# EARTH SCIENCE AND THE ENVIRONMENT

THOMPSON • TURK

# Earth Science and the Environment

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# Preface

Earth Science is a study of the world around us. On your way to work or school you may pass through landscapes that were created by geologic processes. Lofty mountain ranges, fertile prairies, and massive glaciers are familiar through travel, books, and film. Nearly half of the world's population lives adjacent to coastlines and many of us have stood along the shore mesmerized by the waves and the beauty of the sculpted rocks along the beach. Sometimes we open a window to see if the weather is warm or cold, rainy or snowy. Finally, who hasn't gazed at the sky and wondered about distant planets, stars, and faraway galaxies?

Many of the changes that occur within the Earth, its oceans, and its atmosphere affect our lives. Every year tragic losses of life and property occur throughout the world when volcanoes erupt or earthquakes topple buildings, twist highways, and destroy cities. Other geological processes form fuel deposits and ore bodies and have obvious impacts on modern society. Ground-water pollution, the effects of CFCs on the ozone layer, the effects of acid rain on forests and lakes, and changing climate all alter our environment.

The primary purpose of this book is to explain fundamental Earth processes to students who have little or no science background. Earth science is not a set of facts to learn or to memorize. It is, rather, the study of an active, changing, and growing *science of the Earth* that will help you to transform casual observations into understanding.

In this book we explain how discoveries are made and how theories develop. Many of the ideas presented have only recently been developed and some hypotheses are controversial. One example of a hotly debated idea is the hypothesis that giant meteorite impacts caused several catastrophic climate changes that were followed by mass extinctions. Possible climatic changes from the greenhouse effect is another example of a modern scientific controversy. We introduce these and other environmental issues not as advocates of any particular side of the debates, but as scientists studying the world around us. We start by carefully separating observations and experimental results from conclusions, and continue by analyzing the reliability of the data. With these objectives in mind, we have created a text that *teaches* Earth science and *relates* it to many important modern issues.

## Teaching Options

Earth science is a broad field covering many separate scientific disciplines. During the development of this book we communicated with many geologists, geographers, meteorologists, oceanographers, and astronomers who teach Earth science. The pedagogic strategy of this book was derived from several themes emphasized by these scientists.

We recognize that not all students in introductory Earth science courses have backgrounds in chemistry and physics. Therefore, this text explains the workings of planet Earth accurately, but in a language and style that is readily understood by students with little or no college-level science or mathematics background.

An exhaustive treatment of all the topics introduced in this course would involve several books, not just one. While recognizing the inherent limitations of a survey course, we offer balanced coverage of *all* topics. Few professors will assign the entire book in a quarter or semester course; there is just too much material. In order to accommodate a wide range of course emphases, each of the seven units offers a holistic introduction to the focus of the unit. Both the units and the chapters themselves are written to be as independent as possible so that individual professors can pick the topics that are important to their course requirements. Furthermore, students can pursue any subject by independently reading units or chapters that interest them. This book is designed to be a useful reference for all Earth science topics in addition to being a text for a quarter or semester-long course.

### Sequence of Topics

Just as different Earth science courses have many different emphases, a wide variety of logical sequences exist. We have chosen to introduce the Earth's materials and

geologic time, and then to start from the Earth's interior and work outward. Thus the book is divided into seven units:

Unit I: The Earth and Its Materials

Unit II: Internal Processes

Unit III: Surface Processes

Unit IV: The Oceans

Unit V: The Atmosphere

Unit VI: Astronomy

Unit VII: Natural Resources

Some instructors may prefer other sequences. The unit structure of this book allows any alternative topic sequences.

## Special Features

***Special Topics*** In a survey course where many subjects are introduced, it is refreshing to read more in-depth discussions of selected topics. Therefore, interesting special topics are set aside and highlighted in color. These topics are not necessary to the sequential development of each chapter, and they can be ignored without losing the flow of the chapter. However, from our own teaching experience we have learned students are drawn into a subject by specific examples, and at the same time the examples illustrate basic ideas of each chapter. Three types of special topics are included. **Focus On** boxes cover interesting topics in traditional Earth science such as "The Upper Fringe of the Atmosphere." Other boxes, titled, **Earth Science and the Environment** cover currently-active environmental topics such as "Nuclear Waste Storage in North America." Finally, short **Memory Devices** aid the student by explaining relationships between word roots and their modern definitions.

