Chapter 2, The Planet Oceanus

LEARNING OBJECTIVES

- Describe the Earth's interior structure and the differences between the various layers.
- Describe the physiography of the ocean floor, identifying the major features and characteristics of each of the bathymetric provinces.
- Explain the importance of temperature and pressure in determining the physical state of the layers within the Earth.
- Use isostasy to explain why sea floor lies low and continents stand high.
- Describe the various techniques for determining sea surface elevation, depth, rock geologic structure, and geologic properties of rock layers in the crust and outer mantle.

CHAPTER OUTLINE

2-1. The Earth's Structure

A. Earth consists of a series of concentric layers or spheres that differ in chemistry and physical properties.
   1. Knowledge of Earth's interior comes from studying earthquakes, variation in gravity and magnetism, and the release of heat.
   2. **Density** is mass per volume measured in gram per cubic centimeter (g/cm^3).

B. The compositional layers of the Earth are the:
   1. **Crust**—outermost rock shell consisting of low-density rock rich in silicon, aluminum, and oxygen.
   2. **Mantle—**extending from the base of the crust to a depth of 2900 km.
      - It consists of hot, dense rock rich in iron, magnesium, silicon, and oxygen.
   3. **Core—**innermost part of the Earth, extending from the base of the mantle to the Earth's center and composed of iron and nickel.
      - It is subdivided into a molten **outer core** and solid **inner core**.

C. Physical state is determined by the combined effects of pressure and temperature.
   1. Increasing pressure raises the melting point of a material.
   2. Increasing temperature provides additional energy to the atoms and molecules of matter allowing them to move farther apart, causing the material to melt.
   3. Both pressure and temperature increase toward the center of the Earth, but at different rates.
   4. Divisions of the Earth based upon physical state are the:
      a. **Lithosphere**—combined rocks of the crust and the outer rigid mantle where the pressure has raised the melting point above the existing temperature and rocks are solid.
      b. **Asthenosphere**—the portion of mantle below the lithosphere, extending to a depth of about 350 km, where the temperature is sufficiently high to melt a fraction of the rocks causing them to be weak and flow plastically.
      c. **Mesosphere—**the mantle below the asthenosphere where pressure has raised the melting point above the existing temperature and the rocks are rigid.
      d. **Outer core—**liquid portion of the core because the temperature is again higher than the melting point of the rock.
      e. **Inner core**—solid part of the core because pressure has raised the melting point of the rock above the existing temperature.

D. Three fluid spheres surround the rocky portion of the Earth.
   1. **Hydrosphere** includes all of the "free" water of the Earth contained in the ocean, lakes, rivers, snow, ice, water vapor, and **groundwater**.
   2. **Atmosphere** is the gaseous envelope that surrounds the Earth and is mainly a mixture of nitrogen and oxygen.
   3. **Biosphere** refers to all living and non-living organic matter.

2-2. The Physiography of the Ocean Floor

E. Physiography and bathymetry (submarine landscape) allow the sea floor to be subdivided into three distinct provinces: continental margins, deep ocean basins, and midoceanic ridges.
   1. **Continental margins** are the submerged edges of the continents and consist of massive wedges of sediment eroded from the land and deposited along the continental edge. The continental margin can be divided into three parts:
      a. **Continental shelf** is the top of the clastic wedge and slopes seaward at about 0.5^{o} from the shoreline to the **shelf break** where it terminates in water between 130 to 200 m deep.
      b. **Continental slope** extends downward from the shelf break at a slope of about 4^{o} to a depth of 2 to 3 km.
         - Parts of the slope are cut by steep-sided **submarine canyons**.
      c. **Continental rise** is a vast sedimentary plain that begins at the base of the continental slope, inclines seaward at about 1^{o} and merges with the deep ocean province at a depth of about 4 km.
   2. **Deep Ocean Province** is between the continental margins and the midoceanic ridge and includes a variety of features from mountainous to flat plains.
      a. **Abyssal plains** are the flattest areas on Earth.
         - They are seaward of the continental rise in water 3 to 5 km deep where sediment, up to 1000 m thick, has buried all sea floor irregularities.
      b. **Abyssal hills** consist of domes and elongated hills less than 1000 m tall and are mainly volcanoes partially buried by layers of sediment.
      c. **Seamounts** are submerged volcanic mountains over 1000 m tall.
         - **Guyots** are seamounts that were once emergent and their tops have been eroded flat by waves.
      d. **Deep-sea trenches** are steep-sided, long, relatively narrow depressions in the sea floor.
         1. Trenches form the deepest part of the ocean and are located adjacent to volcanic mountain chains or volcanic island arcs.
         2. They are commonly associated with earthquakes and are partially filled with sediments.
   3. **Midoceanic Ridge Province** consists of a continuous submarine mountain range that covers about one third of the ocean floor and extends for about 60,000 km around the Earth.
      a. Most oceanic ridges are not located in the center of the ocean basin.
      b. A **rift valley** occupies the center of the ridge and forms where opposite sides of the ridge have pulled apart.
         1. They are bounded on each side by faults and the rocks in the center have slid downward as the two sides pull apart.
         2. The rift valley is geologically active with earthquakes and volcanic outflows.
      c. **Transform faults** offset the ridge segments along its axis and rocks on opposite sides of the fault grind past each other as the sea floor moves.
         - **Fracture zones** are the inactive parts of the transform faults that extend beyond opposing sides on the ridge and across part of the deep ocean basin.

2-3. Geologic Differences between Continents and Ocean Basins

F. Continents and ocean basins differ in composition, elevation, and physiographic features.
   1. Elevation of Earth's surface displays a bimodal distribution with about 29% above sea level and much of the remainder at a depth of 4 to 5 kilometers below sea level.
   2. Continental crust is mainly composed of **granite**, a light colored, lower density (2.7 g/cm^3) igneous rock rich in aluminum, silicon, and oxygen.
   3. Oceanic crust is composed of **basalt**, a dark colored, higher density (2.9 g/cm^3) volcanic rock rich in silicon, oxygen, and magnesium.
   4. The **moho** is the boundary between rocks of the crust and the denser (3.3 g/cm^3) rocks of the mantle.

G. **Isostasy** refers to the balance of an object "floating" upon a fluid medium. Height of the mass above and below the surface of the medium is controlled by the thickness of the mass and its density (similar to ice floating in water).
   1. Greater the density of the mass, the lower it will sink in the medium.
   2. Greater the thickness of the mass, the higher a portion of it will rise above the medium.
   3. Continents are thick (30 to 40 km), have low density, and rise high above the supporting mantle rocks.
   4. Sea floor is thin (4-10 km), has greater density, and doesn't rise as high above the mantle.