

The conservation of Giovanni Labus's Sculpture of Bonaventura Bavallieri (1844) and Antonio Galli's Sculpture of Carlo Ottavio Castiglione (1855)

Original

The conservation of Giovanni Labus's Sculpture of Bonaventura Bavallieri (1844) and Antonio Galli's Sculpture of Carlo Ottavio Castiglione (1855) / RUIZ BAZAN, Irene; Bresciani, Vittorio; Balloi, Annalisa; Quarto, Alessandra; Marelli, Isabella; Colella, Mario; Arosio, Francesca. - STAMPA. - II:(2016), pp. 1089-1096. (Intervento presentato al convegno 13th International Congress on the Deterioration and Conservation of Stone tenutosi a Pasley nel 6-10 Settembre 2016).

Availability:

This version is available at: 11583/2822194 since: 2020-05-11T18:34:37Z

Publisher:

University of the West of Scotland

Published

DOI:

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)



myresearchspace.uws.ac.uk

Science and Art: A Future for Stone

Hughes, John; Howind, Torsten

Published: 01/01/2016

Document Version
Final published version

[Link to publication on MyResearchSpace UWS](#)

Citation for published version (APA):

Hughes, J., & Howind, T. (Eds.) (2016). *Science and Art: A Future for Stone: Proceedings of the 13th International Congress on the Deterioration and Conservation of Stone, Volume 2*. Paisley: University of the West of Scotland.

General rights

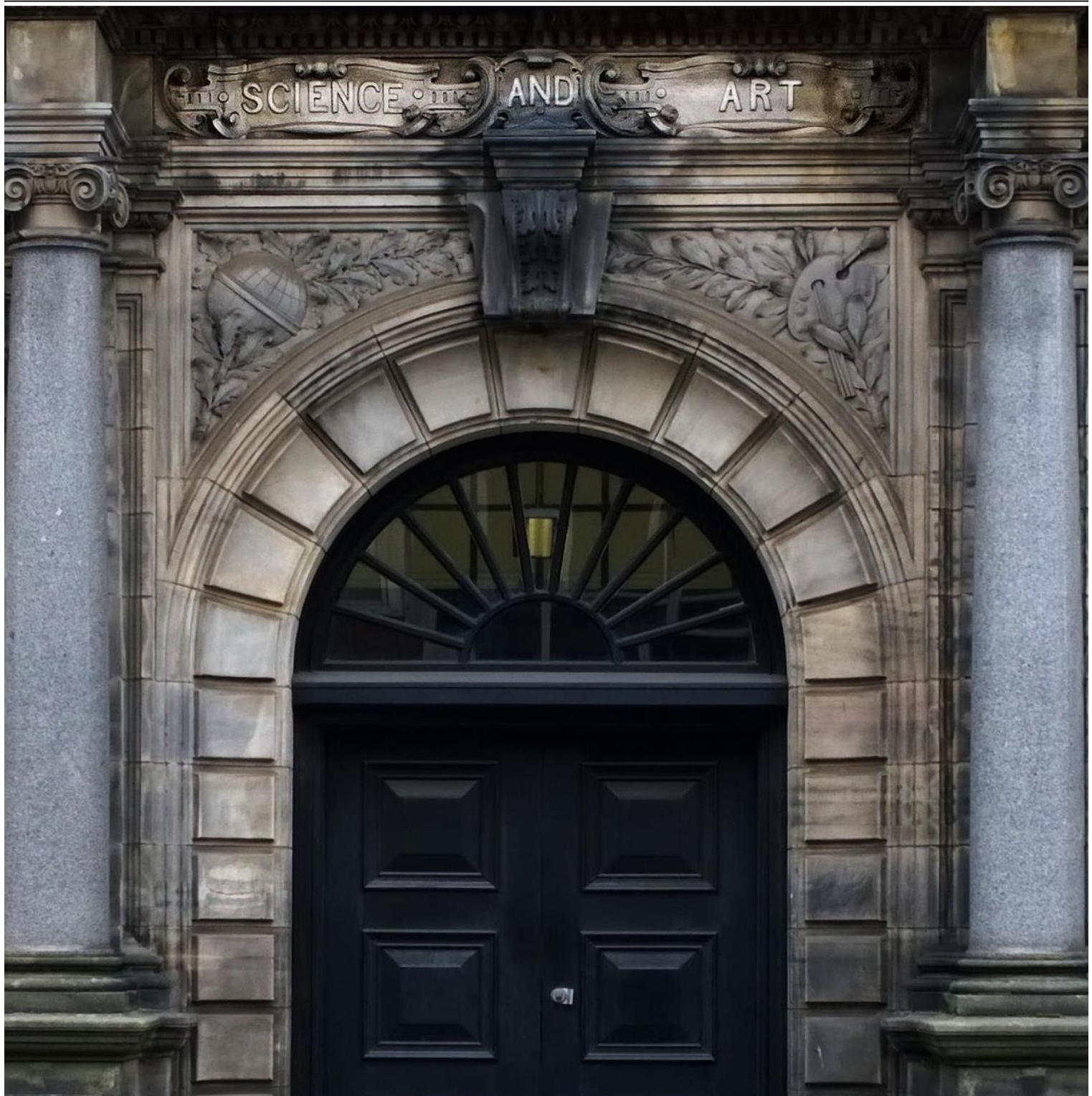
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 29 May 2017



SC16

SCIENCE and ART: A Future for Stone

**Proceedings of the 13th International Congress on the
Deterioration and Conservation of Stone – Volume II**

**Edited by
John Hughes & Torsten Howind**

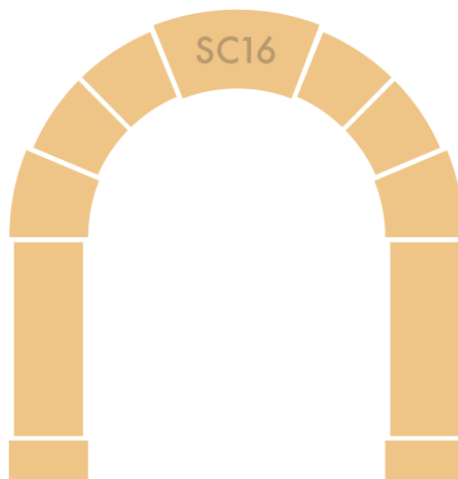
SCIENCE AND ART: A FUTURE FOR STONE

PROCEEDINGS OF THE 13TH INTERNATIONAL CONGRESS ON THE
DETERIORATION AND CONSERVATION OF STONE

6th to 10th September 2016, Paisley, Scotland

VOLUME II

Edited by
John J. Hughes and Torsten Howind



UNIVERSITY OF THE
WEST of SCOTLAND
UWS

© University of the West of Scotland, Paisley, 2016

Licensed under a Creative Commons Attribution 4.0 International License.



ISBN: 978-1-903978-58-0

ISBN: 978-1-903978-55-9 (eBook)

ISBN: 978-1-903978-59-7 (Set: Volume 1&2)

ISBN: 978-1-903978-56-6 (eBook-Set: Volume 1&2)

Hughes J.J. and Howind T. (Editors), “Science and Art: A Future for Stone. Proceedings of the 13th International Congress on the Deterioration and Conservation of Stone”, University of the West of Scotland, Paisley, September 6th to 10th, 2016.

Cover image: The front door of the Paisley Technical College building, now University of the West of Scotland. T.G. Abercrombie, architect 1898. Photograph and cover design by T. Howind.

PREFACE

Standing under the portico of the Paisley Town Hall, completed in 1882, and looking south east towards the West Façade of Paisley Abbey, built in the 13th to 15th Century, it is possible to compare two historical periods in Scottish building where the use of stone was unavoidable. Walking further into the historic centre of Paisley, or any other town or city in Scotland, reveals the ubiquitous use of uncovered natural stone in our architecture, and also the problems that it faces. The challenge in maintaining the essential integral character of our towns for the future, and to recognise and enhance their values is a complex one, but not our challenge alone. Much hard work is still needed to characterise, assess and propose conservation approaches that are compatible with the existing fabric and prevailing philosophies, in Scotland and around the world.

