patterns of stone in relation to the variability of environmental factors and the porosity of materials.

The morphology of a monument also clearly affects the water content. Horizontal and inclined surfaces are directly wetted by rainfall, whereas vertical surfaces (excluding those affected by rising damp or percolation from the top) can be wetted only by wind-driven rain (WDR). Horizontal surfaces, especially if in contact with rising damp, can also host green algae, cyanobacteria, and mosses colonization (Fig. 4).

The potential water content of a material is also highly related to the materials macro and micro-porosity. As higher is the porosity, more easily the stone materials are colonized.

Furthermore, also temperature can have a relevant role in conditioning the biological development, since it is greatly influences the metabolic activities. Temperature affects hydrometric values and condensation in the cooler areas of one room or building, such as corners, which have low ventilation and especially in N exposure. Its role is also especially evident in hypogeal environments, where its value often has a high role in the risk of biodeterioration (Caneva et al. 2020).

For the growth of photosynthesizing organisms on stone (bacteria and cyanobacteria,



Fig. 4
Green algae, mosses and cyanobacteria growing on the mosaics of the archaeological site of Jerash, forming green biofilms or small pulvini.

algae, lichens, mosses, and vascular plants), light, when the humidity is sufficient, can be a further limiting factor exerting a selection in relation to the ecological needs of the different taxa (Gaylarde 2020). Moreover, solar radiation affects temperature and humidity (as relative humidity and absolute values, through evaporation, and a high solar radiation can have ionizing effects on the biological molecules, with consequent negative effects on the survival of the species. As adaptation to environmental stress, microorganisms can protect themselves, through the above-mentioned pigments/EPS or by adopting an endolithic habitat (Lombardozzi et al. 2012).

Nutrients have a major role in influencing the growth of heterotrophic organisms, but the increases of N or P sources can give rise to eutrophication, that highly favour also some autotrophic community, determining a change in the composition of the communities (Caneva et al., 2008).

2 Characteristics of materials

Usually, organic materials are easily attacked by heterotrophic microorganisms, even if some organic molecules (e.g. lignin, cellulose) are attacked only by specific taxa. In case of inorganic materials, such as natural stone or artificial stone materials (bricks or mural paintings), the porosity - together roughness and the related water-holding capacity (such as ageing, maintenance, heat absorption due to color) - greatly influences their bioreceptivity, which is the ability of a material to be colonized by living organisms (Miller et al. 2012, Sanmartín et al. 2021). Interestingly,

small differences in the same typology of stone can have relevance for biological colonization., due to threshold limits defined by the ecological lows

Bioreceptivity varies among stone types, of which basalt and granites have the lowest bioreceptivity values, usually followed by various marbles, limestones, lime mortars, and sandstones. On the contrary, tuffs and other very porous stones, have the highest bioreceptivity values.

The importance of chemical property (acidic or alkaline rocks, presence of heavy metals or of some ions suitable as micronutrients) was also often observed as conditioning factors. We cannot neglect the role of stone geochemistry, which also influence the microbial composition through the availability of chemical elements, such as P, Mn, and Zn (Louati et al. 2020). Some species have a great tolerance to very wide conditions, such as the green alga *Desmococcus olivaceus*, whereas other species have a narrower ecological limit.

Furthermore, when some biological colonization is established on stone materials, the color of the resulting biopatinas can influence the weathering too. Dark coloration often occurs in sunny conditions due to dark pigments, such as melanin or scytonemin (in cyanobacteria), that act as general cell protectants, and their presence can be indicative of stressful, and often polluted, environments (Caneva et al. 2008). However, such colonization directly and indirectly affects conservation efforts, since it has an influencing effect not only on heating/cooling, but also wetting/drying cycles (Warscheid and Leisen 2011; Gaylarde 2020).

3 The assessment of biodeterioration and prevention and control of biological damages

After analysing the biodeterioration processes (i.e. identification of biodeteriorogens, their induced damages and the conditions that favoured their establishment), indirect and indirect intervention are usually carried out.

For the assessment of biodeterioration, a further contribution describes the sampling and microscopic evaluations of the processes (see Sacco Perasso).

When dealing with indirect control methods, the analysis of biological traces and the careful evaluation of biodeterioration pattern is crucial for the development of effective management plans (Caneva et al., 2019). The recognition of specific BPs on stone surfaces was useful in the interpretation of organisms that occurred in the past and related environmental conditions.

Furthermore, the detection of previous colonization tracks of lichens can have practical application for stone conservation, as in the case of the marble surfaces of the *Caestia* Pyramid in Rome (Italy) (Caneva et al. 2020a). On this structure, the presence of recognizable tracks of previous lichen colonization and the evident inhibition areas of subsequent cyanobacterial establishment (Fig. 5) demonstrated the long-lasting, allelopathic properties of some lichen metabolites (e.g., aspicilin, usnic acid), suggesting a future research direction in natural biocides (Caneva et al. 2020a).

Several influencing factors should be considered when the amount of available water exceeds the limiting conditions for microbial establishment, such as water sources and substrate characteristics. Outdoors, the water content of stone material is due primarily to the amount of rainfall received. The resulting water content is also related to morphological features of the building material and the height from the ground level. Another affecting phenomenon is relative humidity (RH); when RH is greater than 60-65% most airborne fungal spores can germinate



Fig. 5

The Caestia Pyramid in Rome (Italy) and its colonization at the beginning of 20th century. (a,b) Biodeterioration patterns (BPs), observed in 1992, related to previous lichen colonization with cyanobacterial regrowth in central areas (c) lichens detachment (whitish surfaces) surrounded by brownish patinas caused by organic compounds and further bacterial and fungal growths (d) whitish circular areas related to past occurrence of lichen thalli, without a subsequent microbial colonization (2017) (from Caneva et al., 2020a).

(Mandrioli et al. 2003; Sterflinger 2010). Relevant differences on the threshold limit and in the optimal conditions can, however, be detected when considering various taxa.

As previously shown, even if microorganisms have different optimal growth temperatures, it is well known that low temperatures reduce biodeterioration risks. When very low temperatures occur, just as when very high temperatures occur, like a hot desert, only specialized endolithic microorganisms, such as certain species of cyanobacteria, meristematic fungi, and lichens, can survive and grow. In subterranean environments, where the temperatures are relatively low and humidity is not a limiting condition, increases in temperature, which occur after the intense heat of the summer season, favor microbial development.

When considering direct control methods, mechanical, physical, chemical and biological methods have been carried out (Caneva et al., 2008). All of them have some positive and negative counterparts. However, very often, mechanical methods are coupled with biocides. The general features of a suitable biocide employed in the restoration field can be summarised as follows:

- Efficacy at low dose against the biodeteriogens.
- Harmless for the restorers.
- Not negative interaction with the substrate.
- Eco-friendly, reducing the possibility of negative impacts on the environment.

During the last years, research in the conservation and restoration field has gathered new sustainable solutions for the microbiological colonisation control of the artefacts. Indeed, in the contemporary management field, new biocontrol methods, using natural compounds (essential oils, plant, animal and fungal derivatives), which are usually safer for restorer and for the environmental health, are proposed to clean and remove biofouling substances while respecting the chemical-physical features of monuments (Li et al. 2018; Sanmartín et al. 2018, Fidanza and Caneva, 2019). Most of the restoration materials derive from the construction industry, while the biocides belong to the farming and medical fields. However, here it is necessary to adopt new eco-friendly products, such as multifunctional nanoparticle coatings, capable of replacing harmful and inefficient biocide products (Ruggiero et al.

2020). The advantage of these new technologies, where the biocide is embedded in microcapsules with slow release, is the safety and the low environmental impact method.

Future perspectives

As futures perspectives for the enhancements of cultural heritage, a training activity for a deeper knowledge of the site and its valorisation will be useful. It will provide methodologies, and instruments for a characterization of materials of biological nature which are present in the archaeological context (pollens, waterlogged woods, carbons, phytoliths) or in museums collections (wood, paper, textiles, parchment). Furthermore, within the complex relationships among Nature and Culture, the topics of phyto iconology and of the cryptic shapes of nature and their symbols as an immaterial cultural heritage- with outstanding examples from Middle East and Greco-Roman contexts (Caneva et al. 2025)- such as the values of the traditional knowledge, and their application to the present landscape of the site, will complete the wide scenario of biological potentials to the cultural heritage.

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Biology Applied to the Conservation of Cultural Heritage

Carlotta Sacco Perasso

Abstract: This chapter examines the role of applied biology in the conservation and restoration of cultural heritage, focusing on the interactions between cultural materials and the surrounding natural and anthropogenic environment. Particular attention is devoted to the processes of biodeterioration, biodegradation, and bioerosion, highlighting the role of microorganisms, plants, and higher organisms in the alteration of both organic and inorganic materials. The analysis distinguishes between autotrophic and heterotrophic organisms and explores the biological successions that develop on cultural assets, emphasizing the importance of understanding metabolic strategies in order to design effective prevention and control measures.

The paper further provides a general view of applied biological sciences to preventive conservation through advanced investigative methodologies, environmental monitoring, and molecular analyses. It underscores the inherently interdisciplinary nature of biology applied to restoration, in dialogue with archaeology, art history, materials science, and conservation practice. Specialized fields such as aerobiology and phytoiconology are discussed as significant extensions of contemporary conservation research and practice.

Finally, the article addresses the strategic role of applied biology in environmentally sensitive contexts, with particular reference to Jordan and the Regional Conservation and Restoration Centre in Jerash. In a setting characterized by extreme climatic conditions and the increasing challenges posed by climate change, applied biology emerges as an essential tool for biological risk assessment, the planning of sustainable conservation strategies, and the strengthening of local expertise, promoting a heritage management model grounded in scientific knowledge, sustainability, and institutional cooperation.

Keywords: Applied biology; Cultural heritage conservation; Biodeterioration; Biodegradation; Preventive conservation; Environmental monitoring; Aerobiology; Jordan; Interdisciplinary conservation.

1 Cultural Heritage as a Complex System

Cultural heritage is traditionally perceived as a set of static objects—monuments, works of art, archaeological structures – preserved and protected within museums or historical sites. This view, however, is now considered limiting. Cultural heritage should instead be interpreted as a complex and dynamic system, composed of a

multiplicity of heterogeneous materials and involved in a continuous exchange of energy and matter with the surrounding natural and anthropogenic environment. Each cultural asset, whether a painting, a sculpture, a historic building, or an archaeological site, is the result of interactions among mineral, organic, and artificial components, often stratified over time. Stone, wood, metals, ceramics, mortars, pigments, textiles, and organic residues may coexist within the same structure, giving rise to an extremely complex material system. Each material possesses specific physical, chemical, and biological properties and responds differently to environmental stressors such as temperature and humidity fluctuations, exposure to natural and artificial light, atmospheric pollutants, and biological agents.

These materials are not isolated entities but constantly interact with external and internal factors that condition their evolution over time. Local climate, soil characteristics, the presence or absence of water, air circulation, and solar radiation profoundly influence processes of alteration and decay. At the same time, living organisms – ranging from microorganisms invisible to the naked eye to plants and animals – colonise cultural materials, establishing complex relationships that may accelerate or modulate transformation processes.

From this perspective, a work of art or a monument can be considered a true cultural ecosystem, in which biotic and abiotic components interact according to dynamics similar to those observed in natural environments. The adoption of this ecosystem-based perspective represents a substantial shift in the field of conservation, as it overcomes a purely materialistic approach and promotes a holistic understanding of heritage, conceived as a living system in continuous evolution and deeply connected to its environmental context.

2 Biodeterioration and Biological Processes Affecting Cultural Materials

Biology applied to conservation focuses on the study and management of alterations in cultural materials caused by the activity of living organisms. The term biodeterioration was formally defined by Hueck in 1968 as «any undesirable change in the properties of a material caused by the vital activities of organisms». This definition highlights the active role of biological systems in degradation processes, distinguishing biodeterioration from purely physical or chemical phenomena.

Biodeterioration is part of broader biological processes such as biodegradation and bioerosion. Biodegradation primarily concerns the transformation of organic macromolecules – such as cellulose, lignin, proteins, and lipids – by microorganisms, allowing their reintegration into natural biogeochemical cycles. Bioerosion, on the other hand, mainly affects inorganic materials, such as stone, plasters, and mortars, which are weakened or removed through mechanical, chemical, or biochemical mechanisms mediated by living organisms.

In natural contexts, these processes are essential to ecosystem balance. In the case of cultural heritage, however, they acquire a negative significance, as they lead to often irreversible modifications that compromise structural stability, aesthetic appearance, and the historical and documentary value of artefacts. Biodeterioration therefore represents not only a problem of material loss but also a loss of cultural meaning.

