dynamic earth

AN INTRODUCTION TO EARTH SCIENCE

HENRY LEPP

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AN INTRODUCTION TO EARTH SCIENCE

To

MAXINE M.

KATHLEEN

STEPHEN

DAVID

and

TAMARA

PREFACE

In this era of exploding populations, of increasing pressures upon the environment, of intensifying demands upon the earth's resources, and of growing opportunities for global and even space travel, it becomes increasingly important for students to learn more about the earth and its neighbors in space. The purpose of this book is to help fill this need. Designed as an introduction to the earth sciences for the general college student, the book does not address itself specifically to the problems of pollution, population, or earth resources; instead, by exploring such topics as the earth's size, composition, structure, processes, relationship to other planets, and history, it attempts to provide a background for understanding some of the current environmental problems. The aim is to provide an understanding of how scientists go about studying an object as large as the earth—to convey how we know about the earth rather than what is known.

The traditional college introduction to earth study is through courses in physical and historical geology. A few decades ago physical geology, as presented in most textbooks, was chiefly a survey of the processes that slowly act to change the landscapes. More recently, with the rapid expansion of knowledge in such earth-centered disciplines as geophysics, geochemistry, meteorology, oceanography, and planetary geology, there has been a move to decrease the space devoted to the evolution of landforms in physical geology books and to provide a more balanced view of the entire planet. Physical geology has thus tended to become more like earth science as presented in textbooks that began to appear about 10 years ago. Although existing introductory courses in earth science differ widely in their coverage, they are related in that all contain some astronomy, meteorology, and oceanography in addition to geology. In other words, most earth science courses tend to cover a complete spectrum of the earth-related sciences. I have tried to follow that pattern in this book.

It was difficult to decide what to include in a first look at so diverse a subject as the earth. No doubt my choice of topics reflects the fact that I have been teaching introductory geology for some 20 years, an experience that has showed me that most college students in introductory geology or earth science courses have only minimal science backgrounds and most will take no further work in the sciences. Consequently, one of my goals has been to convey the interdependence of the earth sciences and the pervading roles of the fundamental sciences of physics and chemistry in the study of the earth. The organization of the book reflects this goal. Instead of arranging the subject matter according to discipline, I have kept the earth as the central theme. Although there is a chapter on oceans, for example, material that might normally be considered in the realm of oceanography appears in other chapters where it is pertinent to the subject being explored.

The book is loosely arranged into three major units. Chapters 1 to 6 examine the earth as a planet, covering its size, shape, motion, composition, internal structure, and relationships to other planets in the solar system. Chapters 7 to 12 deal with the processes acting on and near the surface of the earth and with the energy conversions involved in these processes. They explore such topics as the movements of the atmosphere and oceans, the hydrologic cycle, weathering and soil formation, and the evolution of landscapes. The last unit (Chaps. 13 to 18) is concerned with the earth's internal processes, its history, its environment in space, and its probable origin. No attempt is made to outline earth history; the emphasis is on how history is read from sedimentary rocks and from other earth features.

I became involved with earth science teaching and resource materials in two programs sponsored by the American Geological Institute and supported by the National Science Foundation. The first of these was the 1959 Duluth Conference, charged with developing source materials for use in the rapidly expanding elementary and secondary school earth science programs. Continued growth of earth science in the secondary schools resulted in the organization of the Earth Science Curriculum Project, and I was fortunate to be able to serve as a writer and coordinator during several of the ESCP writing conferences in 1965 and 1966. I am grateful to the above organizations, and particularly to the dozens of earth scientists with whom I was associated in these programs, for broadening my view of planet earth. So many people were involved in these projects that it is impossible to list them all or to identify individual contributions. I am particularly indebted to Robert L. Heller, who was Director of the Duluth Conference and also the first director of ESCP, and to Ramon E. Bisque, Director of ESCP from 1965 to 1967, for inviting me to participate in these ventures.