We sought to bring the 13th Congress to a damp Scotland of decaying stone structures, to share our stone-built heritage with the conservation community and also to focus on the needs of stone conservation for our built heritage in Scotland. We hope that by bringing some global attention to the issue, in the country where, arguably, modern geology began, we demonstrate the sharing of our common heritage and our values in seeking its understanding and protection.

In these volumes you will find the proceeds of the work of many people, the conservators, practitioners and even academics and researchers whose concern is the protection of our stone-made cultural heritage. The Permanent Scientific Committee (PSC) of the Stone Congresses worked to review each contribution followed by revision by the authors. The editing effort by ourselves involved direct improvements to text, in many cases, and by one of us in particular to the formatting. However, beyond the title pages and abstracts, after review by the PSC and revision by the authors, proof correction was limited. The contents and accuracy of the papers are therefore the responsibility of the authors.

John J. Hughes and Torsten Howind

Paisley, Scotland, August 2016

Permanent scientific committee

Christine Bläuer

Conservation Science Consulting Sàrl, Fribourg, Switzerland

Ann Bourgès

Ministère de la culture et de la communication, Paris, France

Susanna Bracci

Italian National Research Council, Rome, Italy

Philippe Bromblet (Vice-President)

Centre Interdisciplinaire de Conservation et Restauration du Patrimoine (CICRP), Marseille, France

Hilde De Clercq (President)

Royal Institute for Cultural Heritage, Brussels, Belgium

Eric Doehne

Scripps College, Claremont, CA, United States of America

Miloš Drdäcký

Academy of Sciences of the Czech Republic, Prague, Czech Republic

Christoph Franzen

Institut für Diagnostik und Konservierung an Denkmälern in Sachsen und Sachsen Anhalt e.V.,
Dresden, Germany

Jadwiga Łukaszewicz

Department for Conservation of Architectonic Elements and Details, Faculty of Fine Arts,
Nicolaus Copernicus University, Toruń, Poland

Antonia Moropoulou

School of Chemical Engineering, National Technical University of Athens, Greece

Stefan Simon

Institute for the Preservation of Cultural Heritage (IPCH), Yale University, West Haven, CT,
United States of America

Ákos Török

Department of Construction Materials and Engineering Geology,
Budapest University of Technology and Economics, Budapest, Hungary

Johannes Weber

Institute of Art and Technology, Conservation Science, University of Applied Arts Vienna, Austria

George W. Scherer

Civil and Environmental Engineering Department, Princeton University, United States of America

David A. Young

Heritage Consultant, Melbourne, Australia

ACKNOWLEDGEMENTS

Historic Environment Scotland, for their assistance and support in the hosting of the Congress Dinner at the Kelvingrove Art Gallery and Museum, Glasgow. Ewan Hyslop, Maureen Young and Christa Gerdwilker are thanked for their voluntary input to the organisation of technical visits to Largs and Glasgow.

The British Geological Survey.

Our commercial sponsors: SINT Technologies, Surface Measurement Systems, GC Laser Systems, Fokus GmbH Leipzig and Remmers.

Renfrewshire Council and the staff of the Town Hall.

The community at Paisley Abbey.

Alexander Collins, excursion guide.

Drew Wilson, Richard Potts and Stuart Johnson of UWS's Corporate Marketing for design and layout of the Congress Logo, programmes and other printed matter.

Finally, thanks must go to Alison Wright (formerly of Glasgow University), who bravely bore our application to host the Congress to New York in 2012, without complaint. On this occasion we must also thank the team at the University of the West of Scotland; Georgia Adam, Irene Edmiston, Gaia Frola, Matt Gilmour and Emma Paterson, without whose efforts the Congress could not have been held.



This page has been left intentionally blank.

CONTENTS

Volume I

Damage	1
Traffic-induced Emissions on Stone Buildings.....	3
<i>M. Auras, P. Bundschuh, J. Eichhorn, D. Kirchner, M. Mach, B. Seewald, D. Scheuvs and R. Snethlage</i>	
Weathering Patterns of the Carved Stone and Conservation Challenges - World Heritage Site of Qutb Complex, New Delhi	13
<i>S.S. Bais and S.C. Pandey</i>	
Effect of Microorganism Activities in a Polluted Area on the Alteration of Limestone used in Historical Buildings	25
<i>C. Balland-Bolou-Bi, M. Saheb, N. Bousserhine, S. Abbad-Andalousi, V. Alphonse, S. Nowak, A. Chabas, K. Desboeufs and A. Verney-Carron</i>	
Granite and Marine Salt Weathering Anomalies from Submerged and Inter-tidal and Coastal Archaeological Monuments in Ireland	33
<i>J. Bolton</i>	
Decay of Mesozoic Saltrio and Viggiù Limestones: Relationship between Micro- structural, Compositional and Environmental Characteristics	41
<i>G. Cavallo, R. Bugini, D. Biondelli and S. Franscella</i>	
Role of Hydro-mechanical Coupling in the Damage Process of Limestones Used in Historical Buildings	49
<i>F. Cherblanc, J. Berthonneau and P. Bromblet</i>	
The Contribution of Traditional Techniques to New Technology to Evaluate the Potential Risk of Stone Deterioration by Microorganisms	57
<i>E. Sirt-Ciplak, A. Cetin-Gozen and E.N. Caner-Saltik</i>	
Porosimetric Changes and Consequences for Damage Phenomena Induced by Organic and Inorganic Consolidation Treatments on Highly Porous Limestone.....	67
<i>P. Croveri, L. Dei, J. Cassar and O. Chiantore</i>	
Alteration of Marble Stones by Red Discoloration Phenomena	75
<i>O.A. Cuzman, S. Vettori, F. Fratini, E. Cantisani, S. Ciattini, L. Chelazzi, M. Ricci and C.A. Garzonio</i>	
Quantifying Salt Crystallization Dynamics in Sandstone Using 4D Laboratory X- ray Micro-CT	83
<i>H. Derluyn, M.A. Boone, J. Desarnaud, L. Grementieri, L. Molari, S. de Miranda, N. Shahidzadeh and V. Cnudde</i>	

Investigation of Salt Solution Behaviour in Building Stones Using Paper Pulp Poultices Under Laboratory Conditions.....	91
<i>I. Egartner and O. Sass</i>	
Experimental Study of the Ageing of Building Stones Exposed to Sulfurous and Nitric Acid Atmospheres	99
<i>S. Gibeaux, C. Thomachot-Schneider, A. Schneider, V. Cnudde, T. De Kock, V. Barbin and P. Vazquez</i>	
Geological Studies on Volcanic Tuffs Used as Natural Building Stones in the historical Center of San Luis Potosí, Mexico	107
<i>R.A. López Doncel, W. Wedekind, N. Cardona-Velázquez, P.S. González- Sámamo, R. Dohrmann, S. Siegesmund and C. Pötzl.</i>	
Weathering and Deterioration of Building Stones in Templo Mayor, Mexico City	117
<i>G. Mora Navarro, R.A. López Doncel, M. Espinosa Pesqueira and W. Wedekind</i>	
Decay Products of the Kersantite Building Stone in the Monument of the Small Staircase at the Kalemegdan Park (Belgrade, Serbia).....	125
<i>N. Novaković, M. Franković, V. Matović, K. Šarić and S. Erić</i>	
Relationship between the Durability and Fabric of Pasargadae Carbonate Stones (Archaeological Site from Achaemenid Period, South of Iran)	133
<i>A. Shekofteh, H. Ahmadi and M. Yazdi</i>	
Biodeterioration of Limestone Built Heritage: A Multidisciplinary Challenge	139
<i>P.J.A. Skipper, H. Schulze, D.R. Williams and R.A. Dixon</i>	
Characterisation of a Pink Discoloration on Stone in the Pnom Krom Temple (Angkor, Cambodia)	147
<i>M. Tescari, F. Bartoli, A. Casanova Municchia, T. Boun Suy and G. Caneva</i>	
Influence of the Villarlod Molasse Anisotropy on Cracking Advances in the Comprehension of the Desquamation Mechanisms	155
<i>M. Tiennot, A. Bourgès and J.-D. Mertz</i>	
Decay phenomena of marbles in the archaeological site of Hierapolis of Phrygiae (Denizli, Turkey)	165
<i>S. Vettori S. Bracci, P. Caggia, E. Cantisani, O.A. Cuzman, T. Ismaelli, C. Riminesi, B. Sacchi, G. Scardozzi and F. D'Andria</i>	
Freezing-thawing Phenomena in Limestones and Consequences for their Physical and Mechanical Properties	173
<i>C. Walbert, J. Eslami, A.-L. Beaucour, A. Bourgès and A. Noumowe</i>	

