CLIMATIC CHANGE IN DESERTS

Past, Present and Future

This book reconstructs climatic changes in deserts and their margins at a variety of scales in space and time. It draws on evidence from land and sea, including desert dunes, wind-blown dust, river and lake sediments, glacial moraines, plant and animal fossils, isotope geochemistry, speleothems, soils and prehistoric archaeology. The book summarises the Cenozoic evolution of the major deserts of the Americas, Eurasia, Africa and Australia and the causes of historic floods and droughts. The book then considers the causes and consequences of desertification and proposes four key conditions for achieving ecologically sustainable use of natural resources in arid and semi-arid areas. *Climatic Change in Deserts* is an invaluable reference for researchers and advanced students interested in the climate and geomorphology of deserts, including geographers, geologists, ecologists, archaeologists, soil scientists, hydrologists, climatologists and natural resource managers.

MARTIN WILLIAMS is Emeritus Professor at the University of Adelaide, Australia. His particular contributions to the field involve using evidence from a wide variety of disciplines to reconstruct prehistoric environments, ranging from the habitats occupied by early hominids in the Afar Rift of Ethiopia to the Neolithic occupation in the Sahara and the Nile Valley to the late Pleistocene wetlands in the arid Flinders Ranges of South Australia. He is a recipient of the Cuthbert Peek Medal from the Royal Geographical Society, the Sir Joseph Verco Medal from the Royal Society of South Australia, the Distinguished Geomorphologist Medal from the Australia and New Zealand Geomorphology Group, and the Farouk El Baz Award for Desert Research from the Geological Society of America. He is the author of more than two hundred research papers (twelve in *Nature*), and has edited and authored twelve books, including *Landform Evolution in Australasia* (with J.L. Davies, 1978), *The Sahara and the Nile* (with Hugues Faure, 1980) and *Quaternary Environments* (with David Dunkerley, Patrick De Deckker, Peter Kershaw and John Chappell, 1993, 1998).

CLIMATE CHANGE IN DESERTS

Past, Present and Future

MARTIN WILLIAMS
The University of Adelaide

CAMBRIDGE
UNIVERSITY PRESS

Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment,
a department of the University of Cambridge.

We share the University's mission to contribute to society through the pursuit of
education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107016910

First published 2014

A catalogue record for this publication is available from the British Library

Library of Congress Cataloging-in-Publication data
Williams, M. A. J., author.
Climate change in deserts : past, present and future / Martin Williams, The University of Adelaide.
pages cm
Includes bibliographical references and index.
ISBN 978-1-107-01691-0 (hardback)
1. Paleoclimatology. 2. Arid regions climate. 3. Climatic changes – Environmental aspects.
4. Deserts – History. I. Title.
QC884.5.A73W55 2014
551.415–dc23 2014009755

ISBN 978-1-107-01691-0 Hardback

Contents

Figures

Tables

Preface

The aridity, which makes life in deserts so difficult, has also preserved abundant evidence of a more humid past. For instance, scattered across the Sahara are numerous prehistoric occupation sites and rock paintings left behind by the Neolithic pastoralists who once roamed this now inhospitable land. Several thousand years older than the Neolithic art are the rock engravings and paintings of elephants, giraffes and other large herbivores that now inhabit the African savanna. Likewise, in the deserts that stretch from Arabia into Russia, China and India, deep rivers once flowed and freshwater lakes filled what are now dry saltpans. The same holds true for the Kalahari, the Atacama and the deserts of Australia and North America, prompting widespread curiosity about the climatic history of our deserts.

Apart from a natural concern over possible future changes in the earth's climate and their impact on the often poor communities of the semi-arid world, there are a number of reasons why a careful evaluation of what we currently know about the climatic history of the arid and semi-arid lands is both timely and worthwhile. One reason stems from plate tectonics, another from isotope geochemistry. An accurate long-term perspective on global climatic change has become possible as a result of recent advances in our understanding of world tectonic history. The combined evidence from deep-sea drilling, seismic investigations and paleomagnetic studies has allowed reconstruction of sea-floor spreading history and of continental apparent polar wandering curves. The data from land and sea are impressive and persuasive. The timing of late Cenozoic ice build-up in the two hemispheres is now known reasonably well, as are some of the associated changes in oceanic and atmospheric circulation, which are in turn related to the origin and expansion of the deserts.

