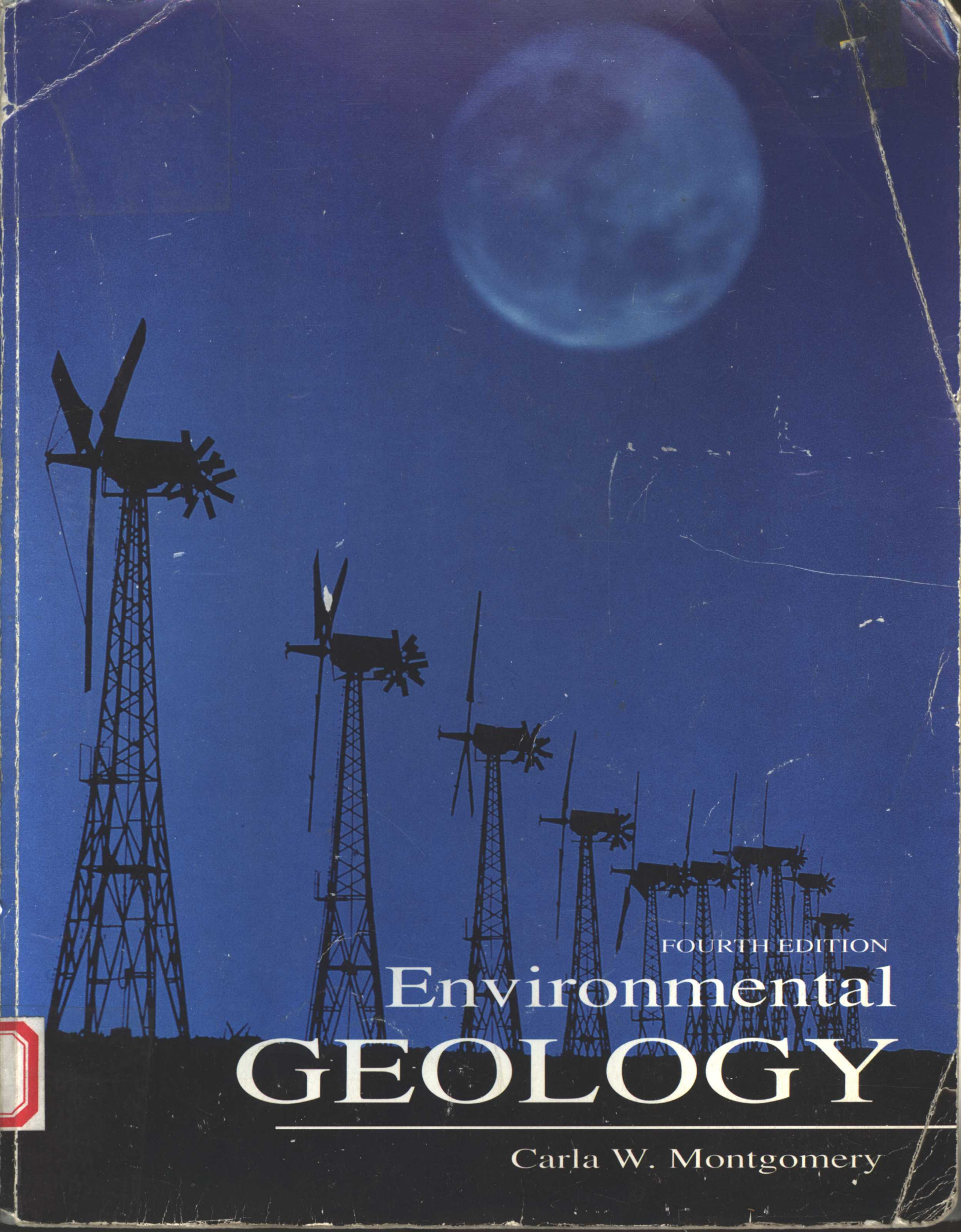

FOURTH EDITION

Environmental GEOLOGY

Carla W. Montgomery

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Carla W. Montgomery
Northern Illinois University

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Preface

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 present. 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. Since 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 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.

