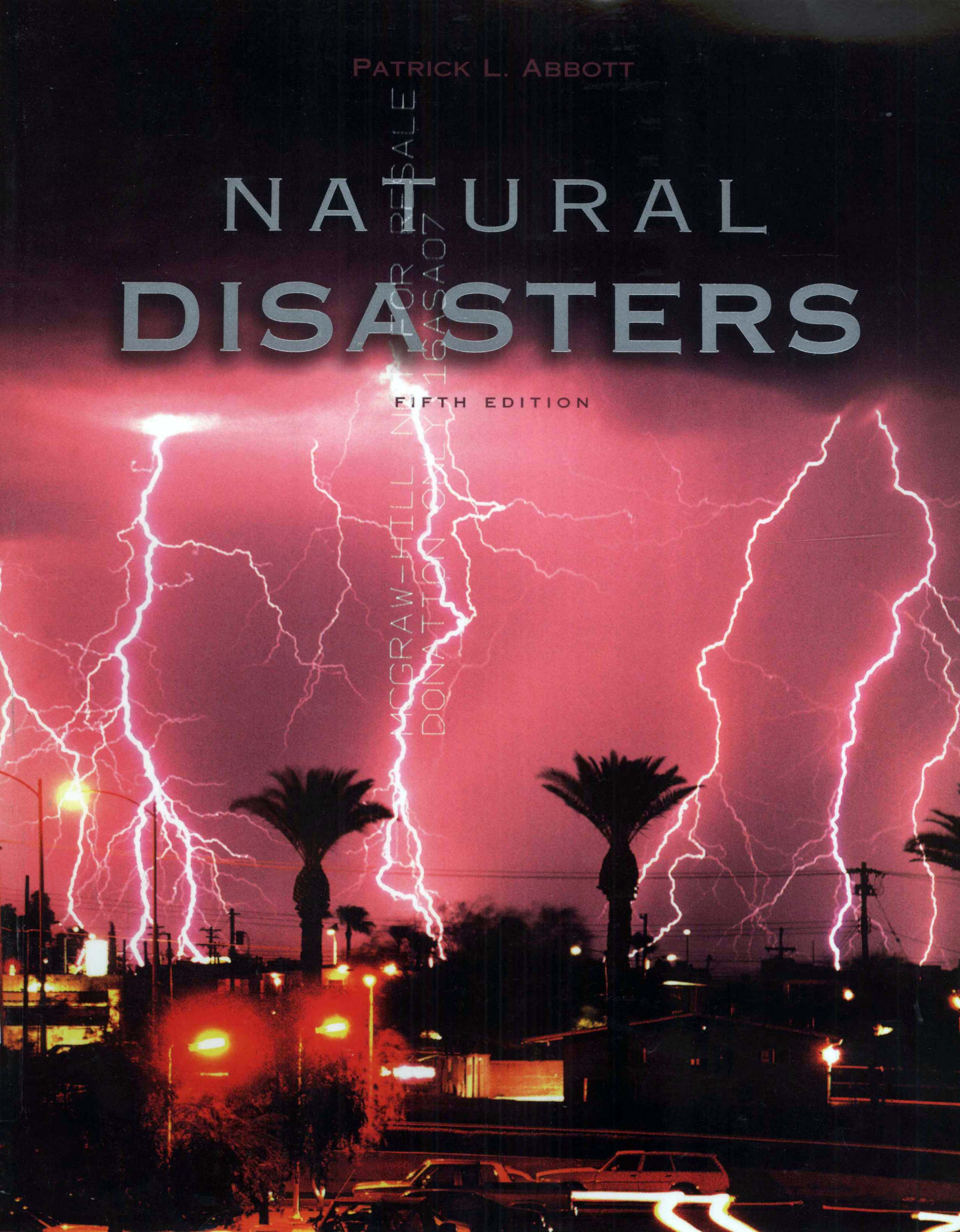
PATRICK L. ABBOTT

NATURAL DISASTERS

FIFTH EDITION



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TO MY PARENTS

Clement L. and Constance V. Abbott
for their lifetime of interest and support
of my activities

• • •

PATRICK L. ABBOTT• • •

Patrick Abbott is a native San Diegan on the faculty of San Diego State University. Pat earned his MA and PhD degrees in geology at the University of Texas at Austin. He benefited greatly from the depth and breadth of the faculty in the Department of Geological Sciences at Austin; this was extended by their requirement to take five additional graduate courses outside the department. Developing interests in many topics helped lead to writing this textbook.

