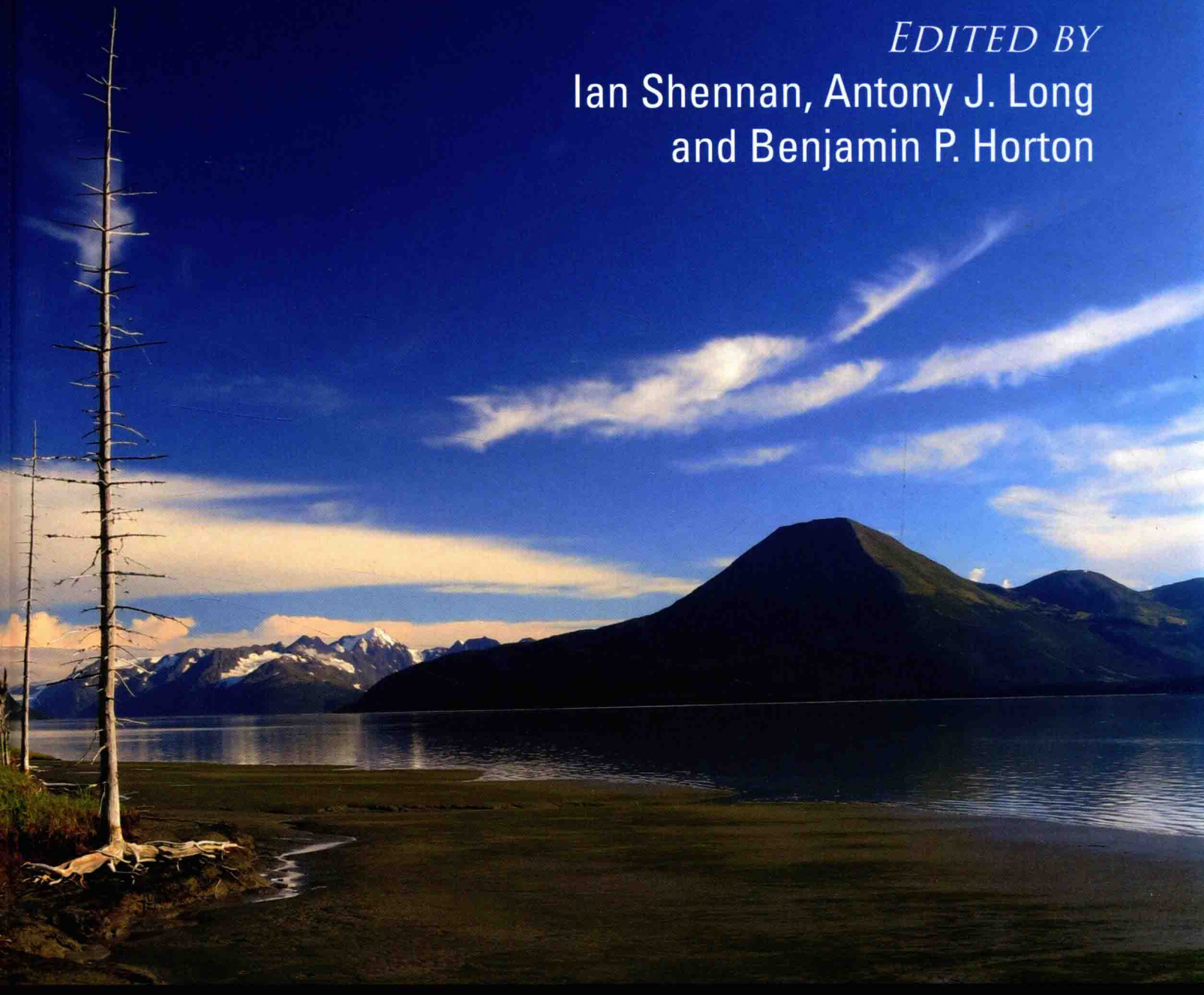
Handbook of Sea-Level Research

Edited by
Ian Shennan, Antony J. Long
and Benjamin P. Horton



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Editorial Offices
9600 Garsington Road, Oxford, OX4 2DQ, UK
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
111 River Street, Hoboken, NJ 07030-5774, USA

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Cover Image: Girdwood marsh and ghost forest, Turnagain Arm, Alaska. The Mw 9.2 earthquake of March 27, 1964 caused ~1.5 m subsidence, death of the trees and the onset of tidal flat sedimentation on the top of the forest peat soil. Land uplift and sedimentation since 1964 aided recolonization of the tidal flat sediment by marsh plant communities in less than 50 years. Sediments from cores through the marsh sediments reveal evidence of six previous great earthquakes in the last 4000 years. Photograph by Ian Shennan, September 2013.

