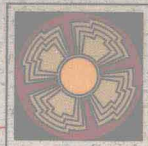


PHYSICAL GEOLOGY

EXPLORING THE EARTH



James S. Monroe

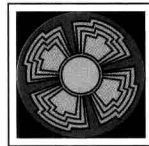


Reed Wicander

PHYSICAL GEOLOGY

EXPLORING THE EARTH

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Frederic Edwin Church was one of America's premier landscape painters of the mid-nineteenth century. His paintings were magnificent in scope and sought to integrate realism with the majesty of nature. *Cotopaxi*, which shows the Ecuadoran volcano erupting, is an excellent example of Church's work. This painting was chosen for the cover because of its realism and to show how geology plays an integral part in the human endeavor.

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P R E F A C E

The Earth is a dynamic planet that has changed continuously during its 4.6 billion years of existence. The size, shape, and geographic distribution of the continents and ocean basins have changed through time, as have the atmosphere and biota. Over the past 20 years, bold new theories and discoveries concerning the Earth's origin and how it works have sparked a renewed interest in geology. We have become increasingly aware of how fragile our planet is and, more importantly, how interdependent all of its various systems are. We have learned that we cannot continually pollute our environment and that our natural resources are limited and, in most cases, nonrenewable. Furthermore, we are coming to realize how central geology is to our everyday lives. For these and other reasons, geology is one of the most important college or university courses a student can take.

Physical Geology: Exploring the Earth was designed for a one-semester introductory course in geology that serves both majors and nonmajors in geology and the Earth sciences. It was written with the student in mind. One of the problems with any introductory science course is that the students are overwhelmed by the amount of material that must be learned. Furthermore, most of the material does not seem to be linked by any unifying theme and does not always appear to be relevant to their lives.

One of the goals of this book is to provide students with a basic understanding of geology and its processes and, more importantly, with an understanding of how geology relates to the human experience; that is, how geology affects not only individuals, but society in general. With this goal in mind, we introduce the major themes of the book in the first chapter to provide students with an overview of the subject and enable them to see how the various systems of the Earth are interrelated. We also discuss the economic and environmental aspects of geology throughout the book rather than treating these topics in separate chapters. In this way

students can see, through relevant and interesting examples, how geology impacts our lives.

➤ TEXT ORGANIZATION

Plate tectonic theory is the unifying theme of geology and this book. This theory has revolutionized geology because it provides a global perspective of the Earth and allows geologists to treat many seemingly unrelated geologic phenomena as part of a total planetary system. Because plate tectonic theory is so important, it is introduced in Chapter 1, and is discussed in most subsequent chapters in terms of the subject matter of that chapter.

We have organized *Physical Geology: Exploring the Earth* into several informal categories. Chapter 1 is an introduction to geology, its relevance to the human experience, plate tectonic theory, the rock cycle, and geologic time and uniformitarianism. Chapter 2 discusses the origin of the universe, the solar system and planets, and the Earth's place in the evolution of this larger system. Chapters 3–8 examine the Earth's materials (minerals and igneous, sedimentary, and metamorphic rocks) and the geologic processes associated with them including the role of plate tectonics in their origin and distribution. Chapter 9 discusses geologic time, introduces several dating methods, and explains how geologists correlate rocks. Chapters 10–14 deal with the related topics of the Earth's interior, the sea floor, earthquakes, deformation and mountain building, and plate tectonics. Chapters 15–20 cover the Earth's surface processes.

We have found, as have many of the reviewers of this book, that presenting the material in this order works well for most students. We know, however, that many instructors prefer an entirely different order of topics depending on the emphasis in their course. We have therefore written this book so that instructors can present the chapters in any order that suits the needs of their course.

CHAPTER ORGANIZATION

All chapters have the same organizational format. Each chapter opens with a photograph relating to the chapter material, a detailed outline, and a prologue, which is designed to stimulate interest in the chapter material by discussing some aspect of the chapter in detail.

