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## Historical Quarries. Global Perspectives and International Research Trends

Canteras Históricas. Perspectivas globales y tendencias de investigación internacionales

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**Abstract:** This monograph integrates research from 12 countries from three continents (Europe, Asia, and America). The publication projects an exceptional international dimension, encompassing studies from Spain, Italy, Greece, Norway, Slovenia, Germany, Portugal, and France in Europe; Qatar, India, and South Korea in Asia; and Brazil in South America. This geographic diversity provides a multidisciplinary perspective from the various research groups that have collaborated on this monograph, documenting the richness of their geodiversity and historical exploitation on a global scale.

The contributions from the different scientific teams underscore the importance of historical quarries as scientific-technical spaces for material traceability. Through the use of advanced methodologies, petrophysical studies, and engineering analysis, these works demonstrate that quarries are not merely exhausted deposits, but authentic laboratories. They allow for the generation of georeferenced inventories and ensure that any restoration intervention respects the petrophysical integrity and originality of the heritage element.

From a heritage perspective, the monograph highlights that the study of these sources is essential for correctly understanding built heritage and its construction history. By linking each building to its territory—as observed in many of the cases presented—the authenticity of the cultural asset is further guaranteed.

The collection of works compiled in this monograph reflects the significance of historical quarries as a key piece

in heritage studies and underlines their value as a first-rate scientific-technical space. It is evident that these sites are not only the material origin of our monuments but laboratories where geology, history, and engineering converge to ensure the authenticity and proper conservation of our built memory.

**Keywords:** Historical Quarries; Stone Materials; Geology; Internationalization.

**Key points:** Historical quarries constitute scientific-technical spaces for material traceability.

The study of historical quarries is essential for documenting construction history and ensuring that any restoration respects the petrophysical and aesthetic integrity of the cultural asset.

This monograph presents an international dimension by integrating research from three continents (Europe, Asia, and America) and a total of 12 countries.

**Resumen:** Este monográfico integra investigaciones de tres continentes (Europa, Asia y América) y un total de 12 países. La publicación proyecta una dimensión internacional excepcional, abarcando estudios desde España, Italia, Grecia, Noruega, Eslovenia, Alemania, Portugal y Francia en Europa, hasta Qatar, India y Corea del Sur en Asia, y Brasil en el continente americano. Esta diversidad geográfica permite aportar una visión multidisciplinar de los diferentes grupos de investigación que han colaborado en la realización del presente monográfico, documentando la riqueza de su geodiversidad y la explotación histórica a escala mundial.

Las contribuciones de los distintos equipos científicos subrayan la importancia de las canteras históricas como espacios científico-técnicos de trazabilidad material. Mediante el uso de metodologías avanzadas, estudios petrofísicos y de ingeniería. Estos trabajos demuestran que las canteras no son yacimientos agotados, sino auténticos laboratorios que permiten generar inventarios georreferenciados y asegurar que cualquier intervención de restauración respete la integridad petrofísica y originalidad del elemento patrimonial.

Desde una perspectiva patrimonial, el monográfico destaca que el estudio de estas fuentes es esencial para entender correctamente el patrimonio construido y su historia constructiva. Al vincular cada edificio con su territorio, como se observa en muchos de los casos expuestos, además, se garantiza la autenticidad del bien cultural.

El conjunto de trabajos recopilados en esta monografía refleja la importancia de las canteras históricas como pieza clave en el estudio del patrimonio y subraya su valor como un espacio científico-técnico de primer orden. Se evidencia que estos lugares no son solo el origen material de nuestros monumentos, sino laboratorios donde convergen la geología, la historia y la ingeniería para garantizar la autenticidad y la correcta conservación de la memoria edificada.

**Palabras clave:** Canteras Históricas; Materiales Pétreos; Geología; Internacionalización.

**Puntos clave:** Las canteras históricas constituyen espacios científico-técnicos de trazabilidad material.

El estudio de las canteras históricas es esencial para documentar la historia constructiva y asegurar que cualquier restauración respete la integridad petrofísica y estética del bien cultural.

