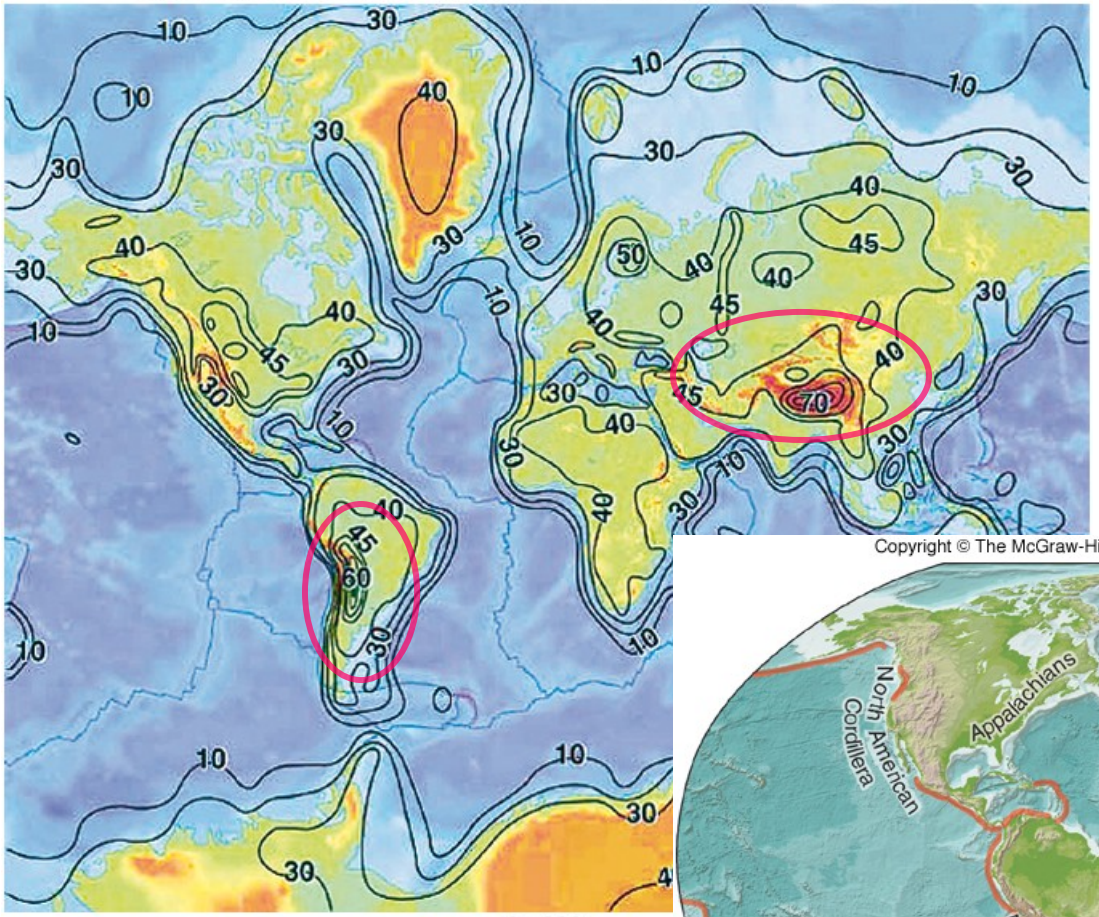
Chapter 6: Mountains

1. Mountains: Why are They There?
2. The Rise and Fall of Mountains and Temperatures

Mountains: Why Are They There?



