Chapter 2
PLATE TECTONICS AND PHYSICAL HAZARDS

CHAPTER OUTLINE

I. Earth Structure
- A. Core, mantle and crust
- B. Lithosphere
- C. Asthenosphere
- D. Isostacy

II. Plate Movement
- A. Lithospheric plates
- B. Plate tectonics
- C. Divergent Boundaries
  1. Mid-Ocean Ridges
- D. Convergent Boundaries
  1. Subduction Zones
  2. Collision Zones
- E. Transform Boundaries
- F. Seafloor spreading

III. Hazards and Plate Boundaries
- A. Divergent Boundaries
  1. Spreading Centers
  2. Rift Zones
- B. Convergent Boundaries
  1. Subduction Zones
  2. Collision Zones
- C. Collision of Continents
  1. Collision Zone
- D. Transform Boundaries
- E. Hotspot Volcanoes
  1. Oceanic Hotspots
  2. Resurgent Calderas

IV. Development of a Theory
- A. Pangaea
- B. Continental Drift
  1. Mountain Ranges
  2. Age of Rocks
  3. Fossils
  4. Glaciation
- C. Seafloor Spreading
  1. Mid-Oceanic Ridge

   2. Magnetic Field
   3. Age of Seafloor
D. Plate Tectonics
E. Scientific Method
F. Hypothesis
G. Theory

KEY TERMS

asthenosphere
collision zone
continental drift
convergent boundary
core
crust
divergent boundary
hotspot volcano
hypothesis
isostacy
lithosphere
lithospheric plate
magnetic field
mantle
mid-oceanic ridge
Pangaea
plate tectonics
rift zone
scientific method
seafloor spreading
spreading center
subduction zone
theory
transform boundary
trench

KEY POINTS

1. Earth Structure and Plates

- Earth is made up of an inner and outer core, surround by a brick mantle and covered by a much thinner crust. The crust and stiff outer part of the underlying mantle is called the lithosphere. The inner, hotter region is the asthenosphere. **FIGURE 2-1**.
- The concept of isostacy explains why the lower-density continental rocks stand higher than the ocean-floor rocks and sink deeper into the underlying mantle. This behavior is analogous to ice (lower density) floating higher in water (higher density). **FIGURE 2-2** and **By the Numbers 2-1**.
- A dozen or so nearly rigid lithospheric plates make up the outer 60 to 200 km of Earth. They slowly slide past, collide with, or spread apart from each other. **FIGURES 2-3** and **2-4**.

2. Hazards and Plate Boundaries

- Much of the tectonic action, in the form of earthquakes and volcanic eruptions, occurs near the boundaries between the lithospheric plates**. FIGURES 2-5** and **2-6**.
- Where plates diverge from each other, new lithosphere forms. If the plates are continental material, a continental rift zone forms. As this process continues, a new ocean basin can develop, and the spreading continues from a mid-oceanic ridge, where basaltic magma pushes to the surface. **FIGURES 2-7** and **2-10**.

- Subduction zones, where ocean floors slide beneath continents or beneath other slabs of oceanic crust, are areas of major earthquakes and volcanic eruptions. These eruptions form volcanoes on the overriding plates. **FIGURES 2-11** and **2-12**.
- Continent–continent collision zones, where two continental plates collide, are regions with major earthquakes and the tallest mountain ranges on Earth. **FIGURE 2-13**.
- Transform faults involve two lithospheric plates sliding laterally past one another. Where these faults cross continents, such as along the San Andreas Fault though California, they cause major earthquakes. **FIGURE 2-14**.
- Hotspots form chains of volcanoes within individual plates rather than near plate boundaries. Because lithosphere is moving over hotspots fixed in the Earth's underlying asthenosphere, hotspots grow as a trailing track of progressively older extinct volcanoes. **FIGURES 2-15** and **2-16**.

3. Development of a Theory

- The hypothesis of continental drift was supported by matching shapes of the continental margins on both sides of the Atlantic Ocean, as well as the rock types, deformation styles, fossil life forms, and glacial patterns. **FIGURES 2-17** and **2-18**.
- Continental drift evolved into the modern theory of plate tectonics based on new scientific data, including the existence of a large ridge running the length of many deep oceans, matching alternating magnetic stripes in rock on opposite sides of the oceanic spreading ridges, and age dates from oceanic rocks that confirmed a progressive sequence from very young rocks near the rifts to older oceanic rocks toward the continents. **FIGURES 2-19** to **2-22**.
- The scientific method involves developing tentative hypotheses that are tested by new observations and experiments, which can lead to confirmation or rejection.
- When hypotheses are confirmed by multiple sources of data over a long time, they become a theory—or widely accepted scientific fact.

LECTURE SUGGESTIONS

1. Discuss the various types of plate boundaries and how they yield natural disasters.
2. It is important that students have a thorough understanding of the types of boundaries and the location in which they occur. By knowing the type of boundary, scientists can determine the type of disasters that is likely to occur, and where.
3. Have students cite popular examples of certain plate boundaries (i.e., the Himalayas or Japanese Islands) and explain what processes are functioning at these locations to create the landscapes that are present.
4. Discuss the structure of the Earth (lithosphere plates, asthenosphere, mantle, etc.) and the processes that go on below the surface of the Earth (isostacy) to create surface landscapes.
5. Explain the scientific method and how it is used by people on a daily basis—not just in a scientific, academic, or research environment.