Reconstruction of changes or fluctuations in oceanic circulation patterns used to depend very largely on sediment and microfossil studies. Analysis of the oxygen isotopic composition of the calcareous tests of suitable benthic and planktonic foraminifera now provides an additional and powerful means of assessing changes in ocean water temperature and salinity at depth and near the surface. After allowing for

local effects, it is also possible to use this technique to estimate changes in global ice volume. Times of lowest world temperature (glacial maxima) were times of greatest aridity in the tropical deserts and their margins, with massive export of desert dust offshore, even to central Antarctica.

Against this general background, this volume has three main aims. One is to examine critically the various lines of evidence from geology, biology and archaeology that have been used to reconstruct climatic change within the arid and semi-arid lands that now occupy some 36 per cent of the land area of the globe. If we include the dry subhumid regions of the world, since they, too, were once more arid than today, we are dealing with nearly 50 per cent of the land area of the Earth.

We also discuss Antarctica – the largest and driest of our cold deserts – and the Arctic, because they have long exerted a powerful influence on global climate. The second aim is to trace systematically the climatic history of the deserts from the inception of Cenozoic aridity some 30 million years ago through the fluctuations of the past 2.5 million years of Quaternary time until the droughts and floods of the present day. The final aim is inherently more speculative, but worthwhile withal, because it seeks to use the insights from our study of past events to envisage how human societies are likely to interact with possible future climatic changes in the desert world.

Acknowledgements

Over the years, many friends and colleagues across the globe have been generous with information and ideas about the desert world, often showing me first hand those starkly beautiful landscapes they have studied with such dedication. Dick Grove first suggested that I might like to replace him on an expedition to Jebel Arkenu in south-east Libya during the northern summer of 1962, an expedition that was organised by Captain (later Lieutenant-Colonel) David Hall RE from the Royal Military Academy, Sandhurst. Claudio Vita-Finzi gave me sage advice on desert travel based on his unequalled knowledge of the northern Libyan Desert.

A second expedition to south-east Libya the following summer, again led by David Hall, provided a welcome change from soil surveys along the Blue and White Nile rivers in Sudan, and enabled us to map and name two hitherto unexplored sandstone plateaux north-east of Tibesti volcano. The contrast between the harsh Saharan summer and the widespread evidence of a prehistoric human presence in that region from Early Stone Age times onwards led me to ask myself when, why and how often had the Sahara been a green and pleasant land and why it was no longer.

A move to Australia in late 1964 and a drive across the 'Red Centre' during a time of severe drought made me wonder about the causes of such droughts; the consequences were all too visible. One cattle owner told me that his eight-year-old son had never seen rain, reminding me of the road through Kufra Oasis, built of salt, in a land where rain fell once in fifty years. Later visits to the Thar Desert of north-western India, the Taklamakan Desert of western China, the Alashan Desert of Inner Mongolia, the Kalahari and Namib Deserts of southern Africa, the Afar Desert of Ethiopia, not to mention Arizona and the Grand Canyon, interspersed with recurrent visits to the drier parts of Ethiopia, Sudan, Niger and Kenya, and more sporadic visits to Algeria, Djibouti, Egypt, Somalia, Mauritania, Tunisia, Jordan and Israel, enabled me to continue my efforts to make sense of when and why our arid lands were once able to support more abundant life than they can today. Almost inevitably, such work led me to consider the causes and consequences of, and possible solutions

to, desertification processes, including the tantalizing question of how to distinguish between human impacts, whether direct or indirect, and 'natural' influences.

None of this research would have been possible without the support and encouragement of my companions and colleagues who shared my passion for desert landscapes. Many weeks of joint fieldwork with Desmond Clark in Niger, Sudan, Ethiopia and India; with Don Adamson in Australia, Sudan and Ethiopia; and with Mike Talbot in Niger and Australia forged ineffable memories. *Valete* Mike, Don and Desmond – you shared the joys as well as the hardships, and I remain the better for having known you.

In France, Théodore Monod, Jean Dresch, Hugues Faure, Françoise Gasse, Jean-Charles Fontes, Pierre Rognon, Georges Conrad, Maurice Taïeb, Nicole Petit-Maire, Michel Decobert, Jean-Louis Ballais, Mohamed Benazzouz, Jean Riser, Raymonde Bonnefille, Annie Vincens, David Williamson, Françoise Chalié, Pascal Lluch, Hélène Jousse, Hélène Roche, Edouard Bard, Xavier Le Pichon, Bruno Hamelin and many others offered wise counsel and spirited discussion, whether in the laboratory or in the field. In Germany, I benefitted from the impressive desert knowledge of Hans-Joachim Pachur, Stefan Kröpelin, Philip Hoelzmann, Baldur Gabriel, Horst Mensching, Dieter Jäkel and Helga Besler.

