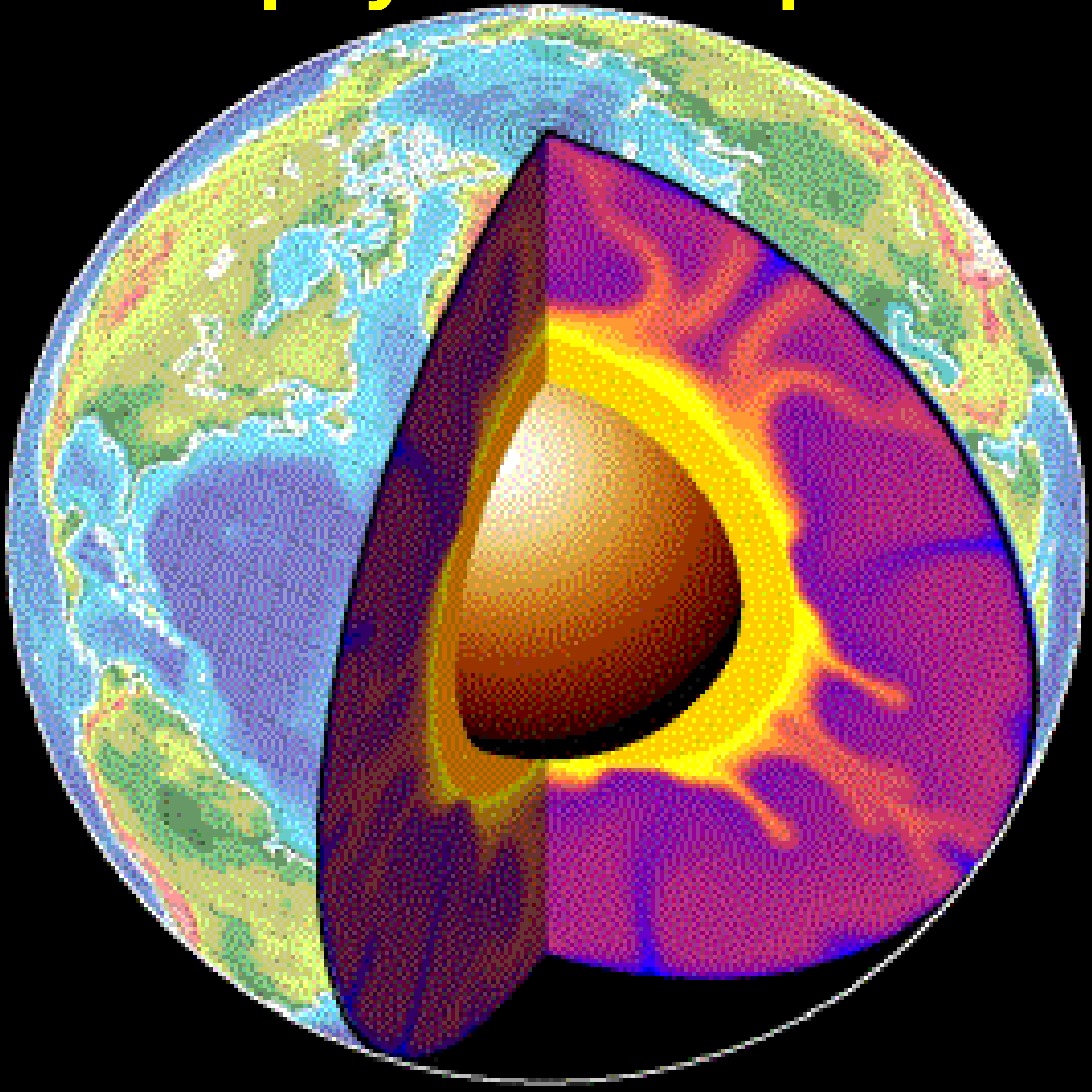
Earth’s Interior and Geophysical Properties



Studying Rocks from Earth’s Interior

- Geologists can’t sample rocks very far below Earth’s surface.
- Deep mines may be 3 km deep.
- Some oil wells reach depths of 8 km.
- No well has ever reached Earth’s mantle.

The Deepest Scientific Well

- 12 km deep
- Penetrated ancient Precambrian basement rocks
- Took 15 years to drill

Second Deepest Well

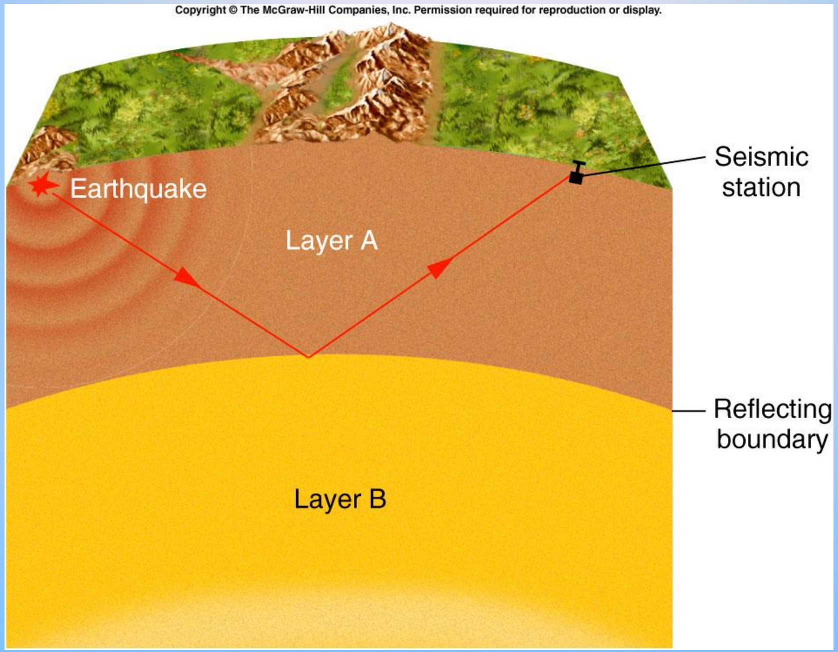
- KTB hole in SE Germany
- Depth of 10 km
- Cost more than $ 1 billion
- Technically as complex as space exploration

Analysis of Indirect Information

- The only method for learning about Earth's interior
- ***Geophysics***
  - The branch of geology that applies physical laws and principles to a study of Earth
  - Includes the study of:
    - Seismic Waves
    - Earth's Magnetic Field
    - Gravity
    - Heat

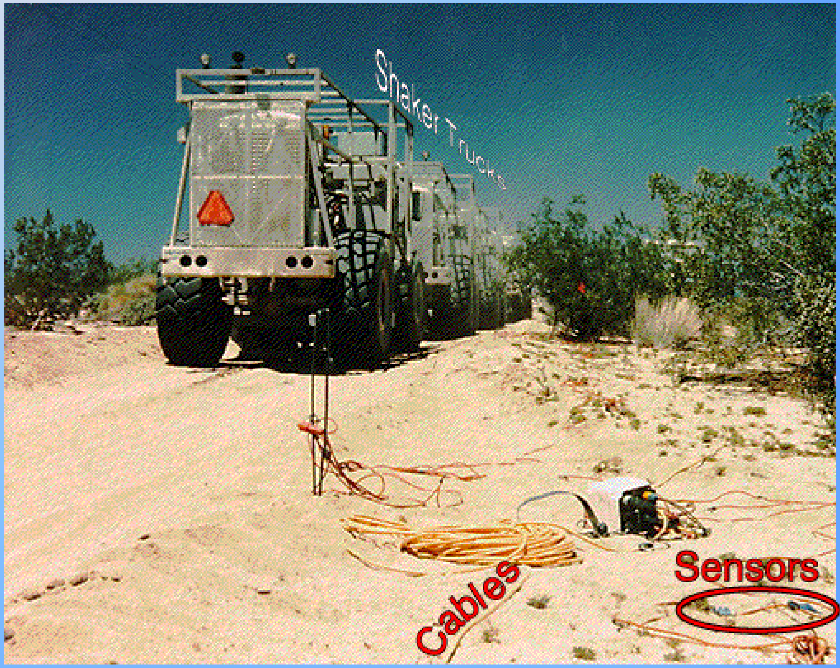
A. Evidence From Seismic Waves

1. Seismic <u>Reflection</u>

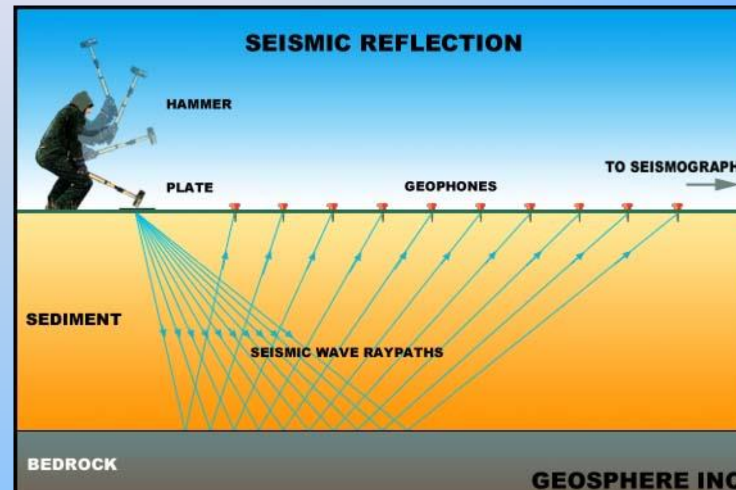


- Return of some energy to Earth's surface from a boundary
- Boundary between two layers of differing density

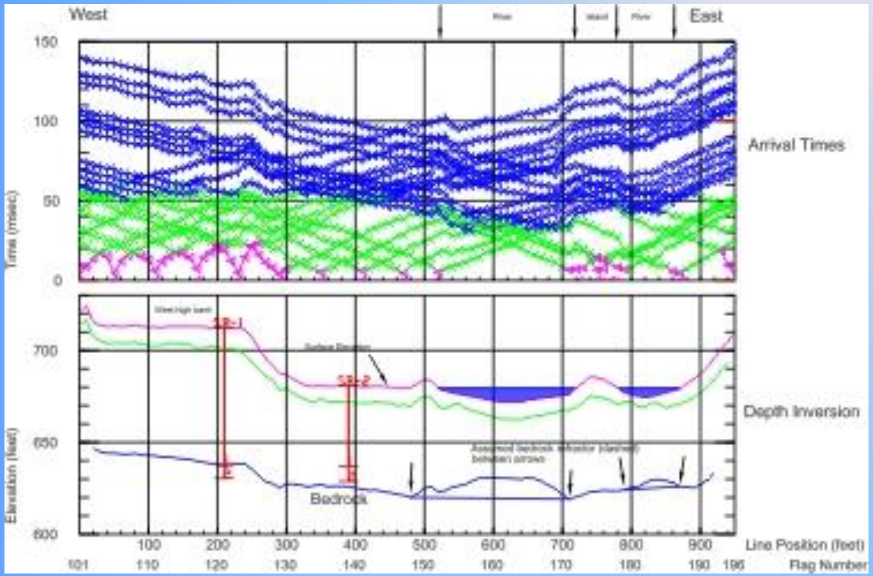
"Artificially" Creating Seismic Waves
Thumper Trucks

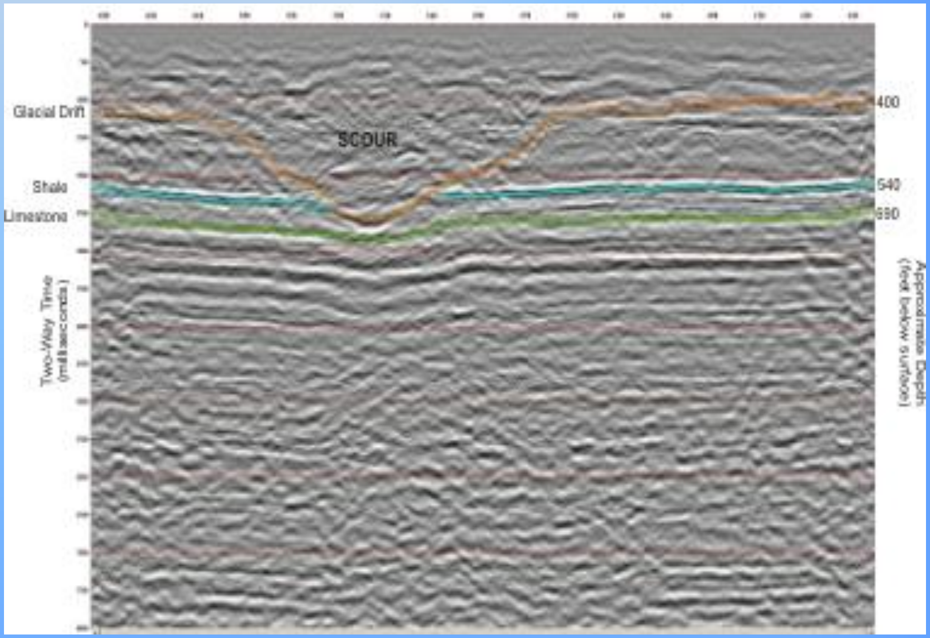


Artificially Creating Seismic Waves “Elbow Grease”



