Activity Overview

Students use a variety of liquids to investigate the effects of density on how a material moves and what effects temperature can have on the density of a material. Students then develop a method to determine the densities of a variety of rocks. Students complete an experiment to determine the forces that cause the subduction of lithospheric plates. Content reading explores evidence for the Earth's layered structure and defines the physical characteristics of each layer of the Earth. Thermal convection as the driving force of plate tectonics is also explained.

Preparation and Materials Needed

If the amount of materials or time available is of concern, consider dividing the class into three groups; each will complete **Parts A, B, C, or D**.

SAFETY NOTES: Make sure that students are aware of all classroom safety precautions with regard to working with glassware, using a heat source, and heating a fluid in the laboratory. Also, make students aware that although vegetable oil and various kinds of syrups are foods, they should not be ingested in the laboratory.

Materials

- 30 mL water
- 30 mL pancake syrup
- 30 mL vegetable oil
- Graduated cylinder (at least 10 mL)
- Balance scale
- Calculator
- Corn syrup
- Pyrex® beaker or wide aluminum pan
- Heat source, like a hot plate
- 3 pieces of balsa wood
- Rock samples from your community
- Samples of granite, basalt, and sandstone
- Large, rectangular tub
- Liquid dish detergent
- Mixing spoon
- Sponge
- Vinyl plastic
- Flat, clear plastic ruler
- Tape

Think about It

Student Conceptions

Some of the students are likely to think that the plates move because they are dragged or acted upon by flow of the underlying mantle. They would be on the right track, but it would be wise to let them know that although that is a natural assumption, there is likely to be more to the answer than just that.

Answer for the Teacher Only

You should be aware that there is still no full consensus about the answer to this question on the part of the experts. It is clear that the motions of the plates is related to convective motions in the underlying mantle asthenosphere, but geometry of the convection is only now becoming clear. Also, there is the troublesome problem of the extent to which the plates themselves drive the convection motions in the mantle, rather than the convective motions driving the plates; this is discussed briefly in the final section of **Digging Deeper**.

Assessment Tool

Think about It Evaluation Sheet

The **Think about It Evaluation Sheet** will help students to understand and internalize basic expectations for the warm-up activity. This evaluation sheet emphasizes that you want to see evidence of prior knowledge and that students should communicate their thinking clearly.

Investigate

Part A: Effects of Density on the Position of Material

Group A will have to pour the liquids into the cylinder carefully, trying not to disturb the liquid already in the cylinder. Oil should float on water, and water should float on syrup, because of the differences in density among the three liquids. Pancake syrup works well.

Teaching Tip

Add food coloring to the water for a more dramatic and easily visible effect. Also, pouring the liquid slowly over an inverted spoon will help the students to not disturb the liquid already in the cylinder.

Part B: Effects of Temperature on Density of a Material

Group B will be working with hot liquids and should be supervised most closely. Students need not boil the fluid; heating the material from the base is sufficient to initiate a convection cell.

Teaching Tip

Circulate from group to group asking questions to help students address the questions being asked. **Parts A** and **C** of this investigation require students to develop an investigation. Encourage them to discuss and record their methods before proceeding.

Assessment Tool

***EarthComm* Notebook Entry-Checklist**
Refer students to the ***EarthComm* Notebook Entry-Checklist** to remind them of the criteria against which they will be assessed. The checklist also provides a quick guide for student self-assessment and also provides you with an opportunity to quickly score student work.

Part C: Density of Earth Materials

Group C should be reminded to tilt the cylinder and place the rocks gently into the graduated cylinder to avoid splashing water (and if glass cylinders are used, to prevent breaking out the bottom of the cylinder).

Teaching Tip

Make sure that the rock samples which you obtain are small enough to fit inside of the graduated cylinder.

