

**Desert Sediments:
Ancient and Modern**

Geological Society Special Publications
Series Editor K. COE

GEOLOGICAL SOCIETY SPECIAL PUBLICATION NO 35

Desert Sediments: Ancient and Modern

EDITED BY

L. E. FROSTICK

Department of Geology
Royal Holloway and Bedford New College
University of London

I. REID

Department of Geography
Birkbeck College
University of London

1987

Published for

The Geological Society by
Blackwell Scientific Publications

OXFORD LONDON EDINBURGH

BOSTON PALO ALTO MELBOURNE

Published for
The Geological Society by
Blackwell Scientific Publications
Osney Mead, Oxford OX2 0EL
(Orders: Tel. 0865 240201)
8 John Street, London WC1 2ES
23 Ainslie Place, Edinburgh EH3 6AJ
52 Beacon Place, Boston Massachusetts 02108, USA
667 Lytton Avenue, Palo Alto California 94301, USA
107 Barry Street, Carlton, Victoria 3053, Australia

First published 1987

© 1987 The Geological Society. Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by The Geological Society for libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, providing that a base fee of \$03.00 per copy is paid directly to CCC, 27 Congress Street, Salem, MA 01970, USA. 0305-8719/87/ \$03.00

Typeset, printed and bound in Great Britain by William Clowes Limited, Beccles and London

DISTRIBUTORS

USA and Canada

Blackwell Scientific Publications Inc.
PO Box 50009, Palo Alto
California 94303
(Orders: Tel. (415) 965-4081)

Australia

Blackwell Scientific Publications
(Australia) Pty Ltd.
107 Barry Street, Carlton
Victoria 3053
(Orders: Tel. (03) 347 0300)

British Library Cataloguing in Publication Data

Desert sediments: ancient and modern.—(Geological Society special publication, ISSN 0305-8719; no. 35).

1. Sedimentation and deposition 2. Deserts

I. Frostick, L. E. II. Reid, Ian

III. Geological Society special publication,

ISSN 0305-8719 IV. Series

551.3'04 QE571

ISBN 0-632-01905-0

Library of Congress Cataloging-in-Publication Data

Desert sediments.

(Geological Society special publication; no. 35)

1. Sediments (Geology) 2. Arid regions.

I. Frostick, L. E. II. Reid, Ian. III. Geological Society of London. IV. Series.

QE471.2.D475 1987 551.3'04 87-11686

ISBN 0-632-01905-0

Contents

List of contributors	vii
Preface	ix
Acknowledgments	xi
INTRODUCTION	
GLENNIE, K. W. Desert sediments: ancient and modern	1
FLUVIAL SEDIMENTS	
Process and form	
SCHICK, A. P., LEKACH, J. & HASSAN, M. A. Vertical exchange of coarse bedload in desert streams	7
GROSSMAN, S. & GERSON, R. Fluvial deposits and morphology of alluvial surfaces as indicators of Quaternary environmental changes in the southern Negev, Israel	17
MAIZELS, J. K. Plio-Pleistocene raised channel systems of the western Sharqiya (Wahiba), Oman	31
Tectonism, climatic change and fluvial desert sediments	
FROSTICK, L. E. & REID, I. Tectonic control of desert sediments in rift basins: ancient and modern	53
OLSEN, H. Ancient ephemeral stream deposits: a local terminal fan model from the Bunter Sandstone Formation (L. Triassic) in the Tønder-3, -4 and -5 wells, Denmark	69
HARVEY, A. M. Alluvial fan dissection: relationships between morphology and sedimentation	87
WILLIAMS, M. A. J., ABELL, P. I. & SPARKS, B. W. Quaternary landforms, sediments, depositional environments and gastropod isotope ratios of Adrar Bous, Tenere Desert of Niger, south-central Sahara	105
AEOLIAN SEDIMENTS	
Dust dynamics and deposits	
WHALLEY, W. B., SMITH, B. J., MCALISTER, J. J. & EDWARDS, A. J. Aeolian abrasion of quartz particles and the production of silt-size fragments: preliminary results	129
PYE, K. & TSOAR, H. The mechanics and geological implications of dust transport and deposition in deserts with particular reference to loess formation and dune sand diagenesis in the northern Negev, Israel	139
GERSON, R. & AMIT, R. Rates and modes of dust accretion and deposition in an arid region—the Negev, Israel	157
VINE, H. Wind-blown materials and W African soils: an explanation of the 'ferrallitic soil over loose sandy sediments' profile	171

