

EARTHSCAPE

A PHYSICAL GEOGRAPHY

WILLIAM M. MARSH



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Introduction to the Student

The quests of the *Starship Enterprise* are fictional expressions of a rich tradition of geographic exploration in the Western world. Several centuries before the voyages of the *Starship Enterprise*, exploration was focused on our own solar system. The manned landing on the moon in 1969, the unmanned landings on Mars in 1975, and the satellite voyages to the outer planets of our solar system in the 1970s and 1980s are also expressions of this great geographic tradition. Only 100 years before the planetary missions, the thrust of American geographic exploration was in the American West where in the 1870s John Wesley Powell traversed the Grand Canyon and F. V. Hayden explored the Yellowstone region. And a hundred years before that Captain James Cook explored the Pacific discovering Antarctica, making the first Western visit to Hawaii, and charting the coasts of New Zealand and Australia.

Quite literally, we are a people preoccupied with learning about what is where, about finding out how things are arranged geographically in the world, the solar system, and the Universe. What motivates individuals and nations to pursue geographic exploration varies—political expansion, economic gain, individual glory, and intellectual curiosity—but the results are often the same. In any case, exploration and geographic discovery in the nineteenth and twentieth centuries have consistently led to mapping projects, and mapping has led to questions about the way things are distributed, what influences distributions, and why the patterns of certain distributions correlate with one another. These questions in turn lead to questions about the forces and processes that control the land masses, climates, vegetation, water features, minerals, human populations, agriculture, diseases, and so on.

Although our drive to explore continues to push the geographic adventure to greater and greater distances from earth, at the same time the job of mapping and analyzing the geographic features of earth continues. In fact, the work of earth-centered geographers grows with each decade as the earth changes, new problems arise (such as the extent and effects of drought in Central Africa), and world population continues to grow and spread.

The efforts of geographers have been advanced tremendously in this century with new and more sophisticated mapping techniques. Prior to 1930 or so, mapping had to be done on foot with surveying instruments. The pace was slow even in easy terrain, and in areas of rugged terrain, mapping was often crude at best. After 1930 aircraft made aerial photography possible, and today we have the capacity to remap all of the United States and Canada each decade at a scale large enough to show individual houses. With the development of radar in World War II, aerial mapping could be done in cloud-shrouded regions because radar can "see" through clouds, something that photography cannot do. In addition, airborne scanning apparatuses were also developed, enabling geographers to detect such things as surface temperatures in land and water, moisture differences in soil, and variations in land use and crop types. And with the advent of earth-orbiting satellites carrying earth-viewing scanners, the earth's atmosphere, oceans, lands, and vegetation can be monitored almost continuously. We see one of the benefits of these modern mapping systems in daily weather reporting and forecasting.

With the types and amounts of geographic data and information increasing each decade, the need to understand how things are interrelated geographically over vast reaches of the earth is also growing. From the standpoint of survival, it has become clear that the world can no longer be treated as a geographically compartmentalized sphere: Witness that the same ocean currents that periodically warm the coast of Peru and influence the fish catch there also cause weather changes that affect the magnitude and frequency of destructive storms in the western United States. Increased sulphur dioxide emissions from power plants in the United States produce acidic rainwater, which has altered the chemical balance of lakes in another country, Canada, causing many of them to become ecologically sterile. And air pollution from the industrialized world as a whole may be causing large-scale climatic changes that could reduce food

production and cause famine in many Third World countries.

But despite the glaring need to understand broadly based earth problems, we in the United States as a society are actually less geographically aware than we were twenty or thirty years ago. Paradoxically, this comes at a time when the opportunities and the need for advancing geographic knowledge are greatest. Our perspectives on the global and international problems of our day—the border wars, mineral depletion issues, regional famine, and international migration—are often frighteningly simple and geographically naive. Not surprisingly, the solutions we propose for these problems often fail to recognize the broad foundation of scientific knowledge we have available to us.

As national and international problems expand in scope and complexity, the need to illuminate the larger picture and illustrate the interconnectedness of the features and processes over the earth's surface is greater than ever. Herein lies one of the most important roles of physical geography in modern college and university education, one that this book is designed to promote.