Rapid Degradation of Styrolitic Limestones Used in Building Cladding Panels	181
<i>T. Wangler, A. Aguilar Sanchez and T. Peri</i>	
Swelling Clay and its Inhibition in the Villarlod Molasse	189
<i>T. Wangler</i>	
First Investigations of the Weathering and Deterioration of Rock Cut Monuments in Myra, Lycia (Turkey)	197
<i>W. Wedekind, R.A. López Doncel, B. Marié and O. Salvadori</i>	
Contour Scaling at the Angkor Temples: Causes, Consequences and Conservation.....	205
<i>W. Wedekind, C. Gross, A. van den Kerkhof and S. Siegesmund</i>	
Georgia Marble at the Minnesota State Capitol: Examining the Correlations between Marble Composition, Local Climate, Climate and Durability	215
<i>P.G. Whitenack and M.J. Scheffler</i>	
Investigation Methods	223
The Effect of Salt Crystallisation on the Mechanical Properties of Limestone: Statistical Correlation between Non-Destructive and Destructive Techniques	225
<i>N. Aly, A. Hamed, M. Gomez-Heras, D. Benavente and M. Alvarez de Buergo</i>	
Computational simulation: Four Important Structural Elements to Protect the Buildings in Ancient Persian Engineering	233
<i>A. AmirShahkarami, M. Mehdiabadi and H. Ashooriha</i>	
Material Analysis of Tarsus' (Mersin, Turkey) Traditional Buildings for the Development of Conservation Strategies.....	243
<i>M.C. Atikoğlu, A. Tavukçuoğlu, B.A. Güney, E.N. Caner-Saltık, O. Doğan, M.K. Ardoğa and M. Mayhar</i>	
Artificial Ageing Techniques on Various Lithotypes for Testing of Stone Consolidants	253
<i>M. Ban, A.J. Baragona, E. Ghaffari, J. Weber and A. Rohatsch</i>	
Applications of Image Analysis to Marble Samples.....	261
<i>R. Bellopede, E. Castelletto, N. Marcone and P. Marini</i>	
The Effects of Commercial Ethyl Silicate Based Consolidation Products on Limestone	271
<i>T. Berto, S. Godts and H. De Clercq</i>	
Field Exposure Tests to Evaluate the Efficiency of Nano-Structured Consolidants on Carrara Marble.....	281
<i>A. Bonazza, G. Vidorni, I. Natali, C. Giosuè, F. Tittarelli and C. Sabbioni</i>	

Electrophoresis as a Tool to Remove Salts from Stone Building Materials – Results from Lab Experiments and an On-site Application.....	289
<i>H. De Clercq, S. Godts, L. Debailleux, Y. Vanhellemont, N. Vanwynsberghe, L. Derammelaere and V. De Swaef</i>	
Salt Weathering of Sandstone During Drying: Effect of Primary and Secondary Crystallisation	299
<i>J. Desarnaud, H. Derluyn, L. Grementieri, L. Molari, S. de Miranda, V. Cnudde and N. Shahidzadeh</i>	
Handheld X-Ray Fluorescence Analysis (HH-XRF): A Non-Destructive Tool for Distinguishing Sandstones in Historic Structures	309
<i>P.A. Everett and M.R. Gillespie</i>	
Intrinsic Parameters Conditioning the Formation of Mn-rich Patinas on Luneville Sandstones	317
<i>L. Gatuingt, S. Rossano, J.-D. Mertz, B. Lanson and O. Rozenbaum</i>	
Smart Hydrophobic TiO ₂ -nanocomposites for the Protection of Stone Cultural Heritage	325
<i>F. Gherardi, A. Colombo, S. Goidanich and L. Toniolo</i>	
Salt Extraction by Poulticing Unravelling?.....	333
<i>S. Godts, H. De Clercq and L. Debailleux</i>	
Quantifying the Damage and Decay for Conservation Projects: Identification, Classification and Analysis of the Decay and Deterioration in Stone	343
<i>P.T. Janbade N. Thakur and B.N. Tandon</i>	
The Potential of Laser Scanning to Describe Stone degradation	353
<i>R. Janvier, X. Brunetaud, K. Beck, S. Janvier-Badosa and M. Al-Mukhtar</i>	
Application of Colorimetry for the Post-Fire Diagnosis of Historical Monuments	361
<i>S. Janvier-Badosa, K. Beck, X. Brunetaud, Á. Török and M. Al-Mukhtar</i>	
Developing Application Technology of Infrared Thermography for Documentation of Blistering Zone.....	369
<i>Y.H. Jo and C.H. Lee</i>	
Stability Evaluation and Behaviour Monitoring of Songsanri Royal Tomb Complex in Gongju, Korea	375
<i>S.H. Kim, C.H. Lee, Y.H. Jo and S.H. Yun</i>	
Simulated Weathering and Other Testing of Dimension Stone	381
<i>D. Kneezel</i>	

IR Thermography Imaging of Water Capillary imbibition into Poursous Stones of a Gallo-Roman Site	391
<i>J. Liu, J. Wassermann, C.-D. Nguyen, J.-D. Mertz, D. Giovannacci, R. Hébert, B. Ledesert, V. Barriere, D. Vermeersch and Y. Mélinge</i>	
Investigation of Urban Rock Varnish on the Sandstone of the Smithonian Castle	399
<i>R.A. Livingston, C.A. Grissom, E.P. Vicenzi, Z.A. Weldon-Yochim, N.C. Little, J.G. Douglas, A.J. Fowler, C.M. Santelli, D.S. Macholdt, D.L. Ortiz-Montalvo and S.S. Watson</i>	
Petrophysical Characterization of Both Original and Replacment Stone Used in Archtecturaal Herritage of Morelio (Mexico)	407
<i>J. Martinez-Martinez, A. Pola Villaseñor, L. García-Sánchez, G. Reyes-Agustín, L.S. Osorio Ocampo, J.L. Macías Vazquez and J. Robles-Camacho</i>	
Assesment of a Non-Destructive and Portable Mini Permeameter Based on a Pulse Decay Flow Applied to Historical Surfaces of Porous Materials	415
<i>J.-D. Mertz, E. Colas, A. Ben Yahmed and R. Lenormand</i>	
Monitoring of Salts Content in Monuments of Toruń Old Town Complex	423
<i>W. Oberta and J.W. Łukaszewicz</i>	
Comparability of Non-Destructive Moisture Measurement Techniques on Masonry During Simulated Wetting	431
<i>S.A. Orr, H.A. Viles, A.B. Leslie and D. Stelfox</i>	
Water Absorption and Pore-Size Ditribution of Silica Acid Ester Consolidated Porous Limestone	439
<i>Z. Pápay and Á. Török</i>	
Conservation Status and Behaviour Monitoring System of Gongsanseong Fortress Wall in Gongju, Korea	445
<i>J.H. Park, K.K. Yang, C.U. Park, Y.H. Jo and C.H. Lee</i>	
Ground Penetrating Radar and the Detection of Structural Anomalies of High Historical Value: A Case Study of a Burgher House in Toruń, Poland	451
<i>M. Pilarska, J. Rogóż, A. Cupa, K. Krynicka-Szroeder and P. Szroeder</i>	
Strategies for the Conservation of Built Heritage Based on the Analysis of Rare Events	459
<i>Y. Praticò, F. Girardet and R.J. Flatt</i>	
Direct Measurement of Salt Crystallisation Pressure at the Pore Scale	467
<i>N. Shahidzadeh, J. Desarnaud and D. Bonn</i>	

