Playing With the Crust: Moving Plates and Molten Rock

By Jake Strouse

Abstract:

There are two activities that help demonstrate plate tectonics and volcanic activity. The first is called "Plate Tectonics in a Box" and is a simple, inexpensive activity to illustrate convergent and divergent boundaries in plate tectonics. The students get to build a setup where the cardboard continents are on moving paper plates. This motion is controlled by threading the paper into a slotted box. The second activity is "Vinegar Volcanoes for Magma Mania." Although the vinegar/baking soda volcano isn't a great representation of the real thing, here it is being used as a way for the students to design and execute an experiment. They get to hypothesize what mixtures of substances will behave in which way, and then compare this to what is occurring with the magma in an eruption.

Grade Level(s): 6^{th}

Objectives:

- To better understand divergent and convergent plate boundaries in the context of plate tectonics.
- To examine the differences in viscosity of different mixtures by design with a link to volcanic eruptions.

National Standards:

Standard A: Science as Inquiry; Abilities necessary to do scientific inquiry
Standard A: Science as Inquiry; Understandings about scientific inquiry
Standard D: Earth and Space Science; Structure of the earth system

New Mexico Standards:

Strand 1, Standard 1: Scientific Thinking and Practice; Use scientific method
Strand 1, Standard 1: Scientific Thinking and Practice; Understand process of scientific investigation
Strand 2, Standard 3: Earth and Space Science; Earth and atmosphere structure

Materials for Part I (per setup):
- Cardboard box
- Two sheets of paper
- Tape
- Scissors

Materials for Part II (per group):
- Plastic shoebox
- 5 baby food jars
- Measuring spoons
- Graduated cylinder
- Spoon
- Baking soda
- Flour
- Salt
- Cornstarch
- Gelatin
- Vinegar
- Water

Background:

<u>Plate Tectonics</u>

In 1912 Alfred Wegener (1880-1930) noticed that close examination of a globe often results in the observation that most of the continents seem to fit together like a puzzle. He proposed that the continents were once compressed into a single proto-continent which he called Pangaea ("all lands"), and over time they have drifted apart into their current position. Initial support for his theory came from the similarities in the fossil records of the continental coasts, such as South America and Africa, or Europe and North America. Glaciation scraping patterns were similar across continental coasts as well. Bases for his theory were weak, however, and many of Wegener's ideas were dismissed. Just before Wegener's death Arthur Holmes elaborated on one of his hypotheses; the idea that the mantle undergoes thermal convection. This idea is based on the fact that as a substance is heated its density decreases and rises to the surface until it is cooled and sinks again. This repeated heating and cooling results in a current which may be enough to cause continents to move. Not until the 1960's did Holmes' idea receive any attention when greater understanding of the ocean floor, and the discoveries of features like mid-oceanic ridges, geomagnetic anomalies parallel to the mid-oceanic ridges, and the association of island arcs and oceanic trenches occurring together and near the continental margins, suggested convection might indeed be at work. These discoveries and more led Harry Hess (1962) and R. Deitz (1961) to publish similar hypotheses based on mantle convection currents, now known as "sea floor spreading."

The main features of *plate tectonics* are:

- The Earth's surface is covered by a series of crustal plates.
- The ocean floors are continually, moving, spreading from the center, sinking at the edges, and being regenerated.
- Convection currents beneath the plates move the crustal plates in different directions.
- The source of heat driving the convection currents is radioactivity deep in the Earth's mantle (this is one theory).

<u>Magma Movement</u>

The following is a general discussion of magma movement associated with a volcano (loosely based on Kilauea in Hawaii, an intraplate volcano). Earthquake epicenters define a pipeline structure beneath the volcano (~40 up to 10 km below) up which magma migrates from the mantle into the crust. This magma is fed into a roughly pear shaped magma chamber 3 to 10 km below the volcano. This flow into the chamber is thought to be relatively constant. The magma in the chamber is then periodically released either sideways along dyke-like conduits or upwards toward the main crater area. This ascent is attributed mostly to buoyant forces (it is less dense than the rest of the crust), while the low-pressure environment toward the surface facilitates nucleation and expansion of volatiles, which may in turn be responsible for accelerating the erupting magma to form more spectacular lava fountains.

