

# ENVIRONMENTAL GEOLOGY

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Barbara W. Murck • Brian J. Skinner • Stephen C. Porter

# ENVIRONMENTAL GEOLOGY

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## ABOUT THE AUTHORS

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*T*he authors of this book bring a wealth of professional and personal knowledge, training, and experience to the project. Among them, they have carried out geologic fieldwork on all

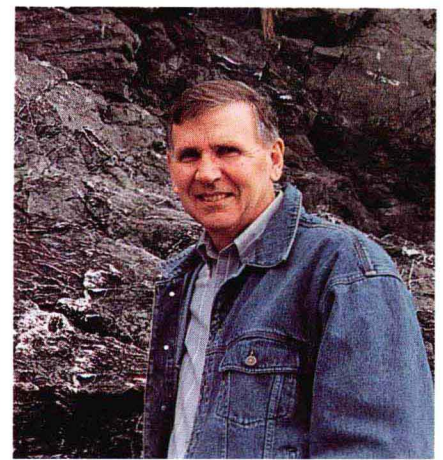
of the Earth's continents. The diversity demonstrated in their own careers reflects the broad range of challenges that characterize Earth science and environmental geology today.



As an undergraduate *Barbara Murck* was a confirmed nonscientist, until an introductory geology course changed her plans. Since then her professional focus has ranged from igneous geochemistry and ore-deposit petrography to alternative energy sources and state-of-the-environment reporting. Her current work focuses primarily on environmental management training for decision makers in developing countries.



Throughout his career as a geologist, *Brian Skinner's* research has focused on the physical properties of minerals and on the genesis of base-metal deposits. He has worked extensively in Australia, Africa, and North America and with students in Asia and Europe. With Yale University colleagues, he has had the opportunity to explore a diversity of Earth science topics, including oceanography and climatic change, volcanic gases, economic models of resource depletion, and the geologic aspects of the space program.



*Stephen Porter's* professional career has largely been concerned with studies of glaciation in many of the world's major mountain systems and with the history of the climatic changes their deposits record. He has also studied the evolution of midocean and continental volcanoes and the products of their prehistoric eruptions and how volcanic eruptions may have influenced the Earth's climate. With colleagues from around the world, he has studied the hazards of large rockfalls in the Alps and the thick, extensive deposits of windblown dust in China that provide one of the longest continuous records of climatic change during the past several million years.

The authors' global perspective is reflected in this book by examples and illustrations from numerous foreign areas, for it is important to emphasize that geology is a global science—a science that recognizes no political boundaries.

Only by studying the Earth in its entirety can we hope to understand how our amazing planet works, how geologic processes affect our lives, and how, in turn, human activities affect the functioning of the Earth system.



**T**he study of the Earth has captured people's interest for as long as scientific enquiry has been conducted. To explore, to question, to seek an understanding of the natural processes that surround us is fundamental to human nature. In the Earth sciences today, more than ever before, we recognize what links the various parts of the Earth system to one another and what links all organisms—including human beings—to the geologic environment. Investigating the nature of these dynamic connections is a central goal of environmental geology and an important focus of this book.

## Why We Wrote *Environmental Geology*

We love geology. We love to study, teach, and learn about geology. It is fun and exciting to help people understand the Earth beneath their feet and the geologic processes that affect their daily lives. It is rewarding when a student says, "I heard about that earthquake on the news last night, and I understood why it happened," or "On our holiday we saw a flood out the window of the airplane, and I explained to my family what was happening." By producing a first-rate text on environmental geology, we hope to facilitate such learning.

As a society (and, increasingly, as a global community) we want to continue to derive benefits from the Earth's resources without jeopardizing the future availability of those resources and without compromising the integrity of natural systems. We hope, also, to minimize the negative impacts of hazardous Earth processes. To achieve these goals we need to foster greater understanding of Earth systems and geologic processes. For those reasons we have chosen to explore environmental geology from a distinctly human perspective. Throughout the book we return to the themes of human-induced environmental change, the impacts of geology on human interests, and societal dependence on the Earth's resources. This book is an exploration of the planet. More precisely, it explores the human-planet relationship: how Earth processes influence human lives on

a daily basis and how human actions, in turn, alter the functioning of Earth systems.

This is an environmental geology textbook. It is not a physical or historical geology textbook, although environmental geology does encompass some aspects of both physical and historical geology. The basic geology topics covered in the book were specifically selected to provide the foundation for concepts and terminology needed to understand the impacts of geologic processes on human interests. Students respond best to background material when they understand the reasons for learning it; hence, frequent explanations are offered. They might ask, for example, Why is it important to learn about the interior of the Earth? (Because internal Earth processes are fundamental in forming the landscape and causing hazardous Earth processes like earthquakes and volcanoes.) Why is it necessary to study the properties of rocks, minerals, and soils? (Because we need these materials as resources and because the properties of Earth materials can affect human interests in a wide variety of ways—in their ability to resist mass-wasting, to absorb wastes, or to hold and transmit oil or water, for example.) Students who read this book will gain the basic geologic background they need to interpret geologic events.