Drilling Resistance Measurement in Masonry Buildings: A Statistical Approach to Characterise Non-homogeneous Materials	475
<i>E. Valentini and A. Benincasa</i>	
<i>In situ</i> Assessment of the Stone Conservation State by its Water Absorbing Behaviour: A Hands-On Methodology	483
<i>D. Vandevoorde, T. De Kock and V. Cnudde</i>	
Surface hardness Testing for the Evaluation of Consolidation OF POROUS STONES.....	491
<i>W. Wedekind, C. Pötzl, R.A. López Doncel, T.V. Platz and S. Siegesmund</i>	
Other Materials.....	501
Long-term Monitoring of Decay Evolution in Bricks and Lime Mortar Affected by Salt Crystallisation.....	503
<i>C. Colla, E. Gabrielli and F. Grüner</i>	
Assessment of the Physical Behaviour of Historic Bricks and their Mechanical Characteristics via Absorption and Ultrasound Tests	511
<i>C. Colla and E. Gabrielli</i>	
Acrylic-based Mortar for Stone Repair: A Viscoelastic Analysis of the Thermal Stresses	521
<i>T. Demoulin , G.W. Scherer, F. Girardet and R.J. Flatt</i>	
Characterization and Test Treatments of Cast-Stone Medallions at the Smithsonian	529
<i>C.A. Grissom, E. Aloiz, E.P. Vicenzi, N.C. Little and A.E. Charola</i>	
Composition of Stone Plasters and Pigmented Plasters Applied in the 1920s and 1930s in Berlin, Germany	537
<i>S. Laue</i>	
Recovering the Architectural Heritage of the Nueva Tabarca Island (Spain) by Studying the Durability of Original and Repair Mortars	545
<i>J. Martinez-Martinez and A. Arizzi</i>	
Stone-mortar Interaction of Similar Weathered Stone Repair Mortars Used in Historic Buildings	553
<i>B. Menendez, P. Lopez-Arce, J.-D. Mertz, M. Tagnit-Hamou, S. Aggoun, A. Kaci, M. Guiavarch and A. Cousture</i>	
Restoration of Weathered Load Bearing Masonry with Optimised Gypsum based mortars	561
<i>B. Middendorf and U. Huster</i>	

Acquisition and Analysis of Petrophysical Properties of the Rock of the Masonry of the Cathedral of Aguascalientes, Mexico	569
<i>R. Padilla Ceniceros, J. Pacheco Martínez and R.A. López Doncel</i>	
The Assessment and Treatment of Two Cast Stone Fountains from the 1920's in Palm Beach, Florida, USA: Technical and Theoretical Issues in the Preservation of Aged Cast Stone	575
<i>M. Rabinowitz, J. Sembrat and P. Miller</i>	
Dating the Pre-Romanesque Church of San Miguel de Lillo, Spain: New Methods for Historic Buildings	583
<i>A. Rojo, L.L.Cabo, C.M. Grossi and F.J. Alonso</i>	
Swelling Inhibition of Clay-Bearing Building Materials used in Architectural Monuments	591
<i>A. Stefanis and P. Theoulakis</i>	
Long-term Mechanical Changes of Repair Mortar Used in Restoration of Porous Limestone Heritage.....	599
<i>B. Szemerey-Kiss and Á. Török</i>	
Proprietary Mortars for Masonry Repair: Developing a Predictive Framework for Assessing Compatibility	607
<i>C. Torney</i>	
Study of Efficiency and Compatibility on Successive Applications of Treatments for Islamic Gypsum and Plaster from the Alhambra	613
<i>R. Villegas Sanchez, F. Arroyo Torralvo, R. Rubio Domene and E. Correa Gomez</i>	
Comparative Studies on Masonry Bricks and Bedding Mortars of the Fortress Masonry of The Teutonic Order State in Prussia: Malbork, Toruń, and Radzyń Chełmiński Castles	621
<i>K. Witkowska and J.W. Łukaszewicz</i>	
Organic Additives in Mortars: An Historical Tradition through a Critical Analysis of Recent Literature	631
<i>K. Zhang, L. Rampazzi, A. Sansonetti and A. Grimoldi</i>	
Abstracts.....	639
Impact of Heat Exposure (Fire Damage) on the Properties of Sandstone.....	641
<i>T. Howind, W. Zhu and J.J. Hughes</i>	
Sandstone Weathering: New Approaches to Assess Building Stone Decay	642
<i>J. Dassow, M. Lee, P. Harkness, S. Hild and A.B. Leslie</i>	

Pore-scale Freeze-Thaw Experiments with Environmental Micro-CT	643
<i>T. De Kock, H. Derluyn, T. De Schryver, M.A. Boone and V. Cnudde</i>	
Conservation Study of Stone Masonries Using IRT: Discover Hidden Information by Thermal Properties.....	644
<i>C. Franzen and J.-M. Vallet</i>	
Active IRT and Theoretical Simulation Inputs for the Voids Determination in Building Material.....	645
<i>K. Mouhoubi, C. Franzen, J.-M. Vallet, V. Detalle, O. Guillon and L. Bodnar</i>	
Evaluation of Harmfulness of Traditional Cleaning Techniques of Stone with 3D Optical Microscopy Profilometry	646
<i>C. Tedeschi , M.P. Riccardi , S. Perego and M. Taccia</i>	
Multifunctional Polymers for the Restoration of the Deteriorated Mineral Gypsum (Selenite) of the Minoan Palatial Monuments of Knossos.....	647
<i>I.E. Grammatikakis, K.D. Demadis and K. Papathanasiou</i>	
Consolidant Efficiency of Newly Developed Consolidant Based on the Soluble Calcium Compounds.....	649
<i>A. Pondelak, L. Škrlep, T. Howind, J.J. Hughes and A. Sever Škapin</i>	
List of Authors	XXI
List of Keywords	XXV

Volume II

Conservation	651
Analysis, Testing and Development of Safe Cleaning Methods of Rusted Stone Material.....	653
<i>J. Aguiar, S. Bracci, B. Sacchi and B. Salvadori</i>	
Preliminary Studies in Using Lime with Additives as a Substitute for Resins as Adhesives in Stone Conservation	663
<i>J. Alonso and M. Franković</i>	
Freeze Thaw and Salt Crystallisation Testing of Nanolime Treated Weathered Bath Stone.....	671
<i>R.J. Ball and G.L. Pesce, M. Nuño, D. Odgers and A. Henry</i>	
Thermosetting Methyl Methacrylate Adhesive for Stone: Characterisation, Application Techniques and Long-term Performance Elevation	679
<i>Z. Barov</i>	

Consolidation Effects on Sandstone Toughness	687
<i>M. Drdácký, M. Šperl and I. Jandejsek</i>	
Is the Shelter at Hagar Qim in Malta Effective at Protecting the Limestone Remains?	695
<i>C. Cabello-Briones and H.A. Viles</i>	
Assessment of the Cleaning Efficiency of a Self-cleaning Coating on Two Stones Under Natural Ageing.....	703
<i>P.M. Carmona-Quiroga, S. Kang and H.A. Viles</i>	
Exploitation of the Natural Water Repellency of Limestones for the Protection of Building Façades	711
<i>C. Charalambous and I. Ioannou</i>	
The Use of New Laser Technology to Precisely Control the Level of Stone Cleaning.....	719
<i>B. Dajnowski and A. Dajnowski</i>	
Cleaning Stone – The Possibilities for an Objective Evaluation.....	729
<i>J. Ďoubal</i>	
The Natural Weathering of an Artificially Induced Calcium Oxalate Patina on Soft Limestone.....	737
<i>T. Dreyfuss and J. Cassar</i>	
A Comparison of Three Methods of Consolidation for Claceros Mixed Stones	745
<i>J. Espinosa-Gaitán and A. Martín-Chicano</i>	
Seasonal Stone Sheltering: Winter Covers	753
<i>C. Franzen and K. Kraus</i>	
Performance and Permanence of TiO ₂ -based Surface Treatments for Architectural Heritage: Some Experimental Findings from On-site and Laboratory Testing	761
<i>E. Franzoni, R. Gabrielli, E. Sassoni, A. Fregni, G. Graziani, N. Roveri and E. D'Amen</i>	
The Impact of Science on Conservation Practice: Sandstone Consolidation in Scottish Built Heritage.....	769
<i>C. Gerdwilker, A. Forster, C. Torney and E. Hyslop</i>	
Use of Local Stone in the Midwestern United States: Successes, Failures and Considerations	777
<i>E. Gerns and R. Will</i>	
Laser Yellowing of Hematite-Gypsum Mixtures: A Multi Scale Characterisation	785
<i>M. Godet, V. Vergès-Belmin, C. Andraud, M. Saheb, J. Monnier, E. Leroy and J. Bourgon</i>	