Whereas the responsibility for errors and omissions in this book is solely mine, several persons have helped to eliminate mistakes and generally to make the book better than it would otherwise have been. Much credit for the text goes to the McGraw-Hill editorial staff, in particular David Beckwith, whose red pencil helped materially in changing my original drafts to a more readable form. Dr. Robert Heller read the entire manuscript, and Dr. Samuel Goldich commented on Chap. 13. Several of the chapters were used by some of my undergraduate students, whose comments and suggestions proved to be most helpful.

Credit for the illustrative materials is given in the figure captions. When I started this project, I was almost as awed by the prospect of assembling the illustrations as I was of writing the text. The courtesy of organizations such as NASA, the U.S. Geological Survey, and the Geological Survey of Canada, together with that of many individuals, made the task much easier than I had anticipated.

Finally, I am indebted to my family for their continued encouragement and help.

Henry Lepp

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EARTH SCIENCE

1-1 THE EARTH SCIENCES

The study of the earth—its rocks and waters, its clouds, its size and shape, its place among the stars—doubtless began soon after man evolved into a thinking being. From our vantage point in the twentieth century, however, we would scarcely consider the earliest written speculations about our planet science. Certainly such works bear little resemblance to the modern earth sciences of geology, geochemistry, geophysics, hydrology, meteorology, pedology, and oceanography, most of which are little more than a century old.

To see how the various disciplines that form earth science evolved we must recognize that the earth has become an increasingly complicated subject for study. The naturalist of 200 years ago could undertake a general approach. His work might have included the investigation of such diverse topics as the nature of certain plants or animals, medicine, the origin of rocks, and the cause of inclement weather. He was able to work on all these topics because so little was known then about any of them. But new discoveries depend on the accumulation of knowledge. Even Sir Isaac Newton, one of the greatest scientists of all time, attributed his success to the fact that he "stood on the shoulders of giants." As information about the earth increased by leaps and bounds, it became increasingly difficult for any one man to master it all. Specialties evolved. The naturalist was replaced by biologists, whose concern is the earth's living things; by physicians, who focus on man's health; by geologists, who work chiefly with the rocks of the earth's crust in attempting to unravel the earth's history; and by meteorologists, whose chief concern is to explain the activity and structure of the atmosphere.

Specialization did not stop there. Today it is much sharper. For example, mineralogy (study of minerals), petrology (study of rocks), paleontology (study of fossils), geomorphology (study of landforms), and structural geology (study of earth structures) are but a few of the many special subdivisions of geology. Other disciplines like oceanography or geophysics are also subdivided. Earth science is a blanket name for all the sciences that collectively strive to understand the earth and its space neighbors. Besides having a common goal, the disciplines and subdisciplines of earth science all apply the same fundamental laws of physics and chemistry to earth study. These are the laws that describe how matter and energy behave.

This book makes no attempt to identify the specific contributions of any particular earth science, but it is important to recognize that this survey of the earth and its place in space represents the work of many specialists.