Traditional geography books focused on telling us what is where: oceans, rivers, minerals, mountains, countries, cities, and so on. In modern geography we are more concerned with figuring out why things are distributed as they are. In physical geography we are concerned with understanding patterns of climate, soil, river systems, vegetation, landforms, and land use—what we call the geographic landscape. This book is aimed at illustrating how the geographic landscape is formed, how it functions, and how it changes under both natural and human influences. To achieve this we have to understand the nature of the *forces* that drive change on the earth's surface. Any change that takes place on the earth is driven by energy, such as radiation from the sun, heat from the earth's interior, and chemical compounds from plants. This energy drives the movement of the atmosphere and the oceans, the exchange of water between air and land, and the growth of plants. How the driving forces are distributed over the earth and what factors influence their distributions are important questions in physical geography. In order to understand the distribution of energy over the earth's surface, it is important to realize that it is arranged in great *systems*. These systems are characterized by energy flows and material among different parts of the environment, such as the flow of solar radiation to the earth's surface, the flow of heat between the soil surface and the lower atmos-

phere, and the flow of heated ocean currents into cold regions of the oceans.

Although the driving forces of energy are at the root of landscape change, the actual instruments of change are surface *processes*. Processes are characterized by movements or changes in earth substances such as air, water, and soil. Processes are the agents of change on earth; they are the tools of the geosystems in a manner of speaking. Understanding the mechanisms of earth surface processes is an important concern to geographers, but equally important is understanding how these processes vary over time, as with the seasons, and over geographic space, as from the Pacific Coast to the interior of North America.

From the question of how processes function we go to the question of the *work* that is accomplished by them. We wish to know not only how much work takes place when water runs over a barren farmfield or waves crash into a shore, but also how the resultant changes are physically manifested in the landscape. These physical manifestations are the features we see in the landscape: forests, mountains, beaches, and so on, as well as human artifacts in the form of cities, farms, and reservoirs—the ingredients of landscape.

The landscape was once described as “the excited

skin of the earth,” meaning that it is vibrant with never-ending change. It is amazing to discover how remarkably different many landscapes were as little as 100 years ago. For example, since the nineteenth century the great forests of many tropical areas have converted to grasslands, stream valleys in many urban areas have been eradicated as cities have grown over them, and extensive areas of harsh, windy desert, such as the Imperial Valley of California, have been transformed into manicured landscapes of agricultural green.

Contemporary landscapes are changing at faster and faster rates, largely because of the increased influences of growing human populations and expanding technology. This is a monumental issue for humans because the landscape is our habitat and its condition is central to our survival. Geographers are chiefly concerned with the causes and forms of landscape change, but as members of society they must also be concerned with the directions of change and with the quality of change when weighed against human values. As you read this book, consider how you stand on various issues and ask yourself what basis you have for your values in different geographic contexts; as a member of a community, region, nation, continent, planet.

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W.M.M.
Flint, Michigan
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Introduction to the Instructor

This book builds on its predecessor, *Landscape*, published in 1981, but it is different in many ways. It is written in a more colloquial style, with more attention given to certain topics such as weather and climate, and ocean circulation. *Earthscope* also introduces an element from old-time physical geography—physiography, which is used as a summary chapter to the book. The quality of the graphics in *Landscape* has been retained and expanded somewhat in *Earthscope*.

The balance of topics (coverage) in *Earthscope* is designed to meet the needs of the one-semester physical geography course. Nine chapters deal with weather and climate, seven with earth materials, crustal processes, and landforms, four with vegetation and soil, three with water, and one with physiography. The general organizational scheme starts with weather and climate (Chapters 1–9), then goes to vegetation

and soils (Chapters 10–14), followed by landforms (Chapters 15–24). The chapters on water are presented in the weather and climate section (Chapter 6) and in the landforms section (Chapters 17 and 18). Water is also discussed in the chapters on vegetation and soils and in the final chapter on the physiography of North America.

