Earth and Planetary Sciences (ES1101)

(Interior of the Earth)
(Autumn 2021 by Gaurav Shukla)

Book: **1) Understanding Earth by Grotzinger & Jordan (Text Book)**
2) Earth: An introduction to Physical Geology by Tarbuck & Lutgens
3) The Solid Earth: An introduction to global geophysics by Fowler

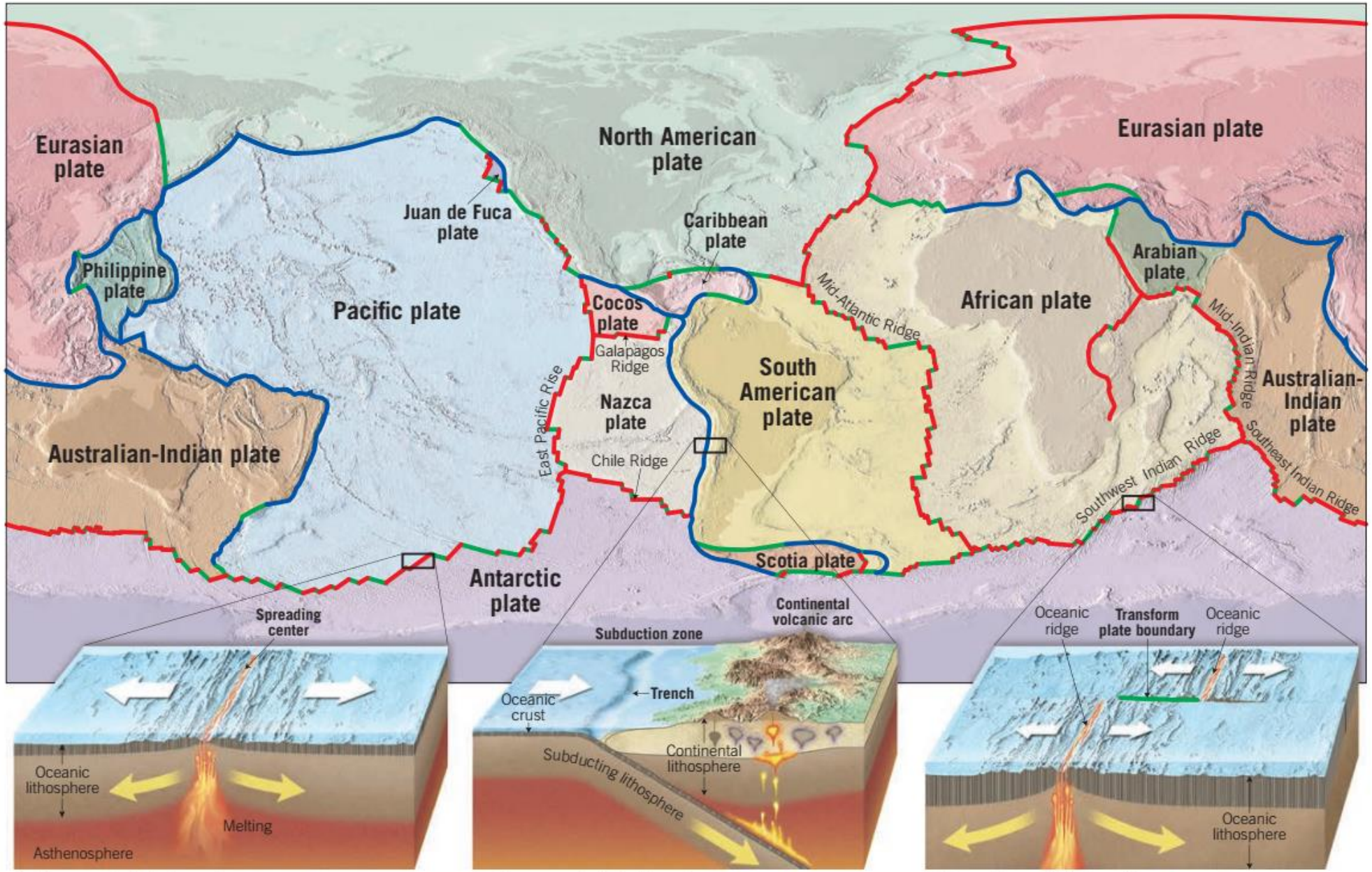
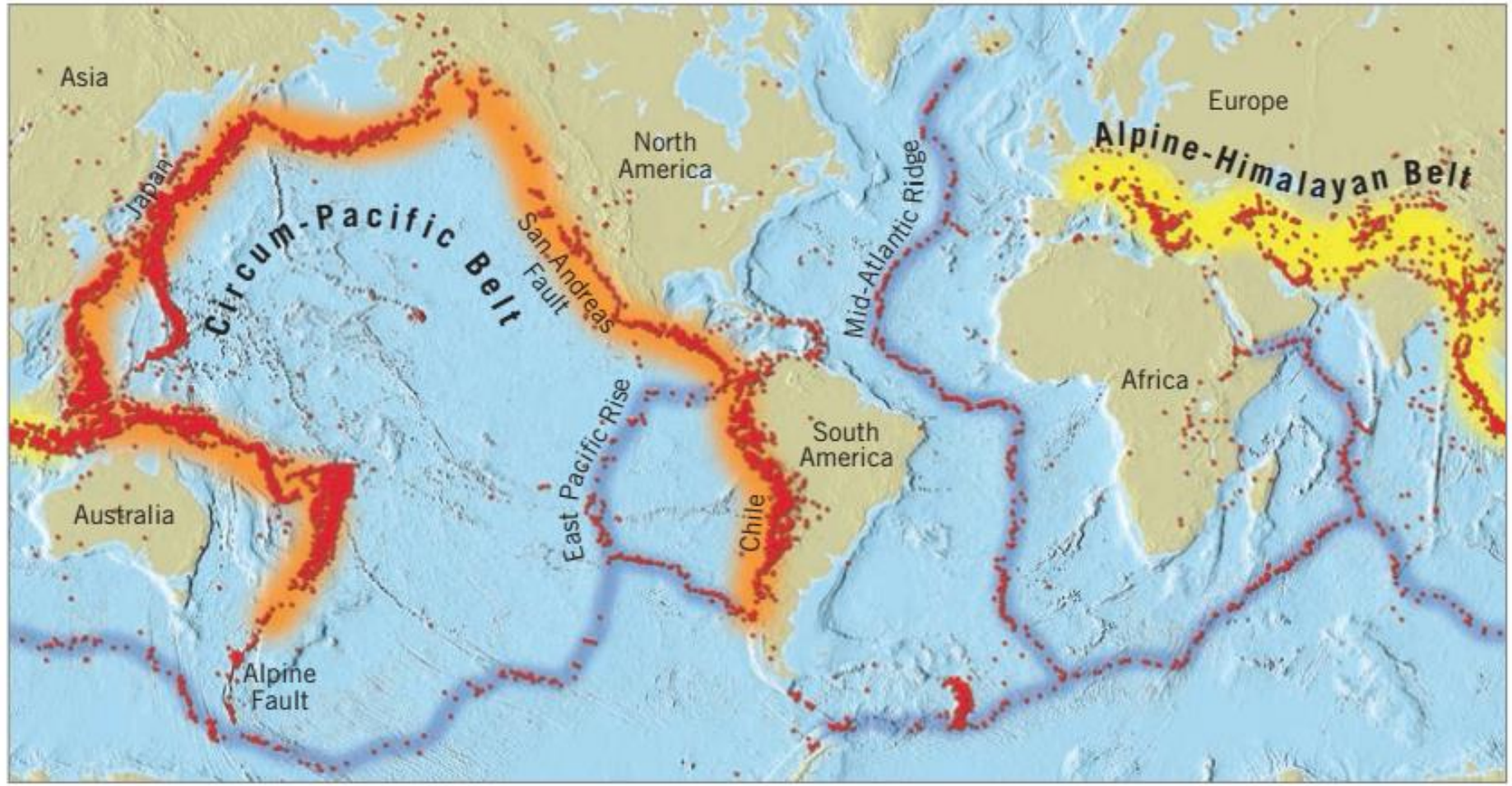
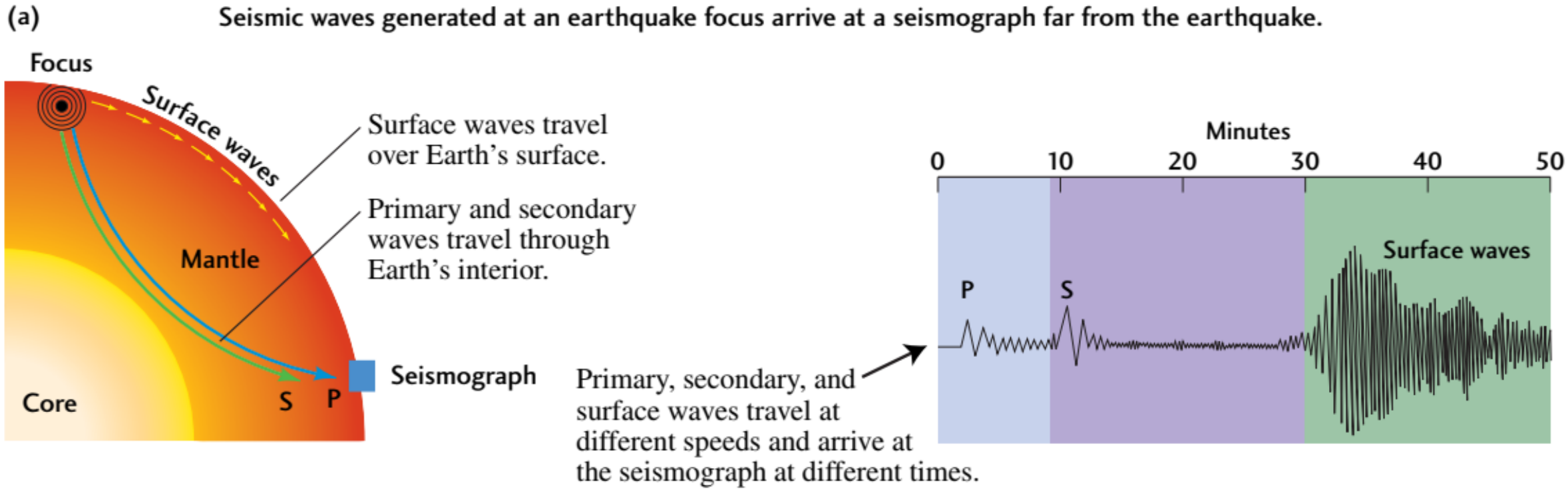

