Chapter 12
Earth's Interior

Odd they chose Etna for their frontispiece. Recent eruptions may suggest that Etna is changing from subduction to hot spot in style

P and S waves moving through a solid

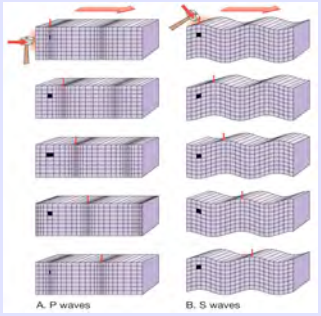
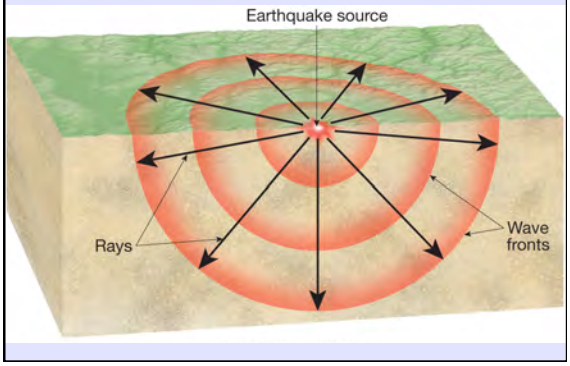
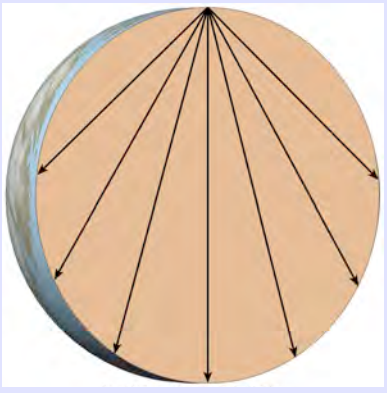


Figure 12.2

Figure 12.2





Probing Earth's interior

- **P waves always faster than S waves**
- **Wave velocity increases with density and stiffness**
- **Passing from one material to another causes waves to refract (bend)**

Figure 12.4

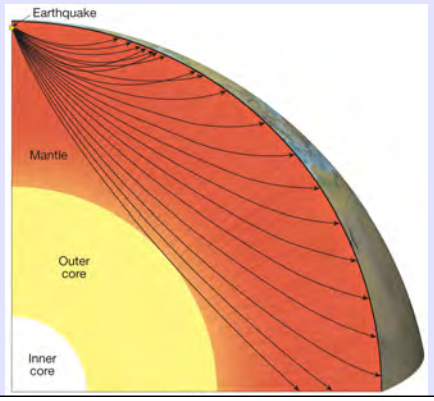


Figure 12.1

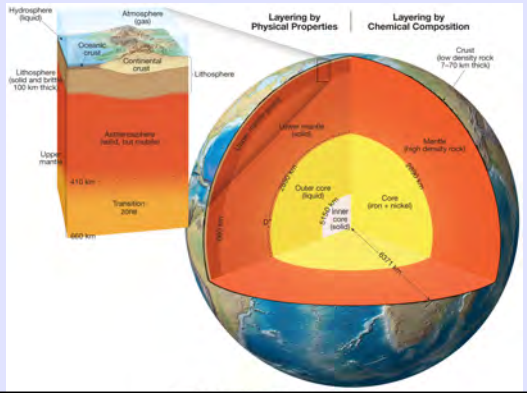
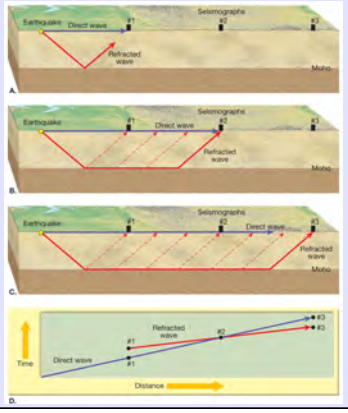