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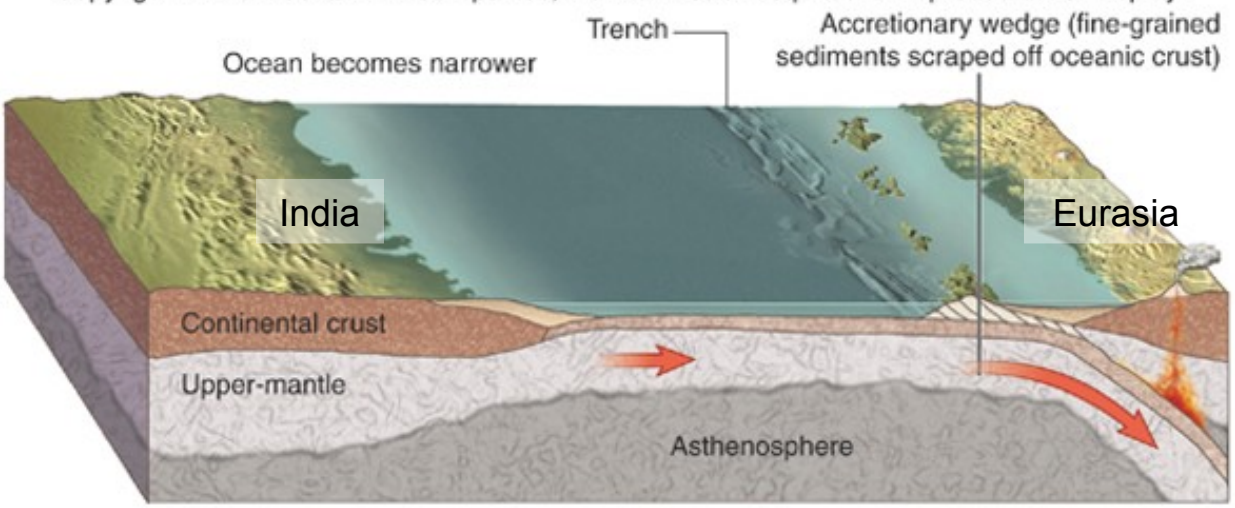
- Thickest crust found below mountains along convergent plate boundaries
  - Himalayas, 70 km thick
  - Andes, up to 60 km thick
  - “normal” crust 40 km thick

Himalayas - thickest continental crust and tallest mountains

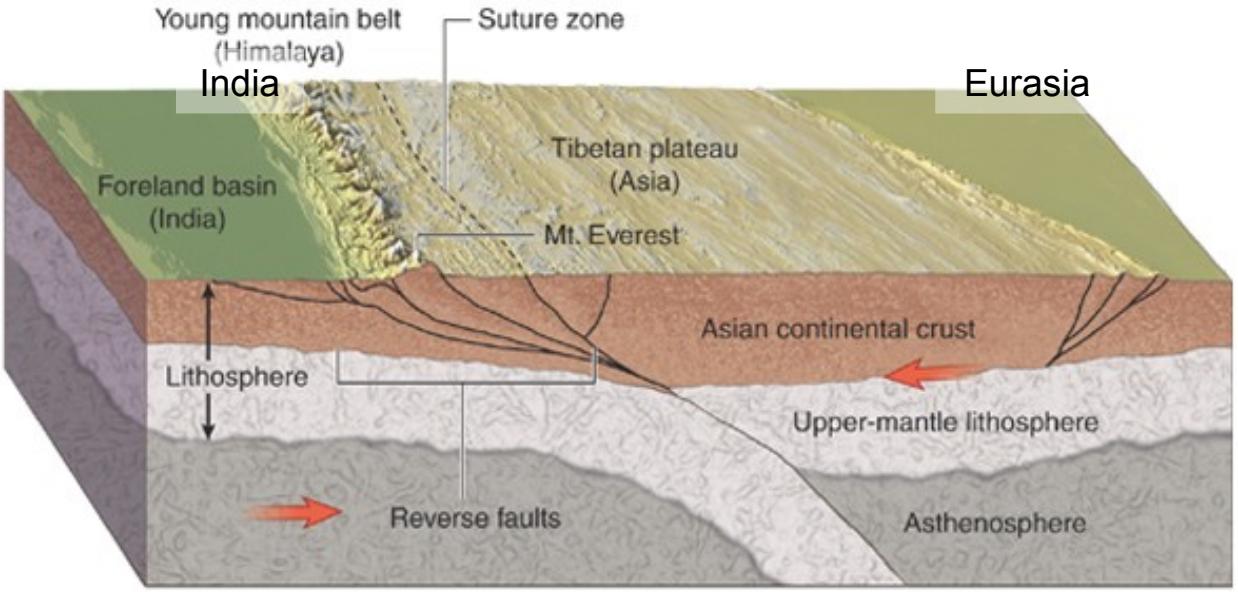
Mountains: Why Are They There?

