Environmental Geology Fifth Edition

Edward A. Keller

ENVIRONMENTAL GEOLOGY

Fifth Edition

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ENVIRONMENTAL GEOLOGY

For Jackie

Preface

Environmental geology is applied geology with a focus on the entire spectrum of possible interactions between people and the physical environment. The Fifth Edition of *Environmental Geology,* like the previous four, is intended as an introduction to the study of applied geology. Students who become keenly interested in the subject may then go on to take courses in such areas as hydrogeology and engineering geology.

The study of environmental geology is facilitated by previous exposure to either physical geology or geography. However, I recognize that students, unless they major in geology, may not have the latitude in their undergraduate studies to take more than a single geology course. Therefore, *Environmental Geology* is designed to allow for the study of applied geology without previous exposure to the geological sciences. I have attempted to present case histories and subject matter that are relevant to a wide variety of students, including those in professional schools such as engineering, architecture, and planning; those in traditional scientific disciplines such as chemistry, biology, geology, physical geography, and physics; and liberal arts students majoring in disciplines such as economics, literature, environmental studies, art, sociology, and human geography.

The organization of the Fifth Edition is essentially the same as the previous four. However, two new chapters are presented. Chapter 4 deals with soils and the use of soils, and Chapter 5 provides an overview of natural processes and hazards. Since consideration of soils is an important part of almost all terrestrial environmental work, I have attempted to present sufficient material to enable students to gain a basic appreciation of what soils are, how they form, and how they are important in environmental problems. The chapter on the overview of natural processes that continue to be hazardous to people and property also includes discussions of risk analysis and the relations between society, the media, and scientists.

Part One introduces physical and fundamental principles important to the study of environmental geology. The objective is to unite the cultural and physical environments and introduce important geological concepts and terminology necessary to understanding the remainder of the book.

Part Two provides an overview of the major natural processes and geologic hazards with detailed discussion of flooding, landslides, earthquakes, volcanos, and coastal processes. New material in Part Two includes consideration of how society deals with natural processes that are hazardous to people, individual adjustments to natural hazards and processes, and how we approach the problem of risk assessment. New case histories include a discussion of the floods in Arizona in 1983; the flood hazard in Las Vegas, which is gambling that its new flood control program will help min-

imize its flood hazard; the 1985 earthquake that devastated Mexico City; and the eruption of the Colombian volcano Nevado del Ruiz, which killed more than 20,000 people in 1985.

Part Three discusses various aspects of human interaction with the environment. Particularly important are hydrogeology as it relates to water supply, use, and pollution; waste disposal, including the topics of solid-waste disposal, hazardous chemical wastes, and radioactive waste management; and geologic aspects of environmental health that are important in assessing relations among people, environment, and chronic disease. Changes in Part Three include a much expanded discussion of water resources and water pollution. Also included is an extensive case history of the Colorado River Basin and the use of its waters. There is considerable new material concerning the management of hazardous waste with a particular reference to potential alternatives to land disposal. Still another new section concerns radiation and radon gas.

Part Four discusses minerals, energy, and environmental issues associated with resource utilization and management. New material in Part Four includes expanded discussions of energy and new concepts related to use and management of energy; expanded discussion of the environmental impact of the development of mineral resources; and discussions of the nuclear accidents at Chernobyl and Three Mile Island.

Part Five discusses issues related to land use and decision making and attempts to draw together material from many parts of the book. Of particular importance is a discussion of environmental impact analysis and how such analysis is being used today in evaluating important environmental issues. A new case history concerning selenium toxicity in the San Joaquin Valley of California is presented, which draws together many of the important principles utilized in environmental impact analysis.

ACKNOWLEDGMENTS

Successful completion of any textbook that includes hundreds of photographs, illustrations, and case histories is not possible without the cooperation of many individuals, companies, and agencies. In particular I wish to thank the U.S. Geological Survey and individual state Geological Surveys, which have provided much of the information and concepts important in the development of environmental geology. To all those individuals who were so helpful in this endeavor I offer my sincere appreciation.

