Guided Tour

A variety of tools within this textbook have been designed to assist with chapter review and critical analysis of chapter topics.

Chapter Outline

Each chapter begins with an outline of the subsections and boxed readings within each chapter.

2 *Chapter 1* The History of Oceanography

Chapter Outline

Oceanography is a broad field in which many sciences are focused on the common goal of understanding the oceans. Geology, geography, geophysics, physics, chemistry, geochemistry, mathematics, meteorology, botany, and zoology have all played roles in expanding our knowledge of the oceans. The field is so broad that oceanography today is usually broken down into a number of subdisciplines.

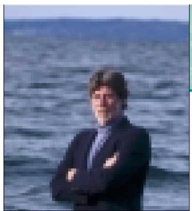
Geological oceanography includes the study of Earth at the sea's edge and below its surface, and the history of the processes that formed the ocean basins. Physical oceanography investigates the causes and characteristics of water movements such as waves, currents, and tides and how they affect the marine environment. It also includes studies of the transmission of energy such as sound, light, and heat in seawater. Marine meteorology (the study of heat transfer, water cycles, and air-sea interactions) is often included in the discipline of physical oceanography...

their first ideas of the oceans from wandering the seashore, wading in the shallows, and gathering food from the ocean's edges. During the Paleolithic period, humans developed the barbed spear, or harpoon, and the gorge. The gorge was a double-pointed stick inserted into a bait and attached to a string. At the beginning of the Neolithic period, the bone fishhook was developed and later the net (fig. 1.1). By 5000 B.C., copper fishhooks were in use.

As early humans moved slowly away from their inland centers of development, they were prepared to take advantage of the sea's food sources when they first explored and later settled along the ocean shore. The remains of shells and other refuse, in piles known as kitchen middens, have been found at the sites of ancient shore settlements. These remains show that our early ancestors gathered shellfish, and fish bones found in some middens suggest that they also used rafts or some type of boat for offshore fishing. Some scientists think that many more artifacts have been lost or scattered as a result of rising sea level. The artifacts that have been found probably give us only an idea of the minimum extent of...

Field Notes Boxes

The essays represented within these boxes are new to this edition and written by oceanographers in the field. These readings highlight relevant oceanographic topics and provide insights into engaging oceanographic careers.



Field Notes

Exploring the Oceans on Earth and Elsewhere

by Dr. John Delaney

Dr. John Delaney is a Professor of Oceanography at the University of Washington, specializing in marine geology. His research focuses on the deep-sea volcanic activity of the Juan de Fuca Ridge in the northeast Pacific Ocean.

Microbes thrive in the toxic, superheated brew of water and dissolved gases that circulates through the volcanic rocks beneath the sea floor. These microbes are called *Archaea.* When the sea floor rocks crack or shift due to an earthquake or a submarine volcanic eruption, the subsurface water and its *Archaea* are released into the marine environment as a potentially significant source of organic material.

This deep biosphere below the sea floor was largely unknown and unexplored until recently. For the past decade, marine scientists have been visiting erupting volcanoes on the sea floor of the Pacific Ocean, and in each case, they found billowing clouds of heated water and microbial material venting from sea floor cracks. After viewing and sampling these venting waters, scientists concluded there is a deep, hot microbial habitat in the volcanically active portion of the oceanic crust. Some of the microbes do not begin to reproduce until the temperatures are higher than 60°C. These life forms do not require sunlight as a source of energy; instead, they use chemicals dissolved out of the rocks and carried in the hot venting water, a process known as chemosynthesis. Speculation is growing that life on Earth may have originated billions of years ago under similar submarine volcanic conditions.

One of today's most compelling questions in the planetary sciences focuses on identifying and quantifying the linkages among a host of plate-tectonic processes and microbial productivity near the sea floor and just below it within Earth's crust. Deformation and volcanism, which occur most frequently near plate margins and less frequently within plate interiors, result in forced fluid flow within the crust. This flow may be uniform with time, may change periodically, or both. The percolating fluid flow operating at spreading centers, subduction zones, along transform faults, or at volcanically active midplate regions transfers heat and chemically active organic and inorganic compounds that provide nutritional support for a widespread but poorly understood microbial biosphere.