Eurasian plate
North American plate
Eurasian plate
Juan de Fuca plate
Caribbean plate
Philippine plate
Pacific plate
Cocos plate
Mid-Atlantic Ridge
African plate
Arabian plate
Mid-Indian Ridge
Galapagos Ridge
South American plate
Australian-Indian plate
East Pacific Rise
Nazca plate
Australian-Indian plate
Chile Ridge
Southwest Indian Ridge
Southeast Indian Ridge
Scotia plate
Antarctic plate
Spreading center
Oceanic lithosphere
Melting
Asthenosphere
A. Divergent plate boundary
Subduction zone
Continental volcanic arc
Oceanic crust
Trench
Continental lithosphere
Subducting lithosphere
B. Convergent plate boundary
Oceanic ridge
Transform plate boundary
Oceanic ridge
Oceanic lithosphere
C. Transform plate boundary

Figure 11.33
Global earthquake belts Distribution of nearly 15,000 earthquakes with magnitudes equal to or greater than 5 for a 10-year period. (Data from USGS)



Earthquake Seismology: Seismic Waves

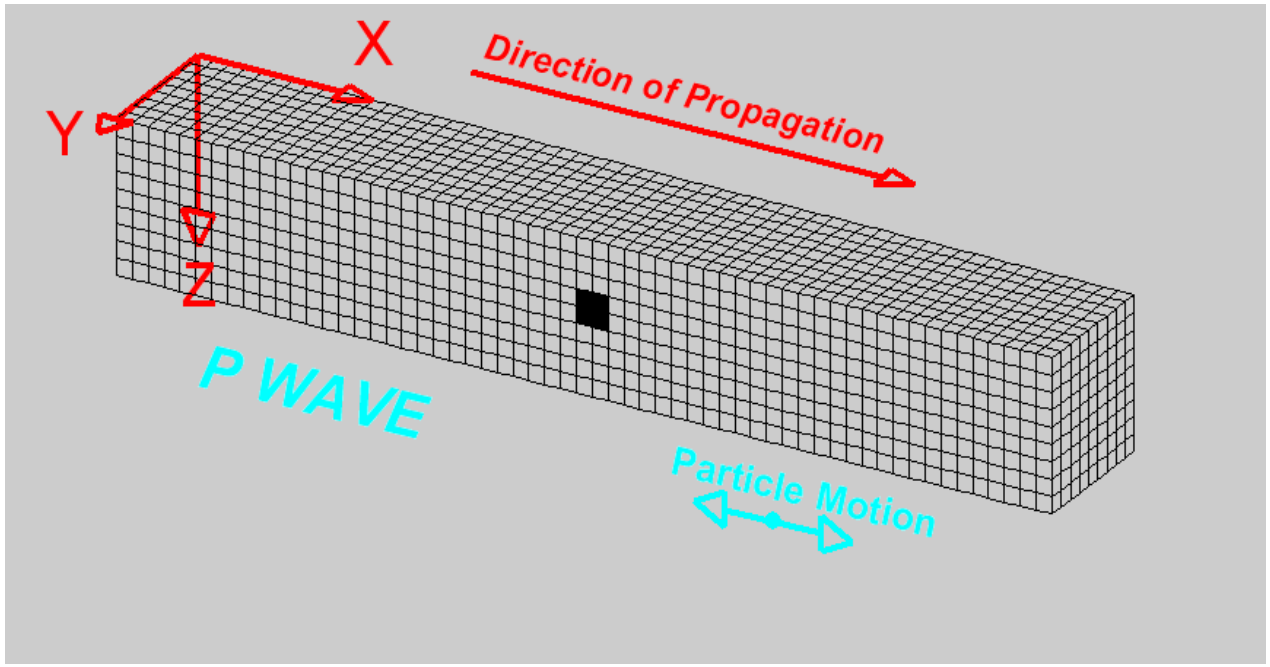


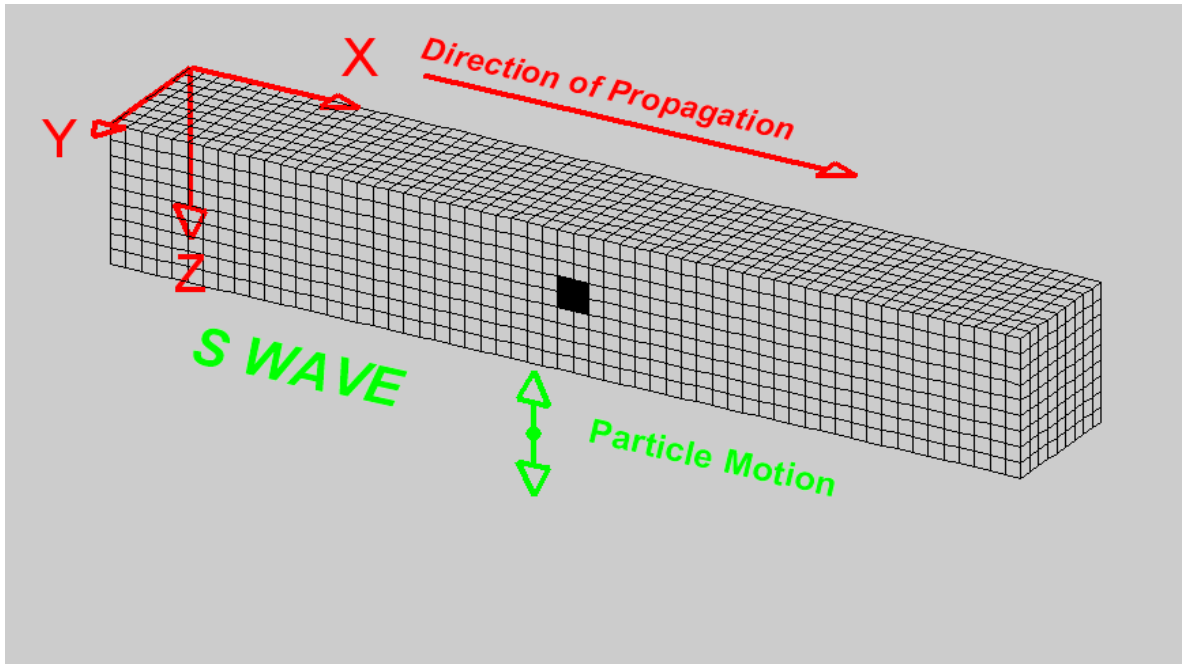
Body Waves: P-wave or Compressional wave
S-wave or Shear wave