## To the Reader

Most likely, you are reading this book in the context of an introductory course on environmental geology. People take such courses for a variety of reasons; consequently, this book may mean different things to different people. If you are planning to become a geologist or an environmental geologist, you can consider the book an introduction to the many fascinating possibilities and challenges that await you in your career. If you are studying environmental geology out of personal interest or perhaps to fulfill a degree requirement, we hope it will help you become more aware of the geologic nature of our environment and the role of

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geoscientists in events of public concern. And we hope that all of our readers will emerge better prepared to make informed decisions about the natural processes that affect our lives on a daily basis.

### Organization

The book is organized in four main parts. In *Part I: Geologic Framework* we provide a brief background in Earth system science and physical and historical geology. In this part you will find basic concepts and terminology concerning the structure and materials of the Earth and the functioning of Earth systems and cycles. The topics covered are not overly technical; they were carefully chosen to provide just the background needed to be able to understand the material presented in subsequent chapters. *Part II: Hazardous Geologic Processes* covers the broad range of geologic events that are damaging to human interests, including Earthquakes, volcanic eruptions, landslides, and floods. In this section we look at both the impacts of such events on humans and the geologic processes that underlie the events. In *Part III: Using and Caring for Earth Resources* we investigate the nature of the Earth's resources, their importance for modern society, the geologic processes that control their formation and occurrence, and some of the environmental implications of their use and management (or mismanagement). *Part IV: Human Impacts on the Environment* focuses on contaminants—waste and pollution, where they come from, how they are transported in the geologic environment, and how they can be managed. This part of the book ends with a look at the impacts of human activity on the atmosphere and at the potential impacts of global atmospheric change.

### Special Features

The following special features of content, organization, graphical presentation, and pedagogy set this book apart from others in similar subject areas.

#### Part Opening Essays

Each of the four main parts of the book opens with an essay. These essays are not add-ons; they are integral to the text. They set the context and provide an overview of the fundamental concepts that recur throughout the ensuing chapters. The essay for Part I, entitled *The Home Planet*, puts Earth in perspective by placing it in the context of the solar system and by examining some of the Earth-forming processes that have made this planet hospitable to life. *Assessing Geologic Hazards and Risks*, the essay for Part II, introduces natural, geologic, technological, and anthropogenic hazards and some of the approaches used to assess human vulnerability to these hazards. In the essay for Part III, *The Nature of Earth Resources*, renewable and nonrenewable resources are introduced, and the finite nature of some Earth resources and the need for appropriate management are discussed. The Part IV

opening essay, *Managing Wastes*, examines waste and contaminants in the context of a “throwaway” society.

#### Chapter-Opening Vignettes

Each chapter opens with a short vignette, or anecdote, illustrated with a chapter-opening photograph on the facing page. The purpose of these vignettes is to provide a glimpse into some aspect of the geologic environment and how that environment affects humans (and vice versa). To a certain extent the opening comments are designed to provide a context or rationale for the chapters. For example, students often wonder why the study of minerals is relevant to environmental geology. The vignette for chapter 2, concerning the properties of asbestos minerals and how they affect human interests, provides an answer.

#### Boxes: *The Human Perspective and Focus On . . .*

Scattered throughout the book you will find material set aside in shaded boxes; at least one box appears in each chapter. Boxes entitled *The Human Perspective* are intended to highlight particular aspects of the human–planet relationship, such as human impacts on the environment, the impacts of geologic processes on human interests, or human institutions (projects, programs, etc.) devoted to some aspect of environmental geology. Boxes entitled *Focus On . . .* are intended to provide an in-depth look at some of the more technical aspects of environmental geology and related sciences. These boxes provide depth and detail for a course that goes beyond the introductory level or is designed specifically for geology or environmental geology majors. If desired, however, the *Focus On . . .* boxes can be skipped without affecting the integrity of the material presented in the rest of the chapter.

#### Artwork

The artwork in this book has been carefully crafted to complement the text and to facilitate learning. For the line drawings, the authors worked closely with illustrators who are familiar with the subject matter and are highly skilled at translating concepts into accurate full-color representations. Intensive research has allowed us to carry on the tradition of beautiful, up-to-date, instructive photographic images for which Wiley's Earth science textbooks are known.