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, from time to time, 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.

About the Book

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 in appendix D, 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 "Terms to Remember" at the end of the chapter for quick review. To emphasize the present relevance of the material in the text and to illustrate the variety of current environmental problems, many chapters include actual case histories or specific examples. To these, each reader could no doubt add others from personal experience. Additional supplementary information is included in boxes set off from the main body of the text. Each chapter concludes with exercises that allow students to test their comprehension of text material and to apply that knowledge to real-world situations.

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.

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 prospects. 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 seem to lead to an increasing volume of waste to be disposed of; thoughtless or inappropriate waste disposal commonly leads to 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 few chapters deal with a more diverse assortment of subjects. Environmental problems spawn laws intended to solve them; the environmental-law chapter looks briefly at a sampling of laws related to geologic matters discussed earlier in the book, as well as at some of the problems with such laws. The land-use planning and engineering geology chapter examines geologic constraints on construction schemes and the broader issue of trying to determine the optimum use(s) for particular parcels of land. Medical geology, a relatively new field covered in the last chapter, concerns the relationship between health and the geologic setting in which we live.

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 gives an introduction to topographic and geologic maps and satellite imagery. Appendix C provides short reference keys to aid in rock and mineral identification.

Available with this text is an Instructor's Manual containing over 750 test questions. The test questions found in the Instructor's Manual are also available on Wm. C. Brown's classroom testing software, for use with the Macintosh® and IBM® PC computers. Also available are 100 acetate transparencies of key text illustrations and 100 color slides. These are designed to aid instructors in class presentations and to enhance student learning activities.

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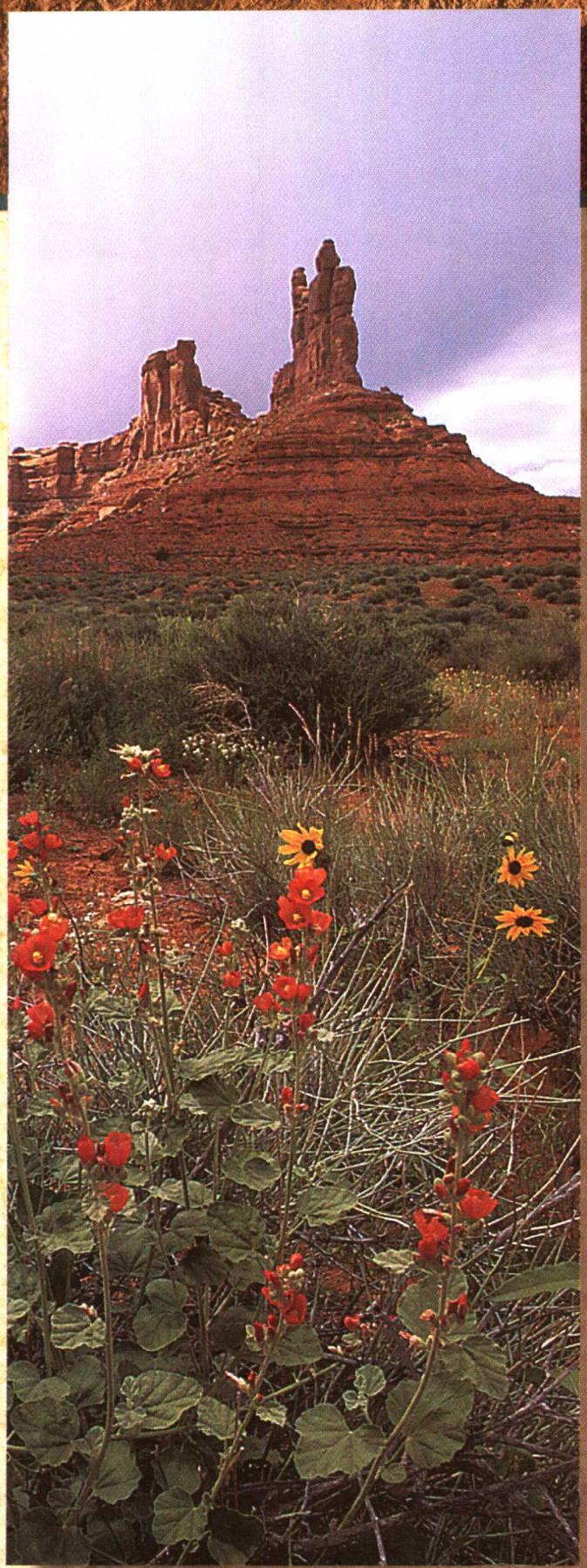
Section I