Pat's research has concentrated on the Mesozoic and Cenozoic sedimentary rocks of the southwestern United States and northwestern Mexico. Studies have focused on reading the history stored within the rocks—depositional environments, provenance, paleoclimate, palinspastic reconstructions, and high-energy processes.

Pat has long been involved in presenting earth knowledge to the public, primarily through local TV news. At present, he has embarked on producing videos for TV broadcast in a series called *Written in Stone.* The first video, *The Rise and Fall of San Diego,* won 2002 awards in the Videographers (Award of Distinction) and AXIEM (Silver Axiem) competitions. The second video, *Earthquake Country—Los Angeles,* was completed in 2004 and is now playing on some California TV stations. To add a little spice to life, Pat played the role of The Professor on season one of the "reality" TV series *The Real Gilligan's Island,* which aired on TBS in late 2004.

PREFACE

Why the Book Was Written

In the early 1970s, Bill Ganus and I developed an environmental geology course at San Diego State University. The growing awareness of the environment and the availability of good textbooks made it natural to offer a general education course looking at geological hazards, resource utilization and disposal, and intelligent planning in concert with the environment. The course had moderately successful enrollments, chugging along at 25 to 35 students per semester for over a decade.

In 1987, Tom Rockwell and I were discussing the environmental geology course and speculating on why it never attracted large enrollments. We agreed that the natural disasters portions of the course were the most popular. So, I formally changed the name of the course to "Natural Disasters" but did not change the course description or textbook, or advertise the change in any way. Yet almost instantly, students reading through the fine print of semester course offerings saw the "Natural Disasters" listing and enrollments skyrocketed. Now we offer multiple sections filling more than 5,000 classroom seats per academic year and still do not satisfy demand.

San Diego State University students do not have to take Natural Disasters. They can select from over 30 courses among 10 departments with offerings such as Biology of Sex, Evolution, Origin of Life, The Oceans, Dinosaurs, and Confronting AIDS. But more students opt for Natural Disasters than any other course. If your department could benefit from higher enrollments of nonmajor students, I strongly recommend offering a Natural Disasters course. Earthquakes, hurricanes, tornadoes, and other high-energy processes of our active Earth affect children's lives. As students, they want to understand why these natural disasters happen. The students' high level of interest can be channeled by the instructor into some significant understanding about how the Earth works.

About the Book

This book focuses on natural disasters: how the normal processes of the Earth concentrate their energies and deal heavy blows to humans and their structures. It largely ignores the numerous case histories describing human actions and resultant environmental responses; these topics are left to the excellent textbooks on environmental geology. Nor does this book address resource extraction, utilization, and disposal; these subjects are covered by fine textbooks on earth resources, minerals, energy, soils, and water. This book is concerned with how the natural world operates and, in so doing, kills and maims humans and destroys their works.

Throughout the book, certain themes are maintained:

- Energy sources underlying disasters
- Plate tectonics and climate change
- Earth processes operating in rock, water, and atmosphere
- Significance of geologic time
- Complexities of multiple variables operating simultaneously
- Detailed and readable case histories

The text aims to explain important principles about the Earth and then develop further understanding through numerous case histories. I hope that students will actually enjoy reading most of this book.

The primary organization of the book is based on an energy theme. Chapter 1 leads off with data describing natural disasters and the human population. Chapter 2 examines the energy sources underlying disasters: (1) Earth's internal energy from

its formative impacts and continuing decay of radioactive elements; (2) gravity; (3) external energy from the Sun; and (4) impacts with asteroids and comets.

Disasters fueled by Earth's internal energy are addressed in chapters 3 through 8 and are organized on a plate-tectonics theme. Chapter 3 provides the basic description of plate tectonics and its relationship to earthquakes. Chapter 4 covers the basic principles of earthquake geology, seismology and tsunami. Chapter 5 uses plate tectonics and historic and prehistoric records to explain earthquakes along western North America. Chapter 6 examines the history and potential for earthquakes throughout the rest of North America. The intent is to cover every geographic area and major historic earthquake. Chapters 7 and 8 discuss volcanoes; their characteristic magmas are organized around the three Vs—viscosity, volatiles, and volume. Eruptive behaviors are related to plate-tectonic setting. As throughout, case histories are employed to enliven the text.

Disasters powered primarily by gravity are covered in chapter 9 on mass movements. Many types are discussed and illustrated, from falls to flows and slides to subsidence.

