Investigation #3

Digging Deeper

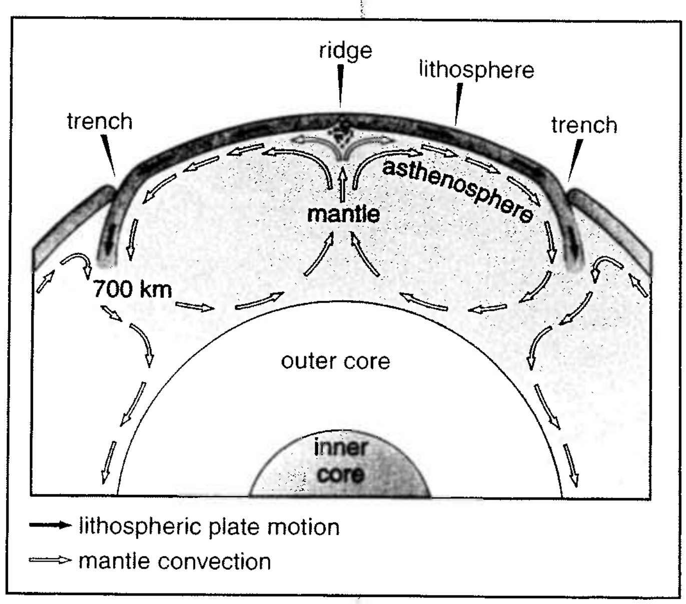
FORCES THAT DRIVE OUR DYNAMIC PLANET

Convection Cells

Convection is a motion in a fluid that is caused by heating from below and cooling from above. The corn syrup and oatmeal in your investigation were convecting. When a liquid is heated, it expands slightly. That makes its density slightly less. The fluid with lower density then rises up, in the same way that a party balloon filled with helium rises up. With the balloon, you can even feel the upward tug on the string! When the heated liquid reaches cool surroundings, it shrinks again, making its density greater. It then sinks down toward where it was first heated. This circulation, which you observed in the corn syrup, and in the water/oatmeal mixture, is called a convection cell.

Convection in the Earth's Mantle

In **Investigation 2** you learned that the Earth's mantle extends down to the hot iron core. It is known that P waves can pass through solids, liquids, and gases, but S waves can go only through solids. Both P waves and S waves go through the mantle, so it must be solid. On the other hand, only P waves go through the core, so its iron must be melted rather than solid. Scientists are now sure that the mantle convects, in the form of gigantic convection cells. How can that be, if the mantle is solid rock?



As You Read...
Think about:
1. *What are the conditions that cause convection cells in a fluid?*
2. *How can the mantle convect if it is a solid?*
3. *What is the typical speed of mantle convection?*
4. *What is the reason for volcanic activity along mid-ocean ridges?*
5. *What kinds of forces drive sea-floor spreading?*