Surface Waves: Love wave
Rayleigh wave

Earthquake Seismology: Seismic Waves

Body waves: **Compressional (P-wave) Shear (S-wave) wave**

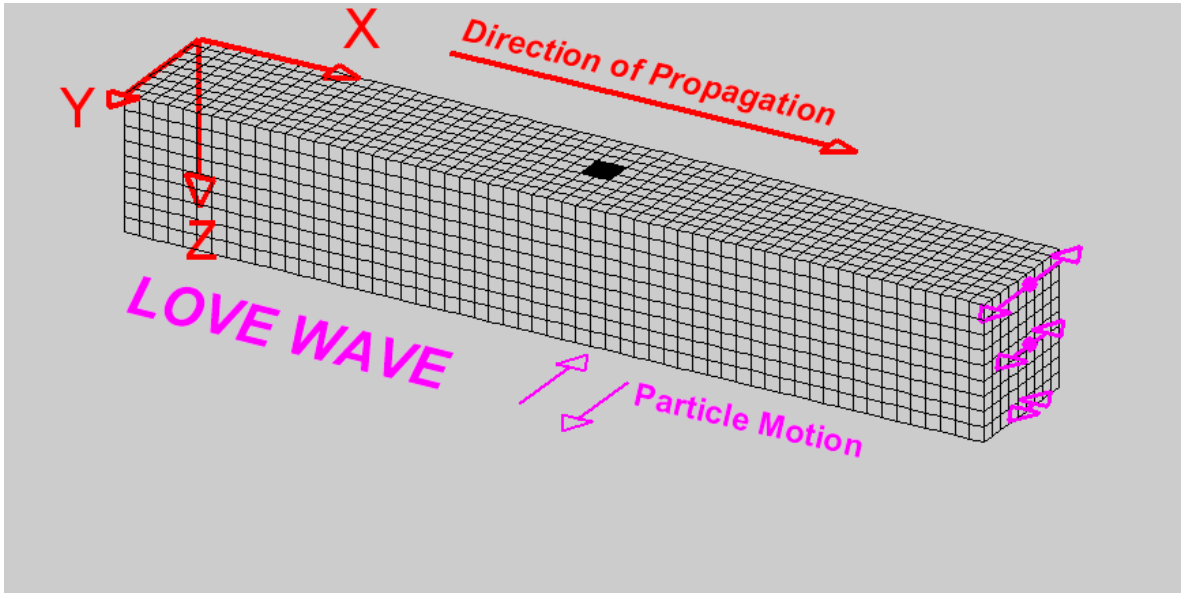


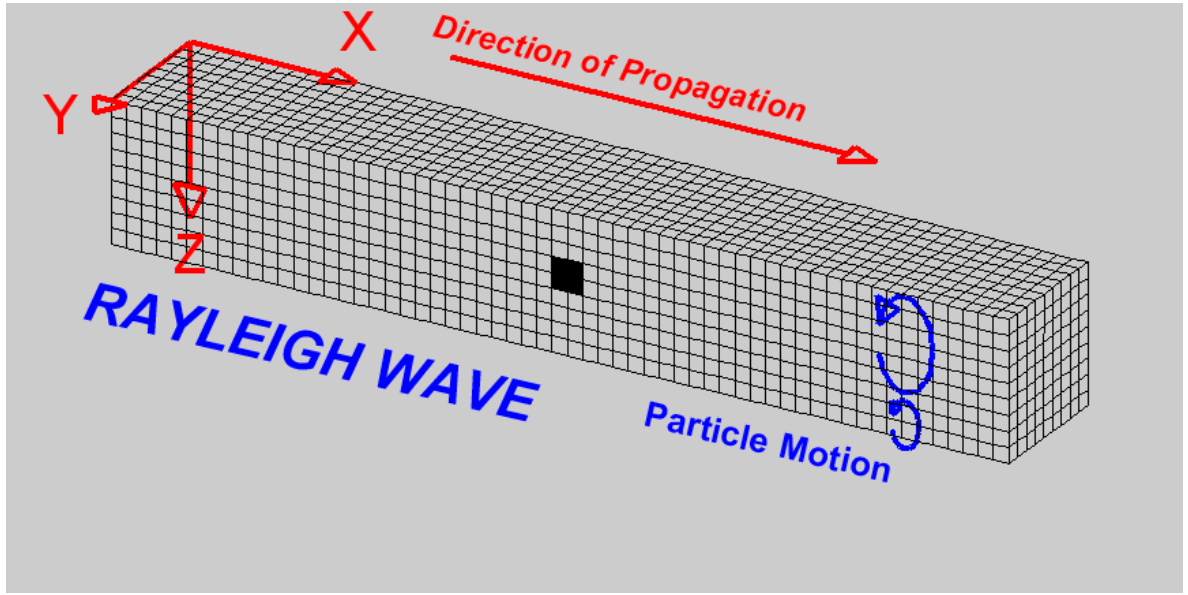


http://www.geo.mtu.edu/UPSeis/waves.html

Earthquake Seismology: Seismic Waves

Surface waves: **Love wave and Rayleigh wave**





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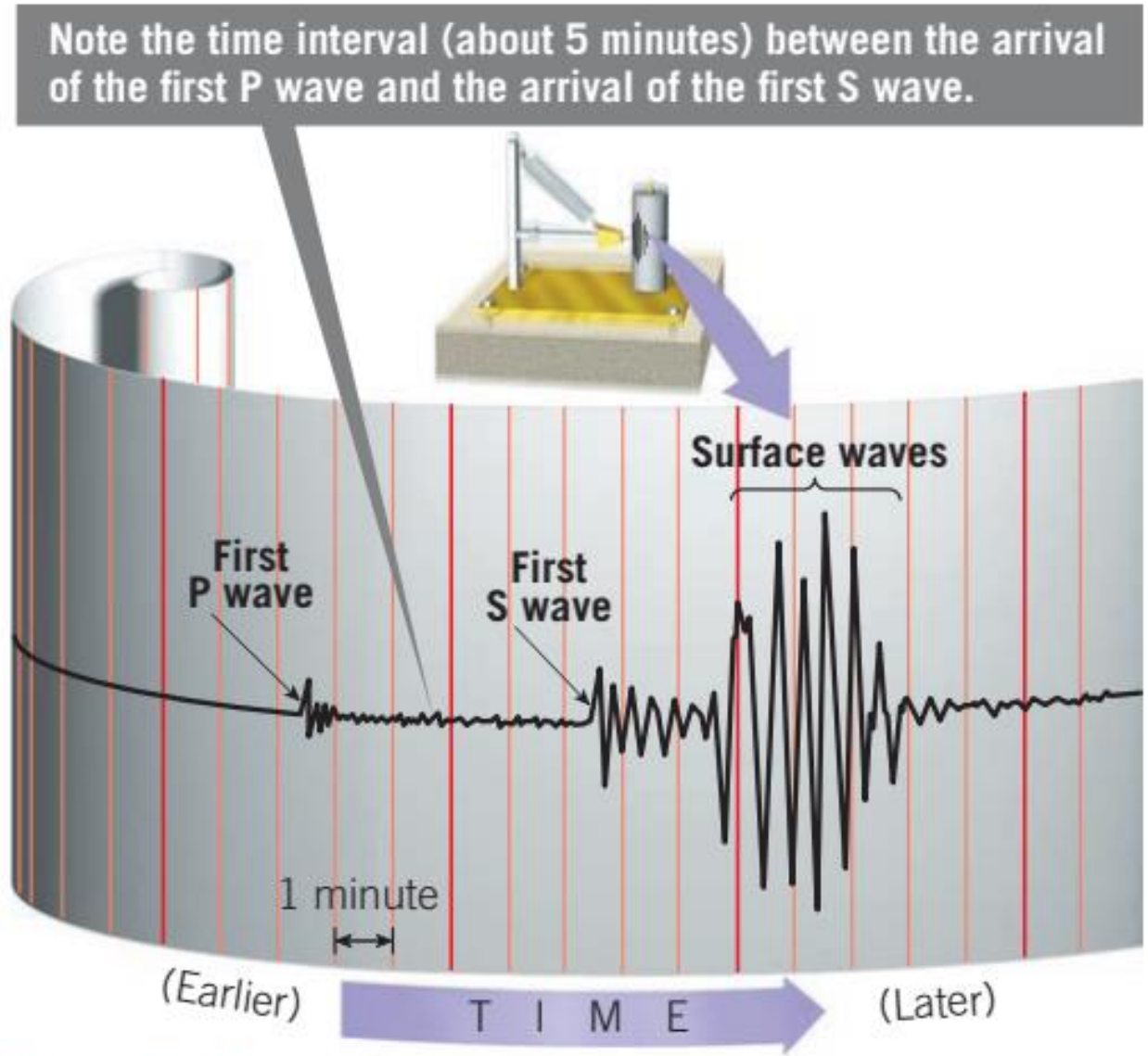


