Introduction to Coastal Processes and Geomorphology

Written for anyone interested in coastal geomorphology, this is the complete guide to the processes at work on our coastlines and the resulting features seen in coastal systems across the world. Accessible to students from a range of disciplines, the quantitative approach of this book helps to build a solid understanding of wave and current processes that shape coastlines. From sandy beaches to coral reefs, the major coastal features are related to contemporary processes and to sea level changes over the past 25 000 years. Key equations describing these processes and standard methods and instrumentation used to collect measurements are all presented in this wide-ranging overview. Designed to support a one- or two-semester course and grounded in current research, this Second Edition has been substantially updated and rewritten — featuring cutting-edge new topics, insights from new models and technologies, additional global examples and an enhanced package of online teaching materials.

Robin Davidson-Arnott has been a Professor in the Department of Geography at the University of Guelph since 1976. He was a member of the Task Force of the International Joint Commission (Canada/USA) Great Lakes Water Levels Reference Study Phase 1 (1987–9), and was seconded as a Scientist to the Ontario Ministry of Natural Resources Development of Ontario Shoreline Management Policy and Technical Guideline (1992–5), and to the International Joint Commission (Canada/USA) Upper Great Lakes Water Level Regulation Study (2007–11). He has worked as a consultant for a number of studies for Ontario Conservation Authorities and Parks, Canada, and been awarded the R.J. Russell Award from the Coastal and Marine Specialty Group of the Association of American Geographers in 2000. His research interests are in coastal geomorphology: on beach and nearshore processes on sandy coasts, nearshore erosion of cohesive coasts, coastal saltmarshes, aeolian sediment transport and coastal dunes. He has received continuous support in his research from the Natural Sciences and Engineering Research Council of Canada for over 30 years. He has authored and co-authored many books and journal articles on the subject, including a contribution to *Geomorphology and Global Environmental Change* (2009, Cambridge University Press).

Bernard Bauer is a process geomorphologist with research and teaching experience in coastal, aeolian, and fluvial environments. He is the recipient of the HydroLab Award from the International Association for Great Lakes Research, the R.J. Russell Award from the Association of American Geographers, and a Presidential Young Investigator Award from the US National Science Foundation (NSF). His research has been conducted in Canada, USA, Australia, New Zealand and Ireland, leading to peer-reviewed publications in major international journals. He has held administrative positions as Department Chair (University of Southern California), Faculty Dean and Associate Provost (University of British Columbia), and he also served as a Programme Director at the US National Science Foundation. He now devotes considerable time as a volunteer member of committees dealing with water sustainability issues in the Okanagan, British Columbia.

Chris Houser is a coastal geomorphologist with a focus on barrier island response and recovery to storms and sea level rise, physical and social dimensions of the rip current hazard, and scale interaction in coastal systems. His research has been conducted in Canada, the United States, Australia, Denmark and Costa Rica, leading to peer-reviewed publications on coastal geomorphology, geology, coastal management and beach safety. He has held academic and administrative positions at the University of West Florida, Texas A&M University and the University of Windsor, and is currently the Dean of Science at Windsor.

Given the impending challenges at the coast under the impacts of global climate change, it is heartening to encounter this well-presented text on the interaction of processes and sediment supply that provide the characteristics of the present coastal features. The writing style is that of being in the classroom and being exposed to the lectures on the topic, replete with background, a variety of perspectives, and areas of continued need for research. It is the essence of communication for the purpose of generating understanding and appreciating the vectors of change at many levels now and into the future. BRAVO!!

Norbert Psuty, Rutgers University

This substantially updated second edition is a well-balanced and authoritative introduction to a wide range of coastal systems, usefully supported by examples drawn from across the globe. Written by acknowledged coastal experts, the text is grounded in morphodynamics yet styled to allow easy access to a wide spectrum of readers, reaching out beyond coastal scientists to include those who manage the coast. The use of special interest boxes serves as an elegant device linking an understanding of morphodynamics to key coastal-management issues. This book is an authoritative key text for all those with an interest in coastal processes and geomorphology.

Jim Hansom, University of Glasgow

There has been a significant increase in the number and quality of studies devoted to coastal geomorphology over the last three decades. Much of this research has been driven by advances in technology and by the development of novel approaches, especially in instrumentation and modelling. At the same time our coasts are now affected by major changes driven by natural and human factors that call for an increasingly cross-disciplinary approach. The book by Robin Davidson-Arnott, Bernard Bauer and Chris Houser is more than a remarkable introduction to coastal geomorphology, building up with team synergy on the first edition published a few years ago by R. Davidson-Arnott. Written by three scientists who have contributed substantively, and still do, to the understanding of coasts and the geomorphic processes involved in the construction, shaping and reworking of coastal landforms, the second edition of this book finely crystallizes cutting-edge research in coastal geomorphology. The book is cast in a quantitative, yet easily comprehensible, format complemented by online teaching materials that will be appealing to students and scholars from a range of disciplines. The text is well-balanced with good, clear diagrams and figures, and each chapter backed by up-to-date references and supplementary information on coastal processes in a box format. This book deserves to appear on your shelves. I will certainly recommend it to students and to colleagues.