Oceanographers have considerable experience studying organic production by photosynthesis at the sea surface and its dependence on sunlight, nutrients, and gas exchange between the ocean and atmosphere. Scientists, however, are currently ill-prepared to assess the importance of fluid-driven, plate-controlled chemosynthetic productivity linked to fluid flow across the water-rock boundary at the bottom of the ocean. The input of active compounds derived from the oceanic crust tends to be localized along faults, fissures, and other venting structures near plate boundaries. The scale and pattern of the venting are variable and cannot be predicted. Studies are required to assess the relative proportions of worldwide organic production from photosynthesis at the sea surface and from chemosynthesis at the sea floor.

The venting of crustal water with its microbial population is a tectonically forced process that operates at rates governed by plate dynamics. The forecasting of where, how, and when nutrient-laden crustal fluids are discharged from the crust into the overlying ocean requires new approaches and may represent the initial steps to understanding a process that also operates on other bodies in our solar system and beyond. The study of these processes at the scale of a single tectonic plate could lead to a new type of deep-sea research, research that is designed to become the basis for a long-term quantitative study of heat, chemistry, and biomass transfers in the deep sea. The local, regional, and global importance of these processes on Earth and on other active, water-bearing planets will be a major focus of research for decades.

To fully explore and understand such a system, scientists must enter and interact will all aspects of the marine environment at the scale of a single tectonic plate, including the water column, sea floor and sub-sea floor. Such studies require long periods of time to allow the collection of data that will reveal patterns and trends on scales of decades rather than a few weeks or a month, as in the traditional ship and underwater vehicle surveys. Advancements in fields including robotics, communications, distributed power, computing, sensor development, and information management are allowing a new phase of oceanographic research and education to emerge.

Integrating these technologies will allow the placement of thousands of sensors in three-dimensional arrays on, above, and within the sea floor. Computers will control monitoring programs and compare measurements against models of plate and oceanic processes. Fiber-optic and power cables will supply power and allow researchers two-way, real-time communication with a network of experiment sites on the sea floor. This observatory system will enable rapid and adaptive responses to changing conditions. Via the Internet, shore-based users will have command and control of ocean-based sensors, instruments, and underwater vehicles. Within the next decade, users on land may have electronic "ringside seats" during submarine volcanic eruptions, thanks to cameras on the sea floor and real-time Internet connections to shore. Indeed, oceanographers today stand on the edge of a revolution.

Efforts to develop coastal and regional cabled ocean observatories are under way in many countries, including the United States, Canada, and Japan, as well as the European Union. A joint

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Chapter Summary

Each chapter's summary provides a quick review of key concepts.

Key Terms

Key Terms are boldfaced and defined within the text, and end-of-chapter key terms listings indicate the most important terms and their locations within each chapter.

Study Questions and Problems

Study Questions and Study Problems serve not only as a concept review, but challenge students to think further about the lessons within each chapter.

50 *Chapter 2* The Water Planet

Summary

The beginning expansion of the universe was followed by the first stars, the reactions that produced the elements, and billions of galaxies. Our solar system is part of the Milky Way galaxy; it began as a rotating cloud of gas. A series of events produced nine planets orbiting the Sun, each planet having unique characteristics. Over approximately 1.5 billion years, Earth heated, cooled, changed, and accumulated a gaseous atmosphere and liquid water.

Reliable age dates for Earth rocks, meteorites, and Moon samples are obtained by radiometric dating. The accepted age of Earth is 4.6 billion years. Geologic time is used to express the timescale of Earth's history.

The distance between Earth and the Sun, Earth's orbit, its period of rotation, and its atmosphere protect Earth from extreme temperature change and water loss. Because Earth rotates, its shape is not perfectly symmetrical. Its exterior is relatively smooth. Natural time periods (the year, day, and month) are based on the motions of the Sun, Earth, and Moon. Because of the tilt of Earth's axis as it orbits the Sun, the Sun appears to move annually between 23½°N and 23½°S, producing the seasons.

