ESA21
Environmental Science Activities for the 21st Century

# The Nature of Tectonic Plates

## Introduction

Imagine a swimming pool that is totally covered with air rafts, with the air rafts neatly lined up end to end and side by side. Then imagine someone running up and doing a cannonball jump into the pool. Logically, the rafts will be thrust about with some of them jamming into each other, others pulling apart, and still others sliding past one another—and so it is with the tectonic plates of Earth: some of the plates are colliding, others are pulling apart, and still others are sliding past one another; therefore, understandably, where there are boundaries between the tectonic plates, a lot of action is involved. This action typically takes the form of volcanoes and earthquakes.

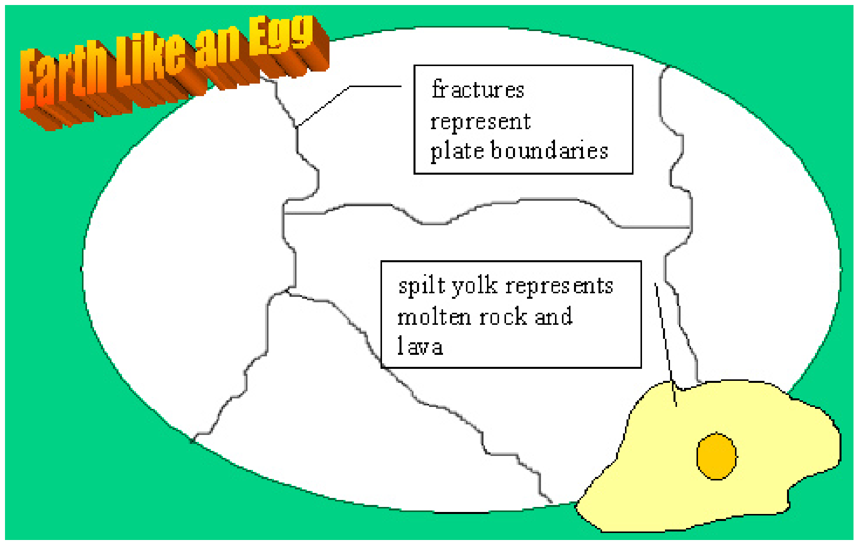


**Fig. 1: Diagram of a cracked egg with leaking yolk**

The cracked egg with the yoke spilling out in Figure 1 is quite analogous to Earth and the tectonic plates composing the crust. Each piece of the eggshell represents a tectonic plate, and the fractures represent the boundaries between the plates. In the lower right of the illustration, you see that some of the liquid interior has spilled out of one of the fractures. Like the egg, the liquid interior of Earth spills out in the form of volcanic activity, and it comes as no surprise that most volcanoes as well as earthquakes are located along the boundaries (i.e. fractures) of the tectonic plates.

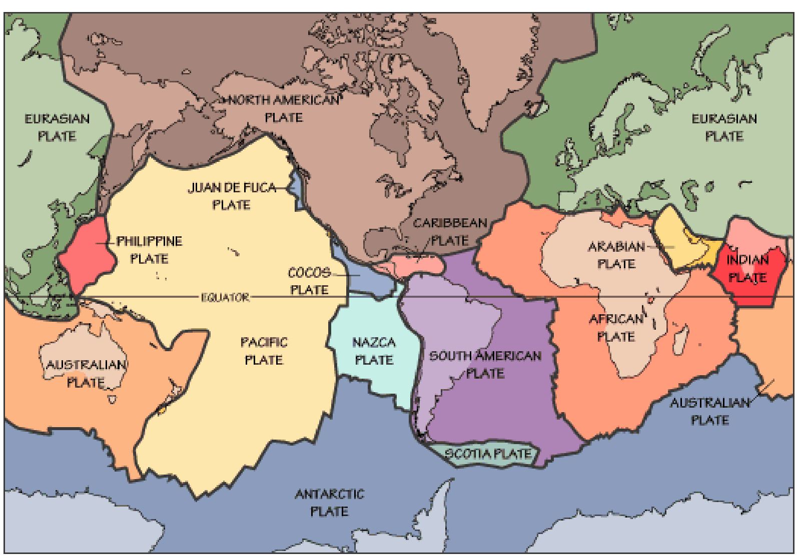


**Fig. 2: Map of the plates on Earth's surface**

Like the fractured eggshell in Figure 1, the crust of Earth is not a "unicrust", but is broken into several pieces (i.e. plates). Each plate has its own unique shape and name, and is moving relative to all of the other plates. The map in Figure 2 shows the names and locations of the major tectonic plates of Earth. (Source: National Park Service; http://www2.nature.nps.gov/geology/usgsnps/pltec/pltec2.html)

### A Lot of Action Involved

If you like the idea of being “shaked and baked”, you will want to live on a plate boundary. Just ask the people in California, Japan, Italy, and many other places. If you live in Florida Panhandle, don’t expect much in the way of earthquakes and volcanoes because that area is quite distant from a plate boundary, although you may want to keep an eye open for tornadoes and hurricanes. To see two maps that show clearly the relationship between plate boundaries and most earthquakes and volcanoes, go to this USGS (United States Geological Survey) web site:

http://vulcan.wr.usgs.gov/Glossary/PlateTectonics/Maps/map_quakes_volcanoes_plates.html