***Chapter Review Material*** Important words are highlighted in bold type in the text. These **key words** with their corresponding page numbers are then listed at the end of each chapter for review. In addition, a short **summary** of the chapter material is provided at the end of each chapter.

***Questions*** Two types of end-of-chapter questions are provided. The **review questions** can be answered in a straightforward manner from the material in the text, and allow the student to test himself or herself on how completely he or she has learned the material in the chapter. On the other hand, **discussion questions** challenge students to apply what they have learned to an analysis of situations not directly described in the text. These questions often have no absolute correct answers.

***Appendix and Glossary*** A **glossary** is provided at the end of the book. In addition, **appendices** cover the elements, mineral classification and identification, metric units, rock symbols, and star maps.

***Interviews*** Often students wonder, what type of life would I lead if I decided to make Earth science my career? With whom would I work and trade ideas? What intellectual rewards would make my life challenging? In order to open a window into these subjects, we have interviewed four prominent scientists whose theories are discussed in the text. These interviews include a brief look at both their professional and nonprofessional lives and are included to encourage students to think about careers in Earth science.

## Ancillaries

This text is accompanied by an extensive set of support materials.

### Instructors Manual with Test Bank

The Instructors Manual, written by the authors of the text, provides teaching goals, alternate sequences of topics, answers to discussion questions and a short bibliography. An extensive test bank, written by Christine Seashore, is included in the instructors manual as well. The test bank includes multiple choice, true or false, and completion questions for each chapter of the text.

### Computerized Test Bank

A computerized version of the test bank is available for both IBM PC and Macintosh. These versions allow instructors the flexibility to add their own questions or modify existing questions. Easy-to-follow commands make customizing tests and quizzes simple and efficient. Instructors without access to computers may receive customized tests within five working days by calling 1-800-447-9457. FAX service is also available.

### Study Guide

The Study Guide, written by Lois Gundrum, provides review and study aids to further enhance the students' understanding of the text. The Study Guide includes chapter objectives, chapter outlines, multiple choice questions that test vocabulary, objective questions that test recall of important factual information, and short answer questions that require students to use and apply important chapter concepts. The student is also asked to think critically about environmental issues or problems.

### Saunders Earth Science Videodisc

The Saunders Earth Science Videodisc is a 60 minute videodisc with more than 1500 still images and a collec-

tion of video clips from Encyclopedia Brittanica and other sources, in addition to animated figures from the text. A directory will accompany the videodisc and will include instructions, barcode labels and reference numbers for every still image and video clip, organized according to the table of contents for the text.

## Overhead Transparencies

A set of one hundred overhead transparencies includes full-color illustrations from the text for use in the classroom or the laboratory.

## 35mm Slides

The Saunders Earth Science Slide Set which includes five hundred 35mm slides of illustrations and photographs covering a wide range of topics such as physical and historical geology, oceanography, meteorology, and astronomy is available for use in the classroom or the laboratory.

## Acknowledgments

We have not worked alone. The manuscript has been extensively reviewed at several stages and the numerous careful criticisms have helped shape the book and ensure accuracy:

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Earth science is a visual science. We can readily observe landforms and weather patterns in our daily lives. Although we cannot see many processes, such as movements of tectonic plates, collisions of air masses, or the violent interior of a galactic nucleus, these events can be visualized through an artist's eye. George Kelvin has painted most of the illustrations in this book. It has been a pleasure to work with him.

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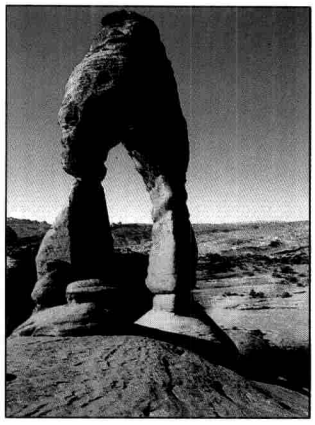
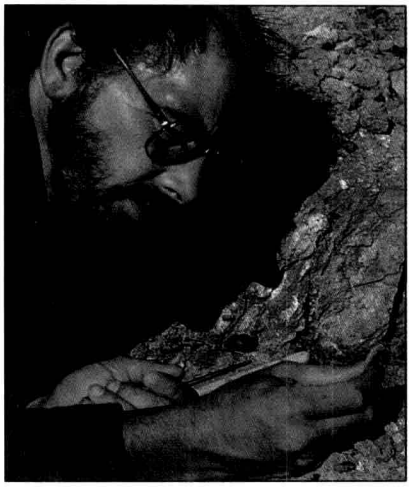
# Contents Overview





