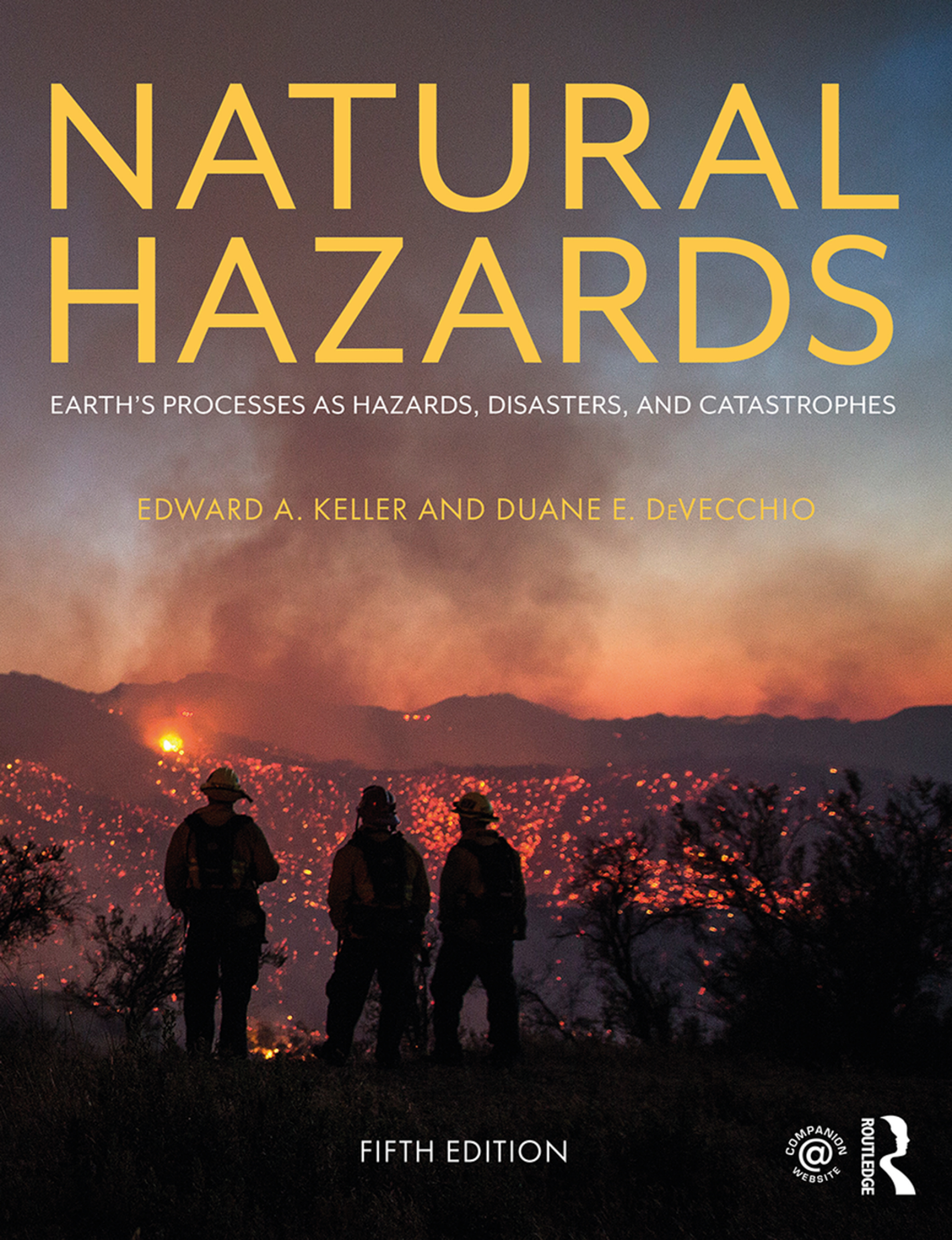
NATURAL HAZARDS

EARTH'S PROCESSES AS HAZARDS, DISASTERS, AND CATASTROPHES

EDWARD A. KELLER AND DUANE E. DeVECCHIO



FIFTH EDITION

COMPANION @ WEBSITE

ROUTLEDGE

NATURAL HAZARDS

The new revised fifth edition of *Natural Hazards* remains the go-to introductory-level survey intended for university and college courses that are concerned with earth processes that have direct, and often sudden and violent, impacts on human society. The text integrates principles of geology, hydrology, meteorology, climatology, oceanography, soil science, ecology, and solar system astronomy.

