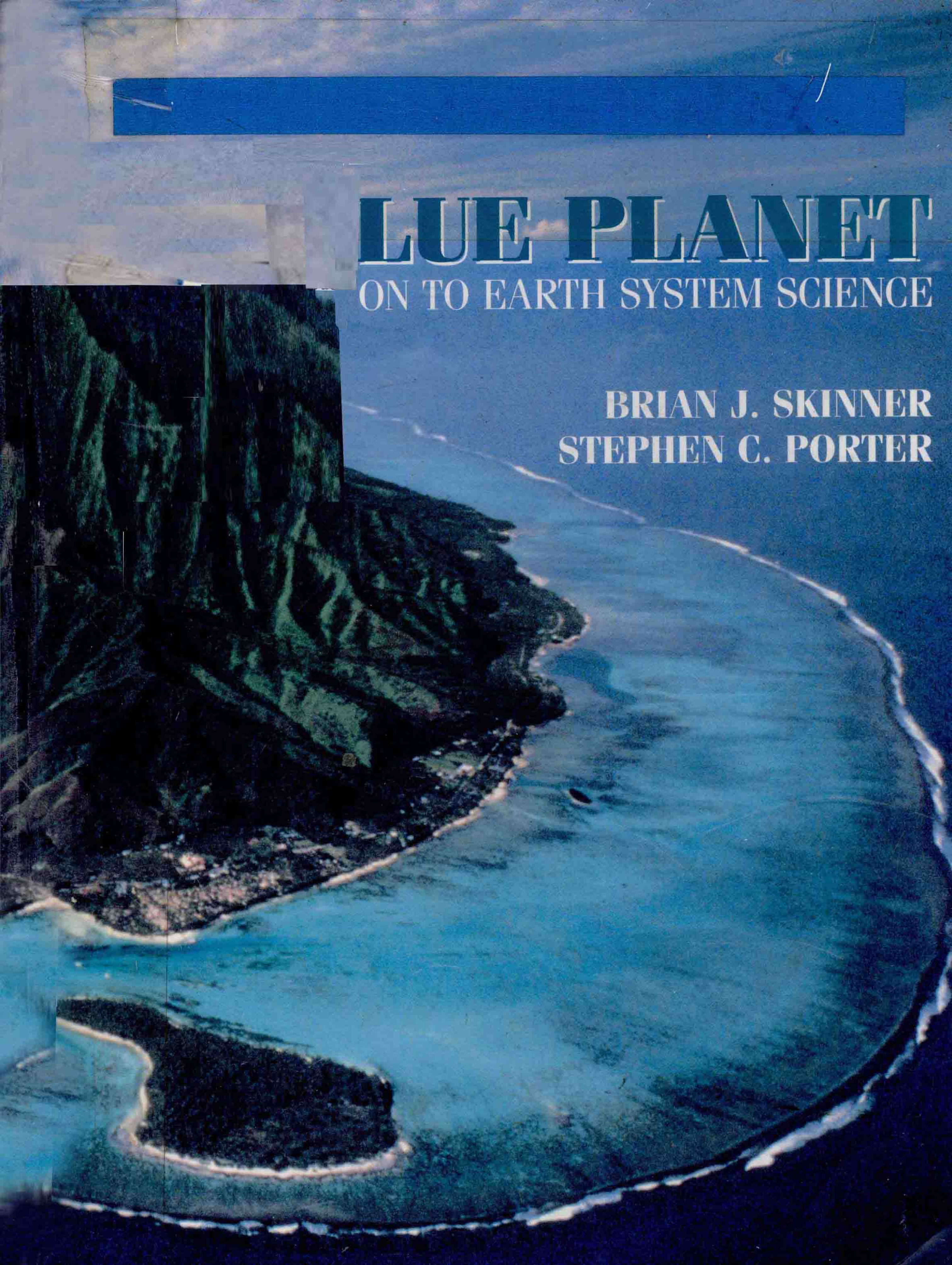
LUE PLANET

ON TO EARTH SYSTEM SCIENCE

BRIAN J. SKINNER
STEPHEN C. PORTER



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The Blue Planet

An Introduction to Earth System Science

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The Blue Planet

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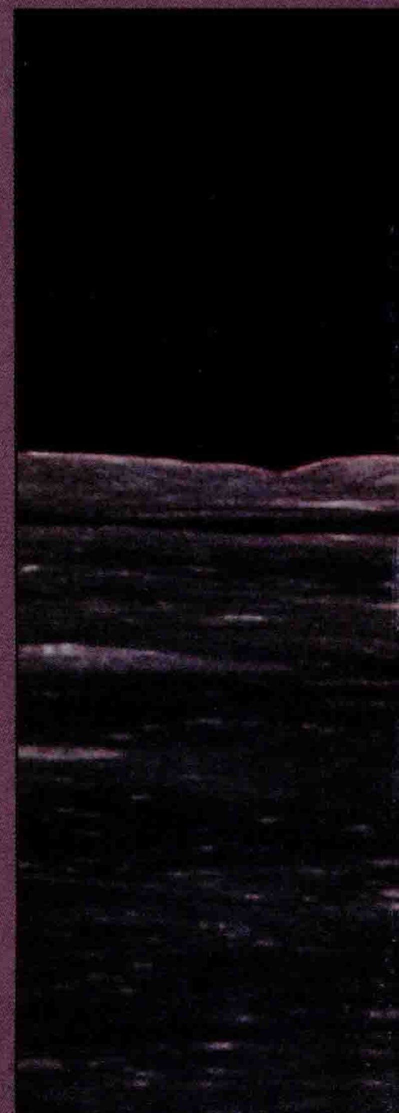
Photographed by an Apollo astronaut, Earth, the blue planet, rises over the stark, gray, lunar landscape. The Earth appears to be blue just as the sky seems blue on a bright, sunny day. The cause is the same in both cases, an optical effect of the atmosphere. We know that air is colorless, not blue, but the atmosphere appears to be blue when viewed from a distance, due to scattering of light rays by molecules of gas in the atmosphere. Exactly how the scattering occurs is discussed in Chapter 8.



ABOUT THE AUTHORS

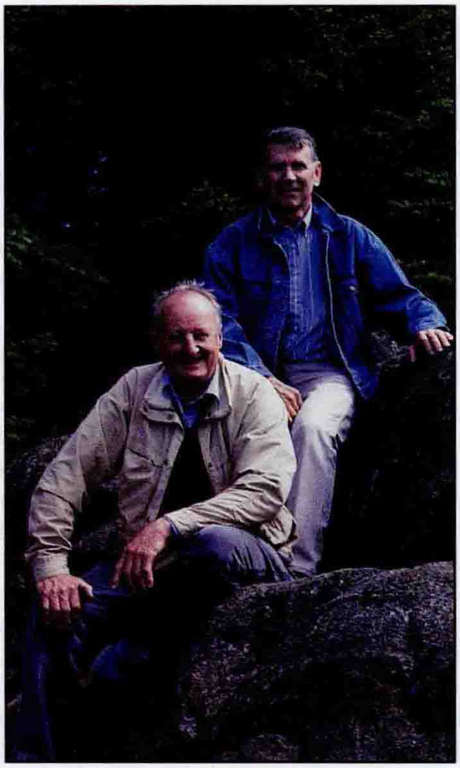
I was born and raised in small country towns in Australia and my early rural experiences did a lot to shape the way I think about the Earth and the way I address problems. I learned to look closely at the world around me, for example, and I saw the giant changes in the landscape as unspoiled bushland was cleared for sheep pastures.

By my twelfth birthday I knew that I wished to be a scientist and the science I fixed my mind on was chemistry. Accordingly, when I entered the University of Adelaide in South Australia in 1946, I selected a course of studies leading to a degree in chemistry. Things never go exactly as planned. Because I had a great-grandfather who had what seemed to me a very mysterious profession, mining engineering, and who had worked at the famous copper mines at Moonta in South Australia, I elected to take a course in geology. My motivation was to find out what had interested my ancestor. What I quickly discovered was my own interest in the subject. I completed my degree in chemistry but I also completed the requirements for graduation in geology.

After experience as a member of an exploration team looking for lead and zinc deposits, and employment as a mining geologist at a tin mine in Tasmania, I entered graduate school at Harvard University. When I emerged $3\,^1/_2$ years later with a PhD I returned to Australia and started teaching and research on the origin of mineral deposits, a subject that continues to occupy much of my time and energy. An unexpected offer to become a member of the research staff of the U.S. Geological Survey brought me back to the United States in 1960.