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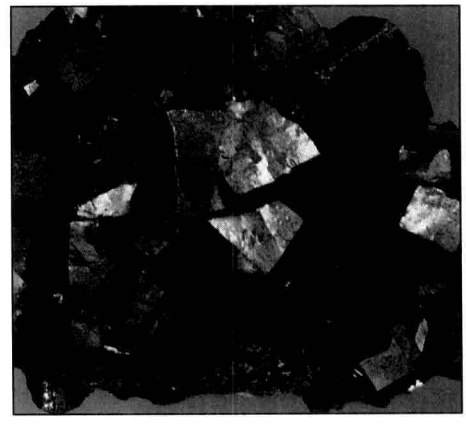

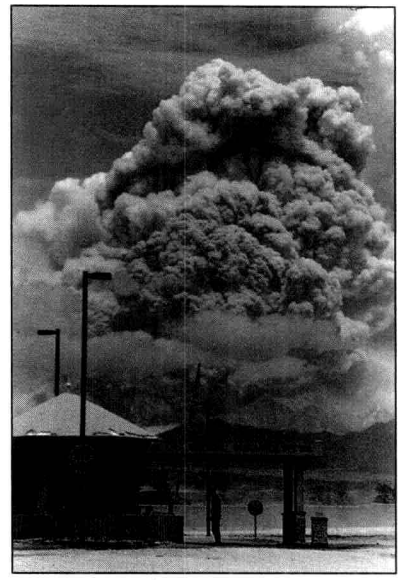



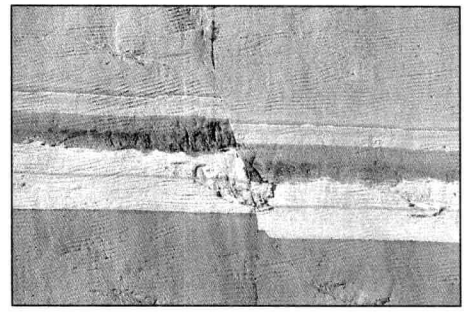



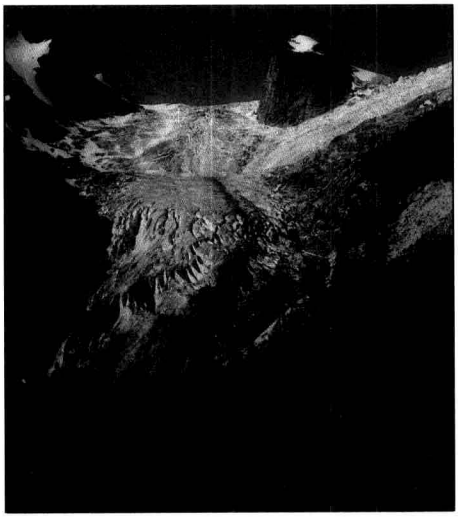



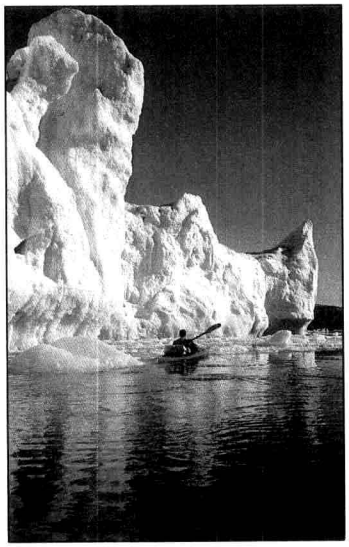

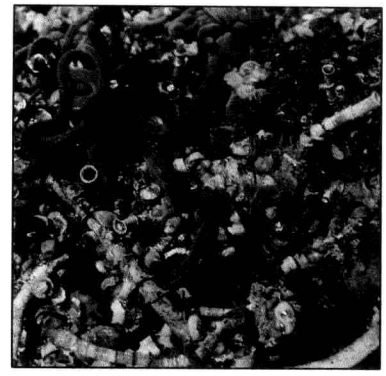





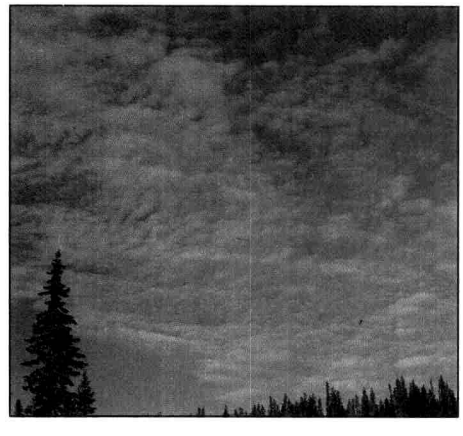

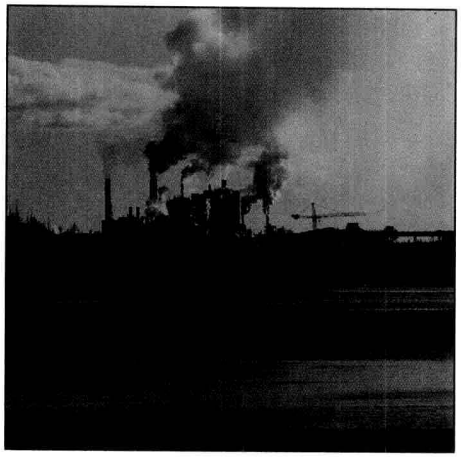

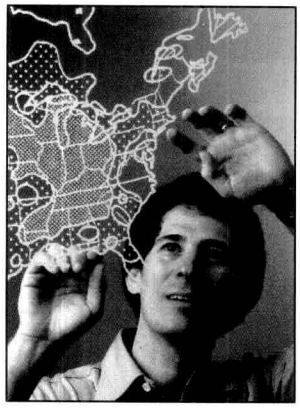

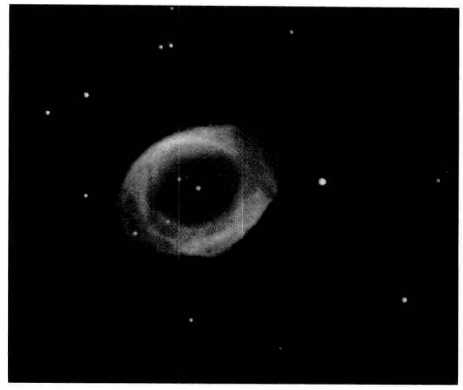



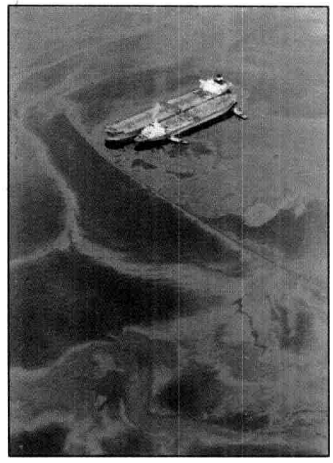

# Earth Science and the Earth's Origin

1



Imagine walking along a rocky coast as a storm blows in from the sea. Wind whips the ocean into whitecaps, gulls hurtle overhead, and waves crash onto shore. Before you have time to escape, blowing spray has soaked your clothes. A hard rain begins as you scramble over the last rocks to your car. During this adventure, you have interacted directly with the four major realms of the Earth. The rocks and soil underfoot are the surface of the **solid Earth**. The rain and sea are parts of the **hydrosphere**, the watery part of our planet. The wind is the **atmosphere** in motion. Finally, you, the gulls, the beach grasses, and all other forms of life in the sea, on land, and in the air are parts of the **biosphere**, the realm of organisms. Earth scientists study all of these realms.

Figure 1–1 shows that the solid Earth is by far the largest of the four realms. The Earth's radius is about 6400 kilometers, 1 1/2 times the distance from New York to Los Angeles. Nearly all of our direct contact with the solid Earth occurs at or very near its surface. The deepest wells ever drilled penetrate only about 10 kilometers, 1/640 of the total distance to the center.

• A storm builds along the Oregon coast.