- Higher, younger mountains along present convergent boundaries (e.g., Himalayas)
- Lower, older mountain belts represent ancient convergent boundaries (e.g., Appalachians)

Mountains: Why Are They There?



a. Ocean-continent convergence

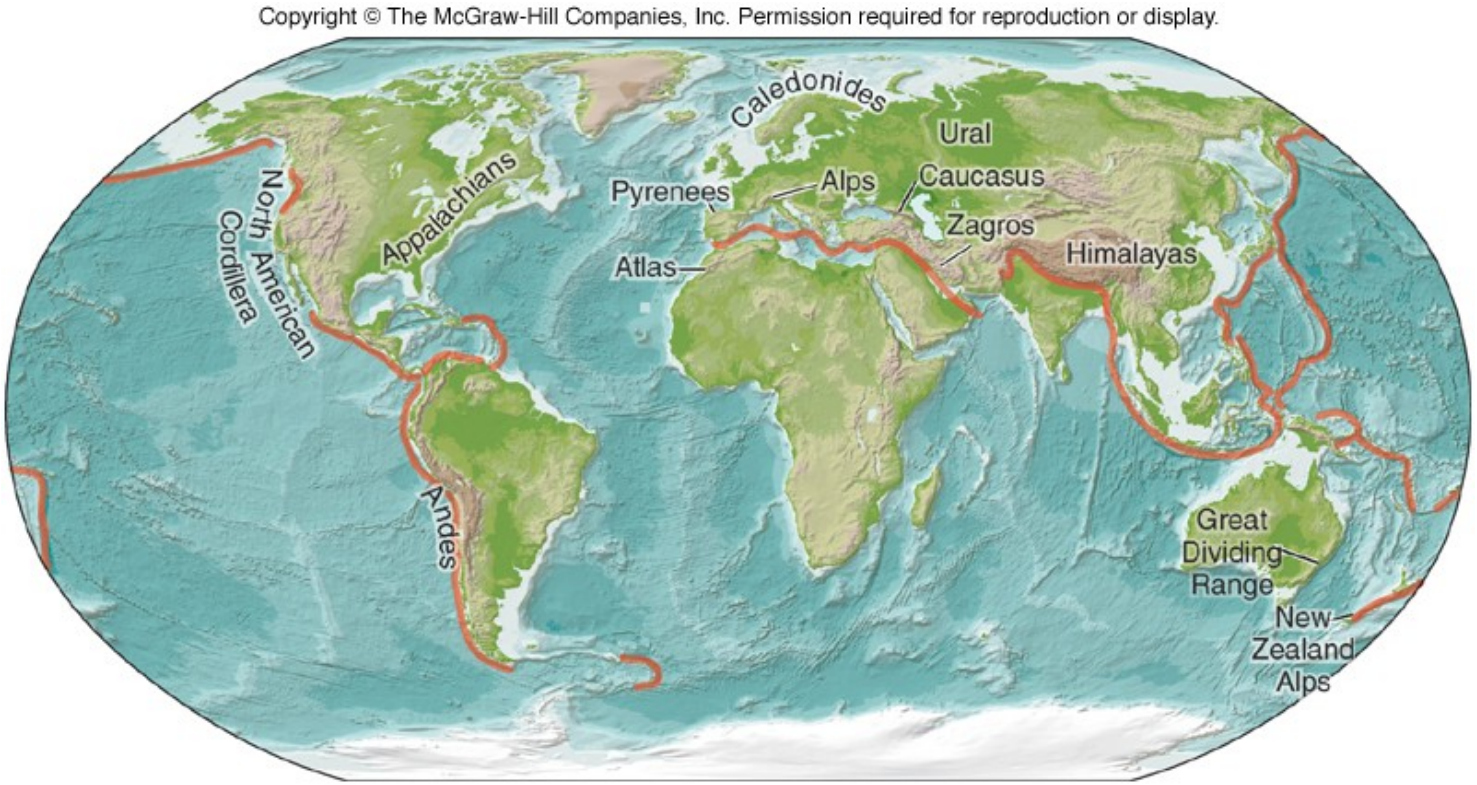


b. Continent-continent collision

- Reverse faults (result of earthquakes) stack up and thicken the crust along convergent plate boundaries
  - Additional thickening of crust where the northern margin of Indian continental crust wedged below southern margin of Eurasia