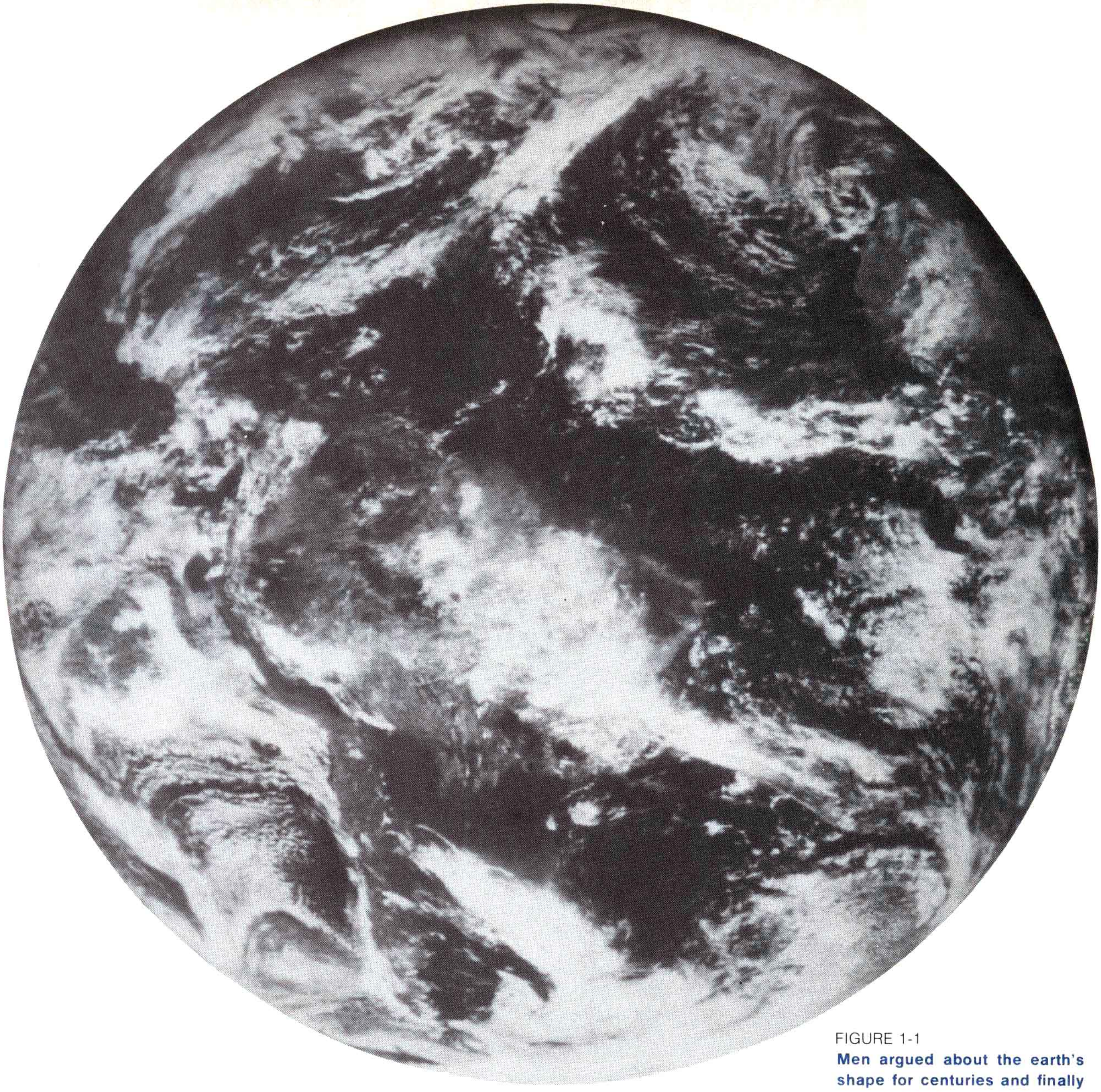

FIGURE 1-1
Men argued about the earth's shape for centuries and finally proved it to be round. Today a single satellite photograph displays an entire hemisphere. *NASA.*

1-2 MAN'S CHANGING VIEW OF THE EARTH

The photograph taken by a telecommunications satellite in November 1967 (Fig. 1-1) shows almost a full hemisphere. South America is visible in its entirety, as well as large parts of Africa, North America, and Europe. The spiral cloud patterns reflect the earth's major wind systems, and the vastness of its oceans is apparent.

