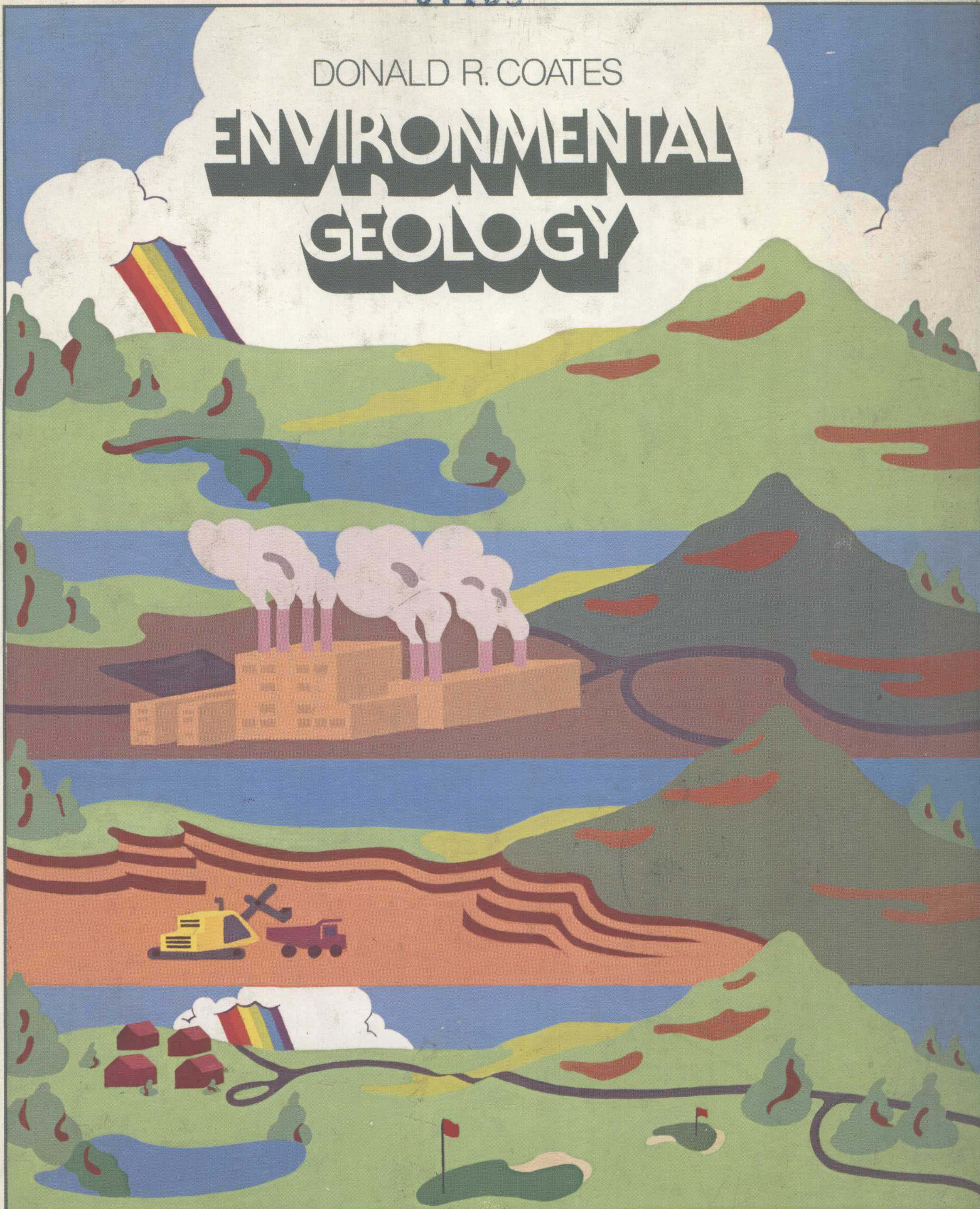
DONALD R. COATES

ENVIRONMENTAL GEOLOGY



ENVIRONMENTAL GEOLOGY

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This book is dedicated to
Jeanne, Cheryl,
Eric, and Lark
So they will know my love for the natural environment

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PREFACE

Geology is the science of the earth. Environmental geology is that subject area which relates this science to human activities. In this book, I hope to convey the importance of geology in environmental affairs and to show the close relationship between it and other science disciplines. These themes have been the focus of my teaching and research during the past 30 years, but my interest in these matters is of an even longer duration. Seeing the topsoil of friends' Nebraskan farmlands being blown away during the Dust Bowl years of the 1930s made an indelible impression and inspired in me a conservation-oriented philosophy. This culminated with my decision to move into geology and environmental activism.