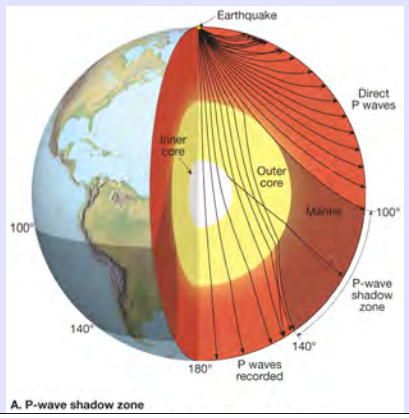
Figure 12.7



Probing Earth's interior

- P waves able to propagate through liquids as well as solids.
- S waves cannot pass through liquids

Figure 12.10A



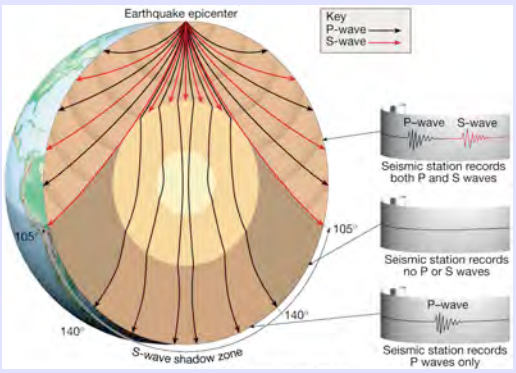
Discovering Earth's major boundaries

- Core-mantle boundary
  - Discovered in 1914 by Beno Gutenberg
  - Based on observation that P waves die out at 105° from earthquake and reappear at about 140°
  - 35°-wide belt is named P-wave shadow zone

Discovering Earth's major boundaries

- Discovery of inner core
  - Predicted by Inge Lehmann in 1936
  - P waves passing through inner core show increased velocity, suggesting inner core is solid

Figure 12.10B (old version)



Discovering Earth's major boundaries

- Moho (Mohorovicic discontinuity)
  - Discovered in 1909 by Andriaja Mohorovicic
  - Separates crustal materials from underlying mantle
  - Identified by change in P-wave velocity

Seismic waves and Earth's structure

- Abrupt changes in seismic-wave velocities that occur at particular depths helped seismologists conclude that Earth must be composed of distinct shells
- Layers are defined by composition

Figure 12.6

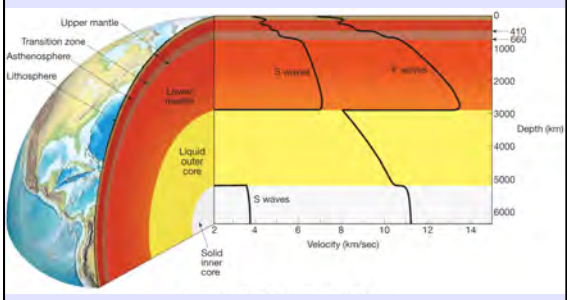
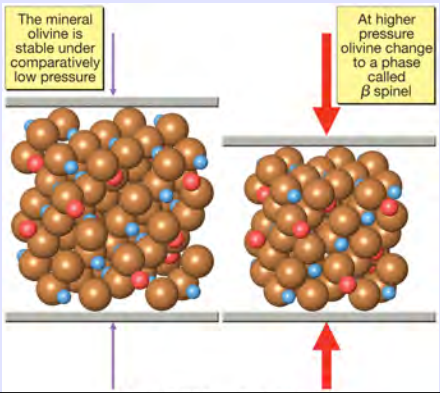


Figure 12.8



Crust

- Two parts
  - Continental crust
    - Average rock density about 2.7 g/cm^3
    - Average composition of granodiorite
    - 30-70 km thick

Crust

- Two parts
  - Oceanic crust
    - Density about 3.0 g/cm^3
    - Composed mainly of igneous rock basalt
    - 8-10 km thick, except at spreading ridges, where it is very thin

Mantle

- Contains 82% of Earth's volume
- Solid, rocky layer
- Upper portion has composition of ultramafic rock 'peridotite'
- Three parts
  - Mantle lithosphere (uppermost mantle) ~70-180 km thick. Density ~3.4 g/cm^3
  - Asthenosphere (upper mantle) ~560 km thick
  - Mesosphere (lower mantle) ~2240 km thick