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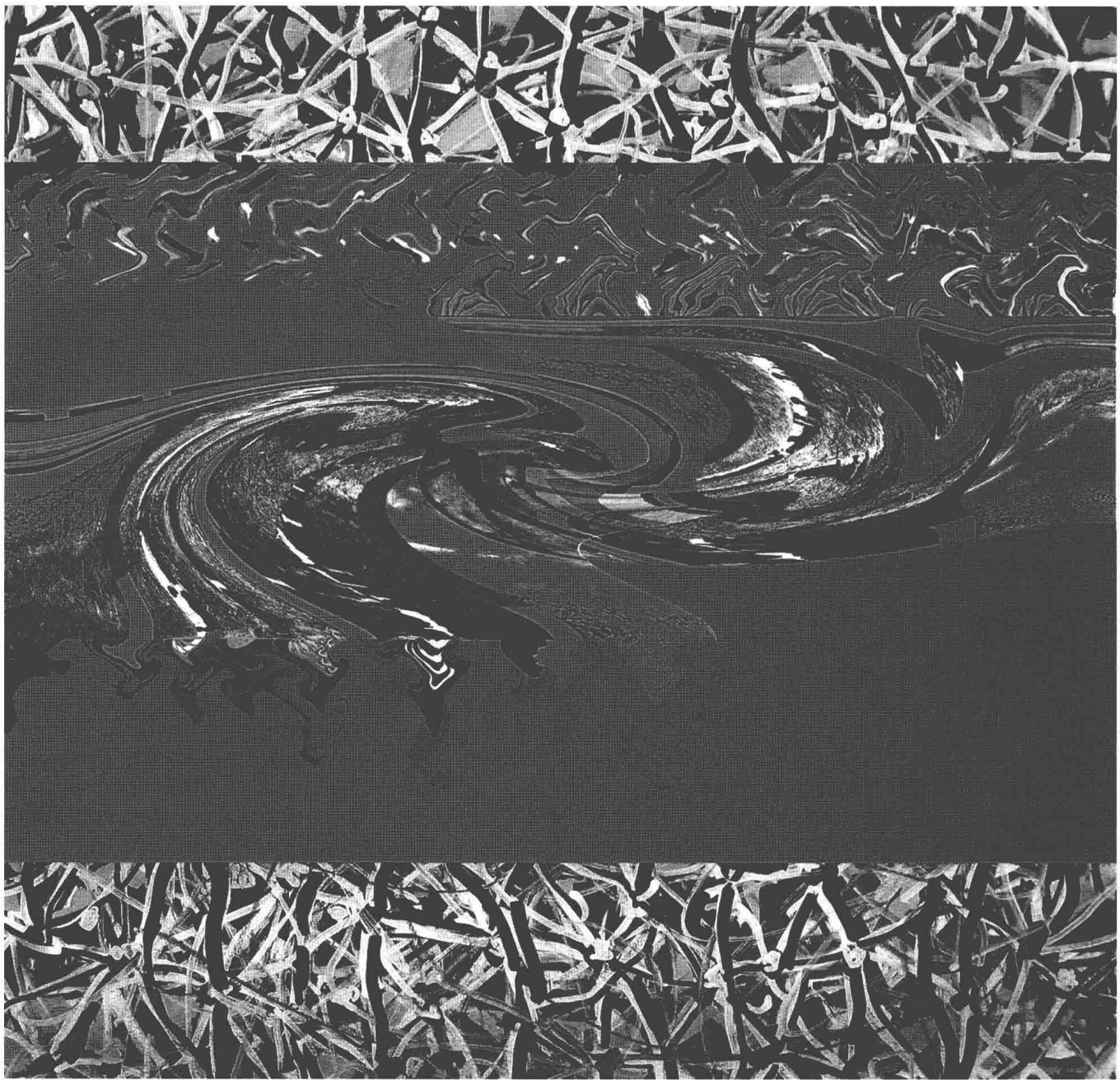
The frontispiece "not in spatial chaos but by time" is a composition by Eleonora Tammes based on one of her paintings – title: "embrace within I" 45 × 55 cm (2012) acrylic, paintmarker, graphite on paper (from the Break Away series), and a set of cross section photographs (Pattagansett River Marsh & Menunketesuck River Marsh, CT) created following Orson's typical coring method ("Orsonian method"). *Source*: Reproduced with permission of Eleonora Tammes