Este monográfico presenta una dimensión internacional, al integrar investigaciones de tres continentes (Europa, Asia y América) y un total de 12 países.

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**Supplementary information** ↓

## 1. INTRODUCTION

Natural stone has been, since the dawn of civilization, the construction material par excellence, granting our cities and infrastructures a unique identity and millenary durability. However, the study of built heritage has often focused on the analysis of the final monument, overlooking the geological origin that makes it possible. This monograph arises from the critical need to reclaim historical quarries, not merely as exhausted extraction sites, but as repositories of scientific and technical knowledge fundamental to the conservation of cultural legacy.

The primary motivation of this publication is to address the existing gap in material traceability. In a global context where monument restoration demands rigorous compatibility, the identification of original quarries becomes a technical and ethical imperative. This volume seeks to demonstrate that the quarry is a geological archive that safeguards the keys to construction history and the petrophysical properties necessary to ensure authentic and lasting restoration interventions.

Over the last decades, research on historical quarries has undergone a profound transformation, establishing itself as a scientific research line within the Earth Sciences. This progress reflects a fundamental shift in mindset: today we understand stone not only as an extractive raw material, but as a historical record with analytical traceability. Thanks to the sophistication of tools such as isotope geochemistry, advanced petrography, and 3D scanning, among others, geology can now accurately reconstruct the origin of materials and predict their behavior over time.

This maturation process has fostered a solid network of experts working at the intersection of geology, architecture, and restoration. The publication of this monograph responds precisely to the need to create a global forum and a meeting point where research groups from 12 countries and 3 continents have succeeded in breaking down academic boundaries, offering a comprehensive vision that ensures the study of our quarries becomes the definitive tool for the conservation of our built memory.

## 2. IGME, CSIC IN THE INVENTORY AND RESEARCH OF HISTORICAL QUARRIES AND ARCHITECTURAL HERITAGE

The Geological and Mining Institute of Spain (IGME-CSIC) has established a benchmark trajectory in the management of stone heritage, particularly through the development of the National Inventory of Historical Quarries since 2014. This ambitious project aims to complete, in the medium term, the comprehensive mapping of Spain's historical quarries associated with its rich built cultural heritage. To date, the plan has successfully inventoried more than 1,500 historical quarries linked to heritage elements, covering 40% of the national territory, with completed works in the regions of Extremadura, Andalusia, and Cantabria.

Crucially, this initiative includes the development of a comprehensive database encompassing all identified quarries, alongside a specialized lithic library and sample collection of construction rocks. This physical and digital repository serves as an essential benchmark for the scientific characterization and identification of the building materials used throughout Spain's architectural heritage.

Beyond the inventory, IGME-CSIC leads cutting-edge research lines in natural stone and historical quarries. These include projects such as RESCUHE, which focuses on climate change and material degradation, as well as specialized research on early medieval quarries in the Iberian Peninsula, conducted in close collaboration with other national and international research groups.

Likewise, it leads other projects related to the study and conservation of Spanish architectural heritage, alongside work regarding historical extraction areas in connection with the planning, production, and construction of historical buildings.

The active participation of IGME-CSIC in European and international projects has flourished in recent years, exemplified by its involvement in European Union research programs, most notably within the GeoERA framework (2018–2022). Under this program, the Institute collaborated on the EuroLithos

project (*European Ornamental stone resources as things of cultural heritage*), a pioneering initiative focused on the harmonization and identification of ornamental stone resources across Europe.

Furthermore, the Institute plays a pivotal role in the scientific community by leading the Natural Stone and Architectural Heritage Symposia within the Geological Congresses of Spain. In addition to these congresses, the IGME-CSIC spearheads numerous other national and international outreach initiatives dedicated to the dissemination of research on natural stone, historical quarries, and architectural heritage.