Procedures:

Part I: Plate Tectonics in a Box

- Cut a narrow slit in the top of a box. Cut a larger square in the side of the box. Slide two pieces of paper through the slit and about half-way into the box.
- Tape a block of cardboard or folded paper on the outside edge of each sheet of paper.
- Demonstrate motion at a divergent plate boundary by pushing the paper up from inside the box. The sheets of paper will move away from each other just like new oceanic crust at mid-ocean ridges.
- Demonstrate motion at convergent plate boundaries by pulling the plain sheet of paper down from inside the box. Pull the two sheets into the box through the slit until the continents collide. As the sheets (plates) are consumed, the continents move closer together and ultimately collide. Such a collision is currently forming up the Himalaya Mountains.

Conclusions:

This activity when used in conjunction with lecture on continental drift and plate tectonics will hopefully give the students a better grasp of a relatively abstract idea. The students can build the entire apparatus, or the boxes can be prepared before; either way they can have some freedom in continent design. The student handout follows below and can be used in evaluation.

Part 1.5:

After this part of the activity it works well to have the students take paper cut-outs of the continents (found online or copied out of a text) and have them try to logically place them together to make Pangaea. Mostly this is a fun cut and paste activity for a class period, but it does help show how well the continents fit back together.

Part II: Vinegar Volcanoes for Magma Mania

The procedures are given in the student portion; they will be making four different types of magma to erupt from a volcano. They have some control over the design.

Conclusions:

Although there is a link to volcanoes, the activity is geared to letting the students have input in experimental design. The students need to reason out their choice in ingredients, and make good observations for comparison. Although messy, the eruptions are quite different from one another depending on what is added. Hopefully, with each volcano, the students can better hypothesize the outcome of the next eruption and finally make the leap into more realistic situations.

References:

Smith, David G., *The Cambridge Encyclopedia of Earth Science*. Crown Publishers Inc./Cambridge University Press, New York 1981.

Judson, Sheldon and Marvin E. Kauffman, Physical Geology 8th Ed. Prentice Hall, New Jersey 1990.

http://www.scotese.com/earth.htm

http://volcano.und.nodak.edu/vwdocs/vwlessons/plate_tectonics/plate_activities.html

<u>Convergent boundaries</u> – the line where two plates move towards each other.

<u>Divergent boundaries</u> – the line where the plates move away from each other.

<u>Plate Tectonics</u> – the earth's crust is broken up into large plates that are in constant motion.

<u>Subduction zone</u> - an area where two plates come together and one slides under another.

<u>Transform faults</u> – a break in the earth's crust where two plates slide past each other.

<u>Viscosity</u> – how thick a liquid is.

Part I - Plate Tectonics in a Box

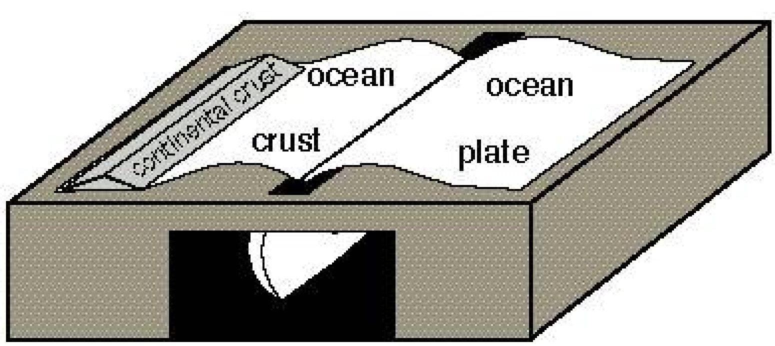
The Theory of Plate Tectonics states that the earth's crust is broken up into large plates that are in constant motion. The motion is caused by convection of molten earth in the mantle below. The theory also helps to explain the concept of continental drift, in which it is theorized that the continents were once one large super-continent called Pangaea and have since split apart, rearranged, and even collided back together. Movement at the plate boundaries can be described as convergent, divergent, or transform faults. This activity will look at convergent and divergent boundaries.