The 1970s were called "the environmental decade," and now the 1980s are being hailed as "the energy decade." Clearly, environment and energy are intricately interwoven, and this relationship is a fundamental theme in this book. There are other themes, too, that we will examine. For example, we should realize that environmental concerns act as a two-way street—human activities greatly alter the land-water ecosystem, and natural processes, in turn, produce grievous losses to society. The use of proven geological principles and prudent engineering practices can reduce environmental deterioration and unnecessary costs. Throughout the text, nearly 700 illustrations and tables amplify and document this delicate balance between human society and the environment.

The post-1970 era has witnessed a renewed public and government awakening and a new perception of environmental matters, which have been manifested in many ways. Numerous environmental laws have been enacted to safeguard people and their investments from pollution and other forms of air, water, and land degradation. There have also been massive environmental changes in the twentieth century. These have been produced by a combination of urbanization, population growth, and new machines and fuels.

An important objective of environmental work and study should be to determine which types of construction and resource extraction methods minimize damages to the land-water ecosystem. This objective must be linked to attempts to understand and find solutions to the environmental problems that exist, whether natural or the result of human activity.

There are at least two differences in this book. One is the occasional use of advocacy. I believe it is important for readers to understand that scientists do have definite opinions and even prejudices on controversial topics. Of course, it is necessary that such beliefs be in accordance with known facts, but it is unrealistic to sit in the middle or on the fence on all issues. Another difference in this book is the use of numerous case histories aimed at providing an in-depth approach to the unusual breadth of topics that are fundamental to a comprehensive knowledge of environmental geology.

The book is divided into six parts. The five principal parts have been grouped to demonstrate the content and scope of the subject. Such organizational coherence should also aid the reader to integrate the material.

The first four chapters set the stage for the study of geology and provide a perspective on the topics of environmental geology. A conceptual base for the study is established and is then followed by historical insights and a thorough explanation of those physical systems that are necessary for a full understanding of the material.

Civilization is entirely dependent on the earth's resources and also the energy derived from the land and water. The next four chapters are devoted to showing this vital relationship and the importance of understanding the geologic components that provide the basic ingredients for industry, commerce, and engineering structures.

The four principal geologic hazards—volcanic activity, earthquakes, landslides, and floods—are discussed in the four chapters of Part 3.

The next five chapters demonstrate both the type and the magnitude of our environmental modifications. Such changes result as by-products, sometimes because of lack of knowledge, and sometimes because of an uncaring attitude about human endeavors; often human impacts that are deliberate also have unforeseen consequences.

The chapters in Part 5 discuss the different kinds of plans, policies, and decisions that constitute the fabric of environmental management. Emphasis is placed on positive methods to prevent or remedy problems, and urban affairs and waste disposal problems provide extensive histories and examples. The significance of environmental law is discussed in chapter 21.

Part 6 shows where we have been, where we are now, and where the future may take us. This part provides an evaluation of the environmental themes stressed in the book and an assessment of mankind's stewardship of the earth. Medical and military geology are briefly mentioned as two other topics in the larger field of environmental geology.

I am indebted to the following agencies and corporations that have generously allowed me to reproduce work that I developed for them as a consultant: U.S. National Park Service, U.S. Army Corps of Engineers, U.S. Department of Commerce, U.S. Geological Survey, New York State (NYS) Attorney General, NYS Department of Transportation, NYS Energy Research and Development Authority, Consolidated Edison of New York, Niagara Mohawk Power Corporation, and many private mining and law firms. Credits are provided at appropriate places throughout the book, and I extend my thanks to all of these persons for their help and generosity which enriched this book. Many scientists contributed their writing skills as reviewers for separate chapters, but Garry McKenzie, Ron Tank, Sam Upchurch, and Charles Babcock struggled through the entire text and offered numerous suggestions for improvement. For this I am deeply appreciative. Special acknowledgment is due John Conners. The John Wiley staff was exceptionally cooperative throughout the production of the book, and Donald Deneck is especially singled out for his infectious enthusiasm and insights. Thus this book is clearly the result of many minds, but its completion is owed to the moral and spiritual support of my wife, Jeanne.

