Preface

About the Course

Environmental Geology Is Geology Applied to Living

The *environment* is the sum of all the features and conditions surrounding an organism that may influence it. An individual's physical environment encompasses rocks and soil, air and water, such factors as light and temperature, and other organisms. One's social environment might include a network of family and friends, a particular political system, and a set of social customs that affect one's behavior.

Geology is the study of the earth. Because the earth provides the basic physical environment in which we live, all of geology might in one sense be regarded as environmental geology. However, the term *environmental geology* is usually restricted to refer particularly to geology as it relates directly to human activities, and that is the focus of this book. Environmental geology is geology applied to living. We will examine how geologic processes and hazards influence human activities (and sometimes the reverse), the geologic aspects of pollution and waste-disposal problems, and several other topics.

Why Study Environmental Geology?

One reason for studying environmental geology might simply be curiosity about the way the earth works, about the *how* and *why* of natural phenomena. Another reason is that we are increasingly faced with environmental problems to be solved and decisions to be made, and in many cases, an understanding of one or more geologic processes is essential to finding an appropriate solution.

Of course, many environmental problems cannot be fully assessed and solved using geologic data alone. The problems vary widely in size and in complexity. In a specific instance, data from other branches of science (such as biology, chemistry, or ecology), as well as economics, politics, social priorities, and so on may have to be taken into account. Because a variety of considerations may influence the choice of a solution, there is frequently disagreement about which solution is "best." Our personal choices will often depend strongly on our beliefs about which considerations are most important.

About the Book

An introductory text cannot explore all aspects of environmental concerns. Here, the emphasis is on the physical constraints imposed on human activities by the geologic processes that have shaped and are still shaping our natural environment. In a real sense, these are the most basic, inescapable constraints; we cannot, for instance, use a resource that is not there, or build a secure home or a safe dam on land that is fundamentally unstable. Geology, then, is a logical place to start in developing an understanding of many environmental issues. The principal aim of this book is to present the reader with a broad overview of environmental geology. Because geology does not exist in a vacuum, however, the text introduces related considerations from outside geology to clarify other ramifications of the subjects discussed. Likewise, the present does not exist in isolation from the past and future; occasionally, the text looks both at how the earth developed into its present condition and where matters seem to be moving for the future. It is hoped that this knowledge will provide the reader with a useful foundation for discussing and evaluating specific environmental issues, as well as for developing ideas about how the problems should be solved.

Features Designed for the Student

This text is intended for an introductory-level college course. It does not assume any prior exposure to geology or college-level mathematics or science courses. The metric system is used throughout, except where other units are conventional within a discipline. (For the convenience of students not yet "fluent" in metric units, a conversion table is included on the inside back cover, and in some cases, metric equivalents in English units are included within the text.)

Each chapter opens with an introduction that sets the stage for the material to follow. In the course of the chapter, important terms and concepts are identified by boldface type, and these terms are collected as "Key Terms and Concepts" at the end of the chapter for quick review. The Glossary includes both these boldface terms and the additional, italicized terms that many chapters contain. Most chapters include actual case histories and specific real-world examples. Every chapter concludes with review questions and exercises, which allow students to test their comprehension and apply their knowledge. The "Exploring Further" section of each chapter includes a number of activities in which students can engage, some involving online data, and some, quantitative analysis. For example, they may be directed to examine real-time stream-gaging or landslide-monitoring data, or information on current or recent earthquake activity; they can manipulate historic climate data from NASA to examine trends by region or time period; they may calculate how big a wind farm or photovoltaic array would be required to replace a conventional power plant; they can even learn how to reduce sulfate pollution by buying SO_2 allowances.

Each chapter includes one or more case studies. Some involve a situation, problem, or application that might be encountered in everyday life. Others offer additional case histories or relevant examples. The tone is occasionally light, but the underlying issues are nonetheless real. (While some case studies were inspired by actual events, and include specific factual information, all of the characters quoted, and their interactions, are wholly fictitious.)

Additional online resources available on the website for each chapter are of two kinds. One is "NetNotes," a modest collection of Internet sites that provide additional information and/or images relevant to the chapter content. These should prove useful to both students and instructors. An effort has been made to concentrate on sites with material at an appropriate level for the book's intended audience and also on sites likely to be relatively stable in the very fluid world of the Internet (government agencies, educational institutions, or professional-association sites). The other is "Suggested Readings/References," some of which can also be accessed online. A previous appendix on maps and satellite imagery included in earlier editions has been moved to the text's website along with other readings formerly in the text.