### 3. HISTORICAL QUARRIES MONOGRAPHIC ISSUE: A GLOBAL NETWORK FOR STONE HERITAGE CONSERVATION

This monographic issue brings together 12 original contributions that reflect the diversity and global reach of current research in this field. The papers cover a wide range of topics, including the identification of provenance, the characterization of weathering processes, and the strategic management of historical extraction sites. Together, they highlight the multidisciplinary nature of historical quarry studies and their critical relevance to both fundamental geology and the conservation of cultural heritage.

This volume is the result of international scientific synergy. The research presented in this volume spans three continents (Europe, Asia, and America) and a total of 12 countries, projecting an exceptional international dimension. This global collaboration encompasses specialized studies from Spain, Italy, Greece, Norway, Slovenia, Germany, Portugal, and France in Europe; Qatar, India, and South Korea in Asia; and Brazil in the Americas. This diversity of geographical and cultural contexts allows for a truly comprehensive understanding of historical quarries and their role in global architectural heritage.

In the first contribution, **“Analysis of the Limestone and Calcareous Rocks Exploited in the Vega de Granada from Sierra Gorda and Surrounding Areas (Granada, Spain) and its Archaeological Use in the Roman Villa of Salar (Granada)”**, Ontiveros *et al.* (2026) provide the first results on the exploitation of local stone varieties in the eastern sector of the Roman province of Baetica. Through a detailed geological and petrographic study of the Sierra Gorda quarries and the surrounding Granada Basin, the paper identifies several key lithotypes, such as Dogger calcareous breccia and nodular limestones, utilized in the Roman villa of Salar. Furthermore, the study offers a critical perspective on material provenance, distinguishing between local supplies and stones likely imported from neighboring provinces like Málaga or Córdoba, thereby advancing our understanding of Roman lithic trade and construction strategies.

The second contribution, entitled **“Petrographic, Petrophysical and Engineering Geological Properties of Stone Materials Employed in the Late Baroque of Val di Noto UNESCO Heritage Sites (Sicily, Italy)”**, Punturo *et al.* (2016) explore the unique relationship between geological context and the post-seismic reconstruction of southeastern Sicily after the 1693 earthquake. The authors focus on the characteristic bichromy resulting from the use of two distinct lithotypes: Hyblean limestones and Etnean lavas. By reviewing fabric-related petrophysical properties—including porosity, seismic behavior, and geo-engineering performance—alongside an analysis of deterioration forms caused by atmospheric agents, this study provides a fundamental diagnostic tool for the conservation and restoration of these UNESCO World Heritage monuments.

In the third contribution, **“The Timelessness of Thassos and Naxos Heritage Ornamental Stones, Greece”**, Laskaridis *et al.* (2026) investigate the historical continuity and physical properties of two iconic Greek marbles. The study explores the 1,200-year extraction history of the gray calcitic marble from the ancient Alykes quarry on Thassos, comparing its aesthetic and mechanical properties with modern counterparts currently being exploited. Additionally, the paper examines the white marble of Naxos, a material used since prehistory for religious and architectural purposes. By determining the mineralogical and physical-mechanical properties of these stones in the Lithos Laboratory, the authors highlight their enduring quality and their vital role as heritage stones in Mediterranean culture.

As an example of a research group from South America, dos Santos *et al.* (2026) present a contribution entitled **“The Intertwined Architectural and Geological Heritage of Ouro Preto, Minas Gerais, Southeastern Brazil”**. This work explores the profound connection between the urban architecture of this colonial city and its complex geological setting within the Iron Quadrangle. The study highlights how the extraction of local ornamental rocks—such as quartzite, soapstone, marble, and gneisses—was fundamental to the construction of Ouro Preto’s Baroque and Rococo heritage, much of which was immortalized by the artist Aleijadinho. By documenting the ancient quarries preserved within the urban and peri-urban landscape, the authors emphasize the dual significance of these sites as both historical remnants and geological landmarks, reinforcing Ouro Preto’s status as a global heritage site where mineral resources and cultural legacy are inextricably linked.