After a number of years in the USGS I moved to the Department of Geology and Geophysics at Yale University and there I have stayed and worked to the present. It was at Yale that I found opportunities to explore the wider aspects of the earth sciences that increasingly occupied my thoughts. For a number of years I was involved in the space program, first the lunar landing experiments and later the unmanned landing experiments on Mars. With Yale colleagues I worked on problems involving oceanography and climatic change, and on such diverse topics as volcanic gases and economic models of resource depletion. Through exposure to such a diverse range of topics I came to understand that everything on the Earth is interconnected and that the way to appreciate how this wonderful planet of ours works is to understand the system by which the disparate parts interact with each other. It was my search for understanding that led to my participation in the preparation of this book about Earth System Science.

B.J.S.



Brian J. Skinner Stephen C. Porter

Growing up on the dynamic coast of southern California, I was introduced to geology in action at an early age, an introduction that included being thrown out of bed and across my room by a major earthquake that jolted Santa Barbara in the early 1940s. Although earth science was not part of the curriculum when I attended high school, sumnmers spent trekking in the High Sierra and the Rocky Mountains awakened in me an interest in mountains that gained momentum in college when rock climbing and mountaineering occupied much of my spare time. At Yale, a distinguished faculty introduced me to the science of geology, and after serving aboard a Navy destroyer in the Pacific Fleet, I returned to Yale for graduate study. There I focused on glacial and Quaternary geology under the guidance of Professor Richard F. Flint, for many years a prominent author of Wiley geology textbooks. I had the chance to "prove" myself during three long summers of field work in the Brooks Range of Arctic Alaska where I worked at unraveling the puzzling complexities of a thick section of intensely deformed sedimentary rocks, without the benefit of plate tectonics to guide the way, and also studied the glacial history of the range.

A faculty position at the University of Washington provided an ideal setting for someone with my interests in glaciers and the ice ages. Within a day's drive of the campus, our earth science students can be introduced in the field to nearly every topic they will hear or read about in class.

The research on mountain glaciation I began in western North America expanded to include many of the world's glaciated mountains: the Alps, the Andes, the Himalaya, New Zealand's Southern Alps, and tropical Mauna Kea on the island of Hawaii. In addition to glacial-geologic studies, my work has also involved analyzing rockfall hazards in the Italian Alps, prehistoric cave sites in northern Spain that served as home to ice-age hunters, and prehistoric eruptions of Cascade and Hawaiian volcanoes. My current research includes collaborative studies with Russian colleagues on mountain glaciation in northeastern Siberia and with Chinese colleagues on the monsoon history of central China and Tibet recorded in deposits of wind-blown dust and ancient soils. Such experiences, together with my duties as editor of *Quaternary Research*, an international interdisciplinary journal on the glacial ages, enable me to keep in touch with other earth scientists throughout the world and help me stay abreast of new advances in a rapidly moving scientific field.

S.C.P.

PREFACE

When historians of the future consider the most important achievements of the 20th century, the chances are that one of the selections will be the development of a holistic view of the Earth. Such a view has come about as a result of the technological and scientific advances that have made it possible to measure the many ways that the different parts of the Earth can interact. For example, how events deep inside the Earth can influence events on the Earth's surface, or how small changes in the water temperature of the ocean can bring about changes in the distribution of land plants and how those changes can lead to the evolution of new plant species.

One of the discoveries that arise from the holistic view of the Earth is that our modern industrial society and our huge population are changing the Earth. We can now measure in real time the innumerable ways by which we humans are changing the global environment as a result of our collective activities.

This book is an introduction to the holistic view of the Earth. It is about the interactions between the different parts of the Earth—the atmosphere, hydrosphere, biosphere, and the solid Earth—and about the balance in the global environment that exists as a result of those interactions. It is a book that presents a new view of the Earth that has come to be called *Earth System Science*.

Purpose of the Book

Earth system science is rapidly changing the way we study and think about the Earth and as a result it is changing the way earth science courses are being taught. We have written this book in order to introduce students to the science of the Earth system.

Courses about the Earth are being taught with increasing frequency. Such courses may have titles such as global change, earth science, biospherics, or even the global environment, but the approach is increasingly that of Earth System Science.

