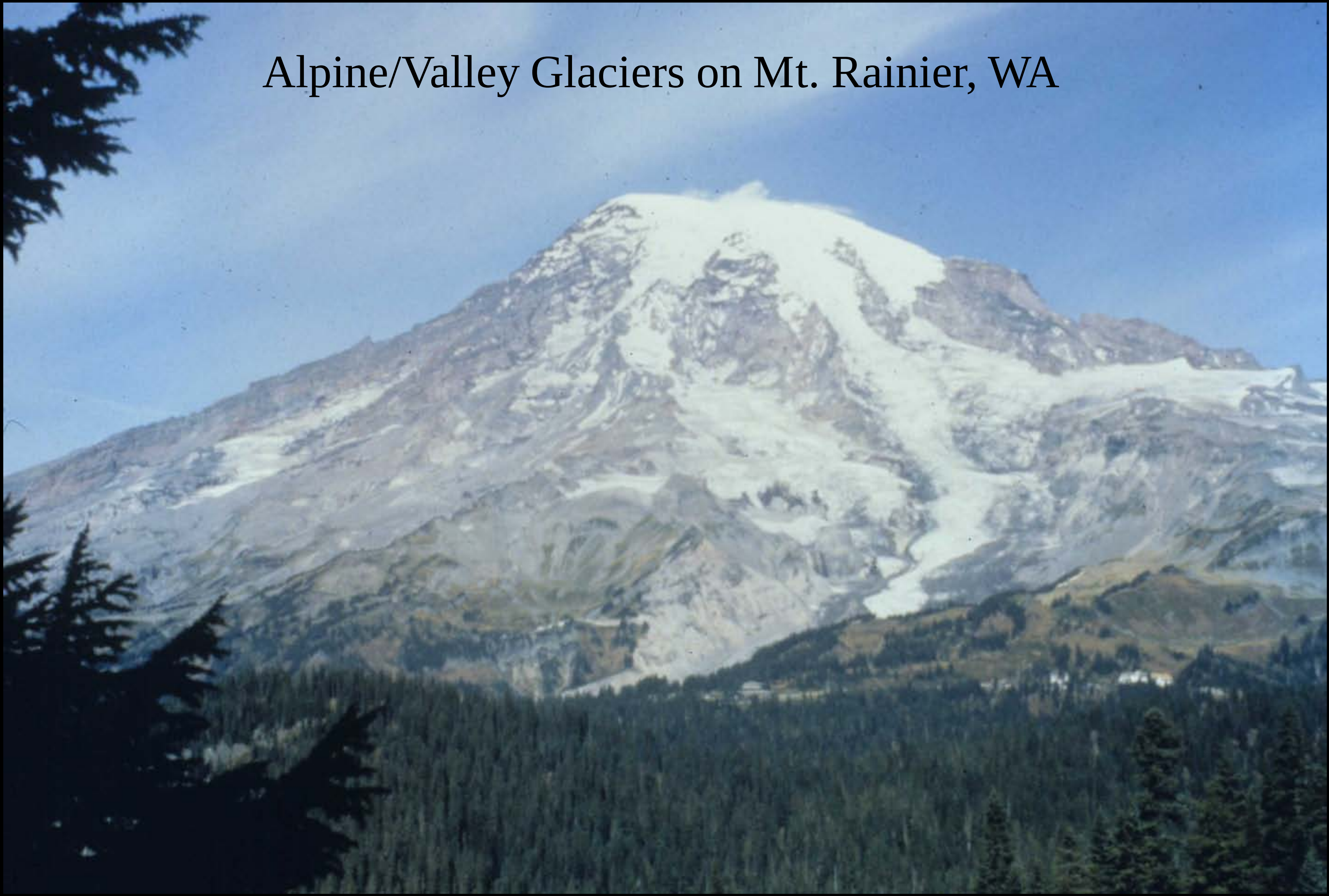
Chapter 18 Amazing Ice: Glaciers and Ice Ages


Alpine/Valley Glaciers on Mt. Rainier, WA

Types of Glaciers

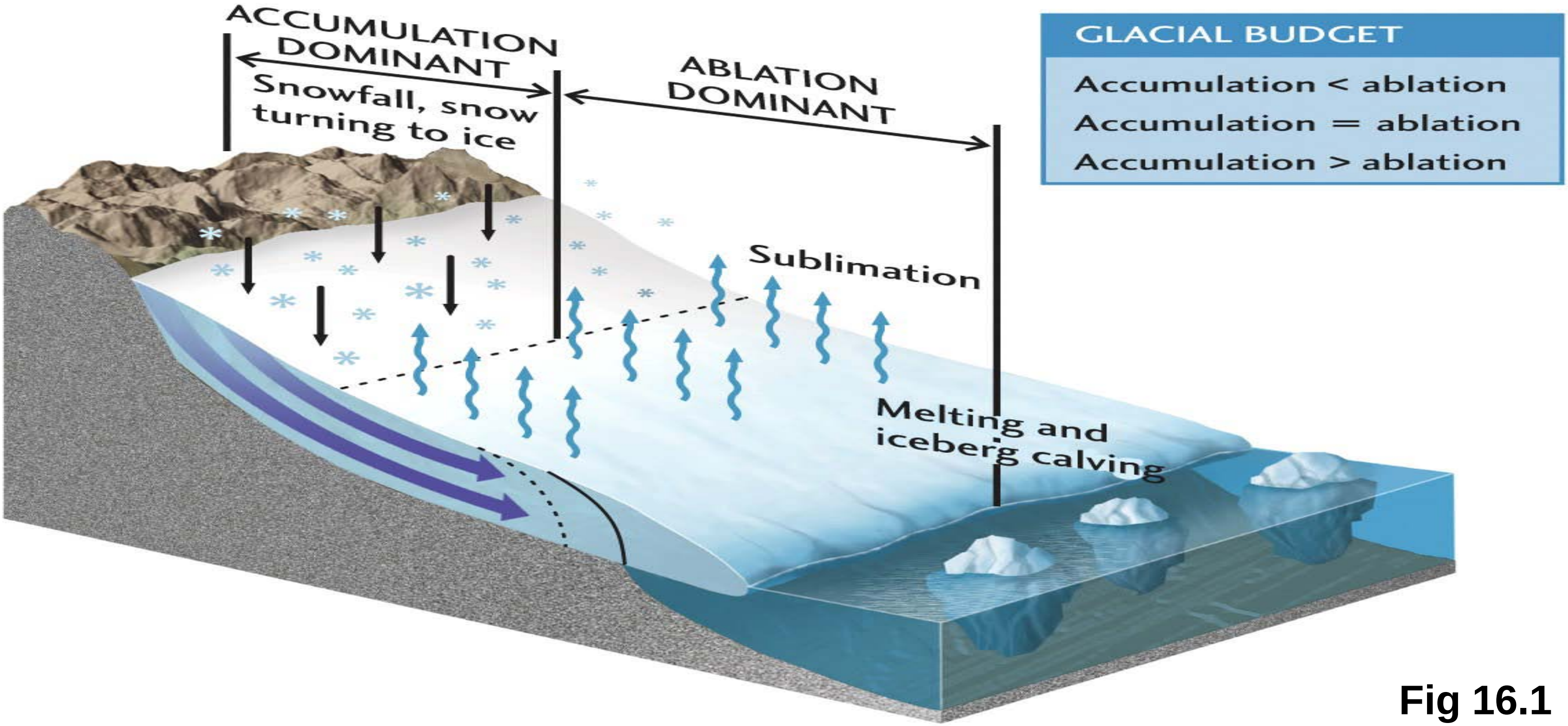
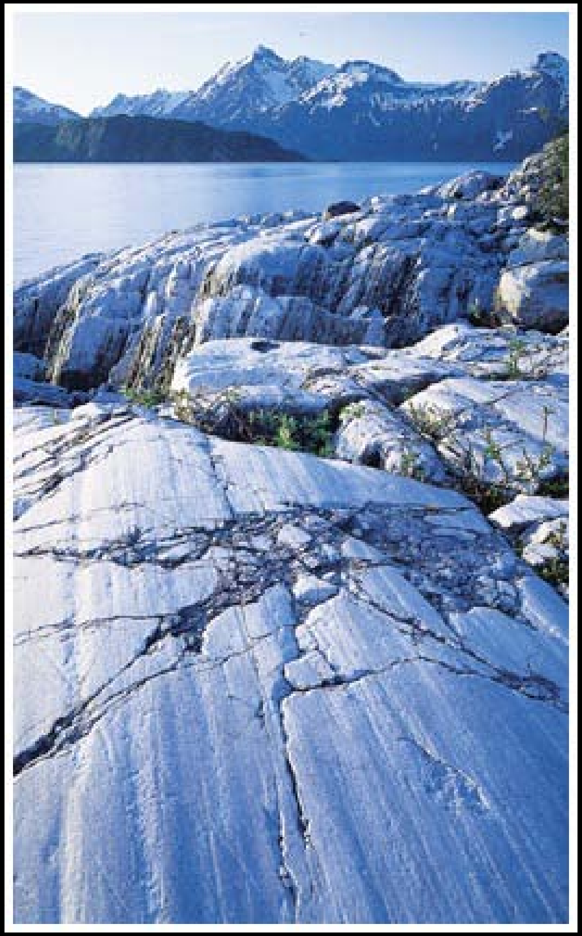


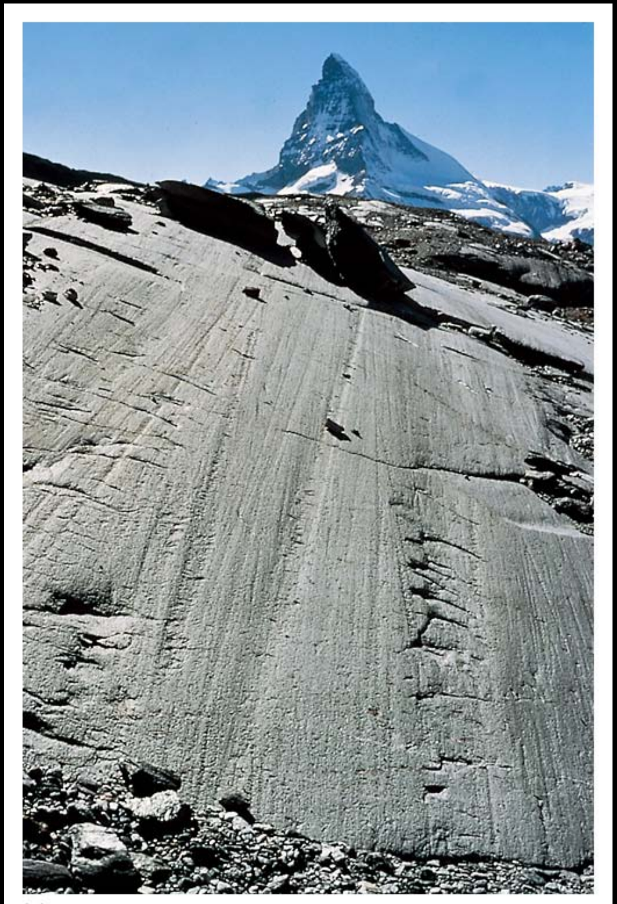
Fig 16.1

The glacier is always in motion, even if it is not physically getting larger.

Glacial Erosion

- **<u>Glacial striations</u>** – parallel scratches show the direction of movement.

