Mountain Building

Objectives

After reading, studying, and discussing Chapter 10, you should be able to:

- Discuss rock deformation and list the factors that influence the strength of a rock.
- List the major types of folds and faults and describe how they form.
- Describe mountain building associated with convergent plate boundaries.
- Describe the process of isostasy and the role of isostatic adjustment during crustal uplifting.

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Summary

If you wish, download an MSWord version of the Chapter Outline. OUTLINE

(NOTE: Downloading the outline requires that you have a program such as RealDownload installed on your computer.)

The following statements summarize the primary objectives presented in the chapter.

- **Deformation** refers to changes in the shape and/or volume of a rock body. Rocks deform differently depending on the environment (temperature and confining pressure), the composition and of the rock, and the length of time stress is maintained. Rocks first respond by deforming **elastically**, and will return to their original shape when the stress is removed. Once their elastic limit (strength) is surpassed, rocks either deform by ductile flow or they fracture. **Ductile deformation** is a solid state flow that results in a change in size and shape of rocks without fracturing. Ductile deformation occurs in a high temperature/high pressure environment. In a near-surface environment, when stress is applied rapidly, most rocks deform by **brittle failure**.
- One of the most basic geologic structures associated with rock deformation are **folds** (flat-lying sedimentary and volcanic rocks bent into a series of wavelike undulations). The two most common types of folds are **anticlines**, formed by the upfolding, or arching, of rock layers, and **synclines**, which are downfolds. Most folds are the result of horizontal **compressional stresses**. **Domes**(upwarped structures) and **basins** (downwarped structures) are circular or somewhat elongated folds formed by vertical displacements of strata.

- Faults are fractures in the crust along which appreciable displacement has occurred. Faults in which the movement is primarily vertical are called **dip-slip faults**. Dip-slip faults include both **normal** and **reverse faults**. Low-angle reverse faults are called **thrust**

faults. Normal faults indicate **tensional stresses** that pull the crust apart. Along spreading centers, divergence can cause a central block called a **graben**, bounded by normal faults, to drop as the plates separate.

- Reverse and thrust faulting indicate that **compressional forces** are at work. Large**thrust faults** are found along subduction zones and other convergent boundaries where plates are colliding.
- **Strike-slip faults** exhibit mainly horizontal displacement parallel to the fault surface. Large strike-slip faults, called **transform faults**, accommodate displacement between plate boundaries. Most transform faults cut the oceanic lithosphere and link spreading centers. The San Andreas fault cuts the continental lithosphere and accommodates the northward displacement of southwestern California.

- **Joints** are fractures along which no appreciable displacement has occurred. Joints generally occur in groups with roughly parallel orientations and are the result of brittle failure of rock units located in the outermost crust.
- The name for the processes that collectively produce a mountain system is **orogenesis**. Most mountains consist of roughly parallel ridges of folded and faulted sedimentary and volcanic rocks, portions of which have been strongly metamorphosed and intruded by younger igneous bodies.
- Major mountain systems form along **convergent plate boundaries**. **Andean-type mountain building** along continental margins involves the convergence of an oceanic plate and a plate whose leading edge contains continental crust. At some point in the formation of Andean-type mountains a **subduction zone** forms along with a **continental volcanic arc**.
- **Continental collisions**, in which both plates are carrying continental crust, have resulted in the formation of the Himalaya Mountains and the Tibetan Plateau. Continental collisions also formed many other mountain belts, including the Alps, Urals, and Appalachians.
- Recent investigations indicate that **accretion**, a third mechanism of orogenesis, takes place where **small crustal fragments collide and accrete to continental margins** along plate boundaries. The accreted crustal blocks are referred to as **terranes**. The mountainous topography of Alaska and the westernmost regions of Canada, the United States, and Mexico formed as the result of the accretion of terranes to North America.
- Earth's less dense crust floats on top of the denser and deformable rocks of the mantle, much like wooden blocks floating in water. The concept of a floating crust in gravitational balance is called **isostasy**. Most mountainous topography is located where the crust has been shortened and thickened. Therefore, mountains have deep, buoyant crustal roots that isostatically support them. As erosion lowers the peaks, **isostatic adjustment** gradually raises the mountains in response. The process of uplifting and erosion will continue until the mountain block reaches "normal" crustal thickness.