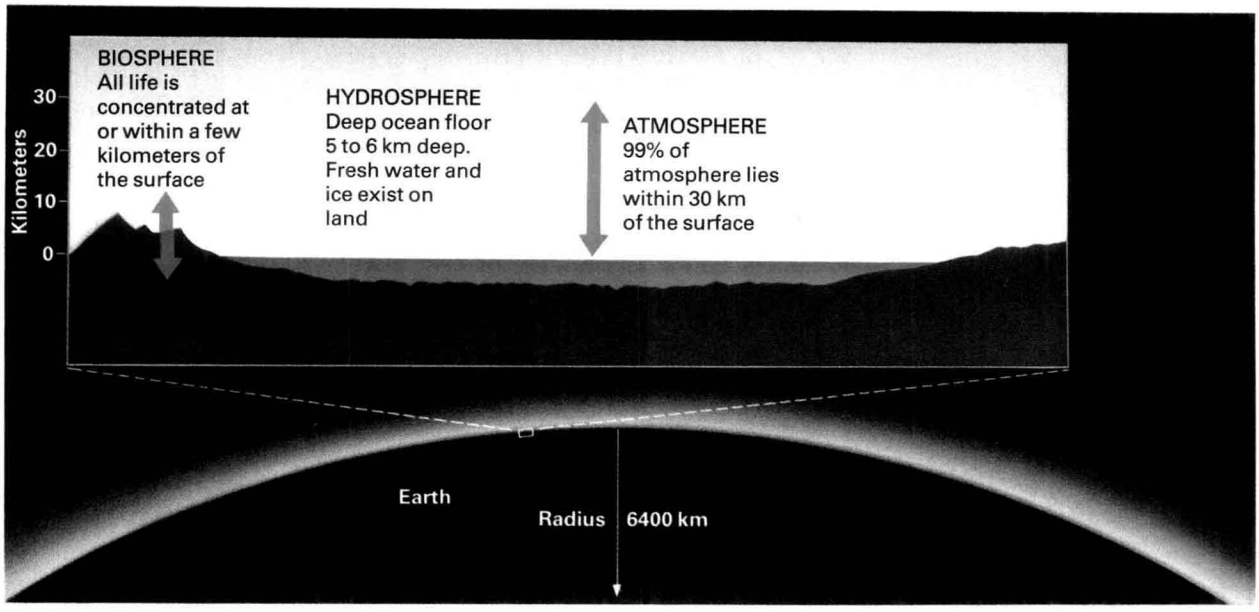


**Figure 1–1** A schematic view of Earth showing the solid Earth, the hydrosphere, the atmosphere, and the biosphere.

The hydrosphere includes water in streams, lakes, and oceans; in the atmosphere; and frozen in glaciers. It also includes ground water that soaks soil and rock to a depth of 2 or 3 kilometers.

The atmosphere is a mixture of gases, mostly nitrogen and oxygen. It is held to the Earth by gravity and thins rapidly with altitude. Ninety-nine percent is concentrated in the first 30 kilometers, but a few traces remain even 10,000 kilometers above the Earth's surface.

The biosphere is the thin zone inhabited by life. It includes the uppermost solid Earth, the hydrosphere, and lower parts of the atmosphere. Land plants grow on the Earth's surface, with roots penetrating at most a few meters into soil. Animals live on the surface, fly a kilometer or two above it, or burrow a few meters underground. Sea life also concentrates near the surface, where sunlight is available. Some bacteria live in rock to depths of a few kilometers, and a few wind-blown microorganisms are found at heights of 10 kilometers or more. But even at these extremes, the biosphere is a very thin layer at the Earth's surface.

If you could drive a magical vehicle from the center of the solid Earth to the outer fringe of the atmosphere at 100 kilometers per hour, you would be within the Earth for 64 hours. In another 20 minutes you would pass through nearly all of the atmosphere and would enter the rarefied boundary between Earth and space. You would pass most living organisms in a few seconds, and the entire biosphere in 6 minutes.

An understanding of the Earth is valuable simply because humans are curious creatures; we wonder about the world around us. As you drive on a highway or walk along the seacoast, you experience the world more richly if you understand how the hills and rocks formed and why the sky is stormy or clear. Looking into the sky, you might wonder how far away the stars are or what is our significance in the Solar System or the Universe.