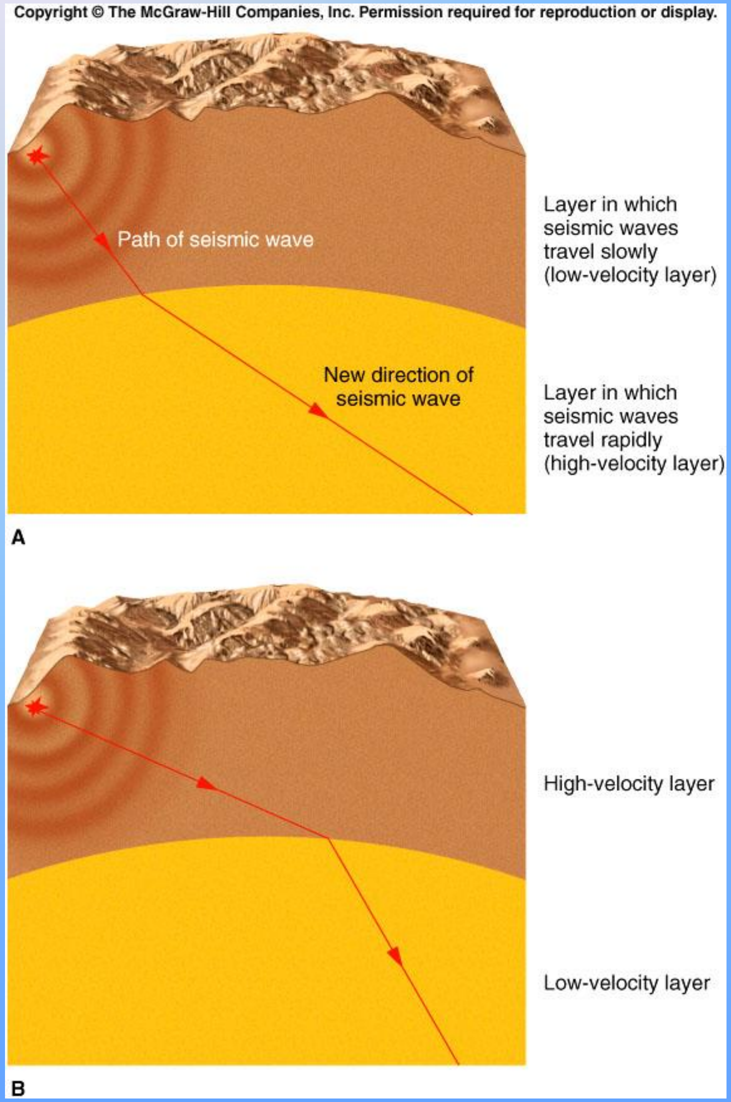
Seismic Reflection Data





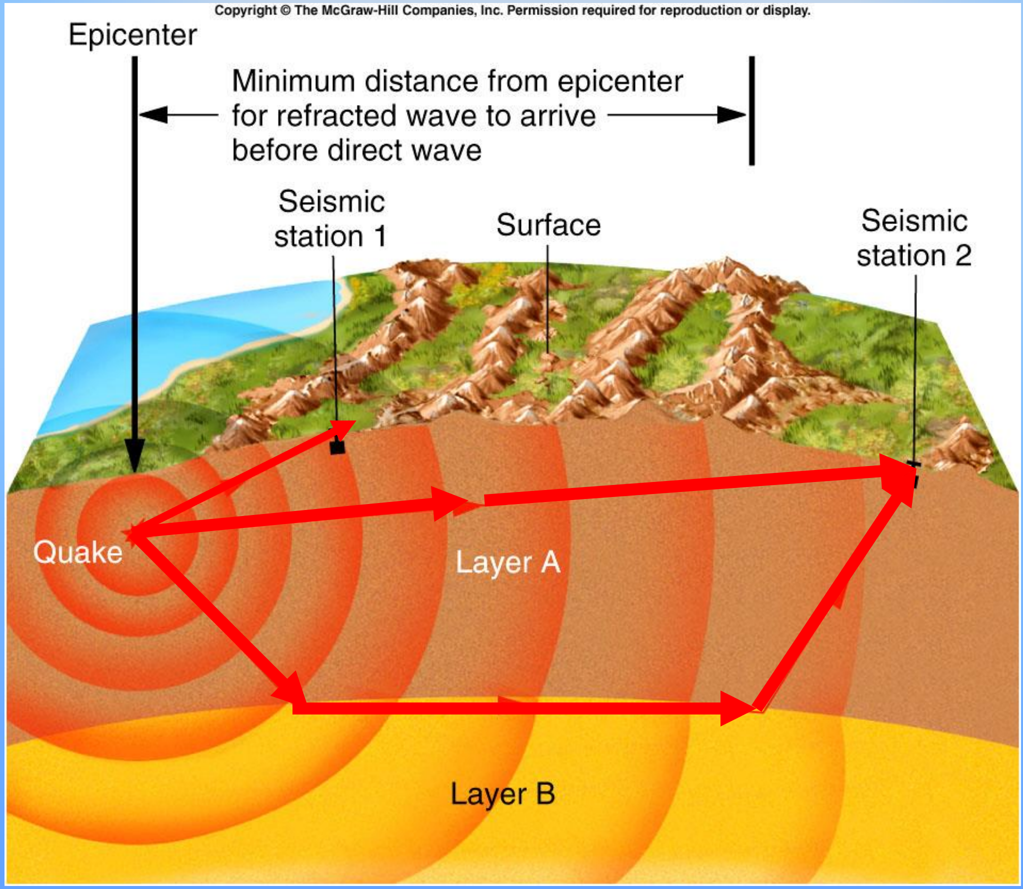
2. **Seismic Refraction**

- Bending of Seismic Waves
- Occurs only if velocity differs in each layer (caused by density differences)



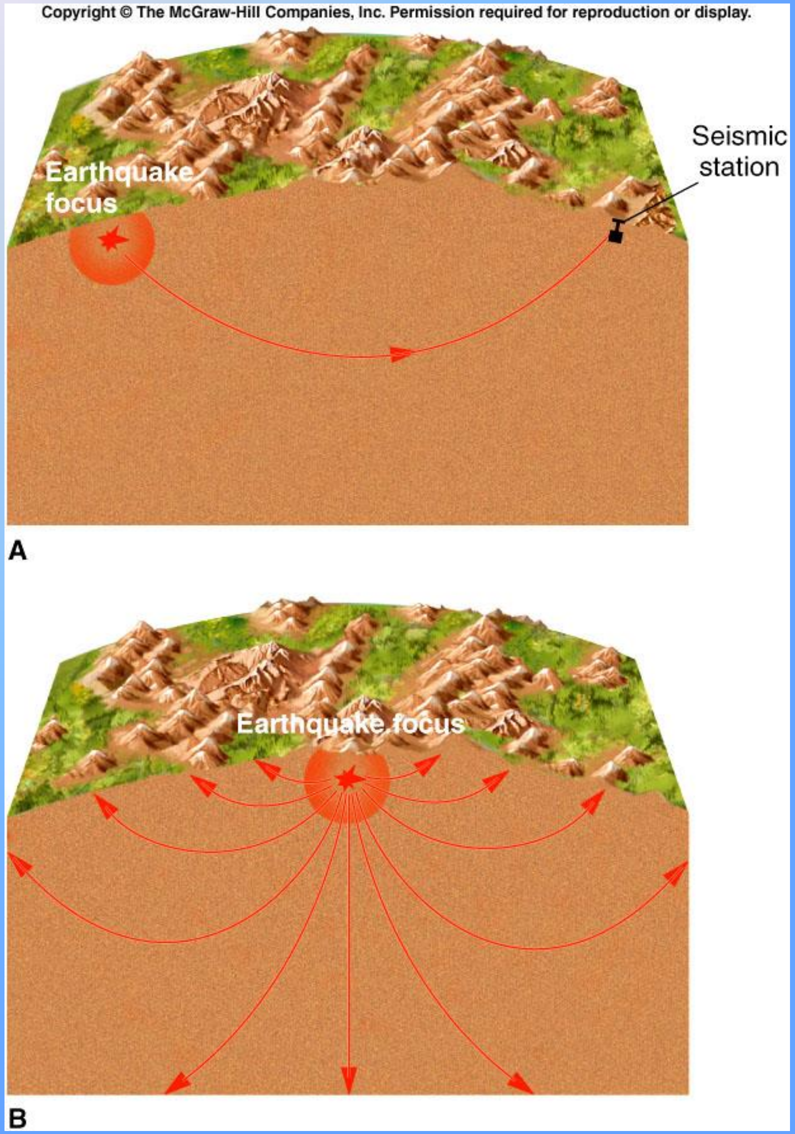
3. First and Second Arrival Seismic Waves

a. Deeper Wave __**refracts**_ and arrives at a seismograph station first.
b. Can infer depth of boundaries between layers



Refraction Without an Interface

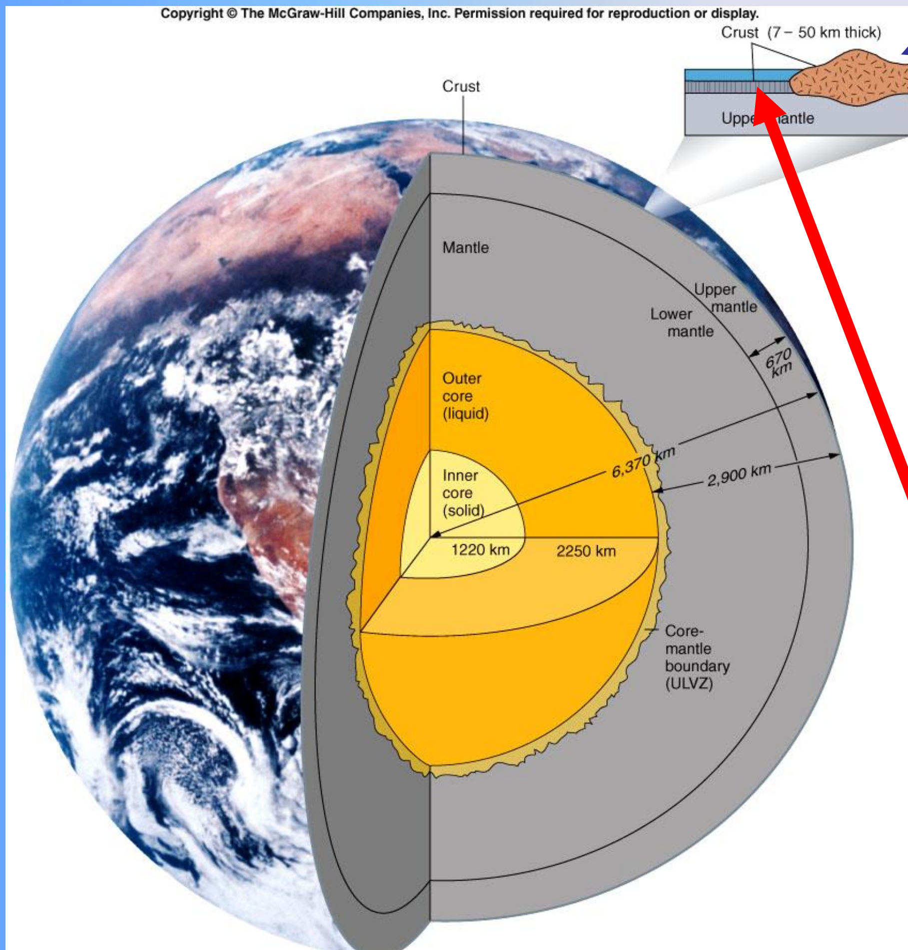
- Increasing density in a thick layer of uniform rock
- Increase in velocity
- Curved paths from many small changes in direction as wave passes through many layers



B. Earth's Internal Structure

1. Crust

Continental Crust -
Thickest under mountains

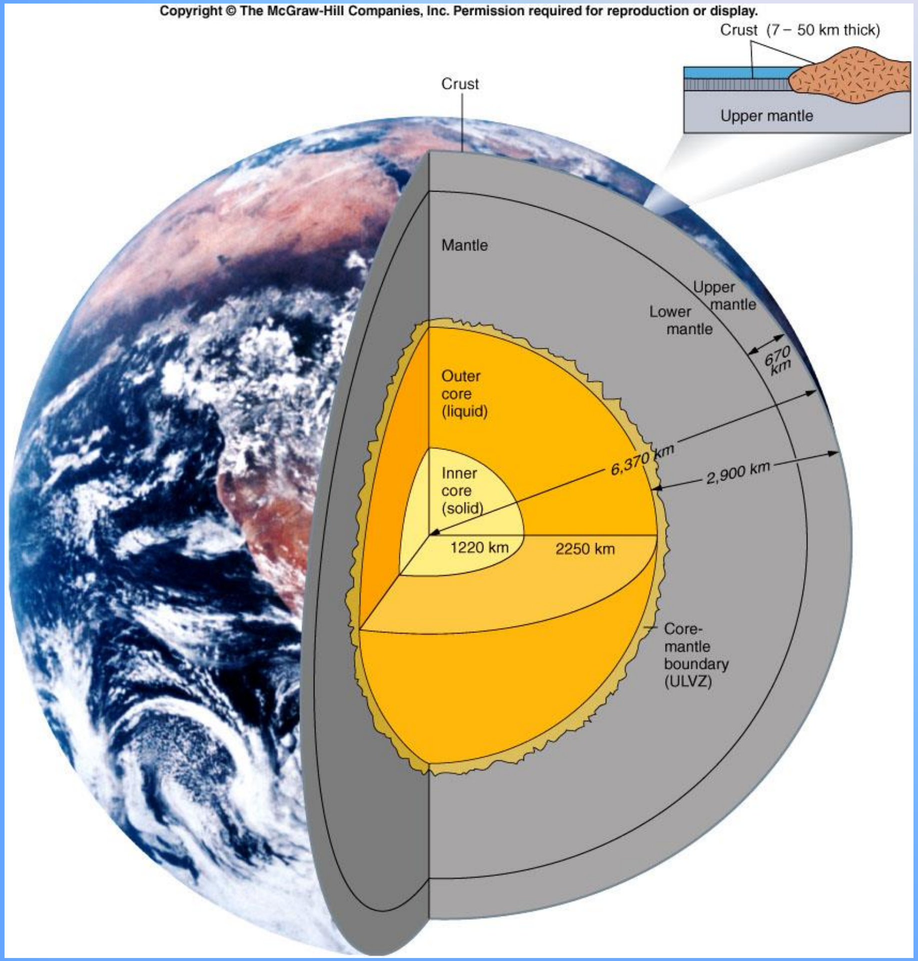


a. Outer thin layer (varies from 7 km to 50 km in thickness)

b. Mohorovičić Discontinuity (called the MOHO)
   (1) A discontinuity is a boundary where seismic waves experience an abrupt change in velocity or direction
   (2) Separates the crust from the mantle

Ocean Crust –
Average Thickness: 7km

2. Mantle

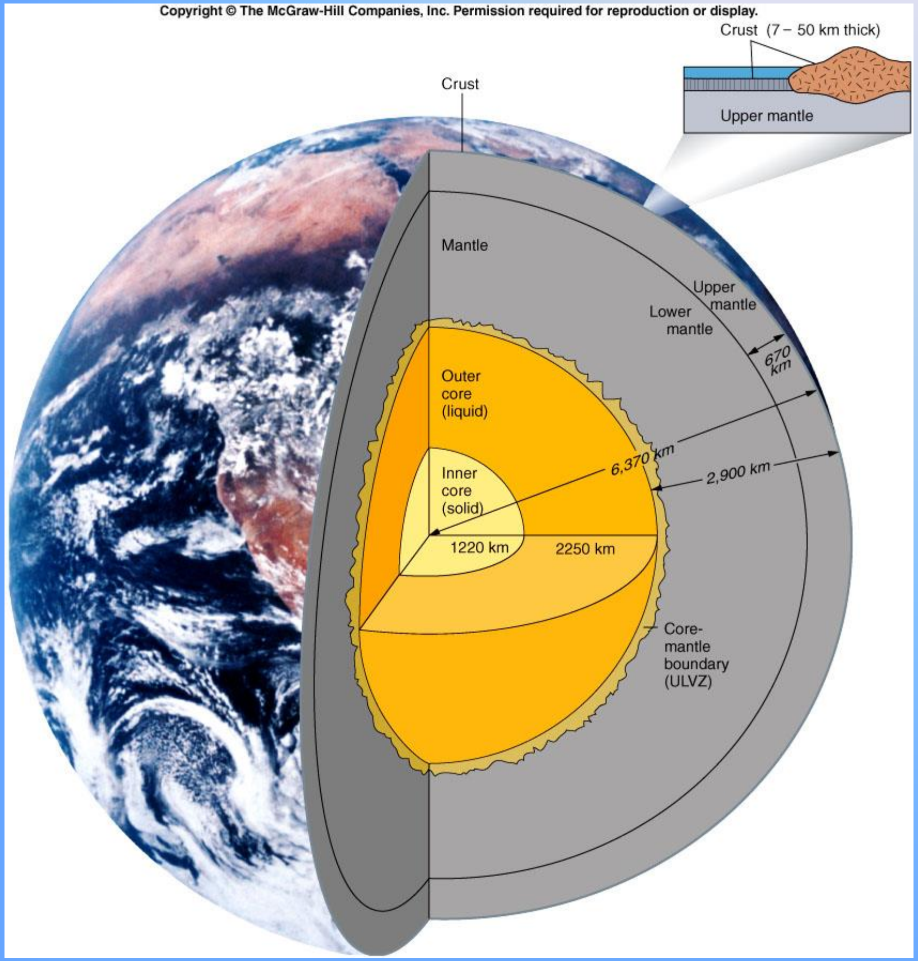


a. Upper Mantle: Part of the **Lithosphere**

(1) Crust and Upper Mantle.