It is important to note that not all earthquakes and volcanoes are associated with plate boundaries. If you go to the web page http://earthquake.usgs.gov/regional/states/us_damage_eq.php , you can see on the map that the red boxes on the US map represent major earthquakes. Notice how a red box is over South Carolina, which is quite distant from a plate boundary. Notice also a red box over the St. Louis, Missouri area. Although this area is not an active plate boundary, geologic history shows that it almost became one in the past, and the geology in the area still possesses instability. You may have heard of the New Madrid Fault System. In 1812, a major earthquake occurred with this fault system. You may have heard about the earthquake that caused the Mississippi River to flow backwards and the church bells to ring as far away as Boston, Massachusetts. In 1990, a scientist predicted it would occur on a certain day of that year. It caused a lot of fear and precaution, but nothing happened. Even to this day, earthquake prediction is difficult, and, if you try to become famous by predicting an earthquake to a single day, you’re likely to look silly although there have been a few accurate predictions.

### Pulling, Pushing, or Sliding By

As mentioned in the opening paragraph, tectonic plates collide, pull apart, and also slide past one another. Related to the particular action of a boundary, geologists have names for the different types of boundaries:

- Divergent boundaries (i.e. pulling apart; e.g. Mid-Atlantic Ridge)
- Convergent boundaries (i.e. pushing together; e.g. Mariana Trench near Guam)
- Transform boundaries (i.e. sliding by; e.g. San Andreas Fault)
- Plate boundary zones (i.e. indistinct but active area; e.g. western Mediterranean)

A web page published by the USGS (United States Geological Survey) elaborately explains the nature of these boundaries. The URL for the web page is the following:

http://pubs.usgs.gov/gip/dynamic/understanding.html

Note that at each type of boundary, you get a different set of natural phenomena. For instance, explosive volcanoes are found at certain convergent boundaries, whereas transform boundaries have never had an example of a volcano.

**Figure 3. The San Andreas Fault presents a dramatic and clear surface manifestation of a transform boundary between two tectonic plates: Pacific Plate on the west and North American Plate on the east. (Photo: USGS)**

Figure 4 shows a map of the Pacific Ocean that identifies the types of boundaries between the tectonic plates. The green coloration represents divergent (i.e. pulling apart) boundaries; the red coloration represents convergent (i.e. colliding) boundaries; the lavender coloration represents transform (i.e. sliding by) boundaries; and the dashed lines represent diffuse plate boundary zones.

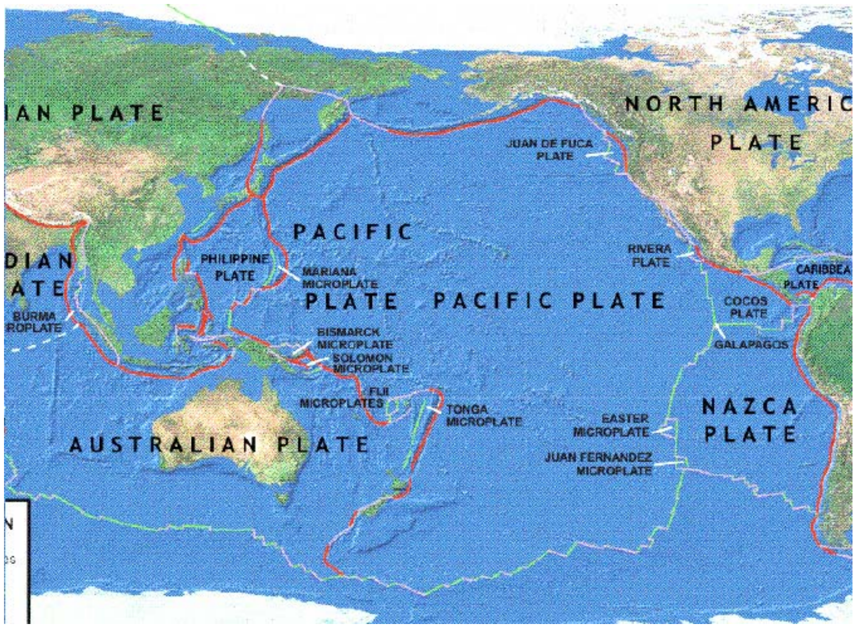


**Fig. 4: Plate boundaries in the Pacific Ocean (*USGS*)**

PBS has a web site with a plate tectonic activity that illustrates in an active fashion what goes on at different plate boundaries and where on the globe the different types of boundaries are located: [http://www.pbs.org/wgbh/aso/tryit/tectonics/#](http://www.pbs.org/wgbh/aso/tryit/tectonics/#) . When you get to the web page, click where it says "Plate Tectonic Activity". The activity requires the software Shockwave, which is free to download if you don't have it on your computer. If you so choose, there is a link on the PBS web page to download Shockwave, which is free.