D.R. Coates

CONTENTS

PART ONE FUNDAMENTALS 3

Chapter 1 Introduction 5
Chapter 2 Basic Concepts 15
Chapter 3 Historical Perspectives 28
Chapter 4 Physical Systems 44

PART TWO GEOLOGIC RESOURCES AND ENERGY 86

Chapter 5 Mineral Resources 90
Chapter 6 Energy and Fossil Fuels 133
Chapter 7 Energy: Alternative Sources 177
Chapter 8 Water Resources 224

PART THREE GEOLOGIC HAZARDS 256

Chapter 9 Volcanic Activity 260
Chapter 10 Earthquakes 289
Chapter 11 Landslides 330
Chapter 12 Floods 360

PART FOUR THE HUMAN MODIFICATION OF NATURE 396

Chapter 13 Surface Changes and Geoengineering 400
Chapter 14 Engineering Impacts on Water Supply 442
Chapter 15 Coastal Environments 474
Chapter 16 Human Impacts on Soil 503
Chapter 17 Weather, Climate, and Civilization 530

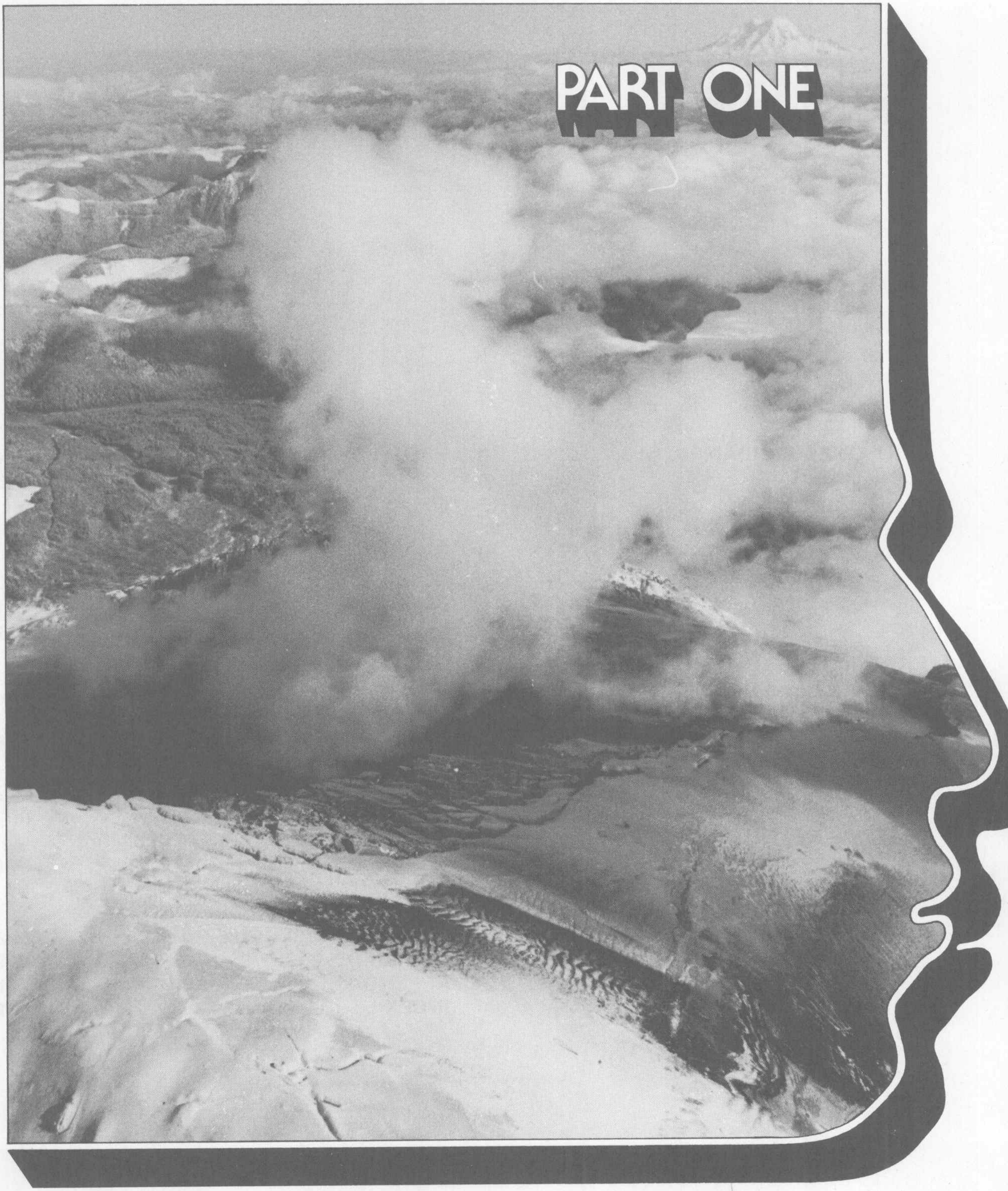
PART FIVE ENVIRONMENTAL MANAGEMENT 568

Chapter 18 Environmental Policy and Decision Making 572
Chapter 19 Urban Areas 607
Chapter 20 Solid Waste and Pollution 635
Chapter 21 Environmental Law 671

PART SIX SYNTHESIS AND EPILOGUE 692

GLOSSARY G1
APPENDIXES A1
INDEX I1

PART ONE



Volcanic peaks in the Cascade Range. Mt. St. Helens (foreground) is seen emitting gases as a precursor to the explosive eruptions that occurred in May, 1980. Another Cascade volcanic peak is in the far background. (Tom Zimberhoff/Sygma.)

