Terrestrial planets

	Mass (in Earth masses)	
Mercury	0.06	
Venus	0.82	
Earth	1	(Moon = 0.01)
Mars	0.11	

Mercury's orbit is the most elliptical, & aligned at 7° to the ecliptic.

Perihelion = 0.31 AU

Aphelion = 0.47 AU

Mass of Earth

The way to find the mass of an astronomical body is to put something in orbit around it.

We have the Moon .....

use Newton's form of Kepler's 3rd law

$$(M_1 + M_2)\,P^2 = A^3$$

units are important here:

Mass in solar masses

Period in years

Distance in AU

Earth – Moon distance = 380,000 km

$= 2.53 \times 10^{-3}$ AU

Orbital period of Moon = 27.3 days

$= 7.48 \times 10^{-2}$ years

$\boxed{\text{Q.}}$ Is this period measured from full moon to full moon? A diagram will help here

Assume that we can ignore the mass of the Moon because it is much smaller than the Earth's

$$M_1 + M_2 = M_{Earth} + M_{Moon} \simeq M_{earth}$$

So $M_{earth} \times P^2 = A^3$

$$M_{earth} \approx \frac{A^3}{P^2}$$

$$= \frac{(2.53 \times 10^{-3}\ AU)^3}{(7.48 \times 10^{-2}\ years)^2}$$

$$= 2.9 \times 10^{-6}\ \text{solar masses}$$

$$= 5.8 \times 10^{27}\ \text{grams}$$

(close to real value)

$\boxed{Q.}$ How could we improve the accuracy of this technique?

$\boxed{Q}$ What are some observations we can make to infer the interior structure of the Earth?

→ mass of the Earth

$\boxed{Q}$ What are some observations we can make from Earth's surface that tell us about its interior?

→ measure radius and we have mean density. This is $5.5\ g/cm^3$, significantly higher than the mean density of rocks on the surface ($\sim 3\ gm/cm^3$)

→ the Earth is differentiated, with heavier material in its core

Deepest hole ever dug ~10 km deep (cf $R_\oplus$ = 6378 km)

Volcanos have brought material from a few 100's of km deep to the surface

For any deeper probing we need to depend on seismology.

Both earthquakes and underground explosions such as nuclear tests propogate pressure waves through the Earth

Q. Will an underground nuclear test work as well as an earthquake for studying the Earth's interior?

The Apollo astronauts left several seismometers on the surface of the Moon. We did not learn as much as we hoped about the Moon's interior because of a shortage of Moonquakes ...... most of seismic waves detected were caused by meteor impacts.

Seismology : use of earthquakes to probe the Earth's interior

Different seismic waves

P-waves (pressure) – will go through anything, solid or liquid

S-waves (shear) – needs a solid to transmit

Surface waves – largest amplitude, no information about interior of Earth.