The PBS activity has arrows that you click on and drag for a dynamic illustration of what happens at the different plate boundaries. Also, clicking on an arrow shows on the map below the arrows the locations of the particular types of plate boundaries.

### Oceans Getting Smaller and Oceans Getting Bigger

In 1492, Columbus sailed the ocean blue. If Columbus were to sail the ocean blue to the New World today like he did in 1492, his sailors would more likely mutiny because the trip would be longer today by about 10 meters. Running down the center of the Atlantic Ocean is a long, volcanic, undersea mountain range known as the Mid Atlantic Ridge. This ridge is a divergent plate boundary; that is, the two plates are separating, thereby making the Atlantic Ocean wider. Europe, the Americas, and Africa were all joined together over 200 million years ago. Given enough geologic time, a huge ocean will develop as a result of continental separation.

The Pacific Ocean, on the other hand, is becoming smaller because most of the oceanic crust is sliding underneath the continental crust that borders the Pacific. Take a look at the map in Figure 4 and you will see that mostly convergent plate boundaries form the borders of the Pacific Ocean, meaning that the tectonic plates underneath the Pacific Ocean are sinking below while the continental plates and other oceanic plates are pushing over the sinking tectonic plates. Because of all the earthquake and volcanic activity at these boundaries, a nickname was given to the border of the Pacific Ocean: the "Ring of Fire". One can find information about the **Ring of Fire** at [http://pubs.usgs.gov/gip/dynamic/understanding.html](http://pubs.usgs.gov/gip/dynamic/understanding.html) .

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**ESA21: Environmental Science Activities**

Activity Sheet
The Nature of Tectonic Plates

Name: ________________________________

1. You are in charge of locating a nuclear power plant in a geologically sound area that is free of volcanoes and strong earthquakes. Using the maps from the lecture part of this activity and perhaps other sources at your disposal, pick <u>one</u> of the locations below for your nuclear power plant site. Explain your reasons for thinking that the location you chose is a geologically safe area in terms of plate tectonics.

   a. St. Louis, Missouri
   b. Tallahassee, Florida
   c. Anchorage, Alaska
   d. Seattle, Washington

2. Based on what you know about the relationship between earthquakes and plate boundaries, how does the history of large earthquakes in South Carolina fit with the plate boundary-earthquake relationship? Don't forget to use the maps linked in the lecture part of this activity to help you.

3. Of the following 6 locations, which 3 locations are possibly excellent locations for geothermal power plants? Explain why you chose them.

   a. Buenos Aires, Argentina
   b. Hokkaido, Japan
   c. Iceland
   d. New York
   e. East Africa
   f. Moscow, Russia

4. The Andes Mountains of South America were formed as part of the process of oceanic crust sliding underneath continental crust. The volcanic islands that compose Japan were produced by oceanic crust of one tectonic plate sliding underneath oceanic crust of another tectonic plate.

   The Himalayans of southern Asia are the highest mountains in the world and are still growing. Answer the following questions: *(The Shockwave activity found at http://www.pbs.org/wgbh/aso/tryit/tectonics/# can be helpful in determining your answers.)*

   a. What is happening to cause the tremendous Himalayan orogeny (i.e. mountain building)?

   b. What tectonic plates are involved, and what is the nature of the plate boundary between these plates?

5. Many people around the world live near plate boundaries because of soil fertility. What logical reason explains why soil tends to be quite fertile near plate boundaries?

6. In 1977, Dr. Robert Ballard, who also discovered the resting place of the Titanic, discovered a strange and bountiful world of life in the deep Pacific Ocean near the Galapagos Islands. The life was near hydrothermal vents whereby water was superheated by magma (i.e. molten rock) near the surface of the ocean floor. It came quite as a surprise to many biologists, who thought that life in the deep ocean was rather scarce. It is now assumed that life can be found anywhere on the deep ocean floor wherever there is heat and hydrogen sulfide, which, interestingly, is the base of the food chain of these light-deprived communities.

   Using the information above, let us now play make believe. Let us pretend that you are captain of a ship transporting plutonium across the Atlantic Ocean to supply a European country with fuel for nuclear power plants. Just after you leave the east coast of the United States, your ship is hijacked by pirates who plan to take the plutonium to another country across the Atlantic for the purpose of making nuclear weapons; therefore, as captain, you must make a decision to save the world, so, you consider dumping the plutonium in the ocean as the lesser of two evils rather than it be delivered for criminal bomb-making. Now, you must decide where in the Atlantic to dump the plutonium. You want to dump it where there is the least likelihood of bountiful life, and you know there is perhaps plentiful life where there are hydrothermal events near where the ocean crust is rather thin and magma is near the ocean floor.

   Here's the question:

   Would you dump the plutonium (a.) ¼ or ¾ of the way across the Atlantic from the US east coast <u>or</u> (b.) ½ of the way across the Atlantic at about the midline of the Atlantic Ocean? Choose one of the two answers and explain why you chose that answer in reference to the relationship between deep ocean life and plate tectonics.