Dune dynamics and deposits

GUNATILAKA, A. & MWANGO, S. Continental sabkha pans and associated nebkhas in southern Kuwait, Arabian Gulf	187
WARREN, A. & KAY, S. Dune networks	205
CLEMMENSEN, L. B. Complex star dunes and associated aeolian bedforms, Hopeman Sandstone (Permo–Triassic), Moray Firth Basin, Scotland	213
WILLIAMS, B. P. J., WILD, E. K. & SUTTILL, R. J. Late Palaeozoic cold-climate aeolianites, southern Cooper Basin, South Australia	233
CARRUTHERS, R. A. Aeolian sedimentation from the Galtymore Formation (Devonian), Ireland	251

Grain size, process and dune environment

FLENLEY, E. C., FIELLER, N. R. J. & GILBERTSON, D. D. The statistical analysis of 'mixed' grain size distributions from aeolian sands in the Libyan Pre-Desert using log skew Laplace models	271
LIVINGSTONE, I. Grain-size variation on a 'complex' linear dune in the Namib Desert	281
THOMAS, D. S. G. Discrimination of depositional environments using sedimentary characteristics in the Mega Kalahari, central southern Africa	293

CHEMICAL SEDIMENTS

HENDRY, D. A. Silica and calcium carbonate replacement of plant roots in tropical dune sands, SE India	309
ROBERTS, C. R. & MITCHELL, C. W. Spring mounds in southern Tunisia	321

REMOTE SENSING OF DESERT SEDIMENTS

BREED, C. S., MCCAULEY, J. F. & DAVIS, P. A. Sand sheets of the eastern Sahara and ripple blankets on Mars	337
ASHOUR, M. M. Surficial deposits of Qatar Peninsula	361
MILLINGTON, A. C., JONES, A. R., QUARMBY, N. & TOWNSHEND, J. R. G. Remote sensing of sediment transfer processes in playa basins	369
INDEX	383

List of contributors

P. Abell
Department of Chemistry
University of Rhode Island
Kingston
Rhode Island 02881
USA

R. Amit
Institute of Earth Sciences
The Hebrew University of
Jerusalem
Jerusalem 91904
Israel

M. M. Ashour
Department of Geography
University of Qatar
Doha
PO Box 2713
Qatar

C. S. Breed
US Geological Survey
Flagstaff
Arizona 86001
USA

R. A. Carruthers
Badley, Ashton and Associates
Ltd
Aveland House
Queen Street
Spilsby
Lincs PE23 5JX
UK

L. B. Clemmensen
Institute of General Geology
Øster Voldgade 10
DK-1350
Copenhagen
Denmark

P. A. Davis
US Geological Survey
Flagstaff
Arizona 86001
USA

A. J. Edwards
Department of Geography
The Queen's University
Belfast BT7 1NN
Northern Ireland
UK

N. R. J. Fieller
Department of Probability and
Statistics
University of Sheffield
Sheffield S3 7RH
UK

E. C. Flenley
Department of Probability and
Statistics
University of Sheffield
Sheffield S3 7RH
UK

L. E. Frostick
Department of Geology
Royal Holloway and Bedford
New College
University of London
Egham Hill
Egham
Surrey TW20 0EX
UK

R. Gerson
Institute of Earth Sciences
The Hebrew University of
Jerusalem
Jerusalem 91904
Israel

D. D. Gilbertson
Department of Archaeology
and Prehistory
University of Sheffield
Sheffield S10 2TN
UK

K. W. Glennie
Shell UK Ltd
Shell-Mex House
The Strand
London WC2R 0DX
UK

S. Grossman
Institute of Earth Sciences
The Hebrew University of
Jerusalem
Jerusalem 91904
Israel

A. Gunatilaka
Department of Geology
Kuwait University
Box 5969
Kuwait 13060

A. M. Harvey
Department of Geography
University of Liverpool
PO Box 147
Liverpool L69 3BX
UK

M. A. Hassan
Department of Physical
Geography
Institute of Earth Sciences
The Hebrew University of
Jerusalem
Jerusalem 91094
Israel

D. A. Hendry
Department of Geography
King's College
University of London
London WC2R 2LS
UK

A. R. Jones
NERC
Institute of Terrestrial Ecology
Penrhos Road
Bangor
Gwynedd
Wales
UK

S. A. W. Kay
Department of Geography
University College
University of London
Gower Street
London WC1E 6BT
UK

J. Lekach
Department of Physical
Geography
Institute of Earth Sciences
The Hebrew University of
Jerusalem
Jerusalem 91094
Israel

I. Livingstone
School of Environmental
Studies
Gloucestershire College of Arts
and Technology
Oxstalls
Gloucester GL2 9HW
UK