Part D: Forces Causing Subduction of Lithospheric Plates

The activity in **Part D** is an elegant demonstration of how lithospheric plates can slide down into the mantle along subduction zones just because they are more dense than the mantle asthenosphere. The materials are simple, but the analogy is close. It may take several tries to make the demonstration work the way it is intended, but it is easy to repeat the process. When the procedure is working well, the students will observe that the leading edge of the plate (the ruler edge of the plastic sheet) starts to sink first, and as it sinks it pulls the rest of the sheet horizontally along the water surface. The point of downbending (corresponding to the trench) migrates back along the plastic sheet, until all of the sheet is underwater.

The ratio of width to thickness of the plastic sheet might seem to you to be far too large. Keep in mind, however, that most of the cross sections that show the interior of the Earth have a lot of vertical exaggeration. The typical thickness of an oceanic lithospheric plate is a hundred kilometers, and the typical width is more like ten thousand kilometers. The ratio of width to thickness is thus of the order of a hundred! That is less than the corresponding ratio for the plastic sheet in the investigation, but it is different by less than an order of magnitude (i.e., a factor of ten).

Teaching Tip

The groups should share what they discovered and explain to the rest of the class exactly what was happening. Each group are the "experts" on the idea they investigated. All students should complete ALL questions working with the experts.

Reflecting on the Activity and the Challenge

Use this opportunity to direct students back to the **Chapter Challenge**. The idea of lower-density materials moving about on the surface of a denser liquid, and the idea that the floating material moves away from the point above the center of the rising column of a convection cell, are important to begin visualizing the movement of lithospheric plates. Be sure to tie this idea in at this time, but also note that the plates are not isolated pieces, as with the "rafts" of wood, but cover the entire surface of Earth. You might also point out to students that the Earth's mantle, on which plates float, is not actually a liquid but that on long time scales it flows slowly as if it were a liquid. This would also be a good time to point out to students that the results of **Part D** of the activity suggest that the plates themselves might play an active part in the motion of the convection cells, rather than being only passive riders, if they become denser than the mantle asthenosphere. You might expect this to happen with oceanic lithospheric plates, because they cool as they move away from the spreading ridge, and as they cool, their density increases.

Digging Deeper

Assign the reading for homework. The questions in **Check Your Understanding** on page 95 can be assigned for homework.

Assessment Opportunity

Use (or rephrase) the questions in **Check Your Understanding** for a brief quiz to check comprehension of key ideas and skills. Use the quiz (or a class discussion about the questions in the textbook) to assess your students' understanding of the main ideas in the reading and the activity.

Another possibility would be to give the students a copy of *Figure 2* on page 93 (using **Blackline Master Plate Tectonics 2.3** provided in the Teacher's Edition) with the labels whited-out. Have students label the drawing and write a brief definition of each term.

Teaching Tips

Use the **Blackline Master** to make an overhead of *Figure 2* (page 93). This illustration can be incorporated into a discussion on the interior structure of the Earth.

Use the **Blackline Master** to make an overhead of *Figure 3* (page 94). This illustration can be incorporated into a lecture on thermal convection. This may be a difficult topic for students to grasp. Visit the *EarthComm* web site to learn more about this topic.

The *EarthComm* web site contains links that provide interesting supplemental information, including a look at the other planets in our solar system, on which plate tectonics does not exist. An interesting class discussion can be focused around the question: "What would Earth be like if plate tectonics did not exist?"

Check Your Understanding

1. You need to know the mass of the Earth and the volume of the Earth. To calculate the average density of the Earth, divide the mass of the Earth by the volume of the Earth. The density of materials in the Earth varies greatly from place to place; the only reasonable thing to calculate is the average density.

2. If the density of materials in the outer part of the Earth, which can be observed and measured directly, is less than the average density of the Earth, calculated as in **Question 1** above, then the density of materials deep in the Earth must be greater than the average.