Figure 11.15
Typical seismogram

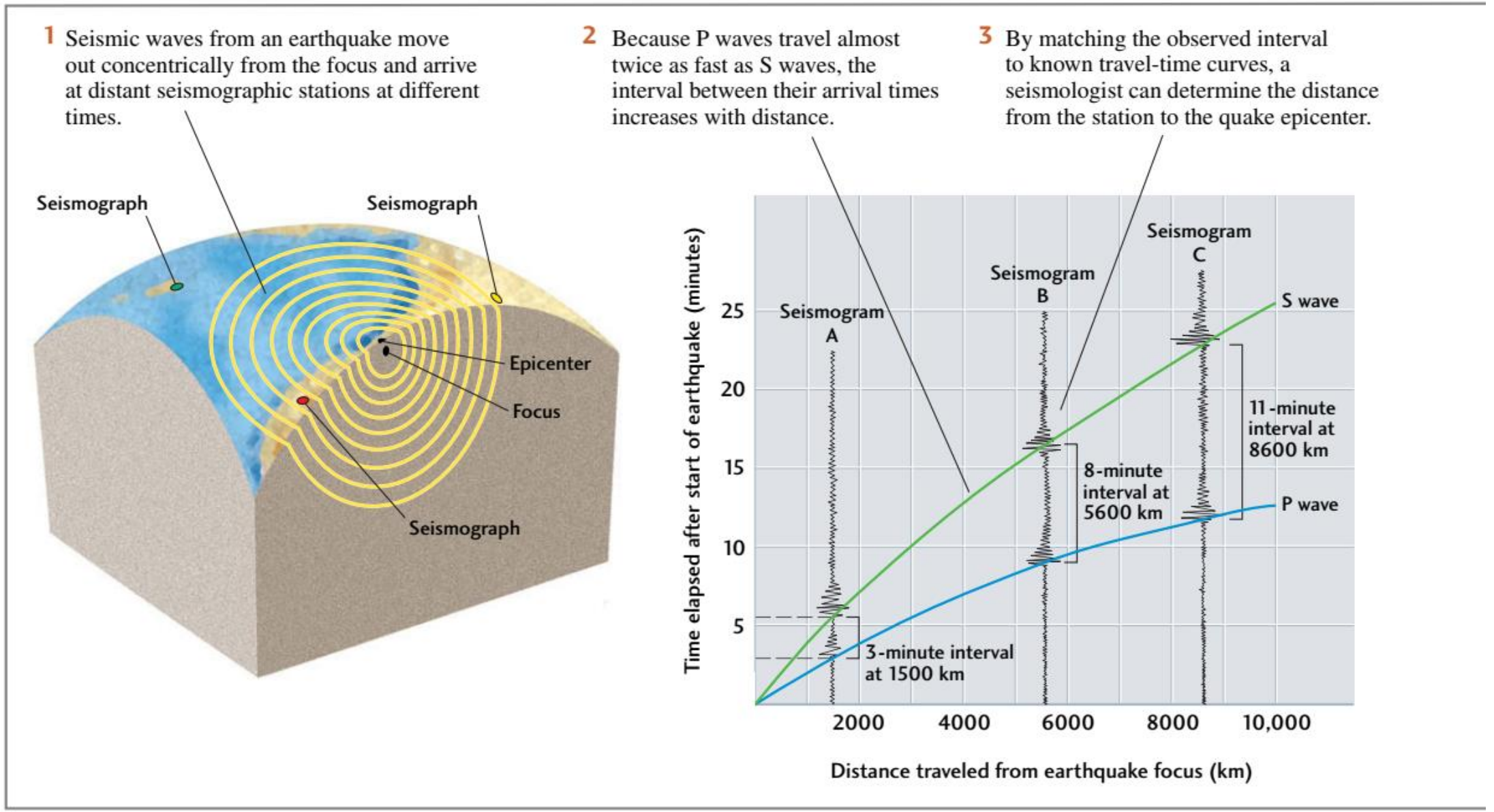


FIGURE 13.10 ■ Readings from three or more seismographic stations can be used to determine the location of an earthquake's focus.

Earthquake Seismology: Seismic Waves

- **Propagation of seismic wave depends on the physical properties of the material through which they propagate.**

- **The specific properties are**
  - **Bulk modulus (K): The ability of material to resist being compressed.**
  - **Shear modulus (μ): The ability of material to resist being sheared.**
  - **Density (ρ)**

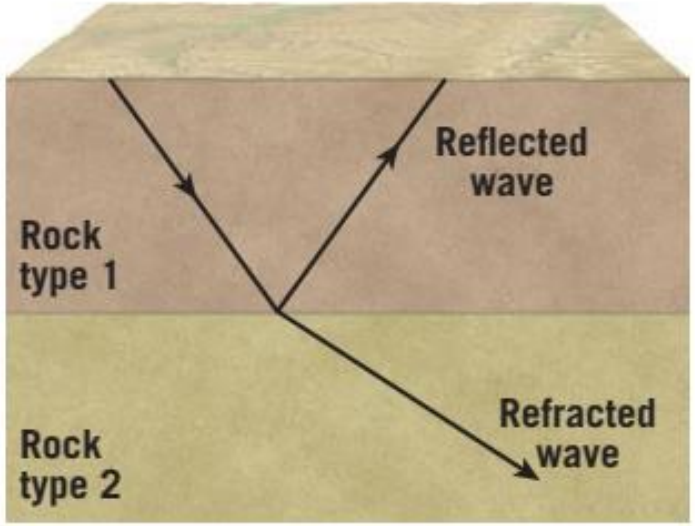
Body wave velocities:

$$V_P = \sqrt{\frac{\left(\frac{4}{3}\mu + K\right)}{\rho}} \qquad \text{and} \qquad V_s = \sqrt{\frac{\mu}{\rho}}$$

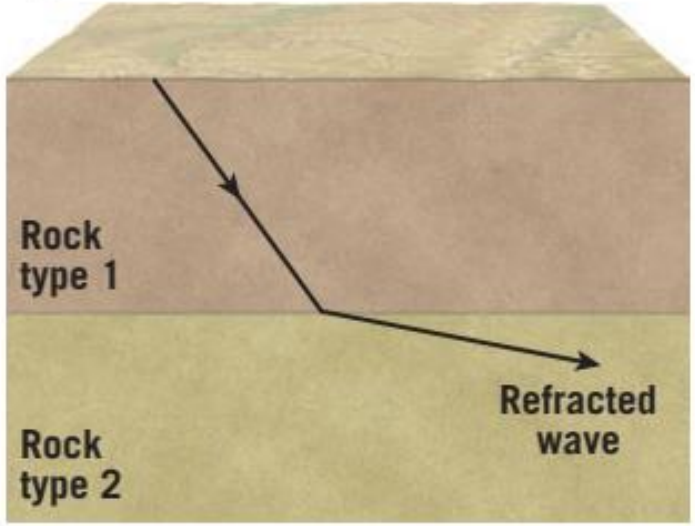
Exploring Earth's Interior using Seismic Waves

- **Reflection and Refraction of the seismic waves as they pass through different material inside the Earth.**

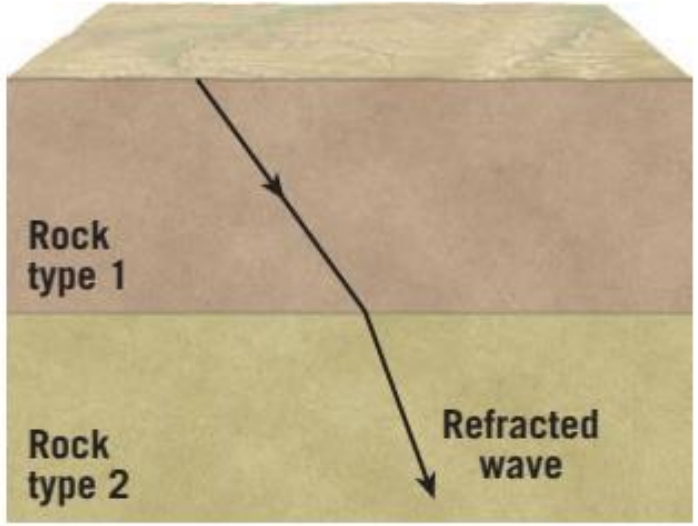
When seismic waves (rays) encounter a boundary between materials with different properties, such as air and water, the energy splits into reflected and refracted (bent) waves.