Biological colonisation can occur along a gradient of increasing complexity, ranging from microbial biofilms to the growth of macroscopic organisms. Bacteria, fungi,

algae, and cyanobacteria are generally the first colonisers of surfaces, especially in the presence of moisture and nutrients. Through their metabolic activity, they may produce pigments, organic acids, chelating compounds, and extracellular substances that alter materials and create microenvironments favourable to further colonisation. Over time, these initial communities may facilitate the settlement of higher organisms – such as lichens, mosses, vascular plants, insects, and vertebrates – giving rise to complex biological successions that accelerate degradation processes.

Understanding biodeterioration phenomena requires basic knowledge of the metabolic strategies of the organisms involved. In this regard, a fundamental distinction is between autotrophic and heterotrophic organisms.

Autotrophic organisms are capable of producing organic matter from inorganic compounds. Plants, algae, and cyanobacteria are mostly photoautotrophs and use light as an energy source for photosynthesis. They frequently colonise stone surfaces, plasters, wall paintings, and archaeological structures exposed to light and moisture, particularly in outdoor or semi-confined environments such as caves, hypogea, and rock-cut sites. Their presence is often associated with chromatic alterations, moisture retention, and accumulation of organic matter.

Some chemoautotrophic bacteria obtain energy from the oxidation of inorganic compounds such as sulfur, iron, or nitrogen. These microorganisms can contribute to chemical reactions that modify the mineralogical composition of substrates, favouring dissolution or salt crystallisation.

Heterotrophic organisms, by contrast, depend on organic substances produced by other organisms. Fungi, many bacteria, insects, and animals fall into this category. In cultural heritage contexts, they are often responsible for the degradation of organic materials such as wood, paper, textiles, leather, and binding media in paintings. Filamentous fungi, in particular, produce extracellular enzymes capable of degrading complex polymeric structures, leading to loss of mechanical strength, deformation, and visual alteration.

The interaction between autotrophic and heterotrophic organisms generates articulated biological successions, influenced by environmental factors, material characteristics, and human intervention. Understanding these dynamics is essential for developing effective prevention and control strategies.

3 The Contribution of Biological Sciences to Conservation and Restoration

Biological sciences represent a fundamental component in the protection and valorisation of cultural heritage. Their contribution extends beyond the identification of harmful organisms to include the understanding of ecological processes governing material colonisation and degradation.

Biological investigations make it possible to:

- accurately identify the biological agents responsible for degradation and the ways in which they interact with materials;
- analyse microclimatic and environmental conditions that favour biological growth;
- develop sustainable prevention and control strategies, minimising the use of biocides and reducing risks to human health and the environment;
- assess the durability and biological compatibility of materials and products used in restoration;
- study constituent organic materials, such as wood, textile fibres, ivory materials,

and organic archaeogems.

Biological investigations therefore develop along two main lines: the study of biodeterioration processes and the characterisation of materials.

Through the integrated use of laboratory techniques, in situ monitoring, and controlled experimentation, biology provides essential data for informed conservation. The use of advanced methodologies – such as electron microscopy, molecular analyses, and continuous environmental monitoring – allows early identification of biological risks and supports a preventive conservation approach, reducing the need for invasive and costly interventions.

4 Biology Applied to Restoration as an Interdisciplinary Discipline

Biology applied to restoration is, by its very nature, a profoundly interdisciplinary discipline, positioned at the intersection of natural sciences, archaeology, art history, materials science, and conservation practice. It acts as a field of scientific mediation, in which biological knowledge cannot be considered autonomous or self-sufficient but acquires full meaning only when interpreted within the historical, artistic, technological, and environmental context of the cultural asset. This complexity makes constant and structured collaboration among specialists with different backgrounds indispensable, enabling the integration of data, methodologies, and interpretative perspectives.

Over recent decades, numerous disciplines belonging to the so-called ‘hard sciences’ have become firmly established within the scientific approach to cultural heritage conservation. Alongside microbiology and environmental biology – fundamental for the study of biodeterioration processes – increasingly specialised research fields have emerged, such as aerobiology, phytoiconology, and marine biology applied to underwater cultural heritage. Each of these disciplines contributes to elucidating specific aspects of the interaction between living organisms, materials, and the environment, expanding the interpretative and operational capacity of contemporary conservation.

Within this framework, aerobiology provides a contribution of growing importance. This discipline studies the biological component of atmospheric particulate matter, including fungal spores, pollen, bacteria, airborne algae, and biologically derived fragments. Applied to cultural heritage, aerobiology allows the assessment of biological contamination risks in museums, archives, libraries, and restoration sites, providing essential data for biodeterioration prevention. Aerobiological monitoring enables identification of major sources of biological inoculum, analysis of seasonal and microclimatic dispersion dynamics, and evaluation of the effectiveness of ventilation, filtration, and environmental control systems. Moreover, this approach plays a crucial role in protecting the health of professionals, contributing to biological risk management in confined and sensitive environments.

Another field of great interest is phytoiconology, which analyses the representation of plants in works of art as a source of historical, botanical, and cultural information. Through iconographic study of paintings, mosaics, sculptures, miniatures, and decorative artefacts, phytoiconology enables reconstruction of the presence and distribution of plant species in the past, including species that are now rare, locally extinct, or extinct. This approach also allows understanding of the symbolic, religious, economic, and medicinal values attributed to plants in different historical periods, offering a valuable tool for interpreting artworks and their cultural

contexts. Phytoiconology thus occupies a privileged position between art history, historical botany, and environmental history, contributing to the reconstruction of past vegetational landscapes and human-environment relationships.

The integration of these disciplines within biology applied to restoration significantly broadens the scope of conservation, transforming it into a global knowledge tool capable of relating materials, organisms, environment, and culture. A truly interdisciplinary approach not only allows more effective management of biological degradation problems but also supports the development of restoration interventions that are scientifically grounded, ethically responsible, and culturally aware, respecting the authenticity and historical complexity of cultural heritage.

5 Strategic role of applied biology in a Regional Conservation Centre: The Case of Jerash

In environmentally and climatically sensitive contexts, such as Jordan, biology applied to conservation assumes strategic importance. The country preserves an exceptionally rich cultural heritage, including millennia-old archaeological sites, rock-cut monuments, historic architectures, cultural landscapes, and museum collections, bearing witness to successive civilisations. This heritage is embedded in a complex environmental context characterised by arid and semi-arid climates, intense solar radiation, limited water availability, and marked daily and seasonal temperature fluctuations.

These environmental conditions exert a decisive influence on alteration and degradation processes affecting cultural materials, directly impacting biological dynamics as well. Extreme environments may limit certain forms of biological colonisation typical of temperate or humid climates, while simultaneously favouring the development of highly specialised organisms such as halophilic, xerophilic, and thermotolerant microorganisms capable of surviving under environmental stress. These organisms may trigger specific biodeterioration mechanisms that are still insufficiently studied and require targeted analytical approaches and intervention strategies.

Global climate change further amplifies these challenges by increasing the frequency and intensity of extreme events such as heatwaves, intense and sudden precipitation, sandstorms, and rapid microclimatic fluctuations. Such phenomena alter local ecological balances and may trigger new forms of biological and chemical degradation, making long-term management of cultural heritage increasingly complex.

In this scenario, the presence of a regional conservation and restoration centre equipped with advanced scientific, conservation, and restoration expertise plays a key role. Applied biology provides essential tools for biological risk assessment, continuous environmental monitoring, and the planning of preventive conservation strategies based on scientific analysis of local contexts. It also contributes to the development of restoration protocols specifically adapted to regional climatic and environmental conditions, avoiding the indiscriminate application of methodologies designed for different climatic settings.

Another highly relevant aspect concerns training and capacity building at the local level. Biology applied to conservation represents a privileged field for educating professionals capable of addressing contemporary environmental challenges by integrating scientific knowledge, cultural sensitivity, and awareness of territorial

specificities. In this sense, conservation becomes not only a technical activity but also an instrument of cultural and institutional development.

The systematic integration of biological sciences into conservation strategies allows, in the long term, increased resilience of cultural heritage, promoting sustainable management and informed valorisation of cultural assets. The models and methodologies developed in Jordan may also serve as a reference for other contexts characterized by similar environmental conditions, fostering the exchange of expertise and best practices at regional and international levels.

From this perspective, one of the main future challenges may be the creation of a structured institutional network involving the Department of Antiquities (DoA) and the universities of the Jerash and Amman governorates, particularly faculties of science, archaeology, and conservation. Such a network could support integrated research programmes dedicated to the study of biodeterioration processes, preventive conservation, and restoration of Jordanian cultural heritage, promoting interdisciplinary projects, advanced training, and knowledge transfer. This approach would strengthen local scientific capacity and consolidate a heritage management model based on knowledge, sustainability, and institutional cooperation.

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Environmental and biological degradation of a façade along the Colonnaded Street of Jerash (Jordan): a case study

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Tasneem Aamar Ahmad Al-Bataineh

Introduction and aims of the case study

This box presents a case study on a stone façade located along the colonnaded street in the northern sector of the archaeological site of Jerash (Jordan), selected for its complex environmental context and the evident presence of biological and physico-chemical deterioration phenomena.

Conducted within the framework of the course Biology Applied to Conservation, the study aims to investigate the interactions between materials, environmental conditions, and biological colonization, contributing to the documentation of the conservation state and the main factors influencing the degradation of this architectural element within one of the best-preserved examples of Greco-Roman urbanism in the Levant.

Architectural description and historical context

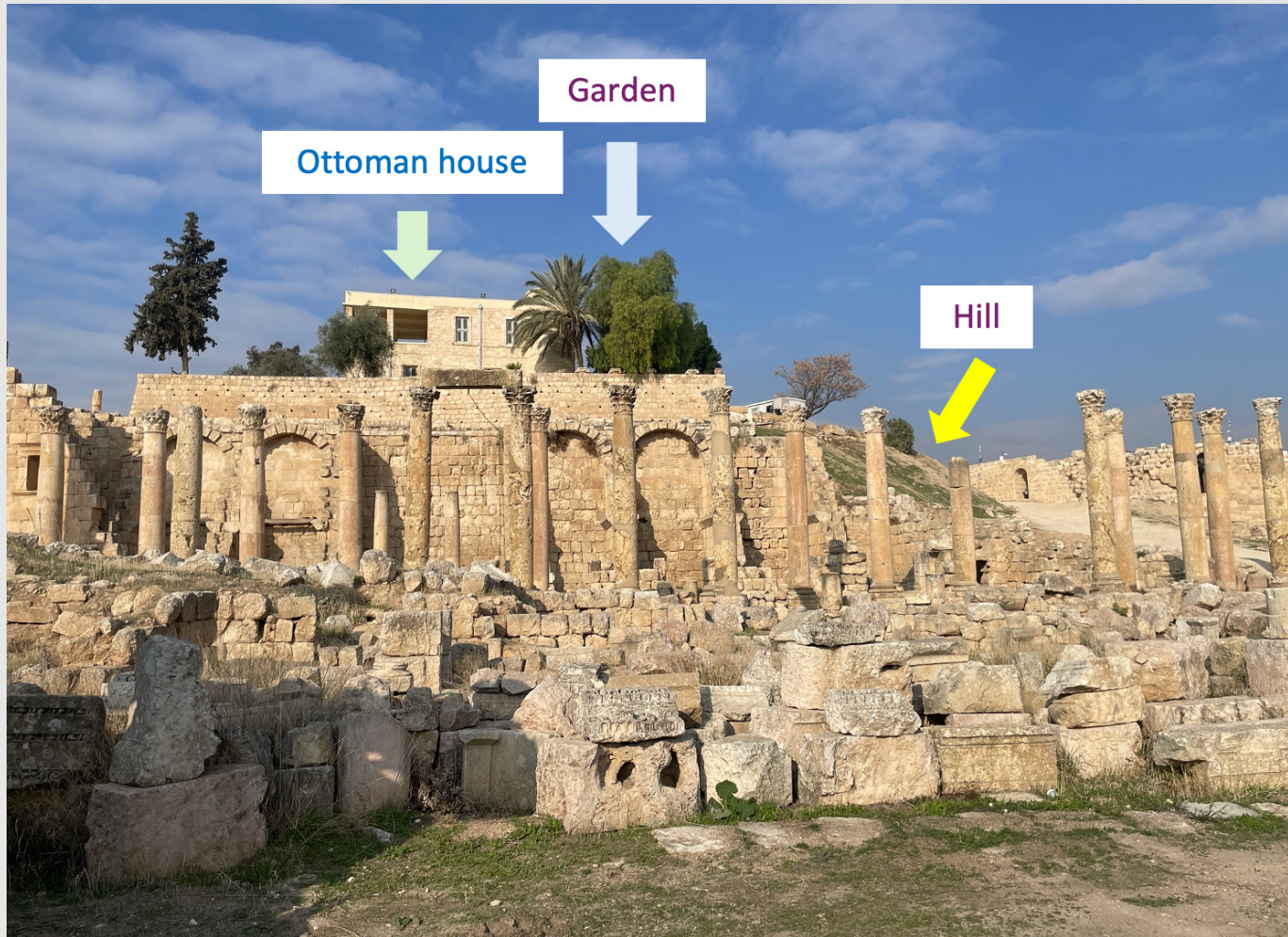
The selected architectural element is a stone façade belonging to two former shops located in the northern section of the colonnaded street at the archaeological site of Jerash (Fig. 1). Built mainly of local limestone and characterized by arched openings typical of Roman commercial architecture, the façade dates to the Roman period, when the colonnaded street functioned as the main commercial axis of the city.