The Book's Organization

The text begins with a discussion of the Earth's place in the solar system and contrasts the Earth's appearance and structure with those of neighboring planetary bodies. A chapter is devoted to the Sun, not only because it is the dominant feature of the solar system, but because it supplies the energy that drives most of the surface processes on our planet and that permits life to exist. Next, we discuss the solid Earth, the minerals and rocks that comprise it, the nature of processes operating deep within the Earth that are inferred indirectly, and the dynamics of the crust that are explained in terms of a relatively new, comprehensive theory, the theory of plate tectonics. Having explored the solid Earth beneath our feet, we next examine the layers of water and ice that cover much of its surface: the oceans, streams, groundwater, snow, glaciers, sea ice, and frozen ground, and we explore how some of these different agents erode and shape landscapes on which we live. In the third part of the book we explore the atmosphere, weather, and climate, and examine the evidence of past changes in climate on various time scales. Having discussed the aspects of the Earth that have made it a habitable planet, we next look at the diversity and dynamics of plants and animals comprising the biosphere and the evidence of biological evolution through Earth history that is recorded in fossiliferous rocks. In the final section of the book, we look at natural resources that have permitted the development and growth of modern civilization, and ways in which human activities contribute to global changes in our environment.

While we have given careful consideration to the organization of the book we realize that not all instructors will favor the one we have adopted. Therefore, the parts and chapters have been written so that some reorganization of topics is possible without serious loss of continuity. For example, the chapters on the solar system could be assigned toward the end of a course, rather than at the beginning, and the chapters on the biosphere could be shifted, or omitted. Where aspects of astronomy or biology are important in discussion of the solid Earth and its surface environments, they are included there as well.