(2) Outer shell of Earth and is strong and brittle

2. Mantle



b. Asthenosphere

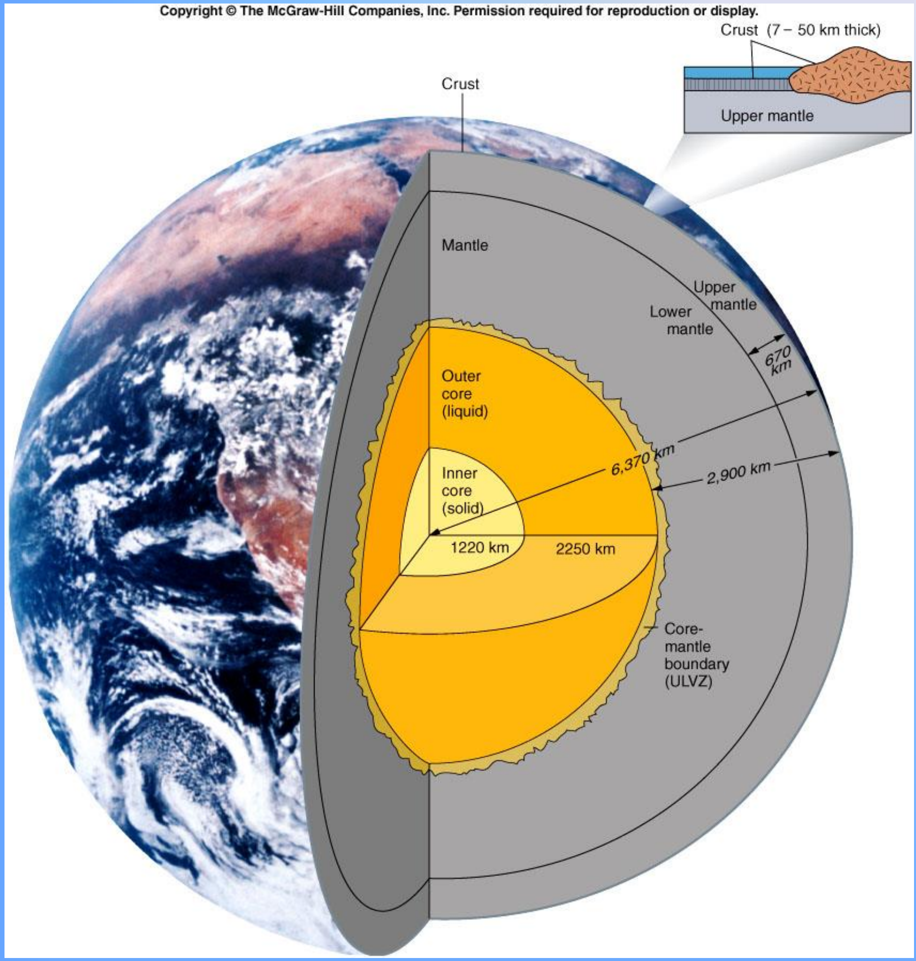
(1) Low-Velocity Zone

(2) Extends to 200 km

(3) Rocks close to melting point (1 to 10% molten.

(4) Rocks may have little strength and be capable of flowing

1. Mantle

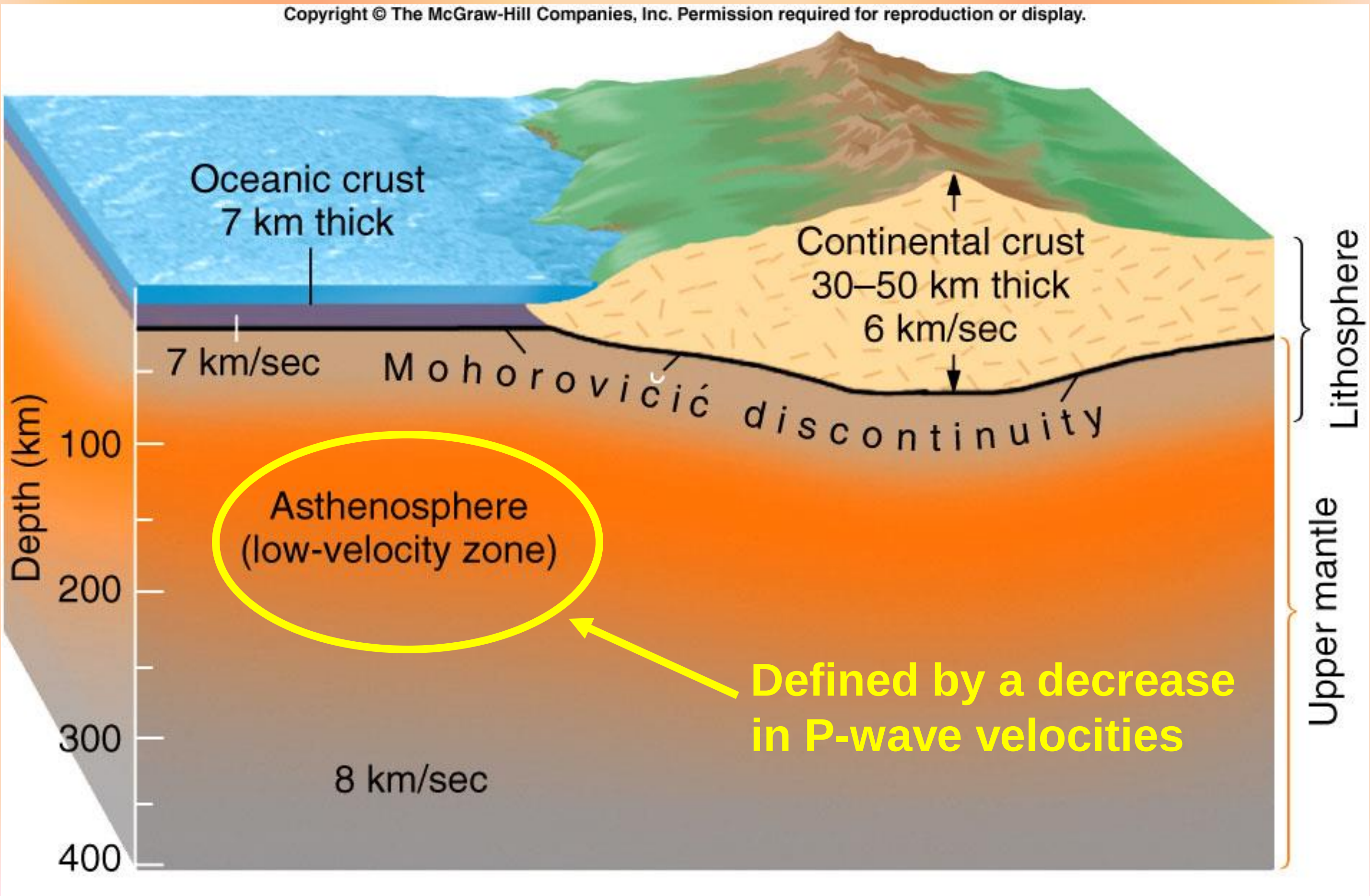


c. Lower Mantle

(1) Consists of mostly silicate and oxides of Mg and Fe (ultramafic rocks

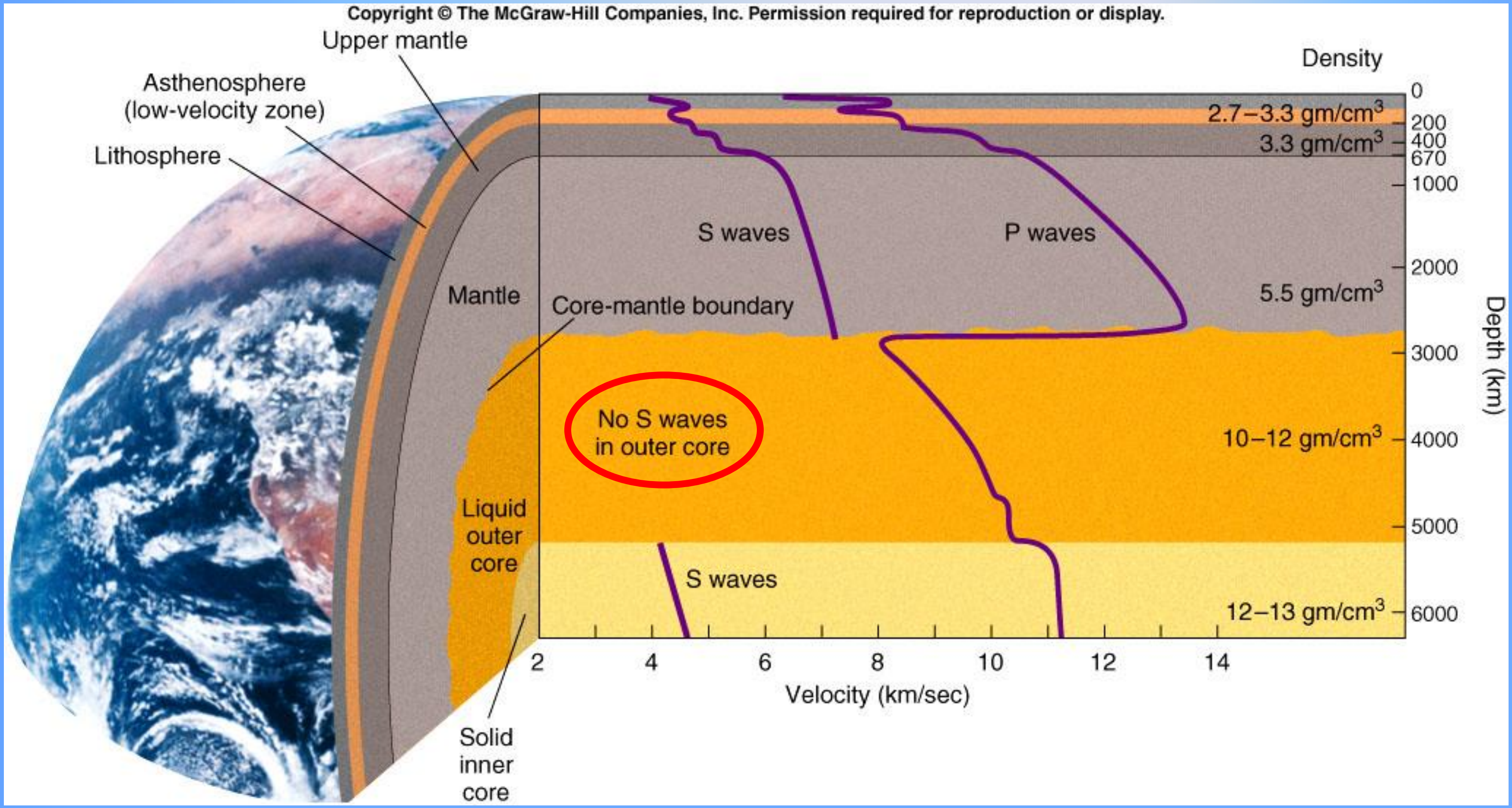
(2) Rearranged into denser and more compact crystals