The Use of Hydroxyapatite for Consolidation of Calcareous Stones: Light Limestone Pińczów and Gotland Sandstone (Part I).....	793
<i>A. Górnjak, J.W. Łukaszewicz, B. Wiśniewska</i>	
Marble Protection by Hydroxyapatite Coatings.....	803
<i>G. Graziani, E. Sassoni, E. Franzoni and G.W. Scherer</i>	
Use of Consolidants and Pre-Consolidants in Sandstone with Swelling Clay at the Muncipal Theatre of São Paulo.....	811
<i>D. Grossi, E.A. Del Lama and G.W. Scherer</i>	
Assessing the Impact of Natural Stone Burial upon Performance for Potential Conservation Purposes.....	817
<i>B.J. Hunt and C.M. Grossi</i>	
Study of Protective Measures of Stone Monuments in Cold Regions	825
<i>T. Ishizaki</i>	
Study of Consolidation of Porous and Dense Limestones by Bacillus Cereus Biomineralization	831
<i>J.M. Jakutajć, J.W. Łukaszewicz and J. Karbowska-Berent</i>	
Assessment of Dolomite Conservation by Treatment with Nano-Dispersive Calcium Hydroxide Solution	839
<i>F. Karahan Dağ, Ç.T. Mısır, S. Çömez, M. Erdil, A. Tavukçuoğlu, E.N. Caner-Saltık, B.A. Güney and E. Caner</i>	
European Project “NANO-CATHEDRAL: Nanomaterials for conservation of European architectural heritage developed by research on characteristic lithotypes”.....	847
<i>A. Lazzeri, M.-B. Coltelli, V. Castelvetro, S. Bianchi, O. Chiantore, M. Lezzerini, L. Niccolai, J. Weber, A. Rohatsch, F. Gherardi and L. Toniolo</i>	
New Polymer Architectures for Architectural Stone Preservation	855
<i>A. Lazzeri, S. Bianchi, V. Castelvetro, O. Chiantore, M.-B. Coltelli, F. Gherardi, M. Lezzerini, T. Poli, F. Signori, D. Smacchia and L. Toniolo</i>	
Trials of Biocide Cleaning Agents on Argillaceous Sandstone in a Temperate Region.....	863
<i>E. S. Long and D.A. Young</i>	
Development of a methodology for the Restoration of Stone Sculptures using Magnets	871
<i>X. Mas-Barberà, M.A. Rodríguez, L. Pérez and S. Ruiz</i>	

The Rock Reliefs “ <i>Steinerne Album</i> ” of Großjena, Germany – Problems of Deterioration and Approaches for a Lasting Preservation	879
<i>J. Meinhardt, T. Arnold and K. Böhm</i>	
Ethyl-silicate Consolidation for Porous Limestone Coated with Oil Paint – A Comparison of Application Methods.....	889
<i>M. Milchin, J. Weber, G. Krist, E. Ghaffari and S. Karacsonyi</i>	
Electro-desalination of Sulfate Contaminated Carbonaceous Sandstone – Risk for Salt Induced Decay During the Process.....	897
<i>L.M. Ottosen</i>	
Permeable POSS-based Hybrids: New Protective Materials for Historical Sandstone.....	905
<i>A. Pan, S. Yang and L. He</i>	
Differential Effects of Treatments on the Dynamics of Biological Recolonisation of Travertine: Case Study of the Tiber’s Embankments (Rome, Italy).....	915
<i>S. Pascucci, F. Bartoli, A. Casanova Municchia and G. Caneva</i>	
Statistical Analysis at the Service of Conservation Practice: DOE for the Optimisation of Stone Consolidation Procedures	923
<i>Y. Praticò, F. Caruso, T. Wangler and R.J. Flatt</i>	
Vacuum-Circling Process: A Innovative Stone Conservation Method.....	931
<i>E. Pummer</i>	
Sustainable Conservation in a Monumental Cemetery	939
<i>S. Salvini</i>	
Consolidation of Sugaring Marble by Hydroxyapatite: Some Recent Developments in Producing and Treating Decayed Samples	947
<i>E. Sassoni, G. Graziani, E. Franzoni and G.W. Scherer</i>	
Application of Ethyl Silicate Based Consolidants on Sandstone with Partial Vacuum: A Laboratory Study.....	955
<i>H. Siedel, J. Wichert and T. Frühwirt</i>	
Mould Attacks! A Practical and Effective Method of Treating Mould Contaminated Stonework.....	963
<i>B. Stanley, N. Luxford and S. Downes</i>	
Injection Grouts based on Lithium Silicate Binder: A Review of Injectability and Cohesive Integrity.....	971
<i>A. Thorn</i>	

Innovative Treatments and Materials for the Conservation of the Strongly Salt-contaminated Michaelis Church in Zeitz, Germany	981
<i>W. Wedekind, R.A. López-Doncel, J. Rüdrich and Y. Rieffel</i>	
Field Trials of Desalination by Captive-head Washing	991
<i>D. Young</i>	
Digitisation	997
Digital Mapping as a Tool for Assessing the Conservation State of the Romanesque Portals of the Cathedral of our Lady in Tournai, Belgium	999
<i>J. De Roy, S. Huysmans, L. Hoornaert, L. Fontaine and N. Verhulst</i>	
Digital Field Documentation: The Central Park Obelisk	1009
<i>C. Gembinski</i>	
Computational Imaging Techniques for Documentation and Conservation of Gravestones at Jewish Cemeteries in Germany	1017
<i>C.A. Graham and S. Simon</i>	
A Metadata-supported Database Schema for Stone Conservation Projects	1025
<i>E. Kardara and T. Pomonis</i>	
3D Photo Monitoring as a Long-term Monument Mapping Method for Stone Sculptures	1031
<i>B. Kozub and P. Kozub</i>	
Emerging Digitisation Trends in Stonemasonry Practice	1041
<i>S. McGibbon and M. Abdel-Wahab</i>	
Digitalisation and Documentation of Stone Deterioration, Using Close-Range Digital Photogrammetry	1051
<i>M.Á. Soto-Zamora, R.A. López-Doncel, G. Araiza-Garaygordobil and I.E. Vizcaino-Hernández</i>	
Recording, Monitoring and Managing the Conservation of Historic Sites: A New Application for BGS SIGMA	1059
<i>E.A. Tracey, N. Smith and K. Lawrie</i>	
Case Studies.....	1067
Condition Survey of Aquia Creek Sandstone Columns From the U.S. Capitol Re-Erected at the U.S. National Arboretum	1069
<i>E. Aloiz, C. Grissom, R.A. Livingston and A.E. Charola</i>	
The Black Surfaces of the Porta Nigra in Trier (Germany) and the Question of Cleaning.....	1077
<i>M. Auras, H. Ettl, W. Hartleitner and T. Meier</i>	