New and Updated Content

Environmental geology is, by its very nature, a dynamic field in which new issues continue to arise and old ones to evolve. Every chapter has been updated with regard to data, examples, and illustrations.

Geology is a visual subject, and photographs, satellite imagery, diagrams, and graphs all enhance students' learning. Accordingly, this edition includes more than one hundred new photographs/images and forty new figures, with revisions having been made to dozens more.

Significant content additions and revisions to specific chapters include:

Chapter 1 Population data and projections have been updated; Case Study 1 includes new lunar data.

Chapter 2 The Libby, Montana, vermiculite case study has been updated and refined.

Chapter 3 The chapter has been reorganized for better flow, and discussion of compressive and tensile stress as related to tectonics and plate boundaries has been clarified.

Chapter 4 Discussion of waves, seismic waves, and seismographs has been enhanced. Much new material has been added on the recent earthquakes in Japan, Haiti, New Zealand, and elsewhere. Case Study 4.1 now includes extensive discussion of the Japanese tsunami, and the chapter notes application of the Japanese earthquake early warning system to this quake. Case Study 4.2 updates information on SAFOD results. The trial of the Italian seismologists who failed to predict the 2009 l'Aquila earthquake is noted.

Chapter 5 New material on the roles of fluid and of pressure reduction in promoting mantle melting has been added. The eruption of Eyjafjallajökull and its effects on air travel are discussed. The status of Redoubt as examined in Case Study 5.2 has been updated, and the possible role of seismic activity in triggering the eruption of Chaitén volcano noted.

Chapter 6 The 2011 Mississippi River flooding is discussed, including the role of deliberate breaching of levees.

Chapter 7 Material on the effects of Hurricanes Irene and Sandy has been added, particularly in Case Study 7.

Chapter 8 The 2010 landslide that buried Attabad, Pakistan, is discussed, together with its aftermath.

Chapter 9 Discussion of possible causes of past ice ages has been expanded, now including the potential role of the evolution of land plants; discussions of Milankovitch cycles and of desertification have been enhanced.

Chapter 10 Data on global temperature changes have been updated, as have data on changes in alpine glacier thickness; changes in the thickness and extent of Arctic sea ice cover are presented, and the breakup of the Wilkins ice shelf in Antarctica noted. Discussion of global-change impacts has been expanded and now includes ocean acidification. Climate-change vulnerability across Africa as identified by the U.N. Environment Programme is examined.

Chapter 11 Status of water levels in Lake Mead and of Lake Chad and the Aral Sea have been updated. Discussion of Darcy's Law has been clarified. Case Study 11 has been expanded, with information on radium in ground water nationally, and a note on bottled versus tap-water quality. New data on water withdrawals, nationally and by state, and on irrigation-water use by state, are presented; groundwater monitoring by satellite illustrates declining water levels.

Chapter 12 Data on soil erosion by wind and water, nationally and by region within the United States, have been updated, highlighting areas in which erosion rates exceed sustainable limits.

Chapter 13 The discussion of resources versus reserves is incorporated early in the chapter. Distribution of world reserves of a dozen key metals has been updated, along with data on U.S. per-capita consumption of select minerals and fuels. All tables of U.S. and world mineral production, consumption, and reserves have been updated. The former Case Study 13 (now 13.2) reflects recent commodity price rises. A new Case Study 13.1 has been added to focus on the rare-earth elements, their importance, and the current dominance of China in the world REE trade.

Chapter 14 All data on U.S. energy production and consumption by source have been updated. Information on shale gas, its distribution, and its significance for U.S. natural-gas reserves has been added, with concerns relating to fracking noted. The Deepwater Horizon oil spill is discussed; discussion of the Athabasca oil sands has been expanded.

Chapter 15 Extensive discussion of the Fukushima power-plant accident has been incorporated in Case Study 15.1. New data on world use of nuclear fission power and on U.S. solar and wind-energy potential across the country are presented. Iceland has been added as a new comparison case in figure 15.33, and data on the remaining countries' energy-source patterns updated.

