

Thermochronological Methods: From Palaeotemperature Constraints to Landscape Evolution Models

The Geological Society of London
Books Editorial Committee

Chief Editor

BOB PANKHURST (UK)

Society Books Editors

JOHN GREGORY (UK)

JIM GRIFFITHS (UK)

JOHN HOWE (UK)

PHIL LEAT (UK)

NICK ROBINS (UK)

JONATHAN TURNER (UK)

Society Books Advisors

MIKE BROWN (USA)

ERIC BUFFETAUT (FRANCE)

JONATHAN CRAIG (ITALY)

RETO GIERÉ (GERMANY)

TOM McCANN (GERMANY)

DOUG STEAD (CANADA)

RANDELL STEPHENSON (UK)

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.

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

LISKER, F., VENTURA, B. & GLASMACHER, U. A. (eds) 2009. *Thermochronological Methods: From Palaeotemperature Constraints to Landscape Evolution Models*. Geological Society, London, Special Publications, **324**.

GLEADOW, A. J. W., GLEADOW, S. J., BELTON, D. X., KOHN, B. P., KROCHMAL, M. S. & BROWN, R. W. 2009. Coincidence mapping – a key strategy for the automatic counting of fission tracks in natural minerals. In: LISKER, F., VENTURA, B. & GLASMACHER, U. A. (eds) *Thermochronological Methods: From Palaeotemperature Constraints to Landscape Evolution Models*. Geological Society, London, Special Publications, **324**, 25–36.

GEOLOGICAL SOCIETY SPECIAL PUBLICATION NO. 324

Thermochronological Methods: From Palaeotemperature Constraints to Landscape Evolution Models

EDITED BY

F. LISKER

Universität Bremen, Germany

B. VENTURA

Universität Bremen, Germany

and

U. A. GLASMACHER

Ruprecht-Karls-Universität Heidelberg, Germany

2009

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 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.

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

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

Online bookshop: 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 2009. 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 0305-8719/09/\$15.00.

British Library Cataloguing in Publication Data

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

ISBN 978-1-86239-285-4

Typeset by Techset Composition Ltd., Salisbury, UK

Printed by Antony Rowe Ltd, Chippenham, UK

Distributors

North America

For trade and institutional orders:

The Geological Society, c/o AIDC, 82 Winter Sport Lane, Williston, VT 05495, USA

Orders: Tel. +1 800-972-9892

Fax +1 802-864-7626

E-mail: gsl.orders@aidcv.com

For individual and corporate orders:

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

Website: <http://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: affiliat@vsnl.com

Preface

This volume comprises a selection of papers presented on the European Conference on Thermochronology 2006 in Bremen. The conference is part of a series of international and European meetings that were initiated in 1980 as International Workshops on Fission-Track Dating, and have continued since 2000 as conferences on Fission-Track Dating and Thermochronology. The change of the meeting titles testifies to the increasing popularity and importance of this field in various respects: the meetings grew from small workshops with a limited number of participants to large conferences, and the discipline Thermochronology (Thermochronometry) developed from merely fission-track dating to a broad field incorporating a whole spectrum of low-temperature radiometric methods. This evolution of thermochronology from a hobby-horse of nuclear physicists almost 50 years ago to one of the most innovative methods within modern Earth sciences was dignified in three remarkable and emotional talks during a special session of the Bremen conference. John Garver (Union College, Schenectady) commenced this historic review with an introduction into the early work of Fleischer, Price and Walker who recognized the potential of lattice damages in minerals as age indicators, while Peter Van den Haute (University of Ghent) referred to the first geological applications of fission-track dating and the concept of the partial annealing zone (PAZ). Barry Kohn (University of Melbourne) reviewed the last decade of fission-track and (U–Th–Sm)/He thermochronology with its increasing influence on various geological disciplines. This Special Publication intends to continue from this point as it not only provides a variety of applied studies but shows some exciting progress with respect to improving existing and developing new thermochronological techniques.

Accordingly, the 21 papers of this Special Publication are arranged into two sections following an introductory review chapter by **Lisker et al.** This opening contribution provides an overview of the application of thermochronological methods to geological problems.