The textbook explains the earth processes that drive hazardous events in an understandable way, illustrates how these processes interact with our civilization, and describes how we can better adjust to their effects. Written by leading scholars in the area, the new edition of this book takes advantage of the greatly expanding amount of information regarding natural hazards, disasters, and catastrophes. The text is designed for learning, with chapters broken into small consumable chunks of content for students. Each chapter opens with a list of learning objectives and ends with revision as well as high-level critical thinking questions. A Concepts in Review feature provides an innovative end-of-chapter section that breaks down the chapter content by parts: reviewing the learning objectives, summary points, important visuals, and key terms. New case studies of hazardous events have been integrated into the text, and students are invited to actively apply their understanding of the five fundamental concepts that serve as a conceptual framework for the text. Figures, illustrations, and photos have been updated throughout.

The book is designed for a course in natural hazards for nonscience majors, and a primary goal of the text is to assist instructors in guiding students who may have little background in science to understand physical earth processes as natural hazards and their consequences to society.

Edward A. Keller is a professor in the Environmental Studies and Earth Sciences Departments at University of California at Santa Barbara, USA.

Duane E. DeVecchio is a research professor in the School of Earth and Space Exploration (SESE) at Arizona State University, USA.



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EDWARD A. KELLER AND
DUANE E. DeVECCHIO

WITH ASSISTANCE FROM
ROBERT H. BLODGETT

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

Fifth edition published 2019
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

and by Routledge
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

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First edition published by Pearson Education, Inc. 2006
Fourth edition published by Pearson Education, Inc. 2015

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Names: Keller, Edward A., 1942– author. |
DeVecchio, Duane E. (Duane Edward), 1970– author.
Title: Natural hazards: earth's processes as hazards, disasters, and catastrophes / Edward A. Keller and Duane E. DeVecchio.
Description: Fifth edition. | New York: Routledge, 2019. |
"Fourth edition published by Pearson Education, Inc. 2015"—
T.p. verso. | Includes bibliographical references and index.
Identifiers: LCCN 2018028016| ISBN 9781138058415
(hardback: alk. paper) | ISBN 9781138057227 (paperback: alk. paper) |
ISBN 9781315164298 (eBook)
Subjects: LCSH: Natural disasters.
Classification: LCC GB5014 .K45 2019 | DDC 551—dc23
LC record available at https://lccn.loc.gov/2018028016

ISBN: 978-1-138-05841-5 (hbk)
ISBN: 978-1-138-05722-7 (pbk)
ISBN: 978-1-315-16429-8 (ebk)

Typeset in Janson Text
by codeMantra

Visit the companion website: www.routledgetextbooks.com/textbooks/9781138057227/

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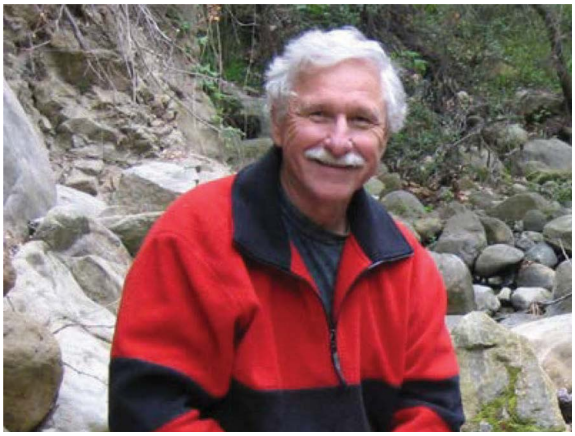
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About the Authors



EDWARD A. KELLER

Ed Keller is a professor, researcher, writer, and most importantly, mentor and teacher to undergraduate and graduate students. Ed's students are currently working on earthquake hazards, how waves of sediment move through a river system following a disturbance, and geologic controls on habitat to endangered southern steel-head trout.

Ed was born and raised in California. He received Bachelor's degrees in geology and mathematics from California State University at Fresno and a Master's degree in geology from the University of California at Davis. It was while pursuing his Ph.D. in geology from Purdue University in 1973 that Ed wrote the first edition of *Environmental Geology*, a text that became the foundation of an environmental geology curriculum in many colleges and universities. He joined the faculty of the University of California at Santa Barbara in 1976 and has been there ever since, serving multiple times as chair of both the Environmental Studies and Hydrologic Science programs. In that time he has been an author on more than 100 articles, including seminal works on fluvial processes and tectonic geomorphology. Ed's academic honors include the Don J. Easterbrook Distinguished Scientist Award, Geological Society of America (2004); the Quatercentenary Fellowship from Cambridge University, England (2000); two Outstanding Alumnus Awards from Purdue University (1994, 1996); a Distinguished Alumnus Award from California State University at Fresno (1998); and the Outstanding Outreach Award from the Southern California Earthquake Center (1999).