The text is written in a clear informal style, making it easy for students to comprehend the material. Numerous diagrams and photographs complement the text, providing a visual representation of the concepts and information presented. Each chapter contains at least two Perspectives that present a brief discussion of an interesting aspect of geology or geological research.

The end-of-chapter materials begin with a concise review of important concepts and ideas in the Chapter Summary. The Important Terms, which are printed in boldface type in the chapter text, are listed at the end of each chapter for easy review, and a full glossary of important terms appears at the end of the text. The Review Questions are another important feature of this book; they include multiple-choice questions with answers as well as short answer and essay questions. Each chapter concludes with a list of Additional Readings, many of which are written at a level appropriate for beginning students interested in pursuing a particular topic.

SPECIAL FEATURES

This book contains a number of special features that set it apart from other physical geology textbooks. Among them are a critical thinking and study skills section, the chapter prologues, guest essays by people who chose geology or geologically related fields for their careers, the integration of economic and environmental geologic issues throughout the book, and a set of multiple-choice questions with answers for each chapter.

Study Skills

Immediately following the Preface is a section devoted to developing critical thinking and study skills. This section contains hints to help students improve their study habits, prepare for exams, and generally get the most out of every course they take. While these tips can be helpful in any course, many of them are particularly relevant to geology. Whether you are just beginning college or about to graduate, take a few minutes to read over this section as these suggestions can help you in your studies and later in life.

Prologues

Many of the introductory prologues focus on the human aspects of geology such as the eruption of Krakatau (Chapter 1), the Loma Prieta earthquake (Chapter 10), or the story of Floyd Collins (Chapter 17).

Economic and Environmental Geology

The topics of environmental and economic geology are discussed throughout the text rather than being treated in separate chapters at the end of the book as is done in many other physical geology books. Integrating economic and environmental geology with the chapter material helps students see the importance and relevance of geology to their lives. In addition, many chapters close with a section on resources, further emphasizing the importance of geology in today's world.

Perspectives

The chapter perspectives often focus on aspects of environmental, economic, or planetary geology such as asbestos and graphite (Chapter 8), radioactive waste disposal (Chapter 17), and wind activity on Mars (Chapter 19). The topics for the Perspectives were chosen to provide students with an overview of the many fascinating aspects of geology. The perspectives can be assigned as part of the chapter reading, used as the basis for lecture or discussion topics, or even used as the starting point for student papers.

Guest Essays

A number of guest essays are interspersed throughout the book. These essays focus on three themes—how and why the individuals became interested in geology as a potential career, their current areas of research, and the possible sociopolitical ramifications of their specific field. The essayists include Randolph H. Bromery (University of Massachusetts at Amherst and former president of the Geological Society of America), Susan M. Landon (a consulting geologist), Michael L. McKinney (a paleontologist at the University of Tennessee), Malcolm Ross (United States Geological Survey), and Steve Stow (head of nuclear waste disposal at Oak Ridge National Laboratories).

Planetary Geology

Planetary geology is discussed in Chapter 2 rather than at the end of the book as it is in many other physical

geology textbooks. This early coverage of comparative planetary geology allows meaningful examples to be introduced later in the book. Furthermore, it enables the student to understand how the origin and early evolution of the Earth fit into the larger context of the origin and history of the solar system. The book has been planned, however, so that Chapter 2 can be covered at any time in the course or omitted altogether if the instructor wishes. The planetary examples later in the book are not dependent on the student having read Chapter 2.

Review Questions

Most physical geology books have a set of review questions at the end of each chapter. This book, however, includes not only the usual essay and thought-provoking questions, but also a set of multiple-choice questions, something not found in other physical geology textbooks. The answers to the multiple-choice questions are at the end of the book so that students can check their answers and increase their confidence before taking an examination.

Unique Illustrations

The figures include many pieces of original artwork designed especially for this book. Many of the illustrations depicting geologic processes or events are block diagrams rather than cross sections so that students can more easily visualize the salient features of these processes and events. In an effort to focus attention on the human aspects of geology, we have also included many paintings, drawings, and historical photographs.