Edward Anthony, Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement, Aix-Marseille University; Editor-in-Chief of *Marine Geology*

… combines an accessible yet scholarly treatment of the underlying processes with a broad range of interesting case studies. …. *Introduction to Coastal Processes and Geomorphology* would certainly be my current choice for a course text in this field.

Geological Magazine

This excellent book is both well-written and illustrated … it will more than satisfy undergraduate coastal geomorphology students yet it is also clear and accessible enough to be of great use to students from a range of disciplines … one of the best coastal geomorphology texts available.

Jim Hansom, University of Glasgow

… an excellent, modern synthesis of key concepts and literature that also provides a sound knowledge base for advanced studies and researchers. Supplemented with … excellent online resources, including field data sets and presentation-quality figures and video clips. This text, and its related resources, is a must have for anyone interested in coastal geomorphology.

Ian J. Walker, University of Victoria

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Second Edition

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CAMBRIDGE
UNIVERSITY PRESS

Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

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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.

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www.cambridge.org
Information on this title: www.cambridge.org/9781108439862

DOI: 10.1017/9781108546126

First edition published 2010
Second edition published 2019

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

ISBN 978-1-108-42427-1 Hardback
ISBN 978-1-108-43986-2 Paperback

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Preface

This textbook is designed for an upper-level undergraduate course in coastal geomorphology, but it would also be appropriate for an entry-level graduate course. The approach adopted by the authors is process oriented rather than morphology based, privileging morphodynamics over landform description. The primary objective is to provide students with a fundamental appreciation of how erosion, transportation and deposition of sediments in the coastal zone act in concert to produce the vast variety of features found along marine, estuarine and lacustrine shorelines around the world. Nevertheless, the discussion necessarily includes the broader context within which these myriad coastal features evolve, including the tectonic and geologic controls that influence the erodibility of coasts, the isostatic, eustatic and meteorologic factors responsible for regional-scale, long-term trends in sea-surface fluctuations, and the biologic and human influences that affect coastal systems. The intent is to provide a comprehensive and authoritative treatise that includes sufficient information for the reader to be able to understand the broad dynamics of coastal systems, that will then enable a more detailed foray into the primary sources found in refereed journal articles and advanced texts on topics such as wave dynamics, nearshore circulation, tides, rip currents and sediment transport mechanics in water and air.

It is assumed that students reading this textbook will have backgrounds in earth sciences, physical geography, or coastal/ocean engineering, although it is written at a level that accommodates those from allied disciplines (e.g., marine biology, environmental science, geography, geology). Ideally, students will have already completed an introductory course in geomorphology or oceanography, and will also have some comfort with mathematical relations and basic physics. However, the text is written in a style that focuses on the meaning of the terms in the equations so as to facilitate a basic understanding of the concepts rather than the mathematical derivation. This is particularly true for Chapter 5 on wave dynamics. The course instructor can further explain how the equations are used in applied ways through laboratory exercises and homework assignments, as appropriate. The hope is that the book will serve as a useful reference beyond the requirements of a single course, and that coastal managers and other scientists and social scientists interested in the coastal zone will also find it useful.

The origin of the book stems from a fourth-year course taught by Dr Robin Davidson-Arnott at the University of Guelph during a career spanning over 30 years. The first edition was released in 2010, and it was adopted widely for many university courses across the world. The current (second) edition of the text is substantially updated and re-written, reflecting the input from Dr Bernard Bauer and Dr Chris Houser, who are close colleagues of Professor Davidson-Arnott. Each of the co-authors has made extensive contributions to the scientific literature on coastal geomorphology and, even though their research interests overlap considerably, they bring special expertise and different perspectives to the second edition of this book. The valuable comments from six anonymous reviewers of the proposal to revise the book has also been useful in informing the overall tone and philosophy of the text, helping to identify weaknesses and gaps in the first edition, and pointing to useful resources that have enhanced the effectiveness of our treatment of the topic.

Nevertheless, the content of the book, by necessity, reflects our personal experiences and biases. For example, each of us is a field-oriented scientist believing that conceptual theories and numerical models are simplifications of reality that should always be tested against what can be measured, observed or experienced in the real world. Such external realities reveal the truth,

unlike a computer code that mimics our limited understanding of the truth. In this context, it is important to note that our experiences, although extensive and geographically varied, are hardly globally representative. Many of our research projects have been carried out in Canada (Atlantic, Pacific and Great Lakes coasts), the United States of America (Atlantic, Pacific and Gulf coasts), western Europe (Ireland, England, Denmark), Australia (New South Wales), New Zealand (South Island), South America (Brazil) and the Caribbean. Our professional and leisurely travels are more extensive, but there are still coastal systems, such as high-latitude ice-dominated coasts, estuaries, deltas, muddy coasts and fjords, with which we have limited experience and expertise. The reader is encouraged to seek out coverage of these coastal topics in texts and scholarly manuscripts that focus on them.

