

Earth and Environmental Science

Transactions of the Royal Society of Edinburgh

volume 108 part 2-3 2019
(for 2017)

Special Issue

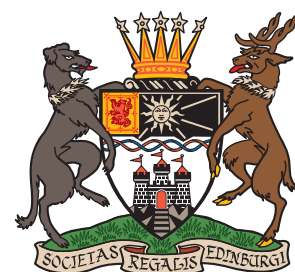
**The Geosciences
in Europe's Urban
Sustainability:
Lessons from
Glasgow and Beyond
(CUSP)**

Editors

**Fiona Fordyce and
Dr Diarmad Campbell**



Published by The RSE Scotland Foundation, 22–26 George Street, Edinburgh EH2 2PQ



The Royal Society of Edinburgh is committed to the widespread dissemination of scientific knowledge and has published the *Transactions of the Royal Society of Edinburgh* since 1785, when James Hutton's 'Theory of the Earth' was published in Volume 1. The journal evolved to the *Transactions of the Royal Society of Edinburgh: Earth Sciences* in 1980 and is now (as from 2007) the *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*. Through this journal, the Society continues to encourage and support the international Earth and Environmental Science communities by:

- publishing a journal of international standing and authorship;
- publishing substantial papers on all scientific aspects of **the Earth and its surface environments**;
- publishing without page or colour charges;
- reproducing photographs and artwork to the highest standard, where appropriate at a size larger than is customary; and
- aiming to have papers reviewed within three months by at least two referees of international standing; and usually publishing within six months of acceptance.

The Editorial Board welcomes original manuscripts in the Earth and Environmental Sciences. It also welcomes proposals for Special Issues in these areas.

Editorial Board (as at 31 July 2018)

Ian ALSOP (*Editor*), University of Edinburgh *Tectonics/structural geology*

Donald DAVIDSON (*Chairman & Editor-in-Chief*), University of Stirling *Soil science; soil conservation; anthropogenic impacts on soils; soil biodiversity; geoarchaeology*

Kevin EDWARDS (*Editor*), University of Aberdeen *Environmental change in northern Europe & North Atlantic; Palynology; palaeoecology; Quaternary science; environmental archaeology*

Tony FALLICK (*Editor*), University of Glasgow *Isotope biogeosciences; economic geology; dating & geochronology; the Palaeoproterozoic & Neoproterozoic*

Fiona FORDYCE (*Editor*), British Geological Survey

John GORDON (*Editor*), University of St Andrews *Geodiversity; geoconservation; Quaternary research*

Alistair MCGOWAN (*Editor*), BioGeoD, Edinburgh *Palaeobiology; biodiversity; invertebrate palaeontology; the Fossil Record*

Andrew ROSS (*Editor*), National Museums Scotland, Edinburgh *Invertebrate palaeontology; palaeobiology; palaeoecology; palaeoenvironment; palaeoclimate*

Chris SOULSBY (*Editor*), University of Aberdeen *Hydrogeology; biogeochemistry*

Philip STONE (*Editor*), British Geological Survey, Edinburgh *Scottish and South Atlantic regional geology and tectonics*

Stig WALSH (*Editor*), National Museums Scotland, Edinburgh *Vertebrate palaeobiology; vertebrate palaeontology*

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 Journals & Archive Officer at the Royal Society of Edinburgh. (publications@theRSE.org.uk).

Earth and Environmental Science Transactions of the Royal Society of Edinburgh is published as one volume of four parts per year, usually in a combination of single and double issues. Volume 108 (2017) will provisionally be published in three parts – one double issue and two single issues.

An annual subscription to *EESTRSE* costs GBP362/ USD663 (Print plus Online); or GBP314/ USD582 (Online only).

Orders should be placed with Cambridge University Press, Journals Fulfilment Department, UPH, Shaftesbury Road, Cambridge CB2 8BS, UK. Telephone: 44 (0)1223 326070; Fax: 44 (0)1223 325150; email: journals@cambridge.org

EESTRSE is indexed/abstracted in the following: Current Contents/Physical, Chemical & Earth Sciences; Biosciences Information Service; Geoabstracts; GEOBASE; Mineralogical Abstracts; Science Citation Index; SciSearch; VINITI (All-Russian Institute of Scientific and Technical Information); *Zoological Record*.