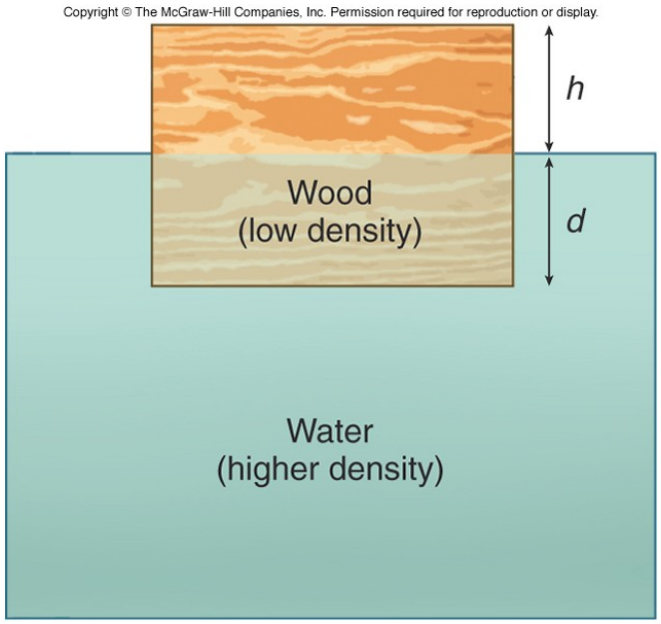
Mountains: Why Are They There?

Crust is ~30 km thicker under the Himalayas. Why are the Himalayas not 30 km higher than the rest of the continents?



The elevation of mountains above sea level is tied to ***density*** *and* ***isostasy****.*

Mountains: Why Are They There?



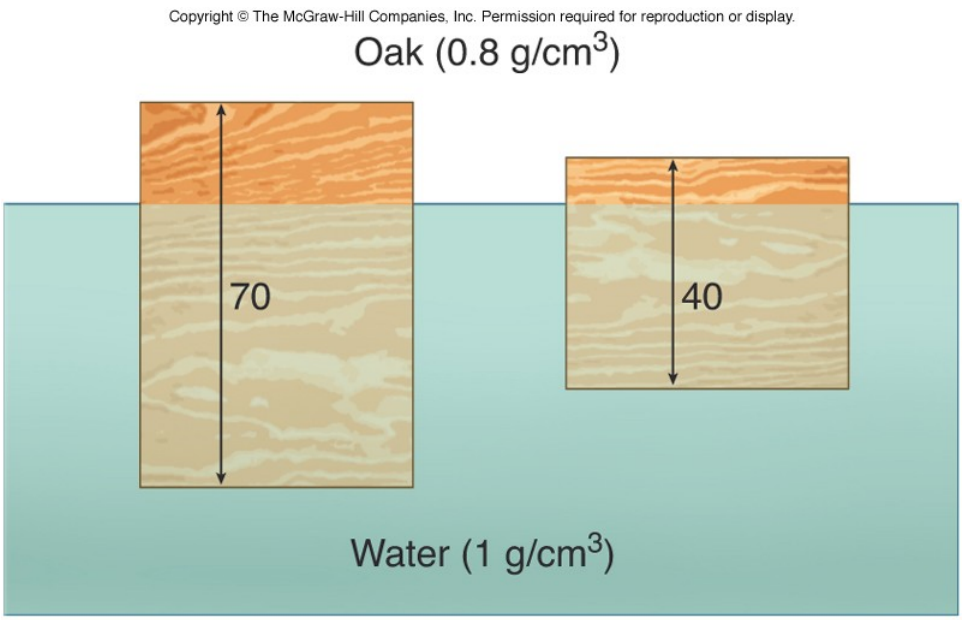
What would happen if we used a block of oak with a density that is 80% that of water?

Density = mass per unit volume

- Density of water = 1 g/cm^3
- Density of pine wood = 0.5 g/cm^3

- Wood floats because it is less dense than water
  - Density of pine is half (50%) the density of water
  - Half of the pine block lies below the water surface

Mountains: Why Are They There?



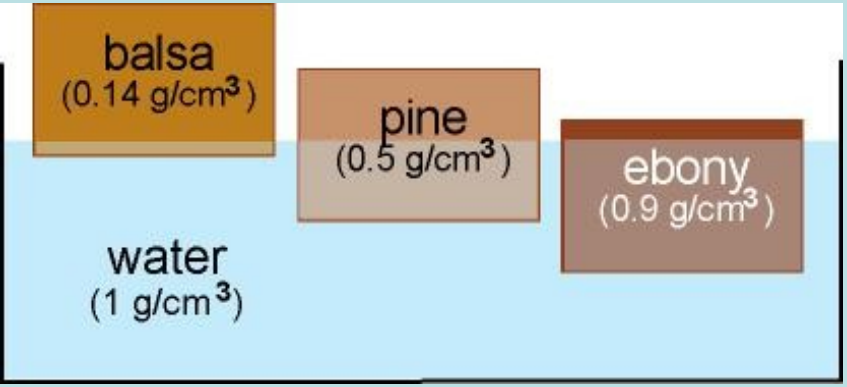
a.