As an example of the application of advanced analytical techniques in Northern Europe, the fifth contribution is entitled **“Linking 12th Century Churches and Marble Quarries in Norway Using C, O, and Sr Isotope Ratios”**. In this study, Heldal *et al.* (2026) address the challenge of identifying the provenance of marble ashlar from the medieval town of Borgund and other churches in the Sunnmøre district. Since local deposits are mineralogically similar and modern quarrying has erased ancient extraction traces, the research employs carbon, oxygen, and strontium isotopic analyses. The isotopic data provided evidence for a major source for the Borgund churches and revealed a complex pattern of resource acquisition in the region, demonstrating that several marble quarries were simultaneously exploited during the 12th century.

Representing the lithic richness of Central Europe, the sixth contribution is entitled **“Origins of Slovenian Architectural Heritage: Resources and Variety of Natural Stones”** (Dolenec *et al.*, 2026). This work provides a panoramic view of Slovenia’s geological diversity, encompassing the three major rock types (sedimentary, igneous, and metamorphic). The author analyzes emblematic examples such as the Pohorje marble and the Podpeč limestone—the latter designated as a *Global Heritage Stone Resource*—with extraction history dating back to Roman times. The study also highlights the aesthetic importance of rudist biostromes in the Karst region and the use of endemic rocks like green cizlakite. By documenting the mineralogical and physical-mechanical characteristics of these quarries, some of which are now protected as natural monuments, the paper underscores how these local materials have bestowed a unique character upon both vernacular architecture and Slovenian monuments listed as UNESCO World Heritage sites.

Addressing the practical challenges of restoration in Western Europe, the seventh contribution is entitled **“Stone Monuments and Abandoned Quarries: Ways of Restoration in Germany Through Times”**. Through the analysis of six emblematic examples, such as Cologne Cathedral, Freiburg Münster, and the Old National Gallery in Berlin, among others, Ehling & Ebel (2026) examine how replacement stones have been selected under various economic and political conditions when the original material was no longer available. The study discusses cases of temporary reactivation of historical quarries versus the use of alternative materials, evaluating the advantages, disadvantages, and decision-making processes in the reconstruction of German heritage. This work provides an essential perspective on the management of limited stone resources and the significance of material availability for the integrity of historical monuments.

Expanding the scope of the Special Issue to the Asian continent, the eighth contribution is entitled **“The Historical Quarries of Jabal Fuwairit (North Qatar): Preliminary Studies for its Enhancement, Conservation and Musealization”** (Freire-Lista *et al.*, 2026). The study analyzes the fossil dunes of Jabal Fuwairit, composed of a highly porous ooidal limestone that facilitated the historical extraction of blocks for the construction of shaikhly residences in the early 20th century. Beyond its geological relevance, the site preserves numerous rock engravings and inscriptions that attest to the link between quarrying activities and the social development of the region. The authors propose that the combination of geological and archaeological elements makes these quarries a privileged setting for transformation into an open-air museum, thereby promoting both their conservation and cultural profitability.

Returning to the Iberian Peninsula, the ninth contribution is entitled **“Ancient Quarries on the Estremoz Anticline (Ossa Morena Zone, Portugal): Exploitation, Use and Dispersion of Estremoz Marbles during Roman Times”**. Lopes *et al.* (2026) document the historical exploitation of crystalline marbles in Alentejo, analyzing how intense 20th-century mining activity, while erasing much of the ancient evidence, has paradoxically helped reveal and preserve certain traces of Roman extraction. Through aerial photography analysis and fieldwork, the authors identify nearly five hundred extraction and exploration sites, discussing ancient exploitation methods and the current geoconservation challenges in a sector that has seen a drastic reduction in active quarries. The paper highlights the need for protection measures for this tangible and intangible heritage, which is essential for differentiating the historical value of this raw material in the global market.