This photograph is truly amazing when we think how long and how hard men worked to get the information it displays. Some 2,000 years ago, Eratosthenes, a

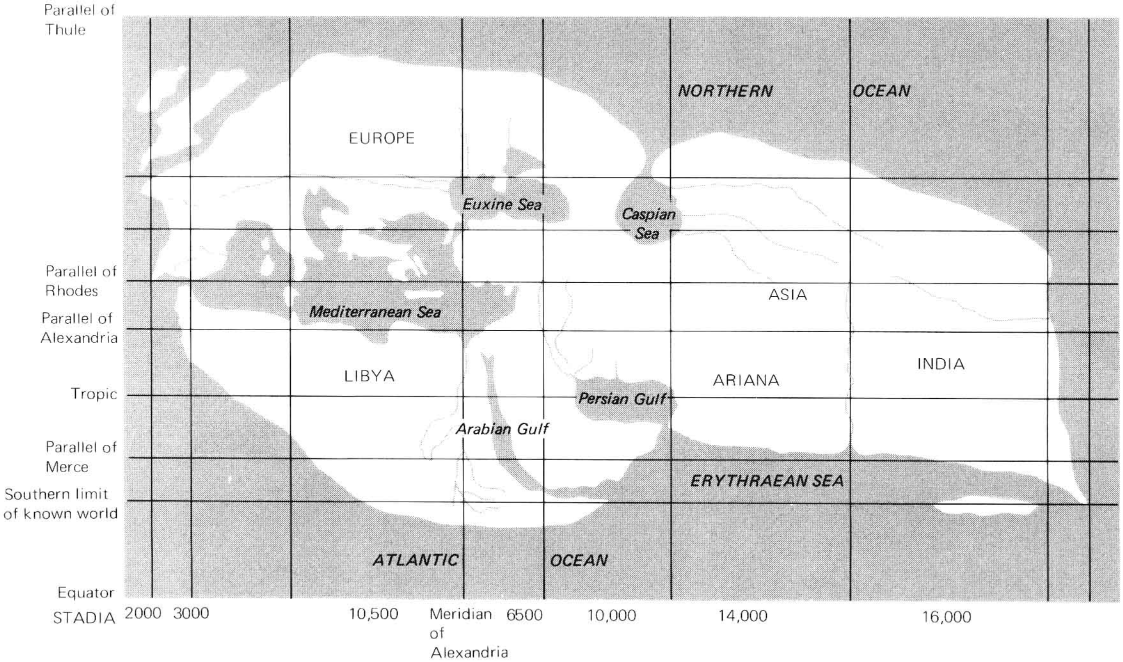

FIGURE 1-2
The world of about 250 B.C. according to Eratosthenes. *M. R. Cohen and R. E. Drabkin, "A Sourcebook in Greek Science," Harvard University Press, 1948.*

Greek geographer, produced the map of the then known world shown in Fig. 1-2. The advance from this crude and incomplete map to modern world maps required centuries of exploration and thousands of man-years of measurement. Now a single photograph provides almost as much information as many centuries of work.

Little was known about the winds and weather until about 200 years ago, which, in view of the complexity and the changing nature of weather is hardly surprising. To discover patterns in the continually changing flow of air, man had to be able to make observations simultaneously at widely scattered places. Early theories about the weather were speculative. For example, the Greek philosopher Aristotle (383–322 B.C.) proposed a causal relationship between weather and earthquakes. He taught that all things were made of air, water, earth, and fire. According to him, violent weather and earthquakes resulted when air entering the body of the earth reacted with the internal fire to escape explosively into the atmosphere. As we now know, earthquakes have little or nothing to do with the weather (they result from internal earth processes). It is the uneven heating of the earth by the sun that drives the global circulation causing weather.