HANDBOOK OF SEA-LEVEL RESEARCH



"not in spatial chaos but by time"

List of contributors

Fabrizio Antonioli
ENEA-UTMEA-TER, Roma, Italy
fabrizio.antonioli@enea.it

Donald C. Barber
Department of Geology, Bryn Mawr College, Bryn Mawr, PA, USA
dbarber@brynmawr.edu

Natasha L. M. Barlow
Sea Level Research Unit, Department of Geography, Durham University, Science Laboratories, Durham, UK
n.l.m.barlow@durham.ac.uk

Mark D. Bateman
Geography Department, University of Sheffield, Sheffield, UK
M.D.Bateman@sheffield.ac.uk

Christopher E. Bernhardt
US Geological Survey, Eastern Geology and Paleoclimate Science Center, Reston, VA, USA
cbernhardt@usgs.gov

Carlo Nike Bianchi
DISTAV, Università degli Studi di Genova, Genoa, Italy
nbianchi@dipteris.unige.it

John F. Boyle
Department of Geography and Planning, School of Environmental Sciences, University of Liverpool, Liverpool, UK
jfb@liverpool.ac.uk

Matthew J. Brain
Sea Level Research Unit, Department of Geography, Durham University, Science Laboratories, Durham, UK
matthew.brain@durham.ac.uk

Dan J. Charman
Department of Geography, College of Life and Environmental Sciences, University of Exeter, Exeter, UK
d.j.charman@exeter.ac.uk

Kim M. Cohen
TNO, Geological Survey of the Netherlands, Utrecht, The Netherlands
Deltares, Applied Geology and Geophysics, Utrecht, The Netherlands
Department of Physical Geography, Utrecht University, Utrecht, The Netherlands
k.m.cohen@uu.nl

D. Reide Corbett
East Carolina University, Greenville, NC, USA
UNC Coastal Studies Institute, Wanchese, NC, USA
corbettd@ecu.edu

Thomas M. Cronin
US Geological Survey, Reston, VA, USA
tcronin@usgs.gov

Jeffrey A. Dorale
Department of Earth and Environmental Science, University of Iowa, Iowa City, IA, USA
jeffrey-dorale@uiowa.edu

Andrea Dutton
Department of Geological Sciences, University of Florida, Gainesville, FL, USA
adutton@ufl.edu

Robin Edwards
School of Natural Sciences, Museum Building, Trinity College Dublin, Dublin, Ireland
robin.edwards@tcd.ie

Simon E. Engelhart
Department of Geosciences, University of Rhode Island, Kingston, RI, USA
engelhart@uri.edu

Tezer M. Esat
Australian Nuclear Science and Technology Organization, Institute for Environmental Research, Kirrawee, Australia
Research School of Earth Sciences and Research School of Physical Sciences and Engineering, The Australian National University, Canberra, Australia
tezer.esat@anu.edu.au

Alvaro B. Fernandez
Department of Earth and Environmental Sciences, Tulane University, New Orleans, LA, USA
afernan4@tulane.edu

James Foster
University of Hawai'i, Honolulu, HI, USA
jfoster@soest.hawaii.edu

W. Roland Gehrels
Environment Department, University of York, Heslington, York, UK
roland.gehrels@york.ac.uk

Stephen D. Griffiths
Department of Applied Mathematics, University of Leeds, Leeds, UK
sdg@maths.leeds.ac.uk