The Conservation of Giovanni Labus’s Sculpture of Bonaventura Bavallieri (1844) and Antonio Galli’s Sculpture of Carlo Ottavio Castiglione (1855)	1089
<i>I. Ruiz Bazán, V. Bresciani, A. Balloi, A. Quarto, I. Marelli, M. Colella, C. Sotgia and F. Arosio</i>	
Restoration Off-set by the Public Exhibition of Decorated Stone Elements Rescued from the demolished Vacaresti Monastery, Romania.....	1097
<i>C. Bîrzu</i>	
Rosslyn Chapel - A Review of the Conservation & Access Project.....	1103
<i>N. Boyes</i>	
Laboratory and in situ evaluation of restoration treatments in two important monuments in Padua: “Loggia Cornaro” and “Stele of Minerva”	1111
<i>V. Fassina, S. Benchiarin and G. Molin</i>	
Investigations Guiding the Stone Restoration of the “Schöner Erker” in Torgau, Germany	1119
<i>C. Franzen, H. Siedel, S. Pfefferkorn, A. Kiesewetter and S. Weise</i>	
Ananalysis and Treatment of the Fire-Damaged Marble Plaque from Thomas Jefferson’s Grave Marker	1129
<i>C. Grissom, E. Vicenzi, J. Giacciai, N.C. Little, C. France, A.E. Charola and R.A. Livingston</i>	
The Diagnostic and Monitoring Approach for the Preventive Conservation of the Façade of the Milan Cathedral.....	1137
<i>D. Gulotta, P. Fermo, A. Bonazza and L. Toniolo</i>	
Enviromental Monitoring and Surface Treatment Tests for Conservation of the Rock-Hewn Church of Üzümlü, Cappadocia	1145
<i>C. Iba, Y. Taniguchi, K. Koizumi, K. Watanabe, K. Sano C. Piao and M. Yoshioka</i>	
Time Tested Repairs: A Review of 11 Years of Cementery Stone Repair	1153
<i>M. Jablonski</i>	
The Current State and Factors of Salt Deterioration of the Buddha Statue Carved onto a Cliff at Motomachi in Oita Prefecture of Japan	1163
<i>K. Kiriya, S. Wakiya, N. Takatori, D. Ogura, M. Abuku and Y. Kohdzuma</i>	
The Durbar Square and the Royal Palace of Patan, Nepal – Stone Conservation Before and after the Great Earthquake of April 2015	1171
<i>G. Krist, M. Milchlin and M. Haselberger</i>	

Restoring the Past Experience of Stone Masonry in Burkina Faso for Fostering the use of Local Materials.....	1181
<i>A. Lawane, A. Pantet, R. Vinai and J.H. Thomassin</i>	
Protection of Medieval Tombstones (Stećci) with Ammonium Oxalate Treatment	1189
<i>V. Marinković and D. Mudronja</i>	
Influence of Water Evaporation on the Degradation of Wall Paintings in Hagia Sophia, Istanbul	1201
<i>E. Mizutani, D. Ogura, T. Ishizaki, M. Abuku and J. Sasaki</i>	
Conservation of Magai-Wareishi-jizo, A Buddha Statue Carved into a Granite Rockface on the Seashore	1211
<i>M. Morii, N. Kuchitsu, T. Kawaguchi, H. Matsuda and S. Tokimoto</i>	
Evaluation of the Preservation State of the Holy Aedicule in the Holy Sepulchre Complex in Jerusalem.....	1219
<i>A. Moropoulou, K. Labropoulos, E. Alexakis, E.T. Delegou, P. Moundoulas, M. Apostolopoulou and A. Bakolas</i>	
Conservation of Machu Picchu Archaeological Site: Investigation and Experimental Restoration Works of the “Temple of the Sun”	1227
<i>T. Nishiura, I. Ono, A. Ito, H. Fujita, M. Morii, F. Astete and C. Cano</i>	
Las Casas Tapadas de Plazuelas – Structural Damage, Weathering Characteristics and Technical Properties of Volcanic Rocks in Guanajuato, Mexico.....	1237
<i>C. Pötzl, R.A. López-Doncel, W. Wedekind and S. Siegesmund</i>	
Desalinating the Asyut Dog in the MUSÉE DU LOUVRE.....	1247
<i>O. Rolland, V. Vergès-Belmin, M. Etienne, H. Guichard, S. Duberson and P. Bromblet</i>	
Investigation of Salt Crystallisation in a Stone Buddha Carved into a Cliff with a Shelter by Numerical Analysis of Heat and Moisture Behaviour in the Cliff.....	1255
<i>N. Takatori, D. Ogura, S. Wakiya, M. Abuku, K. Kiriyaama and Y. Kohdzuma</i>	
Scientific Examination of a Painted Thracian Tomb Discovered Near Alexandrovo Village, Bulgaria	1263
<i>V. Todorov, K. Frangova and T. Marinov</i>	
Case Study of the Episcopal Group of Frejus (France): Diagnosis and Treatment of Clay Containing Sandstones in Marine Environment.....	1271
<i>M. Trubert, B. Brunet-Imbault, P. Bromblet and C. Guinamard</i>	
The Polychromed Bethlehem Portal of Huy, Belgium: Evaluation and Maintenance of a 25 Year Old Treatment.....	1279
<i>J. Vereecke, L. Rossen, K. Raymakers and M. Stillhammerova</i>	

Exploring the Performance of Pompignan Limestone as Exterior Cladding and Pavers in the Mid-Atlantic Region of the United States	1287
<i>R. Wentzel and M. Coggin</i>	
Abstracts	1295
Mechanisms of Carbonate-oxalate Transformation: Effectiveness of Protective Treatments for Marble based on Oxalate Surface Layers	1297
<i>A. Burgos-Cara, C. Rodríguez-Navarro and E. Ruiz-Agudo</i>	
Preservation of Built Cultural Heritage Using Nanotechnology Based Coatings: Responding to Conservation Values?	1299
<i>J.J. Hughes, L.P. Singh, P.C. Thapliyal, T. Howind and W. Zhu</i>	
Innovative Developments in the Field of Stone Conservation by the Acrylic Resin Total Impregnation Process of Natural Stones by the JBACH Company	1300
<i>G. Scholz, R.J.G. Sobott, H.W. Ibach</i>	
MONUMENTUM: Digital 3D Modelling and Data Management for the Conservation of Decorated Stone Buildings	1301
<i>L. De Luca, J.-M. Vallet, P. Bromblet, M. Pierrot-Desseilligny, X. Brunetaud, F. Dubois, M. Bagneris, M. Al Mukhtar, F. Cherblanc, O. Guillon and J. Tugas</i>	
Investigation of Building Stones Used in the Al-Azhar mosque (Historic Cairo, Egypt)	1303
<i>N. Aly, A. Hamed, Á. Török, M. Gomez-Heras and M. Alvarez de Buergo</i>	
The Effect of Reburial on Stone Deterioration: Experimental Case Study, Oxford, England	1304
<i>N. Zaman and H. Viles</i>	
List of Authors	XXIII
List of Keywords	XXVII

This page has been left intentionally blank.

THE CONSERVATION OF GIOVANNI LABUS'S SCULPTURE OF BONAVENTURA BAVALLIERI (1844) AND ANTONIO GALLI'S SCULPTURE OF CARLO OTTAVIO CASTIGLIONE (1855)

I. Ruiz Bazán¹, V. Bresciani², A. Balloi³, A. Quarto⁴,
I. Marelli⁴, M. Colella^{5*}, C. Sotgia⁶ and F. Arosio⁷

Abstract

In this project a cleaning intervention of the neoclassical statues in the Brera Academy courtyard was performed with the use of living microbial cells. These living organisms, belonging to the species *Desulfovibrio vulgaris*, were able to remove chemical alterations, mainly caused by sulfates, from the stone surface of the statues. The method has been chosen because it is highly efficient, respectful to the original material, the environment and the restorer operating it. Thanks to the microorganism's selectiveness, it was possible to remove only the harmful alteration of the stones, respecting the so-called "noble patina" a key element in art pieces. Considering the precarious state of conservation of the hands belonging to the statue of Carlo Ottavio Castiglione, a 3D (Rilievo 3D) survey was taken.