Over time, the area developed into a stratified architectural context: during the Ottoman period, a house and an associated garden were constructed above the Roman remains, reusing earlier structures. This later occupation significantly altered the original environmental conditions of the façade, with its position beneath the Ottoman house and adjacent garden strongly influencing moisture levels, exposure, and biological activity, thereby affecting its current state of preservation.

Fig. 1

Location of the façade within the Jerash site examined in this case study. The orientation is also highlighted in the image.





Environmental setting and microclimatic conditions

The façade is located within a complex environmental setting influenced by a nearby hillside, an overlying garden, and an adjacent Ottoman-period structure surrounded by vegetation (Fig. 2). Unlike sheltered contexts, the area is characterized by effective ventilation and high solar irradiation, which enhance evaporation processes while simultaneously intensifying environmental stress on the stone surfaces. The presence of the hillside favors the accumulation of water and humidity, particularly along the right side of the façade.

The upper garden represents the primary source of organic material, which is transported downslope and redistributed by wind action. Aeolian processes convey dust, soil particles, and organic debris between architectural elements and into joints and interstitial spaces between stone blocks. The adjacent hillside further contributes to material accumulation through runoff and sediment transport.

The combined occurrence of episodic moisture availability, wind-driven particulate deposition, and organic matter accumulation promotes the formation of localized microsites within cracks, joints, and surface irregularities.

These microsites provide favorable conditions for the establishment of annual herbaceous plants on the masonry. Root growth and associated biochemical processes exacerbate stone decay, inducing mechanical stress, surface disruption, and progressive material loss.

Fig. 2

The examined façade and its environmental context within the Jerash site.

Over time, these interacting factors have resulted in localized detachment of stone fragments and visible deterioration, highlighting the strong influence of site-specific environmental dynamics on the current conservation state of the façade.

Documentation and methodological approach

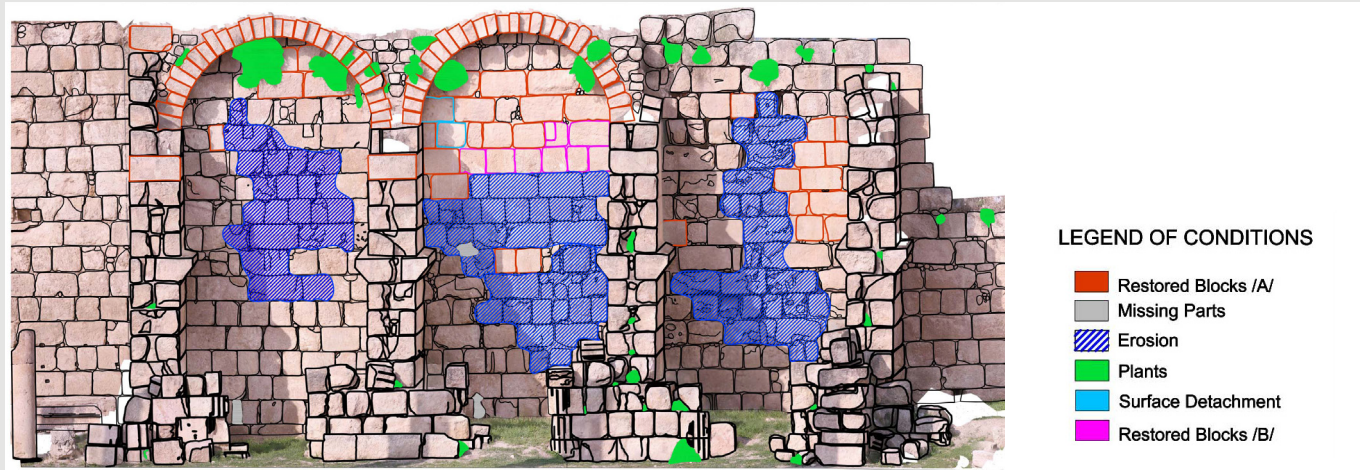
The study began with a preliminary site survey aimed at assessing the surrounding environmental conditions and identifying the initial deterioration processes affecting the façade.

Within the framework of the present case study, a second architectural artifact was also examined. This element is located directly opposite the main façade, at a distance of approximately 20 m, and was selected as a comparative reference to evaluate the behavior of sediment accumulation on stone surfaces under different exposure conditions.

The comparative artifact is a west-oriented limestone architectural element, decorated with carved vegetal and floral motifs. It was documented and mapped using the same methodological approach applied to the main façade. Unlike the adjacent architectural elements, this artifact remains largely shaded for most of the day, allowing a comparative assessment of how reduced solar irradiation influences sediment deposition, moisture retention, and surface decay dynamics.

Fig. 3
Main degradation phenomena identified and documented on the examined surfaces.



**Fig. 4**

Mapping of the degradation of the façade (Graphic elaboration Eng. T. A. Albataineh).

Following the preliminary survey, a systematic documentation process was carried out to record the conservation state and typologies of deterioration (Fig. 3). An initial visual inspection enabled the identification of erosion, fractures, material loss, and biological colonization. Subsequently, high-resolution photographic documentation was acquired from multiple viewpoints, including detailed close-ups of deteriorated areas. These images formed the basis for the development of an analytical model and for the identification and classification of biological and physico-chemical deterioration phenomena.

Based on photographic documentation and in situ observations, a degradation map was produced using AutoCAD, allowing for the spatial analysis of decay patterns. The mapping highlights the coexistence of biological and physico-chemical deterioration processes, with biological colonization preferentially concentrated in areas characterized by higher moisture availability and persistent shading.

The façade is illustrated below (Fig. 4), where different types of deterioration are identified through color coding. Blue areas indicate stone erosion affecting both original and restored stone, characterized by progressive surface material loss due to weathering. Light blue areas represent surface detachment, corresponding to partial separation of stone layers. Grey areas mark missing parts, where original stone blocks are lost, resulting in gaps in the masonry. Green areas indicate biological growth, primarily concentrated in joints and cracks where moisture accumulates, with additional spreading observed in the upper portions of the façade due to rainfall runoff. Red areas identify restored stone blocks from previous interventions (Type A), which appear more severely eroded and are distinguished by regular geometry and jointing. Pink areas represent restored stone blocks from a different intervention phase (Type B), which exhibit a lower degree of erosion.

Overall, the façade reflects a complex condition characterized by material decay, loss of original stone fabric, biological colonization, and the presence of multiple restoration phases.

To further investigate and better understand the degradation phenomena and biological colonisation affecting this area of the site, an additional architectural element was selected as a comparative reference (Fig. 5). This element is located opposite the façade under study but is characterised by a different orientation.

It consists of an architectural fragment exhibiting extensive and well-established biological colonisation. The element is situated in a more shaded area, and its decorative features and mouldings promote the retention and accumulation of rainwater. These microenvironmental conditions favour the development of biological patinas and



Fig. 5

Mapping of the degradation of the architectural element taken as an additional reference (Graphic elaboration by Eng. T. A. Albataineh).

the accumulation of soil particulates, creating a context particularly conducive to biodeterioration processes. The architectural element was mapped in order to highlight the main degradation phenomena, as showed in the photo below. Finally, all collected data were analyzed to understand the main causes of decay and to support the planning of future conservation interventions.

Interpretation and conservation issues

The façade is strongly influenced by surrounding environmental factors. From a biological perspective, the presence of trees and other vascular plants in the surrounding area does not currently constitute an imminent structural threat, as no roots penetrating or crossing the masonry were identified during the survey. Nevertheless, the proximity of vegetation represents a potential long-term risk, as progressive root development and associated biological processes may promote the formation and widening of cracks between stone blocks and should therefore be carefully monitored over time.

The environmental context of the façade contributes to increased erosion, cracking, surface deposits, detachment, and other deterioration phenomena, particularly as a result of prolonged exposure to prevailing eastern and south-eastern desert winds. These winds transport sand and fine particulate matter that are deposited on the stone surfaces, inducing mechanical abrasion and progressive erosion.

The intrinsic properties of the building material also play a key role in the observed decay processes. The façade is constructed of limestone characterized by relatively high porosity, which enhances its capacity to absorb environmental moisture and accelerates deterioration mechanisms. The façade functions as a biologically active stone surface, where moisture availability and favorable microclimatic conditions support biological communities that contribute to deterioration through both mechanical and biochemical processes. Distinctive erosion patterns observed on the limestone surfaces, together with the accumulation of deposits within masonry joints and interstices, further indicate the significant role of wind action. Prolonged exposure to prevailing winds, particularly from the east and south-east, results in the transport and deposition of desert sand and particulate matter, leading over time to

progressive micro-erosion. The resulting erosion products subsequently accumulate between stone blocks, exacerbating material loss and structural weakening.

Conclusions and perspectives for conservation

This case study highlights the strong influence of environmental and microclimatic conditions on biological and physico-chemical deterioration of stone façades in archaeological contexts.

Together, these factors highlight the need to consider biological agents as part of an integrated system involving environmental, material, and architectural conditions when developing effective conservation strategies.

The soft limestone and the winds cause progressive micro-erosion of the stone surfaces, while erosion products and deposits accumulate within joints and interstices between the masonry blocks.

Systematic documentation, degradation mapping, and continuous monitoring are essential tools for understanding decay processes, establishing baseline conditions, and supporting preventive conservation strategies.

This case study highlights the need to consider biological agents, environmental dynamics, material properties, and architectural characteristics as an integrated system when developing conservation strategies. It also represents a starting point for future investigations aimed at understanding the long-term evolution of decay processes. Periodic and systematic monitoring should therefore be planned for sites presenting similar environmental and exposure-related characteristics, as specific orientation, wind regimes, and surrounding vegetation play a decisive role in influencing the conservation state of stone-built heritage.



















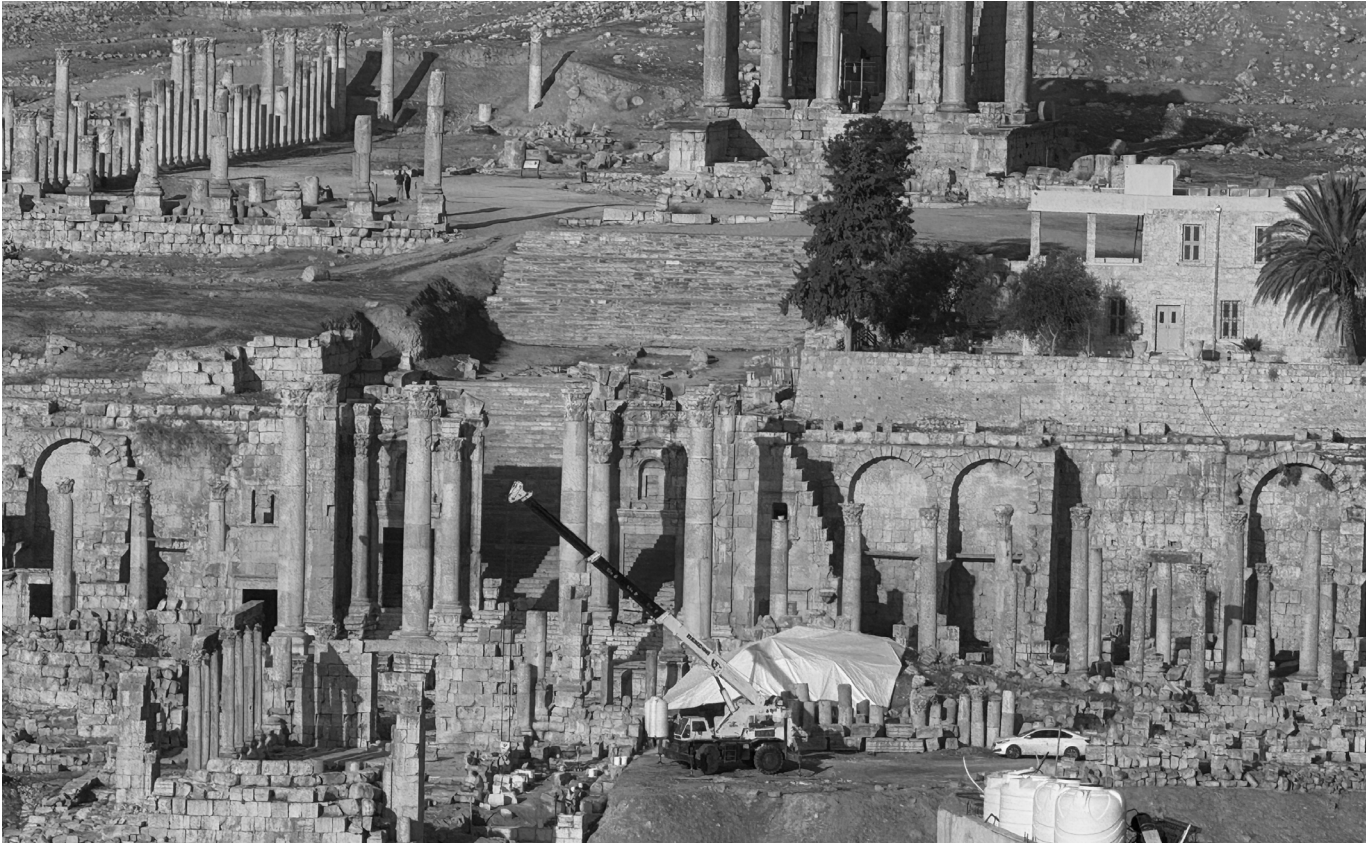




















البيولوجية، ووضع خطط استراتيجية للحفاظ المستدام، ودعم كفاءات الكوادر المحلية، من أجل تعزيز نموذجًا لإدارة التراث يركز على المعرفة العلمية والاستدامة والتعاون المؤسسي.