Peter J. van Hengstum
Department of Marine Sciences, Texas A&M University at Galveston, Galveston, TX, USA
vanhenp@tamug.edu

Marc P. Hijma
Department of Earth and Environmental Sciences, Tulane University, New Orleans, LA, USA
Deltares, Applied Geology and Geophysics, Utrecht, The Netherlands
marc.hijma@deltares.nl

David F. Hill
School of Civil and Construction Engineering, Oregon State University, Corvallis, OR, USA
david.hill@oregonstate.edu

Benjamin P. Horton
Sea Level Research, Department of Marine and Coastal Sciences, Rutgers University, USA
Earth Observatory of Singapore and Division of Earth Sciences, Nanyang Technological University, Singapore
bphorton@marine.rutgers.edu

Ping Hu
Department of Earth and Environmental Sciences, Tulane University, New Orleans, LA, USA
phu@tulane.edu

Harvey M. Kelsey
Department of Geology, Humboldt State University, Arcata, CA, USA
harvey.kelsey@humboldt.edu

Andrew C. Kemp
Department of Earth and Ocean Sciences, Tufts University, Medford, MA, USA
Andrew.Kemp@tufts.edu

Nicole S. Khan
Sea Level Research, Department of Earth and Environmental Science, University of Pennsylvania, Philadelphia, PA, USA
Department of Marine and Coastal Sciences, School of Environmental and Biological Sciences, Rutgers University, New Brunswick, NJ, USA
khann@sas.upenn.edu

Jason R. Kirby
School of Natural Sciences and Psychology, Department of Geography, Liverpool John Moores University, Liverpool, UK
J.R.Kirby@ljmu.ac.uk

Antony J. Long
Sea Level Research Unit, Department of Geography, Durham University, Durham, UK
a.j.long@durham.ac.uk

Nick Marriner
Laboratoire Chrono-Environnement, UMR 6249 CNRS, Université de Franche-Comté, UFR ST, Besançon, France
marriner@cerege.fr

Wil Marshall
School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, UK
wmarshall@plymouth.ac.uk

Aron J. Meltzner
Earth Observatory of Singapore, Nanyang Technological University, Singapore
meltzner@ntu.edu.sg

Hayley Mills
British Oceanographic Data Centre, National Oceanography Centre, Liverpool, UK
haymil@bodc.ac.uk

Glenn A. Milne
Department of Earth Sciences, University of Ottawa, Ottawa, Ontario, Canada
gamilne@uottawa.ca

Christophe Morhange
Université Aix-Marseille, IUF, CEREGE UMR 7330, Europôle de l'Arbois, Aix-en-Provence, France
morhange@cerege.fr

Alan R. Nelson
Geologic Hazards Science Center, US Geological Survey, Golden, CO, USA
anelson@usgs.gov

Bogdan P. Onac
School of Geosciences, University of South Florida, Tampa, FL, USA
bonac@usf.edu

Andrew C. Parnell
School of Mathematical Sciences (Statistics), Complex and Adaptive Systems Laboratory, University College Dublin, Dublin, Ireland
andrew.parnell@ucd.ie

Jessica E. Pilarczyk
Institute of Marine and Coastal Sciences, Rutgers, The State University of New Jersey, New Brunswick, NJ, USA
Earth Observatory of Singapore, Nanyang Technological University, Singapore
jpilar@marine.rutgers.edu

Jeremy Pile
Earth Observatory of Singapore, Nanyang Technological University, Singapore
JeremyPile@ntu.edu.sg

Andrew J. Plater
Department of Geography and Planning, School of Environmental Sciences, University of Liverpool, Liverpool, UK
gg07@livepool.ac.uk

David T. Pugh
National Oceanography Centre, Liverpool, UK
d.pugh@mac.com

David A. Richards
School of Geographical Sciences, University of Bristol, Bristol, UK
David.Richards@bristol.ac.uk

Brad E. Rosenheim
Department of Earth and Environmental Sciences, Tulane University, New Orleans, LA, USA
College of Marine Science, University of South Florida, St. Petersburg, FL, USA
brosenheim@usf.edu