- Density of oak is 80% density of water
  - 80% of oak blocks lie below the surface
  - Smaller blocks don't float as high but don't extend as far below surface
  - Much of the difference in the size of the blocks is in the submerged "root"

Volcanoes and Other Mountains Checkpoint 6.23

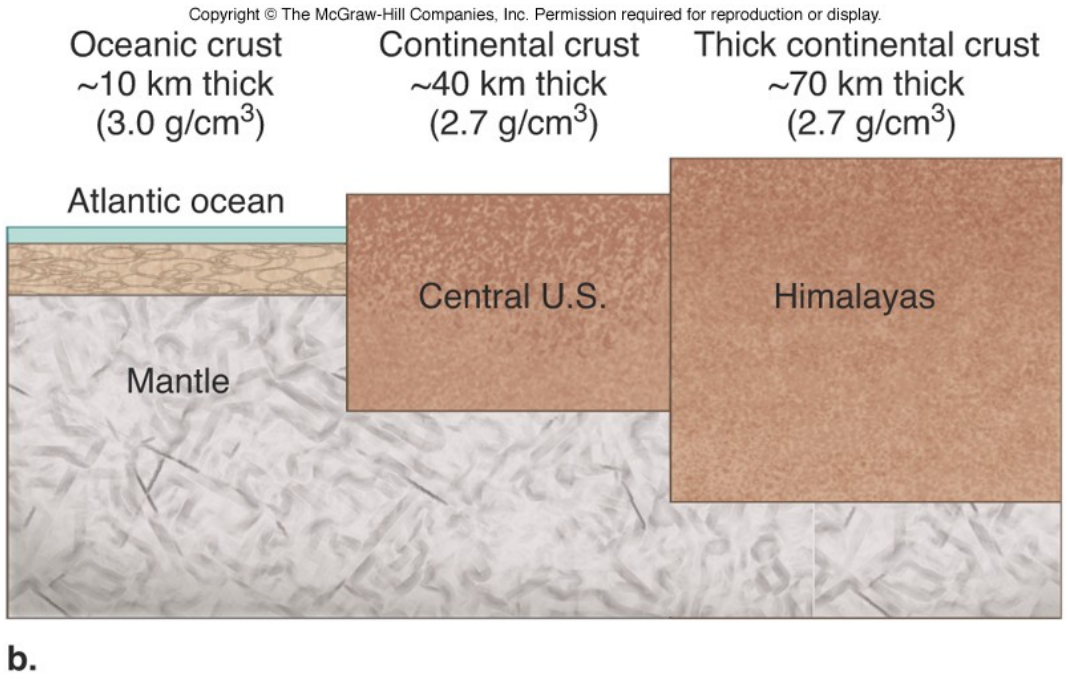
Different types of wood have different densities. The density of pine is 0.5 g/cm^3. Ebony density is higher at 0.9 g/cm^3. Balsa wood density is lower at 0.14 g/cm^3. All would float in water but with different proportions of each block lying above and below the surface.

1. Draw a diagram to show how equal-sized blocks of each type of wood would float on water.
2. What would happen to the blocks if we replaced the water with a liquid with higher density like corn syrup?



if the liquid is denser, the blocks will not sink as far because they only displace an amount of fluid equal to the weight of the block itself. -- Buoyancy (Archimedes Principle)

Mountains: Why Are They There?