➤ INSTRUCTOR ANCILLARY MATERIALS

To assist you in teaching this course and supplying your students with the best in teaching aids, West Publishing Company has prepared a complete supplemental package available to all adopters.

The Comprehensive Instructor's Manual will include teaching ideas, lecture outlines (including notes on figures and photographs available as slides), teaching tips, Consider This lecture questions, Enrichment Topics, global examples, slides, transparency masters and acetates as well as a computerized test bank.

A videodisc for use in lecture has been developed to accompany the text. The videodisc includes, among other things, a wealth of images from around the coun-

try organized by region, all images from the textbook, animated sequences, quiz frames, and clips from appropriate topical films.

Two slide sets will be provided. The first set will include 150 of the most important and attractive figures and photographs of rocks and minerals, as well as photographs from the book, and the second set will contain at least 300 slides illustrating important geologic features. The majority of these photographs will be from North America, but examples from around the world and the solar system will also be provided.

Transparency masters of the important charts, graphs, and figures will be available as well as a set of full-color transparency acetates to provide clear and effective illustrations of important artwork from the text. An important feature of the transparencies is that the maps will all be the same size, so they can be used as overlays to show, for example, volcano and earthquake distributions and plate boundaries.

A Newsletter will be provided to adopters each year to update the book with recent and relevant research disclosures. This will ensure that your students have the most current information available.

Lastly, in addition to publishing a separate student study guide, we have incorporated much of the material usually found in such guides into the book itself. This saves students time and money and also makes the book a more valuable learning tool. For those students who want further study aid, a study guide is also available.

➤ ACKNOWLEDGMENTS

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DEVELOPING CRITICAL THINKING AND STUDY SKILLS

➤ INTRODUCTION

College is a demanding and important time, a time when your values will be challenged, and you will try out new ideas and philosophies. You will make personal and career decisions that will affect your entire life. With this new freedom you will enjoy, one of the most important things you must learn is how to balance your time among work, study, and recreation. If you develop good time management and study skills early in your college career, you will find that your college years will be successful and rewarding.

This section offers some suggestions to help you maximize your study time and develop critical thinking and study skills that will benefit you, not only in college, but throughout your life. While mastering the content of a course is obviously important, learning how to study and to think critically is, in many ways, far more important. Like most things in life, learning to think critically and study efficiently will initially require additional time and effort, but once mastered, these skills will save you time in the long run.

You may already be familiar with many of the suggestions and may find that others do not directly apply to you. Nevertheless, if you take the time to read this section and apply the appropriate suggestions to your own situation, we are confident that you will become a better and more efficient student, find your classes more rewarding, have more time for yourself, and get better grades. We have found that the better students are usually also the busiest. Because these students are busy with work or extracurricular activities, they have had to learn to study efficiently and manage their time effectively.

One of the keys to success in college is avoiding procrastination. While procrastination provides temporary satisfaction because you have avoided doing something you did not want to do, in the long run procrastination leads to stress. While a small amount of stress can be

beneficial, waiting until the last minute usually leads to mistakes and a subpar performance. By setting clear, specific goals and working toward them on a regular basis, you can greatly reduce the temptation to procrastinate. It is better to work efficiently for short periods of time than to put in long, unproductive hours on a task, which is usually what happens when you procrastinate.

Another key to success in college is staying physically fit. It is easy to fall into the habit of eating nothing but junk food and never exercising. To be mentally alert, you must be physically fit. Try to develop a program of regular exercise. You will find that you have more energy, feel better, and study more efficiently.

➤ GENERAL STUDY SKILLS

Most courses, and geology in particular, build upon previous material, so it is extremely important to keep up with the coursework and set aside regular time for study in each of your courses. Try to follow these hints, and you will find you do better in school and have more time for yourself:

- Develop the habit of studying on a daily basis.
- Set aside a specific time each day to study. Some people are day people, and others are night people. Determine when you are most alert and use that time for study.
- Have an area dedicated for study. It should include a well-lighted space with a desk and the study materials you need, such as a dictionary, thesaurus, paper, pens and pencils, and a computer if you have one.
- Study for short periods and take frequent breaks, usually after an hour of study. Get up and move around and do something completely different. This will help you stay alert, and you'll return to your studies with renewed vigor.