1. *What is the difference between convergent and divergent boundaries?*

2. First we need to build our plates. Take two pieces of white paper and tape them together along the short edge. This will represent the ocean plate.

3. Using the piece of cardboard cut out your two continents and tape or glue them to the opposite edges of the sheets of paper that you taped together in the last step.

4. Take your new plates and thread the taped edge into the slot in the box. See the picture below.



5. Pull the paper in the box down so that your continents are touching each other. Now slowly push this paper up so that the continents begin to move away from on another. *What kind of boundary is this?*

6. *If this motion were happening over millions of years where would the oldest ocean floor be, near the continents or near the slot?*

7. Now that your continents are separated from each other, begin pulling down the paper inside the box so that the continents move toward each other. *Which type of boundary is this?*

8. If the two plates continued to move toward each other the continents would eventually collide and force the land up into a mountain range. This type of collision created the Himalayan Mountains as India collided with Asia millions of years ago. Actually, the plates are still colliding, and the mountains rise over an inch a year.

9. As the plates move toward each other the ocean plate moves under the continental plates in what is called a subduction zone. *What do you think happens to the plate as it is forced back into the mantle?*

10. What kinds of natural events happen as a result of plate tectonics?

11. Now for the last question: *Who was the scientist credited with the theory of Continental Drift?*

    a. Albert Einstein
    b. Alfred Wegener
    c. Con T. Nentil
    d. Ripht

Part II - Using the Vinegar Volcano for More Magma Mania

This activity is going to use the baking soda/vinegar volcano that you have probably seen before. This time we are going to look at how magma *viscosity* might affect volcanic eruptions. Viscosity is how thick a liquid is. For example, oil is more viscous than water. Think about how much longer it takes to pour out a cup of oil than a cup of water. We want to make some viscous solutions to represent magma, so how could we make water more viscous? Could we add different substances to it to make it thicker? What kinds of things could we add?

Making the Magmas

1. You are given five baby food jars (labeled 1, 2, 3, 4, and 5) – these are going to be your volcanoes.
2. In four separate cups you have:

    - baking soda
    - salt
    - flour
    - cornstarch
    - gelatin powder

3. We want to make four different types of magma for our volcanoes. Your group gets to choose the ingredients but you have to follow a few rules:

    a. Do not use more than **1 tablespoon** of baking soda.
    b. Baby food jar **#1** should be made with only baking soda as the dry ingredients. This is your control volcano.
    c. Use no more than three total tablespoons of dry ingredients for each volcano.

4. In the following table write down the solid ingredients you added to each of the volcanoes.

Volcano	Solid Ingredients	Vinegar Volume	Observations
1 (Control)			
2			
3			
4			
5			

5. Add 10 mL of water to each one of your created volcanoes, and mix them up. If you want some red food coloring for your volcanoes this is where you can add it too.

6. *Based on what they look and feel like, which volcano of yours do you think will erupt with the most viscous magma?*

7. *Which volcano will have the least viscous eruption?*

8. Decide how much vinegar (less than 5 mL) you want to use, and record that in your table for each volcano. *Should you use the same amount for each volcano?*

9. Make sure your volcanoes are in the plastic shoebox (to catch overflow), and add the vinegar to them one at a time. Record your observations in the table, and be sure and see how each volcano is different from one another.

10. *Were your hypotheses correct in steps 6 and 7? How was the least viscous volcano different from the most viscous volcano?*

11. *What type of magma do you think would be the most impressive in a volcano eruption, a viscous one or a not so viscous one? Think about the explosion and lava flows. Write a short paragraph about what you think.*