Online Exercise: Isostasy

Starting Point:

Note: These first two questions could be topics for discussion/chat for a couple of days that would then lead to the exercise that follows.

A. In your own words, can you explain the principle of isostasy? Please keep your answer simple without reference to the specifics of Airy or Pratt isostasy.

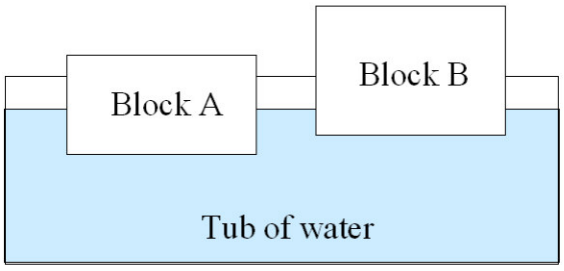
Example answer: Isostasy describe the state of equilibrium of Earth's crust pushing down (gravitational force), while the mantle is pushing up (buoyancy force). When gravity and buoyancy balance, the continental crust floats on the mantle, much like an iceberg in ocean water.

B. Use the principle of isostasy to explain why continental crust underlies areas of higher elevation than oceanic crust?

Example answer: Both crust types are in isostatic equilibrium with the mantle. Ice floats in water because ice is less dense than the water. This analogy can be used with crust type too. Both continental and oceanic crusts are less dense than the mantle, so both float in the mantle. Continental crust floats higher in the mantle than oceanic crust because continental crust is both less dense and thicker than oceanic crust. Because continental crust is thicker, it also sticks up more and down more in the mantle to get equilibrium (as compared to oceanic crust). As a result, continental crust sticks up higher than oceanic crust.

Online Exercise: Isostasy

1. Refer to the diagram below. There are two different blocks of wood, Block A and Block B, which are floating in a tub of water.



a. Which of the two blocks of wood is less dense?

a. Block A

b. Block B

Answer: Block B is less dense because it floats higher in the water. Less dense blocks have proportionally more thickness above the water line than more dense blocks. This is because the pressure at the base of the blocks must be the same as the pressure in the water at the same depth.

b. Explain your reasoning behind your choice in part 1a.

a. Block A is less dense because it is thinner than Block B.

b. Block A is less dense because it sits lower in the tub of water.

c. Block B is less dense because it sits higher in the tub of water.

d. Block B is less dense because it is thicker than Block A.

Answer: *Choice C. Less dense blocks have proportionally more thickness above the water line than more dense blocks. This is because the pressure at the base of the blocks must be the same as the pressure in the water at the same depth. Since B sticks up higher in the water, it is less dense.*

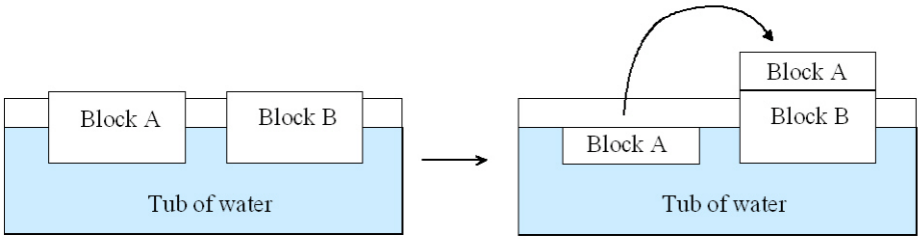
c. In terms of density, how are Blocks A and B analogous to oceanic and continental crust?

a. Block A is analogous to oceanic crust and Block B is analogous to continental crust.

b. Block A is analogous to continental crust and Block B is analogous to oceanic crust

Answer: Choice A. Continental crust is less dense and thicker than oceanic crust. Block B is analogous to continental crust and sits up higher in the mantle than oceanic crust. Block A is analogous to oceanic crust because it is dense,r and therefore sits "lower" into the mantle, and is also thinner than continental crust so that the surface elevation of the block is much lower (and is below current sea level on Earth).

2. Refer to the diagram below. There are two blocks of wood, Block A and Block B, which are floating in a tub of water (left diagram). The two blocks are made of the same type of wood and are the same size and shape. Half of each block rises above the water line. You remove the blocks from the tub of water. You slice off the top half of Block A and put the sliced half onto the top of Block B as illustrated on the right diagram.



a. Predict what will happen to *both* blocks as you place them back into the tub of water. Will the blocks rise or sink isostatically compared to their original positions?