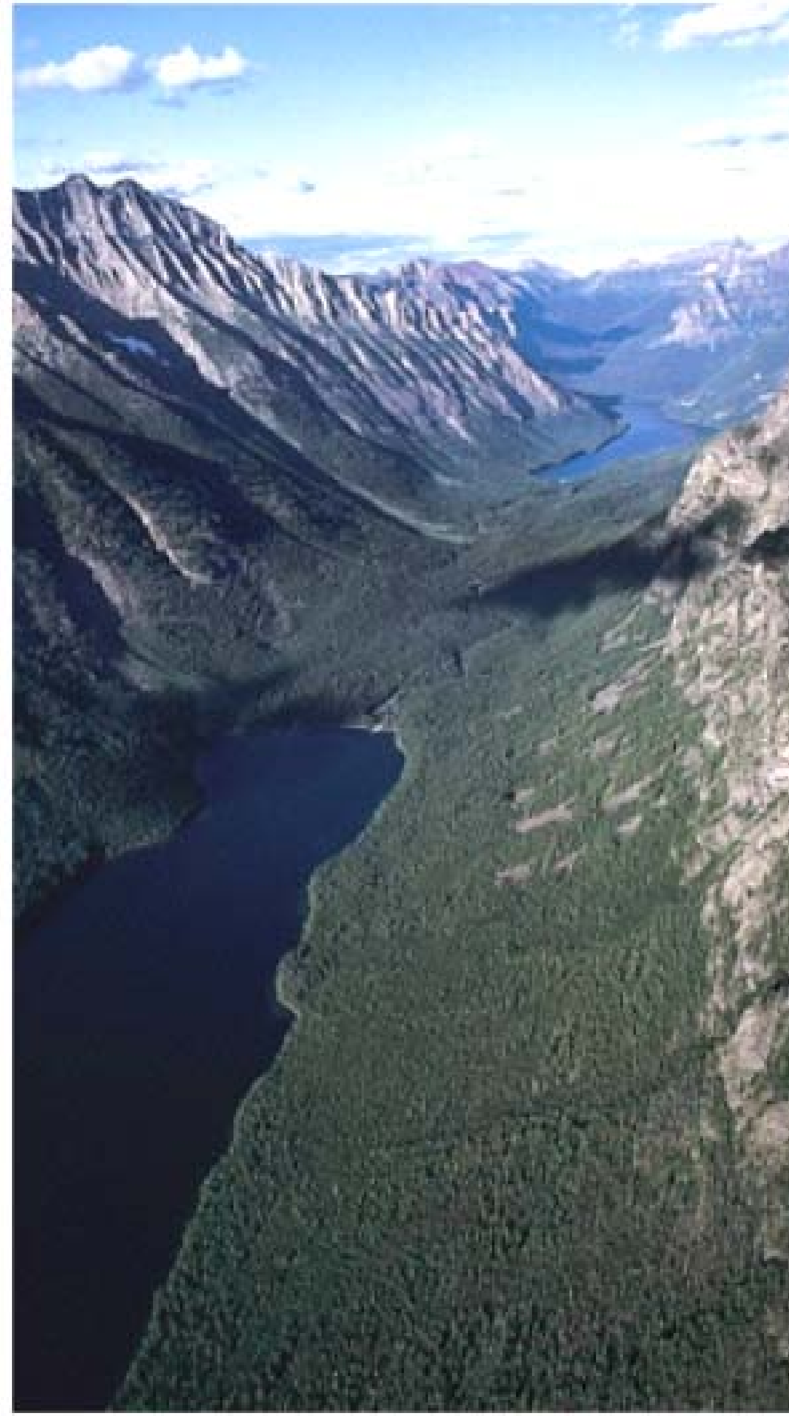




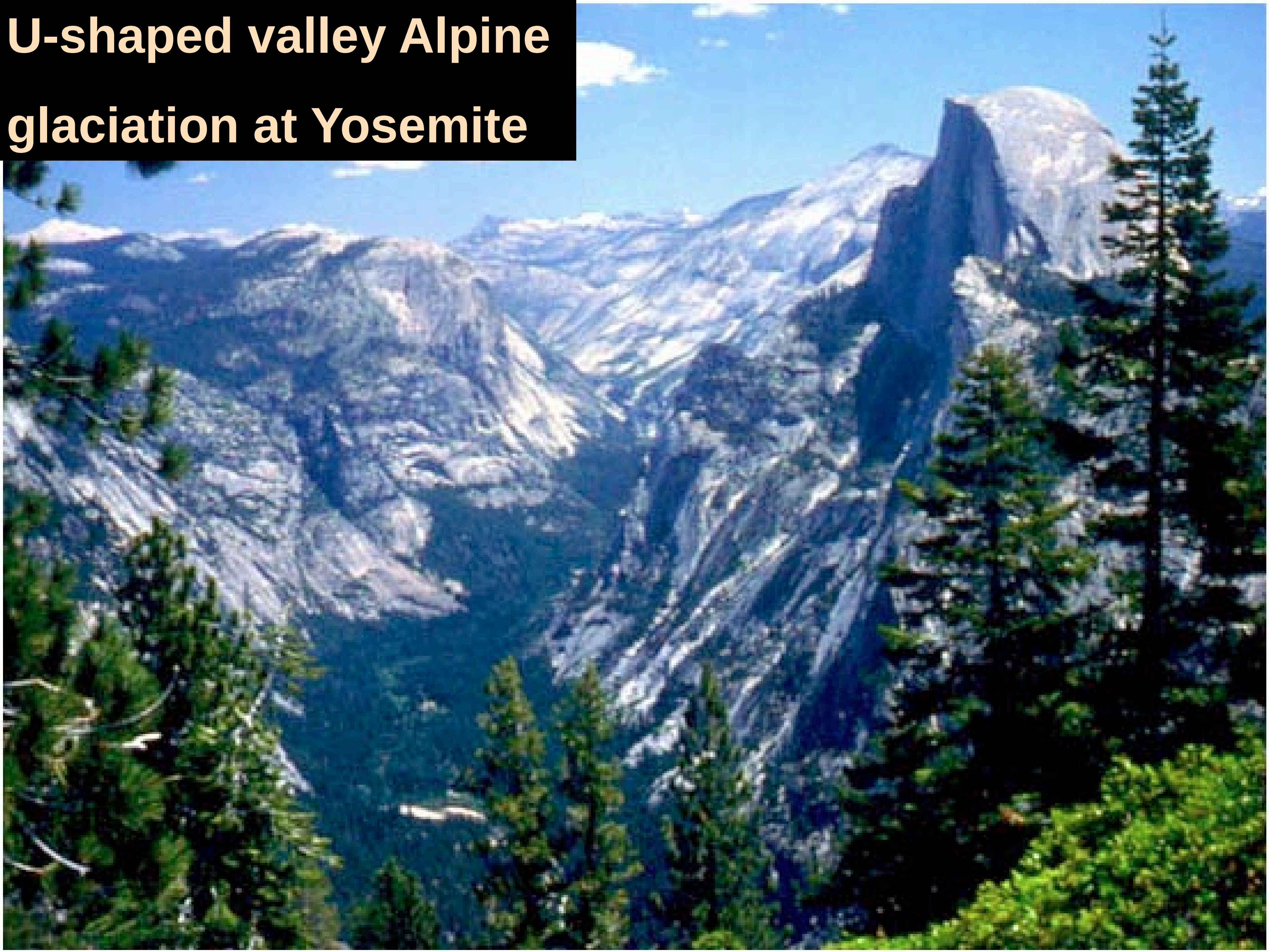
S. C. Porter.

"U-shaped" valley

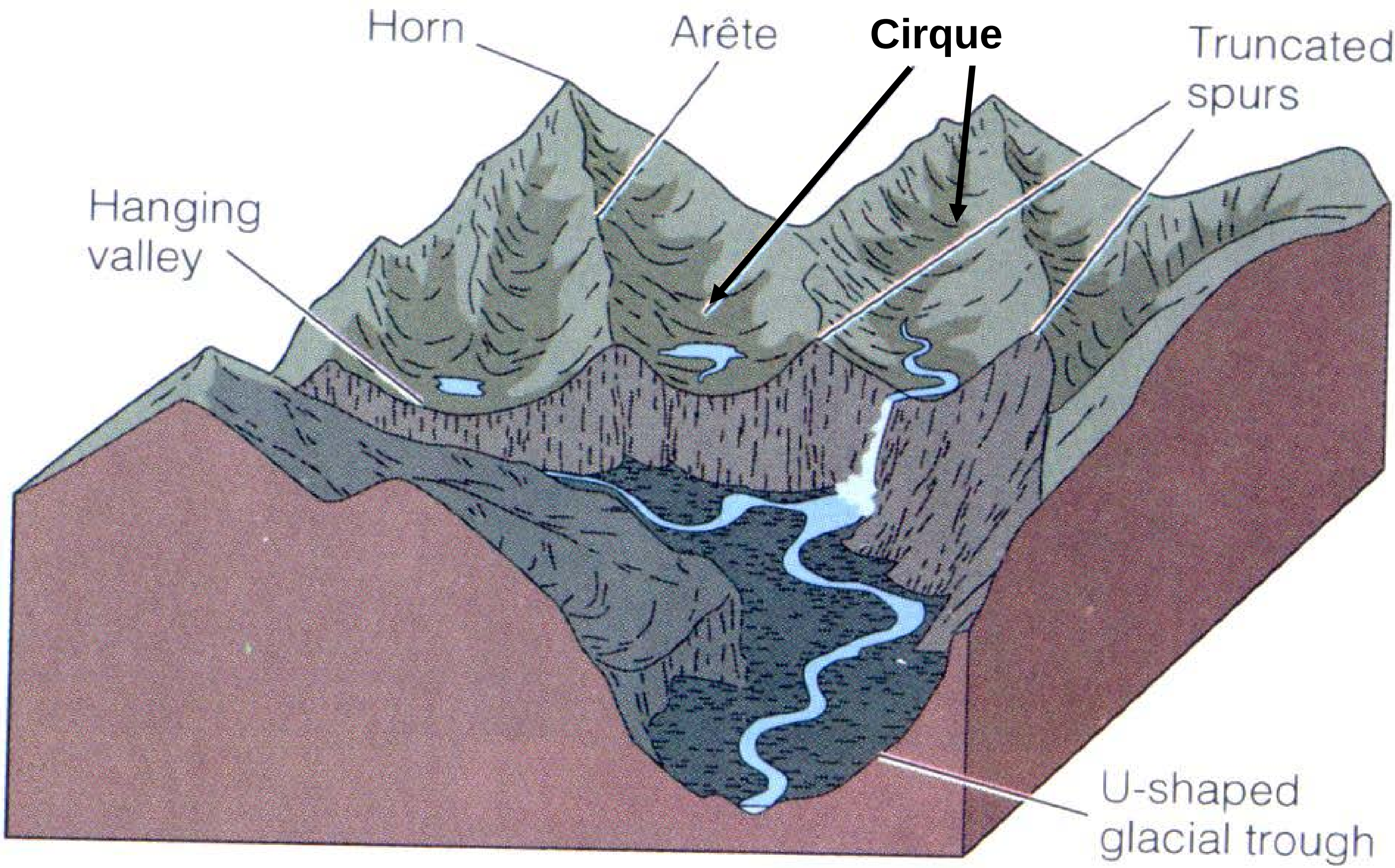
Carved by Alpine glaciers.