الكلمات المفتاحية

البيولوجيا التطبيقية، الحفاظ على التراث الثقافي، التلف البيولوجي والتحلل، الحفاظ الوقائي، الرصد البيئي، البيولوجيا الهوائية، الأردن، الحفاظ متعدد التخصصات

البيولوجيا التطبيقية في مجال الحفاظ على التراث الثقافي

كارلوتا ساكو بيراسو

اميمه احمد ناصر فوده، محمد حسن عبد الكريم البناء، تسنيم أعمار احمد البطاينة: التدهور البيئي والبيولوجي للواجهة على طول شارع الأعمدة في موقع جرش بالأردن - دراسة بحثية

ملخص

يتناول هذا الفصل دور البيولوجيا التطبيقية في مجال الحفاظ على التراث الثقافي وترميمه، مع إيلاء اهتمام كبير للتفاعلات بين المواد الثقافية والبيئة الطبيعية والأنشطة البشرية المحيطة بها. والتركيز بشكل خاص على عمليات التلف البيولوجي والتحلل والحت البيولوجي، مع تسليط الضوء على ما تقوم به الكائنات الدقيقة والنباتات والكائنات العليا في تغيير كلا من المواد العضوية وغير العضوية. ويميز البحث بين الكائنات ذاتية التغذية والكائنات غير ذاتية التغذية، ويفحص التعاقبات البيولوجية التي تتكون على الأصول الثقافية، مؤكداً على أهمية فهم استراتيجيات التمثيل الغذائي بغية اتخاذ تدابير وقائية وتخصيص أدوات رصد فعالة.

كما تقدم هذه الدراسة رؤية عامة فيما يخص العلوم البيولوجية التطبيقية المستخدمة في مجال الحفظ الوقائي من خلال استخدام المنهجيات التشخيصية المتقدمة، والرصد البيئي، والتحليلات الجزيئية. وتؤكد على الطبيعة المتعددة التخصصات المتأصلة في علوم الأحياء التطبيقية المستخدمة في مجال الترميم، وهي في حوار مع علم الآثار وتاريخ الفن وعلم المواد وممارسات الحفظ. وتتناول هذه الدراسة مجالات متخصصة مثل البيولوجيا الهوائية وعلم الأيقونات النباتية باعتبارها امتدادات مهمة لأبحاث وممارسات الحفظ المعاصرة.

وأخيراً، تتناول الدراسة الدور الاستراتيجي للبيولوجيا التطبيقية في السياقات ذات الحساسية البيئية، مع التطرق بشكل خاص إلى الأردن والمركز الإقليمي للصيانة والترميم في جرش. وفي بيئة تتميز بظروف مناخية قاسية وفي ظل التحديات المتزايدة التي يفرضها تغير المناخ، تبرز أهمية البيولوجيا التطبيقية كأداة أساسية لتقييم المخاطر

التدهور البيولوجي والحفاظ على التراث الثقافي الأردني جوليا كانيفا، كلية العلوم، جامعة روما تري

ملخص

من الممكن أن يشكل التلف البيولوجي للتراث الثقافي خطرًا كبيرًا فيما يتعلق بالحفاظ عليه، وذلك عندما تتيح طبيعة المواد المكونة للقطع الأثرية واستجابتها البيولوجية إقامة مستعمرات بيولوجية، ويتم ذلك حينما تكون الظروف البيئية مواتية لنمو الكائنات الدقيقة. ومن الممكن أن يؤدي نمو الكائنات الدقيقة والأشنات والطحالب والنباتات العليا إلى إتلاف هذه المواد عبر عمليات فيزيائية أو كيميائية مختلفة، ولذلك تعد المعرفة بهذه المخاطر أو العمليات التي تؤثر على هذه المواد أمرًا أساسيًا للحد من أثارها السلبية. كما يمكن من خلال التقييم البيئي للمجتمعات البيولوجية، والتي يمكن التعرف عليها عادةً من خلال أنماط التدهور البيولوجي المختلفة، أي الظواهر النمطية للتغير، دعم خطط التدخل التي يضعها المرممون عبر استراتيجيات وقائية (طرق التحكم غير المباشرة). بالإضافة إلى ذلك، كتدخل مباشر، تم استخدام وسائل و/أو منتجات مبيدات حيوية مختلفة، وكذلك تكثيف الأبحاث المخصصة لإيجاد حلول صديقة للبيئة. وخلال الدورة التدريبية التي عقدت في الأردن، تم تقديم رؤية عامة حول هذه المبادئ الأساسية بغية تعزيز قدرات علماء الحفاظ والمرممين لضمان الحفاظ المستدام على الآثار في موقع جرش الأثري والتراث الثقافي الممتد في جميع أنحاء الأردن.

الكلمات المفتاحية

التدهور البيولوجي؛ البيئة؛ المواقع الأثرية؛ الحفاظ الوقائي؛ المبيدات الحيوية

مقدمة في تشخيص المواد الجيولوجية في مجال التراث الثقافي ماريا كريستينا كاجياني وجيانكارلو ديلا فينتورا

بمساهمة من كل من :

محمد البناء، أميمة فوده، مركز جرش.

إدواردو روسي، ماريا كريستينا كاجياني، استخدام المجهر الإلكتروني الماسح ومطيافية
تشتت الطاقة بالأشعة السينية (SEM-EDS) في تحليل قطع الفسيفساء والسيراميك
المزجج في موقع جرش

ملخص

يشكل التشخيص الخاص بالمتعلقات الثقافية المطبق على المواد ذات الأصل الجيولوجي
نهجاً أساسياً يهدف إلى الفهم الكامل للقطع الأثرية، وهو يمثل نقطة الانطلاق الأساسية
ليس فقط من أجل ضرورة الفهم العميق من الناحية الأثرية والتاريخية، ولكن أيضاً
للتمكن من حفظها بشكل صحيح. يتم عرض الأساليب التحليلية المستخدمة عادة لهذا
الغرض بشكل موجز في عدة إطارات في هذا الفصل، وتشمل تقنيات الفحص
الميكروسكوبية والطيفية والحيودية. كما تم تخصيص مساحة لتجربة البرنامج التعليمي
في مركز الصيانة والترميم في جرش.

الكلمات المفتاحية

علم الآثار، المواد الجيولوجية، الرخام، السيراميك، الميكروسكوب، الطيف الضوئي،
تقنيات حيود الأشعة السينية

مقاربة منهجية لتنفيذ خطة تشخيصية تهدف إلى الحفاظ على القطع الأثرية الخطوط التوجيهية للحفاظ على المواد الحجرية

فاسكو فاسينا

ملخص

إن تطبيق المبادئ العلمية وأساليب البحث ذات الصلة على دراسة سلوك المواد أمر بالغ الأهمية لفهم ظواهر التغير التي تطرأ على المواقع الأثرية. يعتمد التشخيص، أي دراسة أسباب التغير، على تطبيق المبادئ العلمية وهو ضروري لتوصيف وتقدير وتفسير وتقييم الأضرار التي تلحق بالمواد المكونة للقطع الأثرية. أولاً، يتم توثيق حالة الحفظ من خلال الملاحظة البصرية، ثم القيام بالتحليلات المخبرية الدقيقة. يتم تحديد الفحوصات الرئيسية التي تم إجراؤها، طبقاً للوائح الفنية الأوروبية، والتي تتيح التوصيف السلوكي للمواد وعلاقتها بالبيئة الجوية التي تتواجد فيها.

الكلمات المفتاحية

التدهور، المواد الحجرية، التزهير، التقشر، الفلورية، المجهر الإلكتروني الماسح

ترميم فسيفساء دياكونيا في كنيسة بروبيليا، الحديقة الأثرية في جرش

الحفظ في الموقع، التعاون الدولي، وموقع العمل التعليمي

سوكول موكا، تيسا بيريلو

ملخص

تتناول هذه المساهمة عرضاً لعمليات الحفاظ والترميم التي شهدتها فسيفساء دياكونيا في كنيسة بروبيليا في جراسا (565 م)، والتي تم التعامل معها باعتبارها حالة بحثية لدراسة وتحليل الإشكاليات النمطية المتعلقة بالأرضيات الفسيفسائية الأثرية المحفوظة في الموقع. وقد تضمن العمل إجراء استقصاءات تقنية، وفحص للمواد والآليات المستخدمة في التنفيذ، وتحليل تاريخ الحفظ، والقيام بتدخلات رامية إلى تأمين الموقع، وعمليات التنظيف، والتثبيت، والترميم بالجص، مع الالتزام بمبادئ التوافق، وقابلية إزالة المواد المضافة، والتدخل الأدنى. وقد تم تنفيذ عمليات الحفاظ والترميم في سياق تعليمي في الموقع، مع التركيز على عنصري التدريب والتعاون. وأخيراً، تم إيلاء اهتمام خاص للحفاظ الوقائي، وذلك من خلال تصميم وإنشاء تغطية مؤقتة ستكون مفيدة في التدخلات المستقبلية على هذه المنشآت وستساهم كذلك في إبراز قيمة الموقع.

الكلمات المفتاحية

الفسيفسائيات الأرضية، الحفظ في الموقع، موقع العمل التعليمي، التعاون الدولي، الترميم الأثري، تغطية مؤقتة

بمساهمة من:

تسنيم أمير احمد البطاينة، تمام خالد عبد القادر المجغف، نجدت مأمون عبد الرؤوف هزايمة، التوثيق

بكر ياسين عبد الله الزواهره، مصطفى محمود سرور الحوامده، مرشود علوان حسين الدوجان، دراسة النقوش

الجوانب البنوية للجدار المحيط بفسيفساء دياكونيا في كنيسة بروبيليا في جرش، الأردن

فلورين كريستينيل ستان، مارتينا بوتشي، سارة فارس، نجدت مأمون عبد الرؤوف
هزايمة، تسنيم أعمار أحمد البطاينة، ستيفانو دي سانتيس، جانماركو دي فيليشي

ملخص

تتناول الدراسة استقرارية الجدار المتبقي من دياكونيا في كنيسة بروبيليا في جرش، وهو بناء بيزنطي شُيد في القرن السادس الميلادي فوق أنقاض مبنى روماني سابق. تم اشتقاق النموذج الهندسي للهيكل من سحابة نقطية عالية الكثافة تم الحصول عليها من خلال المسح التصويري الضوئي ودمجها في كود العناصر المميزة. يتم إجراء تحليلات استاتيكية وديناميكية لمحاكاة ظروف الجاذبية والحمل الزلزالي. ثم يتم تقييم استقرار الجدار وتحديد استراتيجيات الترميم، إلى جانب عمل السقالات المؤقتة اللازمة، التي يتم تصميمها وتركيبها.

الكلمات المفتاحية

البناء، الاستقرار، هيكل الكتل، طريقة العناصر المميزة، المسح التصويري، التحليل البنوي، الترميم

المصلبة الجنوبية في جرش: قراءة تاريخية – تقنيات التشخيص والترميم المحافظ في الموقع.

سوكول موكا، لوشانا فيستا، نيكولاس فاكاليس

بمساهمة من كل من:

نجدت مأمون عبد الرؤوف هزايمة، تسنيم أعمار احمد البطاينة، محمد علي مصطفى
العلاونة، التوثيق في المصلبة الجنوبية، موقع جرش الأثري

ملخص

تقدم هذه المساهمة عرضاً لأعمال الحفاظ والترميم التي أجريت على المصلبة الجنوبية في جرش، وهو نصب روماني يقع عند تقاطع شارع الأعمدة الكاردو ماكسيموس والديكومانوس الجنوبي، وقد تم بحثه كحالة دراسية تتناول مشكلات الحفظ النمطية التي تواجه المباني الأثرية الحجرية المعروضة في موقعها الأصلي. وقد جمعت الدراسة بين التحليل التاريخي، والتحليل التكنولوجي للمواد، والفحوصات التشخيصية الأولية، وتدخلات التنظيف الموجهة، وإزالة المواد غير المتوافقة، والتدعيم والتثبيت باستخدام ملاط من الجير الهيدروليكي الطبيعي. وقد تم إيلاء اهتمام خاص لتوافق المواد، ومعالجة الإضافات الحديثة، والحد من ظواهر التلف البيولوجي. تم تنفيذ العمل على هيئة ورشة عمل تعليمية في إطار مشروع إنشاء المركز الإقليمي للصيانة والترميم في جرش.