The book comprises 13 individual chapters that can be read in any order without much loss of comprehension. However, it will be useful to understand that the chapters are loosely organised into three major sections. The first section (**Part I**) provides introductory material that positions coastal geomorphology among the sciences and introduces basic ideas and terminology. Chapter 1 makes the essential point that the history of human civilisation has been intricately linked to coasts, and that the majority of humans live close to the coast. Thus, there are compelling reasons to understand coastal processes, not the least of which is the future fate of the majority of global mega-cities under the prospect of sea level rise driven by human-induced climate change. Chapter 2 defines the scope of coastal geomorphology for the purposes of this textbook, and introduces essential terminology used by coastal geomorphologists. In this second edition of the book, the discussion of coastal classification has been expanded considerably and sub-sections added on coastal mapping and modelling.

The second section (**Part II**) has five chapters dealing with coastal processes that are most prevalent in oceans but also lakes and bays. Chapter 3 discusses changes in sea level over a range of time scales, but most importantly due to the impacts of climate change since the last glaciation. Tides and storm surges are also covered in this chapter with respect to their dynamic origins as well as the implications for coastal hazard management. Chapters 4 and 5 provide a comprehensive introduction to waves, and these chapters have been completely rewritten in this second edition of the text. Chapter 4 deals with wave description and wave measurement, and then discusses the factors that control their formation. Analytical techniques such as spectral analysis are introduced and related to the statistical properties of wave fields, and the concept of a wave climate is discussed. Chapter 5 is focused on the dynamic aspects of wave motion, beginning with a summary of linear wave theory and many derived quantities such as wave energy and wave power. Higher order wave theories are touched upon briefly so as to make students aware of the limitations of linear wave theory and to show how more complex theories are needed to describe how waves transform as they propagate into shallow water. The chapter ends with a treatment of the integral properties of waves (e.g., radiation stress) and a discussion of the importance of wave groups and infragravity energy in the nearshore circulation. Chapter 6, on surf zone circulation, builds on Chapter 5 by showing how rip currents, undertow, and longshore currents are the necessary manifestation of mass and momentum conservation in the nearshore (i.e., driven by radiation stress gradients due to shoaling and breaking waves). The discussion of rip currents has been updated with an extensive treatment of the hazards they pose. Finally, Chapter 7 draws on the water motion described in the previous three chapters to describe the processes of sediment transport, both cross-shore and alongshore. The basics mechanics of sediment transport are discussed and several models of on–offshore and alongshore transport are summarised, demonstrating how beaches evolve and are maintained in quasi-equilibrium depending on the wave climate. Updated discussions of offshore transport in rip channels and transport modelling are new to this second edition.

The third section of the book (**Part III**) describes a range of different coastal systems.

Sand beaches, barred profiles and nearshore morphodynamics are discussed at length in Chapter 8. New sections on oil spills, satellite monitoring of morphologic change, and morphology-process feedbacks are included in this chapter. Chapter 9 on aeolian processes and forms was completely re-written and re-organised. The basic dune forms are introduced, stressing the unique relationship between foredune evolution and vegetation succession along sandy shorelines. The mechanics of aeolian sediment transport are discussed as a complement to the concepts covered in Chapter 7 related to waves and currents. Beach–dune interaction is treated at the end of the chapter in an attempt to demonstrate the intricate linkages between nearshore processes driven by waves and currents and aeolian processes on the subaerial beach. This leads nicely to a discussion of barrier systems in Chapter 10, which covers the evolution and structure of spits, bay mouth bars, and barrier islands. New sections on barrier island response to sea level rise, on eco-geomorphic feedbacks on barrier systems, barrier island recovery following hurricanes, and anthropogenic influences are included in this second edition. Biologically dependent coasts are treated in Chapter 11 (saltmarshes and mangroves) and Chapter 12 (coral reefs). Both of these have been updated, and there is increased consideration of the response of these systems to sea level rise. Recent understanding of the structure, evolution and sensitivity of coral reefs to storms, ocean warming, acidification and over-fishing are discussed. The book concludes in Chapter 13 with a discussion of processes and forms of cliffed systems, beginning with an examination of the controls on erosion of soft rock coasts and then extending this to hard rock coasts.

