The Magma also Rises

Summary

Students learn about plate motion using basin of water and Styrofoam cutouts. Students will infer what causes plate tectonics based upon their observations of styrofoam plates.
Students will relate convection of magma under the earth's crust to other forms of convection more commonly experienced: water on a stove, thunderstorms, etc.
Students will understand that convection transfers heat to the earth's crust and to the surface, and that the mantle flows very, very slowly: on the order of a centimeter per year.

Time Frame

1 class periods of 90 minutes each

Group Size

Small Groups

Life Skills

Thinking & Reasoning

Materials

Per group:

- beaker
- hot plate
- bunsen burner (optional)
- styrofoam plate
- ice (optional)
- scissors
- dye tablet from easter egg kit (optional)
- pen & markers (optional)

Per student:

- notebook
- pen

Background for Teachers

Mantle convection is often used to explain hot spots and plate tectonics. Although there is still some debate on the latter - whether mantle convection is the primary cause of plate movement -- what is clear is that mantle convection transfers heat from the earth's interior to the surface.
The earth's mantle is made up of solid, but it is in a plasticized state. The rock behaves like glass or silly putty, in that it can flow under stress, albeit very, very slowly.
Heat released from nuclear decay, and residual heat from the earth's formation, maintain a high core temperature. This heat in the earth's interior causes convection currents to form in the mantle. Hot portions of the mantle rise in plumes, while cool portions sink. The hot, rising magma is used to explain the existence of hot spots. Horizontal motions complete the loop. These horizontal motions

are hypothesized to drive plate tectonics by dragging the continents along.
From the persistence of hot spots, we can infer that mantle plumes last a very long time. Long, slow continental drift (assuming convective currents drive tectonics) also provides evidence that these convection currents change very little on human timescales. If they did, then they would impart very little net force in any given direction, any more than taking random turns in your car is likely to get you from home to work.
Convection currents also form when heating liquids on a stove, with the burner as a heat source.
Thunderstorms are convection currents complicated by the presence of moisture. The primary heat source for atmospheric convection is solar heating of the earth's surface. Rising air cools, causing water vapor to condense, releasing more heat and driving further convection. (This condensation has the benefit of making the convection visible. It is also responsible for the formation of precipitation and lightning.)
Timescales for convection vary. The convection in a pan has a timescale of seconds; a warm parcel of water will rise to the surface very quickly (a matter of seconds). A convective storm has a convective timescale of hours. The timescale of a convective plume in the earth's mantle is very, very long. (I guessed based on the mantle being 700 km deep, and motion of about 1 cm per year, that the timescale is on the order of 70,000,000 years.)

Student Prior Knowledge

- mantle
- buoyancy
- tectonic plate
- heat transfer

Intended Learning Outcomes

Use science process and thinking skills. Construct models to describe concepts and principles.

Instructional Procedures

The teacher will explain that students will model convection; a major heat transfer mechanism in the earth.
Students will divide into groups, cut out (and optionally color / label) pieces of styrofoam, fill a beaker with water, and set the styrofoam pieces on the surface of the water. Students will observe the Styrofoam and the water. Identify as a class several trails and testing options, like placement of the beaker on the plate, amount of plate, amount of water, use of a dye tablet, etc.
Students will then experiment with the hot plate (and optionally the Bunsen burner), warming the beaker and observing the behavior of the styrofoam. For example, if the students warm the beaker from just one side, how does the behavior of the Styrofoam change? (One would expect it to settle on the opposite side.)
After some time to experiment (it will probably take several minutes to set up convection currents with each configuration), students will clean up.
The teacher may lead a discussion, or provide the students with a worksheet. Questions can be found in the attached worksheet.

Extensions

Mushroom clouds are an example of a convective plume.
If convection is so slow in the mantle, what about heat transfer by conduction? How quickly does heat travel through rock? What evidence do students use for their guess?

Assessment Plan

Assessment can occur in three stages:
1 - The teacher can assess the progress of the students in creating a testable hypothesis, and in their testing of their hypothesis with the equipment provided.
2 - The attached rubric may be given to the students prior to beginning their experimentation so they know what is to be expected. Students can grade each other's labs.
3 - Students may grade each other's worksheets during a class wrap up discussion.

Rubrics

The Magma Also Rises rubric

Bibliography

Plates, plumes, and planetary processes By Gillian R. Foulger, Donna M. Jurdy
http://en.wikipedia.org/wiki/Mantle_convection

Authors

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