Disasters fueled by the external energy of the Sun are examined in chapters 10 through 14. Chapter 10 begins with principles of atmosphere and ocean underlying weather and climate, and then moves on to long-term climate change over timescales of millions, thousands, and hundreds of years. The time focus shrinks through the chapter, leading into chapter 11 on short-term climate change and severe weather phenomena, such as thunderstorms, lightning, and tornadoes. Chapter 12 examines hurricanes and the coastline. The emphasis on water continues in chapter 13 on floods and how human activities increase flood damage. Chapter 14 on fire examines the liberation of ancient sunlight captured by photosynthesis and stored in organic material.

Before moving to the fourth energy source (impacts), chapter 15 examines the great dyings encased in the fossil record. The intent is to document the greatest of all natural disasters and to use multiple variables in analyzing their causes. Specific mass extinctions are examined using causative factors, such as continental unification and separation, climate change, flood-basalt volcanism, sea-level rise and fall, impacts, biologic processes, and the role of humans in the latest mass dying. Chapter 16 examines impact mechanisms in greater detail and includes plans to protect Earth from future impacts.

There is a lot of material in this book, probably too much to cover in one semester. But the broad range of natural disasters topics allows each instructor to select those chapters that cover their interests and local hazards. The goal is to involve the students for a lifetime in understanding the Earth, atmosphere, oceans, and skies—to observe, think, explain, and discuss.

New to This Edition

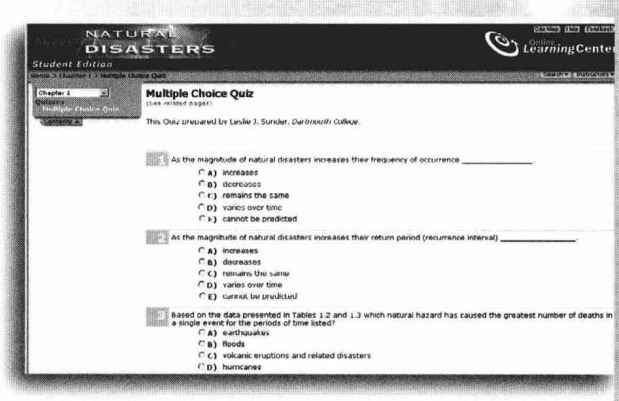
For the fifth edition, *all* chapters have been revised and updated, and many new pieces of line art have been created, and lots of new photos, and new tables have been added. Changes include major reorganizations and expansions. Chapter 1 has more physical and economic data on disasters and hazards and now covers human population, the condensed remains of the former chapter 16. Chapter 2 examines energy flows in Earth history and natural disasters. Chapters 6 and 7 on volcanism have been significantly revised while retaining the continuous sequence based on plate tectonics and magma characteristics, with eruptions explained using the three Vs—viscosity, volatiles, and volume. Chapters 10 and 11 have been radically reorganized. They begin with expanded principles to increase the basis for understanding climate change and severe weather. Chapter 14 on fire has again added several new figures and new tables on wildland fire data and how fires work. Chapter 15 on mass extinctions has added new sections on fossils plus new photos.

Supplements

For the Student

Online Learning Center at www.mhhe.com/abbott5e

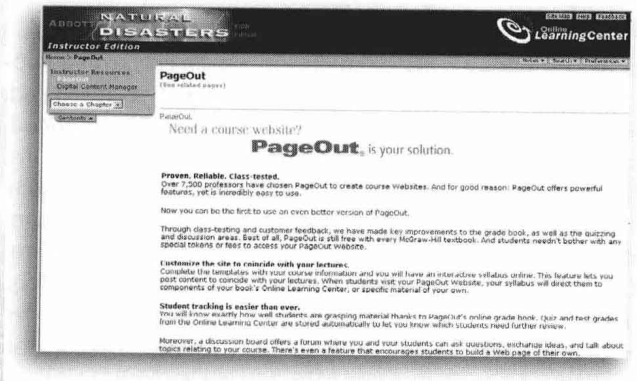
This site gives you the opportunity to further explore topics presented in the book using the Internet. The site contains interactive quizzing with immediate feedback, web links, a career center, and more.