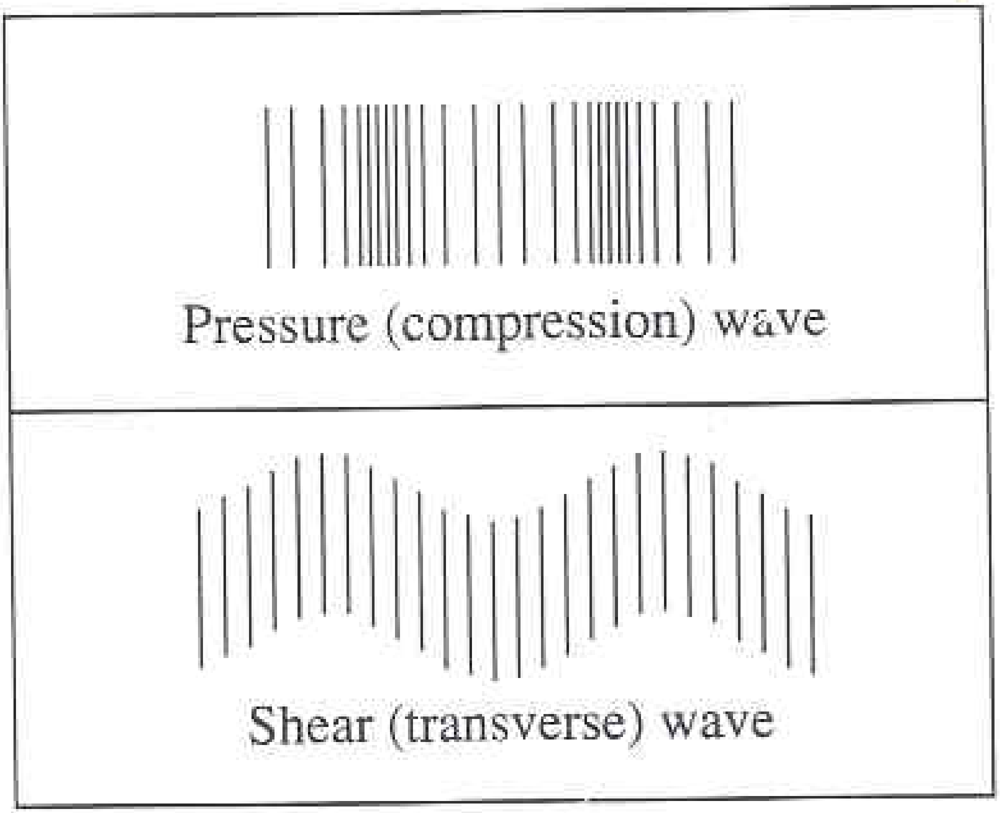


FIGURE 6.3 P and S seismic waves.