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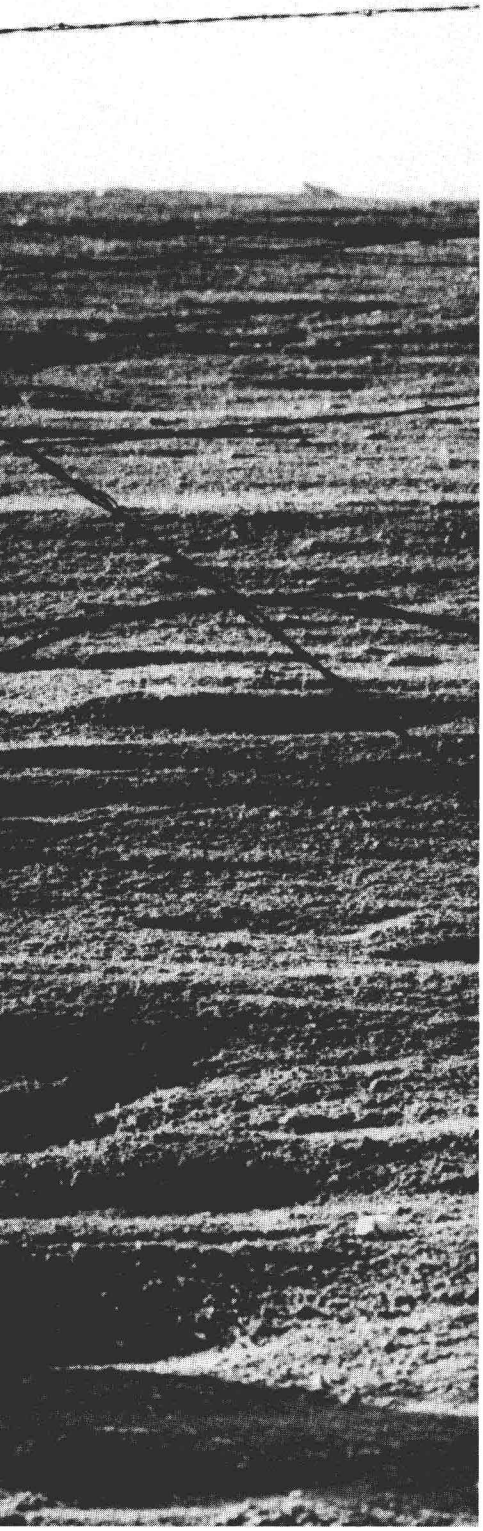
Contents

PART ONE
Philosophy and Fundamental Principles



Everything has a beginning and an end. Our earth began approximately 5 billion years ago when a cloud of interstellar gas known as a *solar nebula* collapsed, forming protostars and planetary sytems; life on earth began about 2 billion years later, or 3 billion years ago. Since then, a multitude of different types of organisms have emerged, prospered, and died out, leaving only their fossils to mark their place in earth's history. Several million years ago, on one of the more recent pages in earth history, our ancestors set the stage for the eventual dominance of the human race. As certainly as our sun will eventually die, we, too, will disappear. The impact of humanity on earth history may not be significant, but to us living now, our children and theirs, our environment is significant indeed.

Environmental geology is applied geology. Specifically, it is the application of geologic information to solving conflicts, minimizing possible adverse environmental degradation, or maximizing possible advantageous conditions resulting from our use of the natural and modified environment. This includes evaluation of *natural hazards* such as floods, landslides, earthquakes, and volcanic activity to minimize loss of human life and property damage; evaluation of the *landscape* for site selection, land-use planning, and *environmental impact analysis*; and evaluation of *earth materials* (such as elements, minerals, rocks, soils, and water) to determine their potential use as resources or waste disposal sites and the effects on human health, and to assess the need for conservation practices. In a broader sense, environmental geology is that branch of earth science that emphasizes the entire spectrum of human interactions with the physical environment.

Environment may be considered as the total set of circumstances that surround an individual or a community. It may be defined to include two parts: first, physical conditions, such as air, water, gases, and landforms that affect the

Photo courtesy of H. G. Wilshire, U.S. Geological Survey.

growth and development of an individual or a community; and second, social and cultural aspects, such as ethics, economics, and aesthetics, that affect the behavior of an individual or a community. Therefore, a complete introduction to environmental geology involves consideration of those philosophical and cultural aspects that influence how we perceive and react to our landscape, as well as the physical earth processes, resources, and landforms that may be more readily recognized by the observant earth scientist.

Chapters 1 through 4 provide the philosophical framework for the remainder of the book. Chapters 1 and 2 integrate the influence of cultural and physical activities into our total environment, and Chapter 3 introduces the physical environment through the geological cycle. The term *cycle* emphasizes that most earth materials, such as air, water, minerals, and rock, although changed physically and chemically and transported from place to place, are constantly being reworked, conserved, and renewed by natural earth processes. Chapter 3 also introduces basic earth science terminology and engineering properties of earth materials excluding soil, while Chapter 4 introduces soil in terms of its development, classification, engineering properties, and other factors important to land-use planning.

Chapter 1 Cultural Basis for Environmental Awareness

The cultural aspect of environmental awareness involves the entire way of life that we have transmitted from one generation to another. Therefore, to uncover the roots of our present condition, we must look to the past and consider various functional categories and social institutions that have developed. The functional categories of society that are especially significant in environmental studies are ethical, economic, political, aesthetic, and, perhaps, religious. The interactions between individuals and the institutions responsible for maintaining these functions are intimately associated with the way we perceive and respond to our physical environment.

ENVIRONMENTAL ETHICS

What started as the "quiet crisis" of the 1960s has evolved into what Stewart Udall, statesman and conservationist, refers to as the "crisis of survival" (1). More important than the certainty of a crisis is whether society believes there is a crisis. In other words, is there a new awareness that is destined to change our life-style, morals, ethics, and institutions, or is environmental concern just another prestigious fad that interests the intellectual community?