Alessio Rovere
Sea Level and Coastal Changes Group, MARUM, University of Bremen & ZMT, Leibniz Center for Tropical Marine Ecology, Bremen, Germany
Lamont Doherty Earth Observatory, Columbia University, Palisades, NY, USA
rovere@ldeo.columbia.edu

Yuki Sawai
Institute of Earthquake and Volcano Geology (IEVG), National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, Japan
yuki.sawai@aist.go.jp

Timothy Shaw
Department of Geography and Planning, School of Environmental Sciences, University of Liverpool, Liverpool, UK
t.a.shaw@liverpool.ac.uk

Ian Shennan
Sea Level Research Unit, Department of Geography, Durham University,
Durham, UK
ian.shennan@durham.ac.uk

Adam D. Switzer
Earth Observatory of Singapore, Nanyang Technological University, Singapore
Division of Earth Sciences, Nanyang Technological University, Singapore
aswitzer@ntu.edu.sg

Richard J. Telford
Department of Biology, University of Bergen and Bjerknes Centre for Climate Research, Bergen, Norway
richard.telford@bio.uib.no

Torbjörn E. Törnqvist
Department of Earth and Environmental Sciences, Tulane University, New Orleans, LA, USA
tor@tulane.edu

Ad J. F. van der Spek
Deltares, Applied Geology and Geophysics, Utrecht, The Netherlands
ad.vanderSpek@deltares.nl

Christopher H. Vane
British Geological Survey, Environmental Science Centre, Keyworth, Nottingham, UK
chv@bgs.ac.uk

Johan H. ten Veen
TNO, Geological Survey of the Netherlands, Utrecht, The Netherlands
johan.tenveen@tno.nl

Geert-Jan Vis
TNO, Geological Survey of the Netherlands, Utrecht, The Netherlands
geert-jan.vis@tno.nl

Peter C. Vos
Deltares, Applied Geology and Geophysics, Utrecht, The Netherlands
peter.vos@deltares.nl

Martyn Waller
Centre for Earth and Environmental Science Research, School of Geography, Geology and the Environment, Kingston University, Kingston upon Thames, Surrey, UK
m.waller@kingston.ac.uk

J. P. Walsh
East Carolina University, Greenville, NC, USA
UNC Coastal Studies Institute, Wanchese, NC, USA
walshj@ecu.edu

Wim E. Westerhoff
TNO, Geological Survey of the Netherlands, Utrecht, The Netherlands
wim.westerhoff@tno.nl

Debra A. Willard
US Geological Survey, Eastern Geology and Paleoclimate Science Center, Reston, VA, USA
dwillard@usgs.gov

Robert C. Witter
US Geological Survey, Alaska Science Center, Anchorage, AK, USA
rwitter@usgs.gov

Colin D. Woodroffe
School of Earth and Environmental Sciences, University of Wollongong, Wollongong, NSW, Australia
colin@uow.edu.au

Sarah A. Woodroffe
Sea Level Research Unit, Department of Geography, Durham University, Science Laboratories, Durham, UK
s.a.woodroffe@durham.ac.uk

Philip L. Woodworth
National Oceanography Centre, Liverpool, UK
plw@noc.ac.uk

Alex Wright
Department of Earth and Life Sciences, VU University of Amsterdam, The Netherlands
zarndee@gmail.com

Yusuke Yokoyama
Atmosphere and Ocean Research Institute, University of Tokyo, Chiba, Japan
Department of Earth and Planetary Science, University of Tokyo, Tokyo, Japan
Department of Biogeosciences, Japan Agency for Marine-Earth Science and Technology Organization, Yokosuka, Japan
yokoyama@aori.u-tokyo.ac.jp

Yongqiang Zong
Department of Earth Sciences, the University of Hong Kong, Hong Kong SAR, China
yqzong@hkucc.hku.hk

Preface

About 15 years ago Orson van de Plassche and we discussed putting together a successor to the extremely successful reference book *Sea-level Research: A Manual for the Collection and Evaluation of Data* that he edited. It was published in 1986 but never re-printed. For at least 15 years it was a widely used reference and highlighted the need for a handbook approach for research that aimed to investigate sea-level changes beyond the range of modern instrumental records. It was especially useful in transferring approaches and skills beyond the research heartlands of NW Europe and North America. By 2000, we had an outline and discussed the complications of organizing topics