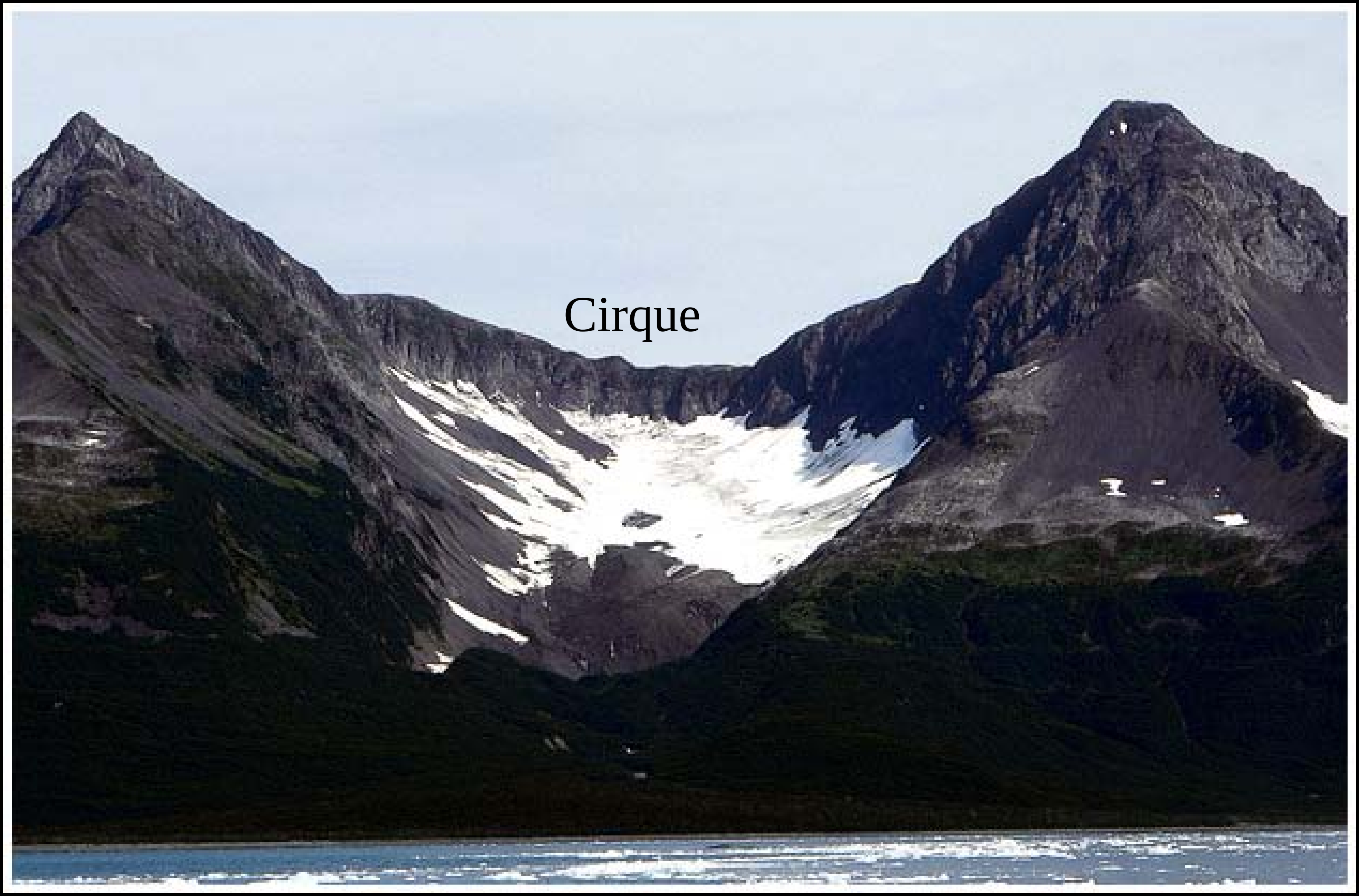
U-shaped valley Alpine glaciation at Yosemite



Erosional Alpine Features



Erosional Alpine Features



<u>Cirque</u> – steep-walled, bowl-shaped

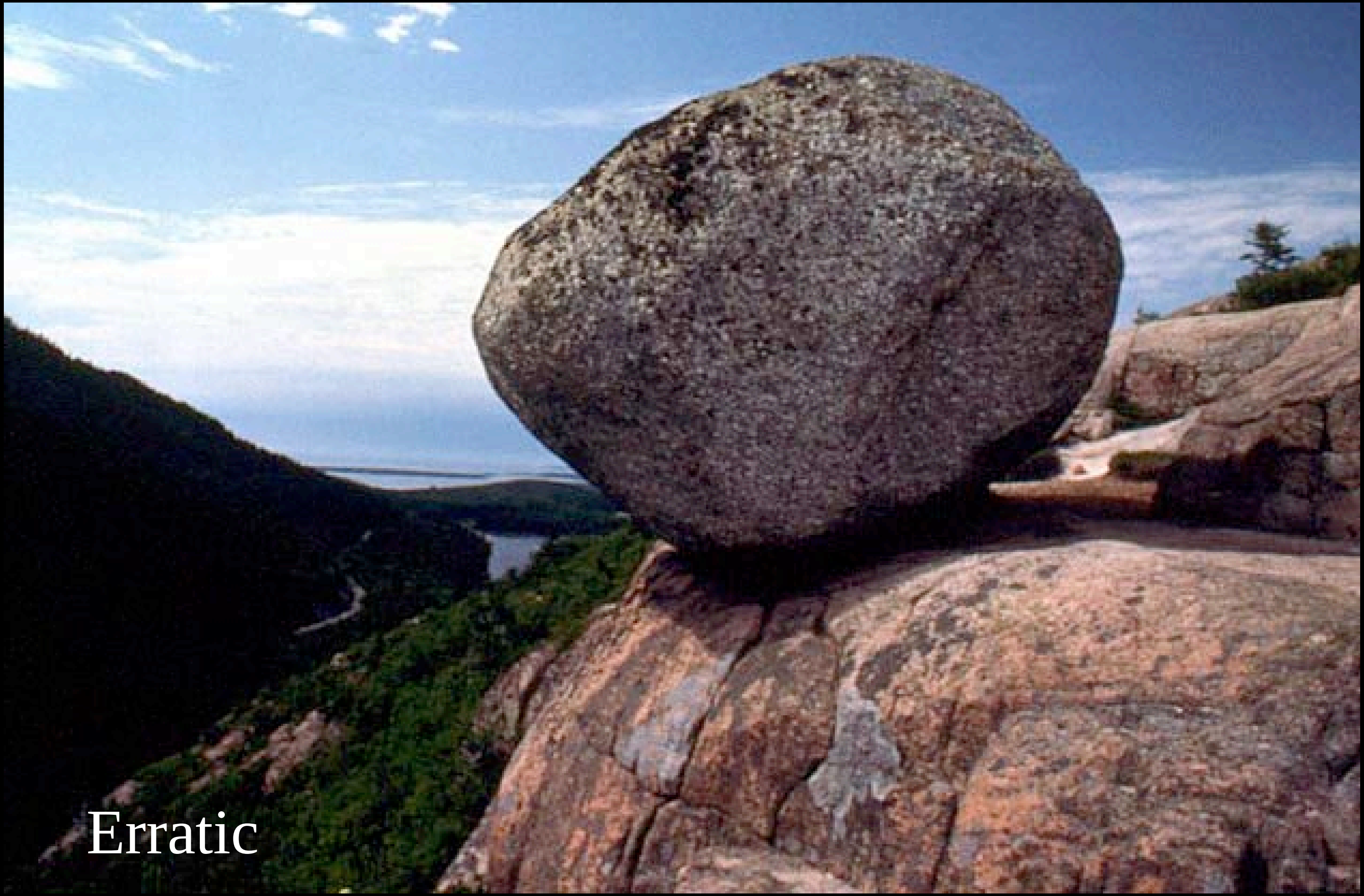
Erosional Alpine Features

Surface features of glaciers

<u>Crevasses</u> – deep fissure or crack in a glacier

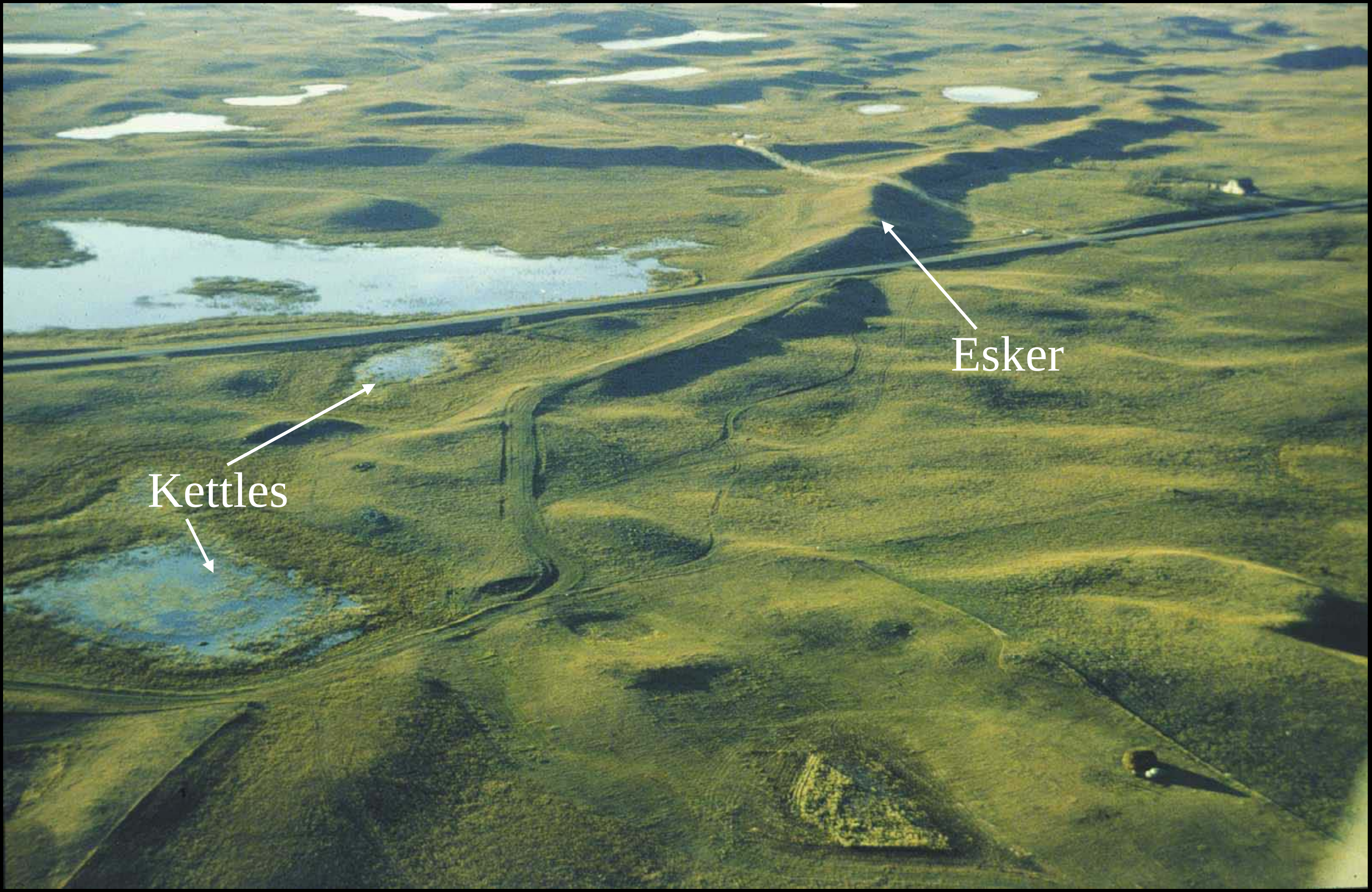
Depositional Alpine Features

Depositional Features



Erratic –a glacially deposited rock different from the bedrock on which it rests.

What type of Glaciation? “Continental”



What glacial features are shown here?