Foundations

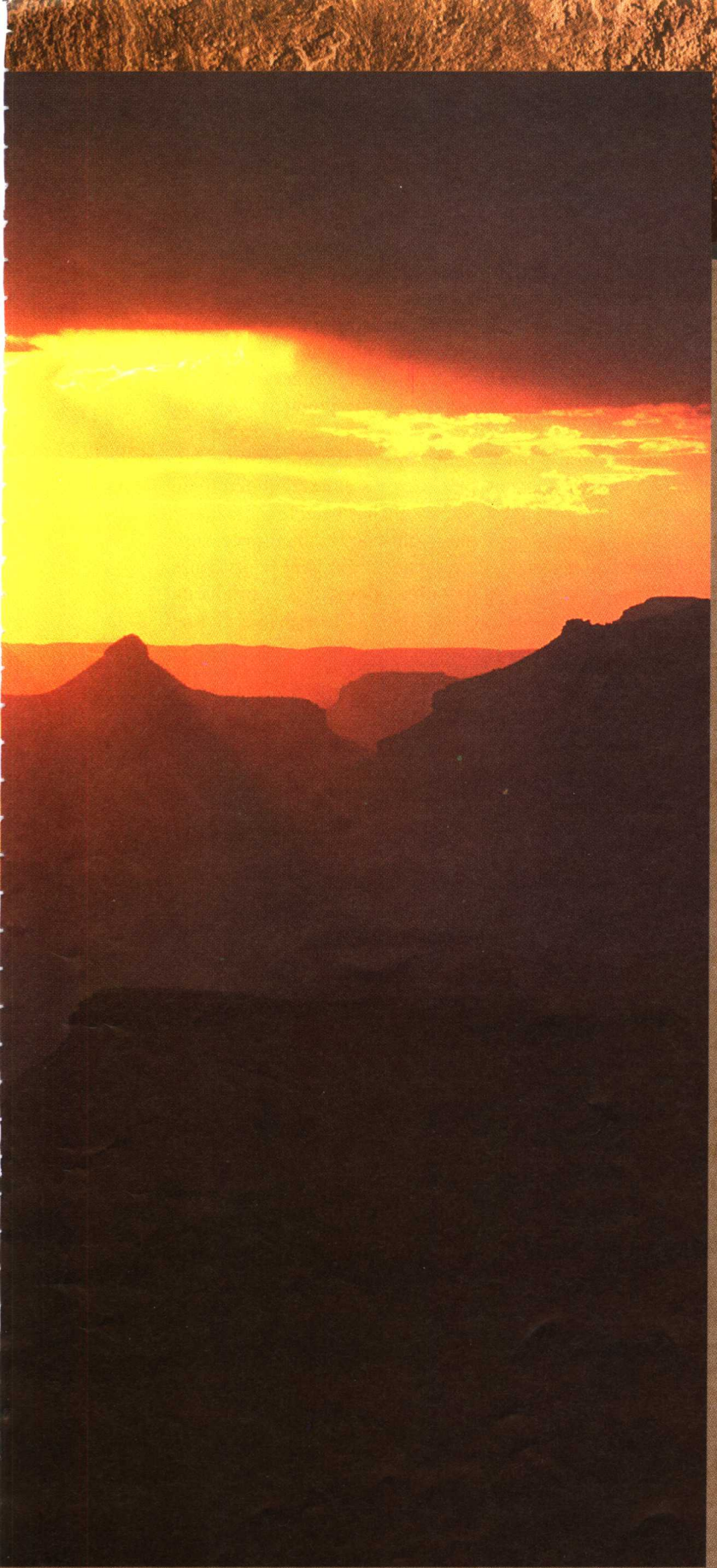
A sense of historical perspective helps us to appreciate current problems and to anticipate future ones. Many modern environmental problems, such as acid rain and groundwater pollution, have come upon us very recently. Others, such as the hazards posed by earthquakes, volcanoes, and landslides, have always been with us. Recognition of the impact of natural hazards is worldwide; the 1990s have been designated the United Nations Decade for Natural Disaster Reduction.