Ed and his wife Valery, who brings clarity to his writing, love walks on the beach at sunset and when the night herons guard moonlight sand at Arroyo Burro Beach in Santa Barbara.



DUANE E. DEVECCHIO

Duane DeVecchio is a research professor in the School of Earth and Space Exploration (SESE) at Arizona State University, where he is deeply engaged in undergraduate education and teaches a broad range of courses to students completing degrees in both the geological sciences and environmental studies. Outside of the classroom, Dr. DeVecchio serves on both the SESE undergraduate education committee and the curriculum redesign committee, where he collaborates with coworkers to develop student learning strategies and curriculum designed to develop student critical thinking skills and scientific literacy, which are particularly important today when cable television and the Internet offer accessibility to vast amounts of information, yet the validity of this information is often questionable or misleading.

Duane grew up in California where he completed his Bachelor's degree at San Francisco State University before moving on to Idaho State University where he completed a Master's degree. In 2009 he graduated with his Ph.D. from University of California Santa Barbara where he honed his teaching skills while conducting a wide range of research in the geological sciences. Dr. DeVecchio has a broad field-based background in the geological sciences, and likes to share stories about his many months living alone in mobile trailers in the mountains and deserts of the western United States. For his Master's degree and post-Master's research he conducted structural and stratigraphic analyses as well as numerical dating of volcanic and volcaniclastic rocks in southeastern Idaho and the central Mojave Desert of California, which record the Miocene depositional and extensional histories of these regions. His dissertation and current research focus on the timing and rates of change of Earth's surface due to depositional and erosional processes that result from climate change and tectonics. When he is not teaching or conducting research, he's hang gliding, but he also enjoys rock climbing, whitewater rafting, snow boarding, and camping.

Preface

Natural Hazards: Earth Processes as Hazards, Disasters, and Catastrophes, Fifth Edition, is an introductory-level survey intended for university and college courses that are concerned with earth processes that have direct, and often sudden and violent, impacts on human society. The text integrates principles of geology, hydrology, meteorology, climatology, oceanography, soil science, ecology, and solar system astronomy. The book is designed for a course in natural hazards for nonscience majors, and a primary goal of the text is to assist instructors in guiding students who may have little background in science to understand physical earth processes as natural hazards and their consequences to society.

In revising the fifth edition of this book we take advantage of the greatly expanding amount of information regarding natural hazards, disasters, and catastrophes. Since the fourth edition was published, many natural disasters and catastrophes have occurred. Becoming the wettest tropical cyclone in U.S. recorded history, Hurricane Harvey in 2017 produced peak accumulations of rainfall of more than 1.5 m (~60 in.) over a three-day period causing catastrophic flooding in the Houston metropolitan area; earthquakes killed more than 8,000 people in Nepal in 2015, and were responsible for widespread destruction in Mexico in 2017; wildfires in northern and southern California in 2017 destroyed more than 7,000 buildings and killed 46 people; and the deadliest U.S. landslide on record killed 43 people in Washington state in 2014. Most of these disasters have a common denominator—they were not unexpected and the effects of these catastrophes could have been minimized had the population been better prepared and the warnings from the scientific community been heeded. In other words, they were largely, in terms of lives lost and property damaged, disasters caused by humans.

On a global scale, climate change is causing glaciers, ice caps, and permafrost to melt; the atmosphere and oceans to warm; and sea levels to rise more rapidly than originally forecast. These changes are caused in part by human activities, primarily the burning of fossil fuels, which releases vast quantities of carbon dioxide and other gases into the atmosphere each day. The interaction between humans and earth processes has never been clearer, nor has the need for understanding these processes as hazards for our economy and society ever been greater. This edition of *Natural Hazards* seeks to explain the earth processes that drive hazardous events in an understandable way, illustrate how these processes interact with our civilization, and describe how we can better adjust to their effects.