© 2019 The Royal Society of Edinburgh

The Royal Society of Edinburgh, Scotland's National Academy, is Scottish Charity No. SC000470

Cover image: River Clyde, Glasgow BGS©NERC.

The Geosciences in Europe's Urban Sustainability: Lessons from Glasgow and Beyond (CUSP)

Editors

Fiona Fordyce and Dr Diarmad Campbell

CONTENTS

F. M. FORDYCE and S. D. G. CAMPBELL Preface	119
T. I. KEARSEY, K. WHITBREAD, S. L. B. ARKLEY, A. FINLAYSON, A. A. MONAGHAN, W. S. MCLEAN, R. L. TERRINGTON, E. A. CALLAGHAN, D. MILLWARD and S. D. G. CAMPBELL Creation and delivery of a complex 3D geological survey for the Glasgow area and its application to urban geology	123
J. D. O. WILLIAMS, M. R. DOBBS, A. KINGDON, R. M. LARK, J. P. WILLIAMSON, A. M. MACDONALD and B. É. Ó DOCHARTAIGH Stochastic modelling of hydraulic conductivity derived from geotechnical data; an example applied to central Glasgow	141
B. Ó DOCHARTAIGH, H. BONSOR and S. BRICKER Improving understanding of shallow urban groundwater: the Quaternary groundwater system in Glasgow, UK	155
F. M. FORDYCE, B. É. Ó DOCHARTAIGH, H. C. BONSOR, E. L. ANDER, M. T. GRAHAM, R. MCCUAIG and M. LOVATT Assessing threats to shallow groundwater quality from soil pollutants in Glasgow, UK: development of a new screening tool	173
F. M. FORDYCE, P. A. EVERETT, J. M. BEARCOCK and T. R. LISTER Soil metal/metalloid concentrations in the Clyde Basin, Scotland, UK: implications for land quality	191
J. WRAGG, A. BROADWAY, M. R. CAVE, F. M. FORDYCE, B. PALUMBO-ROE, D. J. BERIRO, J. G. FARMER, M. C. GRAHAM, B. T. NGWENYA and R. J. F. BEWLEY Linkage between solid-phase apportionment and bioaccessible arsenic, chromium and lead in soil from Glasgow, Scotland, UK	217
A. W. KIM, C. H. VANE, V. L. MOSS-HAYES, D. J. BERIRO, C. P. NATHANAIL, F. M. FORDYCE and P. A. EVERETT Polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) in urban soils of Glasgow, UK	231
J. M. BEARCOCK, P. L. SMEDLEY, F. M. FORDYCE, P. A. EVERETT and E. L. ANDER Controls on surface water quality in the River Clyde catchment, Scotland, UK, with particular reference to chromium and lead	249
D. G. JONES, C. H. VANE, S. LASS-EVANS, S. CHENERY, B. LISTER, M. CAVE, J. GAFEIRA, G. JENKINS, A. LESLIE, N. BREWARD, K. FREEBOROUGH, I. HARRISON, A. W. KIM, A. LACINSKA, T. MILODOWSKI, J. RIDGWAY, J. RIDING, M. STRUTT, D. WAGNER and I. WILKINSON Geochemistry and related studies of Clyde Estuary sediments	269
R. A. LOPES DOS SANTOS and C. H. VANE Tracking natural organic carbon in the River Clyde, UK, using glycerol dialkyl glycerol tetraethers	289
C. H. VANE, R. A. LOPES DOS SANTOS, A. W. KIM, V. MOSS-HAYES, F. M. FORDYCE and J. M. BEARCOCK Persistent organic pollutants (PAH, PCB, TPH) in freshwater, urban tributary and estuarine surface sediments of the River Clyde, Scotland, UK	299

- C. H. VANE, V. MOSS-HAYES, A. W. KIM, K. E. EDGLEY, M. R. CAVE and J. M. BEARCOCK
Mercury, *n*-alkane and unresolved complex mixture hydrocarbon pollution in surface sediment across the rural–urban–estuarine continuum of the River Clyde, Scotland, UK 315
- G. DICK, I. ERIKSSON, J. DE BEER, H. BONSOR and P. VAN DER LUGT
Planning the city of tomorrow: bridging the gap between urban planners and subsurface specialists 327