The twenty-four chapters in *Earthscope* are written so that they can be rearranged to fit several different course organization schemes. For courses that begin with earth materials, crustal processes, and landforms instead of weather and climate, the appropriate sequence of chapters should be as follows:

1. Planet Earth and Its Atmosphere
2. The Forces and Systems on the Earth's Surface
15. Structure and Composition of the Solid Earth

16. Crustal Mechanics, Rock Structures, and Related Landforms
17. Infiltration and Groundwater
18. Runoff, Streamflow, and Flooding
19. Weathering, Slope Processes, and Landforms
20. The Work of Streams in Shaping the Land
21. The Formation of Shores and Coastlines
22. Glaciation, Glacial Landforms, and Landscapes
23. Airflow and the Work of Wind on the Land
13. Soil Materials and Properties
14. Soil Formation, Classification, and Problems
3. The Flow of Radiation to and from the Earth
4. The Heating of Land, Water, and Air
5. The Circulation of the Atmosphere and Oceans
6. Atmospheric Moisture, Precipitation, and Weather
7. The Hydrologic System over Land and Water
8. Climates of the World
9. Climate Change: Then and Now
10. Basic Plants and Vegetation of the World
11. Plant Processes in the Ecosystems
12. Patterns and Processes of Vegetation Distributions
24. The Physiography of the United States and Canada

Another variation that may be more appropriate for some courses is one that places weathering, soils, and water together:

15. Structure and Composition of the Solid Earth
16. Crustal Mechanics, Rock Structures, and Related Landforms
19. Weathering, Slope Processes, and Landforms
13. Soil Materials and Properties
14. Soil Formation, Classification, and Problems
17. Infiltration and Groundwater
18. Runoff, Streamflow, and Flooding
20. The Work of Streams in Shaping the Land
21. The Formation of Shores and Coastlines
22. Glaciation, Glacial Landforms, and Landscapes
23. Airflow and the Work of Wind on the Land
24. The Physiography of the United States and Canada

Five appendices are also presented in *Earthscope*. The first two, “Maps and Map Reading” and “Remote Sensing and Image Interpretation,” are introductions to the materials and techniques in these areas. Appendix C presents supplementary climatic maps for the United States and Canada. Appendixes D and E, Soil Tables and Units of Measurements and Conversions, are for reference purposes.