الكلمات المفتاحية:

ترميم المواد الحجرية، دورات تدريبية، نصب روماني، الحفاظ في الموقع.

تجربة دورة تدريب العاملين مستخدمي الليزر في مركز الترميم في جرش

لورا بارتولي

مؤسسة El. En.

ملخص

التنظيف بالليزر هو تقنية انتقائية وقابلة للتحكم تستخدم في مجال الحفاظ على التراث الثقافي، وتطبق على المواد الحجرية والمعدنية والرسومات. تتناول هذه المساهمة تطور استخدام تكنولوجيا الليزر في مجال الترميم وتجربة دورة تدريب العاملين مستخدمي الليزر التي عقدت في نوفمبر 2023 في المركز الإقليمي للصيانة والترميم في جرش. اشتملت هذه الدورة على دروس نظرية حول المبادئ الفيزيائية، والتفاعل بين الليزر والمادة، واجراءات السلامة، وتضمنت كذلك أنشطة تدريب عملية على القطع الأثرية، مع التأكيد على أهمية صحة المعايير والقياسات بالإضافة إلى التدريب المتخصص.

الكلمات المفتاحية

التنظيف بالليزر، حفظ التراث الثقافي، مستخدمو الليزر، التقنيات المبتكرة

التأهيل والمنهجية في ترميم الفسيفساء: تجربة المركز الإقليمي للصيانة والترميم في جرش

فرانشيسكا مارياني، كريستينا كالدي، سارة شوشا، مارتينا فاجولي

ملخص

تقدم هذه المساهمة تجربة البرنامج التدريبي الذي أُجري في عام 2024 في المركز الإقليمي للصيانة والترميم في جرش، والذي خصص للحفاظ وترميم الفسيفساء المنفصلة. وقد جمع البرنامج بين الدراسة النظرية والتطبيق العملي من خلال دراسة الفسيفساء بالأرضية المحفوظة في قلعة عجلون على شكل ألواح. وقد أتاح تحليل هذه الأجزاء تحديد مختلف استراتيجيات الترميم والحفظ الوقائي اللازمة، مقدمًا بذلك نموذجًا تعليميًا وعمليًا قابلاً للتكرار بغية تحقيق الإدارة المستدامة للفسيفساء المنفصلة.

الكلمات المفتاحية

ترميم الفسيفساء، الفسيفساء المنفصلة، التدريب على الحفاظ، الحفظ الوقائي، الدعامات القابلة للإزالة، العرض المتحفي، مراقبة المناخ المحلي

ترميم وحفظ المواد الحجرية

لوشانا فيستا، نيكولاس فاكاليس

ملخص

يحتوي هذا المقال على تحليل منهجيات ترميم وحفظ المواد الحجرية، مسلطاً الضوء على أهمية الفحوصات التشخيصية والدقة في مرحلة التخطيط وتحديد التدخلات المتوافقة والقابلة للإزالة. كما يتم تناول تجربة البرنامج التعليمي في المركز الإقليمي للصيانة والترميم في جرش، والتي تستند إلى المقاربة متعددة التخصصات، والتي تدمج الدراسة النظرية والممارسة المخبرية واستخدام التقنيات المبتكرة لحماية التراث الثقافي.

الكلمات المفتاحية

المواد الحجرية، التوثيق، التشخيص، تدخلات الحفاظ، الصيانة

استراتيجيات الحفاظ على القطع الأثرية الأردنية المصنوعة من البرونز والحديد

معالجة مشكلات التلف النمطية

شين ييجيا، كريستينا باسيري، إيزابيتا بروناس، أليكس سارا

بمساهمة كل من:

بلال فواز محمد البوريني، قيس عزمي رضوان المومني، محمد علي مصطفى
العلاونة، ايمان سليمان مفلح قرعان، ريتا سليمان يوسف الداود، حسين محمد محمود
قريشات

ملخص

بناء على حالة القطع الأثرية الأردنية المصنوعة من البرونز والحديد التي تم فحصها في المختبر العلمي التابع لبرنامج التعاون الإيطالي الأردني، تهدف هذه الدراسة إلى إتاحة مرجعية تقنية للمتخصصين في مجال حفظ التراث في الأردن. وتقدم الدراسة خطوط توجيهية حول الأساليب والمواد اللازمة لخطوات الحفظ الأساسية، بما في ذلك التنظيف، وإعادة التجميع، وسد الفجوات، ومنع التآكل النشط، وحماية الأسطح، والتدابير الوقائية، وتشمل كذلك ملاحظات الدارسين الأردنيين، مما يوفر رؤية المشاركين في البرنامج بشكل مباشر.

الكلمات المفتاحية

حفظ المعادن، الأردن، برنامج التعاون الإيطالي الأردني، البرونز، الحديد

الحفاظ على الزجاج الأثري

الجزء الأول: ترميم وحفظ الزجاج الأثري - مشاكل منهجية

إليزابيث هوبر

الجزء الثاني: ترميم الزجاج بموقع جرش

مانويلا فايتا

ملخص

تتناول هذه الدراسة المشاكل المنهجية الرئيسية المتعلقة بالحفاظ على الزجاج الأثري وترميمه، وهو مادة ذات درجة عالية من الهشاشة والحساسية تجاه العوامل البيئية. بعد تحديد الخصائص التركيبية وظواهر التدهور، يتم عرض معايير ومنهجيات التدخل الموجهة نحو توافق المواد وحماية الأسطح الأصلية. تشكل حالة الزجاج المنتمي للعصر الروماني من موقع جرش مرجعًا تطبيقيًا في مجال التدريب على الترميم المحافظ.

الكلمات المفتاحية

الزجاج الأثري؛ الترميم المحافظ؛ المنهجية؛ التدهور؛ جرش

المنهجيات والممارسات المتبعة في ترميم السيراميك

نيكولا باجاني، كريستينا باسيري

بمساهمة كل من:

بلال فواز محمد البوريني، قيس عزمي رضوان المومني، محمد علي مصطفى
العلاونة، اميمه احمد ناصر فوده، ريتا سليمان يوسف الداود، حسين محمد محمود
قريشات، ايمان سليمان مفلح قرعان

ملخص

تقدم هذه المساهمة تجربة البرنامج التدريبي في ترميم السيراميك التي تطورت في إطار
التعاون الدولي. من خلال مقارنة منهجية مستوحاة من المدرسة الإيطالية، جمعت هذه
الدورة بين الدراسة النظرية والممارسة العملية في المختبر، مما عزز روح الوعي
النقدي والحوار بين الثقافات والتفكير الأخلاقي فيما يتعلق بتدخلات الحفظ.

الكلمات المفتاحية

الحفاظ على التراث الثقافي؛ منهجية الترميم؛ الترميم الأثري؛ ترميم السيراميك؛ ورشة
تعليمية؛ التكامل اللوني والمادي؛ العمل الجماعي

التوثيق الرقمي في مجال الترميم: التصوير الفوتوغرافي، والتصوير المساحي

الضوئي ثلاثي الأبعاد، ونظم المعلومات الجغرافية

في إطار البرنامج التدريبي في الأردن

ياكوبو روسو

ملخص

تصف هذه المساهمة البرنامج التدريبي الذي أقيم في الأردن، والمعني باستخدام التوثيق في مجال الترميم، وهو برنامج موجه إلى العاملين من ذوي الخبرات المتنوعة. تناول البرنامج دروس وورش ميدانية تشمل كافة مراحل التوثيق: التصوير الفوتوغرافي وكيفية ضبطه من حيث الإضاءة والوضعية واللون باستخدام أداة فحص الألوان، والهندسة الإسقاطية، والمسح المباشر، والتصوير المساحي الضوئي ثلاثي الأبعاد باستخدام Metashape، والصور مصححة الأبعاد الأورتوفوتو ونموذج الارتفاع الرقمي (DEM)، وصولاً إلى الإدارة المتكاملة باستخدام برنامج QGIS على GeoPackage للبيانات النقطية والمتجهة والأبجدية الرقمية من أجل الحصول على خرائط وتحليلات قابلة للتطبيق والتحقق.

الكلمات المفتاحية

التصوير المساحي الضوئي ثلاثي الأبعاد، الصور مصححة الأبعاد الأورتوفوتو،

GeoPackage، QGIS

شبكة الجامعات والمؤسسات البحثية الأردنية: الدعم الاستراتيجي للمركز الإقليمي
للصيانة والترميم في جرش
قيس المومني*، ياسمين ولويل**

* المركز الإقليمي للصيانة والترميم في جرش
** دائرة الآثار العامة الأردنية

ملخص

يتناول هذا الفصل بالتحليل شبكة الجامعات والمؤسسات البحثية والجهات الحكومية والبنى التحتية العلمية والمنظمات الدولية المشاركة في حفظ التراث الثقافي في الأردن. ويبحث كذلك الإسهامات التي تقدمها المؤسسات الأكاديمية الرئيسية والسلطات الوطنية ومراكز البحوث الدولية والهيئات العلمية المتطورة، بما في ذلك "المركز الدولي لضوء السنكروترون للعلوم التجريبية وتطبيقاتها في منطقة الشرق الأوسط". ويسلط هذا الفصل الضوء على الدور الاستراتيجي للمركز الإقليمي للصيانة والترميم في جرش كمركز يقوم بدور تنسيقي يدمج ما بين البحث العلمي والتدريب والممارسات التطبيقية في مجال الحفاظ بغية تعزيز كفاءات القدرات الوطنية ودعم الدور الريادي للأردن على الصعيد الإقليمي في مجال الحفاظ على التراث الثقافي.

الكلمات المفتاحية

الحفاظ على التراث الثقافي، الأردن، المركز الإقليمي للصيانة والترميم، الجامعات والمؤسسات البحثية، علوم التراث، المركز الدولي لضوء السنكروترون للعلوم التجريبية وتطبيقاتها في منطقة الشرق الأوسط، التعاون الدولي.

التدريب التخصصي في مجال الترميم في المركز الإقليمي للصيانة والترميم في

جرش

ماريو ميكيلي*، بلال فواز محمد البوريني**

*جامعة روما تري

**المركز الإقليمي للصيانة والترميم في جرش

ملخص

تستعرض هذه المداخلة مراحل تطور الخبرات في "النظام الإيطالي" في مجال ترميم التراث الثقافي، في سياق ما تم إنجازه على الصعيد الدولي بأكمله في إطار برامج بناء القدرات في مجال مهن الترميم. مع تقديم عرض يتناول مشروع التدريب الذي تم تنفيذه في المركز الإقليمي للصيانة والترميم في جرش، في إطار المشروع الذي تبنته الوكالة الإيطالية للتعاون الإنمائي وعُهد به إلى جامعة روما تري لصالح دائرة الآثار العامة في الأردن. وتمثل هذه التجربة التي أجريت في جرش، مقارنة بسابقاتها من المبادرات التي قامت بها وكالة التعاون الإيطالية في جمهورية الصين الشعبية منذ التسعينيات من القرن الماضي، حالة بحثية دراسية هامة يمكن الاستفادة منها بغية تطوير برامج تدريبية يمكن تكرار تطبيقها في سياقات أخرى من التعاون الدولي.

الكلمات المفتاحية:

نظرية الترميم؛ المعهد المركزي للترميم؛ المعهد الإيطالي للشرق الأوسط والشرق الأقصى؛ مركز التدريب الصيني - الإيطالي؛ تدريب المدربين

الاستمرارية والتمايز والقدرة: ملاحظات المصمم حول نموذج إعادة الاستخدام
التكيفية في المركز الإقليمي للصيانة والترميم في جرش
جمانة بداد، رامي ضاهر، مكتب تراث للدراسات والتصميم

ملخص

الاستمرارية والتمايز هما الأساس في وضع التصميم وإعادة الاستخدام التكيفية لمبنى عام حديث في جرش ليصبح المركز الإقليمي للصيانة والترميم. وانطلاقاً من التقييم متعدد الأوجه وفهم طبيعة ونمط المكان، يأتي دور التدخل التصميمي للفناء الرئيسي مع إدخال إضافات معاصرة ومتعددة الاستخدامات تعزز الأداء الوظيفي العام للمبنى. وبذلك يعيد هذا المشروع صياغة مفهوم الحفاظ كونه إطار تعليمي نشط ومستدام، ويربط حماية التراث ببناء القدرات وتبادل المعرفة على المستوى الإقليمي.