Core

- Larger than planet Mars
- Earth's dense central sphere
- Two parts
  - Outer core - liquid outer layer about 2270 km thick
  - Inner core - solid inner sphere with radius of 1216 km

Core

- Density and composition
  - Average density nearly 11 g/cm^3 and at Earth's center approaches 14x density of water
  - Mostly iron, with 5% to 10% nickel and lesser amounts of lighter elements

Figure 12.9

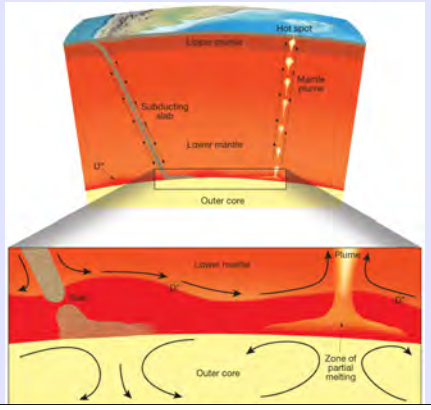
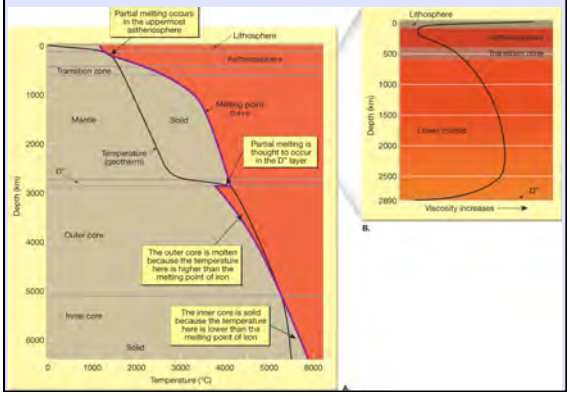


Figure 12.16



- **Origin of the layers**

Core

- **Earth's magnetic field**
  - **Electrically conductive inner and outer core**
  - **Inner core rotates faster than Earth's surface and axis of rotation is offset about 10 degrees from Earth's poles. Makes one extra rotation every 400 years.**

Possible origin of Earth's magnetic field

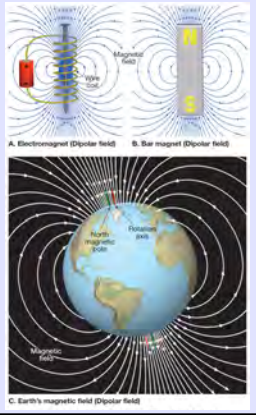
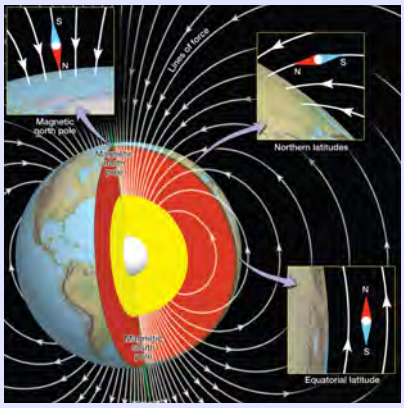


Figure 12.22

Figure 12.23



Magnetic Reversals

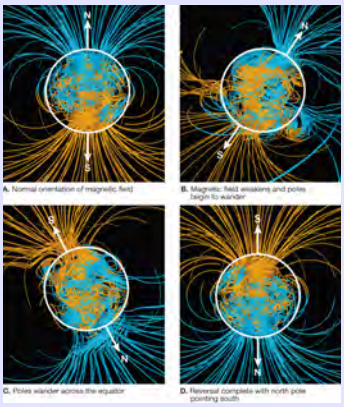


Fig. 12.25

Seismic waves and Earth's structure

- Layers defined by physical properties
  - Main layers of Earth's interior based on physical properties and hence mechanical strength

Seismic waves and Earth's structure

- Layers defined by physical properties
  - Lithosphere (sphere of rock)
    - Earth's outermost layer
    - Consists of crust and uppermost mantle
    - Relatively cool, rigid shell
    - Averages about 100 km in thickness, but may be 250 km or more thick beneath older portions of continents
    - Includes crust and upper mantle