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Chapter 10: **Mountain Building**

I. Deformation

A. Deformation is a general term that refers to all changes in the original form and/or size of a rock body

B. Most crustal deformation occurs along plate margins
C. Factors that influence the strength of a rock
    1. Temperature and confining pressure
    2. Rock type
    3. Time

II. Folds
A. Rocks bent into a series of waves
B. Most folds result from compressional forces which shorten and thicken the crust
C. Types of folds
    1. Anticline – upfolded, or arched, rock layers
    2. Syncline – downfolded rock layers
    3. Anticlines and synclines can be
        a. Symmetrical - limbs are mirror images
        b. Asymmetrical - limbs are not mirror images
        c. Overturned - one limb is tilted beyond the vertical
    4. Where folds die out they are said to be plunging
    5. Other types of folds
        a. Dome
            1. Circular, or slightly elongated
            2. Upwarped displacement of rocks
            3. Oldest rocks in core
        b. Basin
            1. Circular, or slightly elongated
            2. Downwarped displacement of rocks
            3. Youngest rocks in core

III. Faults
A. Faults are fractures (breaks) in rocks along which appreciable displacement has taken place
B. Types of faults
    1. Dip-slip fault
        a. Movement along the inclination (dip) of fault plane
        b. Parts of a dip-slip fault
            1. Hanging wall – the rock above the fault surface
            2. Footwall – the rock below the fault surface
        c. Types of dip-slip faults
            1. Normal fault
                a. Hanging wall block moves down
                b. Associated with fault-block mountains
                c. Prevalent at spreading centers
                d. Caused by tensional forces
            2. Reverse and thrust faults
                a. Hanging wall block moves up
                b. Caused by strong compressional stresses
                c. Reverse fault - dips greater than 45
                d. Thrust fault - dips less than 45
    2. Strike-slip faults
        a. Dominant displacement is horizontal and parallel to the trend, or strike
        b. Transform fault
            1. Large strike-slip fault that cuts through the lithosphere
            2. Often associated with plate boundaries

- 3. Joints
  - a. Fractures along which no appreciable displacement has occurred
  - b. Most are formed when rocks in the outer-most crust are deformed

IV. Mountain belts

- A. Orogenesis refers to processes that collectively produce a mountain belt
- B. Mountain building at convergent boundaries
  - 1. Most mountain building occurs at convergent plate boundaries
  - 2. Aleutian-type mountain building
    - a. Where two oceanic plates converge and one is subducted beneath the other
    - b. Volcanic island arcs forms
      - 1. Found in shrinking ocean basins, such as the Pacific
      - 2. e.g. Mariana, Tonga, Aleutian, and Japan arcs
  - 3. Andean-type mountain building
    - a. Oceanic-continental crust convergence
    - b. e.g. Andes Mountains
    - c. Types related to the overriding plate
      - 1. Passive margins
        - a. Prior to the formation of a subduction zone
        - b. e.g. East Coast of North America
      - 2. Active continental margins
        - a. subduction zone forms
        - b. Deformation process begins
      - 3. Continental volcanic arc forms
      - 4. Accretionary wedge forms
      - 5. Examples of inactive Andean-type orogenic belts include
        - a. Sierra Nevada Range
        - b. California's Coast Ranges
  - 4. Continental collisions
    - a. Where two plates with continental crust converge
    - b. e.g., India and Eurasian plate collision
      - 1. Himalaya Mountains
      - 2. Tibetan Plateau
  - 5. Continental accretion
    - a. Third mechanism of mountain building
    - b. Small crustal fragments collide with and accrete to continental margins
    - c. Accreted crustal blocks are called terranes
    - d. Occurred along the Pacific Coast

V. Buoyancy and the principle of isostasy

- A. Evidence for crustal uplift includes wave-cut platforms high above sea level
- B. Reasons for crustal uplift
  - 1. Not so easy to determine
  - 2. Isostasy
    - a. Concept of a floating crust in gravitational balance
    - b. When weight is removed from the crust, crustal uplifting occurs
      - 1. Called isostatic adjustment
      - 2. Crustal buoyancy can account for considerable vertical movement