Each travels at a different speed

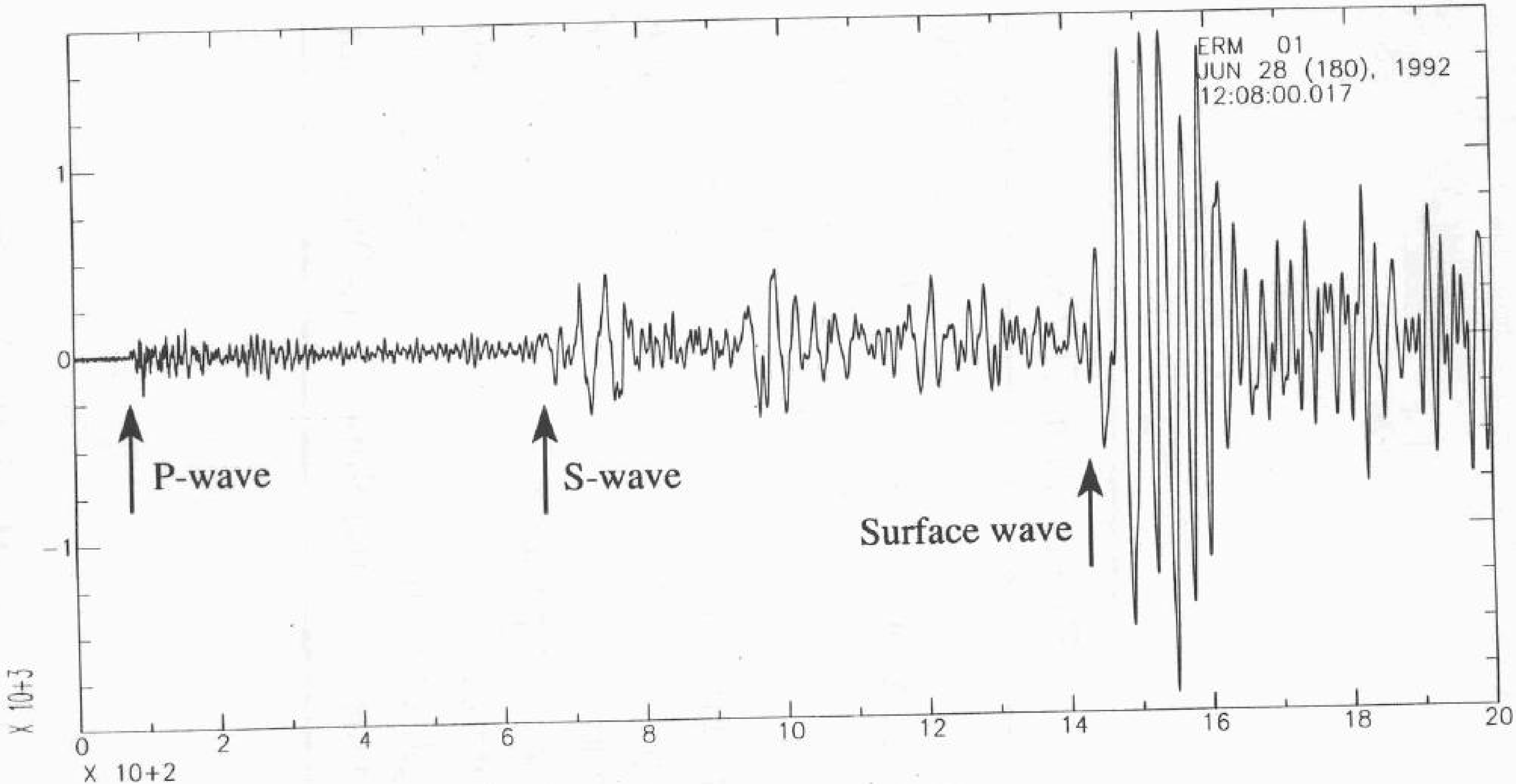


FIGURE 6.4 A seismogram.

