

# Fractal Analysis for Natural Hazards

The Geological Society of London  
*Books Editorial Committee*

B. PANKHURST (UK) (CHIEF EDITOR)

**Society Books Editors**

J. GREGORY (UK)

J. GRIFFITHS (UK)

J. HOWE (UK)

P. LEAT (UK)

N. ROBINS (UK)

J. TURNER (UK)

**Society Books Advisors**

M. BROWN (USA)

R. GIERÉ (Germany)

J. GLUYAS (UK)

D. STEAD (Canada)

R. STEPHENSON (Netherlands)

S. TURNER (Australia)

**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 web site: [www.geolsoc.org.uk](http://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:

CELLO, G. & MALAMUD, B. D. (eds) 2006. *Fractal Analysis for Natural Hazards*. Geological Society, London, Special Publications, **261**.

KIDSON, R., RICHARDS, K. S. & CARLING, P. A. 2006. Power-law extreme flood frequency. *In*: CELLO, G. & MALAMUD, B. D. (eds) *Fractal Analysis for Natural Hazards*. Geological Society, London, Special Publications, **261**, 141–153.

GEOLOGICAL SOCIETY SPECIAL PUBLICATION NO. 261

# Fractal Analysis for Natural Hazards

EDITED BY

**G. CELLO**

University of Camerino, Italy

and

**B. D. MALAMUD**

King's College London, UK

2006

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 9000. 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](http://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 American Geological Institute (AGI), 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](http://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](http://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](mailto:enquiries@geolsoc.org.uk).

For information about the Society's meetings, consult *Events* on [www.geolsoc.org.uk](http://www.geolsoc.org.uk). To find out more about the Society's Corporate Affiliates Scheme, write to [enquiries@geolsoc.org.uk](mailto: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

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

Online bookshop: [www.geolsoc.org.uk/bookshop](http://www.geolsoc.org.uk/bookshop)

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 2006. All rights reserved. No reproduction, copy or transmission of this publication may be made without written permission. No paragraph of this publication may be reproduced, copied or transmitted save with the provisions of the Copyright Licensing Agency, 90 Tottenham Court Road, London W1P 9HE. Users registered with the Copyright Clearance Center, 27 Congress Street, Salem, MA 01970, USA: the item-fee code for this publication is 0305-8719/06/\$15.00.

## British Library Cataloguing in Publication Data

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

ISBN 10: 1-86239-201-3

ISBN 13: 978-1-86239-201-4

Typeset by Techset Composition, Salisbury, UK  
Printed by Cromwell Press, Trowbridge, UK

## Distributors

### USA

AAPG Bookstore  
PO Box 979  
Tulsa  
OK 74101-0979  
USA

Orders: Tel. +1 918 584-2555  
Fax +1 918 560-2652  
E-mail [bookstore@aapg.org](mailto:bookstore@aapg.org)

### India

Affiliated East-West Press Private Ltd  
Marketing Division  
G-1/16 Ansari Road, Darya Ganj  
New Delhi 110 002

India  
Orders: Tel. +91 11 2327-9113/2326-4180  
Fax +91 11 2326-0538  
E-mail [affiliate@vsnl.com](mailto:affiliate@vsnl.com)

### Japan

Kanda Book Trading Company  
Cityhouse Tama 204  
Tsurumaki 1-3-10  
Tama-shi, Tokyo 206-0034  
Japan

Orders: Tel. +81 (0)423 57-7650  
Fax +81 (0)423 57-7651  
E-mail [geokanda@ma.kcom.ne.jp](mailto:geokanda@ma.kcom.ne.jp)