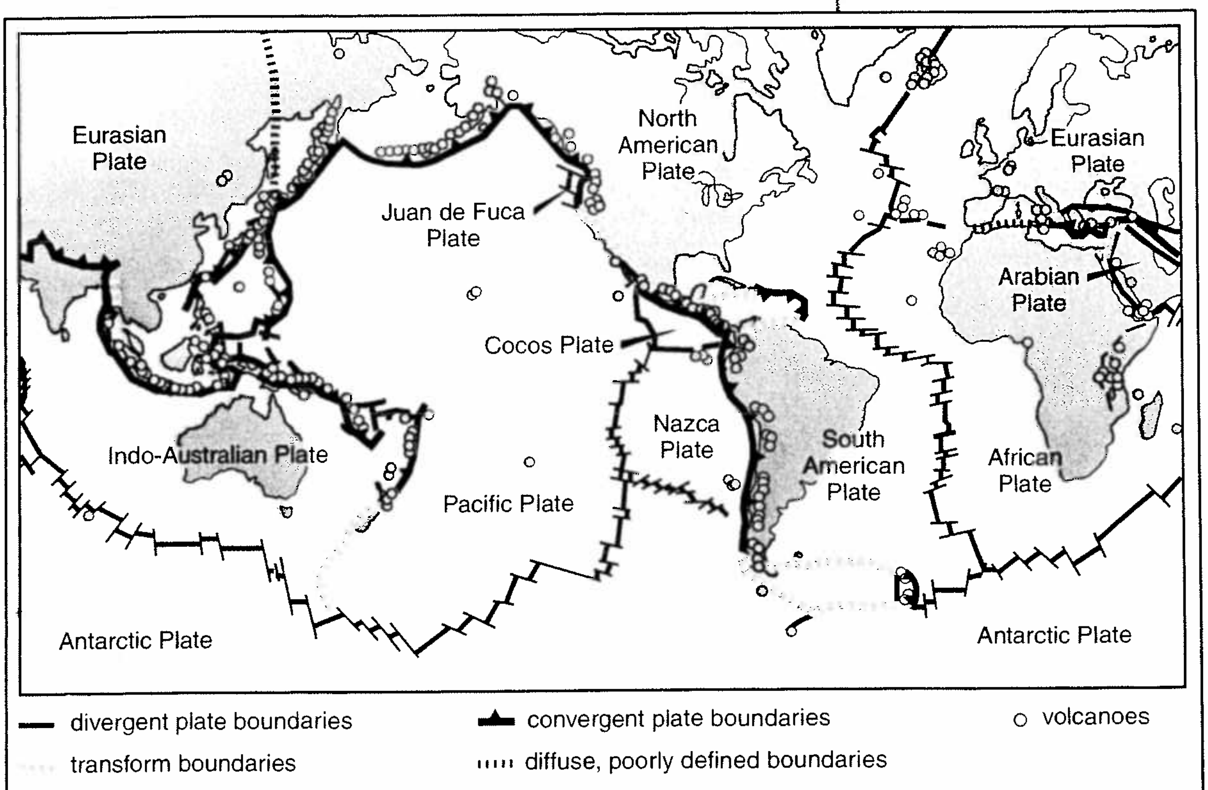
Many materials act like solids on short time scales but like liquids on much longer time scales. If you've ever played with Silly Putty®, you know all about that. Ordinary glass is also a good example. You know that it breaks easily. But if you were to take a long glass rod and hang it horizontally between two supports, it would gradually sag down in the middle. It would have flowed, to take on a new shape, even though it seems like a solid. The Earth's mantle behaves in just the same way. The speeds of flow in the mantle are only a few centimeters per year, but over millions of years of geologic time, that adds up to a lot of movement. Here's a comparison that will give you a good idea of how fast the convection cells in the mantle move: about as fast as your fingernails grow!

The Lithosphere and the Asthenosphere

The outermost part of the Earth, down to a depth of 100 to 200 km in most places, is cooler than the deeper part of the Earth. Because this outermost part of the Earth is relatively cool, it stays rigid, and it does not take part in the convection of the mantle. It is called the lithosphere ("rock sphere"). The lithosphere is made up of the crust and the uppermost part of the mantle. Below the lithosphere is a zone where the mantle rocks are just hot enough and under enough pressure that they will deform and change shape. This zone is right below the lithosphere and is called the asthenosphere. You can think of the lithosphere as a rigid slab that rides on top of the convecting asthenosphere. That is much like the cardboard that rode on top of the syrup in your model. The lithosphere consists of several pieces, each in a different part of the world. These pieces are called lithospheric plates.

Mid-Ocean Ridges

All the Earth's oceans have a continuous mountain range, called a mid-ocean ridge. These ridges are greater than 80,000 km long in total. The Earth's mid-ocean ridges are located above rising currents in mantle convection cells. You might think that the ridges are formed by the upward push of the rising mantle material, but that's not the reason. The ridges stand high because they are heated by the hot rising material. Like most materials, rocks expand when they are heated.



As the hot mantle rock rises up toward the mid-ocean ridge, some of it melts, to form molten rock called magma. The magma is less dense than the surrounding rocks, so it rises up to form volcanoes along the ridge. The reason for the melting is not obvious. As the rock

rises, it stays at about the same temperature, but the pressure on it decreases, because there is less weight of rock above it. It's known, from laboratory experiments, that the melting temperature of most rocks decreases as the pressure decreases. That's why some of the rising rock forms magma.

When the magma reaches the surface of the ridge, it solidifies to form a rock called basalt. That's how new crust is formed in the oceans. As soon as the new crust is formed, it moves away from the crest of the ridge. The movement is partly from the force of the moving mantle below. It is also partly because of the downhill slope of the ridge away from the crest. The movement of new oceanic crust in both directions away from the crest of a mid-ocean ridge is called sea-floor spreading.