In India, Virendra Misra and S. N. Rajaguru inducted me into the subtleties of the Rajasthan desert landscapes, soils and prehistoric archaeology, following my earlier work in the Son and Belan valleys of north-central India with the late Professor G.R. Sharma and his team of keen archaeologists: V. D. Misra, B. B. Misra, D. Mandel, Jagannath Pal and Umesh Chattopadhyaya. The late Professor Liu Tungsheng guided my first footsteps in China, as did Yang Xiaoping, Wang Tao, Ci Long-Jun, Xiao Honglang and Li Aixin on subsequent visits. In the Russian Federation and beyond, I have benefitted from the wisdom and experience of Professors I. G. Gringof, G. S. Kust, I. S. Zonn and A. A. Velichko, and from the stimulation provided by many highly impressive younger researchers.

In Australia, many have contributed to my appreciation of this 'flat brown land', above all Joe Jennings, Jack Mabbutt, Bob Story, Bob Gunn, Bob Galloway, Jim Bowler, Rowl Twidale, Ron Paton, Bob Wasson, John Chappell, Brad Pillans, Peter Kershaw, Patrick De Deckker, Karl-Heinz Wyrwoll, Gerald Nanson, Paul Bishop, Paul Hesse, David Dunkerley, John Tibby, Cameron Barr, Vic Gostin, George Williams, Bob Bourman, Gavin Prideaux, Cliff Ollier and countless generations of students whose questions have kept me alert to new ideas and concepts.

My mentors, friends and colleagues in the United Kingdom have been a source of inspiration over the years: Dick Grove, Bruce Sparks, Dick Chorley, Andrew Warren, Claudio Vita-Finzi, Dave Thomas, Ian Reid, Jamie Woodward, Mark Macklin, Suzanne Leroy and Alayne Street-Perrott. The three months in 1970 working at Adrar Bous in the geographical heart of the Sahara with Desmond Clark, David Hall, Andy

Smith, Alan Pastron, Tony Pigott, Mike Saunders, John Rogers and Richard Trewby are engraved on my memory as one of life's formative experiences.

Visits to North America were enlivened by Tom Dunne, Stan Ambrose, Don Johnson, Dick Hay, Steve Porter, Alan Gillespie, Geof Spaulding, Minze Stuiver, Steve Warren, Estella Leopold, Bernard Hallet, Steve Burges, Kelin Whipple, Leal Mertes, Bob Balling, Will Graf, Ron Dorn, Vance Haynes and Vic Baker, all of whom were as hospitable as they were intellectually stimulating. As always, the field visits were greatly enlightening. Asher Schick, Ran Gerson, Yoav Avni, Aaron Yaïr, Hanan Ginat, Yehouda Enzel and Moti Stein have shared with me their unparalleled knowledge of the arid landscapes of Israel, and in Jordan during my 1975 visit to Wadi Rum and Petra – the 'rose-red city half as old as time' – the local Bedu spoke to me of Moses striking the rock to obtain water as if it were yesterday.

The people of the Sudan have invariably received me with generosity and courtesy during my many visits to 'the land between two Niles' and beyond. I owe particular thanks to Dr Abdelrazig Ahmed and Dr Yusif Elsamani (respectively, past and present Directors of the Geological Research Authority of the Sudan), Dr Yasin Abdl Salaam, formerly at the University of Khartoum, Professor Osman et Tom, former Director of Soils Research at Wad Medani, and Neil Munro, for their patience, wisdom and guidance during my more recent visits, since he who has once drunk the waters of the Nile must needs return.

I owe special thanks to Dr Emi Ito who provided informed advice, incisive comments and an invaluable exchange of publications during the early stages of writing; to Frances Williams for constructive criticism of each chapter and help with certain figures; to Christine Crothers for her meticulous drafting of the majority of the figures; and to Matt Lloyd at Cambridge University Press for editorial encouragement. Any errors, omissions and other solecisms remain my responsibility. The journey has been long but there was always something hidden beyond the ranges, and the golden road to Samarkand was ever there to entice the weary traveller.