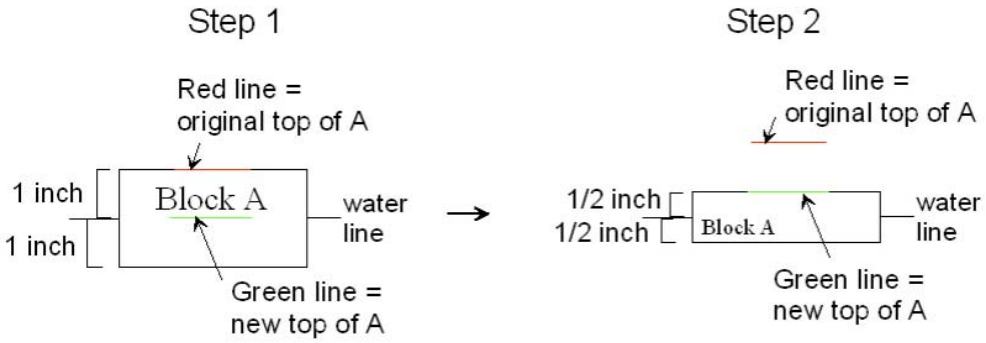
a. A will rise, B will sink; This is because half of A must rise above the water line and B will sink from the additional weight of A added on top of it.

b. A will rise, B will rise; This is because half of A must rise above the water line and B will rise from the added thickness of A.

c. A will sink, B will rise; This is because A is now half as thick and it will need to sink and B will rise because of the added thickness of A.

d. A will sink, B will sink; This is because A is now half as thick and it will need to sink and B will sink because of the added weight of A added on top of it.

Answer: Choice A; along with the following explanation:



Using the green reference line in Step 2, after cutting off half the block, Block A has uplifted or risen relative to the green line in Step 1. Alternatively, notice how the red line in Step 2 has risen compared to the red line in Step 1. This means Block A rises.

b. If you have removed half of Block A, how much of the remaining block will be exposed above water?

a. 25% because half of the original amount is 25%

b. 35% because it is now less dense, so it rises up a bit more

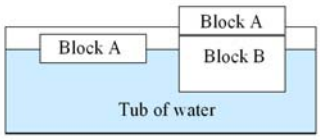
c. 50% because it was 50% exposed before it was cut

d. 75% because making the block thinner makes it rise and float more

Answer: c; The original block was 50% submerged, so no matter how much was removed, the remaining material will need to be 50% submerged to stay in isostatic equilibrium.

c. How would your tub and blocks look like after you sliced off half of Block A and added the sliced half to Block B.

a.



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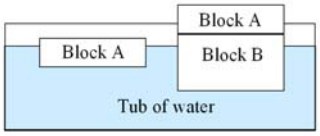
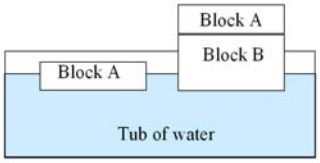
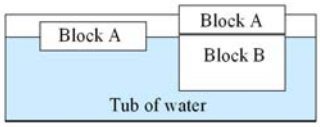


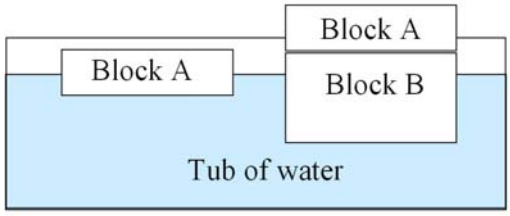
c.



d.



Answer: Choice A. Block A should rise such that 50% is above water. Block B should sink some (because of added weight), but elevation will be higher than original conditions (because of added thickness). Similar to Block A, Block B is also now 50% above the water line. Note that the original Block B is now more submerged under water (isostatically sank). Note that the original Block A is now lower in elevation, but had to isostatically rise to get it back 50% above the water line.



3. Putting the sliced block of wood from Block A to Block B is analogous to what geologic processes? In other words: What does removing the wood from one block represent? What does adding the wood slice to the other block represent?

a. The sliced block of wood from Block A represents subduction, adding the wood slice to Block B represents mountain building.

b. The sliced block of wood from Block A represents tension, adding the wood slice to Block B represents compression.

c. The sliced block of wood from Block A represents erosion, adding the wood slice to Block B represents deposition.

d. The sliced block of wood from Block A represents tectonic uplift, adding the wood slice to Block B represents tectonic sinking.

Answer: Choice C. The sliced block of the wood represents weathering and erosion. The adding of the block of wood is analogous to sediment deposition.

4. Consider that the wood blocks represent the "crust" and the part of each block below the surface of the water represents the "root of the mountains" that extends downward into the "mantle" (the water). Use this analogy to explain how removing wood from the top of Block A explains exposure of metamorphic rocks that are found at the core of mountains.

a. As the top of the mountain is weathered and eroded, the root rises isostatically, eventually exposing the metamorphic rocks formed at depth.

b. As the top of the mountain is removed, the metamorphic rocks slowly convect their way to the top.