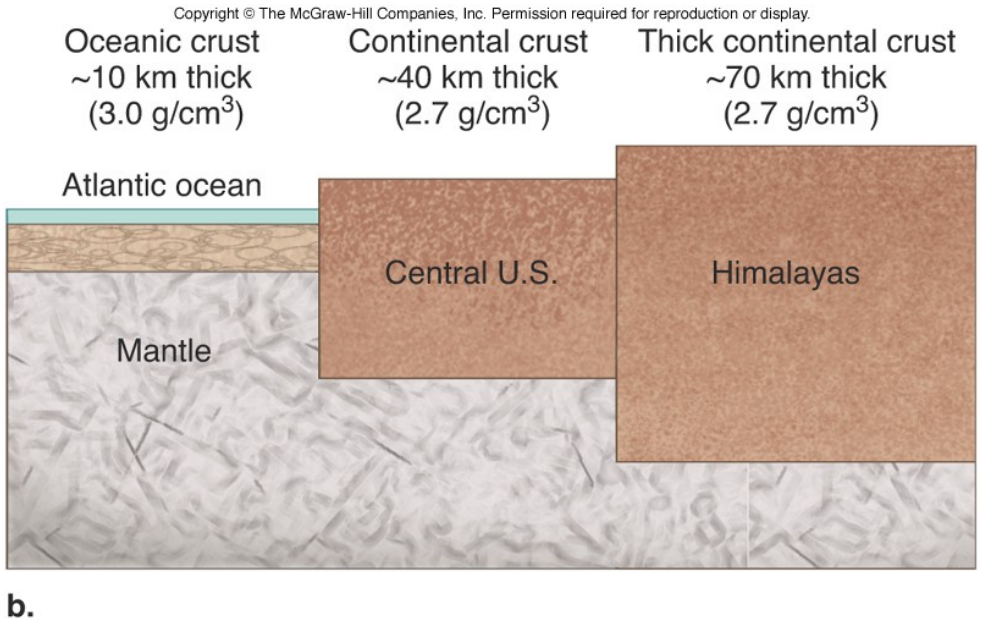


b.

Oceanic crust is thinner than continental crust because it is has higher density.

- Density of continental crust is 80% density of mantle
  - Thicker continental crust rises higher but also extends farther below the surface
  - Much of the difference in the thickness of the continental crust is in the crustal “root”
  - Similar to needing a deeper foundation for taller buildings

Mountains: Why Are They There?



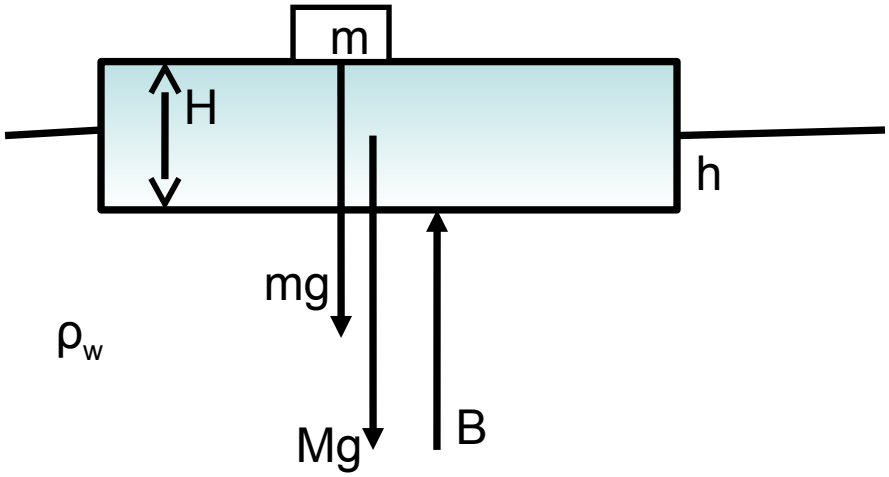
b.

- Elevation of mountains depends on
  - Thickness of crust
  - Density contrast with underlying mantle
- **Isostasy** – balance between topography of Earth's surface and thickness and density of underlying rocks
  - Higher mountains with thicker or less dense rocks

Go to the next section: ***The Rise and Fall of Mountains and Temperatures***

Buoyancy – Partially submerged object

A raft with density ρ_R, bottom area A and thickness H is on partially floats on water with density ρ_W when it is loaded with a mass m. What thickness h of the raft is under water?



$$B = Mg + mg$$

$$\rho_w gAh = \rho_R gAH + mg$$

$$h = (\rho_R/\rho_w)H + m/\rho_w A$$

An iceberg (ρ_{ice}) floats on sea water (ρ_{sw}). What thickness is below the surface?

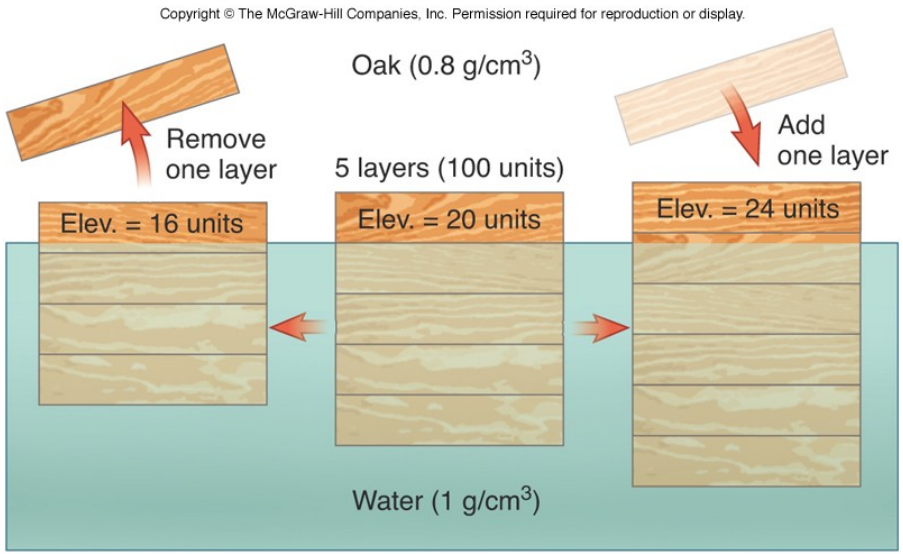
$$\frac{h}{H-h} = \frac{\rho_{ice}}{\rho_{sw}} \sim 90\%$$