As mentioned earlier, there are gaps in coverage in this book related to particular coastal systems and there is no chapter devoted to coastal management. A more comprehensive treatment would have expanded the book considerably and increased the production and purchase costs, as well as taking us outside the domain of our collective expertise. Nevertheless, we felt compelled to add several special interest boxes throughout the book on topics related to coastal management, and most of these are new. Intense media coverage of the impact of major hurricanes and the increasing frequency and intensity of coastal storms recently served to focus public attention on the vulnerability of coastal infrastructure to a range of hazards. There is growing acknowledgement among coastal scientists that the threat of sea level rise and climate change is immediate and substantial. The coastline will respond, but it is not evident that human society will act quickly enough to mitigate the adverse impacts or be able to adapt to the anticipated rapid rates of change.

A variety of supplementary material is available online to complement the material presented in the book. This includes colour versions of all photographs and diagrams and several videos. Virtual field trips providing examples of the coastal environments described in Part III are also available. Finally, data from field experiments that can be used in laboratory exercises for students are included in separate spreadsheets.

Acknowledgements

When I was asked by Cambridge if I would like to produce a second edition of this book I realised immediately that, while I was still active in research, I would need help from people who are still teaching the subject, in addition to doing research. I would therefore like to begin by thanking my colleagues and co-authors Bernie Bauer and Chris Houser for agreeing so readily to join me in this task. Their participation has not only helped to update the text, but it has brought new perspectives and increased the breadth and rigour of the material covered. I am also grateful to my colleagues in what is now the Department of Geography, Environment and Geomatics at the University of Guelph for continuing to provide me with support for ongoing research and for the production of the book. In particular I am grateful that the department has allowed me continued access to the services of our Cartographer Marie Puddister who has once again compiled all the figures for the book, including colour versions for the web, and created many new figures. I have continued to benefit from interacting with colleagues in the field and at conferences and I would like to acknowledge especially Patrick Hesp, Ian Walker, Jeff Ollerhead, and Irene Delgado-Fernandez who have contributed so much to our field experiments in Prince Edward Island. Finally, I would like to thank my family for all the good times we have, and my wife Sharon for sharing my life and for continuing to put up with my ongoing work in retirement.

RD-A

First and foremost I would like to thank Robin Davidson-Arnott for giving me the opportunity to participate in the writing of the second edition of his textbook — I was honoured by the invitation because the first edition was already well known around the world, but more so because I respect Robin immensely. He and I have collaborated fruitfully on a range of research projects spanning 30 years, and I continue to be impressed by his broad knowledge, keen insights, sharp intellect, Puritan work ethic, positive attitude, and overall good nature. He is gentlemanly in a way that is far too uncommon these days, and I have yet to meet anyone that had a disparaging word to say about Robin. We share many common and highly valued colleagues (including Patrick, Ian, Jeff and Irene, as noted above), to which I would also wish to acknowledge Norb Psuty, Karl Nordstrom, Paul Gares, Bill Nickling, Cheryl McKenna Neuman, Steve Namikas and Rob Brander (among others). My interest in coastal processes was stimulated by excellent mentoring and research opportunities provided by Brian Greenwood, which coincided with the initiation of a life-long collaboration with my close colleague and friend Doug Sherman (thanks, dude!). Along the way, we prematurely lost Bill Carter and Jim Allen, both of whom were enthusiastic and unique coastal characters with much more to offer. I gratefully acknowledge Mike Hilton for hosting me as a William Evans Visiting Fellow at the University of Otago during my last sabbatical, which allowed me time to focus on the book and to witness some of the world's most dynamic process geomorphology in action. It is no surprise that the New Zealand coastline figures prominently in the photos of the revised text. The University of British Columbia Okanagan continues to pay my salary, and I can't believe how lucky we are as university professors during tumultuous times of global political, economic, and religious unrest. My bedrock, however, has always been my wife, Bea, and my family.

BOB

I was first introduced to this book as an undergraduate student in the Department of Geography at the University of Guelph in 1996. Robin used an early draft of this text in his Coastal Geomorphology class and it sparked my

interest in coastal systems. While I did foray into the desert for several years with Bill Nickling, I returned to the coast with Brian Greenwood, and I am grateful to both for providing me with a strong background in process geomorphology. This foundation was strengthened through collaborations with Doug Sherman, Rob Brander, Cheryl Hapke, Christian Brannstrom, Sarah Trimble, Brad Weymer and Phil Wernette. None of this would have been possible without my family and their support for my time in the field.

CH

We would all like to thank Matt Lloyd, Earth Sciences Editor, for initiating the project and guiding us through it as well as the many other helpful staff at CUP who have looked after us along the way. Special thanks to Marion Moffatt who did a wonderful job of editing the manuscript. We are also all grateful to Marie Puddister for her outstanding job on the graphics. Thanks also to all of our colleagues who have let us make use of their photographs and research.