A central thesis to this text is that we must first understand that earth processes are not, in and of themselves, hazards. Earthquakes, floods, volcanic eruptions, wildfires, and other processes have occurred for millennia, indifferent to the presence of people. Natural processes become hazards when they impact humanity. Ironically, it is human behavior that often causes the interactions with these processes to become disasters or, worse, catastrophes. Most important is the unprecedented increase in human population in the past 50 years linked to poor land-use decisions.

In addition to satisfying a natural curiosity about hazardous events, there are additional benefits to studying natural hazards. An informed citizenry is one of our best guarantees of a prosperous future. Armed with insights into linkages between people and the geologic environment, we will ask better questions and make

the 5 fundamental concepts

1

Science helps us predict hazards.

Natural hazards, such as earthquakes, volcanic eruptions, landslides, and floods, are natural processes that can be identified and studied using the scientific method. Most hazardous events and processes can be monitored and mapped, and their future activity predicted, on the basis of frequency of past events, patterns in their occurrence, and types of precursor events.

2

Knowing hazard risks can help people make decisions.

Hazardous processes are amenable to *risk analysis*, which estimates the probability that an event will occur and the consequences resulting from that event. For example, if we were to estimate that in any given year, Los Angeles has a 5 percent chance of a moderate earthquake, and if we know the consequence of that earthquake in terms of loss of life and damage, then we can calculate the potential risk to society.

better choices. On a local level we will be better prepared to make decisions concerning where we live and how best to invest our time and resources. On a national and global level we will be better able to advise our leaders on important issues related to natural hazards that impact our lives.

Major New Material in the Fifth Edition

The fifth edition benefited greatly from feedback from instructors using the previous edition, and many of the changes reflect their thoughtful reviews. New material for the fifth edition includes the following:

- **Active, Modular Learning Path.** The fifth edition of *Natural Hazards* is designed for learning with each chapter broken into smaller, more consumable, chunks of content for students. Each chapter opens with a list of learning objectives and students can check their mastery of these objectives with new **Check Your Understanding** questions at the end of each section. Each chapter concludes with a new **Concepts in Review** section: an innovative end-of-chapter section that breaks down the chapter content by section—reviewing the learning objectives, summary points, important visuals, and key terms. All chapters end with high-level critical thinking questions.
- **Applying the Fundamental Concepts.** Every chapter begins with a captivating hazard story that applies the five fundamental concepts that serve as a conceptual framework for the text. We then close each chapter by recapping this hazard story and, through assessment, invite the students to actively apply their understanding of the five fundamental concepts.
- Current hazard coverage on the Tohoku, Japan earthquake and tsunami in 2011, Hurricane Sandy in New Jersey and New York City in 2012, the tornado in Moore, Oklahoma in 2013, historic flooding in Houston in 2017, and the 2017 fire season in California.
- New in-chapter **case studies** and **chapter openers** that highlight hazardous events have been integrated into the text, providing coverage of the most recent natural disasters on earth.
- Updated art program showcases new figures, illustrations, and photos throughout. Each image has been reviewed for accuracy and relevance, focusing on its educational impact.

Distinguishing Features of the Fifth Edition

We have incorporated a number of features designed to support the student and instructor.

A BALANCED APPROACH

Although the interest of many readers will naturally focus on natural hazards that threaten their community, state, or province, the globalization of our economy, information access, and human effects on our planet require a broader, more balanced approach to the study

3

Linkages exist between natural hazards.

Hazardous processes are linked in many ways. For example, earthquakes can produce landslides and giant sea waves called tsunamis, and hurricanes often cause flooding and coastal erosion.

4

Humans can turn disastrous events into catastrophes.

The magnitude, or size, of a hazardous event as well as its frequency, or how often it occurs, may be influenced by human activity. As a result of increasing human population and poor land-use practices, events that used to cause disasters are now often causing catastrophes.

5

Consequences of hazards can be minimized.

Minimizing the potential adverse consequences and effects of natural hazards requires an integrated approach that includes scientific understanding, land-use planning and regulation, engineering, and proactive disaster preparedness.

of natural hazards. A major earthquake in Taiwan affects trade in the ports of Seattle and Vancouver; the economy of Silicon Valley in California affects the price of computer memory in Valdosta, Georgia, and Halifax, Nova Scotia. Because of these relationships, we provide examples of hazards from throughout the United States as well as throughout the world.