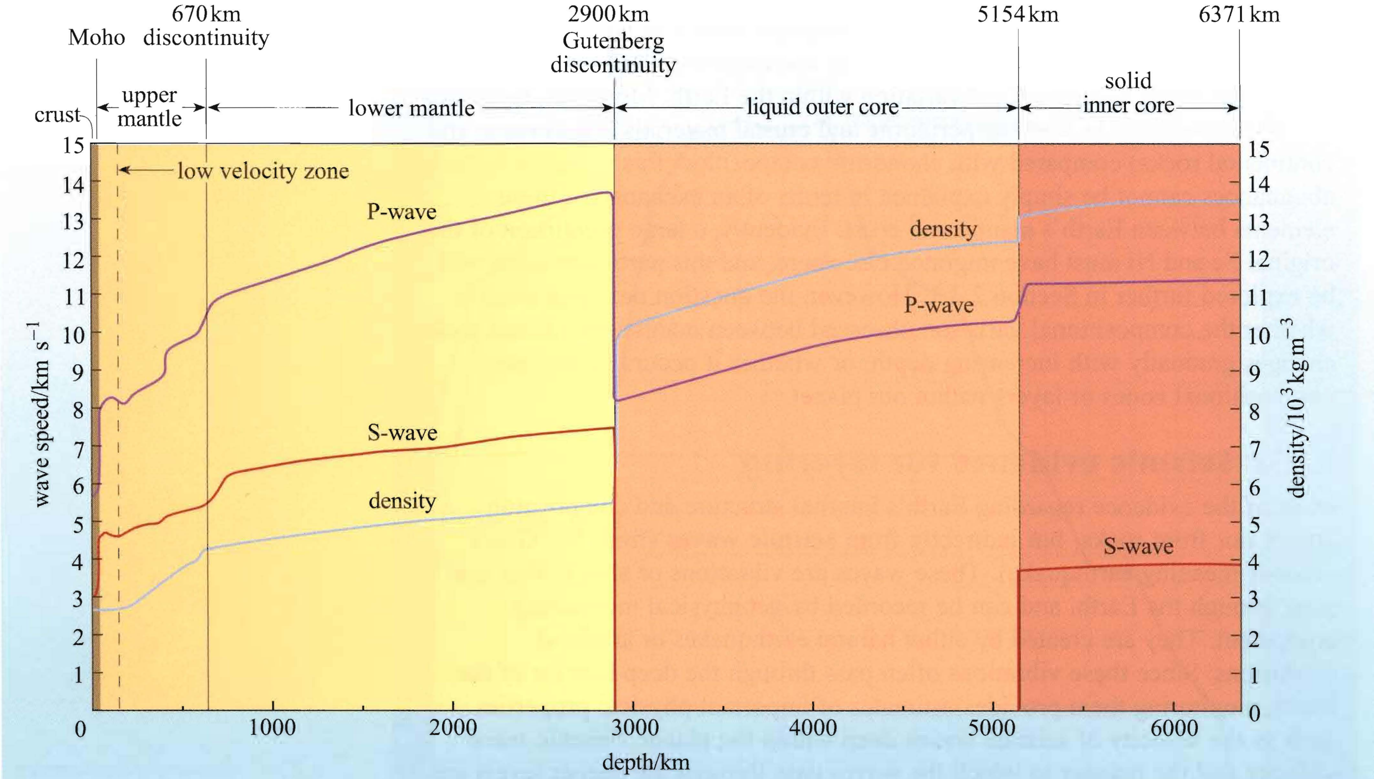


Figure 2.4 Velocity profiles of P-waves and S-waves within the Earth, and inferred densities. The term 'velocity profile' refers to the changes in velocity of seismic waves with increasing depth.

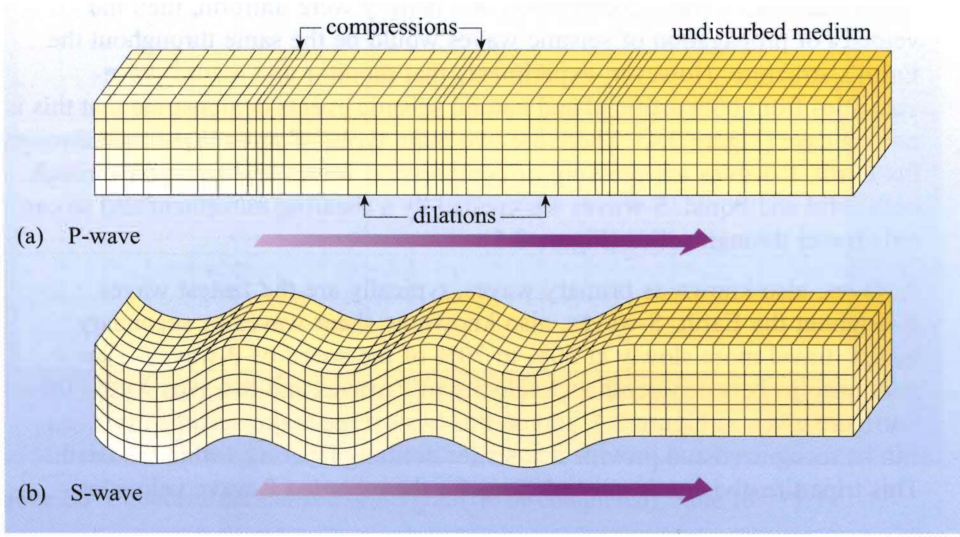


Figure 2.5 Propagation of (a) P-waves and (b) S-waves through a medium.