Continental Ice Sheet Features

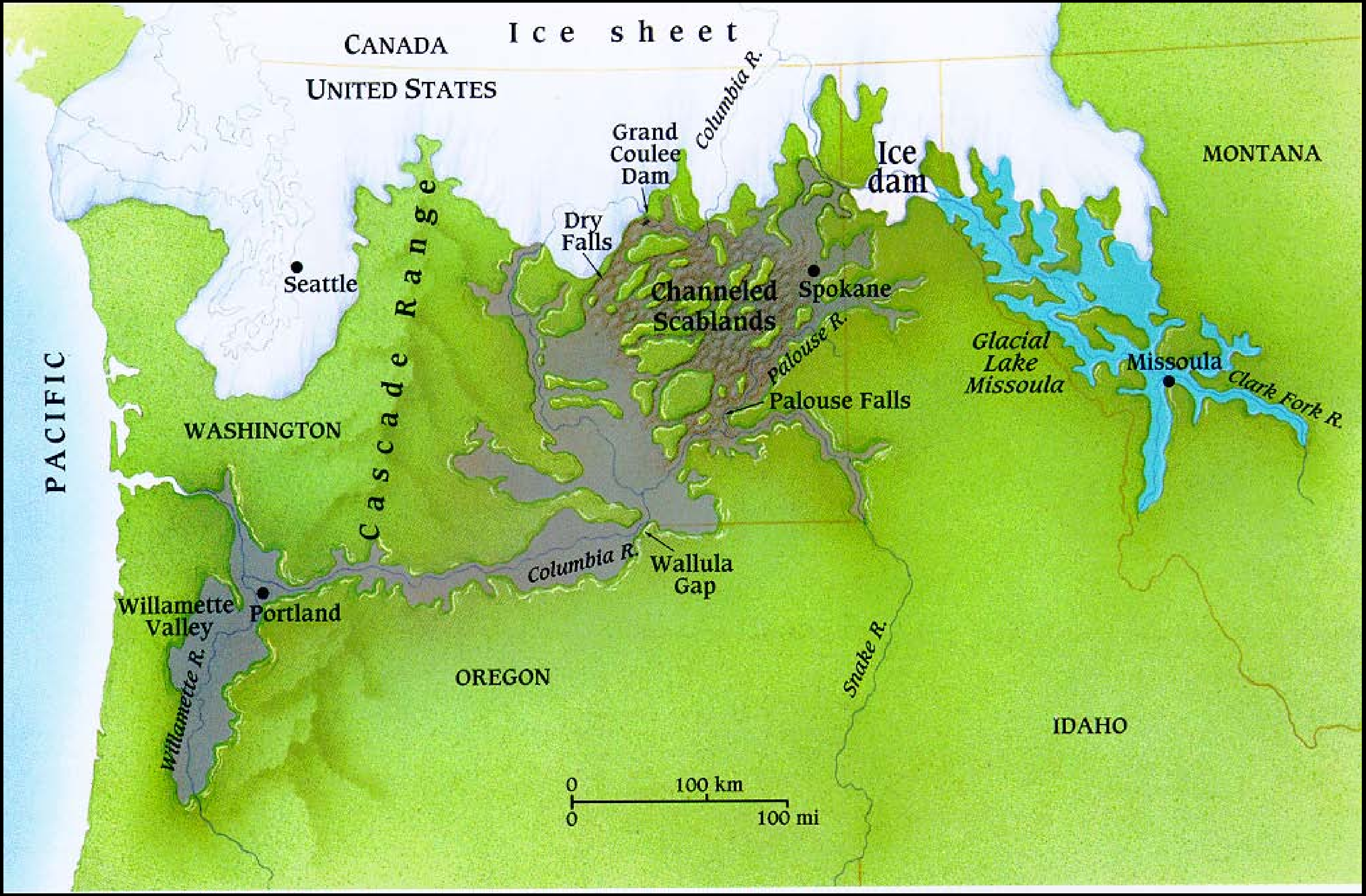
Drumlin – an asymmetric elongate hill, parallel to the ice flow direction, made of glacially deposited sediments.

Climate Change and Ice Ages

Long-Term Causes (Cause of Ice Age)

- Large landmasses at or near poles.
- Land surfaces of relatively high elevation.
- Nearby oceans to provide moisture as snow.

= PLATE TECTONICS



Location of the Channeled Scablands

Chapter 8 A Violent Pulse: Earthquakes

Earthquakes!

Earthquakes are vibrations of the ground created by the sudden release of strain energy accumulating in deformed rocks.

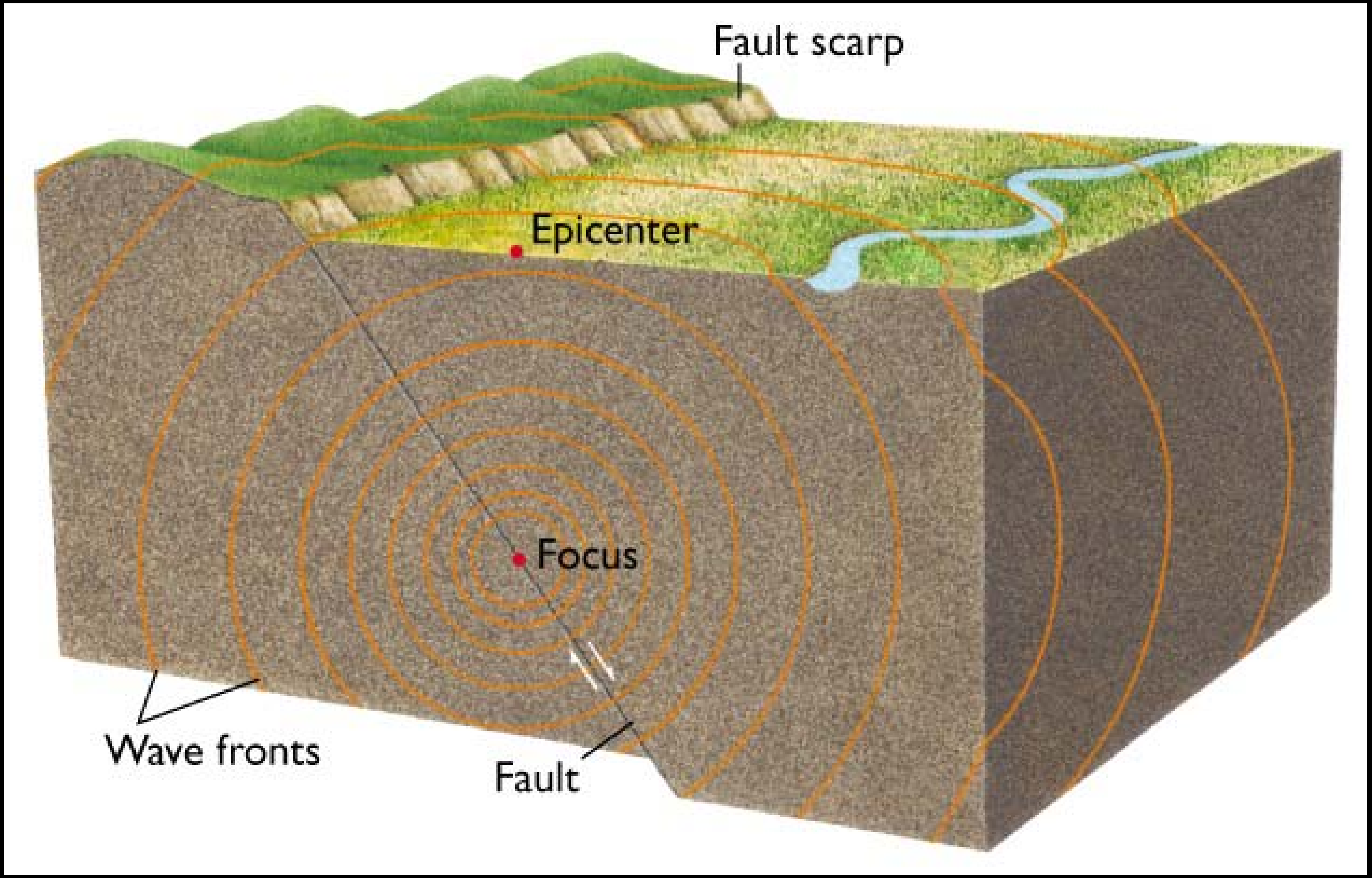
What is an earthquake?

Fault - crack in Earth where slip occurs

Earthquake - slippage along a fault

Earthquake focus (hypocenter) - fault slip location

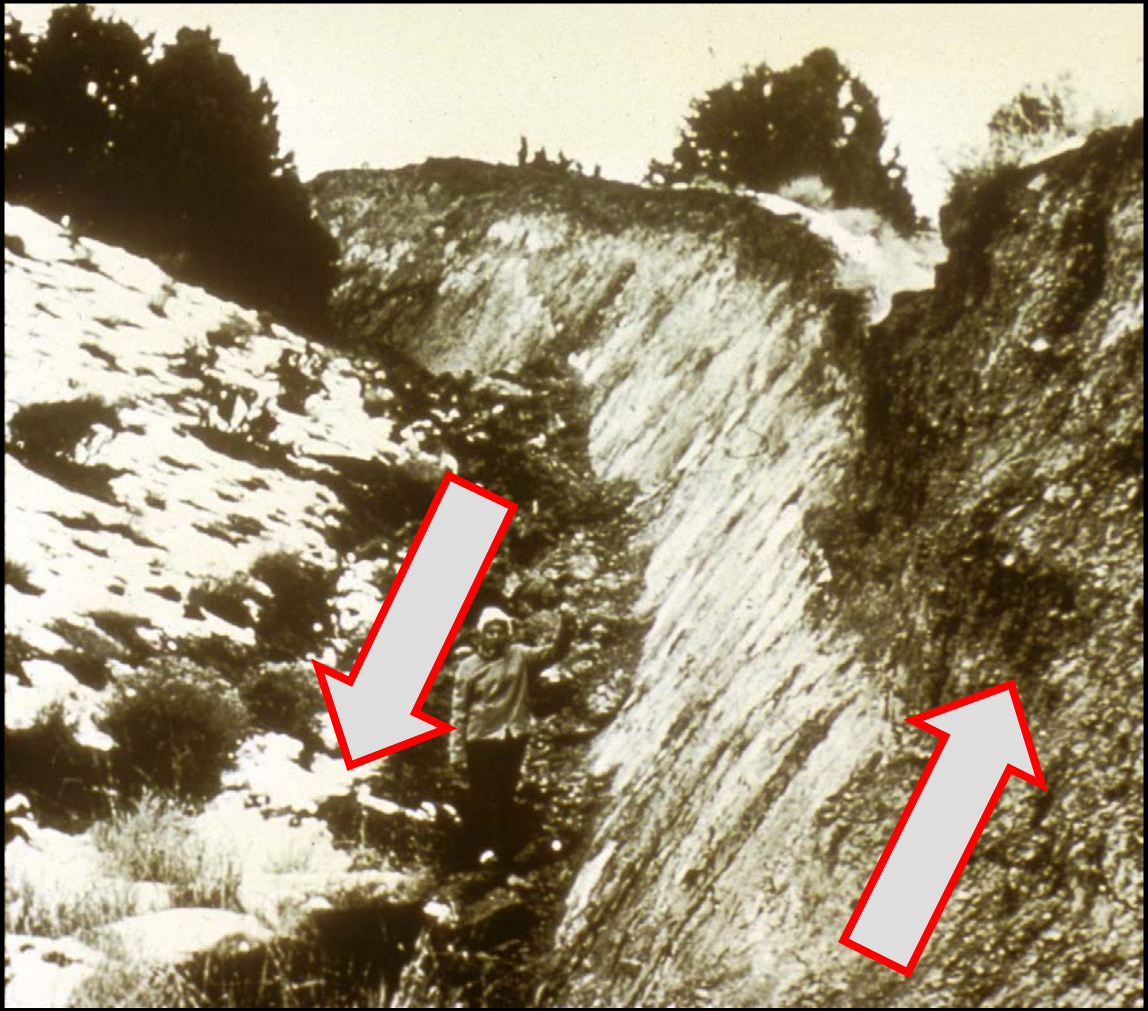
Earthquake epicenter – point on the surface directly above the focus



Modified from M Fouch, ASU

What is an earthquake?

fault scarp - cliff from vertical slip on fault



From M Fouch, ASU

What is an earthquake?

aftershocks

small earthquakes that follow an initial earthquake in same vicinity

foreshocks

small earthquakes that sometimes precede a large one by few days

From M Fouch, ASU

Seismic Waves

The strain energy released by an earthquake is transmitted through the rocks in all directions in the form of waves.

Body Waves

P Waves (Primary Waves)

- waves expand and contact (compressional)
- fastest wave (~6-7 km/sec ; ~4 mi/sec)
- travel through liquid, solid or gas

S Waves (Secondary Waves)

- waves move up/down, side to side
- slower than P wave (~3.5 km/sec;~2 mi/sec)

Surface Waves

- slowest wave (~2.5 km/sec; 1.5 mi/sec) travel along surface of the earth
- side to side
- up and down
- travels through solid only

Measuring Earthquakes

Seismograph – Device that records seismic wave motion.