WEBSITES

http://pubs.usgs.gov/publications/text/dynamic.html
http://www.nature.nps.gov/geology/usgsnps/animate/pltecan.html
http://www.fourmilab.ch/earthview/vplanet.html
http://www.ucmp.berkeley.edu/geology/tectonics.html
http://www.volcano.si.edu/tdpmap/

VIDEOS

Video: Continental Drift and Plate Tectonics. Tanya Atwater, Univ. of California, Santa Barbara.
Video: Plate Tectonics and Continental Drift. Gould Media, Inc., Mount Vernon, NY.
Video: Earth Revealed #1: The Living Machine: The Theory of Plate Tectonics. Annenberg/CPB Collection, P.O. Box 1922, Santa Barbara, CA.
Video: Earth Revealed #5: The Birth of a Theory—Continental Drift and Sea-Floor Spreading. Annenberg/CPB Collection, P.O. Box 1922, Santa Barbara, CA.
Video: Earth Revealed #6: Plate Dynamics. Annenberg/CPB Collection, P.O. Box 1922, Santa Barbara, CA.

REFERENCES

Kious, W. J. and R.I. Tilling, 1995, This Dynamic Earth: The Story of Plate Tectonics: U.S. Geological Survey, 77 p.

ANSWERS TO QUESTIONS FOR REVIEW

1. Describe differences between Earth's crust, lithosphere, asthenosphere, and mantle.

   ANSWER: Earth's crust overlies mantle—distinguished by composition: Oceanic crust is basaltic composition, and continental crust is "granitic" composition. The book notes that the ocean's lithosphere is composed of a low-silica crust, whereas the continental crust is largely composed of high-silica-content minerals. Earth's lithosphere overlies asthenosphere—distinguished by rock properties/behavior/strength: Lithosphere is rigid; asthenosphere is plastic/easily deformed.

2. What does oceanic lithosphere consist of and how thick is it?

   ANSWER: The top 7 km is low-silica crust; it contains iron- and magnesium-rich minerals (basalt over peridotite) and is about 60 km thick.

3. What are the main types of lithospheric plate boundaries, described in terms of relative motions? Provide a real example of each (by name or location).

   ANSWER: Divergent Boundary: Plates move apart, new crust is created. Examples are the Mid-Atlantic Ocean Ridge and the East African Rift Zone. Convergent Boundary: Plates collide, old crust is destroyed. Examples include ocean-continent collision, such as the Cascade Ranges and the Andes in South America; ocean-ocean collision, such as the Japanese Islands and Indonesia; and continent-continent collision, such as the Himalayas. Transform Boundary: Crust is neither created nor destroyed, horizontal displacement.

An example is the San Andreas Fault

4. Why does oceanic lithosphere almost always sink beneath continental lithosphere at convergent zones?

   ANSWER: Oceanic lithosphere is denser/heavier than continental lithosphere.

5. Along which type(s) of lithospheric plate boundary are large earthquakes common? Why?

   ANSWER: Although earthquakes occur at all plate boundaries, convergent boundaries produce the largest earthquakes. As one plate is being subducted beneath another, the overlying crust deforms. Eventually the stress applied to the rock is greater than the strength of the rock causing the crust to fracture.

6. Along which type(s) of lithospheric plate boundary are large volcanoes most common? Provide an example.

   ANSWER: Continent–ocean convergent boundary (Cascadia subduction zone/High Cascades volcanoes) and ocean-ocean convergent boundary (Japanese Islands).

7. What direction is the Pacific Plate currently moving, based on FIGURE 2-15? How fast is this plate moving?

   ANSWER: West-northwest; approximately 9 cm per year.

8. Before people understood plate tectonics, what evidence led some scientists to believe in continental drift?

   ANSWER: Geographic fit of continents by matching coastlines across the Atlantic Ocean, match of rock formations across the Atlantic Ocean, match of ages of continental rocks across the Atlantic Ocean, match of fossils across the Atlantic Ocean, and glacial patterns.

9. If the coastlines across the Atlantic Ocean are spreading apart, why isn’t the Atlantic Ocean deepest in its center?

   ANSWER**:** New ocean floor wells up and forms a ridge in the middle of the Atlantic Ocean (Mid-Atlantic Ridge).

10. What evidence confirmed seafloor spreading?

    ANSWER: Reversals of the Earth’s magnetic field are preserved in ocean-floor basalt, as matching patterns across the mid-oceanic ridge. The youngest ocean-floor basalt is at the ridge.

11. Why are high volcanoes such as the Cascades found on the continents and in a row parallel to the continental margin?

    ANSWER: They are the surface expression of the active subduction zone.

12. Explain how the modern theory of plate tectonics developed in the context of the scientific method.

    ANSWER: The scientific method is based on logical analysis of data to solve problems. The evidence for continental drift and additional data such as magnetic patterns in the ocean-floor were used to test the hypothesis of plate tectonics.

13. How does the height of a mountain range compare with the thickness of the crust or lithosphere below the mountain? Relate this to the percentage of an iceberg above the water line.

    ANSWER: The height of an iceberg above the water line or a mountain range above the average continent is dependent on the difference in density between the submerged part of the iceberg or mountain and the surrounding water or mantle. Because the density of ice is 90% of the density of the surrounding water, 10% of the iceberg is above the water. The density of average continental rocks is 84% of the density of the mantle. This results in 16% of the mountain being exposed.

ANSWERS TO GLOBAL GEOSCIENCE WATCH QUESTIONS

1. b
2. c
3. east