- Try to review each subject every day or at least the day of the class. Develop the habit of reviewing lecture material from a class the same day.
- Become familiar with the vocabulary of the course. Look up any unfamiliar words in the glossary of your textbook or in a dictionary. Learning the language of the discipline will help you learn the material.

➤ GETTING THE MOST FROM YOUR NOTES

If you are to get the most out of a course and do well on exams, you must learn to take good notes. This does not mean you should try to take down every word your professor says. Part of being a good note taker is knowing what is important and what you can safely leave out.

Early in the semester, try to determine whether the lecture will follow the textbook or be predominantly new material. If much of the material is covered in the textbook, your notes do not have to be as extensive or detailed as when the material is new. In any case, the following suggestions should make you a better note taker and enable you to derive the maximum amount of information from a lecture:

- Regardless of whether the lecture discusses the same material as the textbook or supplements the reading assignment, read or scan the chapter the lecture will cover before class. This way you will be somewhat familiar with the concepts and can listen critically to what is being said rather than trying to write down everything. Later a few key words or phrases will jog your memory as to what was said.
- Before each lecture, briefly review your notes from the previous lecture. Doing this will refresh your memory and provide a context for the new material.
- Develop your own style of note taking. Do not try to write down every word. These are notes you're taking, not a transcript. Learn to abbreviate and develop your own set of abbreviations and symbols for common words and phrases: for example, w/o (without), w (with), = (equals), \wedge (above or increases), \vee (below or decreases), < (less than), > (greater than), & (and), u (you).
- Geology lends itself to many abbreviations that can increase your note-taking capability: for

example, pt (plate tectonics), iggy (igneous), meta (metamorphic), sed (sedimentary), rx (rock or rocks), ss (sandstone), my (million years), and gts (geologic time scale).

- Rewrite your notes soon after the lecture. Rewriting your notes helps reinforce what you heard and gives you an opportunity to determine whether you understand the material.
- By learning the vocabulary of the discipline before the lecture, you can cut down on the amount you have to write—you won't have to write down a definition if you already know the word.
- Learn the mannerisms of the professor. If he or she says something is important or repeats a point, be sure to write it down and highlight it in some way. Students have told me (RW) that when I stated something twice during a lecture, they knew it was important and probably would appear on a test. (They were usually right!)
- Check any unclear points in your notes with a classmate or look them up in your textbook. Pay particular attention to the professor's examples. These usually elucidate and clarify an important point and are easier to remember than an abstract concept.
- Go to class regularly, and sit near the front of the class if possible. It is easier to hear and see what is written on the board or projected onto the screen, and there are fewer distractions.
- If the professor allows it, tape record the lecture, but don't use the recording as a substitute for notes. Listen carefully to the lecture and write down the important points; then fill in any gaps when you replay the tape.
- If your school allows it, and they are available, buy class lecture notes. These are usually taken by a graduate student who is familiar with the material; typically they are quite comprehensive. Again use these notes to supplement your own.
- Ask questions. If you don't understand something, ask the professor. Many students are reluctant to do this, especially in a large lecture hall, but if you don't understand a point, other people are probably confused as well. If you can't ask questions during a lecture, talk to the professor after the lecture or during office hours.