Pattagansett River Marsh, East Lyme, CT; one of the sites used in sea-level research, illustrating the resilience of marsh environments to extreme events (van de Plassche et al., 2004, 2006). The upper photograph is from August 2010 and the lower one from March 2013, five months after Hurricane Sandy and the accompanying surge which caused significant damage along the east coast of the USA. The marsh survived relatively intact, with a thin veneer of fine-grained sediment unevenly distributed across only some parts of the marsh, with localized erosion, including small marsh cliffs and the foundation of an access road. The sign in the foreground of the 2010 photograph was also destroyed by the storm surge. Photographs courtesy of Andy Kemp.

Pattagansett River Marsh, East Lyme, CT. July 2013. Photography by Eleonora Tammes. The inscription reads "Dr Orson van de Plassche. He was a leading light in sea level and hurricane research, a meticulous and energetic field scientist and one of the best coastal geologists and stratigraphers of his generation. The wetlands will benefit us all into the future, and we thank him. East Lyme/Niantic Land Trust (2009)."

into chapters. With sea-level research covering such a wide range of disciplines, approaches, timescales, spatial scales, environments, laboratory methods, and analytical procedures, we found it challenging to decide on a framework of chapters that would be practical yet minimize repetition. In the end, we outlined sections and chapters that reflected the actual sequence of activities that many, but not all, researchers followed at that time.

Unfortunately, we never got it off the ground before Orson's untimely passing in 2009.

Orson spent much of his career seeking answers to research questions about the overprinting and interlinking of millennial-scale sea-level change with shorter-term variations, changes over the last 150 years, hurricanes, and storm surges. Having defined the question, his research typically encompassed meticulous fieldwork in marsh environments (photographs page xi), sample collection, innovative methods of dating, multi-proxy evidence of environmental reconstruction, and rigorous data analysis, incorporating modeling procedures where relevant.

Having received widespread approval and support at the final meeting of IGCP 495 in 2009 and then from IGCP 588, the idea was revived and we started inviting authors from across the research community.

The organization of the book broadly follows the structure we had outlined with Orson around 2000. Chapters 1 and 2 introduce the aims and context of the *Handbook*, what it does and does not aim to cover, approaches to sea-level research, common terms, and some suggestions for promoting clearer understanding, both within and beyond the sea-level research community. We have organized the remaining chapters into parts that broadly reflect different activities in research. Part 1 comprises nine chapters on field techniques for reconstructing sea level, and Part 2 provides 11 chapters on the main laboratory techniques. Five chapters on dating methods form Part 3, followed by 7 chapters on different modeling approaches in Part 4. The final chapter, in Part 5, focuses on the instrumental record of sea-level change.

For all who have had the privilege to work with Orson or be inspired by his work, we hope that this Handbook will be a suitable successor to the 1986 Manual. Just as the marsh was resilient to Hurricane Sandy, so the plaque was replaced as the sentiments expressed on it are equally resilient. Similarly, this Handbook follows the Manual as an illustration of how the pursuit of excellence in sea-level reconstruction continues.

Ian Shennan, Antony Long and Ben Horton
Durham and New Brunswick, January 2015

The Handbook is a contribution to IGCP 588 *Preparing for coastal change: A detailed process-response framework for coastal change at different timescales* and PALSEA2.

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About the companion website

This book is accompanied by a companion website:

www.wiley.com/go/shennan/sealevel

The website includes:
Pdfs of all figures from the book for downloading
Powerpoints of all tables from the book for downloading
High-resolution images of microfossils
Modeling code
Database materials

Contents

Chapter 1
Introduction

IAN SHENNAN[1], ANTONY J. LONG[1], AND BENJAMIN P. HORTON[2,3]

[1] *Sea Level Research Unit, Department of Geography, Durham University, Durham, UK*
[2] *Sea Level Research, Department of Marine and Coastal Sciences, Rutgers University, USA*
[3] *Earth Observatory of Singapore and Division of Earth Sciences, Nanyang Technological University, Singapore*