Chapter 16 Data on the composition and fate of U.S. municipal wastes have been updated. A discussion of the challenge of estimating the effects of low-level radiation exposure has been added, and the status of Yucca Mountain and of world development of high-level nuclear-waste repositories updated.

Chapter 17 The significance of trace elements to health and the concept of the dose-response curve are incorporated early in the chapter. New data on nutrient loading in the Gulf of Mexico from the Mississippi River basin are presented. The growing problem of pharmaceuticals in wastewater is noted, and maps modeling nutrient and herbicide concentrations in ground water across the country are examined.

Chapter 18 Data on sources of U.S. air pollutants, air quality, and acid rain across the country have been updated. Trends in air pollution in selected major U.S. cities are shown, and particulate air pollution around the globe, including its varied sources, is considered. New data on ground-level ozone in the United States and stratospheric ozone globally are presented, and the recently recognized Arctic "ozone hole" is discussed.

Chapter 19 Seafloor imaging as it relates to resource rights under the Law of the Sea Treaty is illustrated. Discussion of the Montreal Protocol has been expanded to include the evolving problem of HFCs and HCFCs and ozone depletion. The Keystone XL pipeline has been added to Case Study 19.

Chapter 20 New data on land cover/use, recent population change, and population density for the United States are examined. In the engineering-geology section, discussions of the cases of the Leaning Tower of Pisa and of the St. Francis Dam have been expanded, and the case of the Taum Sauk dam failure added.

The online "NetNotes" have been checked, all URLs confirmed, corrected, or deleted as appropriate, and new entries have been added for every chapter. The "Suggested Readings/References" have likewise been updated, with some older materials removed and new items added in each chapter.

Organization

The book starts with some background information: a brief outline of earth's development to the present, and a look at one major reason why environmental problems today are so pressing—the large and rapidly growing human population. This is followed by a short discussion of the basic materials of geology—rocks and minerals—and some of their physical properties, which introduces a number of basic terms and concepts that are used in later chapters.

The next several chapters treat individual processes in detail. Some of these are large-scale processes, which may involve motions and forces in the earth hundreds of kilometers below the surface, and may lead to dramatic, often catastrophic events like earthquakes and volcanic eruptions. Other processes—such as the flow of rivers and glaciers or the blowing of the wind—occur only near the earth's surface, altering the landscape and occasionally causing their own special problems. In some cases, geologic processes can be modified, deliberately or accidentally; in others, human activities must be adjusted to natural realities. The section on surface processes concludes with a chapter on climate, which connects or affects a number of the surface processes described earlier.

A subject of increasing current concern is the availability of resources. A series of five chapters deals with water resources, soil, minerals, and energy, the rates at which they are being consumed, probable amounts remaining, and projections of future availability and use. In the case of energy resources, we consider both those sources extensively used in the past and new sources that may or may not successfully replace them in the future.

Increasing population and increasing resource consumption lead to an increasing volume of waste to be disposed of; thoughtless or inappropriate waste disposal, in turn, commonly creates increasing pollution. Three chapters examine the interrelated problems of air and water pollution and the strategies available for the disposal of various kinds of wastes.

The final two chapters deal with a more diverse assortment of subjects. Environmental problems spawn laws intended to solve them; chapter 19 looks briefly at a sampling of laws, policies, and international agreements related to geologic matters discussed earlier in the book, and some of the problems with such laws and accords. Chapter 20 examines geologic constraints on construction schemes and the broader issue of trying to determine the optimum use(s) for particular parcels of land—matters that become more pressing as population growth pushes more people to live in marginal places.

Relative to the length of time we have been on earth, humans have had a disproportionate impact on this planet. Appendix A explores the concept of geologic time and its measurement and looks at the rates of geologic and other processes by way of putting human activities in temporal perspective. Appendix B provides short reference keys to aid in rock and mineral identification, and the inside back cover includes units of measurement and conversion factors.

Of course, the complex interrelationships among geologic processes and features mean that any subdivision into chapter-sized pieces is somewhat arbitrary, and different instructors may prefer different sequences or groupings (streams and ground water together, for example). An effort has been made to design chapters so that they can be resequenced in such ways without great difficulty.

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Carla W. Montgomery