- Seismogram – Record of shaking

When an earthquake occurs, three types of waves are formed:

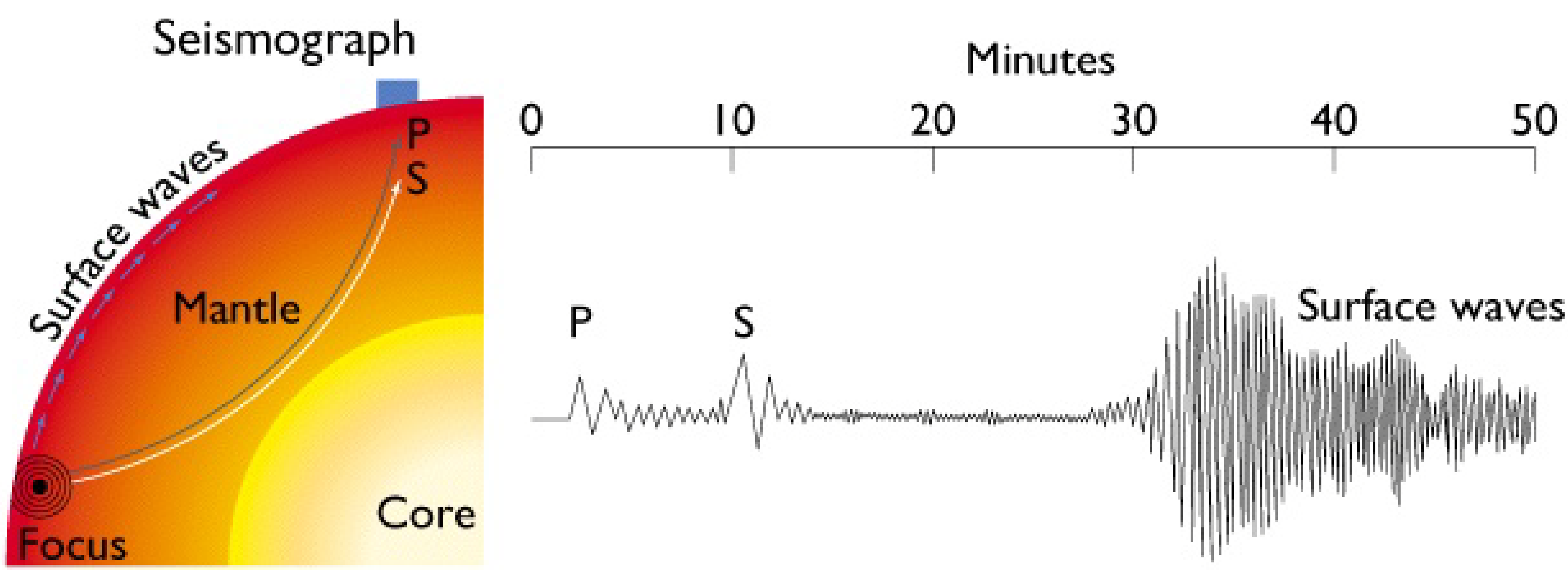
1. P-waves: “Primary” – they are compressional (think of a slinky)

2. S-waves: “Secondary” – shear waves

Body Waves

3. Surface waves

“Surface wave”



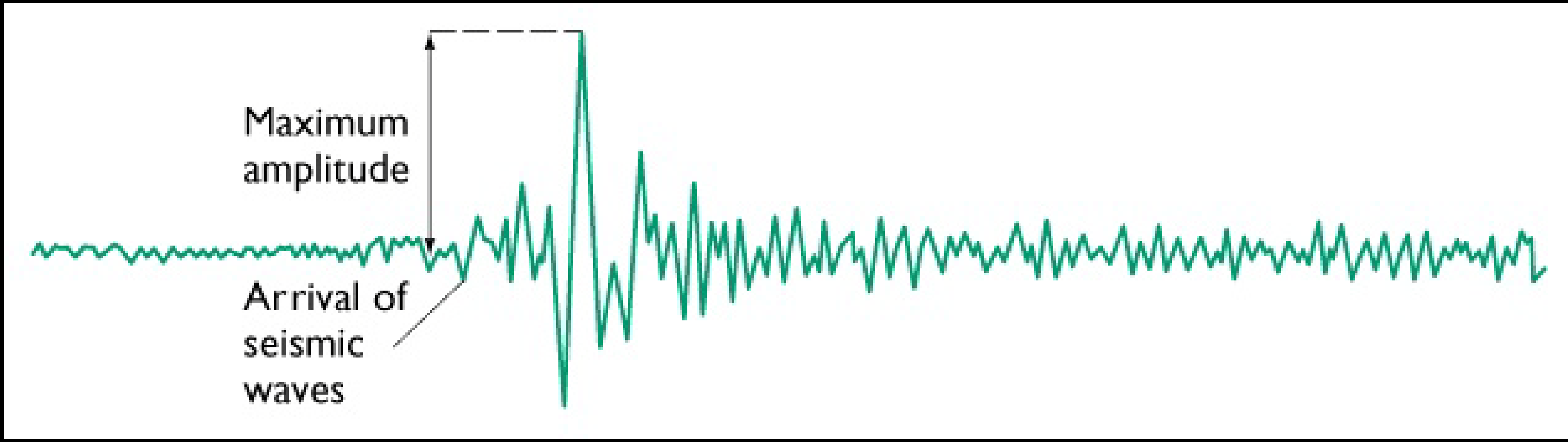
Measuring Earthquakes

Modified Mercalli scale

- based on relative destruction and observations by people
- Delineates 12 intensity levels

The Richter scale

- scale of 1-10
- based on max amplitude of S-wave on seismogram, each number represents 10x the shaking power
- 33x increase in energy released with each number
- Works best on CA rocks.



The Richter scale uses the maximum amplitude to determine the earthquake’s magnitude at a standard distance form the earthquake epicenter (100km)

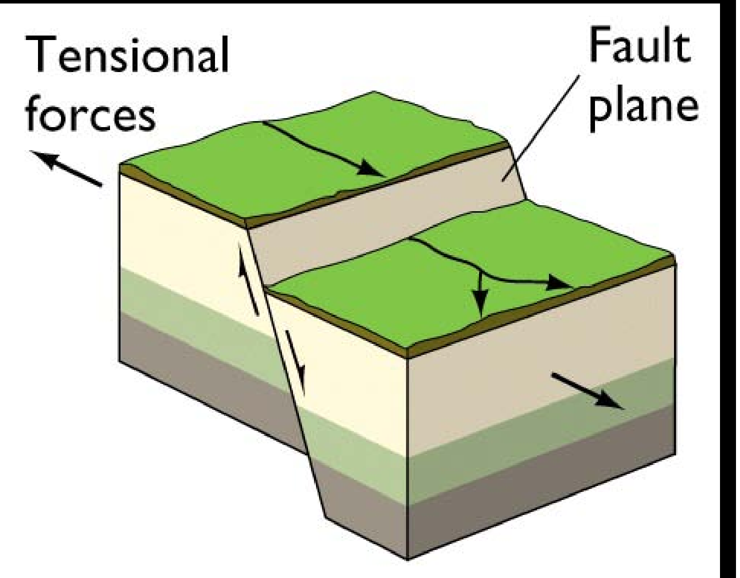
Measuring Earthquakes

Moment magnitude

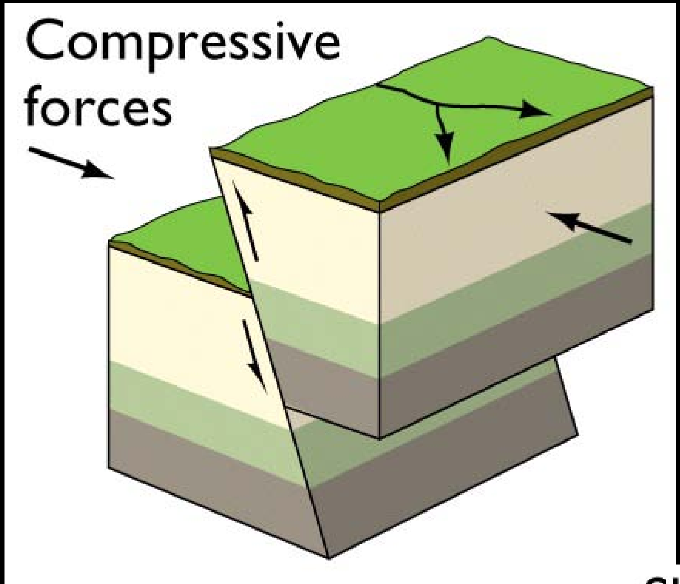
- depth of fault
- total amount of slip (movement) on fault
- strength of rock type

The Richter and Moment magnitude produce roughly the same numerical values, the moment magnitude scale is preferred by seismologists.

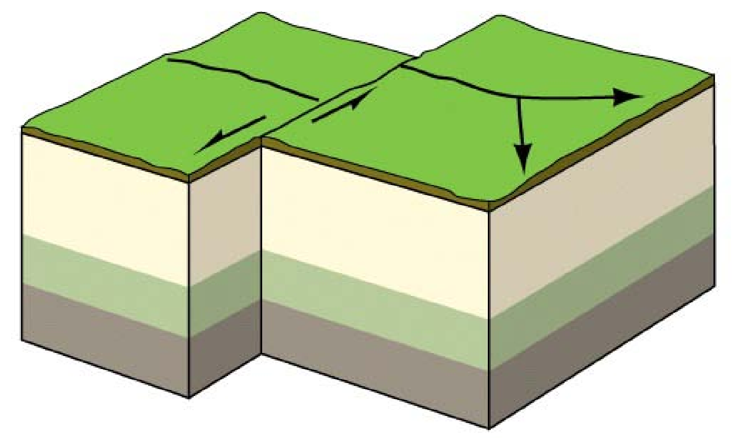
Why would earthquakes with nearly the same intensities (magnitude) produce such different results?



(b) Normal fault



(c) Thrust fault



(d) Strike-slip fault

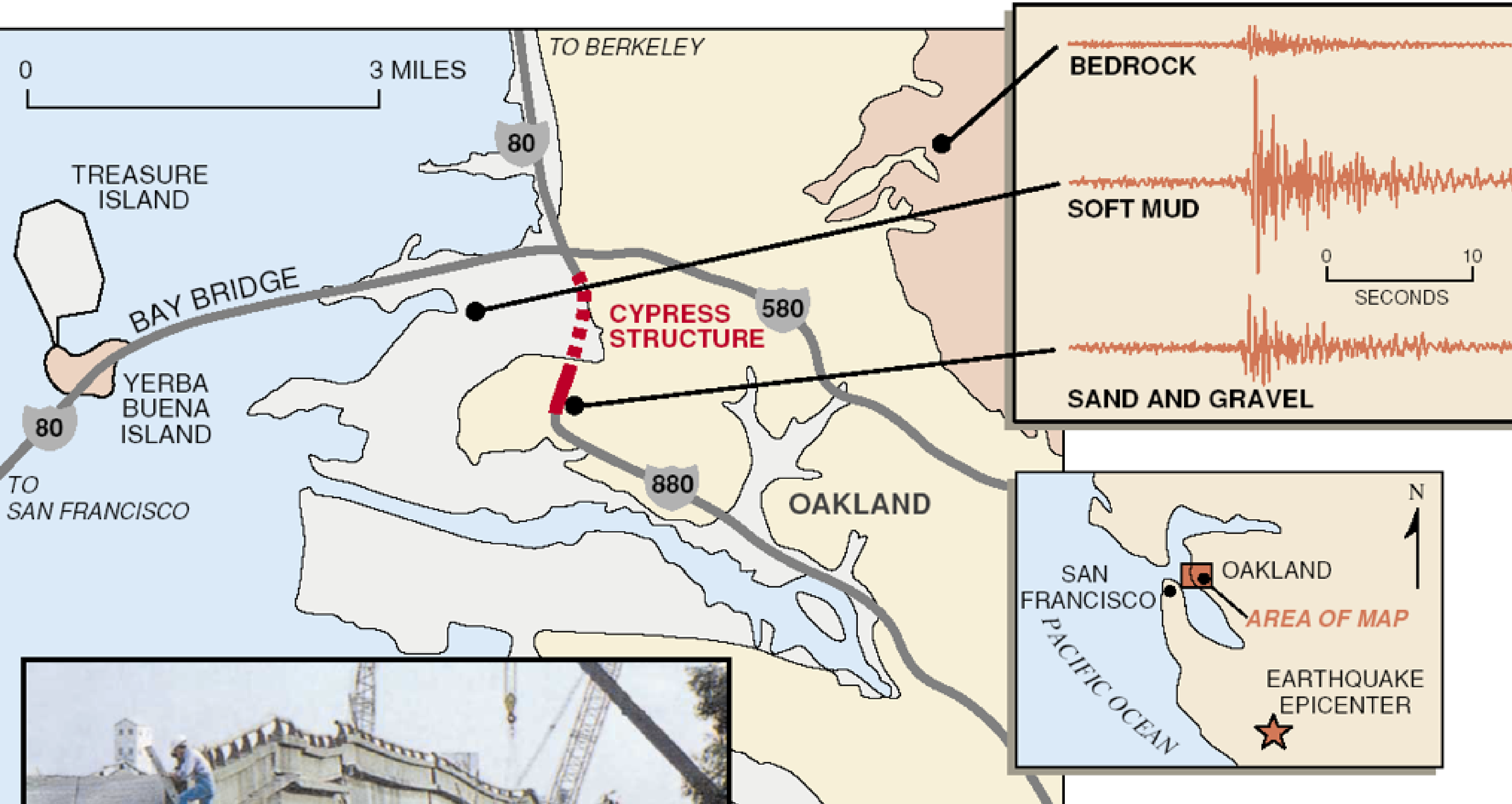
1. **Different type of ground movement is possible with different faults.**

Why would earthquakes with nearly the same intensities (magnitude) produce such different results?