➤ GETTING THE MOST OUT OF WHAT YOU READ

The old adage that “you get out of something what you put into it” is very true when it comes to reading textbooks. By carefully reading your text and following these suggestions, you can greatly increase your understanding of the subject:

- Look over the chapter outline to see what the material is about and how it flows from topic to topic. If you have time, skim through the chapter before you start to read in depth.
- Pay particular attention to the tables, charts, and figures. They contain a wealth of information in abbreviated form and illustrate important concepts and ideas. Geology, in particular, is a visual science, and the figures and photographs will help you visualize what is being discussed in the text and provide actual examples of features such as faults or unconformities.
- As you read your textbook, highlight or underline key concepts or sentences, but make sure you don't highlight everything. Make notes in the margins. If you don't understand a term or concept, look it up in the glossary.
- Read the chapter summary carefully. Be sure you understand all of the key terms, especially those in bold face or italic type. Because geology builds on previous material, it is imperative that you understand the terminology.
- Go over the end-of-chapter questions. Write out your answers as if you were taking a test. Only when you see your answer in writing will you know if you really understood the material.

➤ DEVELOPING CRITICAL THINKING SKILLS

Few things in life are black and white, and it is important to be able to examine an issue from all sides and come to a logical conclusion. One of the most important things you will learn in college is to think critically and not accept everything you read and hear at face value. Thinking critically is particularly important in learning new material and relating it to what you already know. Although you can't know everything, you can learn to question effectively and arrive at conclusions consistent with the facts. Thus, these suggestions for critical thinking can help you in all your courses:

- Whenever you encounter new facts, ideas, or concepts, be sure you understand and can define all of the terms used in the discussion.
- Determine how the facts or information was derived. If the facts were derived from experiments, were the experiments well executed and free of bias? Can they be repeated? The current controversy over cold fusion is an excellent example. Two scientists claim to have produced cold fusion reactions using simple experimental laboratory apparatus, yet other scientists have as yet been unable to achieve the same reaction by repeating the experiments.
- Do not accept any statement at face value. What is the source of the information? How reliable is the source?
- Consider whether the conclusions follow from the facts. If the facts do not appear to support the conclusions, ask questions and try to determine why they don't. Is the argument logical or is it somehow flawed?
- Be open to new ideas. After all, the underlying principles of plate tectonic theory were known early in this century, yet were not accepted until the 1970s in spite of overwhelming evidence.
- Look at the big picture to determine how various elements are related. For example, how will constructing a dam across a river that flows to the sea affect the stream's profile? What will be the consequences to the beaches that will be deprived of sediment from the river? One of the most important lessons you can learn from your geology course is how interrelated the various systems of the Earth are. When you alter one feature, you affect numerous other features as well.

➤ IMPROVING YOUR MEMORY

Why do you remember some things and not others? The reason is that the brain stores information in different ways and forms, making it easy to remember some things and difficult to remember others. Because college requires that you learn a vast amount of information, any suggestions that can help you retain more material will help you in your studies:

- Pay attention to what you read or hear. Focus on the task at hand, and avoid daydreaming. Repetition of any sort will help you remember

material. Review the previous lecture before going to class, or look over the last chapter before beginning the next. Ask yourself questions as you read.

- Use mnemonic devices to help you learn unfamiliar material. For example, the order of the Paleozoic periods (Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian) of the geologic time scale can be remembered by the phrase, Campbell's Onion Soup Does Make Peter Pale, or the order of the Cenozoic epochs (Paleocene, Eocene, Oligocene, Miocene, Pliocene, and Pleistocene) can be remembered by the phrase, Put Eggs On My Plate Please. Using rhymes can also be helpful.
- Look up the roots of important terms. If you understand where a word comes from, its meaning will be easier to remember. For example, *pyroclastic* comes from *pyro* meaning fire and *clastic* meaning broken pieces. Hence a pyroclastic rock is one formed by volcanism and composed of pieces of other rocks. We have provided the roots of many important terms throughout this text to help you remember their definitions.
- Outline the material you are studying. This will help you see how the various components are interrelated. Learning a body of related material is much easier than learning unconnected and discrete facts. Looking for relationships is particularly helpful in geology because so many things are interrelated. For example, plate tectonics explains how mountain building, volcanism, and earthquakes are all related (Chapter 13). The rock cycle relates the three major groups of rocks to each other and to subsurface and surface processes (Chapter 1).
- Use deductive reasoning to tie concepts together. Remember that geology builds on what you learned previously. Use that material as your foundation and see how the new material relates to it.
- Draw a picture. If you can draw a picture and label its parts, you probably understand the material. Geology lends itself very well to this type of memory device because so much is visual. For example, instead of memorizing a long list of glacial terms, draw a picture of a glacier and label its parts and the type of topography it forms.

