

Stone in Historic Buildings

Characterization and Performance

Edited by

**J. Cassar, M. G. Winter, B. R. Marker, N. R. G. Walton,
D. C. Entwisle, E. N. Bromhead and J. W. N. Smith**



Geological Society

Special Publication 391



Stone in Historic Buildings: Characterization and Performance

The Geological Society of London
Books Editorial Committee

Chief Editor

RICK LAW (USA)

Society Books Editors

JIM GRIFFITHS (UK)

DAVE HODGSON (UK)

HOWARD JOHNSON (UK)

PHIL LEAT (UK)

DANIELA SCHMIDT (UK)

RANDELL STEPHENSON (UK)

ROB STRACHAN (UK)

MARK WHITEMAN (UK)

Society Books Advisors

GHULAM BHAT (India)

MARIE-FRANÇOISE BRUNET (France)

JAMES GOFF (Australia)

MARIO PARISE (Italy)

SATISH-KUMAR (Japan)

MARCO VECOLI (Saudi Arabia)

GONZALO VEIGA (Argentina)

MAARTEN DE WIT (South Africa)

Geological Society books refereeing procedures

The Society makes every effort to ensure that the scientific and production quality of its books matches that of its journals. Since 1997, all book proposals have been refereed by specialist reviewers as well as by the Society's Books Editorial Committee. If the referees identify weaknesses in the proposal, these must be addressed before the proposal is accepted.

Once the book is accepted, the Society Book Editors ensure that the volume editors follow strict guidelines on refereeing and quality control. We insist that individual papers can only be accepted after satisfactory review by two independent referees. The questions on the review forms are similar to those for *Journal of the Geological Society*. The referees' forms and comments must be available to the Society's Book Editors on request.

Although many of the books result from meetings, the editors are expected to commission papers that were not presented at the meeting to ensure that the book provides a balanced coverage of the subject. Being accepted for presentation at the meeting does not guarantee inclusion in the book.

More information about submitting a proposal and producing a book for the Society can be found on its website: www.geolsoc.org.uk.

It is recommended that reference to all or part of this book should be made in one of the following ways:

CASSAR, J., WINTER, M. G., MARKER, B. R., WALTON, N. R. G., ENTWISLE, D. C., BROMHEAD, E. N. & SMITH, J. W. N. (eds) 2014. *Stone in Historic Buildings: Characterization and Performance*. Geological Society, London, Special Publications, **391**.

PEREIRA, D. & COOPER, B. J. 2014. Building stone as a part of a World Heritage Site: 'Piedra Pajarilla' Granite and the city of Salamanca, Spain. In: CASSAR, J., WINTER, M. G., MARKER, B. R., WALTON, N. R. G., ENTWISLE, D. C., BROMHEAD, E. N. & SMITH, J. W. N. (eds) *Stone in Historic Buildings: Characterization and Performance*. Geological Society, London, Special Publications, **391**, 7–16. First published online October 14, 2013, <http://dx.doi.org/10.1144/SP391.3>.

GEOLOGICAL SOCIETY SPECIAL PUBLICATION NO. 391

Stone in Historic Buildings: Characterization and Performance

EDITED BY

J. CASSAR

University of Malta, Malta

M. G. WINTER

Transport Research Laboratory (TRL), UK

B. R. MARKER

Consultant, UK

N. R. G. WALTON

University of Portsmouth, UK

D. C. ENTWISLE

British Geological Survey, UK

E. N. BROMHEAD

Consultant, UK

and

J. W. N. SMITH

Sheffield University, UK

2014

Published by
The Geological Society
London

THE GEOLOGICAL SOCIETY

The Geological Society of London (GSL) was founded in 1807. It is the oldest national geological society in the world and the largest in Europe. It was incorporated under Royal Charter in 1825 and is Registered Charity 210161.

The Society is the UK national learned and professional society for geology with a worldwide Fellowship (FGS) of over 10 000. The Society has the power to confer Chartered status on suitably qualified Fellows, and about 2000 of the Fellowship carry the title (CGeol). Chartered Geologists may also obtain the equivalent European title, European Geologist (EurGeol). One fifth of the Society's fellowship resides outside the UK. To find out more about the Society, log on to www.geolsoc.org.uk.