2. <u>The ground can amplify the shaking.</u>

   - Building on bedrock is the best

   - Building on landfill is the worst



The part of the Cypress freeway structure in Oakland, California, that stood on soft mud (dashed red line) collapsed in the 1989 magnitude-6.9 Loma Prieta earthquake, whose epicenter was 55 miles to the south. Adjacent parts of the structure (solid red) that were built on firmer ground remained standing. Seismograms (upper right) show that the shaking was especially severe in the soft mud. Photo, Lloyd S. Cluff.

Why would earthquakes with nearly the same intensities (magnitude) produce such different results?

3. Depth to the focus

Nisqually Earthquake (2001): Depth ~ 30 miles

Northridge Earthquake (1994): Depth ~ 11 miles
Kobe Earthquake (1995): Depth ~ 10 miles

Why would earthquakes with nearly the same intensities (magnitude) produce such different results?

4. Duration of earthquake shaking

Nisqually Earthquake (2001): 40 sec

Northridge Earthquake (1994): 15 sec

Kobe Earthquake (1995): 20 sec

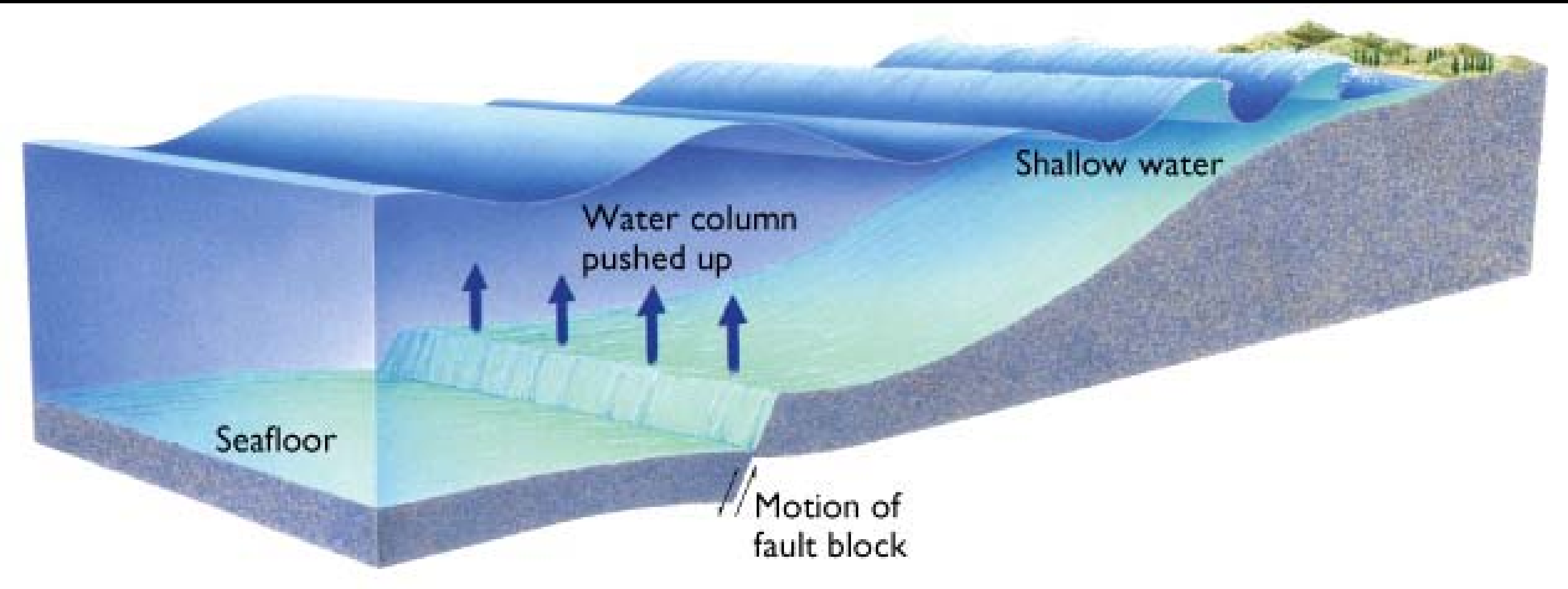
Effects of Eathquakes

- **Tsunami - a sea wave triggered by an under water earthquake**
- Landslides
- **Liquefaction** – Unconsolidated sediment becomes water saturated and flows.
- **Seiches** – Water sways back and forth over enclosed body of water (lakes, swimming pools).
- Ground Shift
- Fires

Effects of Earthquakes

- **Tsunami** – Fast moving seismic sea waves generated by faulting. Ground motion displaces sea water above, generates wave. Move at speeds up to 800 km/hr (500 mi/hr), up to 100 ft high.

Tsunami


Shallow water
Water column
pushed up
Seafloor
Motion of
fault block

Effects of Eathquakes

- **Tsunami**
- Mass wasting
- **Liquefaction** – Unconsolidated sediment becomes water saturated and flows.
- **Seiches** – Water sways back and forth over enclosed body of water (lakes, swimming pools).
- Ground Shift
- Fires

Slump

Earthquake-induced mass wasting

Liquifaction

Interlude D Seeing Inside the Earth

The Earth’s Interior

Information about the earth's interior (density, thickness and composition) comes from the behavior of seismic waves.

The Earth's Interior

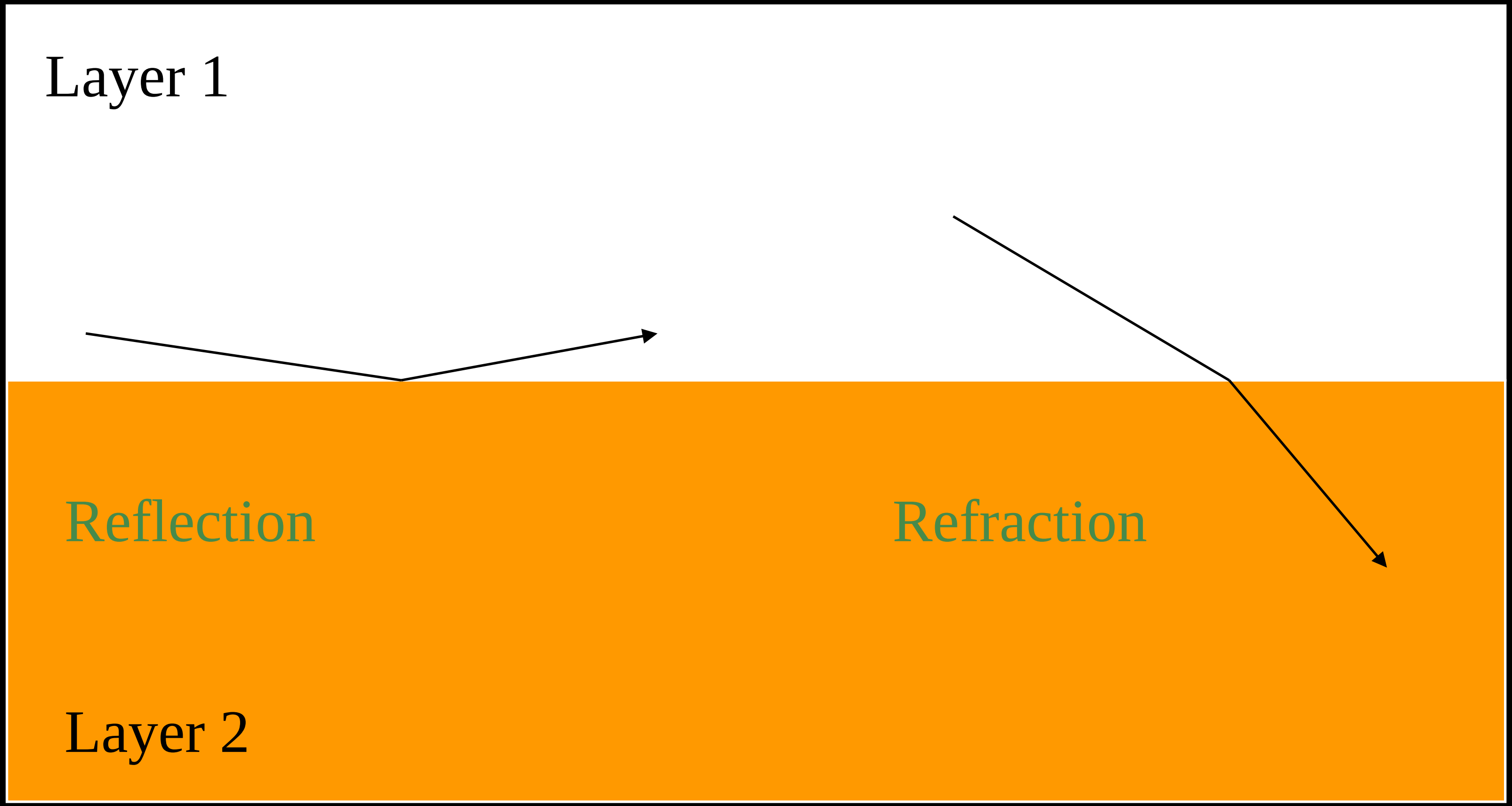
P Waves
- Able to move through solid rock and molten rock.
- Travel more quickly through solid rock (Velocity increases with increased density).

S Waves
- Able to move through solid rock (Velocity increases with increased density).
- Cannot travel through molten rock.

The Earth's Interior

- As waves travel through earth layers with different properties, seismic wave velocity or direction may change.
- Seismic reflection
  - Shallow angle – waves bounce off
- Seismic refraction
  - Steeper angle – waves bend