Fundamentals

In order to profit from an exposure to environmental geology, the reader must first become aware and informed of the background rudiments that constitute the fabric of this science, which is a subdiscipline of geology. Therefore, the four chapters that comprise Part One have been designed to provide the necessary overview of the field and to indicate those building blocks that will enhance the understanding of the entire book.

Environmental geology is that area of specialization that takes mankind as the focal point of investigation. Thus it is an applied and practical science. The primary objective of "environmental" work and study should be to determine which types of construction and resource extraction methods minimize distortions of the land-water ecosystem. However, the subdisciplines of economic and engineering geology have now been joined by a consortium of other subdisciplines, and the purists in the various subfields may find themselves in conflict on some of the problems. For example, the economic geologist might point to the necessity for mining a particular resource at a specific locality, whereas the environmental geomorphologist might argue that such an action will cause irreparable damage to flow regimes of the watershed streams. There are no easy solutions for the complex problems of today, but they can be more appropriately addressed when evaluated by teams of interdisciplinary experts . . . not only in science and engineering, but also in the social and cultural fields.

Chapter 1 introduces the topic of environmental geology and shows how its fabric is interwoven into the entire character of nature and ecology. This setting along with the evolution of the subject matter provide a basis that delineates the timeliness of the topic.

Chapter 2 provides a listing of most of the salient themes that comprise the heart of the book. These basic concepts serve as benchmarks that occur repeatedly throughout the highly diverse field of environmental geology. Such coordinating principles show that, in spite of diversity, there is a smaller group of unifying ideas that serve to focus the material into an integrated pattern.

Chapter 3 discusses in panoramic fashion the environmental mood that has persisted throughout history and the feats that have been accomplished. This historical setting is amplified throughout the book to reinstate the old cliché, as paraphrased, "Whoever does not know or understand history is destined to repeat its mistakes." The degradation of the environment was not invented by modern man, because throughout all history mankind has routinely destroyed many aspects of his habitat. Fortunately many segments of society now realize the importance of inhibiting such molestation wherever possible, and the various conservation and environmental crusades bear witness to this mood.

Chapter 4 contains some information on physical geology so that a nonspecialist can read the remainder of the book with greater insight. The emphasis throughout this book is on the physical aspects of the environment; therefore, a basic understanding of the physical materials, and systems that affect them, are vital in the interpretation of environmental matters. Thus the principal purpose of Part One is to give the reader an increased awareness of the role of environmental geology in modern-day life.

Chapter One

Introduction

ACCIDENT AT THREE MILE ISLAND NUCLEAR PLANT JEOPARDIZES SAFETY OF LARGE REGION

The March 28 malfunction of a water pump and valve along with instrumental errors and human confusion at this atomic power facility set in motion a chain of events that has threatened 950,000 lives residing in the four-county area near the plant. (Harrisburg, Pennsylvania, *Times*)

SEVERE EARTHQUAKE DEVASTATES COASTAL RESORT AREA

The April 15 earthquake killed more than 235 people along a 100 km scenic coastline of the Adriatic Sea between Yugoslavia and Albania. (Belgrade, Yugoslavia, *People's Daily*)

DAMAGES FROM PEARL RIVER FLOODING IN EXCESS OF $600 MILLION

April 12 rains that dumped 50 cm of water in this Jackson, Mississippi, area caused the most extensive flooding during the century. The Pearl River crested at 13.2 m, which is 7.5 m above flood stage, and was 1.8 m higher than other floods of the century. Thousands had to be evacuated throughout the entire region and property losses were the greatest in the history of this area. (Jackson, Mississippi, *Ledger*)

RUNAWAY OIL WELL THREATENS ECOLOGY OF GULF COAST REGION

Oil leakage from an uncapped Mexican well in the Bay of Campecho started disgorging on June 3 more than 1 million gallons a day into the beautiful waters of the Gulf of Mexico. Parts of the Mexican and Texas coasts received the brunt of this spillage, which became the largest in history, exceeding the 54 million gallons from the wrecked tanker *Amoco Cadiz* of March 1978 along the French Coast. (Corpus Christi, Texas, *Bugle*)

ACID RAIN CONTINUES TO RUIN LAKES IN EASTERN NORTH AMERICA

New studies by Canadian and American scientists during 1979 have indicated that fallout from acid rain is ruining countless lakes in these two nations. Swedish scientists first called attention to this type of problem in the 1950s when thousands of their lakes had become so sterile that fish were decimated. The cause of the problem is polluted particulates and emissions from coal-burning power plants and industry. (*The Montreal Telegram*)