The Geological Society Publishing House (Bath, UK) produces the Society's international journals and books, and acts as European distributor for selected publications of the American Association of Petroleum Geologists (AAPG), the Indonesian Petroleum Association (IPA), the Geological Society of America (GSA), the Society for Sedimentary Geology (SEPM) and the Geologists' Association (GA). Joint marketing agreements ensure that GSL Fellows may purchase these societies' publications at a discount. The Society's online bookshop (accessible from www.geolsoc.org.uk) offers secure book purchasing with your credit or debit card.

To find out about joining the Society and benefiting from substantial discounts on publications of GSL and other societies worldwide, consult www.geolsoc.org.uk, or contact the Fellowship Department at: The Geological Society, Burlington House, Piccadilly, London W1J 0BG: Tel. +44 (0)20 7434 9944; Fax +44 (0)20 7439 8975; E-mail: enquiries@geolsoc.org.uk.

For information about the Society's meetings, consult *Events* on www.geolsoc.org.uk. To find out more about the Society's Corporate Affiliates Scheme, write to enquiries@geolsoc.org.uk.

Published by The Geological Society from:

The Geological Society Publishing House, Unit 7, Brassmill Enterprise Centre, Brassmill Lane, Bath BA1 3JN, UK

The Lyell Collection: www.lyellcollection.org

Online bookshop: www.geolsoc.org.uk/bookshop

Orders: Tel. +44 (0)1225 445046, Fax +44 (0)1225 442836

The publishers make no representation, express or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility for any errors or omissions that may be made.

© The Geological Society of London 2014. No reproduction, copy or transmission of all or part of this publication may be made without the prior written permission of the publisher. In the UK, users may clear copying permissions and make payment to The Copyright Licensing Agency Ltd, Saffron House, 6–10 Kirby Street, London EC1N 8TS UK, and in the USA to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, USA. Other countries may have a local reproduction rights agency for such payments. Full information on the Society's permissions policy can be found at: www.geolsoc.org.uk/permissions

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library.

ISBN 978-1-86239-376-9

ISSN 0305-8719

Distributors

For details of international agents and distributors see:

www.geolsoc.org.uk/agentsdistributors

Typeset by Techset Composition India (P) Ltd, Bangalore and Chennai, India

Printed by Berforts Information Press Ltd, Oxford, UK

Contents

Foreword	vii
CASSAR, J., WINTER, M. G., MARKER, B. R., WALTON, N. R. G., ENTWISLE, D. C., BROMHEAD, E. N. & SMITH, J. W. N. Introduction to stone in historic buildings: characterization and performance	1
PEREIRA, D. & COOPER, B. J. Building stone as a part of a World Heritage Site: 'Piedra Pajarilla' Granite and the city of Salamanca, Spain	7
TURMEL, A., FRONTEAU, G., THOMACHOT-SCHNEIDER, C., MOREAU, C., CHALUMEAU, L. & BARBIN, V. Stone uses in Reims Cathedral: provenance, physical properties and restoration phases	17
DE KOCK, T., DEWANCKELE, J., BOONE, M., DE SCHUTTER, G., JACOBS, P. & CNUUDE, V. Replacement stones for Lede stone in Belgian historical monuments	31
CALIA, A., SILEO, M. & MATERA, L. Provenance, characterization and decay of a porous calcarenite of the Puglia region ('Pietra Gentile')	47
FRATINI, F. & RESCIC, S. The stone materials of the historical architecture of Tuscany, Italy	71
BRISTOW, C. M. The geology of the building and decorative stones of Cornwall, UK	93
CORDINER, R. J. The variety and distribution of building stones used in the churches of West Sussex, England, from AD 950 to 1850	121
CALIA, A., LAURENZI TABASSO, M., MECCHI, A. M. & QUARTA, G. The study of stone for conservation purposes: Lecce stone (southern Italy)	139
ANDRÉ, M.-F., VOLDOIRE, O., VAUTIER, F., ROUSSEL, E., PHALIP, B. & MOREL, D. Impact of cement repointing on rates of sandstone decay in medieval churches of the French Massif Central	157
LAYCOCK, E. A. & WOOD, C. Understanding and controlling the ingress of driven rain through exposed, solid wall masonry structures	175
Index	193