The evolution of ethics (Figure 1.1) is an important environmental trend. Aldo Leopold emphasizes the lack of ethics regarding property through the story of Odysseus, who, upon returning from Troy, hanged a dozen slave women for suspected misbehavior during his absence. His right to do this was unquestioned; the women were property, and the disposal of property was a matter of expediency, much as it is today. Although concepts of right and wrong were present in Greece three thousand years ago, these ethical values did not extend to slaves (2). Since that time, ethical values have been extended to many other areas of human behavior; but, apparently, only within this century has the relationship between civilization and its physical environment begun to emerge as a relationship with moral considerations.

Ecological ethics involve limitations on social as well as individual freedom of action in the struggle for existence in our stressed environment (2). A land ethic assumes that we are ethically responsible not only to other individuals and society but also to the total environment, that larger community consisting of plants, animals, soil, atmosphere, and so forth. The environmental ethic proposed by Leopold affirms the right of all resources, including plants, animals, and earth materials, to continued existence and, at least in certain locations, continued existence in a natural state. This ethic effectively changes our role from that of conqueror of the land to that of citizen and protector of the environment. This role change obviously requires us to revere and love our land and not, for instance, to allow economics to determine all land use.

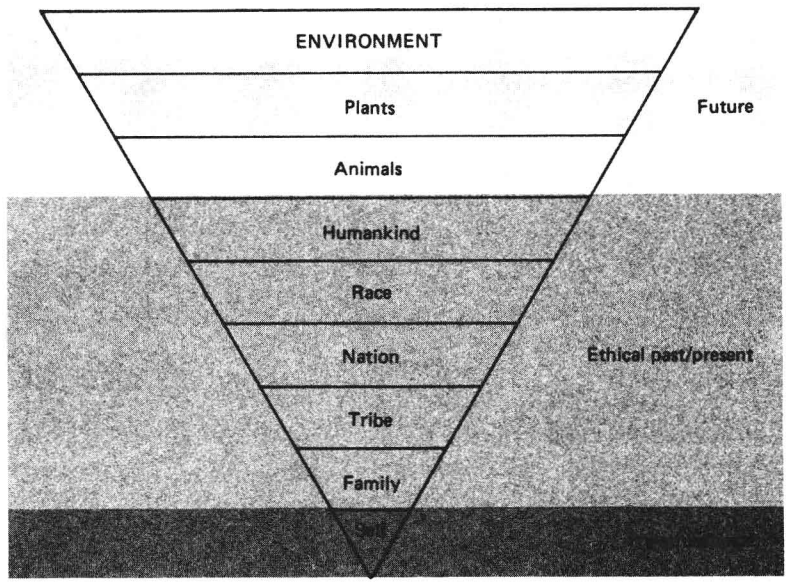


FIGURE 1.1
The evolution of ethics. (After Roderick Nash, "Do Rocks Have Rights?" *The Center Magazine*, November-December, 1977.)

A possible dichotomy or source of confusion exists between an ideal and a realistic land ethic. To give rights to the plants, animals, and landscape might be interpreted as granting to individual plants and animals the fundamental right to live. If we are to be part of the environment, however, we must extract the energy necessary to survive. Therefore, although the land ethic assigns rights for animals such as deer, cattle, or chickens to survive as a *species*, it does not necessarily assign rights to an *individual* deer, cow, or chicken. The same argument may be given to justify the use of stream gravel for construction material, or to mine and use the other resources necessary for our well-being. However, unique landscapes with high aesthetic value, like endangered species, are in need of complete protection within our ethical framework.

The implications of environmental ethics and moral responsibility are restated by Stewart Udall. Each generation has its own rendezvous with the land, for despite our fee titles and claims of ownership, we are all brief tenants on this planet. By choice or by default, we will carve out a land for our heirs. We can misuse the land and diminish the usefulness of resources, or we can create a world in which physical affluence and spiritual affluence go hand in hand (1).

The resounding message is that humanity is an integral part of the environment. A person is no more than any other being, and has a moral obligation to those beings who will follow. This obligation is to insure that they will also have the opportunity to experience the pleasure of belonging to and cooperating with the entire land community.

ECONOMIC AND POLITICAL SYSTEMS

Arriving in late fall of 1620, after two months on the stormy North Atlantic, 73 men and 29 women from the *Mayflower* confronted what they considered a wild and savage land. The colonists were not equipped with the skills and knowledge necessary to adapt quickly to their new environment. Regardless of these shortcomings and despite their fear of the wilderness, they brought three things that assured their success in the New World. First, they brought a new technology. Reportedly, when the Pilgrims landed, they did not even have a saw, but they did have Iron Age skills necessary to insure relentless subjugation of the land and its earliest inhabitants, Native Americans. In the long run, the ax, gun, and wheel asserted their supremacy. Second, the colonists brought with them the blueprints to remake the New World. They knew how to organize work, use work animals, and sell their surplus to overseas markets. Third, they brought with them a concept of land ownership completely different from that of the Native Americans, whose bonds to the land were religious and held by kinship with nature rather than exclusive possession. The colonists' idea of ownership involved an absolute title to land regardless of who worked the land or how far away the owner was. After the Native Americans were displaced, land use or abuse depended entirely on the attitude of the owner.*

America now, as in its early years, suffers greatly from the *myth of superabundance*. This myth assumes that the land and resources in America are inexhaus-

*Stewart Udall, *The Quiet Crisis*, pp. 25–27.