3. Core, mantle, and crust.

4. The inner core is at almost the same temperature as the outer core, but it is under even greater pressure than the outer core because of the even greater weight of overlying material. The melting temperature of iron, which is the main constituent of the core, increases with increasing pressure. At the lower pressure of the outer core, the material is slightly above the melting temperature, and is therefore liquid, but at the higher pressure of the inner core, the material is slightly below the melting temperature, and is therefore solid.

5. Convection currents develop in any fluid that is heated in one place and cooled in another place while in a gravitational field. The differential heating and cooling produces differences in density, and the fluid moves under the influence of gravity to try to reestablish a stable density stratification. The circulation continues for as long as the temperature differences from place to place are maintained.

6. The mantle asthenosphere, located beneath the mantle lithosphere but above the core, is in motion due to density differences.

Understanding and Applying What You Have Learned

1. a) As the two plates move away from each other, new oceanic crust is created in the rift formed by the divergence, and becomes part of the new lithosphere on both plates.

   b) (i) One of the plates is subducted under the other. The oceanic plate is more dense than the continental plate, so it is subducted.
   (ii) If they both had the density of continental lithosphere, neither would be subducted. One would work its way beneath the other for some distance until it became stalled because of the buildup of friction.

2. Suggested answers to questions are shown on the next page:

Students should draw a picture that shows the following relationships: heat source = outer core (base of mantle); syrup = mantle; wood rafts = lithospheric plates (not crust). Students should use arrows to draw the flow of heat and matter in a convection cell within the mantle and within the syrup.

3. Volcanoes, including associated hot springs and geysers, provide evidence for unequal heating within the Earth. Another kind of direct evidence is from measurements of heat flow at the Earth's surface. With the appropriate instruments, it is not difficult to measure the rate at which heat is transferred upward from the interior to the surface. These rates vary from place to place, largely because of differing temperatures in the interior.

4. The most obvious candidate for the list is volcanism. Thermal springs and fumaroles in a volcanic area would also be good answers. Divergent plate motions at spreading ridges are another process that is clearly related to upward heat transfer from the interior to the surface. Subduction is related as well, although less clearly. Vertical motions of the lithosphere (uplift and subsidence) can be caused just by the thermal expansion and contraction of the lithosphere (among other things), and is an important geologic process. This is likely to be much less obvious to students than things like volcanism.

5. Density is determined by dividing the mass of an object by its volume. Students should be able to solve the equations by rearranging the variables to put the unknown on one side of the equation. The volume of iron in the sample provided in the table is 5.5 cm^3. The density of quartz in the sample provided is 2.65 g/cm^3. The mass of gold in the sample is 154.4 g.

Preparing for the Chapter Challenge

This question requires that students think in terms of Earth system science. Systems consist of reservoirs and fluxes. Reservoirs are "containers" with a supply of a material (e.g., a "bucket of water"). Fluxes or flow rates are the movement of matter and energy from one reservoir to another (e.g., poking a hole in the bottom of a bucket of water creates a flow of water out of the bottom. Pouring water into the bucket to restore the water that is lost is another flux or flow rate). In representing a system, reservoirs are usually shown as boxes and flows are shown using arrows. An open system allows matter in and out (a container of water without a lid and set outdoors, where water can evaporate and also enter as rainfall). A closed system allows only energy in and out (a clear sealed container of water).

Encourage students to represent the flow of matter and energy in terms of reservoirs and fluxes.

Inquiring Further

1. Investigating driving forces for plate motions

Recommend that students visit the USGS web site (which they can link to through the *EarthComm* web site) and do a search on the term "plate tectonics." Be sure to help students to identify web sites that represent the voice of the Earth science community. The United States Geological Survey is an excellent point for web-related research. Students who simply go to a search engine and type the term "plate tectonics" may uncover a variety of non-scrutinized, non-scientific web sites, including the web pages of secondary-school students who may have no better understanding of plate tectonics than your students. Visiting the web early in the chapter will help your students to prepare for a web-based **Chapter Report** because it will expose them to various ways of presenting scientific ideas.