Foreword

The scientific approach to stone conservation dates back to a few contributions from the second half of the 19th century when the practical aspects of cleaning, consolidating and protecting buildings were the main subjects of study and were certainly favoured over work to understand the causes and mechanisms of deterioration. The understanding of these causes and mechanisms is necessary to achieve durable success in the field. Such a situation continued during the following century, with a few notable exceptions in the 1930s when, in Great Britain and Austria, the significant effects of air pollution on building stones, and the intrinsic influences of the minerog-petrographic characteristics of lithotypes on their deterioration were investigated. But it was only at the end of the 1960s and in the following decades, with the repeated monographic Bologna meetings and the commencement of the International Congresses on the deterioration and conservation of stone, that the current, more rational, approach to the restoration of stone monuments was progressively established. The first of the International Congresses took place in 1972 at La Rochelle (France); the 12th and most recent one took place in 2012 in New York City.

These major meetings produced a wealth of useful information in their proceedings and were very often integrated with other meetings, such as those on the Conservation of Stone in the Mediterranean Basin; the next, and ninth, of the Mediterranean Basin symposia will be held in Ankara in June 2014. Several other more specialized and/or monographic meetings have addressed single aspects of deterioration or conservation of lithic materials, such as salt decay, the formation of oxalate patinas (the Milan conferences of 1989 and 1996), the decay of volcanic rocks and tufa, the methods of evaluation of the effectiveness of conservation products (Rome 1985), for example, and were accompanied by very useful volumes of proceedings. One should also mention the very many other colloquia organized on a regional scale, often of a very high quality and of the utmost interest, as well as the numerous miscellaneous books on deterioration and conservation of cultural heritage that collect contributions on many aspects of the sciences applied to stone materials.

The current volume adds to the ongoing development of the understanding of the various aspects of general and applied geology, chemistry, physics, and so on, of stone of diverse geographical origins and subject to various conservation

problems. This understanding is both a fundamental requirement for the effective application of conservation treatments and a near guarantee of the success of such treatments if applied correctly and effectively.

The mass of such contributions published on paper and/or online is now very impressive in scale, although it is often quite difficult for single individuals, especially in the less well developed countries, to remain up-to-date with the significant progress achieved.

In general, it is true to say that the overall knowledge of most of the phenomena involved in the physical decay and chemical alteration of stone in natural environments, and in the exterior and interior of monuments, has progressed significantly in recent years. The depth to which this knowledge has reached is, of course, variable: we know, for example, a great deal about limestones, marbles, sandstones and much less about breccias, granites and volcanic rocks. Our knowledge of conservation and maintenance materials and methods is also not totally satisfactory and much basic research is needed for several treatment materials. In the past, a few handbooks summarized contemporaneous materials and methods; these were most welcome and very useful. Unfortunately these are now all at least partially obsolete: updates of such volumes are necessary and it would be desirable to critically review and articulate the state-of-the-art knowledge and application of all aspects of stone deterioration and conservation.

Research in the sciences that encompass stone conservation has become highly interdisciplinary and complex in recent years, and before further real progress can be made, the general deterioration concepts, conservation methods, treatment materials and strategies (including programmed monitoring and maintenance) must be defined, understood and capable of application in all countries with a significant legacy of monumental architecture and statuary to preserve. Further coordinated research, scientific cooperation and basic communication between the disciplines and the scientists themselves must be promoted in order for conservation science to advance towards the best results. The results of such work should be presented so as to be easily understood by practitioners (primarily conservators and restorers) and widely disseminated.

*LORENZO LAZZARINI
Università IUAV of Venice, Italy*