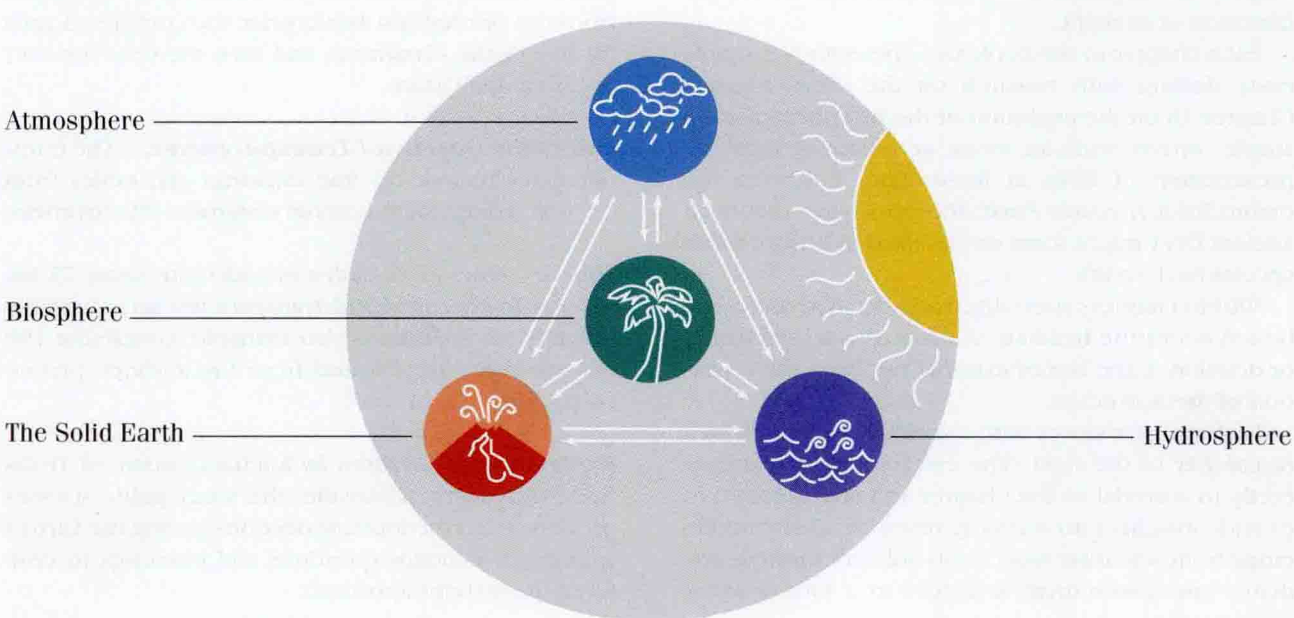
The Artwork

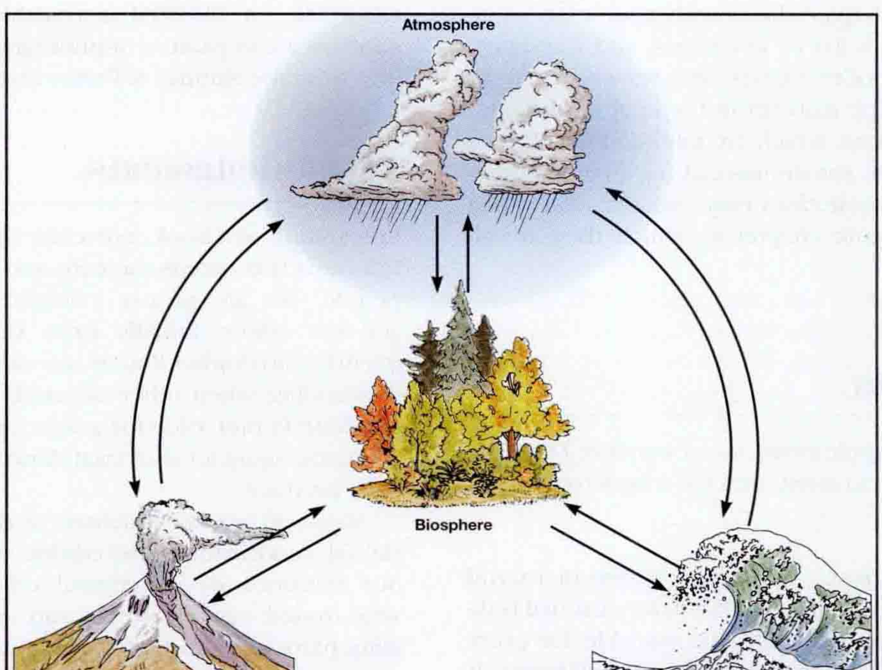
Special attention has been devoted to producing artwork and photographs that illuminate discussions in the text. Because no continent or country holds a monopoly on relevant and interesting examples, we have attempted to provide photographs, maps, and illustrations from around the world to provide a global perspective of Earth System Science. The art program has benefitted from talented artists who have worked closely with the authors to make their illustrations both attractive and scientifically accurate. Two hundred and twelve photographs and line drawings, all in full color, have been selected.

THE SYSTEMS APPROACH

The key to understanding the Earth system is an appreciation of the interactions between the spheres. Interactions are emphasized by the four icons shown below, each of which represents a part of the system.

The icons appear throughout the book and help the reader identify sections in the text where interactions are discussed. For example, in the discussion of streams and drainage systems in Chapter 9, the icons for water, air and land are introduced to emphasize the interactions between those three parts of the Earth system.





Features

Each of the six parts in the book opens with a brief essay on a special aspect of the topics covered within the chapters of the part. The intent of the essays is to emphasize that the different parts of the Earth system are interdependent. For example, Part V, *The Dynamics of Life*, opens with an essay on how some migrating birds find their way by using the stars while others employ the magnetic field and still others use the polarization of sunlight.

Each chapter in the book also opens with a topical essay dealing with research on the chapter topic. Chapter 16 on the evolution of the biosphere, for example, opens with an essay on research into the preservation of DNA in fossils and, following the theme from *Jurassic Park*, the possibility that such ancient DNA might some day be used to bring extinct species back to life.

Within chapters specialized and detailed topics are boxed under the heading "A Closer Look". Inclusion or deletion of the boxed material can be at the discretion of the instructor.

Each chapter closes with a guest essay written by a researcher in the field. The essay subjects relate directly to material in the chapter and are intended to provide insights into on-going research. Essay writers range from scientists working in industry through academic and government scientists to a former astronaut.

Finally, each chapter closes with a summary of in-chapter material, a list of key terms, and questions. The questions are of two kinds: first, review questions relate strictly to the material in the chapter; second, discussion questions, which are intended for class or section discussion, sometimes call for a bit of library research, and in most cases raise broader issues than those in the specific chapter to which they are attached.

Supplements

A full range of supplements to accompany *The Blue Planet* is available to assist both the instructor and the student.

Laboratory Manual. Written by Marcia Bjornerud of Miami University, Ohio, the laboratory manual is divided into six modules with labs available for every part of the text, flexibly arranged to cover all topics. It includes many computer-based exercises and hands-on activities that students can do locally.

Instructor's Manual and Test Bank. Written by Barbara Murck, of Toronto University, this guide includes a table of contents, chapter summaries references, and approximately 85 test questions per chapter.

Computerized Test Bank. A computerized test bank is available in both IBM-compatible and Macintosh versions. This easy-to-use test generating program enables instructors to choose test questions from the printed test bank, print the completed tests for use in the classroom, and save the tests for later use on modification.