Lithosphere and Upper Mantle

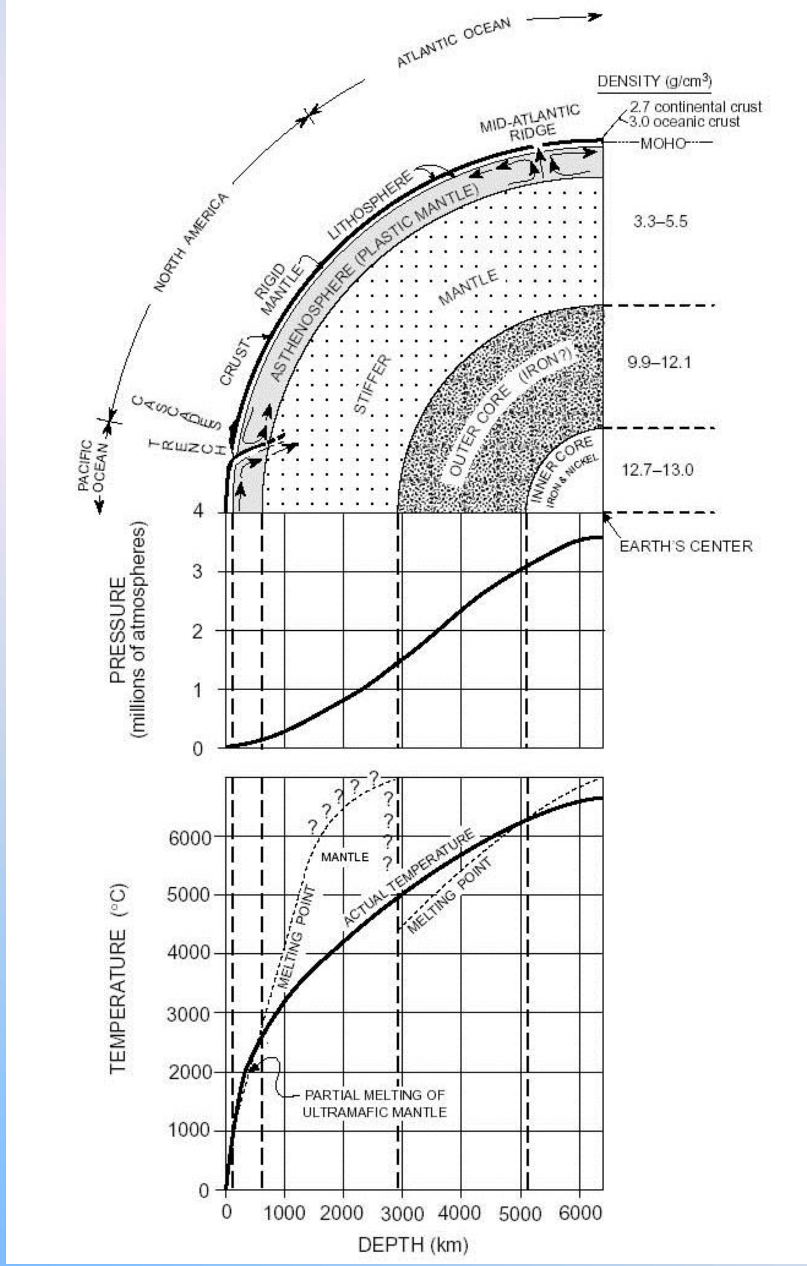


Earth's Concentric Shell Structure

Inferred from P- and P- Wave Velocity Variations



Inferred Properties of Earth's Interior



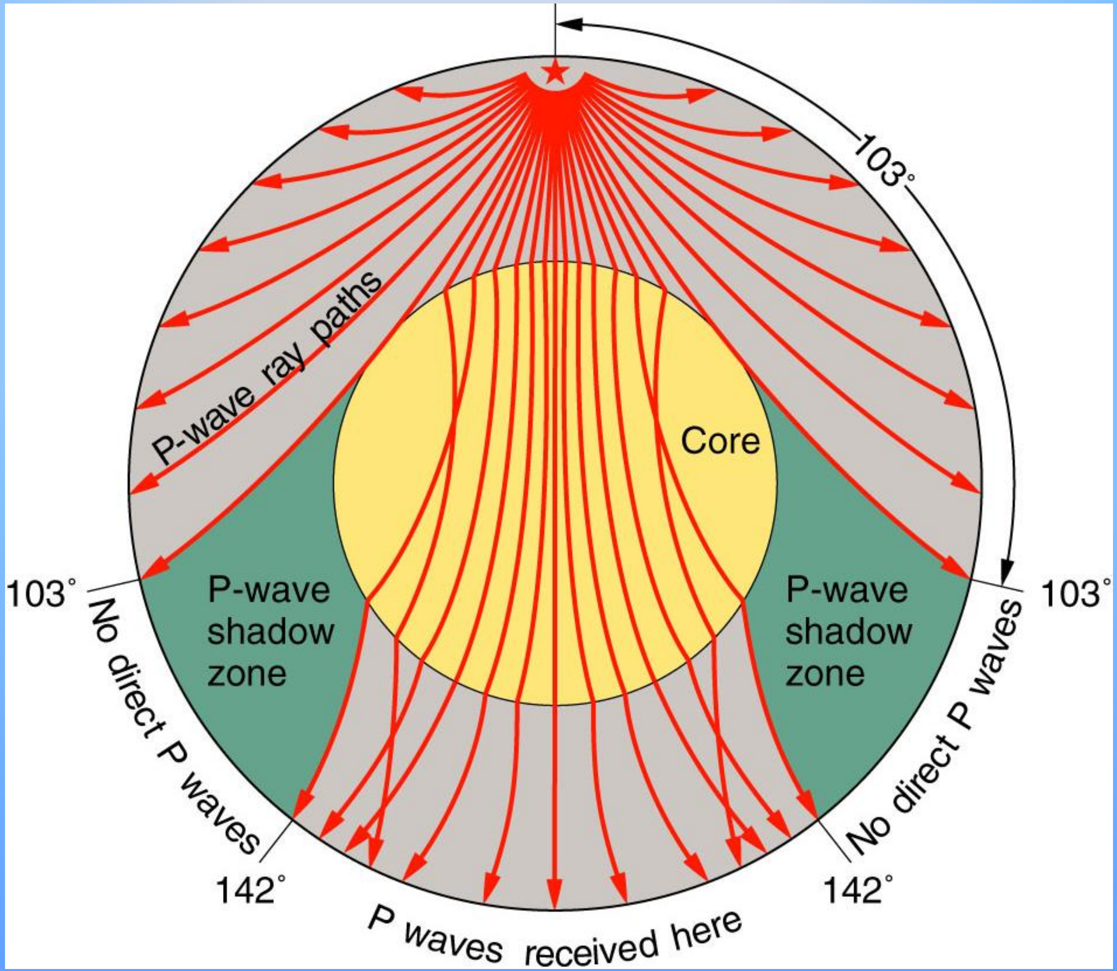
3. The Core

a. **Shadow** Zones:

Seismic Waves do not reach certain areas on the opposite side of Earth from a large Earthquake

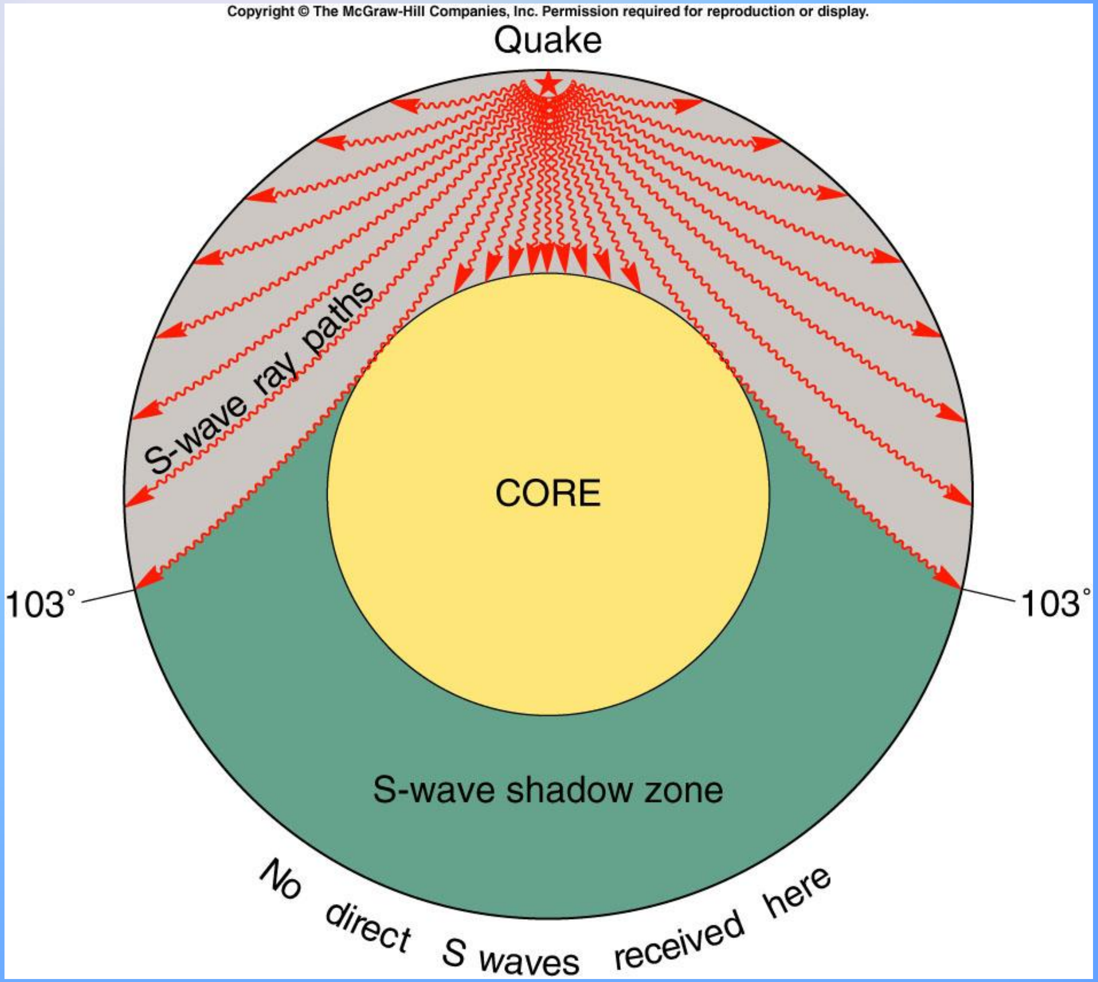
(1) P-Wave Shadow Zone

- Refraction of P-waves when they encounter the core boundary
- Size and shape of core can be determined because the paths of P-waves can be accurately determined.



(2) S-Wave Shadow Zone

- Larger than the P-wave shadow zone
- Direct S-Waves are not recorded in the entire region more than 103º from the epicenter
- Indicates that S-waves do not pass through the core at all



(3) Conclusions

(a) Infer that the core has **two** ______ parts

(b) Outer core is **liquid** ____________.

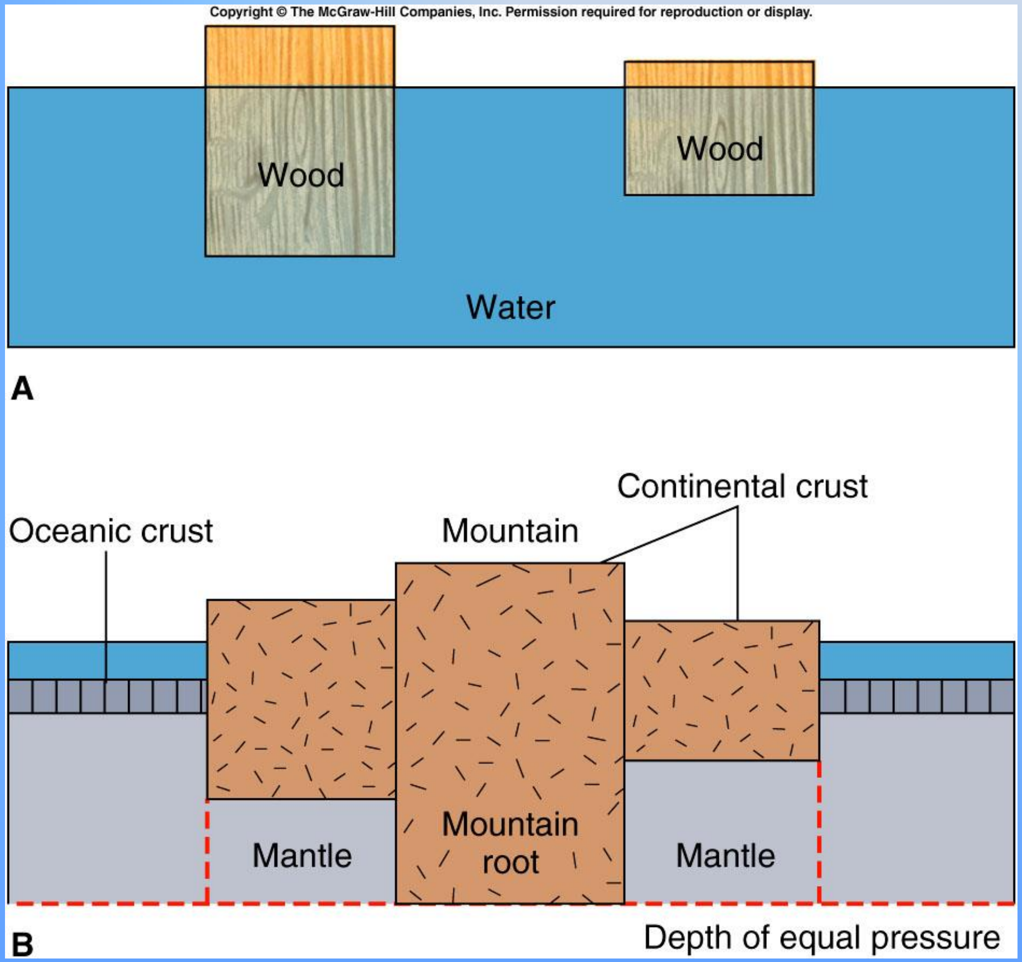
(c) Inner core is a **solid** __________ iron crystal

Composition of the Core

(1) Density is very high when averaged with crust and mantle
(2) Evidence for iron
- (a) Meteorites may represent basic material that created the solar system and 10% are composed of Fe and Ni (may represent the cores of fragmented planetismals and asteroids
- (b) Seismic and density data along with assumptions based on meteorite composition, point to a largely iron core
- (c) The presence of Earth’s magnetic field also suggests a metallic core.

Isostacy

A. Balance or ___**equilibrium**___ of adjacent rocks of brittle crust that float on the plastic mantle.



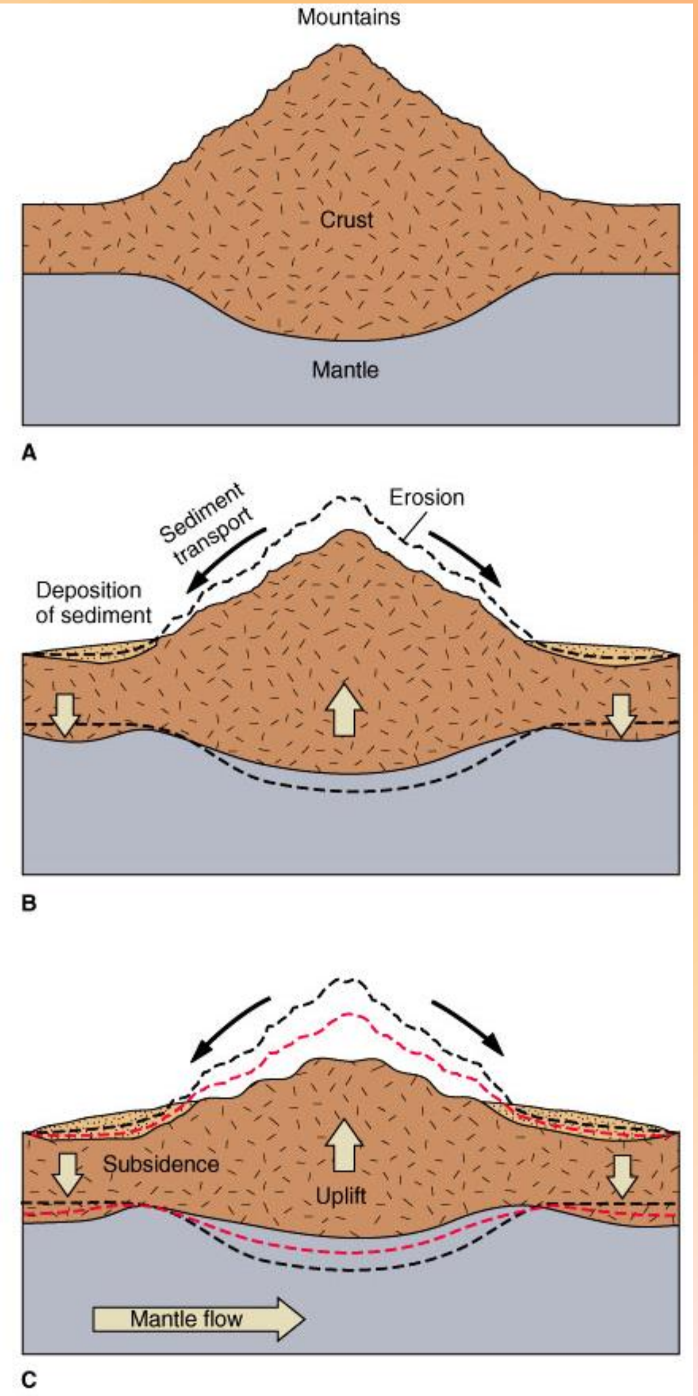
Wood blocks float in water with most of their mass submerged

Crustal blocks "float" on mantle in a similar way.