When the velocity of seismic waves increases as they pass from one layer into another, the waves refract (bend) toward the boundary separating the layers.



When the velocity of seismic waves decreases as they pass from one layer into another, the waves refract (bend) away from the boundary separating them.



Exploring Earth's Interior using Seismic Waves

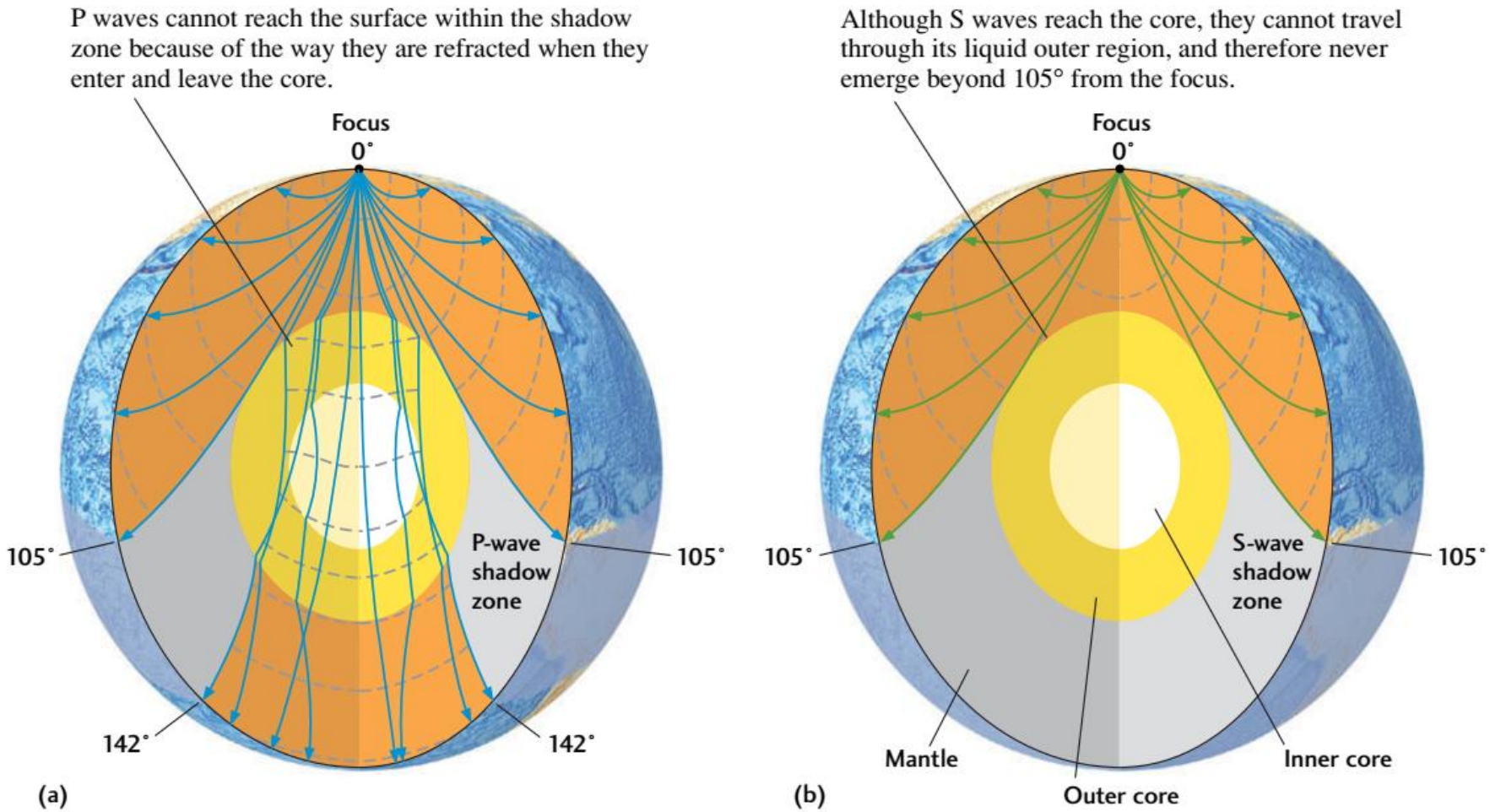


FIGURE 14.2 ■ Earth's core creates P-wave and S-wave shadow zones. The ray paths of the seismic waves from an earthquake focus through Earth's interior are shown by solid lines (blue for P-waves, green for S-waves). The dashed lines show the progress of the waves at 2-minute intervals. Distances are measured in angular degrees from the earthquake focus. (a) The P wave shadow zone extends from 105° to 142°. (b) The larger S-wave shadow zone extends from 105° to 180°.