WESTERN INDIAN DAM DISASTER WORST IN HISTORY

Heavy rains on August 13 deluged the Machu River basin and caused the collapse of the dam and the surge of a 6 m wall of water which overwhelmed this city [Morvi] of 60,000. Total deaths will exceed the previous catastrophe at Vaiont, Italy, where 2200 were lost in 1963. (Morvi, India, *News*)

LARGEST HURRICANE OF THE CENTURY MAULS CARIBBEAN

The week of September 10th saw the spawning and full fury of the killer Hurricane David. Winds in excess of 240 km per hour, heavy rains, and storm surge have created havoc throughout the region and drowned more than 1100 people near Santo Domingo alone. The storm's fury also produced flooding along the American southeast coast. (*The Miami Herald*)

FREDERIC FLAYS GULF COAST

Only a massive evacuation of 400,000 people during the week of September 15th saved most lives in this ruined area. Mobile bore the brunt of the most ruinous storm in the history of the region. Hurricane Frederic with 210 km per hour winds along with waves and rain caused $1.7 billion in property damages throughout the Alabama-Florida coastal area, with $1 billion of this in Mobile. Because of sufficient warning, evacuation, and preparation, the loss of lives was reduced to nine people. (Mobile, Alabama, *Sentinel*)

FREAK TSUNAMI HITS FRENCH RIVIERA

An unsuspected powerful wave raced across the Mediterranean and washed ashore along this vacationer's haven, causing more than $10 million damages and drowning 13 who were not quick enough to race for safety and high ground. (Nice, France, *Journal*)

SOUTHERN CALIFORNIA ROCKED BY STRONG EARTHQUAKE

California has once again lived up to its reputation of producing large seismic activity. A 6.4 M earthquake, the largest since the San Fernando quake of 1971 in the United States, was felt over a several thousand square kilometer area in southern California. Much of the energy was concentrated in the verdant Imperial Valley during this October 16 event, and damages will run in the millions of dollars (El Centro, California, *Herald*)

These 10 events describe some of the types of environmental events that we witnessed during 1979. The headlines and lead paragraphs are factually accurate statements as they might have been described by the news media for those cities near the areas involved in the action. However, such hazards and disasters represent only one part of the study of environmental geology. Yet these are often the events that attract public interest and even the financial support from government sources, which provides for studies and engineering schemes aimed at protecting society from nature's power—or even nature from our own tampering of the earth's processes.

WHAT IS ENVIRONMENTAL GEOLOGY?

Is the terminology **environmental geology** redundant and unnecessary? Many geologists who view their science as *environmental*—related to the earth and changes on it, whether from natural causes or human activities—would say it is redundant. However, some fields of geology relate to mankind more than others. For example, **economic geology** is concerned with obtaining the natural resources of the earth in order to sustain the endeavors of mankind. **Engineering geology** is involved with the evaluation of earth materials and their stability during and after use in construction, to ensure the safety and welfare of those who use it. Since we live, work, and play on the surface of the earth, nearly all our human activities change or distort the land-water ecosystem. **Geomorphology,** the study of landforms and the processes that transform them is also used by the environmental geologist because it can determine the type and rate of change expected from mankind's alteration of the earth's surface (Fig. 1-1). In similar ways, many other subdisciplines in geology have important environmental roles to play. The **geophysicist** can provide valuable information about earthquakes; the **volcanologist** can assist in giving important information about volcanic hazards; the **geochemist** can give significant data on pollution and waste products; and the **geohydrologist** can offer helpful insights in water resource analysis and management. Thus environmental geology is a collage of many geological subdisciplines. Furthermore, it considers mankind as a force that changes nature. Finally, it is the practical application of the geological sciences in the service of society.

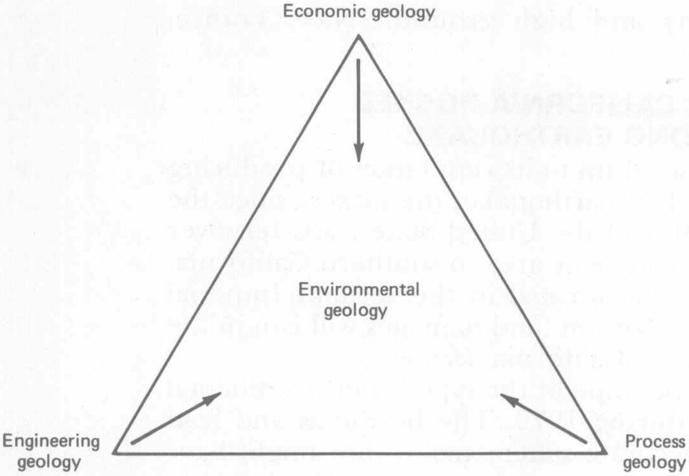


Figure 1-1 The principal fields of environmental geology.