Continuing the analysis of European heritage, the tenth contribution is entitled **“Ancient and Modern Quarries of Building Stone in North-East France: Main Limestone Deposits and Rock Types”** (Fronteau *et al.*, 2016). This study focuses on the Paris Basin, a region that has provided a vast quantity of dimension stone, particularly Jurassic and Cenozoic limestones. The authors trace the legacy of famous quarries such as Euville and Savonnières, as well as those now forgotten, examining how these materials historically competed with stones from Belgium and Burgundy. By comparing old maps and archives with the analysis of facies and petrophysical properties of currently accessible rocks, the work allows for a refinement of cultural heritage restoration criteria and provides deeper insight into the trade and utilization of these emblematic limestones.

Expanding the perspective to the studies and research groups on the Asian continent, Kaur (2026) presents the eleventh work entitled **“Selected Historical Quarries of India: An Account”**. This contribution highlights the crucial role of the Indian subcontinent’s geodiversity in shaping its vast monumental heritage, linking emblematic rocks such as Makrana Marble, Deccan Basalt, and Western Ghats Laterite to iconic UNESCO sites like the Taj Mahal and the Konark Sun Temple. The author notes that seven of these stones have recently been recognized as *IUGS Heritage Stones*. The paper emphasizes the urgent need to locate and preserve these historical quarries, not only as cultural archives but also as essential sources of compatible material for the restoration of monuments affected by both anthropogenic and natural factors.

Finally, completing this international journey in the Far East of Asia, the twelfth work is presented, entitled **“Iksan Granite and Stone Monuments in the Sabi Period of the Baekje Kingdom, Korea”** (Choie & Lee, 2026). This study focuses on the Iksan granitic batholith, one of the most important quarrying areas in South Korea, with an exploitation history dating back to the 6th century. The authors analyze how the textural and geochemical homogeneity of this granite—while granting it exceptional value as a natural resource for over 1500 years—poses scientific challenges for identifying specific historical quarries through conventional analysis. The paper reviews existing literature, compares the geochemical compositions of monuments and quarries from the Sabi period (538-660 AD), and proposes new analytical methods for tracking stone provenance when whole-rock geochemistry proves insufficient, highlighting the cultural legacy of the Baekje Dynasty.

In conclusion, this Special Issue encompasses a diverse array of research contributions that advance our understanding of historical quarries, their geological significance, and their critical role in the preservation of built heritage. The studies presented here highlight the multifaceted nature of stone resources and emphasize the ongoing need for interdisciplinary research that bridges geology, architecture, and restoration science. As progress is made, it is imperative that the potential of historical quarries continues to be explored, not only as sources of raw material but also as strategic geological archives. These sites link fundamental lithic research with societal challenges such as the conservation of UNESCO World Heritage, sustainable resource management, and the protection of cultural identity. The contributions in this Special Issue serve as a testament to the rich history and future prospects of historical quarry research, inviting further exploration and international collaboration within the scientific community.

The Guest Editors wish to express their sincere gratitude to all the authors for their high-quality contributions and to the reviewers for their rigorous and constructive feedback, which ensured the scientific excellence of this Special Issue. Furthermore, we would like to acknowledge the editorial team of the *Boletín Geológico y Minero* for their invaluable support throughout the publication process. We hope that this collection will serve as a useful reference for researchers and practitioners working in the fields of historical quarries, stone provenance, and architectural heritage conservation.

### Supplementary information

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#### Authorship contribution statement

Enrique Álvarez Areces: Conceptualization, Formal analysis, investigation, project administration, validation, Writing – original draft, Writing – review & editing.

Jorge Fernández Suárez: Conceptualization, Formal analysis, investigation, project administration, validation, Writing – review & editing.

Javier Martínez Martínez: Conceptualization, Formal analysis, investigation, project administration, validation, Writing – review & editing.

Rafael Navarro Domínguez: Conceptualization, Formal analysis, investigation, project administration, validation, Writing – review & editing.

#### Competing interests

The authors of this article declare that they have no financial, professional, or personal conflicts of interest that could have inappropriately influenced this work.

#### Statement on the use of Artificial Intelligence

Not applicable.

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