Exploring Earth's Interior using Seismic Waves

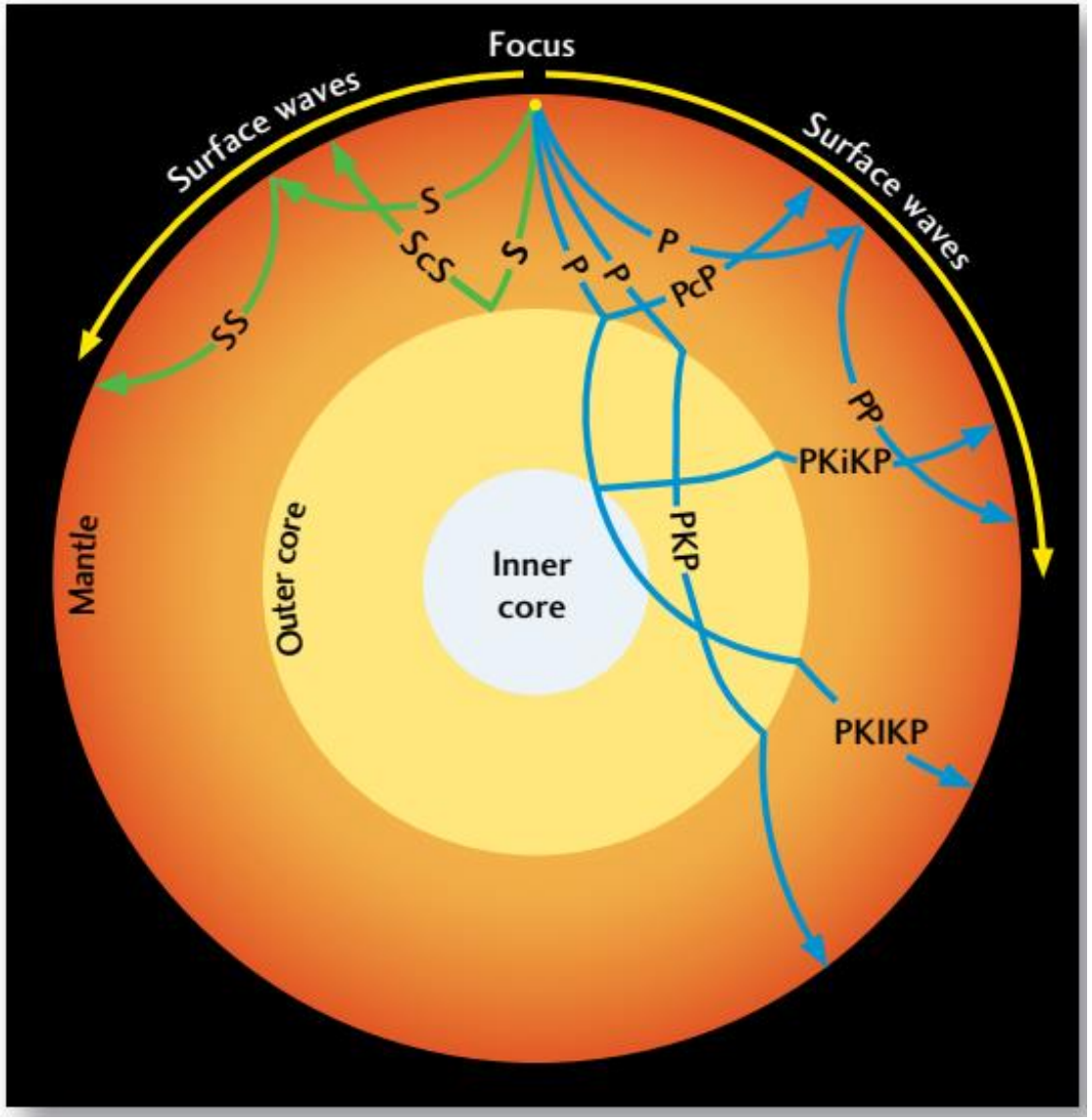


FIGURE 14.3 ■ Seismologists use a simple labeling scheme to describe the various ray paths taken by seismic waves. PcP and ScS are compressional and shear waves, respectively, that are reflected by the core. PP and SS waves are internally reflected from Earth's surface. A PKP wave travels through the liquid outer core, a PKIKP wave travels through the solid inner core, and a PKiKP wave is reflected by the inner core. Surface waves propagate along Earth's outer surface, like waves on the surface of a pond.

Exploring Earth's Interior using Seismic Waves

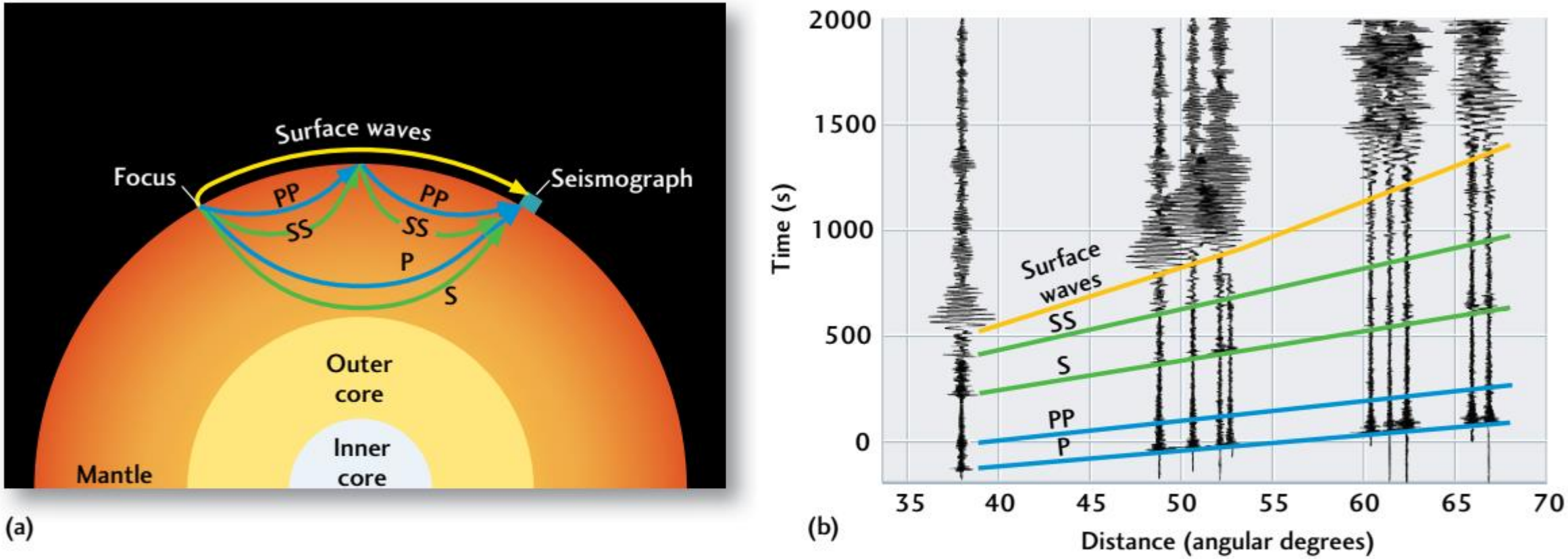


FIGURE 14.4 ■ (a) P and S waves are refracted upward in the mantle and also can be reflected from Earth's surface. A seismic wave that has been reflected once from Earth's surface is labeled with a double letter (PP or SS). (b) Seismograms recorded at various distances from an earthquake focus in the Aleutian Islands, Alaska. The colored lines identify the arrival times of the P and S waves, the surface waves, and the PP and SS waves reflected from Earth's surface.