Ratio below / above

The Rise and Fall of Mountains and Temperatures

- Changes in elevation depends on the relative density of crust and mantle (depth of root)

The height of wood blocks and continents will decrease (float lower) as mass is removed



The height of wood blocks and continents will increase (float higher) as mass is added

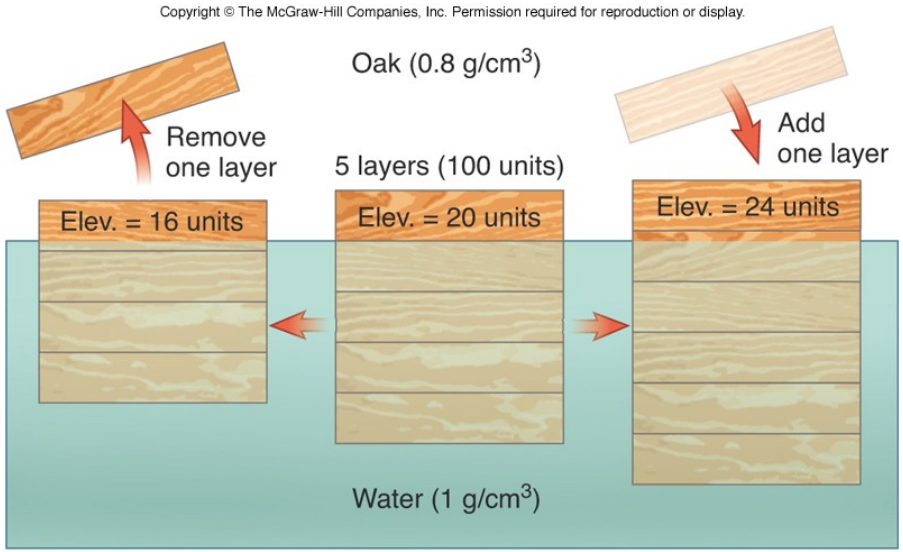
Elevation only changes by 20% of added/removed material