Chapter 1 briefly summarizes the major events in the earth's development, and allows us to begin to see where human activities fit in. It provides some information about the solar system to help the reader judge the degree to which other planets might provide solutions to such problems as lack of resources and living space. It also introduces the concept of cyclicity in natural processes, and points out that the interrelationships among natural processes may be complex.

The size and growth of earth's human population bear strongly on the ways and extent to which geology and people interact, which is what environmental geology is all about. In fact, many of our problems are as acute as they are simply because of the sheer number of people who now live on the earth. This point will be particularly evident in discussions of resources, pollution, and waste disposal. Again, the global impact of the issues is underscored by the fact that in 1992, more than 170 nations came together in Rio de Janeiro for the United Nations Conference on Environment and Development, to address such issues as global climate change, sustainable development, and environmental protection.

It is difficult to talk for long about geology without discussing rocks and minerals, the stuff of which the earth is made. Chapter 2 introduces these materials and some of their basic properties. Specific physical and chemical properties of rocks and soils are important in considering such diverse topics as resource identification and recovery, waste disposal, assessment of volcanic or landslide hazards, weathering processes and soil formation, and others.

For the most part, the earth has been shaped by slow processes operating over very long periods of time; millions of years of sediment deposition create thick beds of sedimentary rocks like these. Thousands of years of erosion by wind and water have shaped them into the forms we see today. Valley of the Gods State Park, Utah.



Chapter 1

An Overview of Our Planetary Environment

Billions of years ago, out of a swirling mass of gas and dust, evolved a system of varied planets hurtling around a nuclear-powered star—our solar system. One of these planets, and one only, gave rise to life. Over time, a tremendous diversity of life forms and ecological systems developed, while the planet too evolved and changed, its interior churning, its landmasses shifting, its surface constantly being reshaped. Within the last several million years, the diversity of life on earth has included humans, increasingly competing for space and survival on the planet's surface. With the control over one's surroundings made possible by the combination of intelligence and manual dexterity, humans have found most of the land on the planet inhabitable; they have learned to use not only plant and animal resources, but minerals, fuels, and other geologic materials; in some respects, humans have even learned to modify natural processes that inconvenience or threaten them. As we have learned how to study our planet in systematic ways, we have developed an ever-increasing understanding of the nature of the processes shaping, and the problems posed by, our geological environment. As the human population grows, however, it becomes increasingly difficult for that population to survive on the resources and land remaining, to avoid those hazards that cannot be controlled, and to refrain from making irreversible and undesirable changes in environmental systems. The urgency of perfecting our understanding, not only of natural processes but also of our impact on the planet, is becoming more and more apparent.

The Grand Canyon and its environment, also millions of years in the making, are not immune to short-term human impacts: tourist traffic on trails accelerates erosion, pollution makes the air over the canyon hazier, and the desire for ever more energy leads to consideration of damming the Colorado River for hydropower and creating a reservoir on the canyon floor.