Latitude and longitude are used to form a grid system for the location of positions on Earth's surface. Different types of map and chart projections have been developed to show Earth's features on a flat surface. These projections distort Earth's features to some extent. Bathymetric and physiographic charts and maps use elevation and depth contours to depict Earth's topography.

To determine longitudinal position, one must be able to measure time accurately. This need required the development of accurate seagoing clocks for celestial navigation.

Modern navigational techniques make use of radar, radio signals, computers, and satellites. A satellite network provides very accurate position readings and maps storms, tides, sea level, and properties of surface waters.

Water is a vitally important compound on Earth. Of Earth's surface, 71% is covered by its oceans. There is a fixed amount of water on Earth. Evaporation and precipitation move the water through the reservoirs of the hydrologic cycle. Water's residence time varies in each reservoir and depends on the volume of the reservoir and the replenishment rate.

The Northern Hemisphere is the land hemisphere; the Southern Hemisphere is the water hemisphere. Earth has three large oceans extending north from Antarctica. Each has a characteristic surface area, volume, and mean depth. The hypsographic curve is used to show land-water relationships of depth, elevation, area, and volume. It is also used to determine mean land elevation, mean ocean depth, Earth sphere depth, and ocean sphere depth.

Key Terms

All key terms from this chapter can be viewed by term or by definition when studied as flashcards on this book's Online Learning Center at **www.mhhe.com/sverdrup8**.

electromagnetic spectrum, 27
Big Bang, 27
galaxy, 28
light-year, 28
cluster, 28
nebula, 29
dayglow, 30
radiometric dating, 33
isotope, 33
half-life, 33
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Tropic of Cancer, 35
summer solstice, 35
Arctic Circle, 35
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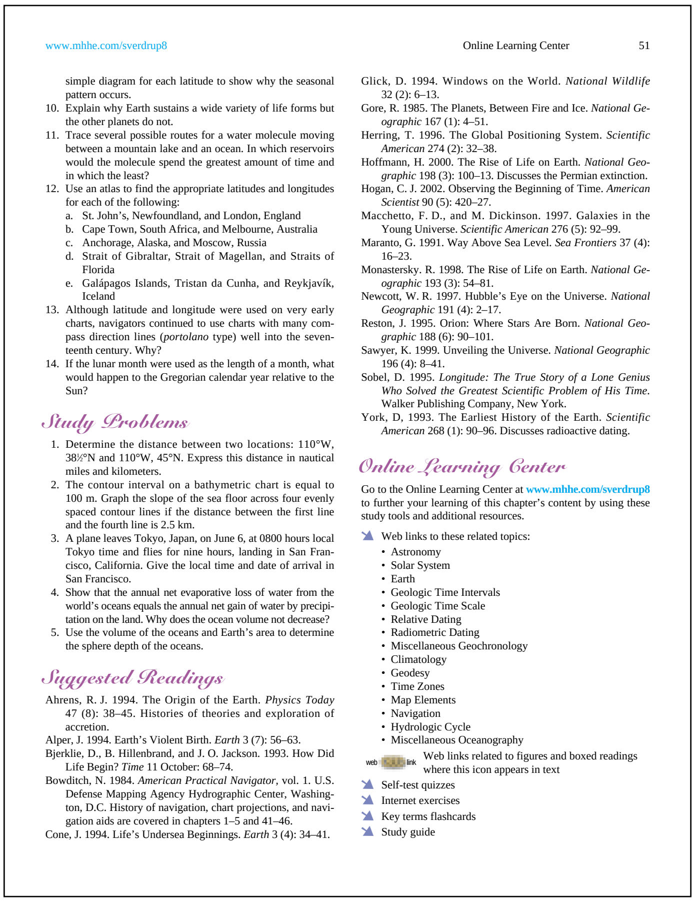
mean ocean sphere depth, 49

