**Unit 5:** Relationship of internal to external energy processes (2 hours)

**Purpose**

You will use what you have learned in the previous units to link the above-ground part of the rock cycle (driven by the hydrologic cycle, energy from the Sun, and gravity) to the below-ground part of the rock cycle (driven by Earth’s internal heat energy). You will work with a group to interpret a rock cycle diagram and the role of the hydrologic cycle, identifying energy transfers (including sources and sinks), and describing hypothetical rock material transfer pathways. You will also make connections between erosion and plate tectonics by reading, “*How Erosion Builds Mountains.*”

**Q. *How do the internally driven and externally driven processes influence each other?***

**Initial Ideas** – on your own

1. Where does the energy come from to transport sediment in a stream? Go as far back to the ultimate energy source as possible and explain your reasoning.
2. What changes might happen to sediment if it piles up at the end of the river and gets deeply buried (many kilometers) for millions of years? What is the source of energy that is ultimately responsible for those changes? Explain your reasoning.
3. Does the hydrologic cycle play a role in the rock cycle? Explain your thinking.
4. Could the removal of many kilometers of rock from a mountaintop by erosion over millions of years affect any of Earth’s internal processes? Explain your reasoning.

Discuss these questions with your group and prepare a whiteboard explaining your ideas. Be prepared to discuss them with the rest of the class.

Class Discussion

**Collecting and Interpreting Evidence**

Part 1. Linking sediments to the rock cycle

You learned about the rock cycle earlier in this course. Now let us put the stream studies that you did in Units 1-2 into this larger context. In your group, discuss answers to the following questions and write in the spaces below:

1. Review the different rock types that you learned about earlier in the course and the processes by which they formed. Summarize in the space below.

1. In Unit 1, you used stream tables as a model for real stream systems. In that model, your starting material was sediment, and the sediment was moved from one place to another. What rock types can be eroded to produce the sediment that is transported in streams?
2. Let us say that an igneous intrusive/plutonic rock is the rock type exposed in the headwaters of a stream. Where in Earth did that intrusive/plutonic rock originally form? How might it have gotten to Earth’s surface (slowly over millions of years) so that now it is at the headwaters of the stream?
3. Once the intrusive/plutonic rock is exposed at the surface, how might the hydrologic cycle that you studied in Unit 1 slowly cause changes in that rock?
4. What is the ultimate energy source for those changes? Explain your thinking.
5. The type of rock that a river or stream flows through will affect stream profile. Brainstorm in your group why this might be.
6. If the intrusive/plutonic rock is eroded, and the resulting sediment is transported downstream, it will eventually be deposited somewhere. What might then be the fate of that sediment? Come up with at least two scenarios for what might happen to that sediment in the next few million years.
7. Now that your group has brainstormed rock cycle processes in the questions above, look at the rock cycle diagram. Do your answers to questions 3, 4, and 7 fit within the rock cycle framework? Are there any modifications you would make to your answers? To the rock cycle diagram? If so, write them after your previous answers in a different color ink or pencil.



Brainstorm below what other things can happen to a rock as it traverses the rock cycle over million of years:

1. Now look at the following diagrams that show the below-ground and above-ground processes in the context of plate tectonics. How specifically does the hydrologic cycle interact with the rock cycle at the interface illustrated on the diagram?



Image from Geological Society of London and used with permission.
http://www.geolsoc.org.uk/ks3/gsl/education/resources/rockcycle.html

Class discussion: Create a whiteboard that describes your group’s answers to questions 8 and 9. Be prepared to share your whiteboard with the class.

Class Discussion

In the space below, jot down any new ideas you learned from the class discussion

Part 2: Thinking about energy transfers

Your group has focused on material-transfer processes — the movement of rock and sediment from one place to another. Now we will take some time to think about the energy transfers that accompany this material transfer.

In Unit 1 you diagrammed the energy transfers that occur during the hydrologic cycle. Now, your group will diagram the energy transfers that occur as the hydrologic cycle interacts with the rock cycle.

1. Review the energy transfer that occurs as water evaporates from a large body of water, and provide an explanation for that transfer.

***Evaporation of water***

RECEIVER

SOURCE

Water

Sun

Energy Transfer

Explanation:

1. Now describe the energy transfer that occurs as that evaporated water condenses and falls out as precipitation:

***Condensation of water***

RECEIVER

SOURCE

Atmosphere

Evaporated water

Energy Transfer

Explanation:

What would happen to the water in this cycle if the Sun didn’t continuously supply energy input?

1. As the condensed water falls as precipitation (due to gravity), its kinetic energy increases. It may enter a stream or river and interact with rock (let us say the igneous intrusive/plutonic rock from Part 1) along a stream profile. Small pieces of that intrusive/plutonic rock are removed (eroded) and join the other sediment that the stream is carrying. Map the energy transfer that occurs during that erosion process. The receiver object and its type of energy have been done for you. Provide an explanation of that energy transfer. [Note: We have skipped the energy transfer that occurs as the rain is falling. That would just be conversion of potential energy (condensed water high in the atmosphere) to kinetic energy (condensed water falling as rain).]