J. J. McAlister
Department of Geography
The Queen's University
Belfast BT7 1NN
Northern Ireland
UK

J. F. McCauley
US Geological Survey
Flagstaff
Arizona 86001
USA

J. K. Maizels
Department of Geography
University of Aberdeen
St Mary's
High Street
Old Aberdeen AB9 2UF
Scotland
UK

A. C. Millington
Department of Geography
University of Reading
Whiteknights
Reading
Berkshire RG6 2AH
UK

C. W. Mitchell
Department of Geography
University of Reading
Whiteknights
Reading
Berkshire RG6 2AH
UK

S. Mwangi
Department of Geology
Kuwait University
Box 5969
Kuwait 13060

H. Olsen
Geological Survey of
Greenland
Øster Voldgade 10
DK-1350
Copenhagen K
Denmark

K. Pye
Department of Earth Sciences
University of Cambridge
Downing Street
Cambridge CB2 3EQ
UK

N. Quarmby
NERC
Unit for Thematic Information
and Services
University of Reading
Whiteknights
Reading RG6 2AB
Berkshire
UK

I. Reid
Department of Geography
Birkbeck College
University of London
Malet Street
London WC1E 7HX
UK

C. Roberts
Department of Geography
College of St Paul and St Mary
The Park
Cheltenham
Gloucester GL50 2RH
UK

A. P. Schick
Department of Physical
Geography
The Hebrew University of
Jerusalem
Jerusalem 91094
Israel

J. J. Smith
Department of Geography
The Queen's University
Belfast BT7 1NN
Northern Ireland
UK

R. J. Suttill
South Australian Oil and Gas
Corporation Pty Ltd
Adelaide
South Australia 5000
Australia

D. S. G. Thomas
Department of Geography
University of Sheffield
Sheffield S10 2TN
UK

J. R. G. Townshend
NERC
Unit for Thematic Information
and Services
University of Reading
Whiteknights
Reading RG6 2AB
Berks
UK

H. Tsoar
Department of Geography
Ben Gurion University of the
Negev
Beer Sheva 84120
PO Box 653
Israel

H. Vine
2 Swale Close
Oadby
Leicester LE2 4GF
UK

A. Warren
University College
University of London
Gower Street
London WC1E 6BT
UK

W. B. Whalley
Department of Geography
The Queen's University
Belfast BT7 1NN
Northern Ireland
UK

E. K. Wild
Department of Geology
University of Bristol
Bristol BS8 1RJ
Avon
UK

B. P. J. Williams
Department of Geology
University of Bristol
Bristol BS8 1RJ
Avon
UK

M. A. J. Williams
Department of Geography
Monash University
Clayton
Victoria
Australia 3168

Preface

Deserts provide an excellent subject for interchange between Earth scientists of differing sub-disciplines. The aridity of climate and the sparseness of plants and animals, especially Man, encourage surface processes that produce sedimentary deposits sufficiently distinctive to be recognized unequivocally both throughout the passage of time and from one planet to another. Because of this, and because Lyell's dictum of uniformitarianism is probably most appropriate in desert settings where the impingement of evolving life forms has been least, an exchange between scientists concerned with the living deserts of Earth and beyond, on the one hand, and with ancient Earth counterparts, on the other, is extremely fruitful. Lessons are learned on all sides.

This was the spirit that encouraged 185 participants to gather at a Special Scientific Meeting of the Geological Society of London in May 1986. It is also the underlying rationale for this Special Publication which incorporates a substantial proportion of the contributions made at that Meeting.

This was not the first time that desert sediments have brought students of the ancient and modern together (see, e.g. McKee, E. D. (ed.) 1979. *Global Sand Seas. US Geological Survey Professional*

Paper 1052; Brookfield, M. E. & Ahlbrandt, T. S. (eds) 1983. *Eolian Sediments and Processes. Developments in Sedimentology*, 38). However, previously there has been a tendency to emphasize the process, form and structure of wind-blown sand. This reinforces the popular view of deserts as areas of marching dunes and of little else. In fact, wind-formed dunes cover only a fraction of the Earth's present deserts, and there is no reason to suspect that the same is not true of bygone ages. Because of this, both the Meeting at the Geological Society and this volume have attempted to match studies of aeolian dunes with those of riverine and chemical deposits. As a result seven papers deal with the fluvial domain and two with chemical deposits (Fig. 1). Even the papers that champion the wind as an agent of erosion (twelve in number) highlight its ability to redistribute material of grain sizes both smaller and larger than those which bank characteristically into dune forms. Hence, four papers deal with the dynamics and accumulation of dust, and one compares sheet accumulations on Earth and Mars that contain a substantial gravel component.