This book discusses each hazardous process as both a natural occurrence and a human hazard. For example, the discussion of earthquakes balances the description of their characteristics, causes, global distribution, estimated frequency, and effects with a description of engineering and nonstructural approaches to reduce their effects on humans, including actions that communities and individuals can take.

The five concepts introduced in Chapter 1 and revisited in every chapter are designed to provide a memorable, transportable, and conceptual framework of understanding that students can carry with them throughout their lives to make informed choices about their interaction with and effect upon earth processes.

CASE STUDIES: SURVIVOR STORIES, PROFESSIONAL PROFILES, AND CLOSER LOOKS

Many of the chapters contain personal stories of someone who has experienced the effects of a hazardous event, such as a flood, earthquake, or wildfire, a profile of a scientist or other professional who has worked with a particular hazard, and Closer Look boxes that use life events and data to enhance the understanding and comprehension of not only the hazard but also the mitigation that coincides with the hazard. Most of us in our lifetimes will experience (directly or indirectly) a flood, wildfire, volcanic eruption, tsunami, or major hurricane, and we are naturally curious as to what we will see, hear, and feel. For example, a scientific description of wildfire does not convey the fear and anxiety when a fire is rushing toward your home. Likewise, the stream gauge records for the Rio Grande River do not give us the sense of excitement and fear felt by Jason Lange and his friends when their spring-break canoe trip in West Texas nearly turned to tragedy (see Case Study 6.1: Survivor Story). To fully appreciate natural hazards we need both scientific knowledge and human experience. As you read the survivor stories, ask yourself what you would do in a similar situation, especially once you more fully understand the hazard. Knowledge from reading this book could save your life someday, as it did for Tilly Smith and her family on the beach in Phuket, Thailand, during the Indian Ocean tsunami (see Case Study 4.2: Indonesian Tsunami).

People study and work with natural hazards for many reasons—scientific curiosity, monetary reward, excitement, or the desire to help others deal with events that threaten our lives and property. As you read the professional profiles, think about these people's motivation, the type of work that they do, and how that work contributes to increasing human knowledge or to saving people's lives and property. For example, for many years Bob Rasely worked as a geologist with the U.S. Natural Resources Conservation Service studying what happens to hillslopes after wildfires in Utah (see Case Study 7.5: Professional Profile). For Bob, geology had long been both a vocation and an avocation. He maintains an intellectual curiosity as to how Earth works and a practical goal of predicting the likelihood and location of debris flows following a fire. Working with other state and federal scientists, Bob develops plans for hillslope recovery and helps communities downslope from burned land establish warning systems to protect lives and property. Nearly all the survivor stories and professional profiles are based on interviews conducted exclusively for *Natural Hazards* by Kathleen Wong, a science writer from Oakland, California, and Chris Wilson, a former journalism student at the University of Virginia.

For the Instructor

The Instructor Resource Center provides a collection of resources to help teachers make efficient and effective use of their time. All digital resources can be found in one well-organized, easy to access place. The IRC (download only) includes:

- Pre-authored Lecture Outline PowerPoint presentations, which outline the concepts of each chapter with embedded art and can be customized to fit instructors' lecture requirements
- The test bank includes over 1,000 multiple-choice, true/false, and short-answer test questions on the science of natural hazards and their effects on the world and humankind. Questions are correlated against chapter-specific learning outcomes and Bloom's Taxonomy to help teachers better map the assessments against both broad and specific teaching and learning objectives. TestGen software for both PC and Mac.

The Instructor Resource content is available online at www.routledgetextbooks.com/textbooks/ 9781138057227/#instructors.

For the Student

This title has recently been acquired by Taylor & Francis. Due to rights reasons, any multimedia resources will not be available from Taylor & Francis. Mastering Geology incorporating Hazard City will still be available for purchase from Pearson.

Acknowledgments

Many individuals, companies, and agencies have helped make this book a success. In particular, we are indebted to the U.S. Geological Survey and the National Oceanic and Atmospheric Administration for their excellent natural hazard programs and publications.