Keywords: 3D survey, convergent photogrammetry, bio-restoration, sculpture, marble, cleaning

¹ I. Ruiz Bazán
Architect, Milan, Italy and Zaragoza, Spain

² V. Bresciani
Bresciani s.r.l., Milan, Italy

³ A. Balloi
Micro4yoU s.r.l., Milan, Italy

⁴ A. Quarto and I. Marelli⁴
Soprintendenza Belle Arti e Paesaggio, Milan (Italy)

⁵ M. Colella*
Servabo Conservation Studio, Milan, Italy
servabo.colella@gmail.com

⁶ C. Sotgia
C.S.G. Palladio s.r.l., Vicenza, Italy

⁷ F. Arosio
Amici di Brera, Milan, Italy

*corresponding author

1. Introduction and historical background

Designed by Francesco Maria Richini (1584-1658) for the Jesuit College, the Brera Academy courtyard (1615) hosts in its arcades stone busts and statues figuring the most illustrious Milanese artists, scientists and philosophers. Thanks to the coworking of: Associazione Amici di Brera, Musei Milanesi, the Milanese superintendence BSAE and the generous contribution of Pirelli it was possible to restore the statues of Bonaventura Cavallieri and Carlo Ottavio Castiglione.



Fig. 1: Brera courtyard (Silver Bromide fixed on paper (1920-1940) from: Raccolte Grafiche e Fotografiche del Castello Sforzesco, Civico Archivio Fotografico, RI 14344).

Of Milanese birth Bonaventura Cavallieri (1598-1647) studied mathematics at the University of Pisa where he was student of Galileo Galilei. Bonaventura's fame is due to his approach to the method of the indivisibles, useful to determine areas and volumes. His studies were of fundamental importance for the future development of infinitesimal calculus. The statue representing this great mathematician was created by Giovanni Antonio Labus (1806-1857) who was a teacher at the Brera Academy and operated in the most outstanding construction sites of his times like the Duomo of Milan and the Arco della Pace. This extremely eloquent statue is one of his greatest achievements.

Carlo Ottavio Castiglione (1784-1849) was a numismatist and a scholar of Semitic and Indo-European languages. In 1819 he published a detailed description of Kufic coins, minted by the Normans and kept in the Brera cabinet. His main work regard the study of oriental languages and researching the origins and history of the city of Barbary (Tripoli) whose name can still be found on ancient Arab coins. Sculptor Antonio Galli (1812-1862) studied at the Brera Academy and moved to Rome to work in Thorvaldsen's studio. After this Roman stay he returned to Milan to work in the Duomo construction site. Galli presents Castiglione purposely seen from below with an intense look pointing his finger directly to a coin held in his hand.



Fig. 2: Initial phases of the conservation of Antonio Galli's sculpture of Carlo Ottavio Castiglione (1855). Height of statue plus the pedestal 503 cm (198 inches), Just the statue 305 cm (120 inches). The original surface appears hidden by a layer of aged protective varnish.

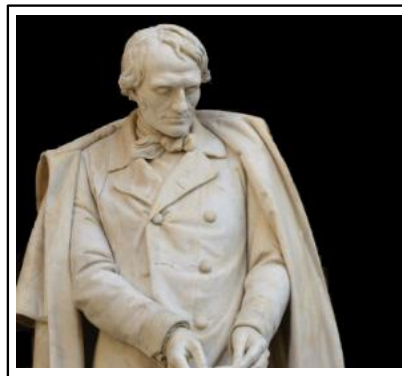


Fig. 3: Final phase of the conservation - Cleaning by sulphate reducing bacteria has given back the surface's original smoothness caused by the use of fine chisel for surface finishing and reveal a compact saccharoidal white limestone that is very similar in appearance to Venato Apuano marble.

2. 3D Survey by convergent photogrammetry

Since the hands are probably the most fragile parts on the sculpture a 3D model of the hands of the statue has been created as a preventive measure before the restoration to allow for future reproduction of those pieces. Due the difficult morphology of this area of the statue, we chose the convergent photogrammetry technique, which is one of the most used methods on sculpture. The basis of this method is the reinterpretation of the conic perspective through the use of an assemblage of pictures taken of the sculpture. Unlike lasers, this method does not reflect light back to the camera which makes it very useful for mapping complex surfaces. Another advantage of this method is that we obtain a map of the real texture of the surface which can then be incorporated in the 3D model thus significantly improving the accuracy documentation. With this high degree of accuracy it is possible to create an exact replica of the object.

3. Diagnostic phase

Two samples were taken: the first from the sculpture of Carlo Ottavio Castiglione in a yellowed area, the second from the sculpture of Bonaventura Francesco Cavalieri in a blackened area. Sample 1 was embedded in polyester resin to prepare a specimen of the cross section. First the cross section was examined by optical microscopy before proceeding with investigations including the use of an electron microscope (ESEM) and a FTIR spectrophotometer. Especially, the latter was used to determine inorganic and organic compounds, for example products due to previous conservation work, which might be responsible for surface alteration. For the characterization of the composition of sample 2, which consisted of powder, XRD and EDS analyses were carried out.

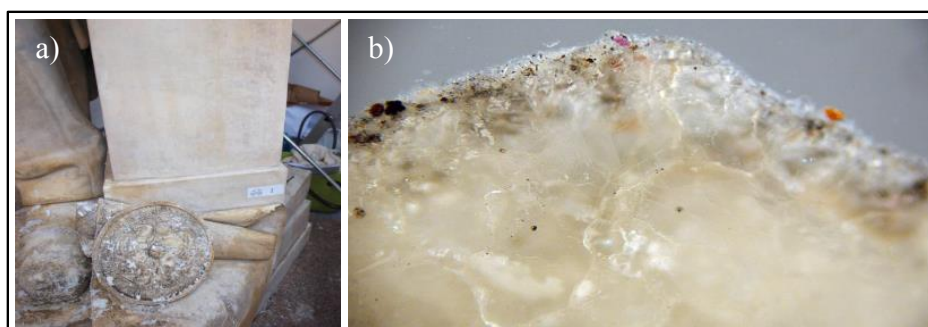


Fig. 4: a) Sampling point for sample 1; b) Micrograph of the cross section of sample 1 (magnification: $\times 240$).

In both samples analysed it has been revealed the presence of gypsum and specific air pollution: this is related to a widespread surface sulfation. In particular in sample 1 the electron microscope images show an advanced state of decohesion of the stone material. The spectrophotometric FTIR analysis has revealed calcium carbonate, gypsum and silicate but also very weak absorptions of probably synthetic resin and/or oxalates. The oxalates are usually referred to the organic substances degraded. In sample 2 both XRD analysis and EDS measurements could confirm the presence of sulfates in the form of gypsum (calcium sulfate dihydrate) and of bassanite (calcium sulfate hemihydrate). The EDS analysis has revealed silicates and also fluorine: these can be linked to conservation attempts based on fluorinated compounds or fluorosilicates undertaken in the 1970s and 1980s.

4. Conservation

The conservation work took place in the months of June, July and August 2015 in the Brera Academy courtyard. In the case of Antonio Galli's sculpture of Carlo Ottavio Castiglione Castiglione the cleaning effort has given back the surface's original smoothness produced by a fine chisel. The Bonaventura statue surface is rougher, with intentionally visible circular furrows made by the chisel. The statues in which we intervened are made of white compact saccharoidal marble, which is thought to be an apuano marble in between the common white Carrara marble and the so called Venato Apuano marble. It is a white marble with intense grey veins which the sculptor has let fall obliquely on the drapery.

During these conservation interventions there was no access to first hand data specifying the quarries from which these marbles came from. Judging by the aesthetic appearance of these marbles it can be assumed that this type of sculpting stone comes from Tuscany more specifically from the zones between Minucciano (Lucca), Cantonaccio and Fivizzano

(Massa Carrara). The tone is compact and of a medium fine grain, with a light greyish colour with abundant dark grey veins. These dark grey veins intersect each other, creating an intense dense superficial weave. There are also rare small (not more than a couple of millimetres) grey spots on the surface. A large part of the surface is covered by deposits of atmospheric particles and a conspicuous sulfation. Thin section analysis has revealed sulfation to measure circa 5 mm deep. In particular the ESEM images have revealed a remarked decohesion in the intergranular spaces of the calcite crystals (Fig. 5).