- **The thicker the block the deeper it extends into the mantle.**

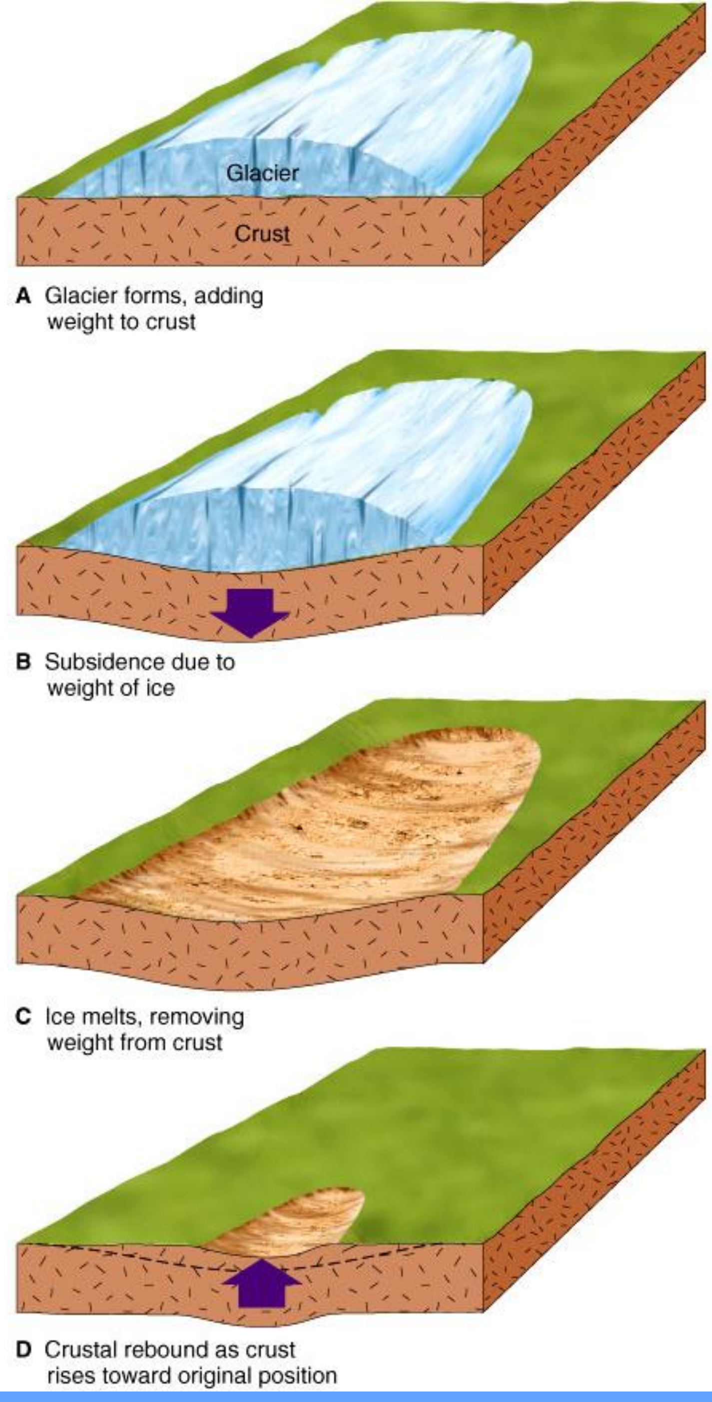
Isostatic Adjustment

A. Areas that lose mass __rise__.
B. Areas that gain mass __sink__.
C. Isostatic Adjustment
   1. __Vertical__ movement to reach equilibrium
   2. __Depth of Equal Pressure__: Depth where each column of rock is in balance with others.



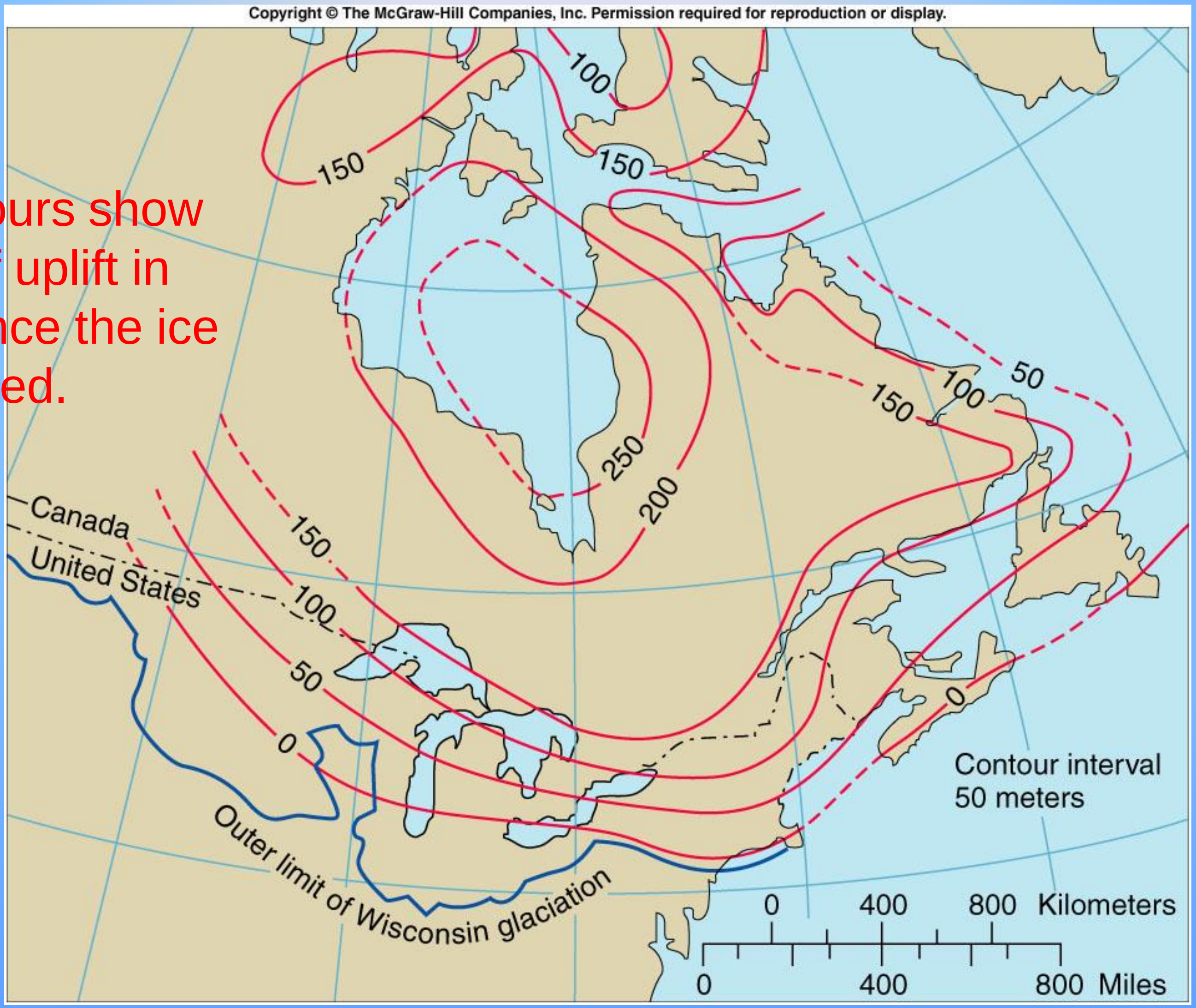
E. Crustal Rebound

1. Upward movements of the crust
2. Loss of huge mass of ice (glaciers) at the end of the Pleistocene Epoch

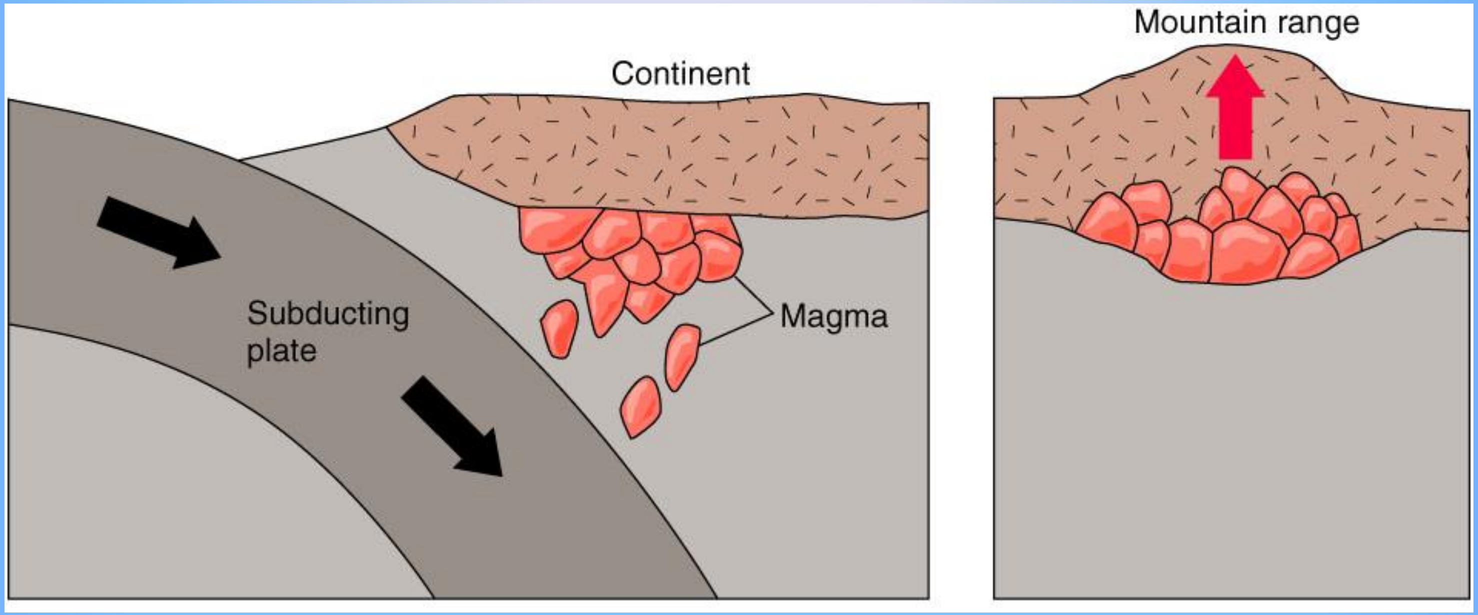


Crustal Rebound in Canada and the northern United States

Red contours show amount of uplift in meters since the ice disappeared.



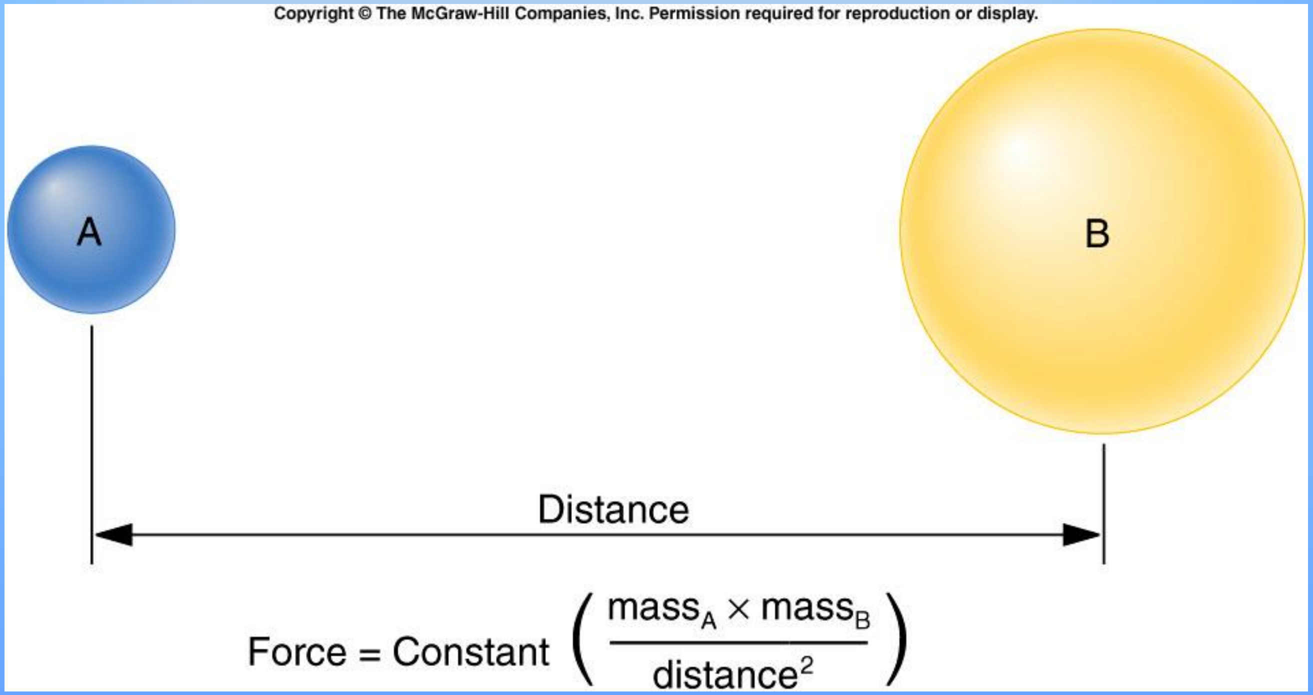
Isostatic Adjustment Due to the "Underplating" Theory



- Rising blobs of magma accumulate at a the base of a continent
- The continent becomes thicker due to *underplating*.
- The thickened continental crust causes it to be out of isostatic equilibrium, so it rises.