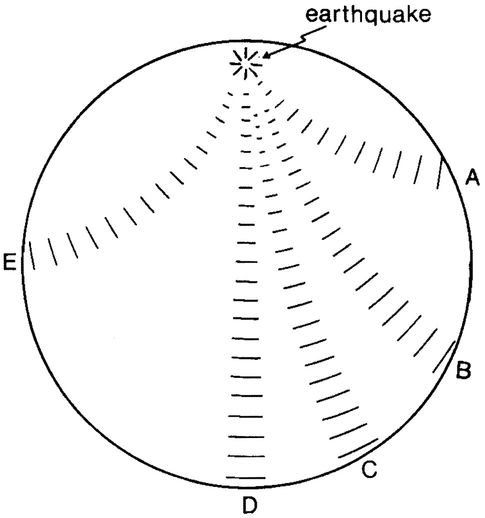


Figure 8.6: An earthquake sends out P and S waves in all directions into the Earth. These waves travel through the Earth and are detected by seismographs located in various places on the Earth. If the Earth is homogeneous, the sound waves travel along curved paths as shown. The wave reaching seismographs A through D are shown travelling directly through the Earth's interior; an example of a wave reflected from the surface is the one going to seismograph E.

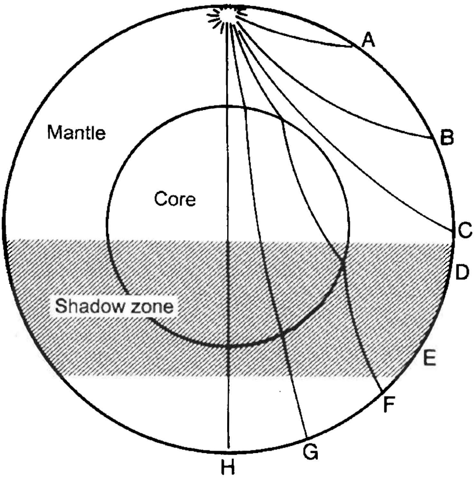


Figure 8.7: The paths followed by beams of sound waves emitted by an earthquake are shown for a two-layer Earth in which the speed of sound is lower in the core than in the mantle. The waves are observed by seismographs at locations A through H. The ring around the Earth on the opposite side of the planet from the earthquake labelled "shadow zone" is the region in which direct P-waves from the earthquake are not detected. The shadow zone for S-waves includes both that for P-waves and the cap on the opposite side of the Earth where P-waves are received.

Q

Why might part of the Earth's core be liquid when the rocky surface layers are solid?

- What might the original source of this heat be?

- Why is the inner core solid?

Surface of Earth (crust) has continents and oceans.

Continents : generally granitic

Sea floor : basalts (denser)

Beneath the crust is the mantle : rigid at the top, viscous below ~100 km where it is called the <u>asthenosphere</u>.