The Earth's Interior

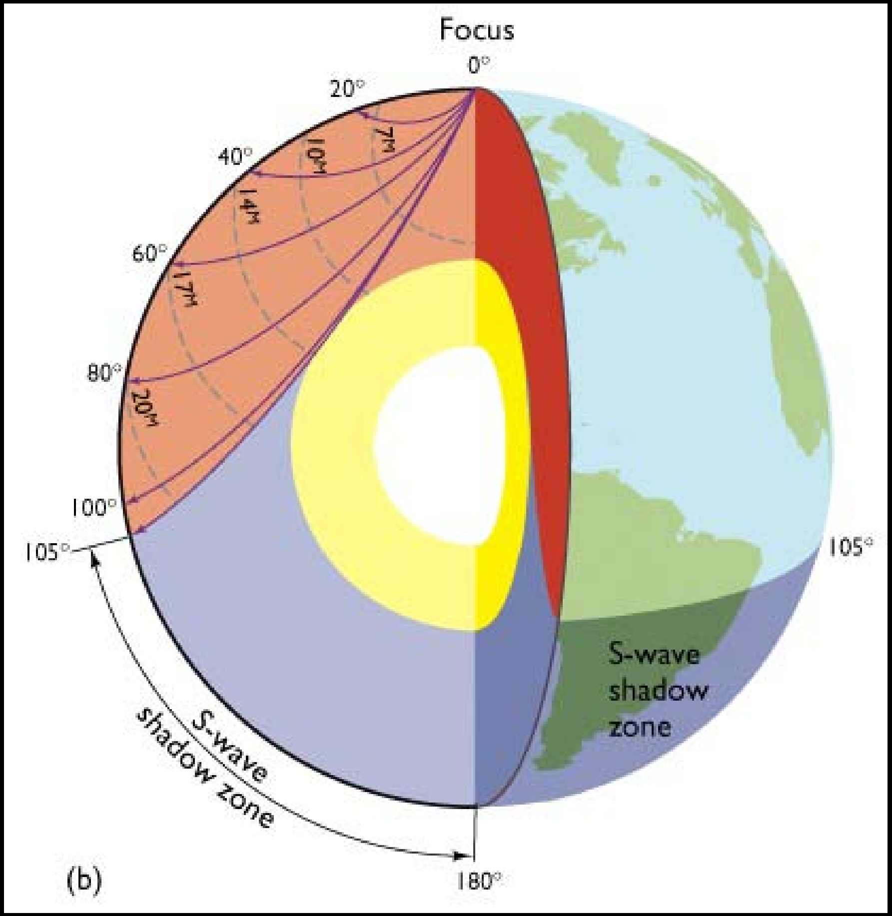


Seismic Shadow Zones

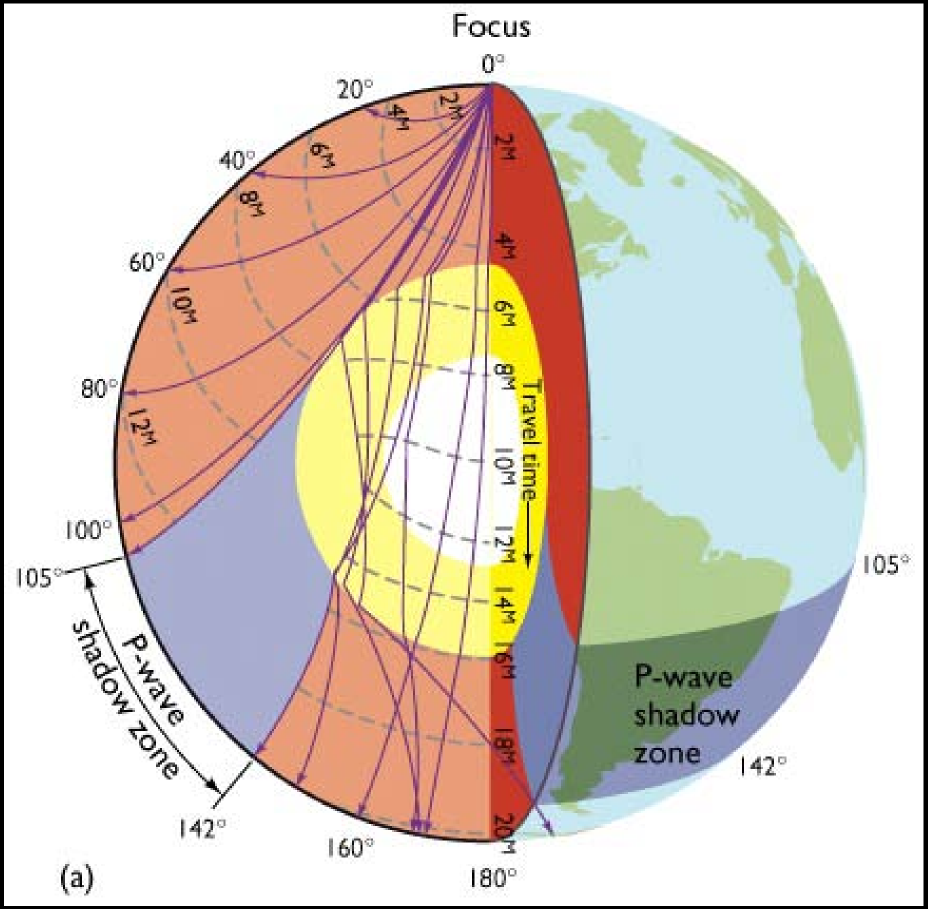
Shadow Zones – Area where seismic waves are not recorded opposite an earthquake epicenter.

S-wave

P-wave



Focus
0°
20°
40°
60°
80°
100°
105°
105°
7M
10M
14M
17M
20M
S-wave
shadow
zone
S-wave
shadow zone
180°
(b)



Focus
0°
20°
40°
60°
80°
100°
105°
105°
2M
4M
6M
8M
10M
12M
14M
16M
18M
20M
Travel time
P-wave
shadow zone
P-wave
shadow
zone
142°
142°
160°
180°
(a)

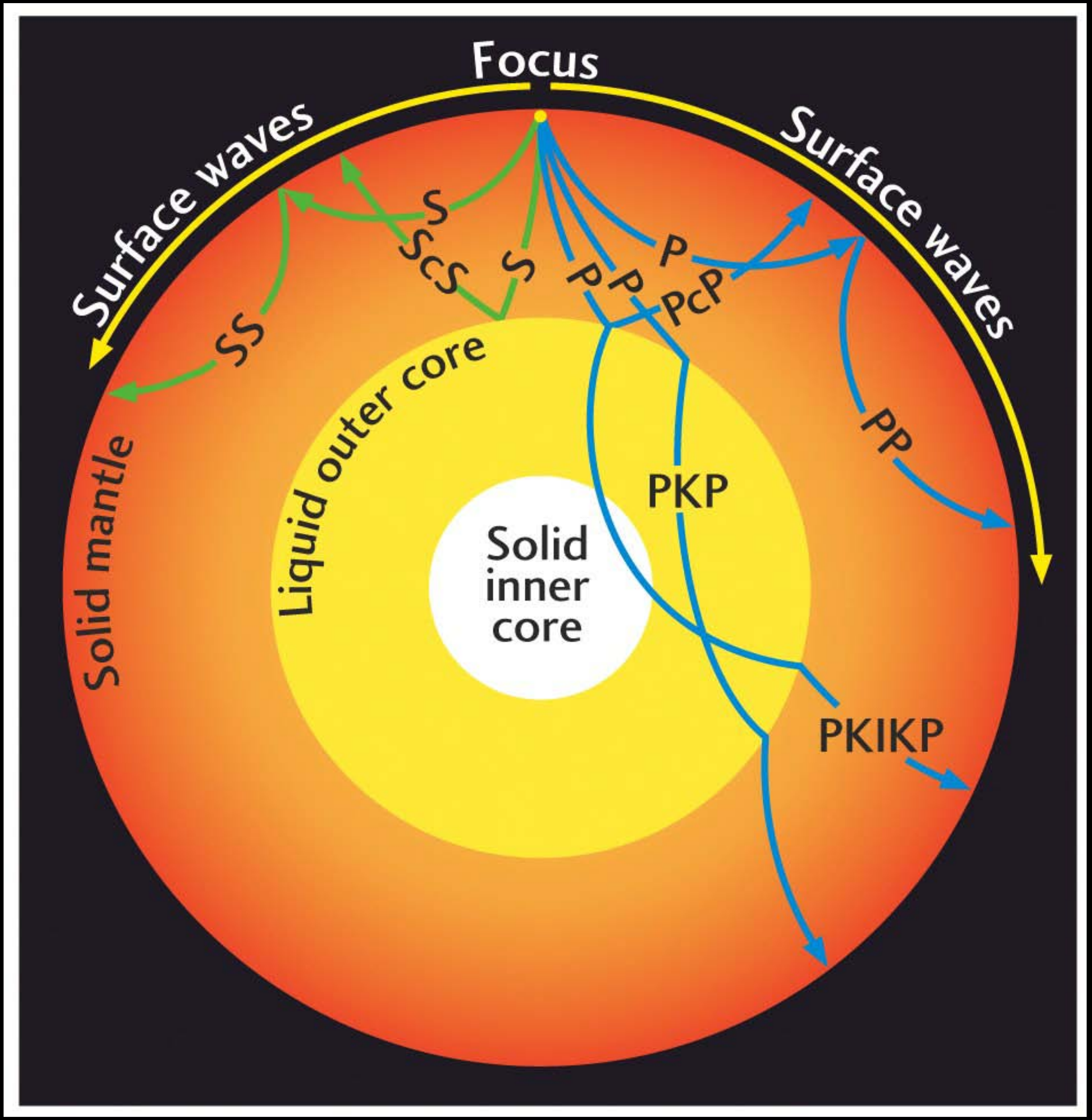
Shadow Zones

Both P and S wave shadow zones form as a result of the molten outer core of the earth.

- P waves are refracted by the outer core.
- S waves disappear in the outer core.

Fig. 21.2

Years of worldwide earthquakes and nuclear explosions allow the interior of the Earth to be mapped