To authors of papers cited in this book, we offer our thanks and appreciation for their contributions. Without their work, this book could not have been written. We must also thank the thoughtful scholars who dedicated valuable time reviewing chapters of this book. The following reviewers' comments helped us significantly improve the fifth edition:

Stephen P. Altaner, *University of Illinois*
Allison Beauregard, *Northwest Florida State College*
Hassan Boroon, *California State University at Los Angeles*
Patrick Burkhart, *Slippery Rock University*
Andrew Curtis, *University of Southern California*
Tim Dolney, *Penn State University-Altoona College*
Sean Fitzgerald, *University of Massachusetts*
Jennifer Haase, *Purdue University*
Michael Hamburger, *Indiana University*
Brian A. Hampton, *Michigan State University*
Brenda Hanke, *Northern Kentucky University*
James Hibbard, *North Carolina State University*
Jean Hoff, *St Cloud State University*
Richard W. Hurst, *California State University at Los Angeles*
Bridget James, *San Francisco State University*
Blair Larsen, *Utah State University*
Todd Leif, *Cloud County Community College*
Susan McGeary, *University of Delaware*
Debra Metz, *Delaware County Community College*
Stephen Nelson, *Tulane University*
William Newman, *University of California at Los Angeles*
Scott Nowicki, *University of Nevada at Las Vegas*
Beth Rinard, *Tarleton State University*
Sarah de la Rue, *Purdue University at Calumet*
Isabelle Sacramento Grilo, *San Diego State University*
Lisa Skinner, *Northern Arizona University*
Jennifer Snyder, *Delaware County Community College*
Christine Stidham, *Stony Brook University*
Michael Wacker, *Florida International University*
Robin Whatley, *Columbia College Chicago*

Thanks also to the following reviewers who helped us put together the first, second, third and fourth editions:

Bob Abrams, *San Francisco State University*
David Best, *Northern Arizona University*
Beth Nichols Boyd, *Yavapai College*
Katherine V. Cashman, *University of Oregon*
Jennifer Cole, *Northeastern University*
Bob Davies, *San Francisco State University*
John Hermance, *Brown University*
Jean M. Johnson, *Shorter College*
Jamie Kellogg, *University of California at Santa Barbara*
Stephen Kesler, *University of Michigan at Ann Arbor*
Guy King, *California State University at Chico*
Timothy Kusky, *Saint Louis University*
Gabi Lakse, *University of California at San Diego*
Thorne Lay, *University of California at Santa Cruz*
William P. Leeman, *Rice University*
Alan Lester, *University of Colorado at Boulder*
Lawrence McGlinn, *Rensselaer University*
Rob Mellors, *San Diego State University*
Richard Minnich, *University of California at Riverside*
Stephen A. Nelson, *Tulane University*
Mark Ouimette, *Hardin Simmons University*
Gigi Richard, *Mesa State College*
Jennifer Rivers, *Northeastern University*
Tim Sickbert, *Illinois State University*
Don Steeples, *University of Kansas*
Paul Todhunter, *University of North Dakota*
Robert Varga, *College of Wooster*
Tatiana Vislova, *University of St. Thomas*
John Wyckoff, *University of Colorado at Denver*

Special thanks to Kathleen Wong and Chris Wilson for locating and interviewing many of the natural hazard professionals and survivors. All of us are especially grateful to these people who told us their stories. Thanks also to Jim Kennett for reviewing the case study on the Younger Dryas Boundary event; to Joel Michaelsen for reviewing the chapters on meteorology, hurricanes, and extratropical cyclones; and to Rob Thieler for his review of the case study on Folly Island. Ed would like to thank Tanya Atwater, William Wise, and Frank Spera for their assistance in preparing the content on plate tectonics, rocks and minerals, and impacts, respectively. Thanks to Kenji Satake, David Cramer, Gordon Wells, Theresa Carpenter, and David Rogers for providing photographs and graphics for use in the fourth edition.

Special thanks are extended to Professor Bob Blodgett who as coauthor worked very hard on the first two editions. Much of the fifth edition reflects his excellent contributions.

We are particularly indebted to our publisher and editors at Taylor & Francis. First and foremost we are grateful to Andrew Mould and Egle Zigaite for their outstanding coordination work, Veronica Jurgena for her great developmental editing and many suggestions,

and Donna Mulder and Bill Norrington for editing. Our appreciation is extended to Gina Cheselka and Janice Stangel in production. We would also like to thank photo researcher Marta Johnson, Director of Development Jennifer Hart, Andrew Troutt and his team at Precision Graphics, Rebecca Dunn at CodeMantra, and Editorial Assistant Sarah Shefveland for all of their hard work.

Last, but certainly not least, Ed would like to thank his wife Valery for her encouragement and support.

Duane would like to offer special thanks to his family and friends, and to all of the students who continue to ask good questions, reinforcing and reminding him of the importance of science today.

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