Environment, Ecology, and Ecosystems

Environment describes the entire composition of our human surroundings and all our works. It also includes those conditions and materials that influence the character of the natural setting—such as the weather, water, soils, rocks, flora, and fauna. **Ecology** is the science that deals with the analysis and interpretation of life forms and their relation to the environment. The word *ecology* is derived from the Greek *oikos* meaning "place to live." The emphasis in ecology is placed on the organic, whereas in environmental geology it is placed on the inorganic. Thus, the ecologist is an environmental biologist who is primarily interested in the relationships among organisms, populations, and their community.

A **biotic community** is an assemblage of plants and animals that inhabit a common area and affect one other. The interactions of the biotic community with its physical environment constitute an **ecosystem.** Man as an organism cannot be divorced from these relationships, because he has an integral part in creating changes in both the organic and inorganic components that constitute the systems. Although there are many different types of ecosystems, they have common elements; ecosystems involve the transference of matter and energy into new forms that represent stability for the system. A forest ecosystem can become unbalanced when certain tree species are removed or killed by outside invaders. A drainage basin constitutes one variety of a land-water ecosystem in which the stream characteristics and its channel are adapted to the physical variables inherent in the basin . . . the soils, rocks, topographic properties, precipitation, and so forth. When we alter these components, physical changes will occur in the hydrologic character of the streams, which then affect the channel morphology.

The human environment consists of the earth's natural resources and the cultural, human modifications of them. It includes "the built environment," that is, the structures—buildings, roads, bridges, dams, tunnels, canals—that we *build*, often in a disrupting way. In the broadest sense, **natural resources** are those materials, organisms, localities, and earth processes that are useful or of value to society. If such a definition is adopted, nearly everything on the earth qualifies as a resource—the air, the water, the soil, many minerals and rocks, organisms, and even solar energy. The visual amenities that comprise a beautiful recreational resort are resources for that locality. Similarly some of the earth processes such as waterfalls, geysers, ocean waves, and tides also constitute a resource.

To sustain the human environment, two

different classes of resources are necessary: renewable and nonrenewable resources. Renewable resources are living organisms and those resources that are continuous and enduring. Nonrenewable resources are metals and fossil fuels. When they are mined out, there will be no second crop. These resources are produced at such slow rates that new sources cannot be anticipated within a normal human lifetime. We must remember that the human environment is a **biosphere,** or that part of the planet in which life exists and forms an interacting process. For example, solar energy is a resource that is available and may activate chemicals in water, soil, and rock, which then become the building blocks for living things.

Some Fields of Interest

The scope of environmental geology is so broad that it encompasses not only the subdisciplines of geology but also areas that are of interest to other physical sciences, as well as the biological and social sciences. Later in this book we will look at some of the special aspects of engineering, geography, landscape architecture, and soil science. Thus environmental geology is a multidiscipline with an interdisciplinary character.

The subject matter of environmental geology includes the human-related aspects of earth materials, earth processes, landforms, and certain rate and time considerations. It comprises a wide spectrum of such topics as the location and mining of natural resources; evaluation of the physical changes in the land-water ecosystem when human action rearranges earth materials or interferes with natural processes; assessment of earth forces and hazards that affect human health and safety; and determination of energy and sediment systems for use, storage, and elimination of waste products. Implicit in the knowledge of these topics is the inclusion of such themes as the conservation of materials and processes, and the reclamation of damaged terrain. Thus, environmental geologists become involved in policy matters. They become part of the decision-making process when it involves planning and management of an arena where they have expertise. This is even true when time is a component and when predictions of the future are necessary. For example, the planning and construction of some developments are linked to certain benefit-cost ratios, which in turn determine the type and size of the structures. Nuclear power plants in the United States are built for a lifespan of 40 years, so the engineering of the buildings is linked to soil and rock stability during that period. Many flood-control projects are designed for the 100-year flood event, and storm water sewers in many cities are designed for the 25-year flood event. The data that the environmental geologist supplies in such enterprises are crucial to the design of the project. A primary objective of environmental geology is to aid in those studies and decisions in order to minimize the human impact on the environment. In accomplishing these goals it is vital that geologists interact with all interested parties and authorities. Only through the establishment of strong communication systems and cooperation can environmental justice be achieved.