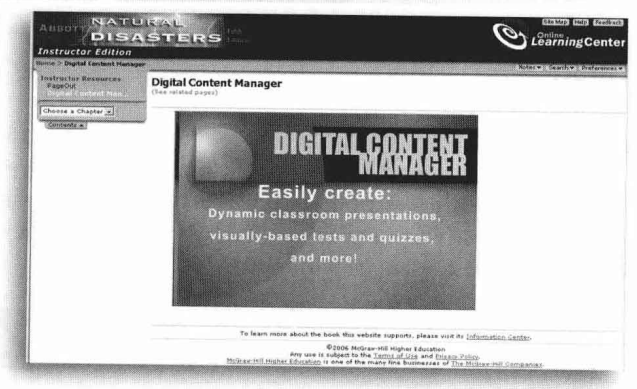
For the Instructor

Online Learning Center at www.mhhe.com/abbott5e

Take advantage of the instructor's manual, PowerPoint lecture outlines, and access to PageOut—McGraw-Hill's course management tool.



DIGITAL CONTENT MANAGER CD-ROM This CD-ROM contains **all of the line art, photographs, and tables** from the book to make customizing your multimedia presentation easy. You can organize figures in any order you want; add labels, lines, and your own artwork; integrate materials from other sources; edit and annotate lecture notes; and then have the option of placing your media lecture into a presentation program, such as PowerPoint.



INSTRUCTOR'S TESTING AND RESOURCE CD-ROM This cross-platform CD-ROM provides a wealth of resources for the instructor. Supplements featured on this CD-ROM include computerized testing software that allows instructors to quickly create customized exams. This user-friendly program allows instructors to sort questions by format, edit existing questions or add new ones; and scramble questions for multiple versions of the same test.

Other assets on this CD are grouped within easy-to-use folders. The Instructor's Manual and Test Item File are available in both Word and PDF formats. Word files of the test bank are included for those instructors who prefer to work outside of the test-generator software.

ACKNOWLEDGMENTS

I am deeply appreciative of the help given by others to make this book a reality. The photograph collection in the book is immeasurably improved by the aerial photographs generously given by John S. Shelton, the greatest geologist photographer of them all. The collection of John Shelton photographs in this book is second in number only to his classic book *Geology Illustrated.* Many of the older figures were drafted by Rene Wagemakers of San Diego State University.

I am indebted to other geologists who provided photographs: Alan Mayo of GeoPhoto Publishing Company on the Winter Park sinkhole and Tucson flooding; Gerald G. Kuhn of San Diego from his space shuttle image collection; Michael W. Hart of San Diego on mass movements; Al Boost of Caltrans on the San Fernando earthquake; Peter Weigand of California State University Northridge, Greg Davis of University of Southern California, and Kerry Sieh of Caltech on the Northridge earthquake; Anne Jennings of the University of Colorado on climate; José Aguirre on the Berkeley fire; and the photo libraries of the USGS, NOAA, and NASA.

For the first edition several chapters benefited from helpful reviews by San Diego State University colleagues: Michael J. Walawender on volcanism, J. David Archibald and Richard H. Miller on great dyings, and David L. Kimbrough on impacts.

The quality of the book was significantly improved by the insights provided by comments from the following reviewers of the fourth and earlier editions:

Judson Ahern, *University of Oklahoma*
Sandra Allen, *Lindenwood University*
Cathy Busby, *University of California–Santa Barbara*
Victor E. Camp, *San Diego State University*
Wang-Ping Chen, *University of Illinois at Urbana-Champaign*
Patrick Colgan, *Northeastern University*
Michael Conway, *Arizona Western University*
Stanley Dart, *University of Nebraska–Kearney*
John Dooley, *North Hennepin Community College*
John Dunbar, *Baylor University*
Michael Forrest, *Rio Hondo Junior College*
Kevin P. Furlong, *Pennsylvania State University*
David Gonzales, *Fort Lewis College*
Paul K. Grogger, *University of Colorado–Colorado Springs*
John Hidore, *University of North Carolina–Greensboro*
George Hupper, *University of Wisconsin–LaCrosse*
Ernest L. Kern, *Southeast Missouri State University*
Alan Lester, *University of Colorado*
Sue Morgan, *Utah State University–Logan*
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Leslie Sonder, *Dartmouth College*
Don Steeples, *University of Kansas*
Donald J. Stierman, *University of Toledo*
Philip Suckling, *University of Northern Iowa*

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Edward Catanzaro, Fairleigh Dickinson University
John Dassinger, Chandler–Gilbert Community College
John F. Dewey, University of California–Davis
Kevin Furlong, Pennsylvania State University
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I am grateful for the help of others at San Diego State University: Jacobe Washburn for his original line drawings, Tony Carrasco for invaluable aid on the computer with photos and line drawings, and Marie Grace for forming many of the tables.