Study Questions

1. How and why have estimates of the age of Earth changed over the past few hundred years? Do you think the present estimate of Earth's age will change in the future?
2. Describe the distribution of water and land on Earth.
3. Why does Earth's average surface temperature differ from the surface temperature of other planets in the solar system?
4. Why is the twilight period at sunset shorter at low latitudes than it is at high latitudes?
5. The route of a ship sailing a constant compass course on a Mercator projection is indicated by a straight line that cuts all longitude lines at the same angle. This is a rhumb line. Discuss how this line appears (a) on a polar conic projection, (b) on a globe, and (c) on a tangent plane projection centered on the polar axis.
6. Discuss how the hypsographic curve is used to determine the mean depth and sphere depth of the oceans.
7. Why are the Arctic and Antarctic Circles located at 66½°N and 66½°S respectively?
8. What are some advantages of using satellites for oceanographic research? Are there any disadvantages?
9. How will the seasons change over a calendar year at each of these latitudes: (a) 10°N; (b) 70°N; (c) 30°S? Make a



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simple diagram for each latitude to show why the seasonal pattern occurs.

10. Explain why Earth sustains a wide variety of life forms but the other planets do not.
11. Trace several possible routes for a water molecule moving between a mountain lake and an ocean. In which reservoirs would the molecule spend the greatest amount of time and in which the least?
12. Use an atlas to find the appropriate latitudes and longitudes for each of the following:
    a. St. John's, Newfoundland, and London, England
    b. Cape Town, South Africa, and Melbourne, Australia
    c. Anchorage, Alaska, and Moscow, Russia
    d. Strait of Gibraltar, Strait of Magellan, and Straits of Florida
    e. Galápagos Islands, Tristan da Cunha, and Reykjavík, Iceland
13. Although latitude and longitude were used on very early charts, navigators continued to use charts with many compass direction lines (*portolano* type) well into the seventeenth century. Why?
14. If the lunar month were used as the length of a month, what would happen to the Gregorian calendar year relative to the Sun?

Study Problems

1. Determine the distance between two locations: 110°W, 38½°N and 110°W, 45°N. Express this distance in nautical miles and kilometers.
2. The contour interval on a bathymetric chart is equal to 100 m. Graph the slope of the sea floor across four evenly spaced contour lines if the distance between the first line and the fourth line is 2.5 km.
3. A plane leaves Tokyo, Japan, on June 6, at 0800 hours local Tokyo time and flies for nine hours, landing in San Francisco, California. Give the local time and date of arrival in San Francisco.
4. Show that the annual net evaporative loss of water from the world's oceans equals the annual net gain of water by precipitation on the land. Why does the ocean volume not decrease?
5. Use the volume of the oceans and Earth's area to determine the sphere depth of the oceans.

Suggested Readings

Ahrens, R. J. 1994. The Origin of the Earth. *Physics Today* 47 (8): 38–45. Histories of theories and exploration of accretion.
Alper, J. 1994. Earth's Violent Birth. *Earth* 3 (7): 56–63.
Bjerklie, D., B. Hillenbrand, and J. O. Jackson. 1993. How Did Life Begin? *Time* 11 October: 68–74.
Bowditch, N. 1984. *American Practical Navigator*, vol. 1. U.S. Defense Mapping Agency Hydrographic Center, Washington, D.C. History of navigation, chart projections, and navigation aids are covered in chapters 1–5 and 41–46.
Cone, J. 1994. Life's Undersea Beginnings. *Earth* 3 (4): 34–41.
Glick, D. 1994. Windows on the World. *National Wildlife* 32 (2): 6–13.
Gore, R. 1985. The Planets, Between Fire and Ice. *National Geographic* 167 (1): 4–51.
Herring, T. 1996. The Global Positioning System. *Scientific American* 274 (2): 32–38.
Hoffmann, H. 2000. The Rise of Life on Earth. *National Geographic* 198 (3): 100–13. Discusses the Permian extinction.
Hogan, C. J. 2002. Observing the Beginning of Time. *American Scientist* 90 (5): 420–27.
Macchetto, F. D., and M. Dickinson. 1997. Galaxies in the Young Universe. *Scientific American* 276 (5): 92–99.
Maranto, G. 1991. Way Above Sea Level. *Sea Frontiers* 37 (4): 16–23.
Monastersky. R. 1998. The Rise of Life on Earth. *National Geographic* 193 (3): 54–81.
Newcott, W. R. 1997. Hubble's Eye on the Universe. *National Geographic* 191 (4): 2–17.
Reston, J. 1995. Orion: Where Stars Are Born. *National Geographic* 188 (6): 90–101.
Sawyer, K. 1999. Unveiling the Universe. *National Geographic* 196 (4): 8–41.
Sobel, D. 1995. *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*. Walker Publishing Company, New York.
York, D, 1993. The Earliest History of the Earth. *Scientific American* 268 (1): 90–96. Discusses radioactive dating.