However, any imbalance in treatment of the various process domains (wind, water, etc.) inevitably reflects the range of high quality papers

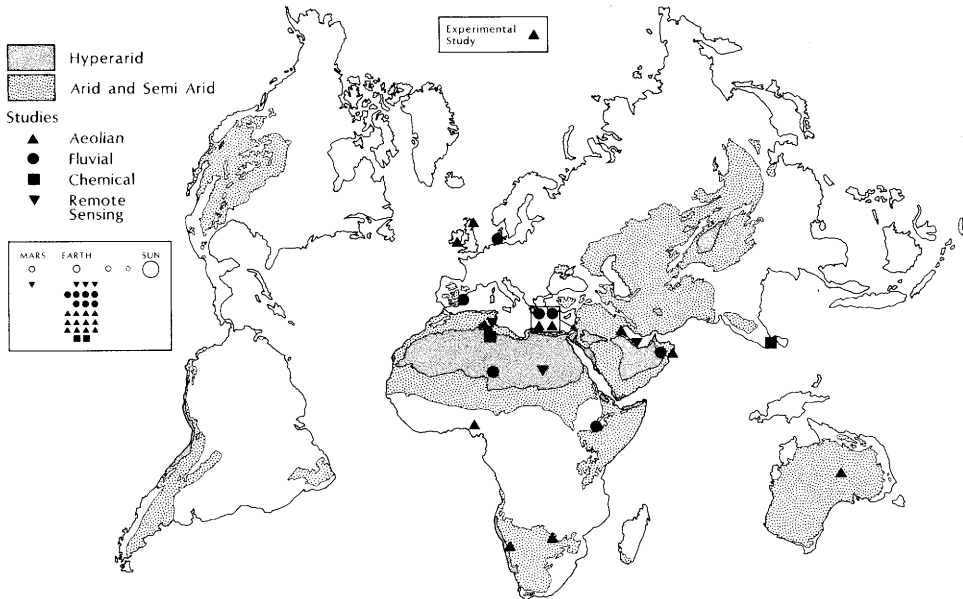


FIG. 1. Distribution of the Earth's hot deserts (after UNESCO 1977) and the location of studies in this volume.

proffered for inclusion. It also reflects the fascinations of those Earth scientists who conduct their research in deserts, ancient or modern. Thus, twenty-two papers seek to describe the processes and forms of clastic sediments, while only two directly address the problems of chemical sediments, and only three tackle weathering processes and diagenesis.

After an introduction, the volume is arranged so that fluvial sediments are covered first. This recognizes the significance of water in shaping the desert landscape. Here there are two papers whose setting is modern, and five which deal with

ancient counterparts. The volume *then* moves to aeolian sediments (seven modern; five ancient) if only because wind-blown materials often find their ultimate source in fluvial deposits. Two papers deal with contrasting chemical processes and deposits of modern age, before the volume moves to consider deserts at synoptic scale with the application of remote sensing techniques (three papers, all dealing with modern settings).

LYNNE FROSTICK
IAN REID
London, 1987

Acknowledgments

We have many people to thank. In the first instance, the permanent staff of the Geological Society and our own research officers played a vital part in the success of the Meeting that spawned this volume. We particularly mention Richard Bateman and Carolyne Symmonds, Jerry Jarvis and Angela Clark. We are indebted to the Geological Society for the generous provision of funds which allowed the participation of so many from beyond British shores. As for the production of this Special Publication, we thank the authors of each contribution for meeting each successive deadline. However, we especially thank our referees for their unsparing hard work. They were:

J. A. Allen, P. A. Allen, J. R. L. Allen, V. R. Baker, M. J. Barnsley, A. C. Brayshaw, M. E. Brookfield, J. A. Catt, C. P. Chalmers, W. G. Chaloner, L. Clemmensen, P. J. Curran, G. Evans, P. Friend, R. A. M. Gardner, R. Gerson, D. D. Gilbertson, K. W. Glennie, A. S. Goudie, A. T. Grove, A. M. Harvey, G. E. Hollis, D. K. C. Jones, P. Jungerius, D. J. Kinsman, N. Lancaster, M. M. Mainguet, J. Maizels, L. McFadden, J. McManus, A. C. Millington, G. Nanson, W. Nemeč, K. Pye, H. G. Reading, C. C. Reeve, K. S. Richards, J. Rose, A. P. Schick, H. Scoging, R. C. Selley, I. J. Smalley, R. P. Steele, M. M. Sweeting, D. B. Thompson, J.-J. Tiercelin, H. Tsoar, I. Tunbridge, B. R. Turner, C. Vita-Finzi, A. Warren, R. J. Wasson, I. West, M. A. J. Williams, M. J. Wilson, D. H. Yaalon.