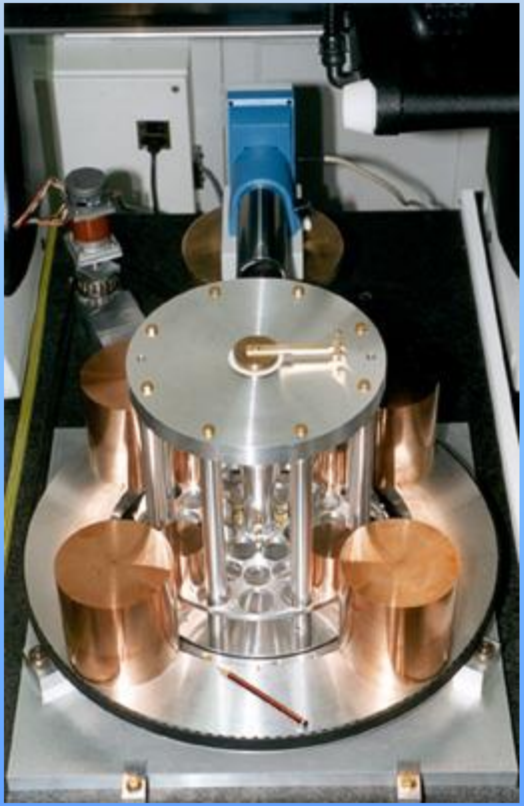
Gravity Measurements

A. Force of gravity is affected by the _**distance**_ between two masses and the masses of the two objects



B. Gravity Meter (Gravitometer)

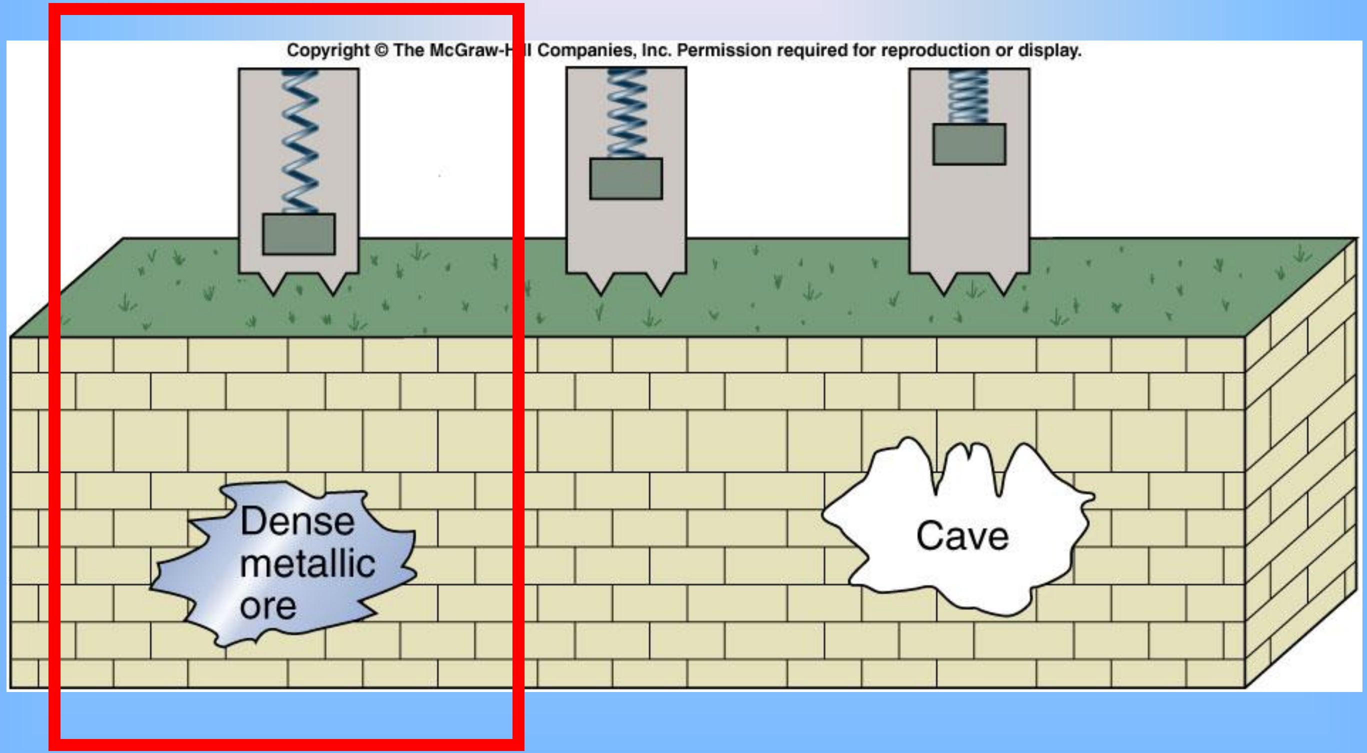
- Measures gravitational attraction between Earth at a specific location and mass within the instrument



C. Gravity is affected by

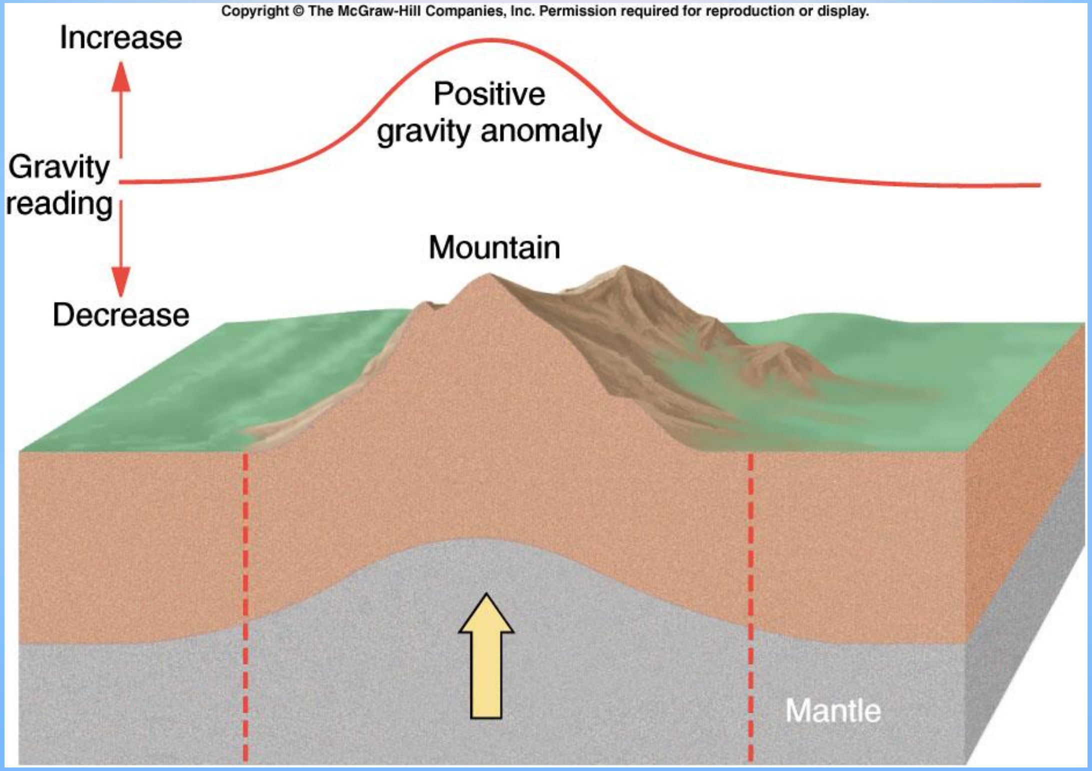
1. **Denser** rock underground (such as metallic ore deposits)
2. Degree of isostatic equilibrium of a region

D. Positive Gravity Anomaly



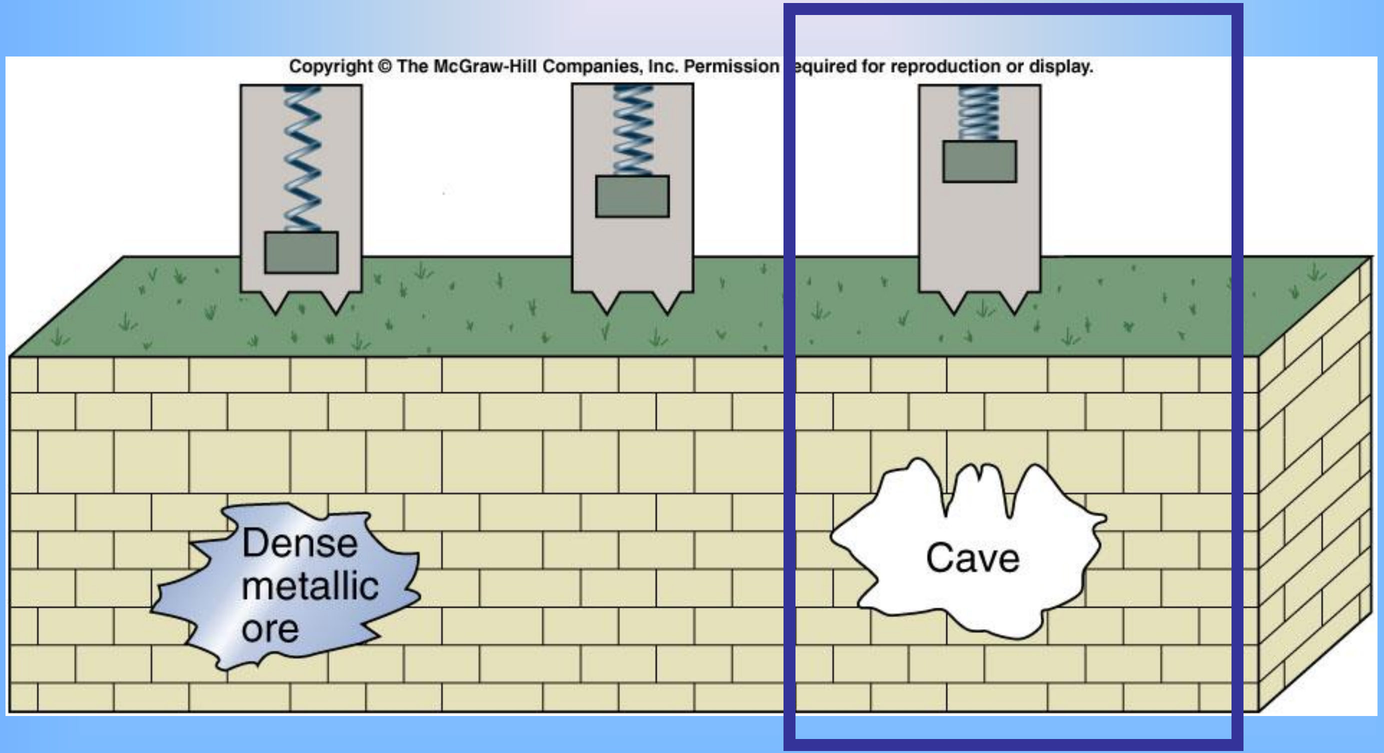
1. <u>Higher</u> than normal gravity measurements
2. Can indicate location of metallic subsurface ores and rocks

Positive Gravity Anomoly



- Uplift creates a mountain range without a mountain root.
- There is a thicker section of denser mantle rock under the mountain range.
- The central “column” has more mass.