The first section, *New approaches in thermochronology*, comprises seven papers that present the most recent developments in thermochronological methods, and show the growing interest in alternative thermochronometers and modelling techniques. It starts with a contribution by **Gleadow et al.** who present the first fully automated counting system for fission tracks in natural minerals – for long only a chimera in fission-track

analysis. **Hasebe et al.** promote the use of laser ablation inductively coupled plasma mass spectrometry (ICP-MS) to directly measure uranium concentration for both apatite and zircon fission-track chronometry as an alternative to traditional time-consuming thermal neutron-induced fission tracks. **Dobson et al.** present a method for determining zircon (U–Th)/He ages, and show the potential of the zircon He chronometer to constrain thermal histories, and to quantify cooling in different tectonic settings. This new thermometer may fill the ‘gap’ between $^{40}\text{Ar}/^{39}\text{Ar}$ and zircon fission-track ages and apatite fission-track data. **Carter & Foster** describe a new approach in detrital thermochronology based on measuring Nd isotopic compositions on single apatites by laser ablation ICP-MS, and show how the combination of $^{143}\text{Nd}/^{144}\text{Nd}$ ratios with apatite fission-track ages provide better constraints on the source rock. **Murrell et al.** verify the influence of etching on the kinetic parameter *D*_{par}, and therefore on the thermal history modelling of apatite fission-track data. **Timar-Geng et al.** analyse the influence of hydrothermal fluids circulating in fault zones on fission-track ages by numerical modelling techniques. **Wang & Zhou** propose a simple method to reconstruct past relief using thermochronological data.

The 14 papers of the second section, *Applied thermochronology*, refer to the long-term landscape evolution of various geological settings, to provenance studies and to small-scale tectonic processes. Eight papers describe Phanerozoic geological processes in Europe, with the first three of them being Alpine studies. **Glotzbach et al.** investigate the influence of the topography on isotherms on the example of the Gotthard Massif, whereas **Dunkl et al.** and **Malusà et al.** present provenance studies. Based on fission-track data of pebbles and detrital apatites from modern river sediments, respectively, they refine the denudation history of specific source regions within the Alpine orogen. **del Río et al.** report the thermal and denudation history of the Iberian Range in NW Spain. **Xu et al.** and **Ventura et al.** examine the post-Variscan evolution in Central Europe, with special focus on the Ardennes, and on the northern Bohemian Massif, respectively. **Kohn et al.** address the problem of apatite fission-track and (U–Th–Sm)/He cross-over ages on examples of the Fennoscandian Shield and similar settings in southern Canada and Western Australia. Their arguments against substantial influence of α -radiation-enhanced annealing of fission tracks at low temperatures contribute to an ongoing debate. Combining apatite

fission-track and terrestrial cosmogenic nuclide data, **Kuhlemann *et al.*** study the dependency of weathering rates of granite and regolith from precipitation and brittle deformation in Corsica.

The remaining six papers present a number of study cases from various geological settings from other continents. **De Grave *et al.*** reconstruct the thermo-tectonic history of the Siberian Altai basement from the Early Palaeozoic to the present using a multi-method chronometric approach. Two multi-thermochronometer-based African studies of **Daszinnies *et al.*** and **Kounov *et al.*** focus on rifting processes and eventually the dispersal of Gondwana in the vicinity of Mozambique and South Africa, and conclude on the evolution of the respective passive margin segments. **Ruiz *et al.*** apply apatite and zircon fission-track analyses on plutonic rocks from the Western Cordillera of Peru to verify the relationship between uplift and denudation within this part of the Andes. **Emmel *et al.*** concentrate on the thermal and denudation history of Dronning Maud Land (East Antarctica), and relate its landscape development to tectonic activity. **Yamada *et al.*** use apatite and zircon fission-track data to detect an ancient thermal anomaly associated with fault displacements

within the regional Atotsugawa Fault of central Japan.

The editors are very grateful to the Geological Society of London for making this book possible, in particular to Angharad Hills for her constant support, and to Tamzin Anderson, Helen Floyd-Walker and Phil Leat. We would like to thank the following friends and colleagues and six anonymous referees who kindly reviewed the articles submitted to this book: P. Andriessen, J. Barbarand, L. Barbero, M. Bernet, P. Bierman, A. Blythe, J. Braun, M. Brix, B. Carrapa, A. Carter, C. Cederbom, P. Clift, I. Dunkl, G. Fellin, P. Fitzgerald, R. Galbraith, K. Gallagher, U. A. Glasmacher, A. Gleadow, A. Hartley, A. Henk, A. Hurford, J. Jacobs, R. Jonkheere, P. Kamp, R. Ketcham, P. Koons, F. Lisker, L. Nasdala, J.-O. Näslund, P. O'Sullivan, C. Persano, M. Raab, M. Rahn, L. Ratschbacher, G. Ruiz, C. Schlüchter, E. Sobel, F. Stuart, K. Stüwe, R. Thiede, P. Van den Haute, P. Van der Beek, B. Ventura, G. Viola, G. Wagner, M. Wipf and M. Zattin.

F. LISKER
B. VENTURA &
U. A. GLASMACHER