Above this (rigid mantle + crust) is called the <u>lithosphere</u>

Changes in plasticity of mantle caused by increasing pressure toward center

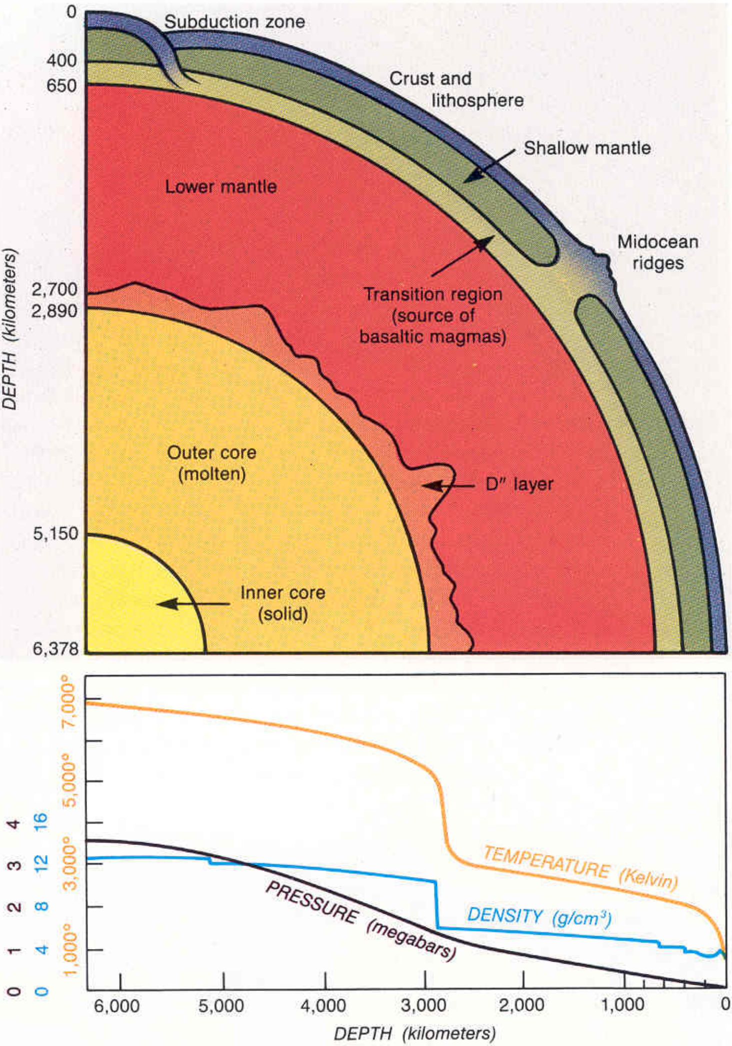


Figure 5. **Early in its history, the Earth differentiated into a series of layers with distinct physical and perhaps compositional properties.**

Continents and sea floor are both ~~[illegible]~~ than underlying mantle, so they 'float' on mantle like blocks of ice in water

Plate tectonics theory is now well substantiated

$\boxed{Q}$ What are some of the pieces of evidence for it?

PLATE TECTONICS

EVIDENCE

shapes of continents

plants / geology

position of mountains, volcanos, earthquakes

rock ages

sea floor depths

BASIC CONCEPTS

~10 rigid plates form lithosphere

move with speeds ~ 2–20 cm/yr

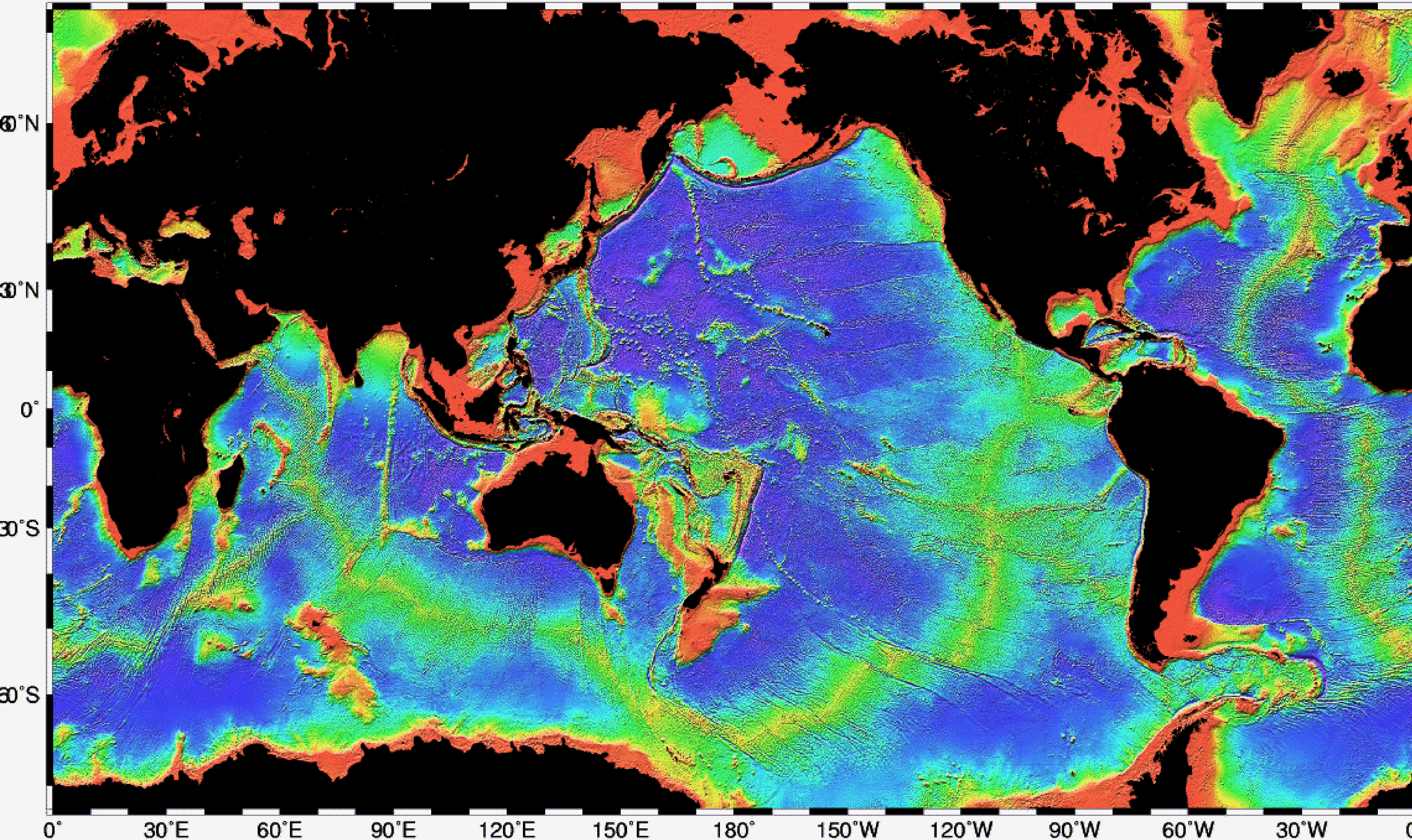
sea floor spreading, lava rises to fill crack