***Erosion of metamorphic rock along a stream profile***

RECEIVER

SOURCE

Small pieces of intrusive rock (sediment)

Energy Transfer

Explanation:

1. Once that sediment loses its kinetic energy (due to frictional interactions and the slowing stream), it will be deposited. More sediment will continue to cover it, and it will eventually get buried. Over millions of years, the increased pressure will cause that loose sediment to turn into sedimentary rock. So, an igneous intrusive/plutonic rock at Earth’s surface was slowly eroded over time to become sediment; that sediment was continuously transported by a river (whose energy ultimately came from the Sun and gravity) to be deposited and buried, and finally, over millions of years, turned into a sedimentary rock. Sketch this pathway on a rock cycle diagram.
2. You learned earlier in this course that the rocks inside Earth are hotter deeper beneath the surface due to the Earth’s original heat and from radioactive decay. As that sedimentary rock from the previous question continues to get buried over millions of years (usually by plate tectonic processes such as subduction, or other mountain building processes), it will get hotter and be subjected to higher pressures. If it gets hot enough for long enough (>250° C), it will turn into a metamorphic rock. Map this energy transfer as a sedimentary rock receives thermal energy to be turned into a metamorphic rock. Provide an explanation.

***Heating of sedimentary rock to create metamorphic rock***

RECEIVER

SOURCE

Sedimentary rock

Energy Transfer

Explanation:

1. Now let us say that the mountain-building process that caused enough heating and burial to turn the sedimentary rock into metamorphic rock also caused high mountains to form at the surface above the metamorphic rock. How will the hydrologic cycle interact with those high mountains?
2. If rain and snow from the hydrologic cycle are responsible for erosion of the high mountains over millions of years, do you think it is possible to get that buried metamorphic rock back to Earth’s surface again? Explain your thinking.

**Homework**: Read “How Erosion Builds Mountains” and answer questions on the student response sheet (see end of Activity 5). The subject of the article is on feedbacks between uplift and erosion. Turn this homework in to your instructor.

Summarizing Questions

1. Where does the energy come from to transport sediment in a stream? Go as far back to the ultimate energy source as possible and explain your reasoning.
2. What changes might happen to sediment if it piles up at the end of the river and gets deeply buried (many kilometers) for millions of years? What is the source of energy that is ultimately responsible for those changes? Explain your reasoning.
3. Does the hydrologic cycle play a role in the rock cycle? Explain your thinking.
4. Could the removal of a many kilometers of rock from a mountaintop by erosion over millions of years affect any of Earth’s internal processes? Explain your reasoning.
5. The northern Andes mountain range and the mountains of southeast Alaska are both large mountain ranges that are actively uplifting. Based on your homework reading, and given the difference in climate between the two (the northern Andes are desert, southeast Alaska is very rainy), which mountain range would you expect to be rising faster? Explain your reasoning.
6. Describe a hypothetical rock material transfer pathway as follows: You live on the banks of a medium-sized river. The river floods during high rains. When the water finally recedes, there is a new layer of fine-grained sediment everywhere in your neighborhood. Using the rock cycle diagram and a whiteboard, your group should describe a hypothetical rock cycle pathway for that sediment that traverses at least one time through the rock cycle. Make sure you describe interaction with the hydrologic cycle and plate tectonics. Write down your resulting pathway below and *make sure you include any required energy transfers*:

Class Discussion

Create a whiteboard with your group on your answer to #6 above. Be prepared to share with the class.

Also, be prepared to have a general discussion of the answer to #5 above.

As the discussion ensues, write down some new ideas in the space below.

**Unit 5 Homework — How erosion builds mountains**

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Scientists’ Ideas about Mountains, Isostasy, and Erosion**

Reading: “How Erosion Builds Mountains” by Nicholas Pinter and Mark Brandon, April 1997 *Scientific American*. Downloadable from *http://earth.geology.yale.edu/~markb/Eprints/Pinter&Brandon1997.pdf*

The study of isostasy (motionless, balanced floating) reveals that when a floating object loses mass, the object rises (floats higher) to restore the balance. (You can review this by playing with the isostasy simulator: <http://www.geo.cornell.edu/hawaii/220/PRI/isostasy.html>).

We also know that igneous intrusive and metamorphic rock types formed deep in Earth’s crust. We use the term “uplift” to explain how these types of rock can now be found at the surface and as high mountains. Can erosion of mountains be likened to the melting and rising of icebergs?

What processes build mountains? How can isostasy explain how mountains grow? How can erosion of mountains factor into explaining mountain uplift?

Read about the ideas of two geologists whose research specializes in looking at answers to these questions in the *Scientific American* article “How Erosion Builds Mountains” by Nicholas Pinter and Mark Brandon. Then, answer the following questions:

1. By using the isostasy simulator (<http://www.geo.cornell.edu/hawaii/220/PRI/isostasy.html>), you can see that the proportion of an object exposed above the fluid it is floating in depends on the difference in density between the object and the fluid it floats in. Describe how the buoyant mountainous continental crust might be compared to this simulator analogy.

2. The article describes the dominant way that mountains are built from plate tectonics. Summarize (briefly!) some ways that mountains can form.

3. What are some examples of how climate affects erosion of mountains?

4. “Isostasy is the key mechanism that links a mountain’s tectonic, or internal evolution to its geomorphic, or external development.” In your own words, using the principle of isostasy, describe how erosion at the surface can cause uplift of mountains.

5. How do feedbacks between tectonics, erosion, and climate processes interplay to influence mountain building?

6. Evidence from the rock record suggests to scientists that during the past 40 million years there has been an unusual surge of tectonic activity and mountain building as well as global cooling. Did the surge of mountain building cause the global climate shift? Or did a climate shift itself produce uplift that looks like a surge in mountain building? Explain the rationale for each of these interpretations. Which cause and effect relationship do you align with? Why?