الكلمات المفتاحية

إعادة الاستخدام التكيفية، التدخل المعماري، الحفاظ التعليمي

البعثة الأثرية الإيطالية في جرش

دانيلا بالدوني*، ماسيمو بريتسي*، رافايلا بيروبون بنويت**

*مؤمينا أورينتاليا (Monumenta Orientalia)

**أستاذة سابقة في جامعة نابولي فيديريكو الثاني

ملخص

تستعرض هذه المساهمة خمسين عامًا من نشاط البعثة الأثرية الإيطالية في جراسا / جرش، محددة أصولها وتطور منهجياتها وآفاقها المستقبلية. تأسست البعثة في عام 1976 بمبادرة من جورجو جوليني وتحت إشراف روبرتو بارابتي، وجمعت بين البحث الأثري، والترميم المحافظ، والتدريب المهني، والتقييم التشاركي للتراث الأثري. من بين التدخلات العديدة التي تم تنفيذها، تم اختيار ثمانية مشاريع أجريت في معبد أرتميس وفي المنطقة الأمامية بروبيليا والتي تعد معبرة بشكل خاص عما قدمته البعثة من إسهامات علمية.

الكلمات المفتاحية

جراسا / جرش، البعثة الأثرية الإيطالية، معبد أرتميس، حفظ وترميم التراث الأثري.

الوكالة الإيطالية للتعاون الإنمائي والمركز الإقليمي للصيانة والترميم في جرش

إميليو كاباسينو

الوكالة الإيطالية للتعاون الإنمائي

ملخص

تتناول هذه المساهمة عملية تأسيس وتنفيذ مشروع إنشاء المركز الإقليمي للصيانة والترميم في جرش بالأردن، وكذلك طرحه كنموذج للتعاون الإنمائي في مجال التراث الثقافي. فقد تم إنجاز هذا المشروع بالعمل في إطار الشراكة الوطنية والمستمرة مع السلطات المحلية، وذلك من خلال ترميم مبنى تاريخي وتزويده بمعدات تخصصية وعمل برنامج تدريب متقدم. تم تنفيذ الأنشطة من قبل هيئة دولية وجامعة إيطالية حكومية، وبمشاركة متخصصين إيطاليين رفيعي المستوى، مما ساهم في تطوير قدرات الكوادر المحلية، وتعزيز الاستدامة المؤسسية للمنشأة وانتقال المعرفة والإجراءات اللازمة لترميم التراث الثقافي، ليس فقط في الأردن، ولكن أيضاً على صعيد منطقة الشرق الأوسط وشمال إفريقيا.

الكلمات المفتاحية

التعاون الإنمائي؛ الشراكة؛ التراث الثقافي؛ الترميم؛ التدريب المتخصص؛ الأردن

يجسد مشروع المركز الإقليمي للصيانة والترميم في جرش تجربة نموذجية للمهمة العامة للجامعة المعاصرة والمتمثلة في إنتاج المعرفة، وتنمية الخبرات، وبناء المؤسسات. وقد أظهرت جامعة روما تري هويتها كجامعة عامة مبتكرة على الساحة الدولية، مما يدل على قدرتها على دمج التجديد المادي والمسؤولية المدنية والحوكمة متعددة المستويات. وتُظهر تجربة جرش أن التعاون الجامعي، عندما يسترشد برؤية استراتيجية متسقة، يصبح وسيلة للدبلوماسية الثقافية ويساهم في تعزيز قدرات المؤسسات. ويحدد التدريب المتخصص والإدارة التي تتسم بالشفافية وتنمية قدرات الكوادر المحلية نموذجًا قابلاً للتطبيق في مجال التعاون، تمثل فيه الثقافة البنية التحتية للتنمية المشتركة. ومن هذا المنظور، تؤكد جامعة روما تري والوكالة الإيطالية للتعاون الإنمائي على قيمة الشراكة التي توحد السياسة والعلوم والإدارة ضمن إطار واحد من المسؤولية العامة والتقدم المستدام.

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المشاريع بالتنسيق التشغيلي والمتابعة الفنية والإدارية وإعداد التقارير. ويتولى الإدارة التنفيذية مسؤولون حكوميون رفيعو المستوى في الجامعة وهم مفوضون بمسؤولية التدويل والمهمة الثالثة، ومكلفون بترجمة التخطيط الاستراتيجي للجامعة إلى تنفيذ عملي للمشروع. ويدمج هذا الدور مستويات التخطيط المختلفة – الخطة الاستراتيجية الثلاثية للجامعة، وخطة الأنشطة والتنظيم المتكاملة (المرسوم التشريعي 2021/80)، وأهداف الشراكة للوكالة الإيطالية للتعاون الإنمائي في إطار متسق يشمل النتائج والمؤشرات والتأثيرات.

يتيح هذا الهيكل التنظيمي التوافق بين الرؤية والتنفيذ، مانعًا بذلك حدوث فجوة بين التوجه السياسي والتنفيذ الإداري. وتعمل الإدارة العامة كجسر يربط بين المجالين الأكاديمي والمؤسساتي، مما يضمن التطبيق المعرفي المنتج في معامل جامعة روما تري على مواقع الترميم في جرش، وأن النتائج التي يتم إنجازها في الخارج تعود بالنفع على التخطيط الداخلي للجامعة. ويساعد هذا النموذج للإدارة العامة في الجامعة على سد الفجوة التي غالبًا ما تكون واضحة بين التخطيط الاستراتيجي رفيع المستوى والتنفيذ العملي له، من خلال ربط الكفاءة الإدارية للهيئات العامة مع ثقافة تمتد جذورها في البحث والتدريب المتخصص.

وبذلك يصبح مركز جرش للصيانة والترميم نموذجًا للتعاون المستدام، حيث يترجم بناء القدرات إلى خبرة مؤسسية: يشمل تدريب الكوادر المحلية، ومشاركة الخطوط التوجيهية لصالح دائرة الآثار العامة، وبروتوكولات الحفظ الوقائي، والأرشفة الرقمية، وشبكة الشراكة الأكاديمية الإقليمية. إن ضمان الاستدامة لهذا المركز لا يتحقق من خلال الموارد المادية والبنية التحتية فحسب، بل وقبل كل شيء من خلال نموذج حوكمة يقوم على تشارك المسؤولية ونقل المعرفة، مما يجعل من المؤسسات المحلية عناصر فاعلة رئيسية في حماية هذا التراث.

ومن هذا المنطلق، يمثل نموذج جرش مزيجًا من التعاون التقني والدبلوماسية العلمية – وهو مشروع حكومي وأكاديمي يوضح كيف يمكن للتدريب المتخصص، عندما يسترشد بحوكمة متعددة المستويات، أن يولد قيمة دائمة وقابلة للتكرار. ويشير نجاح هذا المشروع إلى الاتجاه الاستراتيجي في مجال التعاون الجامعي الدولي، والذي يتمثل في الانتقال من نطاق التدخلات المنعزلة إلى أنظمة قدرات دائمة، تعمل فيها الجامعات والإدارات العامة كهيكمل واحد للمعرفة والمسؤولية.

ينقل برنامج تدريب المرممين والفنيين والكوادر المحلية - الذي تم تطويره بالتعاون مع الوكالة الإيطالية للتعاون الإنمائي ودائرة الآثار العامة الأردنية - المنهجية المتكاملة لجامعة روما تري، والتي تجمع فيها عناصر البحث العلمي والتدريب المتخصص والحوكمة المؤسسية في إطار عمل واحد، إلى السياق المتوسطي.

وفي هذا السياق، يجدد نموذج جرش، على الصعيد الدولي، مبدأ «القدرة التحويلية المؤسسية» الذي يميز جامعة روما تري. ففي روما، يعتبر التجديد العمراني أداة للمواطنة؛ وفي الأردن، يصبح التجديد الثقافي وسيلةً للدبلوماسية العلمية والتعاون المستدام. وفي كلا السياقين، فإن المادية المكانية وجودة الترميم ينمان عن مفهوم الجامعة باعتبارها شكلاً من أشكال البنى التحتية للمدينة، القادرة على الجمع بين الخبرة الأكاديمية والمسؤولية العامة. ويؤكد الاتساق مع اتفاقية وزارة الشؤون الخارجية والتعاون الدولي والوكالة الإيطالية للتعاون الإنمائي 2025-2027 التي تعزز الشراكة بين الجهات المؤسسية والأكاديمية والتقنية في تخطيط المشاريع ومراقبتها، الأهمية المستمرة لهذا النهج العام والأكاديمي للتعاون.

تم تصميم المركز الإقليمي للصيانة والترميم في جرش ليكون بمثابة منصة للتدريب ونقل المهارات، انطلاقاً من أن فكرة التعاون الثقافي لا تكون فاعلة إلا عندما تكون قادرة على خلق قدرات مستقلة ومنشآت مستدامة داخل البلد الشريك. وهذا يعني أن المركز هو أكثر من مجرد كونه معمل تقني للترميم، بل هو ساحة للتعليم والحوكمة، حيث يتشابك التدريب مع البحوث التطبيقية والإدارة المشتركة. ويهدف نهج بناء القدرات الذي تدعمه جامعة روما تري إلى تعزيز كفاءات الكوادر المحلية من خلال الدورات المهنية وتأهيل المختبرات التشخيصية واعتماد برامج تعليمية تشمل كلا من الدراسة النظرية والممارسة العملية طبقاً للمعايير الأوروبية والتميز الإيطالي في مجال الحفظ، وكذلك مع تبني منهجية متكاملة تشمل جميع التخصصات العلمية والتكنولوجية والإنسانية.

تعكس البنية الإدارية للمشروع المنطق متعدد المستويات الذي حددته اتفاقية وزارة الشؤون الخارجية والتعاون الدولي والوكالة الإيطالية للتعاون الإنمائي 2025-2027. وتضمن لجنة توجيهية مؤلفة من كبار الممثلين - من بينهم المدير العام لجامعة روما تري، ونظرائه من الوكالة الإيطالية للتعاون الإنمائي، ودائرة الآثار العامة الأردنية - الاتساق الاستراتيجي والتوجيه السياسي والمؤسسي للمبادرة. وتقوم وحدة إدارة

وفي هذا السياق، تقوم جامعة روما تري بدور عام في مجال الريادة المؤسسية والعلمية. حيث أنها تشارك بصفقتها هيئة تنفيذية وشريكاً تقنياً بموجب المادة 26 من القانون 125/2014، وتساهم في تطوير نماذج بناء القدرات القائمة على التدريب المتخصص والبحوث التطبيقية والإدارة المشتركة للتراث الثقافي.

يمثل مشروع المركز الإقليمي للصيانة والترميم في جرش، الذي ترعاه الوكالة الإيطالية للتعاون الإنمائي، ودائرة الآثار العامة الأردنية، وجامعة روما تري المنسق العلمي للمشروع، نموذجاً تتجسد فيه كيفية نقل هذه المبادئ إلى حيز الممارسة العملية، حيث يجمع بين التعاون الثقافي والدبلوماسية العلمية، ويعزز نموذج متكامل للحوكمة تتفاعل فيه الأبعاد الأكاديمية مع المستويات السياسية والإدارية والتقنية، وفقاً لمنطق التنسيق والشفافية الذي أرسنه الاتفاقية.

شكلت جامعة روما تري هويتها المؤسسية المميزة حول أبعاد مادية وتحولية. وقد كان قرار إنشائها في مناطق أثرية صناعية – بدءاً من مجزر تيسنتاتشيو ووصولاً إلى مصنع الزجاج السابق بمنطقة سان باولو وفاسكا نافالي – انعكاساً معمارياً لمنظورها العام للتعليم: المعرفة باعتبارها إحياءاً للمدينة ولتراثها المادي. وكما يلاحظ أتاناسيو وريسبولي (2024)، «أثبتت روما تري، على مدار ثلاثين عاماً من وجودها، أنها محركاً للتحويل، وأنها قادرة على إلهام التغيير والمساهمة في بناء مدينة أكثر شمولية وديناميكية واستدامة». أدى إعادة تطوير المساحات الجامعية إلى إعادة كتابة المشهد العمراني من خلال الثقافة، وإعادة الإحياء ومشاركة هذه الأماكن مع المجتمع. أصبحت المباني المعاد توظيفها مصانعاً للمعرفة - مراكز متميزة للتدريس والبحث وأنشطة المهمة الثالثة¹ - تجسد مبدأ الاستمرارية فيما بين الذاكرة والوظيفة والمستقبل.

يشكل هذا البعد المادي، الذي يُنظر إليه على أنه حوار قائم بين البيئة العمرانية والمعرفة، النموذج الذي تصدره جامعة روما تري أيضاً إلى العمل في مجال التعاون الدولي. ويمثل إنشاء المركز الإقليمي للصيانة والترميم في جرش امتداداً رمزياً وعملياً لها: من جامعة تعمل على تجديد المساحات العمرانية إلى شريك عام يعمل على إحياء التراث الثقافي. وكما هو الحال في مشاريع إعادة التطوير التي تم تنفيذها في روما، فإن العمل في جرش يتجاوز نطاق الترميم المادي للمواقع ليتركز على بناء مجتمع من الخبراء.