E. Negative Gravity Anomaly

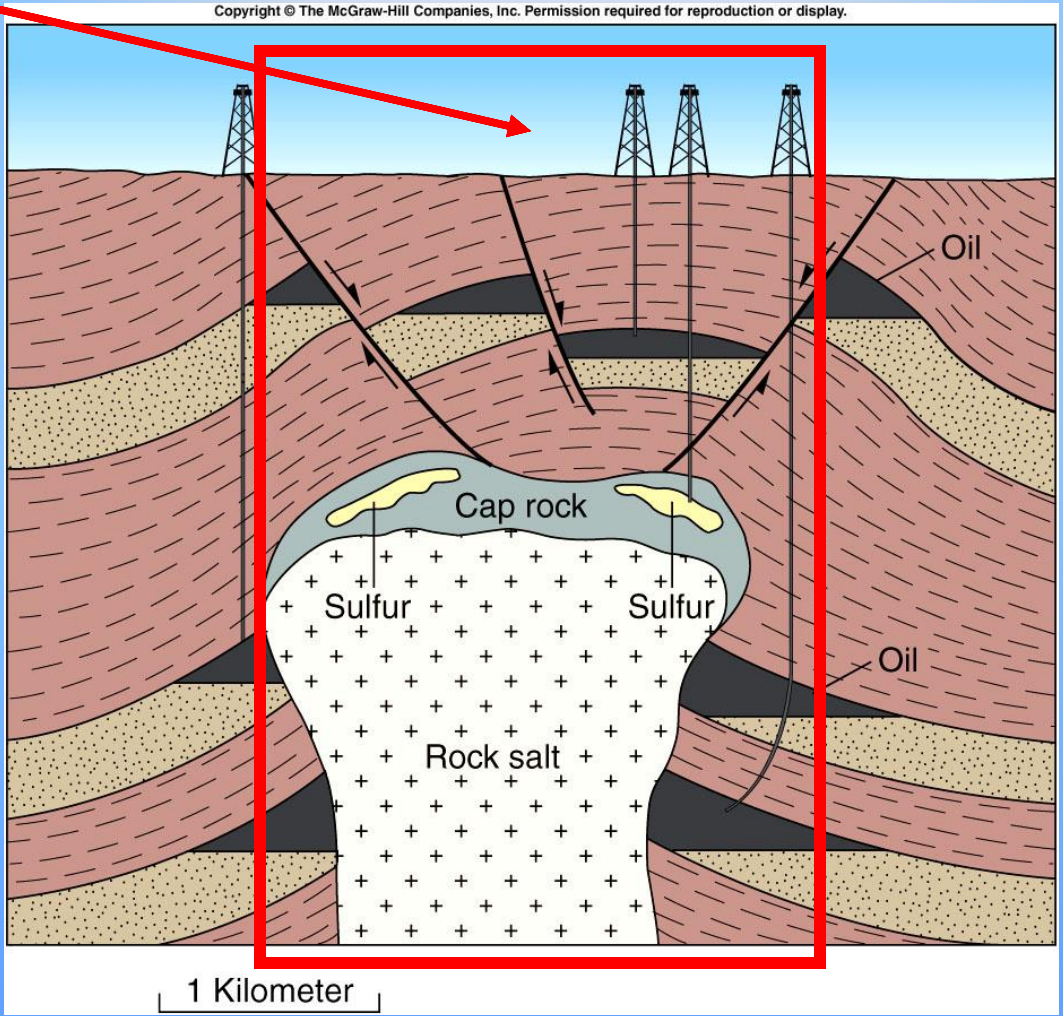


1. A region with ___**low**___ gravity measurements

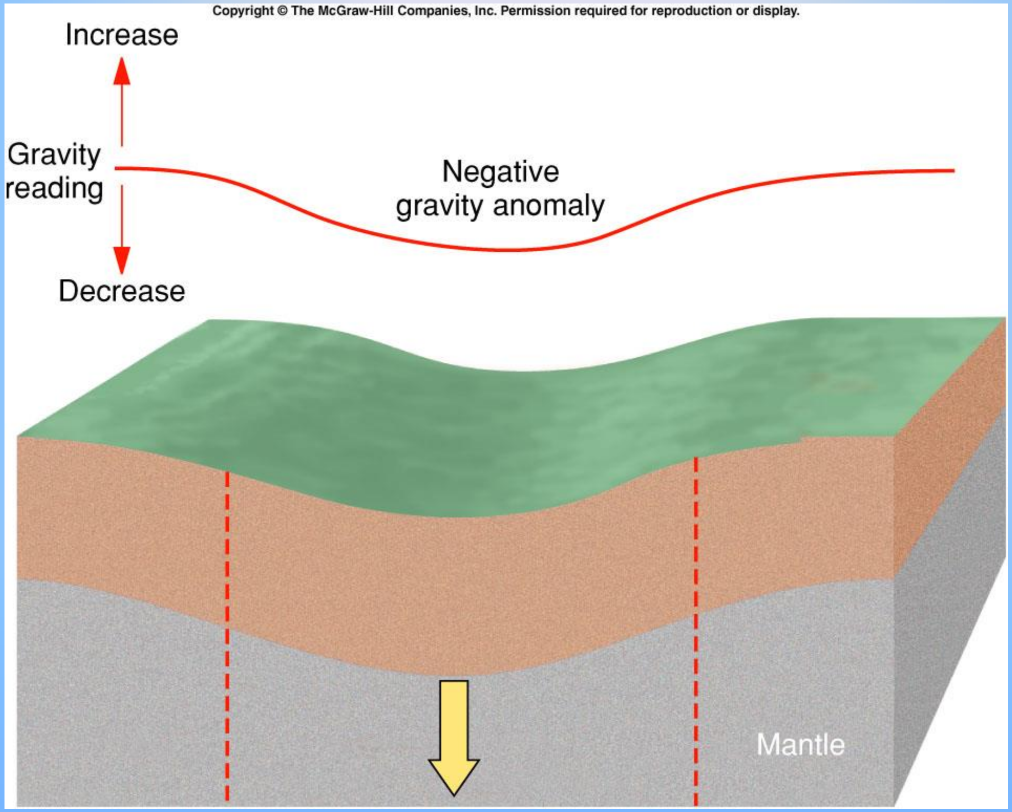
Salt Domes

Salt is less dense than the surrounding rocks

Negative Gravity Anomaly

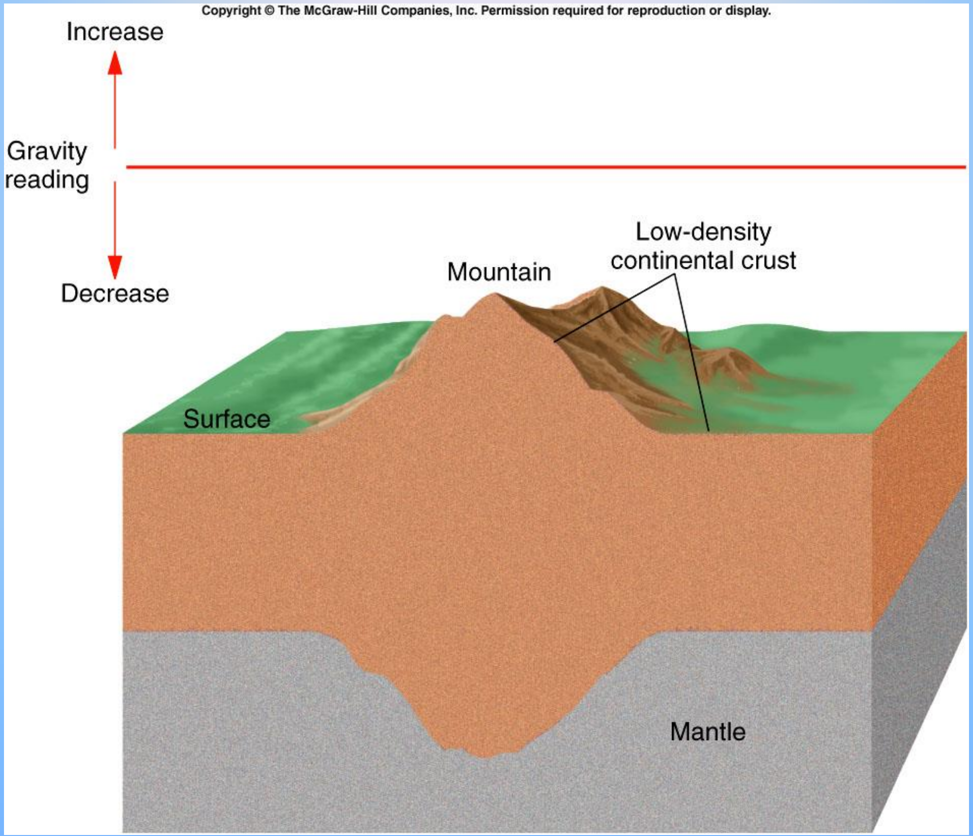


Negative Gravity Anomaly



- Regions with mass deficiencies
- Areas still experiencing isostatic rebound

F. Isostatic Balance

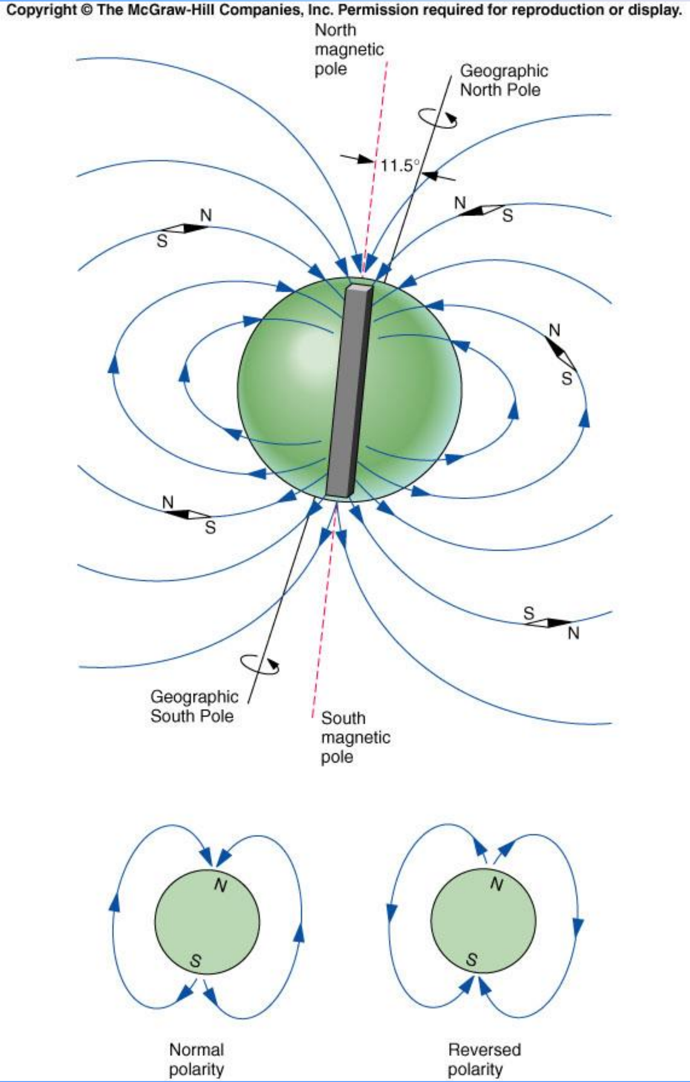


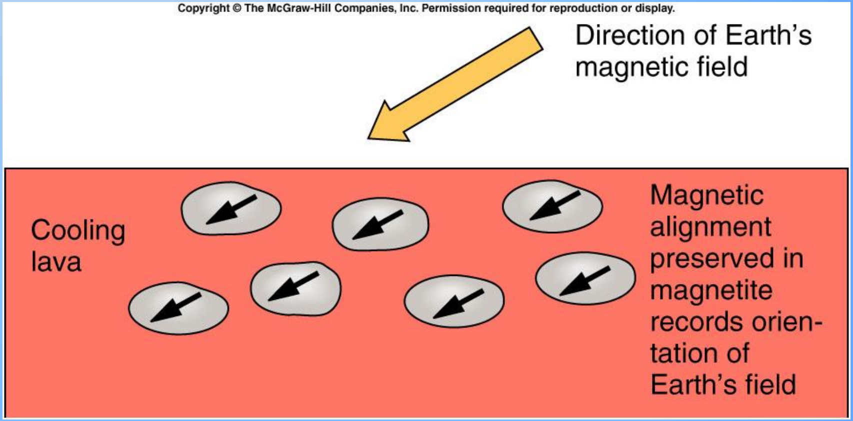
- Uniform gravity readings
- Corrections for differences in elevation

Earth's Magnetic Field

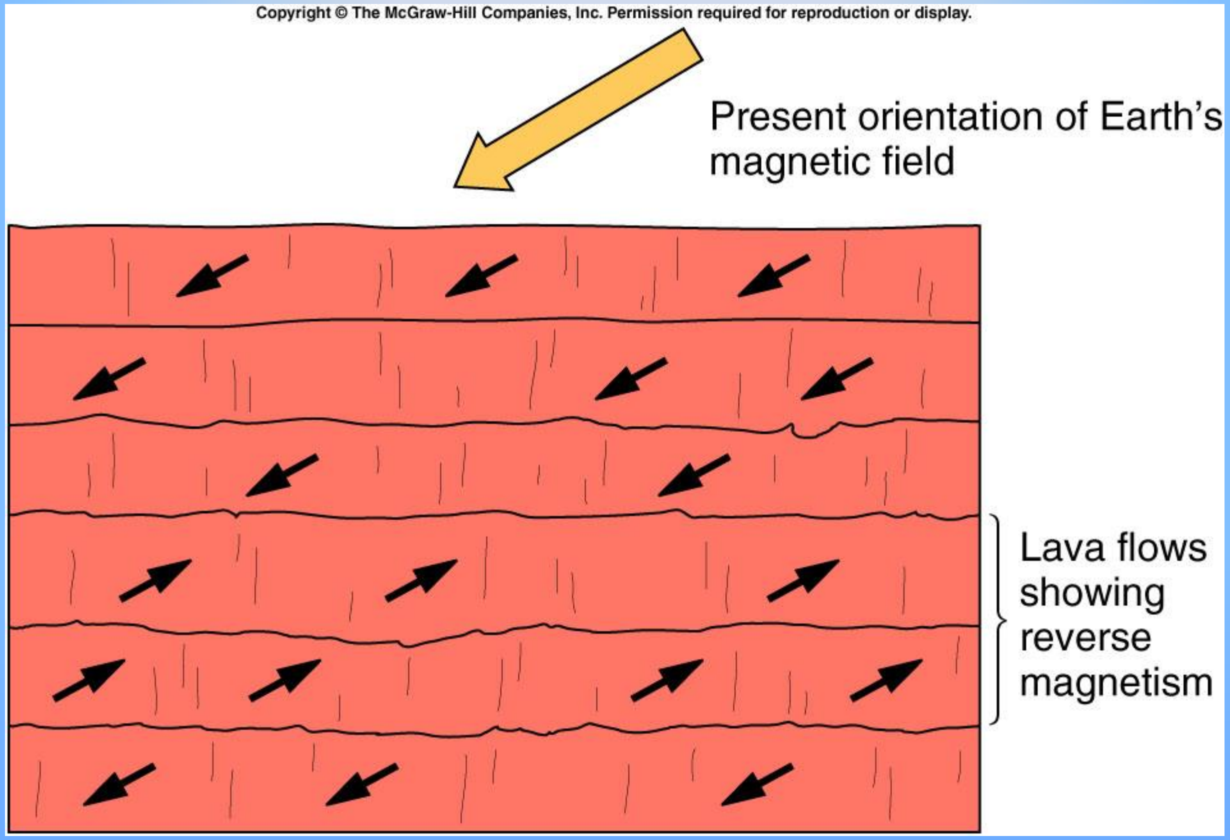
A. Believed to be generated in the __**outer**__ core.
   1. The hot liquid outer core flows and convecting metal creates electric currents.
   2. Current along with Earth's rotation create a magnetic field.