1.1 AIMS OF THE HANDBOOK

Every year, countless articles, books, social media, and TV programs debate the importance (or not) of sea-level change; the change debated is mainly sea-level rise, but sea-level fall is also possible and important. Millions of people live along the coast, estuaries, and adjacent coastal lowlands and many will concur with the view that "Due to sea level rise projected throughout the 21st century and beyond, coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion." (IPCC 2014, page 17). Significant debate over some of the causes and consequences of recent and future sea-level change remains within and between many communities including science, the media, coastal residents, industry, politics, and governments. Environments, communities, livelihoods, real-estate, and cash are all at stake. While improved understanding of the causes, impacts, and responses to sea-level change are of undeniable importance in many disciplines, these are not the subject of this book. With the range of technology available today, we can measure changes every few minutes with tide gauges and across entire oceans using satellites. Yet these offer only a small part of the wider picture. How does the variability we observe using these technologies fit with longer-term trends? Do our decades of instrumental observations adequately cover the natural variability and extreme events of the past and those we are likely to experience in the future? Most researchers would probably give a very guarded answer; some would give a forthright "No". We need to bring together the evidence across a greater range of timescales, from seconds to millennia or even longer, for a complete analysis.

The aims of this book are therefore to entice and guide the reader beyond their initial interest and discipline, to enable them to tackle new questions. This will hopefully also lead to the reader asking new questions and, ultimately, proposing new answers based on carefully collected observations, analyses, and models developed in the field and the laboratory from sites all over the world.

1.2 SEA-LEVEL RESEARCHERS

Sea-level research is primarily an observational science and we must realize what imperfect observers we are. Unlike experimental science where observations can usually be replicated and verified by others using the same or equivalent methods, we frequently deal with observations that have incomplete distributions through time and/or space. When looked at by another researcher, objectively and dispassionately, how many interpretations deteriorate into a collection of inferences, guesses, or hunches based on too little data, much of which is inconclusive or influenced by decisions made by the original author? With this in mind, it is easy to state that one clear recommendation of this Handbook is to encourage all researchers to make available their data for others to use as the basis for alternative analyses and interpretation. If we are fortunate to act as a reviewer or an editor for a peer-reviewed publication, we must ask authors to include the raw data either in the paper or an online repository linked to the article.

While our interpretations may remain unchallenged or un-falsified for only a few years, we should aim for our data to stand the test of time and be readily available. After all, digital media, international data repositories, and scientific journals encouraging online supplementary information files make this much more feasible than it has ever

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been. But the reality is that we are human beings, living in different socio-economic and political environments where different pressures may work against this aspiration of openness. Career progression and demands from employers, research funding bodies, government, peers, students, and the media may all influence a researcher at different times throughout their career; we cannot hide from this fact. Similarly, our educational background, training, and experiences will influence the approach we take.

A review of sea-level research since the publication of Orson's original Manual (van de Plassche, 1986) will quickly reveal examples of how theories we thought we had right were in fact wrong. As a consequence, this Handbook does not set out to promote a single paradigm for sea-level research or a single "right" way of doing things. Rather, it aims to illustrate approaches and methods that have produced observations, analyses, and interpretations which have then stood the test of scrutiny by peers, mainly through the review process of scientific journal publication, but also at conferences and field discussion meetings. For many sea-level researchers we should acknowledge that defending one's work in the field or at a small workshop may well be more intimidating and rigorous than at an international meeting or through the journal review process. Despite the need to publish for career progression, we should not underestimate the value of field meetings and workshops, through international organizations such as the International Geoscience Programme (IGCP) and the International Union for Quaternary Science (INQUA), to generate open debate and different perspectives on the way we make observations. Such debates and perspectives can provide the catalyst for new ideas and the development of new methods and techniques for data collection, analysis, and hypothesis testing. Attendance at such meetings can however be difficult due to their location, their cost, or other reasons. This is where we hope that this handbook will serve a real purpose by making available to readers many of the approaches and methods of sea-level research developed at such events in a single volume. If we come close to achieving this aim, we will have achieved one of the prime motivations of the first Manual and produced something that is fitting testimony to Orson's original vision.

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