¹ المهمة الثالثة: هي دور الجامعة في خدمة المجتمع ونقل المعرفة، وتأتي تكاملاً مع المهمتين الأساسيتين (التدريس والبحث العلمي).

(MAECI-AICS 2025-2027) - كفلت الشفافية والتنسيق والاستمرارية المؤسساتية. وقد تجلّى التآزر بين الأبعاد السياسية والإدارية والعلمية كعامل حاسم في نجاح هذه المبادرة وقابلية تكرار تطبيقها.

يشير نموذج جرش أنه عندما يتم إدماج التدريب والإدارة ضمن إطار موحد، يمكن أن يشكلًا معًا نموذجًا مستدامًا ومبتكرًا في مجال التعاون الثقافي بين القطاعين العام والأكاديمي، مع إمكانية تطبيقه في سياقات أخرى سواء في منطقة البحر الأبيض المتوسط أو على الصعيد الدولي.

بناء القدرات والحوكمة متعددة المستويات في إطار التعاون الدولي: نموذج المركز الإقليمي للصيانة والترميم في جرش

تم إنشاء المركز الإقليمي للصيانة والترميم في جرش بناء على القانون رقم 125 المؤرخ 11 أغسطس 2014، والذي يعرّف التعاون الإنمائي على أنه «جزء أساسي ومحوري من السياسة الخارجية الإيطالية» (المادة 1) ويعهد بإدارته إلى مجموعة من الجهات الفاعلة من القطاع الحكومي وتلك المعنية بالشأن المجتمعي، بما في ذلك الجامعات والهيئات البحثية. ويؤسس هذا القانون لنظام حوكمة متعدد المستويات قائم على الشراكة بين وزارة الشؤون الخارجية والتعاون الدولي والوكالة الإيطالية للتعاون الإنمائي والشركاء المنفذين – سواء من القطاع العام أو الأكاديمي - ضمن إطار موحد للتعاون.

ترسم الاتفاقية اللاحقة لوزارة الشؤون الخارجية والتعاون الدولي والوكالة الإيطالية للتعاون الإنمائي 2025-2027 إطارًا مؤسسيًا واضحًا ومحدثًا، حيث تحدد الأهداف والإجراءات الإدارية وأدوات المراقبة الخاصة بمبادرات التعاون. وهي «تحدد، للفترة من 1 يناير 2025 إلى 31 ديسمبر 2027، أهداف الوكالة وتنظم العلاقة بين الوزارة والوكالة» (المادة 2). ومن بين أولوياتها إنشاء قاعدة بيانات مركزية تسمح بـ «إظهار جميع مراحل مشروعات التعاون [...] بما في ذلك تلك الموكلة إلى منظمات المجتمع المدني والكيانات العامة» (المادة 3، الحرف ب.6)، وتطوير منهجيات للتحقق من النتائج النوعية والكمية ومراقبتها [...] وفقًا للمادة 12، الفقرة 4، من القانون التأسيسي» (المادة 3، الحرف ب.8).

بناء القدرات والحوكمة متعددة المستويات في إطار التعاون الدولي نموذج المركز الإقليمي للصيانة والترميم في جرش

ألبرتو أتاناسيو المدير العام لجامعة روما تري

روبن ريسبولي مدير قسم إدارة التدويل، والتقييم المعرفي، والتوجيه وإدارة الأقسام
بجامعة روما تري

يمثل مشروع إنشاء المركز الإقليمي للصيانة والترميم في جرش، الذي تم دعمه من قبل الوكالة الإيطالية للتعاون الإنمائي، ودائرة الآثار العامة الأردنية، بالتعاون مع جامعة روما تري الشريك العلمي المنفذ، حالة نموذجية لكيفية دمج التدريب المتخصص والحوكمة متعددة المستويات في التعاون الدولي لحماية التراث الثقافي.

تقع أغلب مقرات جامعة روما تري في مناطق صناعية أثرية، حيث تم تحويل مواقع إنتاج سابقة إلى أماكن للتعليم والبحث. يعكس هذا الاختيار المعماري والتخطيطي العمراني مبدأً أساسياً وهو أن كلا من البيئة العمرانية والتراث المعماري يعبران عن الهوية وهما محفزان للتحويل الحضري. يضمن الحفاظ عليهما وإعادة الاستخدام التكيفي لهما الاستدامة والاستمرارية على مر الزمن، مما يدمج الجامعة نفسها في حوار مستمر بين التاريخ والنسيج العمراني للمجتمع.

وبالتوازي مع ذلك، طورت روما تري خبرة علمية معترف بها في مجال الحفاظ على التراث الثقافي وترميمه، على الصعيدين الوطني والدولي. وتتجسد هذه الخبرة في البحوث التطبيقية، والأساليب المبتكرة للتحليل والتدخل، وتدريب أجيال جديدة من المتخصصين. وهذه هي ذات الرؤية التي تم الاستناد إليها في إنشاء المركز الإقليمي للصيانة والترميم في جرش (الأردن)، الذي روجت له الوكالة الإيطالية للتعاون الإنمائي ودائرة الآثار العامة الأردنية.

وفي الوقت نفسه، فإن إدارة المشروع - التي تتمحور حول لجنة توجيهية ووحدة إدارة المشاريع وقسم إداري مخصص وآليات مراقبة أنشئت بموجب اتفاقية وزارة الشؤون الخارجية والتعاون الدولي والوكالة الإيطالية للتعاون الإنمائي 2025-2027

تعد دائرة الآثار العامة واحدة من أقدم مؤسسات الدولة الأردنية، والتي تأسست بموجب مرسوم أميري صادر عن جلالة الملك الراحل عبد الله الأول بن الحسين، أمير إمارة شرق الأردن آنذاك، في 27 يونيو 1923، لتكون الجهة الرسمية المسؤولة عن حماية وحفظ التراث الأثري والثقافي للمملكة الأردنية الهاشمية.

ومنذ تأسيسها أخذت دائرة الآثار العامة على عاتقها المسؤولية الوطنية لحماية وإدارة وحفظ التراث الثقافي الأردني، وفقاً لأعلى المعايير العلمية والمهنية، وتقديمه كجزء لا يتجزأ من الموروث الإنساني الحضاري المشترك. وقد لعب الهاشميون دوراً أساسياً ومحورياً في حماية وتعزيز التراث الثقافي، إدراكاً منهم لأهميته في ترسيخ الهوية الوطنية والارتقاء بالوعي التاريخي.

ويسير عمل دائرة الآثار العامة بالتوافق مع رؤية التحديث الاقتصادي التي أطلقها جلالة الملك عبد الله الثاني بن الحسين، والتي يشكل فيها قطاع الآثار ركيزة استراتيجية تساهم في دفع عجلة الاقتصاد الوطني والمضي قدماً في تحقيق التنمية المستدامة. كما يُعد التراث الأثري بمثابة القوة الدافعة لتمكين المجتمعات المحلية، وخلق فرص عمل، والنهوض بالسياحة الثقافية.

وانطلاقاً من هذه الالتزامات، تسعى دائرة الآثار العامة جاهدةً لضمان استدامة التراث الأثري الأردني، وحفظ وإبراز قيمته ومكانته العالمية، والارتقاء به كأداة مساهمة في النمو الاقتصادي وتنمية المجتمعات المحلية. كما تسعى إلى توفير بيئة مواتية وإطار مؤسساتي وتشريعي حديث يعزز مكانة التراث الأثري الأردني محلياً وإقليمياً ودولياً، من خلال شراكات فعالة، والالتزام بتطبيق أفضل الممارسات، ودمج التقنيات المتطورة في الحماية والتوثيق والإدارة والعرض المتحفي.

أ.د / فوزي أبودنه

مدير عام دائرة الآثار العامة الأردنية

ومن بين هذه المشاريع، المشروع المخصص لإنشاء المركز الإقليمي للصيانة والترميم في جرش، الذي يهدف إلى إعادة تأهيل مبنى تاريخي، وإمداده بمعدات متخصصة، وتدريب موظفي دائرة الآثار العامة. وهو يعد مثالا رائعا على الشراكة مع السلطات المحلية وتطبيق الخبرات والكفاءات المتميزة لمنظمة دولية مثل مكتب الأمم المتحدة لخدمات المشاريع في الجانب الهيكلي، وجامعة إيطالية مثل جامعة روما تري في الجانب التعليمي.

ونأمل أن تكون استجابتنا في هذا السياق قد أتت بثمارها بشكل فعال وبما يلبي احتياجات شركائنا الأردنيين في الحصول على منشأة مجهزة بشكل مناسب وفريق من المهنيين المدربين على أعمال الترميم والحفاظ على التراث الثقافي للبلد. وبناء عليه، يمكن أن يشكل المركز في السنوات القادمة مرجعية حقيقية لمواصلة التبادل المتميز بين الخبرات الإيطالية والزملاء العاملين في منطقة الشرق الأوسط.

كتاب المركز الإقليمي للصيانة والترميم في جرش، الأردن

مقدمة

ماركو ريكاردو روسكوني، مدير الوكالة الإيطالية للتعاون الإنمائي

مثل قطاع التراث الثقافي والثقافة أداة متميزة لتعزيز الريادة الإيطالية، كما شكل ركيزة للقوى الناعمة على الصعيد الدولي، ويحظى بتقدير كبير بين الدول الشركاء في مجال التعاون الإنمائي.

وكان لوزارة الشؤون الخارجية والتعاون الدولي الإيطالية، بفضل ما تبذله من جهود متواصلة، دور حاسم في مجال الدبلوماسية الثقافية، التي دعمت خلال السنوات الماضية ما يقرب من ثلاثمائة بعثة أثرية وعلمية إيطالية نشطة في أكثر من سبعين دولة، والتي تتواجد العديد منها في منطقة الشرق الأوسط.

في السنوات الأخيرة، وبالتوازي مع ترسيخ مبدأ الاستدامة في النماذج التنموية، اتخذت العلاقة بين الثقافة والتنمية شكلاً أكثر وضوحاً على المستوى الدولي. فقد أصبح للثقافة دوراً محورياً معترف به في التنمية البشرية، ويُعتبر تعزيزها مكوناً أساسياً للتنمية المستدامة، ليس فقط من الناحية الاقتصادية والمالية، بل أيضاً - وعلى وجه الخصوص - لما لها من آثار على المستويين الاجتماعي والبيئي.

وفي إطار هذه المقاربة، قامت الوكالة الإيطالية للتعاون الإنمائي، منذ افتتاح مقر لها في عمّان عام 2016، ومن خلال التنسيق الوطيد مع السلطات المحلية المختصة وبما يتوافق مع الوثائق البرامجية للدولة، بتنفيذ العديد من المبادرات، بقيمة تزيد عن 16 مليون يورو، مخصصة للتنمية السياحية وحفظ وترميم وتقييم التراث الثقافي المحلي الهام، باعتباره عنصراً فعالاً يلعب دوراً أساسياً في جذب التدفقات السياحية الدولية.

وقد استهدفت هذه التدخلات الحفاظ على المواقع الأثرية والتاريخية ودعمها، مثل البتراء ووادي رم والشوبك ومادبا وجرش والسلط والمدرج الروماني في عمّان، من خلال مشاريع قامت بها وكالات تابعة للأمم المتحدة، مثل اليونسكو وبرنامج الأمم المتحدة للمستوطنات البشرية (مؤئل الأمم المتحدة) ومكتب الأمم المتحدة لخدمات المشاريع، بالإضافة إلى جامعات إيطالية متميزة، مثل جامعة فلورنسا والتي تشمل كلية التميز التي تضم أقسام التاريخ وعلوم الآثار والجغرافيا والفنون والترفيه (SAGAS)، وجامعة بيروجيا، وجامعة بوليتكنيكو في ميلانو.

بسم الله الرحمن الرحيم

المملكة الأردنية الهاشمية وزارة السياحة والآثار

وزارة السياحة والآثار

إن التراث الثقافي للأردن ليس مجرد سرداً زمنياً لأحداث التاريخ، بل هو شاهد عيان على الحضارات التي شكلت هذه الأرض، وهو إرث عظيم يجب علينا حمايته بالمعرفة والمسؤولية واستشراف المستقبل. وانطلاقاً من هذه القناعة الراسخة، وبفضل القيادة المستنيرة لجلالة الملك عبد الله الثاني بن الحسين، أدرجت المملكة الأردنية الهاشمية حماية هذا التراث وحفظه وإدارته بشكل مستدام في صميم رؤيتها الوطنية.