Seismic waves & Earth's Interior

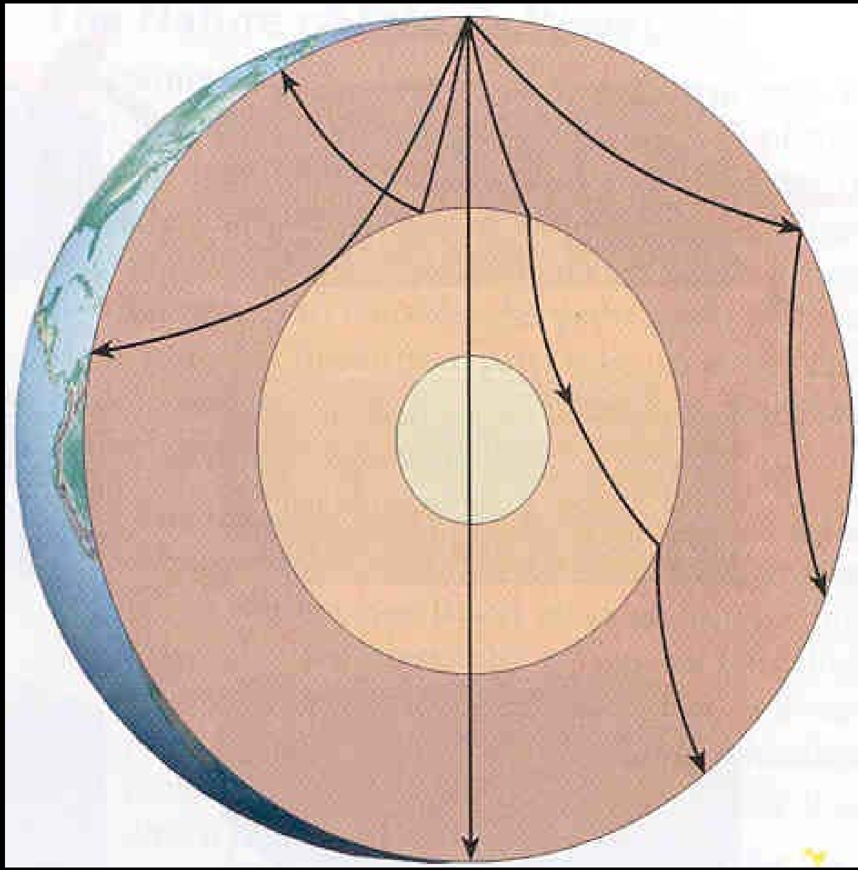
☞ Compositional layers

crust *3-70 km thick*

mantle *down to 2900 km depth*

core *2900-6370 km depth*

iron-nickel + Sulfur or Oxygen

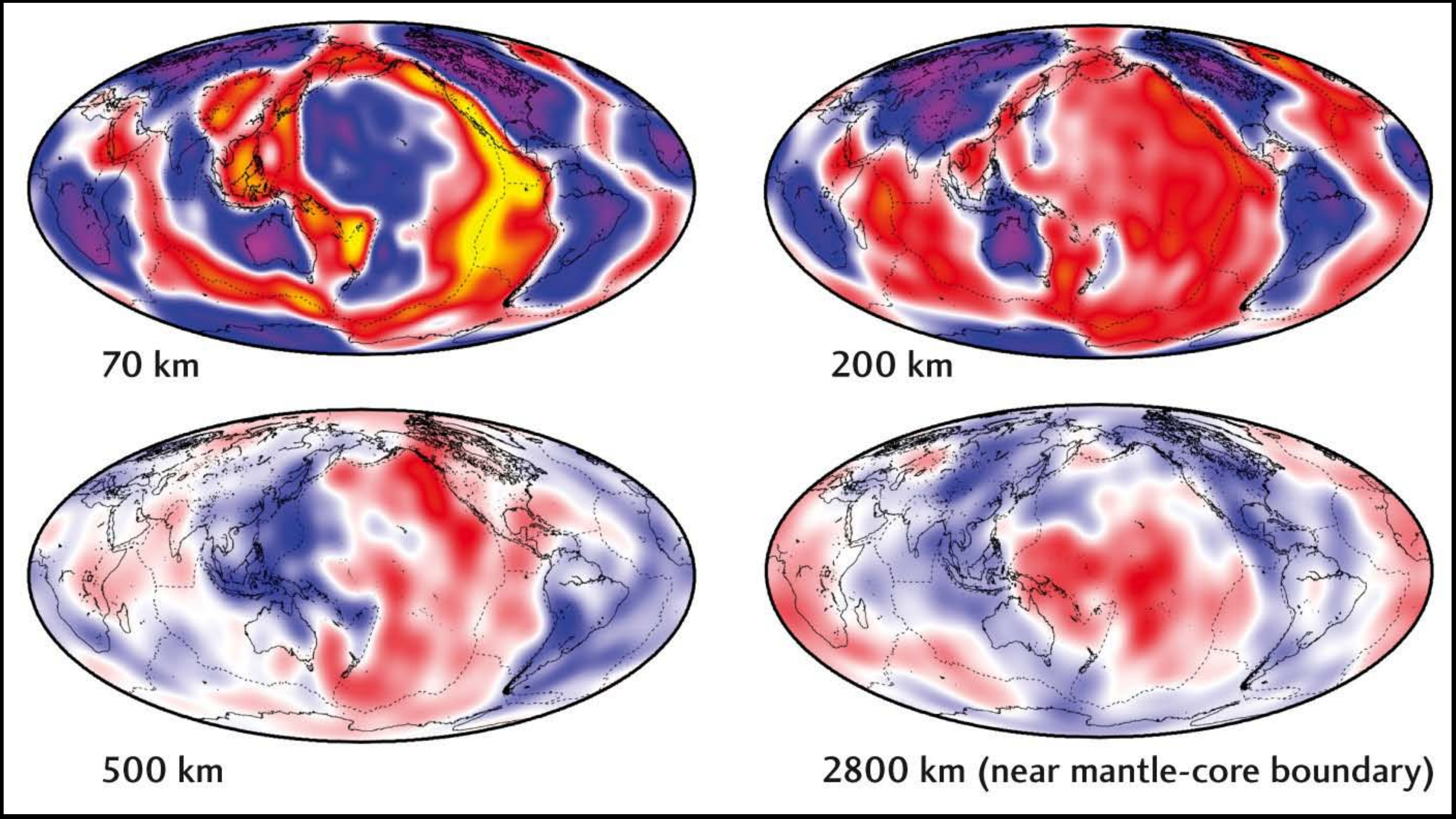


☞ Mechanical layers

	layer	*depth*
lithosphere	*stiff/strong,*	*0-100 km*
asthenosphere	*soft/weak,*	*100-660 km*

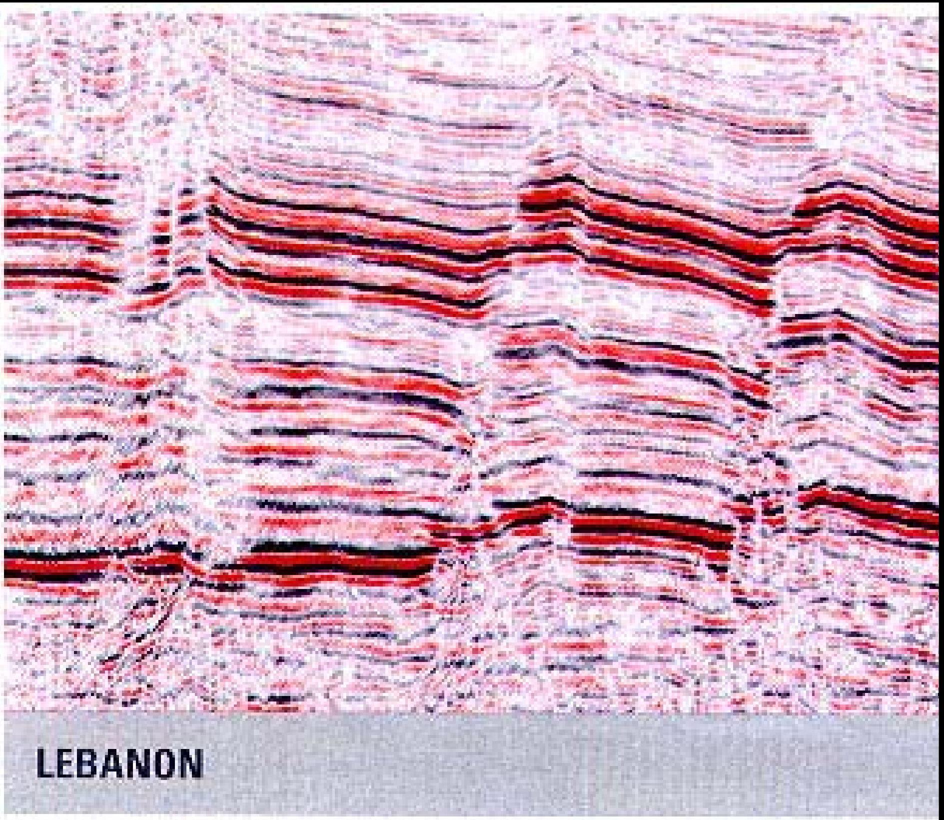
From M Fouch, ASU

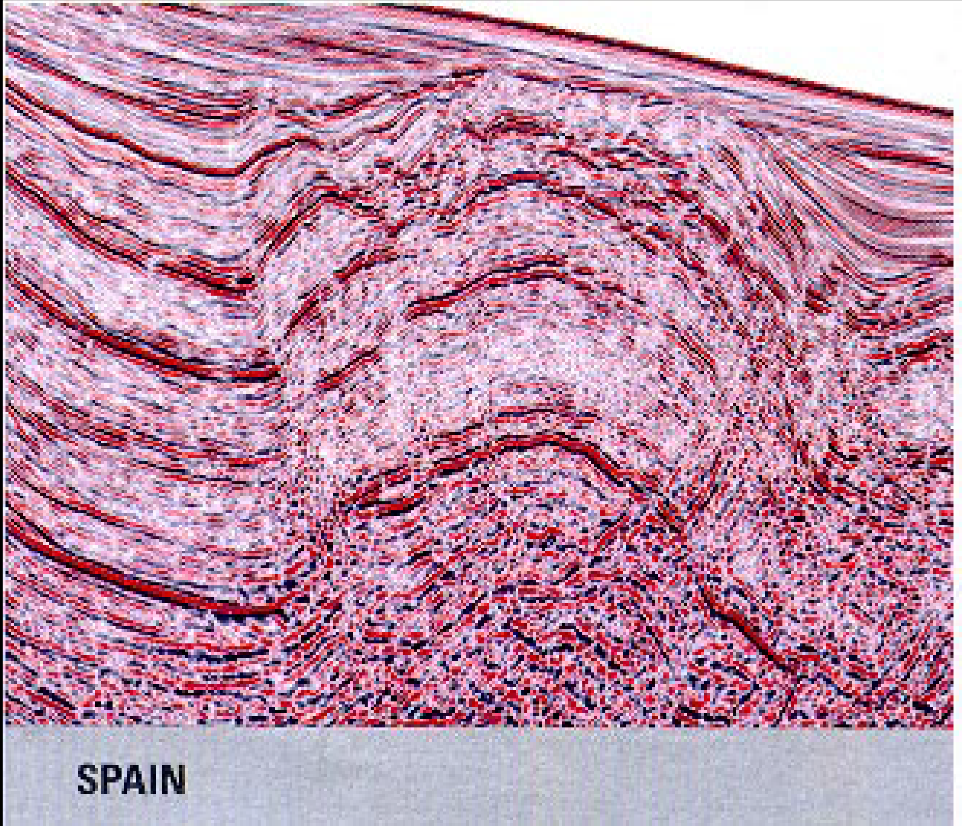
Similar to a CAT scan which reveals the interior structure of the Human body, seismic tomography can reveal the interior structure associated with mantle convection.



So, how does the use of seismic waves affect your life?

Seismic waves are used to image the subsurface geology to locate structures (anticlines, synclines and faults) for oil and gas exploration.



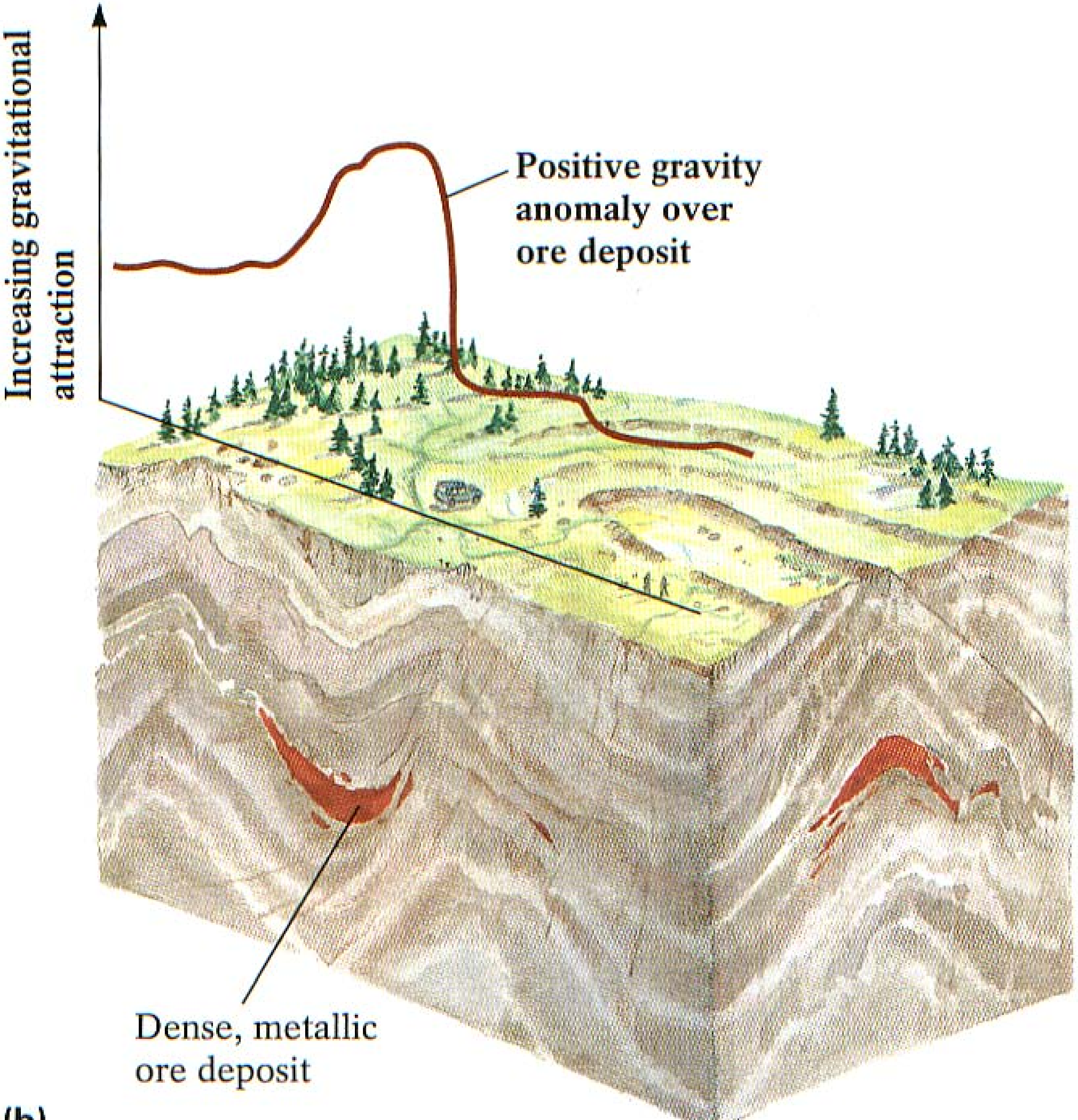


Other techniques use the Earth's

Gravity and

Magnetic Field

not only to help locate oil and gas deposits, but also mineral deposits.


Increasing gravitational attraction
Positive gravity anomaly over ore deposit
Dense, metallic ore deposit
(b)

Conclusion:

The interior of the Earth can be explored with:

1. **Seismic waves**
2. **Gravity variations**
3. **Magnetic variations**