I sincerely appreciate the talents and accomplishments of the McGraw-Hill professionals in Dubuque who took my manuscript and produced it into this book. For the shortcomings that remain in the book, I alone am responsible. I welcome all comments, pro and con, as well as suggested revisions.

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Brief Contents

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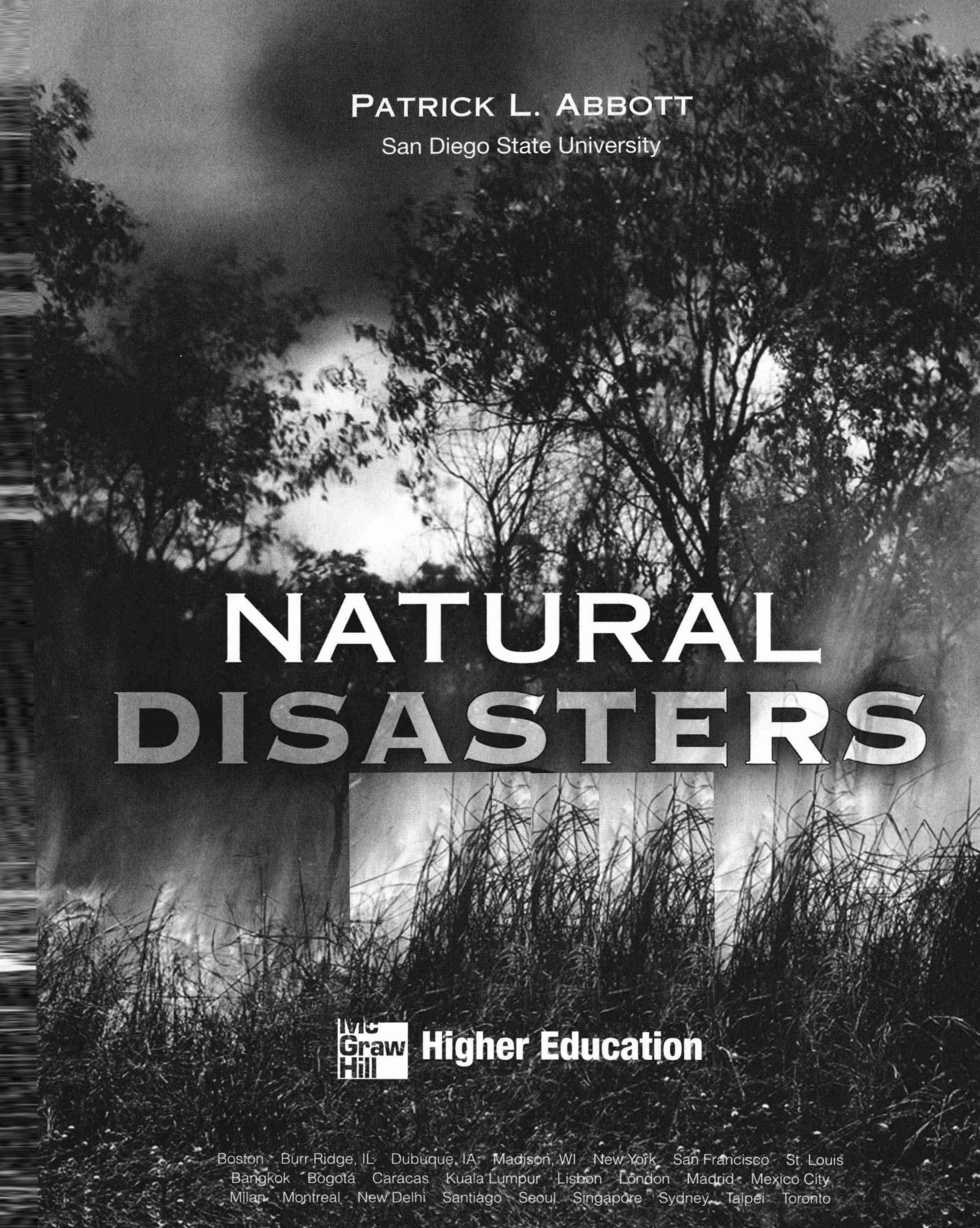
PATRICK L. ABBOTT
San Diego State University



NATURAL DISASTERS

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Survivors had to bury many of the 41,000 dead people in mass graves following the 26 December 2003 earthquake in Bam, Iran.

CHAPTER 1

NATURAL DISASTERS AND THE HUMAN POPULATION

"Mankind was destined to live on the edge of perpetual disaster. We are mankind because we survive."

James A. Michener, 1978, Chesapeake

OUTLINE

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