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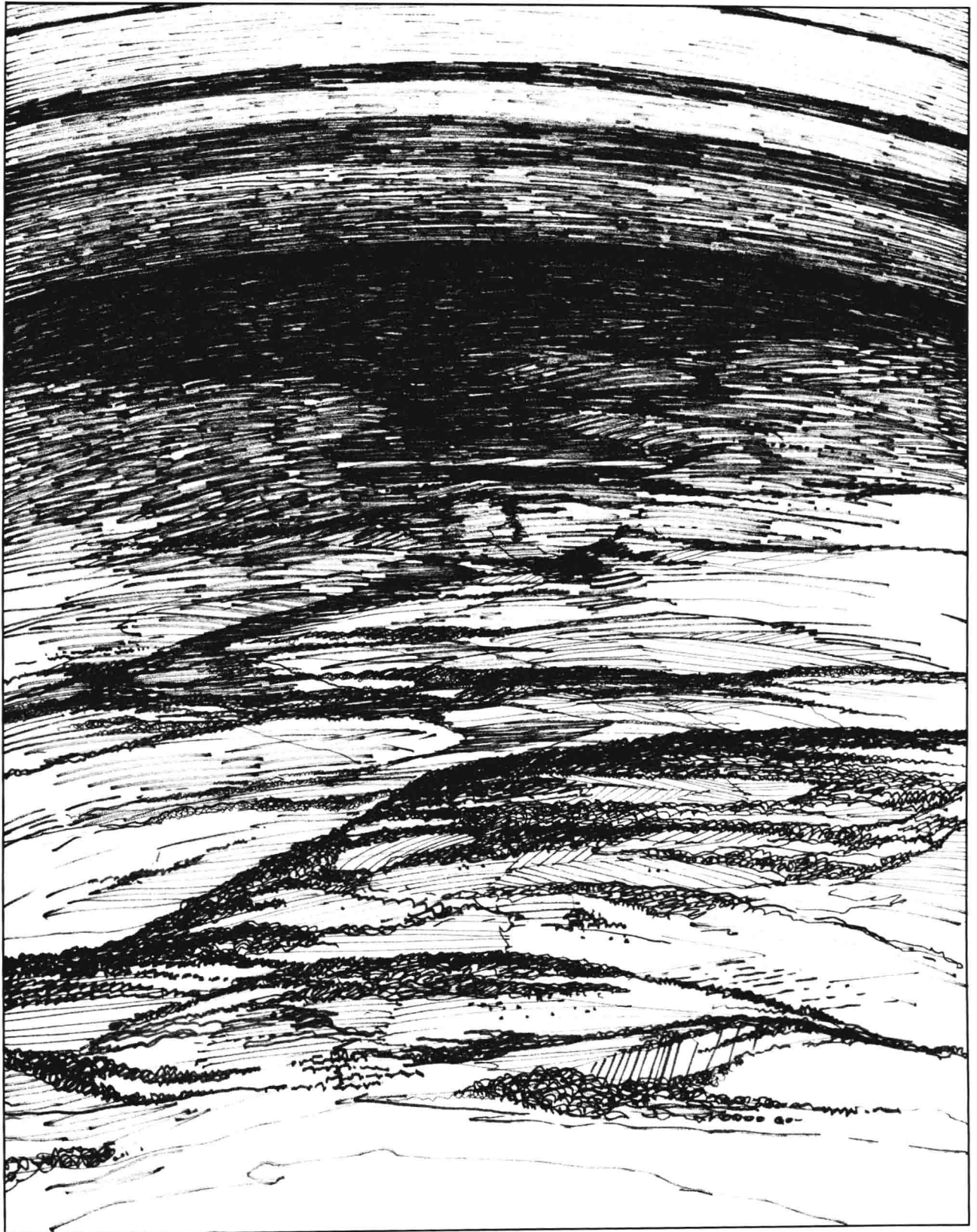
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EARTHSCAPE
A PHYSICAL GEOGRAPHY



Chapter 1

Planet Earth and Its Atmosphere

Geographic curiosity is one of the deeply rooted passions of Western culture and modern science. The size and shape of the earth, for example, have been a source of inquiry for centuries. Modern science continues to work on these and related questions because they are important in furthering our understanding of earth, its atmosphere, and climates. What controls the seasons? What is the nature of the great envelope of gas that surrounds earth? How does the earth's diverse surface composition influence the atmosphere?

Almost every culture we know about has created a story about the nature of the earth and its origins. Why? Certainly not because such stories are necessary for human survival. The more likely answer is that they are somehow necessary for human intellect. The Eskimo (or Inuit), various groups of American Indians, and, of course, the ancient Greeks each had their own stories. The Greeks envisioned the earth as a great organism whose organs were thought to be the volcanoes, the rivers, the seas, and so on.

Western culture also has its stories about the earth. In the past several centuries another story has unfolded built mainly on information supplied by exploration and scientific inquiry. From this information we have shaped hypotheses, built theories about the origin of the earth and its inhabitants, and discovered new questions for investigation.

Scientific investigation in any form depends on measurement; we know about the earth's size, fea-

tures, and motion, for example, because we have measured them in some way. Measurement and observation are essential to our culture; they are part of our system of norms or standards of proper behavior. When we have a question about nature, we are inclined to pursue it by observing and measuring things for ourselves rather than just wondering about it or seeking answers in dreams or divine revelations.

Much of our technology today is devoted to building devices, such as cameras, weather observation aircraft, orbiting satellites, surveying instruments, and computers for making measurements, storing the data, and analyzing the results. Our story about the earth has been built and refined over the centuries from repeated observations and measurements. The chapters to the story are the scientific theories, such as the theory of plate tectonics and the theory of evolution. Once written, however, the story is subject to constant revision and repair as new information is

brought to light on the different theories. Thus, we must bear in mind that the science we read today represents only the best approximation of a portrait of the earth to date.