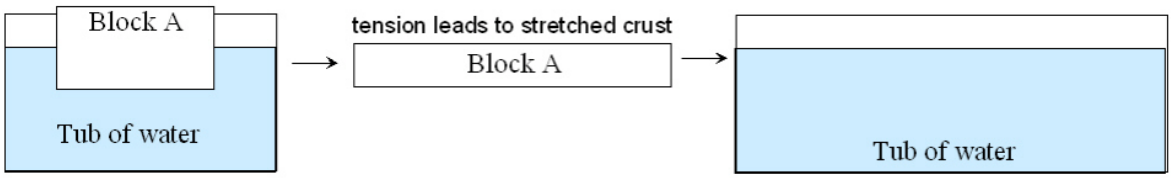
c. As the top of the mountain is eroded, the root spreads out laterally, which exposes the metamorphic rocks.

d. As the top of the mountain is removed, this lowers the density of the mountain and causes the metamorphic rock to rise and get exposed.

e. As the top of the mountain is removed, the now exposed rock is metamorphosed because of the resulting change in temperature and pressure.

Answer: Choice A. The removal of the wood represents weathering and erosion. This eventually leads to the removal of rock and isostatic uplift of crust, exposing the metamorphic roots of mountains at Earth's surface.

5. Using the diagram below, what would happen to Block A if we did not cut off half of the block, as in question #2, but instead stretched it? (a) Would Block A isostatically rise or sink? (b) What will happen to the elevation of Block A? (c) What happens to the "root" of Block A?



a. Block A will sink, the surface elevation will decrease, and the root will become thicker.

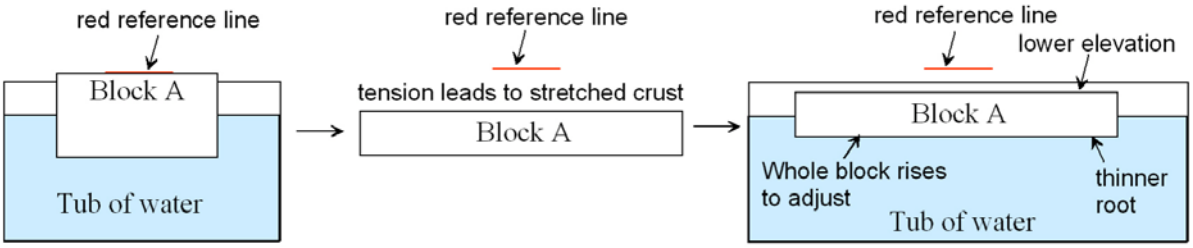
b. Block A will rise, the surface elevation will increase, and the root will become thinner.

c. Block A will sink, the elevation will increase, and the root will become thicker.

d. Block A will rise, the elevation will decrease, and the root will become thinner.

e. Block A will rise, the elevation will decrease, and the root will become thicker.

Answer: Choice D. Tension, or the thinning of crust, leads to isostatic sinking. The elevation of Block A is now lower and the root has thinned.



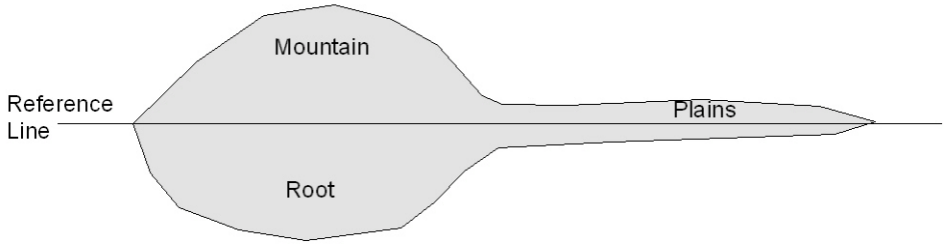
Using the red refenence line, after stretching the crust, Block A has subsided or sank relative to the red line. This means that Block A isostatically sinks.

6. Mountains stand high compared to nearby plains. Which region, high mountains or low plains, do you predict will have the thicker crustal root?

a. The mountains would have a thicker crustal root.

b. The plains would have a thicker crustal root.

Answer: Choice A. If the mountains are standing up higher, the implication is that the root below them is thicker and less dense such that they stick up higher above the "mantle." This would be analogous to a thick block of wood in a tub of water.



Note: These could be topics for discussion/chat for a couple of days AFTER the exercise.

Follow Up Discussion:

C. Why is oceanic crust always covered up by sea water? Another way to ask the same question, why is oceanic crust always found under water?

Example answer: Oceanic crust is relatively dense compared to continental crust, but less dense than the mantle. As a result, oceanic crust sits isostatically lower in the mantle than continental crust. This allows ocean water to flow over and cover the oceanic crust leaving the continental crust to sit above sea level.

D. What is flexural isostasy and why is it a more realistic view of geologic processes than blocks of wood floating in a tub of water?

Example answer: Instead of blocks of crust with faults that run down to the mantle and these blocks bob up and down, flexural isostasy indicates that the crust flexes down and bulges up in

response to addition and removal of weight. This more accurately reflects that the crust slowly responds instead of quickly bobbing up and down. For instance, if a large glacier grew on top of the crust, the crust directly below the glacier would subside and the flanks of the crust would bulge to accommodate mantle flow from below.

Adopted from Instructor's Resource Guide, "*How Does Earth Work?*" 2e, by Smith and Pun, Pearson, 2010.