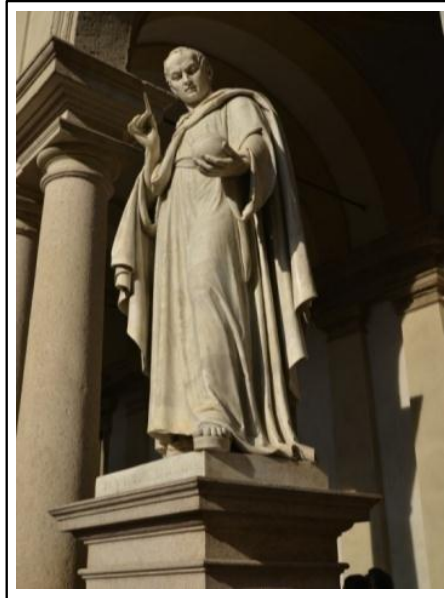


Fig. 6: The removal of aged yellowed protective layer and dirt has revealed the original surface texture the statue of Bonaventura which presents signs of scratches and abrasion related to the use of a fine but large chisel (circular furrows) for the surface finish.

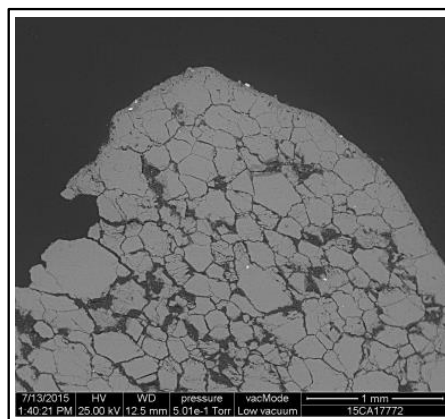


Fig. 5: SEM-BS image (low vacuum mode) of sample 1 showing the intergranular decohesion is apparent throughout the thickness of the sample.

Since the statue hands had reached such a critical state it was opted for consolidation by submerging them in a low viscos acrylic dispersion with either Primal[™] B60 or Primal[™] WS-24 (by Rohm & Haas) and water (dip coating, Fig. 7). The web of acrylic dispersion which is generated inside the pores increases the mechanical properties of the treated

surface, reducing its porosity though not obstructing the pores and respecting the surface's qualities. The consolidation resulted in the creation of bridges in the spaces in between the grains of the degraded stone.

Sulfation caused by smog is a widespread problem in all major urban centres. Sulfur dioxide in the presence of humidity, is transformed into sulfite ions, these in contact with oxidants such as oxygen become sulfate ions. Sulfate ions, once in contact with the stone, cause a consequent chemical transformation of the calcium carbonate (CaCO_3) into calcium sulfate dihydrate or gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) During the crystallization of gypsum, airborne pollutants, such as carbonaceous particles (soot), are embedded in the mineral matrix and cause the formation of black crusts in sheltered areas. Sulfate-reducing bacteria belonging to the species *Desulfovibrio vulgaris*, thanks to their metabolism are able to dissociate gypsum into Ca^{2+} and SO_4^{2-} ions. SO_4^{2-} ions are then reduced by the bacteria into H_2S , while the Ca^{2+} ions react with carbon dioxide to form new calcite. The commercial name of the microbial product used in this work is Micro4Art, made by Micro4yoU Srl and distributed by Bresciani Srl.

With the help of Dr. Annalisa Balloi sulfate-reducing bacteria through a gelatinous medium were applied on sulfated areas that appeared altered. The gelatinous medium was left overnight on the stone surface until the desired result where obtained. The bacteria contained in the gel attack and eliminate the sulfate. Local interventions of traditional cleaning were limited to the removal of varnish drops that had fallen from above. These interventions have been performed by swabbing soluble non-polar solvents. The conservation intervention was then concluded with a mild application (4% micro-dispersed acrylic in water) with a protective patina on all the surfaces, to reduce the absorption of meteoric and condensation water (albeit for a limited time).



Fig. 7: a) Scheme of the consolidation system adopted (dip coating); b) Dr. Annalisa Balloi during the application of sulfate-reducing bacteria through a gelatinous medium on the areas that were altered and covered by sulfates.



Fig. 8: Signature of Antonio Galli on the statue of Carlo Ottavio Castiglione (1855) before the application of sulfate-reducing bacteria by a gelatinous medium.



Fig. 9: Signature of Carlo Ottavio Castiglione's statue (1855) during the cleaning using sulfate-reducing bacteria applied to the surface with the aid of a gelatinous medium. The cleaning has brought to light (for example in the right area of the cartouche) some punctual spots along the surface. FTIR analysis carried out by Palladio Analisi s.r.l. laboratories identified calcium carbonate, gypsum, silicates, and very feeble traces fluorosilicate absorptions, which are most probably left by residues of protective and polishing products used in the past.

5. Conclusion

The use of sulfur-reducing bacteria was found to be much more effective when removing sulphate from stone surfaces than the traditional solvents, which sometimes can cause harm to both the art piece and the operator. Other advantages of Bio-Restoration are:

- Growing bacteria on large scale does not require great disbursements are easily applied on surfaces.
- Using bacteria does not imply any ethical conflict, since these microbes are not genetically modified.
- Bacteria represent no harm for sculptures and people working with them.

References:

- Bacci M., F. Baldini, R. Carlà, and R. Linari: "A Color Analysis of the Brancacci Chapel Frescoes. Part I" *Applied Spectroscopy* 45 (1991), 26-30.
- Bacci M., S. Baronti, A. Casini, F. Lotti, M. Picollo and O. Casazza: "Nondestructive spectroscopic investigations on paintings using optical fibers", *Mat. Res. Soc. Symp. Proc.*, 267 (1992) pp. 265-283.
- Bacci M., M. Picollo, B. Radicati and R. Bellucci: "Spectroscopic Imaging and non-destructive reflectance investigations using fiber optics", 4th Intern. Conf. Non-Destructive Testing of Works of Art Proc., Berlino (1994), pp. 162-174.
- Bacci M. and M. Picollo: "Non-destructive detection of Co(II) in paintings and glasses", *Studies in Conservation* 41 (1996), 136-144.
- Chiari R., Picollo M., Porcinai S. and Radicati B.: "Non Destructive Reflectance Spectroscopy in the discrimination of two authigenic minerals: gypsum and weddellite" 1996, 2nd Intern. Symp. The Oxalate films in the conservation of works of art Proc., Milano (1996), 379-389.
- Bacci M., M. Picollo, S. Porcinai and B. Radicati: "Spectrophotometry and colour measurements" *Techne* 5 (1997), 28-33.
- Cappitelli, F. *et al.*, 2007. Advantages of using microbial technology over traditional chemical technology in removal of black crust from stone surfaces of historical monuments. *Applied and Environmental Microbiology*. 73: 5671-5675.
- Polo, A. *et al.*, 2010. Feasibility of removing surface deposits on stone using biological and chemical remediation methods. *Microbial Ecology*. 60: 1-14.
- Gioventù E. 2010. Comparing the bioremoval of black crusts on colored artistic lithotypes of the Cathedral of Florence with chemical and laser treatment. *International Biodeterioration & Biodegradation*. 65: 832-839
- Jazayeri I., Fraser C.S., Cronk S., Automated 3D object reconstruction via multi-image close-range photogrammetry. *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXVIII, Part 5 Commission V Symposium, Newcastle upon Tyne, UK. 2010, 305-310.
- Remondino, F. Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning. *Remote Sens*. 2011, 3, 1104-1138.
- McCarthy, J. Multi-image photogrammetry as a practical tool for cultural heritage survey and community engagement. *Journal of Archaeological Science*. Volume 43, March 2014, pages 175-185.