Most changes occur in “crustal root” below the surface

The Rise and Fall of Mountains and Temperatures

Elevation only changes by 20% of added/removed material

Most changes occur in “crustal root” below the surface



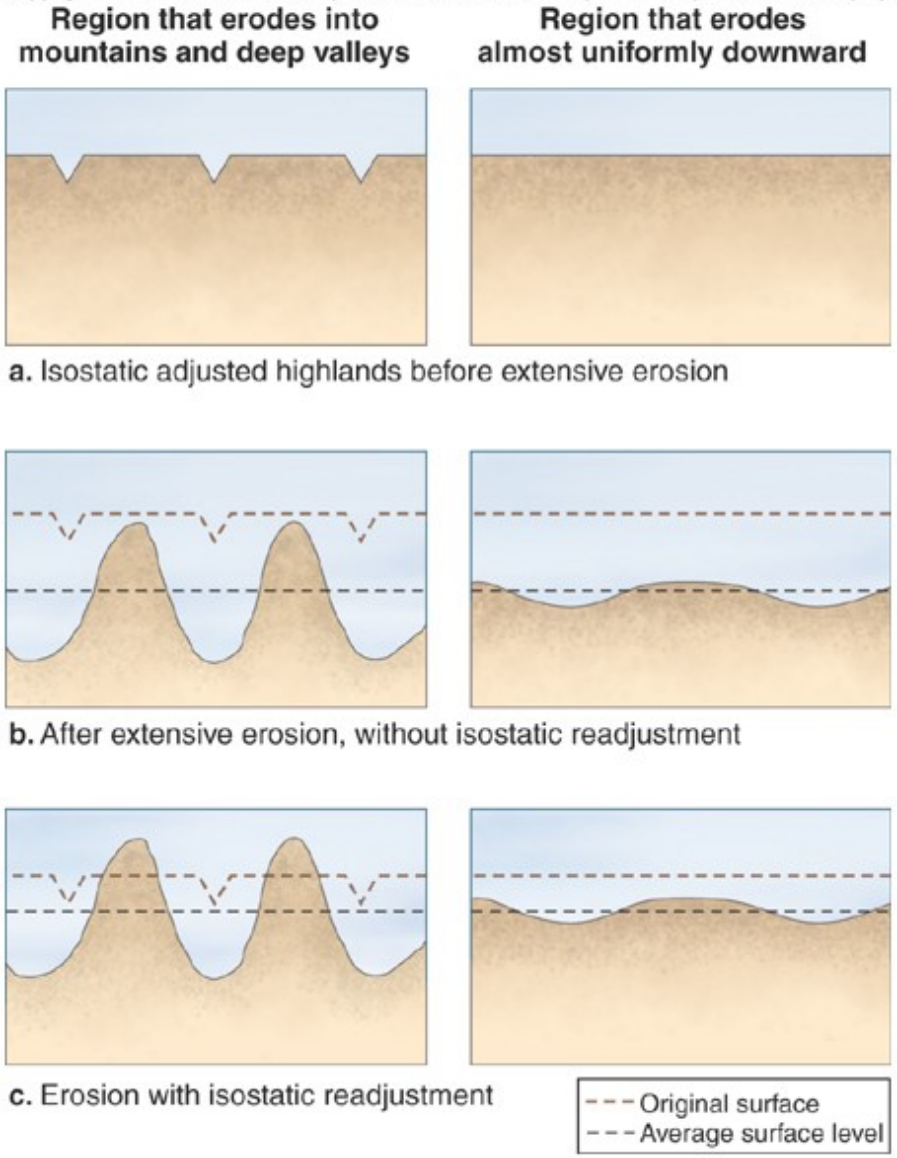
- **Isostasy** compensates for added material by building a bigger root or for lost material by raising the pile

Volcanoes and Other Mountains Conceptest

How would the elevations of mountains differ if Earth's crust was composed of denser rocks? Mountains would be

A. Higher
B. Lower (Root deeper and elevation above Earth's surface lower)
A. Unchanged in elevation

The Rise and Fall of Mountains and Temperatures



- For every 1,000 meters of rock eroded from mountains, isostasy results in just ~200 meters decrease in elevation
  - 800 meters of change accommodated by raising the crustal root
  - Evenly distributed erosion causes uniform lowering of mountains
  - Erosion concentrated in valleys, can cause peaks to become higher

The Rise and Fall of Mountains and Temperatures

- Mountains are long-lived features on Earth
  - Approximate erosion rates → 0.1-0.2 mm/year
  - Rate depends of rock types, climate, other factors
  - 5-10 Myrs to erode 1 km of rock
  - But isostasy will replace 80% of this erosion
  - 200 meter change in elevation every 5-10 Myrs
  - 25-50 Myrs to lower mountains by 1 km
- Mountains ranges will persist on the landscape for hundreds of millions of years

The Rise and Fall of Mountains and Temperatures

- Mountains are long-lived features on Earth
  - Still forming Himalayas began to form ~50 Myrs ago
  - Lower Appalachian Mountains formed ~300 Myrs ago

Volcanoes and Other Mountains Checkpoint 6.26

Use the information from this section to explain:

1. Why are the ten tallest U.S. peaks all in Alaska?

   relation between active subduction zone (convergent plate boundary), erosion and isostasy

2. Why are the Rocky Mountains taller than the Appalachian Mountains?

   Appalachians older than Rockies, more erosion

3. Why we can drive across former mountains in Canada without rising in elevation?

   over 1 billion years old, former mountains eroded to root

The Rise and Fall of Mountains and Temperatures

- Erosion of the Himalayan Mountains
  - Warm, moist air from Indian Ocean rises over Himalayas to form monsoon rains
  - Rain feed rivers that erode mountains
  - Sediment deposited in Bay of Bengal and Arabian Sea

The Rise and Fall of Mountains and Temperatures

- Mountains influence climate patterns
  - Monsoon rains strip carbon dioxide from atmosphere
  - Removal of CO_2 has been going on for 20 Myrs
  - Reduction of this greenhouse gas has lowered global average temperatures by ~5°C
  - Adding CO2 raises global average temperatures (more later)

The End