TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH



EARTH SCIENCES

Volume 89 Part 4

PUBLISHED BY THE RSE SCOTLAND FOUNDATION 22–26 GEORGE STREET · EDINBURGH · EH2 2PQ 1999 (for 1998) The Royal Society of Edinburgh is committed to the widespread dissemination of scientific knowledge. Through the Transactions of the Royal Society of Edinburgh: Earth Sciences, the Society continues to encourage and support the international Earth Sciences community by:

- publishing a journal of international standing and authorship;
- publishing substantial papers on all scientific aspects of the solid earth and its surfaces;
- publishing without page charges:
- reproducing photographs and artwork to the highest standard, where appropriate at a size larger than is customary; and
- having papers reviewed by two referees of international standing within three months, and usually publishing within six months of receipt of revised papers.

Editorial Board

J. McMANUS University of St Andrews (Chairman)

E. N. K. CLARKSON University of Edinburgh (Executive Editor)

C. M. CLAPPERTON University of Aberdeen

J. H. HULL

British Geological Survey, Edinburgh

I. PARSONS

University of Edinburgh

A. H. F. ROBERTSON University of Edinburgh D I FETTES

British Geological Survey (Executive Editor)

A. B. SMITH

Natural History Museum (Executive Editor)

W. E. STEPHENS University of St Andrews

M. F. THOMAS University of Stirling

M. ANDERSON University of Edinburgh

(Curator)

Consulting Editors

SHOHEI BANNO Kyoto University

W. L. BROWN

Centre de Recherches Pétrographiques et Géochimiques, Vandoeuvre-les-Nancy

R. L. CARROLL

McGill University, Montreal

B. W. CHAPPELL

Australian National University, Canberra

J. M. COLEMAN

Louisiana State University, Baton Rouge

J. F. DEWEY

University of Oxford

S. J. GOULD

University of Harvard

R. W. HUTCHINSON

Colorado School of Mines

Charles University, Prague

D. B. MCINTYRE

Kinfauns, Perth

K. J. MÜLLER

Rhein. Friedrich-Wilhelms-Universität Bonn

D. F. STRONG

University of Victoria, B.C.

V. C. THAKUR

Wadia Institute of Himalayan Geology

S. UYEDA

University of Tokyo

R. WOODALL

Western Mining Co., Adelaide

Journals Officer: Royal Society of Edinburgh: Vicki Ingpen

COPYRIGHT: It is the policy of the Royal Society of Edinburgh not to charge any royalty for the production of a single copy of any one article made for private study or research. Specific permission will not be required for photocopying multiple copies of copyright material, to be used for bona fide educational purposes, provided this is done by a member of the staff of the university, school or other comparable institution, for distribution without profit to student members of that institution and provided the copies are made from the original journal. Requests for the copying or reprinting of any article for any other purpose should be sent to the Royal Society of Edinburgh.

Transactions of the Royal Society of Edinburgh: Earth Sciences publishes one volume per year, usually in three or four parts. Volume 90 (1999) will be published in three parts: 90.1, 90.2/3 (double issue) and 90.4. An annual subscription costs £110, or \$178. Orders should be placed with CAB International (to whom cheques should be made payable), Wallingford, Oxon OX10 8DE, UK. (Tel 01491 832111; Fax 01491 826090; email: orders@cabi.org)

Transactions is indexed in the following: Current Contents/Physical, Chemical & Earth Sciences, SciSearch, CABS Database, Mineralogical Abstracts, Biosciences Information Service, Geoabstracts and GEOBASE.

© 1999 The Royal Society of Edinburgh.