THE PHYSICAL CHARACTER OF EARTH

Although we have done pretty well in measuring our planet's physical features, we have not done so well in figuring out its origins. This is not surprising, for the measurements needed to pursue questions of events that happened billions of years ago, such as the formation of the planet's early rocks, are difficult to make. One model of the earth's formation as a planet holds that in the first stage of development, debris (both gaseous and solid) from a stellar explosion gathered (condensed) about a nucleus of some sort. As the mass of debris grew, its gravitational force also grew, compressing the mass into a denser body. As this process took place, the various chemical substances that made up the debris began to rearrange

themselves according to their density into a gravitationally stable configuration, meaning that the heavier substances were pulled by gravity farther toward the interior of the young planet than the lighter substances. This entailed movement of huge volumes of material, and we reason that this was possible because some of the internal substances had turned liquid under the high temperatures of the heat from compression within the planet.

The densest matter, such as iron and nickel, migrated toward the center of the mass while the lighter substances, such as silicon and nitrogen, were displaced outward. In this way, the major zones or *spheres* of the planet were formed: the *lithosphere* (core and mantle), with the highest densities, in the center; the *hydrosphere* over the lithosphere; and the *atmosphere*, where densities are lowest, forming the outer envelope. When life developed on the planet, a fourth sphere was formed—the *biosphere*, where matter achieved densities intermediate between water and air (Fig. 1.1).

The biosphere is the most tenuous sphere of all. Here all but a tiny part of life is housed in a zone only

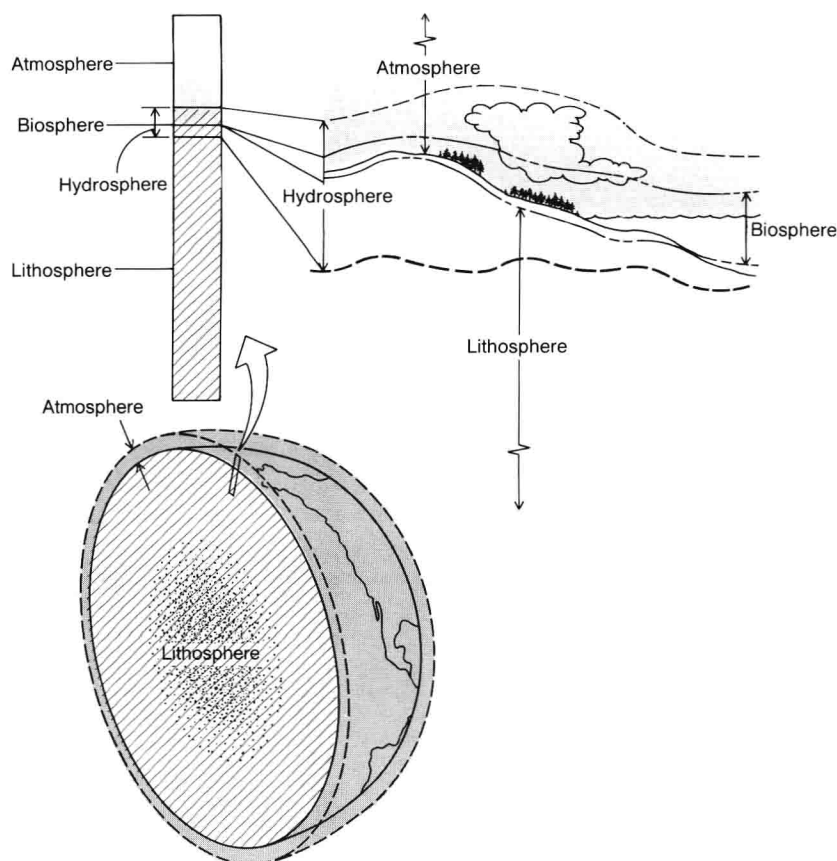


Figure 1.1 The principal spheres of the earth. At the land surface all four spheres merge, forming the landscape.