OUR RELATIONSHIP TO NATURE

We *are* part of nature. What we are and what we produce are both **natural** and **cultural.** As part of the natural and animal kingdom we have the same needs and drives as other members of this realm, such as protection, nourishment, shelter, and reproduction. Our cultural characteristics are seen in our activities and products. In this book, however, the word **nature** will be used to mean only those parts of the environment that are not our creations. We will talk about the natural forces of erosion. Waves erode beaches and transport sediments, redepositing them elsewhere, just as streams erode their channels and banks. Therefore, change is an integral part of nature. The mountains and hills will eventually be eroded and lowered, regardless of our presence, and such denudation is referred to as **normal, natural,** or **geologic erosion.** However, when man enters the scene, which he may change by design or by careless neglect, setting up slope configurations, disturbing the soil, or modifying processes, a new set of stresses are superimposed on the norm. This additional force accelerates natural process changes and creates what is termed **man-induced** or **accelerated** erosion.

It is important for environmental geologists to know what is normal and what is in harmony with natural systems, for without such a yardstick they would be unable to evaluate abnormal human influences. The prediction of the type, direction, and magnitude of manmade changes in natural systems is therefore dependent on recognition and precise measurements of normal equilibria. Natural forces are constantly at work, changing the landscape, weathering the rocks, producing soils, and supplying products to streams for removal. Such land-water ecosystems achieve certain levels of balance and growth. For example, soil scientists use the terms **tolerable erosion** to define those processes acting on soils in which the production and delivery systems are stabilized. This may amount to as much erosion as 5 tons a year per acre (1835 kilograms per year per hectare) in humid regions soils. Such losses are canceled and not harmful because new soil is being created at similar rates of growth.

Our influence on natural systems has been alarmingly accelerated during the twentieth century. As we have become more populous and our tools of destruction more efficient there are fewer and fewer places that remain untrammeled and unmolested. The exponential growth of the human species when coupled with unmitigated, wanton, and relentless desecration of the earth's air, land, and waters has led to what some observers call **the environmental crises.** Those that champion this view call attention to the deteriorating character of soils, increasing levels of pollution, expanding populations with alarming numbers of starving and malnourished peoples, droughts, floods, energy problems, and so on.

Thus, the two aspects of the relationship that exists between man and nature constitute a **law of reciprocity.** On the one side, man creates multitudinous changes in nature's materials and processes. These impacts invariably cause imbalances, which can lead to problems and hardships. The other side of this relationship consists of those influences and impacts that nature forces on man. These range from the dramatic effects produced by earthquakes and hurricanes to the presence of mountain ranges that restrict man's mobility and habitations. The study of the physical influences of nature on man is known as **anthropogeography.**

Although the term *anthropogeography* is rarely used now, specialization in the subject was in vogue as late as the 1930s. The discipline was initiated in 1817 with the works of Karl Ritter in Germany and amplified in the writings of Ratzel and by Ellen Semple in the United States. The purpose of the discipline is to show the importance of the geographic (environmental) setting for human life, especially in settlement patterns and cultural designs and activities. When extended to the extreme, the environmental setting has been said by some to even affect the human level of civilization and the physical appearance of humans. Hippocrates, writing in the fourth century B.C., attributed the small stature of the Scythians to the severe climate and barreness of their lands, whereas the Phasians' gross body habit and yellow complexion stemmed from their marshy environment. Even Aristotle used geographic explanations in propounding the assumed superiority of the Greeks over the barbarians, whereas Roman writers explained their ability to reach advanced political and cultural levels by referring to an environmental doctrine. More recently, Ellsworth Huntington throughout his publications had argued that climate is one of the controlling factors of history. He suggested that the development of human races, their attitudes, and their achievement levels is dependent on whether their climate is vigorous and seasonal, or uniform and hot. He believed that the vigorous climates were responsible for the ascendancy of the European peoples, and that tropical climates caused slower development in inhabitants.

There are, however, other and more likely ways in which the environmental setting has influenced human behavior and residence. The physical descriptions of lands have often been directly responsible for colonization and settlement patterns. The early biblical accounts of Canaan as a land flowing with milk and honey was sufficient inducement for the Israelites to invade and possess those lands. The favorable accounts of eastern United States by foreign travelers after the Revolutionary War was responsible for increasing the number of immigrants. In a similar manner the descriptions of the American West, especially after the Civil War, led to the accelerated development and growth of that region. Although the roots of World War II were complexly interwoven with such factors as the harshness of the Versailles Treaty and ideological conflicts, environmental considerations, termed "geopolitical" at the time, were very significant. Germany spoke of the need for "lebensraume" (more living space for their population) and the requirement of more mineral wealth. The war was frequently called the war of the "haves" (the Allies) versus the "havenots" (the Axis nations).