Aristotle's theory of a relationship between earthquakes and weather is typical of much early "science," which lacked the benefit of experiment and continued observation. After centuries of observation some of the details of atmospheric circulation were finally unraveled. Again, the achievement of many centuries of

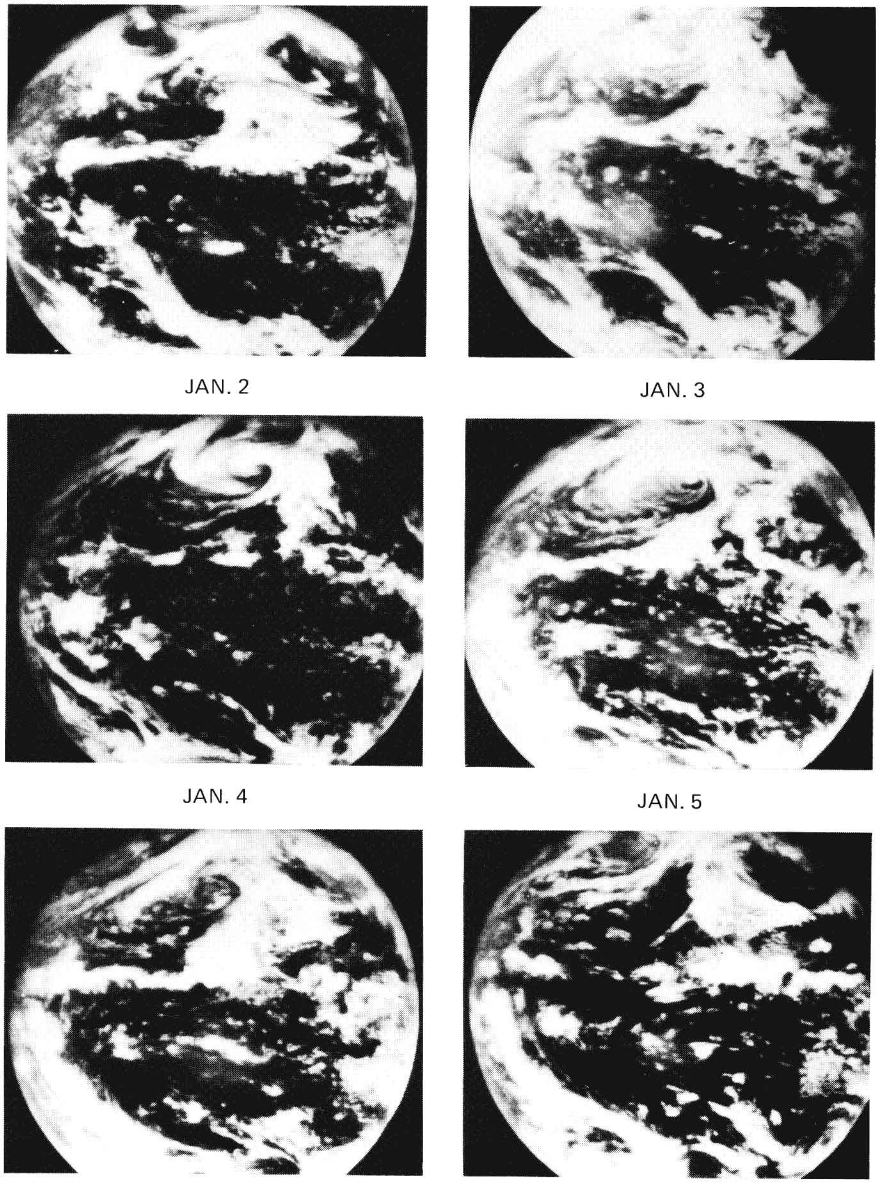

FIGURE 1-3
This sequence of pictures taken by ATS-1 gave meteorologists one of their first opportunities to study the life cycle of a cyclonic storm in detail. The storm can be seen as it developed on January 2, 1967, in the left part of the picture just above the equator. It progressed in a northeasterly direction, reaching a peak on January 4 and 5, when it showed as a distinct spiral whorl in the upper central part of the earth's disk. By January 6 it had begun to dissipate, and the spiral circulation was gone by January 7. *NASA.*

work is captured in the few space photographs of Fig. 1-3, which show the earth on several consecutive days. The birth and death of a cyclonic storm is clearly visible in the Northern Hemisphere. The overall cloud patterns mark the general global circulation pattern.