- Focus on what is important. You can't remember everything, so focus on the important points of the lecture or the chapter. Try to visualize the big picture, and use the facts to fill in the details.

➤ PREPARING FOR EXAMS

For most students, tests are the critical part of a course. To do well on an exam, you must be prepared. These suggestions will help you focus on preparing for the examination:

- The most important advice is to study regularly rather than try to cram everything into one massive study session. Get plenty of rest the night before an exam, and stay physically fit to avoid becoming susceptible to minor illnesses that sap your strength and lessen your ability to concentrate on the subject at hand.
- Set up a schedule so that you cover small parts of the material on a regular basis. Learning some concrete examples will help you understand and remember the material.
- Review the chapter summaries. Construct an outline to make sure you understand how everything fits together. Drawing diagrams will help you remember key points. Make up flash cards to help you remember terms and concepts.
- Form a study group, but make sure your group focuses on the task at hand, not on socializing. Quiz each other and compare notes to be sure you have covered all the material. We have found that students dramatically improved their grades after forming or joining a study group.
- Write out answers to all of the end-of-chapter questions. Review the key terms. Go over all of the key points the professor emphasized in class.
- If you have any questions, visit the professor or teaching assistant. If review sessions are offered, be sure to attend. If you are having problems with the material, ask for help as soon as you have difficulty. Don't wait until the end of the semester.
- If old exams are available, look at them to see what is emphasized and what type of questions are asked. Find out whether the exam will be all objective or all essay or a combination. If you have trouble with a particular type of

question (such as multiple choice or essay), practice answering questions of that type—your study group or a classmate may be able to help.

➤ TAKING EXAMS

It is now time to take the exam. The most important thing to remember is not to panic. This, of course, is easier said than done. Almost everyone suffers from test anxiety to some degree. Usually, it passes as soon as the exam begins, but in some cases, it is so debilitating that the individuals do not perform as well as they should. If you are one of those people, get help as soon as possible. Most colleges and universities have a program to help students overcome test anxiety or at least keep it in check. Don't be afraid to seek help if you suffer test anxiety. Your success in college depends to a large extent on how well you perform on exams, so by not seeking help, you are only hurting yourself. In addition, the following suggestions may be helpful:

- First of all, relax. Then look over the exam briefly to see its format and determine which questions are worth the most points. If it helps, quickly jot down any information you are afraid you might forget or particularly want to remember for a question.
- Answer the questions that you know the best first. Make sure, however, that you don't spend too much time on any one question or on one that is worth only a few points.
- If the exam is a combination of multiple choice and essay, answer the multiple-choice questions first. If you are not sure of an answer, go on to the next one. Sometimes the answer to one question can be found in another question.

Furthermore, the multiple-choice questions may contain many of the facts needed to answer some of the essay questions.

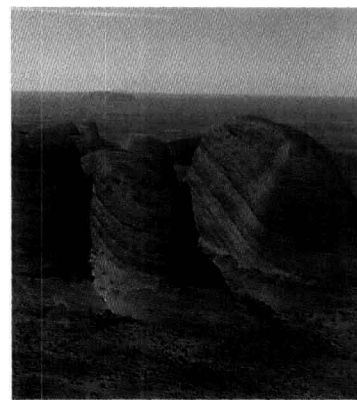
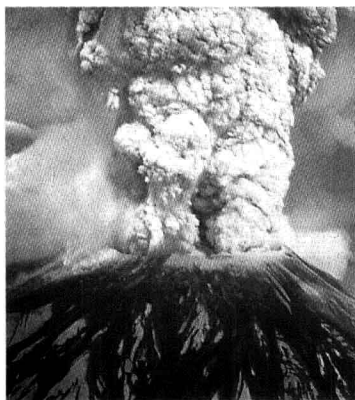
- Read the question carefully and answer only what it asks. Save time by not repeating the question as your opening sentence to the answer. Get right to the point. Jot down a quick outline for longer essay questions to make sure you cover everything.
- If you don't understand a question, ask the examiner. Don't assume anything. After all, it is your grade that will suffer if you misinterpret the question.
- If you have time, review your exam to make sure you covered all the important points and answered all the questions.
- If you have followed our suggestions, by the time you finish the exam, you should feel confident that you did well and will have cause for celebration.