pushes continents apart

subduction where plates meet

transform faults

volcano and mountain formation



Walter H. F. Smith and David T. Sandwell, Seafloor Topography Version 4.0, SIO, September 26, 1996

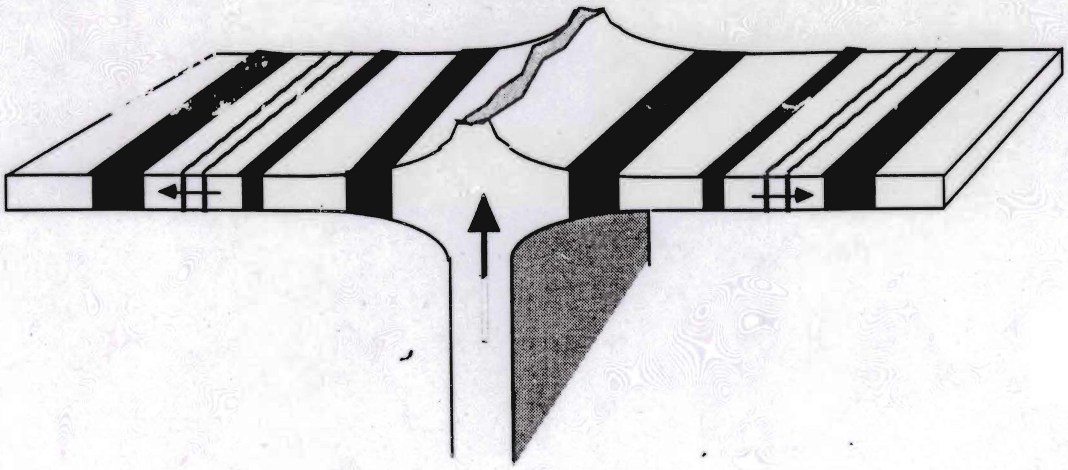


FIGURE 6.5 Magnetic stripes on the sea floor, represented here by dark lines, spread out away from mid-ocean ridges symmetrically in both directions.

Magnetometer data from mid-Atlantic ridge; magnetic fields in volcanic rock flip back and forward with distance away from spreading center