Exploring Earth's Interior using Seismic Waves

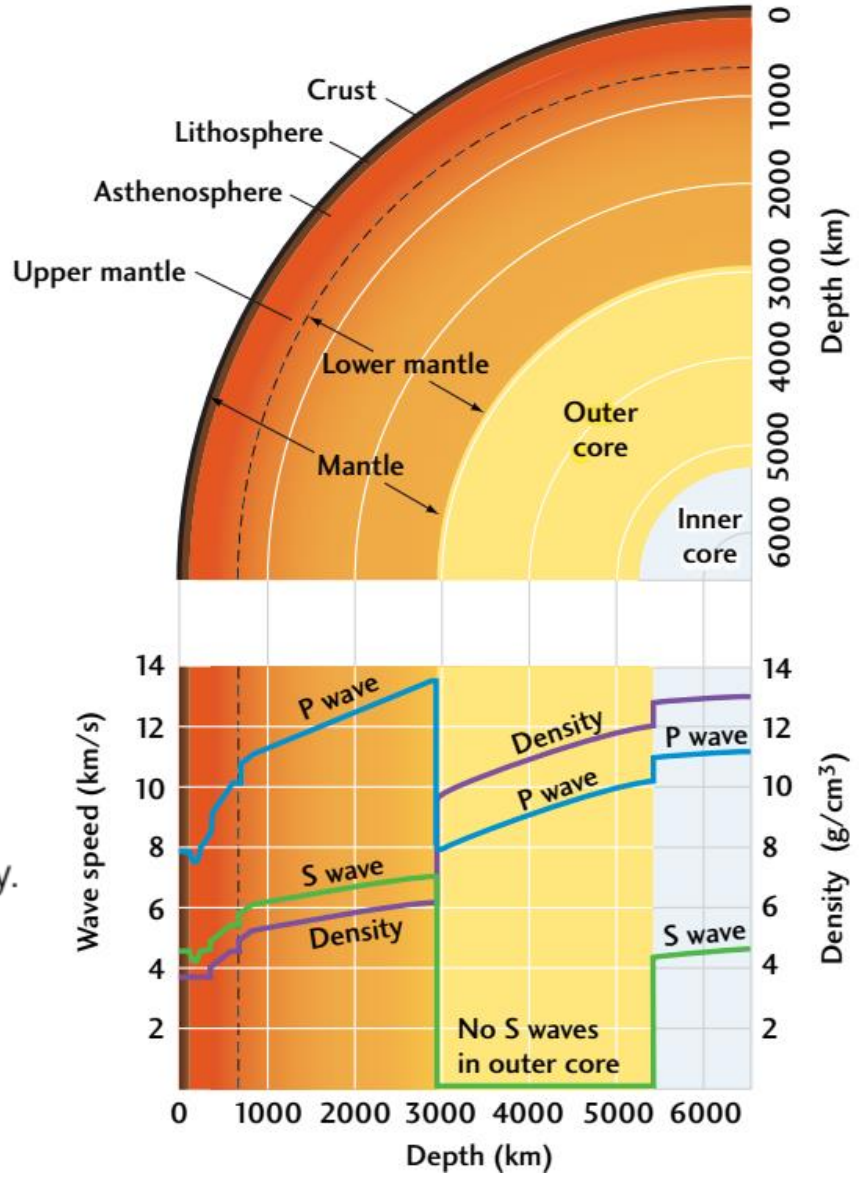


FIGURE 14.7 ■ Earth's layering as revealed by seismology. The lower diagram shows changes in P-wave and S-wave velocities and rock densities with depth. The upper diagram is a cross section through Earth on the same depth scale, showing how those changes are related to the major layers (see also Figure 1.12).

Exploring Earth's Interior using Seismic Waves

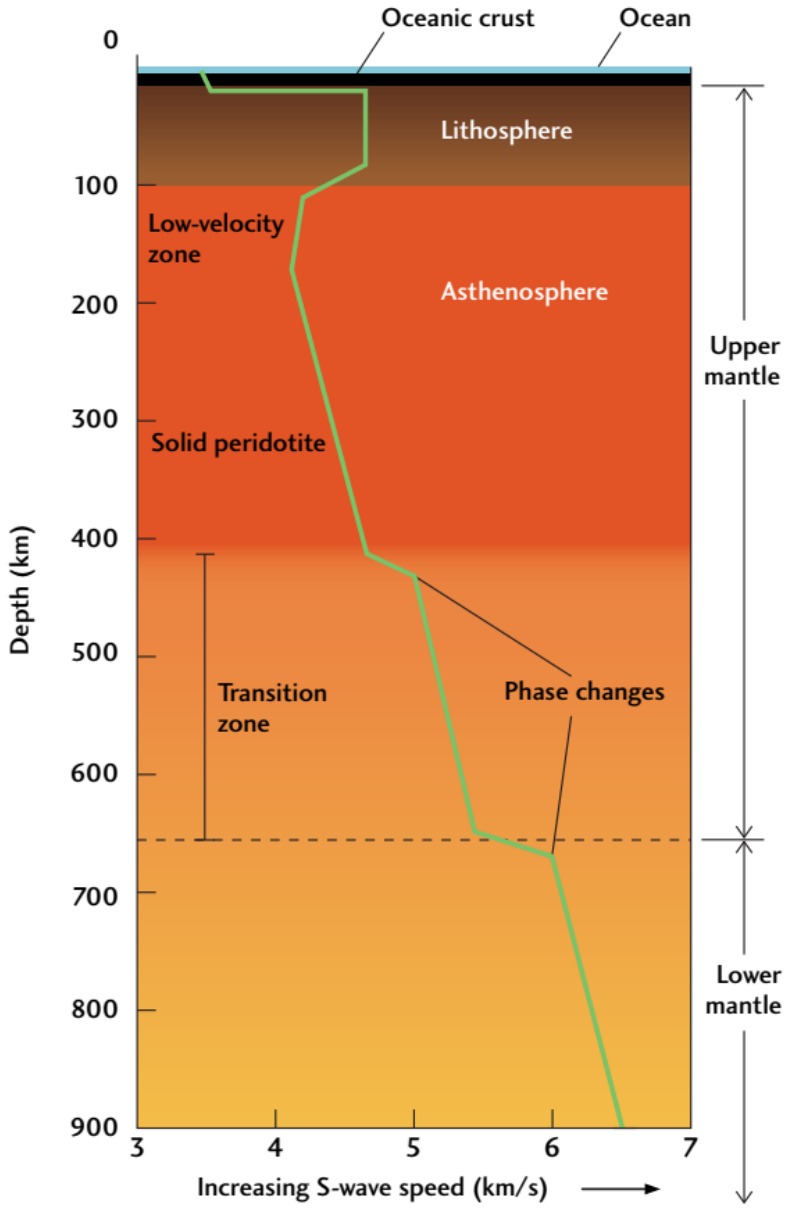


FIGURE 14.8 ■ The structure of the mantle beneath old oceanic lithosphere, showing S-wave velocities to a depth of 900 km. Changes in S-wave velocity mark the strong, brittle lithosphere, the weak, ductile asthenosphere, and a transition zone, in which increasing pressure forces rearrangements of atoms into denser and more compact crystal structures (phase changes).