ويشكل المركز الإقليمي للصيانة والترميم في جرش علامة فارقة حاسمة نحو تحقيق هذا الهدف المستدام. فهو أكثر من مجرد كونه منشأة للترميم، بل يجسد هذا المركز رؤية تقدمية: وهي إنشاء مركز إقليمي دائم للتدريب المتقدم والبحوث الرائدة بالإضافة إلى تبادل الخبرات. وهو يدل على التزام الأردن بتعزيز القدرات الوطنية والإقليمية، وتمكين جيل جديد من المتخصصين، ودعم المنهجيات العلمية التي تتماشى وأعلى المعايير الدولية.

ويأتي هذا الإنجاز الهام كثمرة للشراكة الوطيدة والبناءة بين وزارة السياحة والآثار والوكالة الإيطالية للتعاون الإنمائي، والتي عززتها المساهمات الأكاديمية القيمة من قبل الجامعات والمؤسسات الإيطالية المتخصصة.

يُعد هذا الكتاب، الذي يوثق هذا المشروع الريادي، مرجعاً أساسياً لجميع الأطراف المعنية، حيث يسلط الضوء على الإجراءات التقنية الدقيقة لعملية الترميم، ويتبنى الرؤية التي تتخذ من التراث محفزاً أساسياً للهوية الثقافية والتضامن الاجتماعي والسياحة المستدامة.

لذلك، أود أن أعرب عن خالص امتناني لجميع شركائنا وخبرائنا وكوادرنا المخلصين الذين ساهموا بالتزامهم في إنشاء هذا المركز وجعلوا إصدار هذا الكتاب أمراً ممكناً.

وأنا على ثقة من أن المركز الإقليمي للصيانة والترميم في جرش سيكون منارة للتميز، يعكس دور الأردن كمركز إقليمي للتراث، ويضمن استمرار تراثنا المشترك للأجيال القادمة.

د. عماد حجازين

وزير السياحة والآثار

المملكة الأردنية الهاشمية

وأخيراً، أود أن أؤكد على الدلالات الإقليمية لمركز جرش. والذي يجب دعم تنميته في هذا السياق بغية الحفاظ على هذا التعاون المثمر الذي تجلّى في الإسهامات المختلفة الواردة في هذا الكتاب، والذي يشهد من ناحية على ما تم إنجازه في إطار التعاون الإيطالي، ومن ناحية أخرى يمثل بداية للتنمية المستقبلية لهذا المركز الهام.

سعادة السيد / لوتشانو بيتسوتي

سفير إيطاليا في عمان

إن التاريخ الحديث للعلاقات الإيطالية الأردنية تمتد جذوره إلى أبعد من السبع والسبعين عامًا التي تمثل بداية العلاقات الدبلوماسية بين البلدين.

ففي عام 1927، أسس الطبيب الشاب فاوستو تيسيو، وهو من مقاطعة بيمونتي، الذي أرسلته «جمعية الإغاثة للمبشرين الإيطاليين» إلى إمارة شرق الأردن، المستشفى الإيطالي في عمان .

وفي العام نفسه، عُيّن عالم الآثار الكبير جاكومو جويدي رئيساً لبعثة أثرية وقاد حملة تنقيب أولى في أكروبول عمان، وهي الأبحاث التي واصلها ريناتو بارتوتشيني حتى عام 1938. وفي منتصف السبعينيات من القرن العشرين، كثفت إيطاليا جهودها في الأردن في مجالي الآثار والحفظ بوجود شخصيتين بارزتين، هما جورجو جولينى والأب ميكيلي بيتشيريلو .

ويُختتم هذا القرن الحافل بتاريخ من الدبلوماسية الثقافية بتأسيس المركز الإقليمي للصيانة والترميم في جرش، بمبادرة من الوكالة الإيطالية للتعاون الإنمائي، والتي تعد إحدى دعائم سياساتنا الخارجية في الأردن.

يتناول هذا الكتاب قراءة في هذه العملية المتشابكة الأطراف التي أتاحت الفرصة لإنشاء هذا المركز الجديد المخصص للحفاظ على التراث الثقافي داخل دائرة الآثار العامة / وزارة السياحة والآثار.

وقد استغرق بدء تشغيله عامين من التدريب المكثف الذي عهدت به الوكالة الإيطالية للتعاون الإنمائي إلى جامعة روما تري، التي وظفت ثلاثين خبيراً في مختلف المجالات المتعلقة بالحفظ والذين ينتمون إلى "النظام الإيطالي للترميم"، وهو قطاع لا يزال حتى اليوم يجعل بلدنا يحتل قيمة مرجعية على الصعيد الدولي .

أمل أن يصبح مركز جرش مركزاً رئيسياً لشبكة ممتدة داخل الأردن حتى يمكن الاستفادة من خبرات الجامعات ومراكز البحث الدولية مثل "المركز الدولي لضوء السنكروترون للعلوم التجريبية وتطبيقاتها في منطقة الشرق الأوسط (سيسامي)" المرموق في منطقة علان، والذي يديره عالم إيطالي ويضم 28 دولة ومنظمة دولية بصفة أعضاء ومراقبين .

تم إصدار هذا الكتاب لينقل تجربة تعاون علمي وثقافي والتي تعبر بوضوح عن الرسالة العامة لجامعة روما تري. وتشهد المجهودات والتأملات التي تم سردها هنا على مسيرة عمل مشترك، يركز في صميمه على جودة البحث، والتدريب المتقدم، والتداول المسؤول للمعرفة.

تبرز أهمية حماية وتقييم التراث الثقافي كمجالات تلقت فيها الكفاءات المختلفة وتتجاوز فيما بينها. وفي هذه المساحة من التواصل، تتبلور ممارسات بمقدورها المزج بين الدقة العلمية والتجديد المنهجي والعناية بالسياقات المجتمعية والمحلية. وفي هذا الإطار، فإن الحفاظ على التراث الثقافي يعد بمثابة تجربة مفتوحة ونابضة بالحياة، وعلى صلة وطيدة بالمجتمعات والأماكن.

يشهد المسار الموثق في هذه الصفحات على قوة تعاون دولي بُني على مر الزمن، تنميه إسهامات الأساتذة والباحثين والمهنيين والمديرين والطلاب. وبهذا تثبت الجامعة مكانتها كمنبر للفكر النقدي وكفاعل مسؤول في تطوير كفاءات مستدامة موجهة نحو التعاون والتنمية المشتركة.

ويأتي هذا المشروع كتعبيراً ملموساً عن دور جامعة روما تري المؤسساتي وتجسيداً لما تبذله من جهود في إطار التدويل والمهمة الثالثة. حيث يتداخل إنتاج المعرفة ونشرها، في هذا السياق، مع بناء علاقات راسخة، قائمة على احترام التعددية الثقافية وعلى رؤية تنموية تستند إلى المساواة والاستدامة.

أود أن أتوجه بخالص الشكر إلى جميع الأشخاص والمؤسسات الذين ساهموا في إصدار هذا الكتاب. وأمل أن يرافق هذا الكتاب عمل الباحثين والمختصين وصناع القرار، وأن يتيح آليات فكرية وعملية في مجالات الحفظ والبحث والتعاون الدولي.

البروفيسور / ماسيميليانو فيوروتشي
رئيس جامعة الدراسات روما تري

لورا بارتولي

تجربة دورة تدريب العاملين مستخدمي الليزر في مركز الترميم في جرش

المواقع الميدانية التعليمية

سوكول موكا، لوشانا فيستا، نيكولاس فاكاليس

المصلبة الجنوبية في جرش: قراءة تاريخية – تقنيات التشخيص والترميم المحافظ في الموقع
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فلورين كريستينيل ستان، مارتينا بوتشي، سارة فارس، نجدت مأمون عبد الرؤوف هزايمة، تسنيم

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الجوانب البنيوية للجدار المحيط بفسيفساء دياكونيا في كنيسة بروبيليا في جرش، الأردن

سوكول موكا، تيسا بيريلو

ترميم فسيفساء دياكونيا في كنيسة بروبيليا - الحفظ في الموقع، التعاون الدولي، وموقع العمل التعليمي
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الدراسة البحثية للنقوش

الجزء الثاني

أطر البرنامج التدريبي في المركز الإقليمي للصيانة والترميم

ياكوبو روسو، التوثيق الرقمي في مجال الترميم

التصوير الفوتوغرافي، والتصوير المساحي الضوئي ثلاثي الأبعاد، ونظم المعلومات الجغرافية في إطار البرنامج التدريبي في الأردن

نيكولا باجاني، كريستينا باسيري

المنهجيات والممارسات المتبعة في ترميم السيراميك
بمساهمة كل من:

بلال فواز محمد البوريني، قيس عزمي رضوان المومني، محمد علي مصطفى العلونة، أميمة أحمد ناصر فوده، ريتا سليمان يوسف الداود، حسين محمد محمود قریشات، إيمان سليمان مفلح قرعان

إليزابيث هوبر، مانويلا فايثا

الحفاظ على الزجاج الأثري

شين ييجيا، كريستينا باسيري، إليزابيتا بروناس، أليكس سارا

استراتيجيات الحفاظ على القطع الأثرية الأردنية المصنوعة من البرونز والحديد: معالجة مشكلات التلف النمطية

بمساهمة كل من:

بلال فواز محمد البوريني، قيس عزمي رضوان المومني، محمد علي مصطفى العلونة، إيمان سليمان مفلح قرعان، ريتا سليمان يوسف الداود، حسين محمد محمود قریشات

نيكولاس فاكاليس، لوشانا فيستا

ترميم وحفظ المواد الحجرية

فرانشيسكا مارياني، كريستينا كالدي، سارة شوشا، مارتينا فاجولي

التأهيل والمنهجية في ترميم الفسيفساء: تجربة المركز الإقليمي للصيانة والترميم في جرش

المقدمة

ألبرتو أتاناسيو، روبن ريسبولي

بناء القدرات والحوكمة متعددة المستويات في إطار التعاون الدولي: نموذج المركز الإقليمي للصيانة والترميم في جرش

الجزء الأول

المركز الإقليمي للصيانة والترميم في جرش

إيميليو كاباسينو

الوكالة الإيطالية للتعاون الإنمائي والمركز الإقليمي للصيانة والترميم في جرش

دانيلا بالدوني، ماسيمو بريتسي، رافاييلا بيروبون بنويت

البعثة الأثرية الإيطالية في جرش

جمانة بداد، رامي فاروق ضاهر

الاستمرارية والتمايز والقدرة - ملاحظات المصمم حول نموذج إعادة الاستخدام التكيفية في المركز الإقليمي للصيانة والترميم في جرش

ماريو ميكيلي، بلال فواز محمد البوريني

التدريب التخصصي في مجال الترميم في المركز الإقليمي للصيانة والترميم في جرش

قيس عزمي رضوان المومني، ياسمين فؤاد أحمد موسى ولويل

شبكة الجامعات والمؤسسات البحثية الأردنية - الدعم الاستراتيجي للمركز الإقليمي للصيانة والترميم في جرش

ساهم في البرنامج التدريبي

الأساتذة

لورا بارتولي، ماسيمو بريتسي، كريستينا كالدي، ماريا كريستينا كاجياني، جوليا كانيفا، ماركو كاردينالي، جانماركو دي فيليشي، جانكارلو ديلا فينتورا، مارتينا فاجولي، مانويلا فايتا، فاسكو فاسينا، لوشانا فيستا، آنا ماريا جيوفانيولي، إليزابيث هوبر، سارة إيفراتي، فرانثيسكا مارياني، سوكول موكا، نيكولا باجاني، كريستينا باسيري، كارلوتا ساكو بيراسو، إليزابيتا بروناس، ياكوبو روسو، أليكس سارا، صوفيا سكياتوني، سارة شوشا، تيسا بيريلو، جوليا سيمونيللي، نيكولاس فاكاليس، بيچيا شين.

الدارسون

بلال فواز محمد البوريني، قيس عزمي رضوان المومني، تسنيم أعر احمد البطاينة، محمد مصطفى العلوانة، ريتا سليمان يوسف الداود، مرشود علوان حسين الدوجان، تمام خالد عبد القادر المجفف، محمد حسن عبد الكريم البناء، بكر ياسين عبد الله الزواهره، ولاء ابراهيم عيسى عتوم، اميمة أحمد ناصر فوده، احمد لورنس مليحان حموري، نجدت مأمون عبد الرؤوف هزايمة، مصطفى محمود سرور الحوامده، حسين محمد محمود قريشات، إيمان سليمان مفلح قرعان

الفهرس

تقديم

البروفيسور / ماسيميليانو فيوروتشي
رئيس جامعة روما تري

سعادة السيد / لوتشيانو بيتسوتي
سفير الجمهورية الإيطالية في عمان

معالي السيد / عماد حجازين
وزير السياحة والآثار - الأردن

السيد / ماركو ريكاردو روسكوني
المدير العام للوكالة الإيطالية للتعاون الإنمائي

البروفيسور / فوزي أبو دنه
المدير العام لدائرة الآثار العامة الأردنية



المحررون
ماريو ميكيلي وبلال فواز محمد البوريني
مساعدة التحرير
مارينا بوتشي

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المحررون

ماريو ميكيلي وبلال فواز محمد البوريني



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