Even the roots of civilization, according to some writers, can be correlated with the human necessity to cope with the environment. For example, Wittfogel developed the thesis that the great early civilizations had one important common element—the need to manage water resources. It was the need to harness and use this resource that provided the unifying force in society. These "hydraulic civilizations" required enormous water importation schemes to irrigate the semiarid lands. Skilled scientists and engineers were needed to evaluate water and food resources and design the canals and water distribution systems. A labor force was necessary to dig the ditches, terrace the lands, and farm the fields. Managerial staff had to deal with the apportionment of the waters, and laws had to be formulated to equalize and set limits to wages, costs, and policies. Thus all the important elements of society were focused and influenced by the "water-based" economy, and the administration of the system revolved around water-based resources.

Environmental settings can be either a positive or negative factor in settlement patterns. Of the 13 largest cities in the United States, only one (Denver) is not located on a major water body. The early population of the United States was concentrated along the Atlantic Ocean or the rivers of the Fall Line (the intersection of the Appalachians and the Piedmont Provinces) where hydraulic energy was available because of steep river gradients. Here the 3 million population was concentrated, with less than 5 percent of the people living more than 10 mi (16 km) from the Fall Line or the coast. Whereas water has attracted settlements, mountains and deserts have generally been barriers or unfavorable for habitation. Thus in mountain terrain transportation is arduous, soils are poor or infertile, temperatures and storms may discomfort inhabitants and produce hazards, and insularity causes poor communications and an unsatisfactory exchange of goods and services. Under such conditions inhabitants become provincial and their rate of "progress" is inhibited.

Finally, what may be called the "human spirit" may also be a reflection of environmental conditions as manifested in literature, art, and music. Sir Archibald Geikie once wrote:

The landscapes of a country, the form, height and trend of mountain-ranges, the position and extent of its plains and valleys, the size and direction of its rivers, the varying nature of its soils and climate, the presence or absence of useful minerals, nearness to or distance from the sea, the shape of the coast-line whether rocky or precipitous, or indented with *creeks and harbors - all these and other aspects of the scenery of the land have contributed their share to the molding of natural history and character [1905, p. 1-2].*

Geikie also pointed out how the "placid scenery" of England influenced the literary works of such writers as Chaucer, Shakespeare, and Milton. The character of the English-Scotch border with its rivers, glens, and dales was clearly the source of inspiration for many of Robert Burns' poems wherein he captures that mood and essence.

INFORMATION SOURCES

Although the term *environmental geology* was first used in the modern sense in 1962 (Betz), those aspects that now comprise the discipline have been used and practiced for millennia. For example, since early times we have mined materials for our use. However, the first book to sound the alarm was written by George Perkins Marsh in 1864, *Man and Nature.* In it Marsh stated that man had become so powerful and destructive that he was placed in jeopardy by his own ability to cope and survive in the deteriorating environment. Similar themes were echoed in such books as *Vanishing Lands* (Jacks and Whyte, 1939), *Our Plundered Planet* (Osborn, 1948), and *Man's Role in Changing the Face of the Earth* (Thomas, 1956). Dasmann was the first to employ the term *environmental* in the modern context in his book, *Environmental Conservation* (1959). In the 1960s, a new wave of highly popularized paperback books was published. By the 1970s, the movement was in full bloom, and this flowering has led some to call this period **the environmental decade.**

Each of the geology disciplines has made contributions to environmental geology in their more specialized books and journals, and a host of social science books has dramatized the wide range of problems. However, no country, discipline, or set of books or journals has a monopoly on the literature dealing with environmental geology. Indeed, the publications have become so vast and staggering that they are contributing to a printed-page explosion, making it impossible to keep up with all the sources. There are countless journals, magazine symposia proceedings, government reports, agency reports, and a huge "gray literature" in the form of open-file communications, as well as environmental impact statements written by scientists in government, industry, consulting firms, and academic institutions. This bewildering array of documentation on environmental affairs is continuing at a frantic and accelerating pace. To those who specialize in its analysis, I wish them luck and good reading.

Perspectives—WHY STUDY ENVIRONMENTAL GEOLOGY?

Now that we have some background information on the topic of environmental geology, why should we teach or study it? One of the answers should be "because it is here." Only an ostrich or a slumbering Rip Van Winkle can be oblivious to what is steadily happening on the environmental scene. It is a rare week that passes without headlines blaring of droughts, floods, earthquakes, energy crises, nuclear site disasters, pollution, strip mining, starvation and malnutrition, and many other related topics. For example, the September 13, 1979 front-page headlines of the Binghamton *Evening Press* carried four environmental stories: "Hurricane Frederic rips 4 states," "Indonesia quake dumps town into the sea," "Eruption kills 9 on Mt. Etna," and "Acid rain forecast getting worse."

The status of the environment has also