#### Pedagogical Material

Each chapter includes a list of *Important Terms to Remember*. A page reference is given for each of the important terms, and a glossary is provided at the end of the book. The chapters also include a *Summary* of key points presented in a numbered list. The *Questions and Activities* that end each chapter are meant to stimulate independent thought and study and critical thinking. Some of the activities are appropriate for group discussions, projects, or field trips; others lend themselves to term-paper or essay assign-

ments. The *Appendices* provided at the end of the book contain useful reference information for students (and instructors) on units and conversions, the chemical elements, and the geologic time scale.

## Supplements

A full range of supplementary material to accompany *Environmental Geology* is available to assist both instructors and students. The *Study Guide*, prepared by Barbara Murck, provides an inexpensive way for students to derive full benefit from this textbook. It includes chapter summaries; brief discussions of the most important terms and key points in each chapter; study pointers and guidelines; and practice questions to help students review and apply concepts and to prepare for examinations.

The *Instructor's Manual and Test Bank* was also prepared by Barbara Murck. It includes chapter synopses and lecture lead-ins; sample syllabi and options for course organization; suggestions for further reading; a full description of supplementary materials; and additional written, audio-visual, and computer resources. The *Test Bank* is also available in computerized format for both IBM and Macintosh applications. The computerized format features an easy-to-use test-generating program that allows instructors to select test questions from the printed test bank, print the completed tests for use in the classroom, and save the tests for later use or modification.

*Environmental Science Activities*, by Dorothy B. Rosenthal, provides forty-six interdisciplinary student activities that require a hands-on approach and inspire critical thinking. Through the use of readily available materials, this supplement allows students to investigate, analyze, and appreciate the world around them in a class or on their own.

The *Wiley Geology Transparency Set* includes 150 full-color textbook illustrations, resized and edited for maximum effectiveness in large lecture halls. The *Wiley Geology Slide Set* comprises the 150 images provided as transparency acetates in 35-mm slide form. The *Environmental Geology Overhead Transparency Set* consists of full-color line drawings from this book, resized for maximum visibility in large lecture halls. These images are also available as 35-mm slides in the *Environmental Geology Slide Set*.

The *Wiley Geosciences CD-ROM* contains many images from *Environmental Geology*, as well as from *Dynamic Earth* and *The Blue Planet*, both by Brian J. Skinner and Stephen C. Porter. Available for Macintosh or IBM and compatible computers, the CD-ROM includes an image manager that

allows instructors to customize their presentations, and eight animations that illustrate key geological concepts.

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It has been a pleasure to work with the talented, efficient, and ever patient professionals at John Wiley & Sons and the freelance experts associated with them. Thanks to everyone involved with this project; you deserve a gold medal (and a vacation) for consistent good humor in dealing with chronically truant authors.

The concept of an environmental geology text originated with Barry Harmon, then Earth sciences editor, and publisher Kaye Pace and continued under the editorial guidance of Chris Rogers. Developmental editor Rachel Nelson prodded, advised, commiserated, and otherwise guided the project to a successful conclusion. Others who contributed their considerable talents to the success of the project include (in no particular order): Bonnie Cabot, who oversaw an extremely tight production schedule; Stella Kupferberg, Alexandra Truitt, Kim Khatchaturian, and Michelle Orleans, who found just the right photographs for the text; Anna Melhorn, who managed (or juggled) the illustration program; Karin Kincheloe, the designer of the book; John Woolsey and his staff, who exhibited amazing skill at translating crude sketches into accurate full-color representations; Eric Stano, who coordinated the supplementary materials; Carolyn Smith, whose ruthless green pen greatly improved the readability of the text; Catherine Faduska, who developed the marketing program for the book; Diane Kraut, permissions editor; and Beth Brooks and Pui Szeto, who provided editorial assistance. Special mention is due to Judith Peatross, who contributed valuable suggestions on organization, pedagogy, and scientific content throughout the early stages of manuscript development. Judith also wrote a number of the *Human Perspective* and *Focus On . . .* boxes; thank you for these contributions.

Geology in general—and environmental geology in particular—is an interdisciplinary endeavor, one that encompasses many areas of expertise. For this reason we sought the input of colleagues who collectively represent a wide range of experience in all aspects of research and teaching related to environmental geology. The careful reading and extensive commentary by these colleagues improved the book immeasurably. Their thoughtful suggestions touched on every aspect of the volume, from the overall organization to the tiniest details. They helped keep us up-to-date in a science that is constantly changing. More importantly, through their comments the reviewers made available to us their many years of collective experience in conveying this material to beginning students of geology and environmental geology. Thank you to those who assisted us by reviewing all or part of the manuscript. They are:

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