➤ CONCLUDING COMMENTS

We hope that the suggestions we have offered will be of benefit to you not only in this course, but throughout your college career. While it is difficult to break old habits and change a familiar routine, we are confident that following these suggestions will make you a better student. Furthermore, many of the suggestions will help you work more efficiently, not only in college, but also throughout your career. Learning is a lifelong process that does not end when you graduate. The critical thinking skills that you learn now will be invaluable throughout your life, both in your career and as an informed citizen.

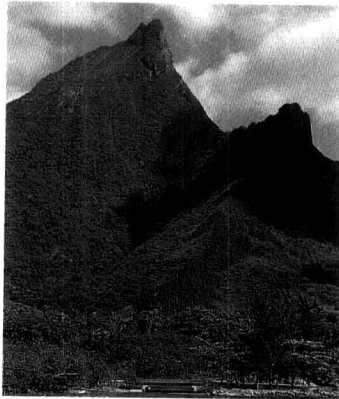
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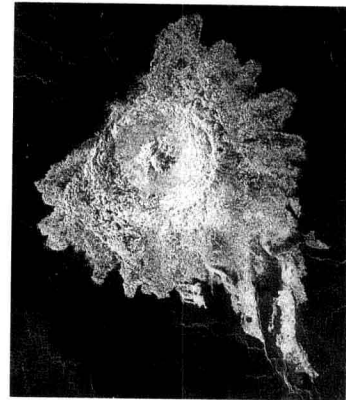


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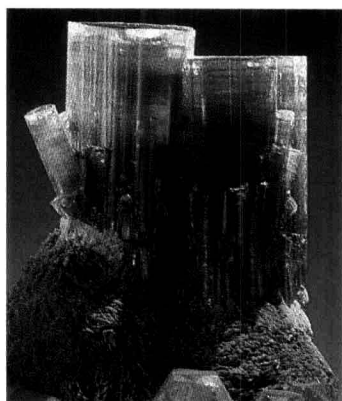


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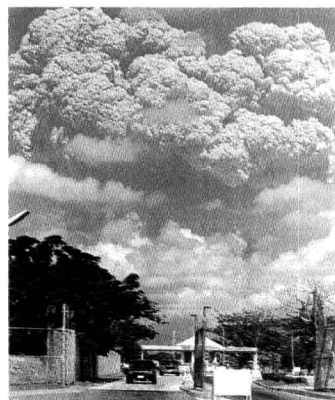


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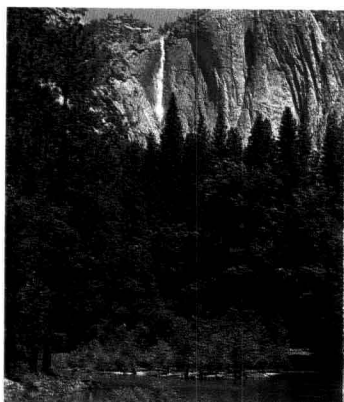


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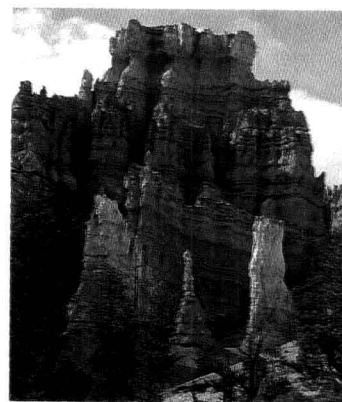


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