# Contents

Preface	vii
MALAMUD, B. D. & TURCOTTE, D. L. An inverse cascade explanation for the power-law frequency–area statistics of earthquakes, landslides and wildfires	1
LEI, X. Typical phases of pre-failure damage in granitic rocks under differential compression	11
DAVY, P., BOUR, O., DE DREUZY, J.-R. & DARCEL, C. Flow in multiscale fractal fracture networks	31
PAPARO, G., GREGORI, G. P., POSCOLIERI, M., MARSON, I., ANGELUCCI, F. & GLORIOSO, G. Crustal stress crises and seismic activity in the Italian peninsula investigated by fractal analysis of acoustic emission, soil exhalation and seismic data	47
POSCOLIERI, M., LAGIOS, E., GREGORI, G. P., PAPARO, G., SAKKAS, V. A., PARCHARIDIS, I., MARSON, I., SOUKIS, K., VASSILAKIS, E., ANGELUCCI, F. & VASSILOPOULOU, S. Crustal stress and seismic activity in the Ionian archipelago as inferred by satellite- and ground-based observations, Kefallinia, Greece	63
ZVELEBIL, J., PALUŠ, M. & NOVOTNÁ, D. Nonlinear Science issues in the dynamics of unstable rock slopes: new tools for rock fall risk assessment and early warnings	79
TELESCA, L., LAPENNA, V. & MACCHIATO, M. Multifractal variability in self-potential signals measured in seismic areas	95
TURCOTTE, D. L., MALAMUD, B. D., GUZZETTI, F. & REICHENBACH, P. A general landslide distribution applied to a small inventory in Todi, Italy	105
MARCHEGIANI, L., VAN DIJK, J. P., GILLESPIE, P. A., TONDI, E. & CELLO, G. Scaling properties of the dimensional and spatial characteristics of fault and fracture systems in the Majella Mountain, central Italy	113
CELLO, G., MARCHEGIANI, L. & TONDI, E. Evidence for the existence of a simple relation between earthquake magnitude and the fractal dimension of seismogenic faults: a case study from central Italy	133
KIDSON, R., RICHARDS, K. S. & CARLING, P. A. Power-law extreme flood frequency	141
MILLINGTON, J. D. A., PERRY, G. L. W. & MALAMUD, B. D. Models, data and mechanisms: quantifying wildfire regimes	155
Index	169

## Preface

Self-similarity and fractals, the idea that an object's pattern will approximately repeat itself at multiple scales, was conceptualized and formalized by the Polish-born French scientist Benoit Mandelbrot, in his pioneering 1967 *Science* paper 'How long is the coast of England: statistical self-similarity and fractional dimension'. Since this publication, over 22,000 peer-review papers have been published in the broad social and physical sciences that use the ideas of fractals, along with the publication of many hundreds of books on the subject.

In the Earth Sciences, the concept of self-similar scaling (scale invariance) and fractal geometry over a given range of scales is well recognized in many natural objects, for example sand dunes, rock fractures and folds, and drainage networks. However, the use of fractals for spatial and temporal analyses has been less used (and accepted) in the Earth Sciences, particularly for the study of natural hazards. This book brings together twelve contributions that emphasize the role of fractal analyses in natural hazard research, with the

papers based on a scientific session at the 32nd International Geological Congress held in Firenze, Italy, August 2004.

The main natural hazards discussed in these papers include landslides and rock falls, wildfires, floods, catastrophic rock fractures and earthquakes. A wide variety of spatial and temporal fractal-related approaches and techniques are applied to 'natural' data, experimental data, and computer simulations. These approaches and techniques include probabilistic hazard analysis, cellular-automata models, spatial analyses, temporal variability, prediction, and concepts such as self-organizing behaviour.

The main aims of this volume of papers are (a) to present current research on fractal analyses as applied to natural hazards, and (b) to stimulate the curiosity of advanced Earth Science students and researchers in the use of fractal analyses for the better understanding of natural hazards.

GIUSEPPE CELLO and BRUCE D. MALAMUD

Some words from the colleagues and friends of Giuseppe Cello: On the 5th of July 2006, during the editing process of this book, Giuseppe Cello passed away due to heart failure. Of the scientist, we will always remember many useful discussions, constructive suggestions, and his innovative approach to the broad areas of Structural Geology. Of the man, we will never forget his genuine friendship, his sincerity and his love for every little thing in life. Peppe's memory will remain indelible in all of us.