Online Learning Center

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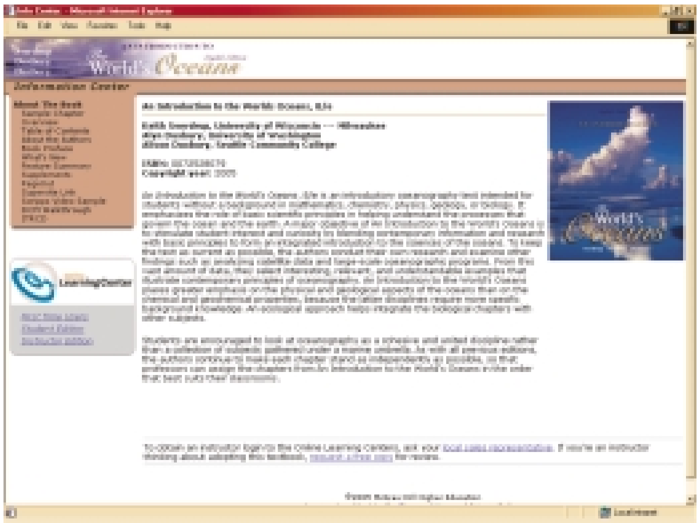
  - Earth
  - Geologic Time Intervals
  - Geologic Time Scale
  - Relative Dating
  - Radiometric Dating
  - Miscellaneous Geochronology
  - Climatology
  - Geodesy
  - Time Zones
  - Map Elements
  - Navigation
  - Hydrologic Cycle
  - Miscellaneous Oceanography
- web link: Web links related to figures and boxed readings where this icon appears in text
- Self-test quizzes
- Internet exercises
- Key terms flashcards
- Study guide

Online Links to Related Topics

Find Internet links to each chapter's content, boxed readings, and figures inside the Online Learning Center for this text at www.mhhe.com/sverdrup8. This icon web link within text indicates that a web link is provided for further reading within the Online Learning Center.

Visit Our Online Learning Center: www.mhhe.com/sverdrup8

This text-specific website hosts many useful tools for the instructor, as well as features to help students sharpen their study skills and make the grade in their oceanography course. The **Instructor's Manual** can be found within the password-protected Instructor Resources section of the Online Learning Center. Students will find a complete **Study Guide** for each chapter, which includes Chapter Objectives, Key Concepts in lecture outline format, and a variety of self-test tools to help understand and retain the content found within each chapter of the textbook. Also available are interactive Key Term Flashcards, related web links



for figures, boxed readings, and chapter topics from the text, and chapter quizzing. PowerWeb, which is available through the Online Learning Center, provides articles from current magazines, newspapers, and journals; weekly updates of current issues; web research tips; an online library of updated research links to help you locate the right information; up-to-the-minute headlines from around the world; plus online quizzing and assessments to measure your understanding of course material.

Instructors: Explore the Digital Content Manager

The Digital Content Manager 2-CD set provides instructors with photos and art from this text in multiple formats to assist in creating customized classroom presentations, dynamic course website content, or attractive printed support materials. This cross-platform CD set also contains additional photos, animations, 34 videos from Scripps Institution of Oceanography, and chapter-specific PowerPoint Lecture Outlines. All of these digital assets are grouped within easy-to-use folders, and sorted by chapter to correlate with the text.