B. Magnetic Reversals: Evidence in sea-floor rocks





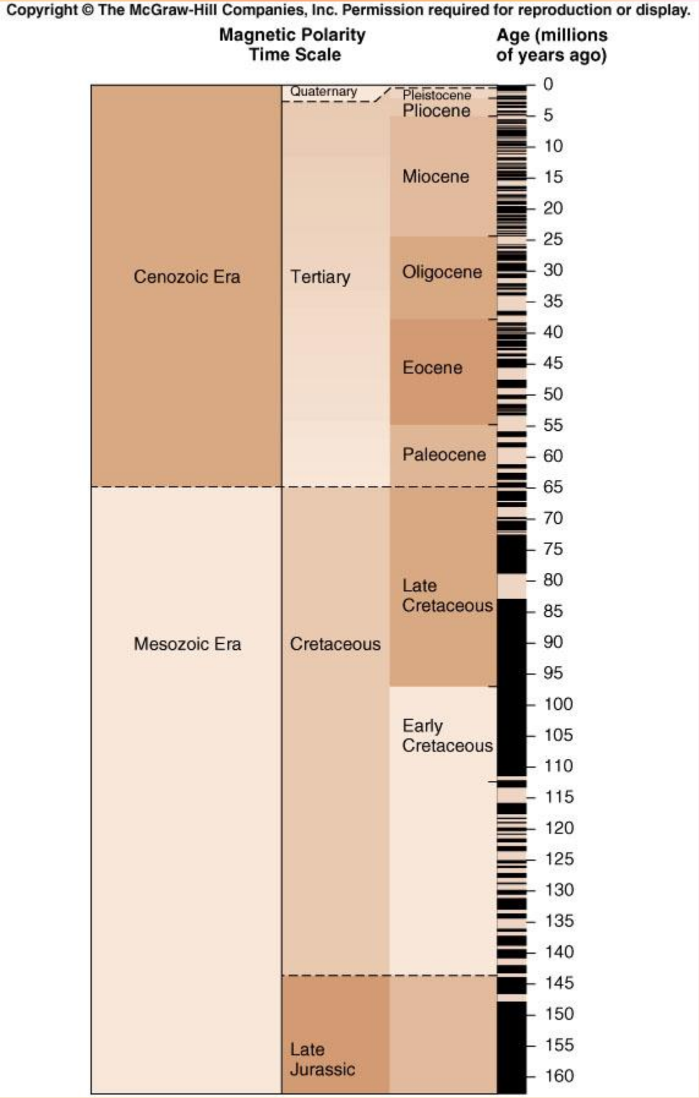
Evidence of Magnetic Reversals in Lava Flows



Worldwide Magnetic Polarity Time Scale (Mesozoic and Cenozoic Eras)

- Black indicates normal polarity

- Tan indicates reversed polarity



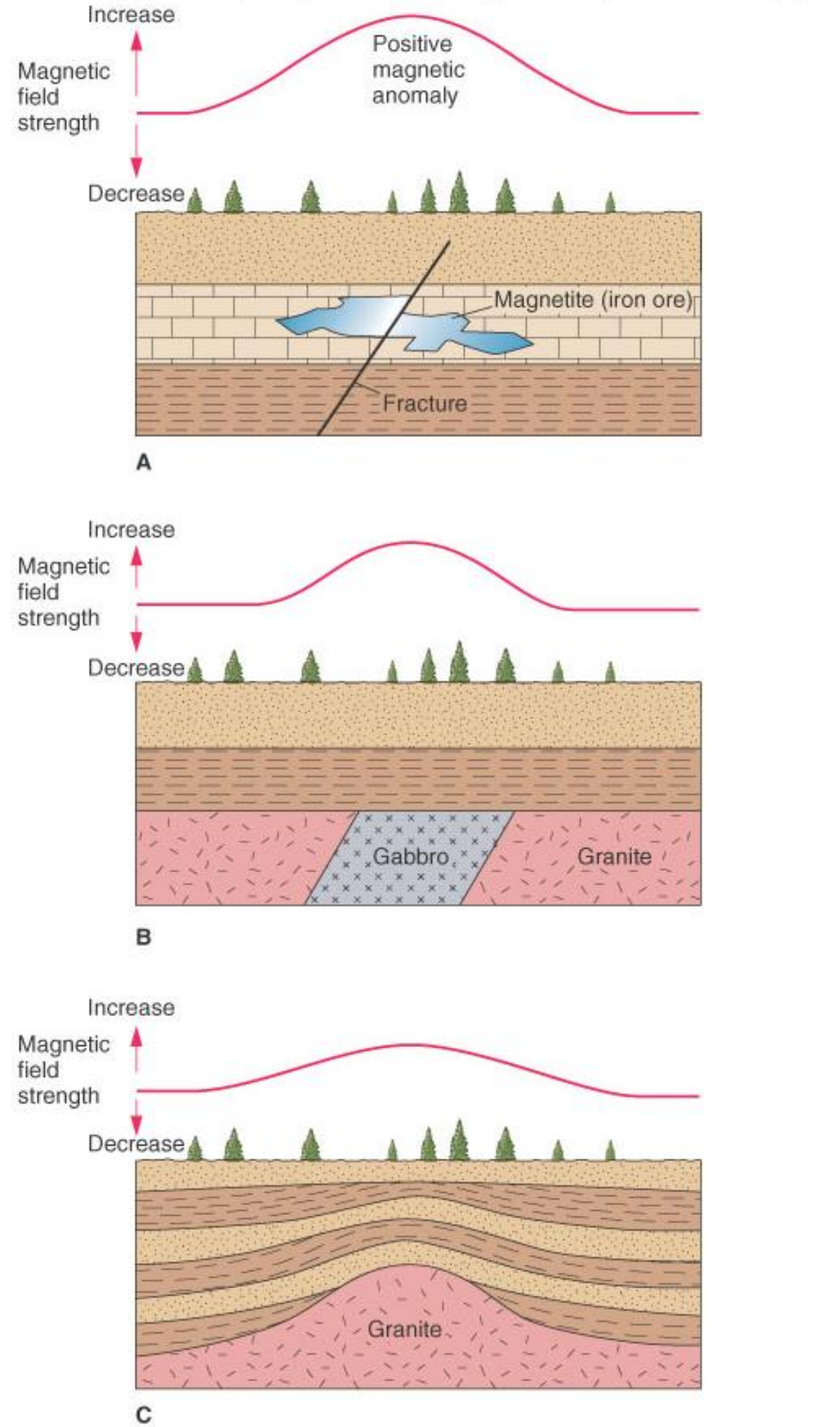
C. Magnetic Anomalies

1. Positive Magnetic Anomalies

a. Higher than normal.

b. Can be caused by

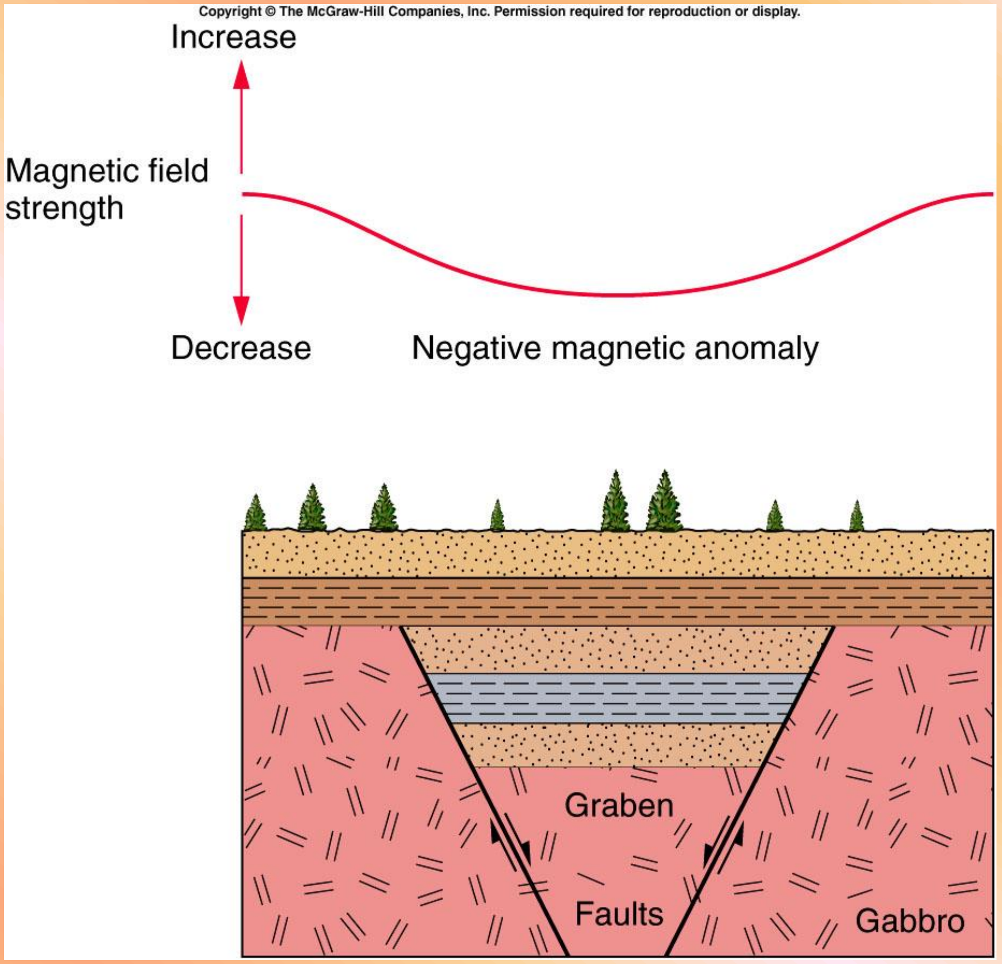
- concentration of magnetite ore
- concentration of denser minerals in mafic rocks
- Hidden geologic structures



2. Negative Magnetic Anomalies

a. Lower than normal

b. Can be caused by downdropped fault blocks



- The End

Earth's Heat Buoys Up Its Crust

New Information Published in 2008 (June 23rd *Journal of Geophysical Research*)

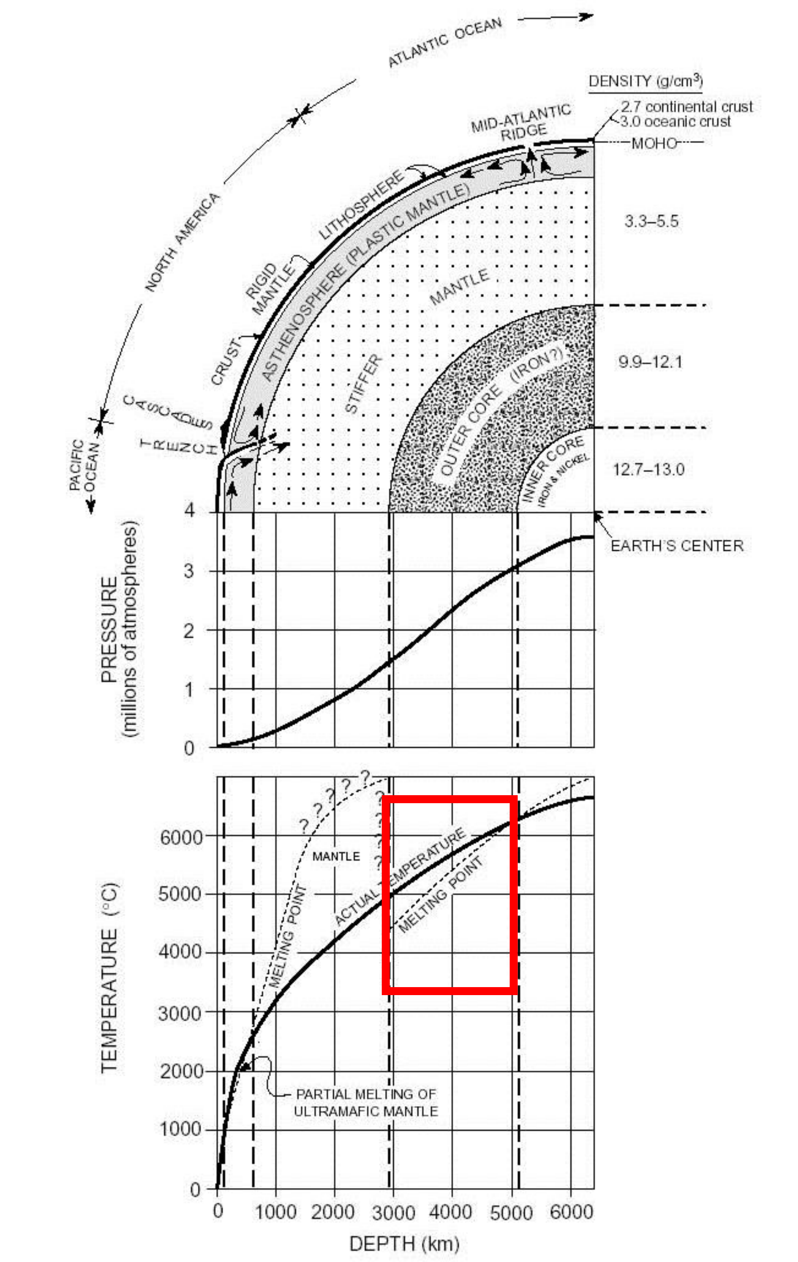
Denser Rock Beneath N. America Was Located Using Seismic Data

- Researchers
  - David Chapman, Geophysicist at the University of Utah
  - Derrick Hasterok, a graduate student at the university
- Compared seismic results with known densities of various rocks
  - Determined crustal density at a location
- After correcting for this variability in density, they determined how much of an impact temperature has on elevation

Heat Alone Accounts for Half of the Elevation of Most Parts of N. America

- If the crust beneath cities such as New York and Los Angeles cooled to an average of 400^{o} C (about 750^{o} F)
  - The same temperature as the continent's oldest crust
- These areas would sink

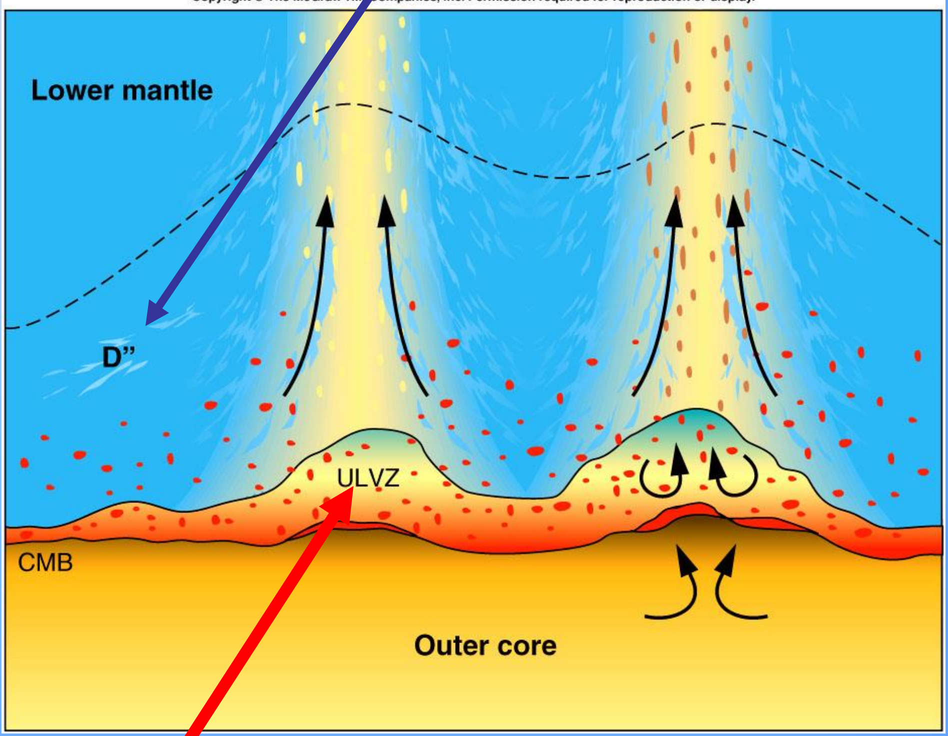
Inferred Properties of Earth's Interior



The Core-Mantle Boundary

- Great changes in seismic velocity
- ULVZ may be due to hot core that partially melts overlying rock
- Less dense silicate “sediment”
  - Iron silicates formed from reaction of lighter iron alloys in the liquid outer core reacting with silicates in the lower mantle
  - Collects in uneven layers and is squeezed out of pore spaces
  - Forms an electrically conductive layer and explains the low seismic velocities
- Both the mantle and core undergo convection.

- **Transition Zone up 200 km thick**
- **Decrease in P-wave velocities**



Ultralow-Velocity Zone

A Faster Rotating Core

- Seismic waves indicate the core rotates 1º/year faster
- Solid line - Shows position of a point in the core relative to Earth's surface
- Dashed line – Shows where the point was in 1900