Full-Color Overhead Transparencies. The transparencies include 75 line drawings and tables from the text, edited for maximum classroom effectiveness.

Slides. One set of slides includes the same 75 images as in the overhead transparency set; a supplementary set of slides is also available, containing 150 images from the text and from the authors' private collections.

Study Guide. Written by Michael Jordan, of Texas A&M University, Kingsville, the study guide stresses processes and the interconnections among the Earth's spheres. It contains questions and exercises to reinforce the systems approach.

CD-ROM. A CD-ROM is available to adoptors and contains a compilation of photographs and line drawings from the Skinner & Porter texts.

Acknowledgments

Preparation of a book, especially the first edition of a full color text, needs the help and expertise of many people. We are greatly indebted to our publisher and our editor, initially Barry Harmon and subsequently Christopher Rogers, for supporting us, for understanding when other demands meant we had to put *Blue Planet* aside for a time, and for maintaining an encouraging level of confidence that we would finally produce.

Above all we are indebted to Brent Peich for his skillful coordination and editing of the Guest Essay our freelance developmental editor, Irene Nunes, who ironed out our syntax and undangled our dangling participles; to Barbara Heaney, our in-house developmental editor, who kept things flowing smoothly and did the thousand things we overlooked.

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Our many colleagues who prepared part or chapter closing essays did so with grace and professional acumen. We are very grateful to them. Besides the essay writers, each of whom is identified by name and photo adjacent to their entry, we are extremely grateful for the guidance and judgment provided by colleagues who discussed this project in encounter groups and who reviewed all or part of the manuscript. They are:

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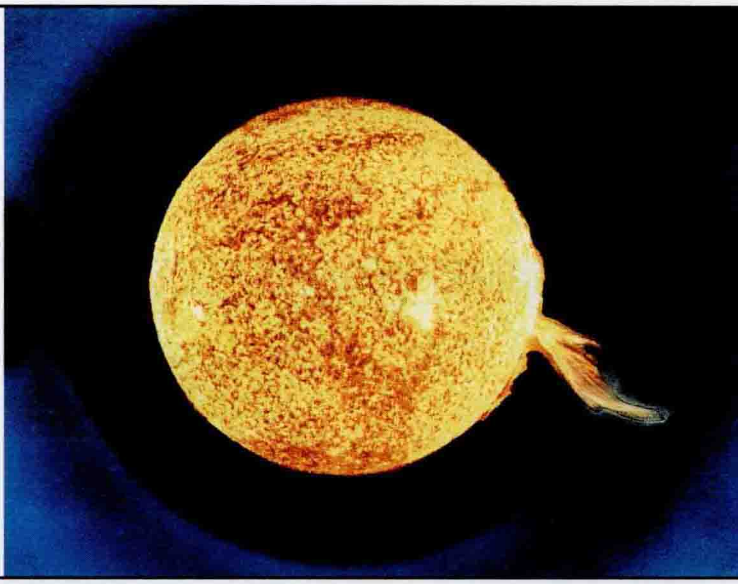
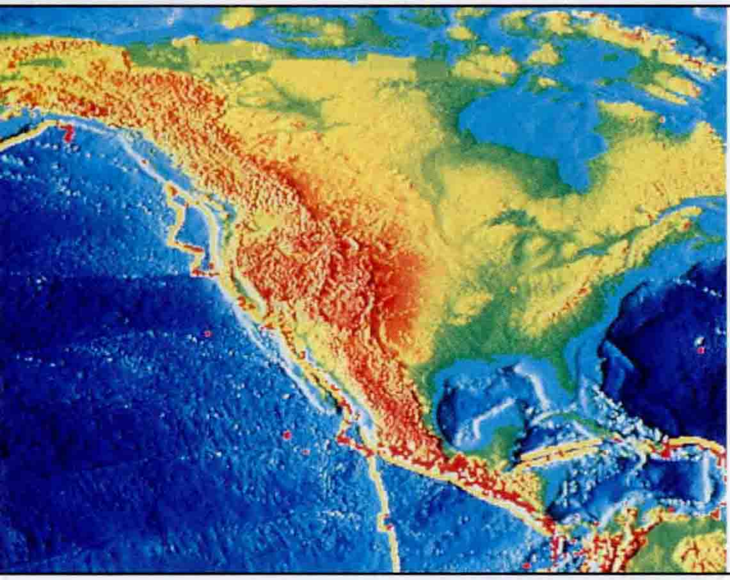


The Earth in Space /20



PART TWO