Earth science also has a practical side. We depend on fossil fuels—coal, oil, and natural gas—and mineral resources such as metals, sand, and gravel. We also depend on soil to support crops and other plants. Weather affects us daily, and climate influences agriculture, travel, and land use. Recently, Earth scientists have learned that industrial activities such as burning of fossil fuels and release of pollutants from other sources may now be altering the atmosphere and changing global climate. The oceans provide food and sea lanes for commerce and travel. Clean, fresh water is vital to agriculture, industry, and human consumption.

**Earth science** is a broad term for several sciences that study the Earth and extraterrestrial bodies: geology, oceanography, climatology, meteorology, and astronomy. Let us briefly consider each.

## 1.1 Geology and the Solid Earth

**Geology is the study of the solid Earth: its rocks and minerals, the physical and chemical changes that occur on its surface and in its interior, and the history of the planet and its life.**

Geologists seek to understand both the interior and the surface of the Earth. They study our planet as it exists today and look back at its history.

## The Earth's Materials: Rocks and Minerals

Below a thin layer of soil and beneath the ocean water, the outer layers of the Earth are composed entirely of **rock**. Geologists study these rocks, their composition, their formation, and their behavior. Even a casual observer sees that rocks are different from one another: some are soft, others hard, and they come in many colors. Most rocks are composed of tiny, differently colored grains, each of which is a **mineral** (Fig. 1–2).

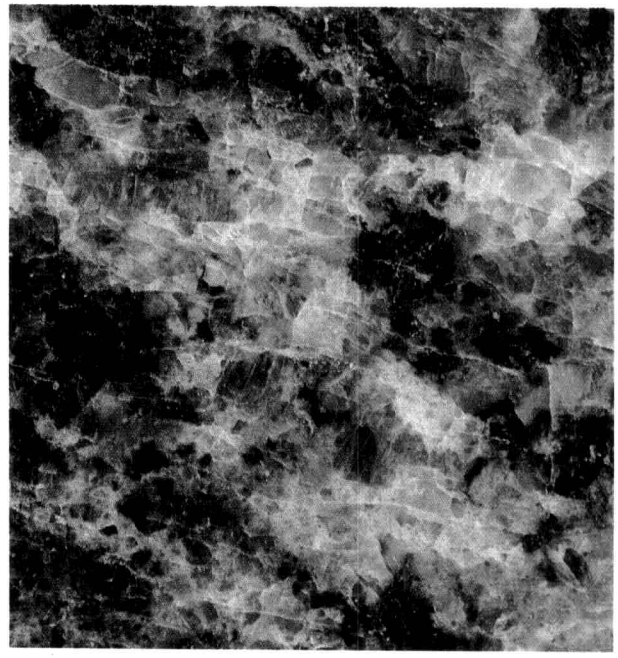

**Figure 1–2** Each of the differently colored specks in this rock is a mineral.

## The Earth's Internal Processes

The Earth is an active planet. Events and processes that occur or originate within the Earth are called **internal processes**. Earthquakes and volcanoes are internal processes that are familiar because they occur rapidly and dramatically. However, the same mechanisms that cause volcanoes to erupt and earthquakes to shake the land also cause slower events such as mountain building and movements of continents. Builders, engineers, and city planners might consult with Earth scientists and ask, "What is the probability that an earthquake will occur in our city? How destructive is it likely to be? Is it safe to build skyscrapers or a nuclear power plant in the area? or What is the likelihood that a volcano will erupt to threaten nearby cities?"

## The Earth's Surface Processes

Most of us have seen water running over soil after a heavy rainstorm. You may have noticed that the flowing water dislodges tiny grains of soil and carries them downslope. After a few hours of heavy rain, an exposed hillside may become scarred by gullies. If you stretch your imagination over thousands or millions of years, you can envision flowing water shaping the surface of our planet, enlarging tiny gullies into great valleys and canyons (Fig. 1–3). These and other natural activities that change the Earth's surface are called **surface processes**.

Both theoretical and practical questions arise when we think of surface processes. Why do desert landscapes differ from those in humid climates? How do river valleys change with time? Is a flood likely to destroy a housing development in this valley? How will acid rain affect a lake where people swim and fish? How will soil erosion affect our ability to grow crops and our food supply?

Eruption of Ngauruhoe volcano, New Zealand. *(Don Hyndman)*