Seismic waves and Earth's structure

- Layers defined by physical properties
  - Asthenosphere (weak sphere)
    - Beneath lithosphere, in upper mantle from depths of ~100 km to ~ 660 km
    - Small amount of melting in upper portion mechanically detaches lithosphere from layer below, allowing lithosphere to move independently of asthenosphere

Seismic waves and Earth's structure

- Layers defined by physical properties
  - Mesosphere or lower mantle
    - Rigid layer between depths of 660 km and 2900 km
    - Rocks are very hot and capable of very gradual flow

Seismic waves and Earth's structure

- Layers defined by physical properties
  - Outer core
    - Composed mostly of iron-nickel alloy
    - Liquid layer
    - 2270 km (1410 miles) thick
    - Convective flow within outer core generates Earth's magnetic field

Seismic waves and Earth's structure

- Layers defined by physical properties
  - Inner core
    - Sphere with radius of 3486 km (2161 miles)
    - Behaves like solid

Earth's layered structure

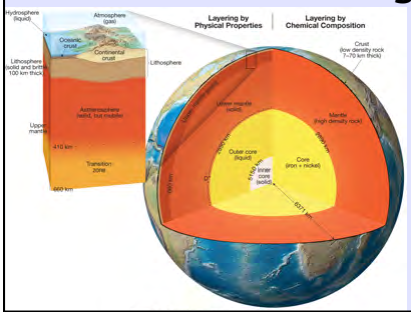


Figure 12.1

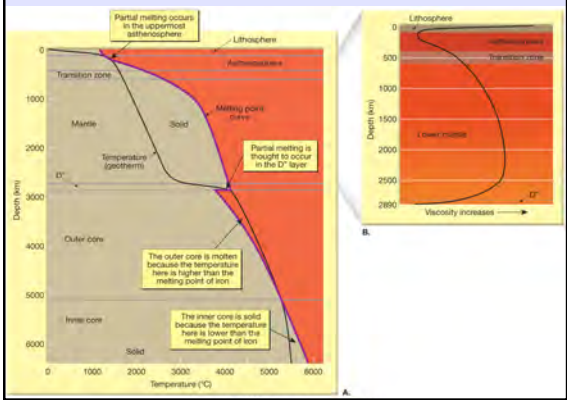
Earth' internal heat engine

- Earth's temperature gradually increases with depth at rate known as geothermal gradient
  - Varies considerably from place to place
  - Averages between about 20°C and 30°C per km in crust (rate of increase is much less in mantle and core)

Earth' internal heat engine

- Major processes that have contributed to Earth's internal heat
  - Heat emitted by radioactive decay of isotopes of uranium (U), thorium (Th), and potassium (K)
  - Heat released as iron crystallized to form solid inner core
  - Heat released by colliding particles during formation of Earth
  - Compression from increasing pressure during accretion

Figure 12.16



Earth' internal heat engine

- Heat flow in crust
  - Process called conduction
  - Rates of heat flow in crust varies
- Mantle convection
  - Mantle must have effective method of transmitting heat from core outward

Earth' internal heat engine

- Mantle convection
  - Probably limited to asthenosphere
  - Mesosphere very viscous and could only convect very slowly.

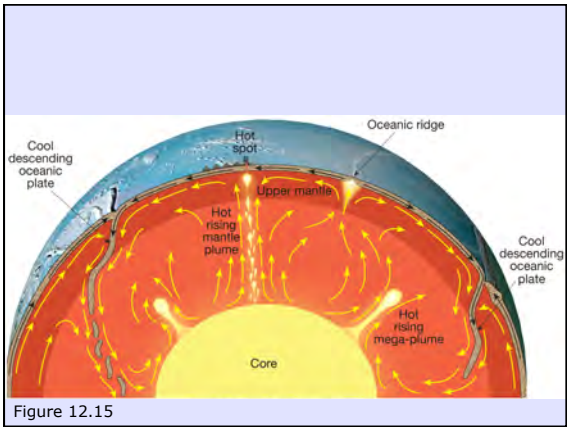


Figure 12.15

Figure 12.20 We can 'see' the convection in the mantle