Using Google Earth to Explore Plate Tectonics

Laurel Goodell, Department of Geosciences, Princeton University, Princeton, NJ 08544 laurel@princeton.edu

Inspired by, and borrows from, the GIS-based <u>Exploring the Dynamic Earth</u> series of Saquaro exercises authored by Michelle K. Hall, Science Education Solutions, Los Alamos, NM (http://www.scieds.com/).

In order to understand "how the earth works," it is important to understand <u>*plate tectonics*</u> - the unifying framework for understanding the dynamic geology of the Earth.

For this preparation assignment, you will examine several types of patterns on Earth – the topography of the earth's surface above sea level, the bathymetry of the ocean floor below sea level, and the distribution of earthquakes and volcanoes - and investigate how these features are used to define tectonic plate boundaries.

You will be using the program Google Earth, Google Earth overlays created by various members of the scientific community, and information from the United States Geologic Survey.

A. Set up your computer with Google Earth

- 1. Download (for free) and install Google Earth from http://earth.google.com/
- 2. Download and open the following file in Google Earth **Dynamic_Earth.kmz**
- 3. Once the data file is in Google Earth, move it from "Temporary Places" to "My Places." It will now be available every time you open Google Earth on this particular computer.
- 4. Ok, with an active internet connection, you now have an interactive view of the earth including plate boundaries, sea floor age, volcano locations, and earthquake locations. Take a few minutes to explore the Earth with Google Earth. For example:
 - Zoom in and out, grab and spin the globe, etc. The resolution will change as you zoom.
 - Expand the Dynamic_Earth files by clicking on the plus signs. Clicking on the minus signs reduces them. Turn the various layers on and off by clicking and un-clicking the boxes.
 - Right-click on a volcano or an earthquake to get information on that item.
 - Type your home address (or any place of interest) into the <u>Search/Fly to</u> window and click the magnifying glass.

While it is tempting to keep on "Google-surfing" the Earth, we must carry on to the rest of the assignment...

B. Topographic Patterns Uncheck all of the layers and focus on topographic features of the earth. **Topography of the earth** *ABOVE* **sea level**

- 5. Are mountains randomly distributed on the continents, or do they tend to occur in particular patterns (clusters, linear chains, arcs, etc.)?
- 6. Look up and give the elevation of Mt. Everest, the highest point on earth: ft = meters

Topography of the earth BELOW sea level

7. Before maps of sea floor topography became available, most people believed that the seafloor was relatively flat and featureless. Personal experience with lakes and rivers suggested that the deepest part of the ocean should be near the middle. Mapping of ocean floor, however, revealed some surprises. On Google Earth, the bathymetry of the ocean floor is shown with shades of blue; the darker the blue the deeper the water.

Examine the Atlantic Ocean between South America and Africa. Does it have a smooth bottom? Does depth increase or increase toward the middle? Describe the topography that you find in the middle of the Atlantic Ocean (a plain, a valley, a mountain chain, etc.)

8. Features like the one running down the middle of the Atlantic Ocean are called *mid-ocean ridges* or *spreading ridges* (more on the "spreading" later). Zoom in enough to see that although the ridge is a topographic high, it also has a valley (the "rift valley") running along the middle of it. In the space below, complete the topographic profile of the Atlantic Ocean floor between South America and Africa.

South America	Atlantic Ocean	Africa
	Allantic Occum	~

9. If the earth's lowest spots aren't in the middle of the ocean, where are they? Focus on the west coast of South America, and in the space below complete the topographic profile of the Pacific Ocean floor from South America westward about 600 miles (1000 km).

South America Pacific Ocean

The deep linear features, the lowest points on Earth, are called *ocean trenches*.

- 10. Using Google Earth, "fly to" Challenger Deep, the deepest place on Earth (once Google Earth gets you there, you may have to zoom out to see where you are). Where is it?
- 11. Challenger Deep reaches 11 km (36,000 ft) below sea level. Which is greater, the elevation of Mt Everest (see question 6) above sea level, or the depth of Challenger Deep below sea level, and by how much? Does this surprise you?

C. Earthquake Patterns

An earthquake is a vibration of Earth caused by the sudden release of energy, usually as an abrupt breaking of rock along planar fractures called *faults*. But only rocks that are cold and brittle can be broken in earthquakes. Rocks that are hot and ductile will stretch and deform slowly over time without breaking – and thus do not produce earthquakes. So observing where earthquakes occur, both horizontally and with depth, tells us something about where stress is concentrated, and about the material properties of the earth.

12. Expand the "Earthquake" folder by clicking the plus sign. .

Click off (if necessary) the other earthquake layer(s), and click on the "M+, past 7 days, plotted by magnitude" layer. Keep clicking until you expand the "Colored by age" layer and see a list of the number of earthquakes of each magnitude that have occurred in the last week. Record the information below:



Graph this information below. Note that the y-axis is a log scale.



13. Using your graph, predict about how many earthquakes of magnitude 0 have occurred in the past week (yes, earthquake magnitudes can be 0 and even less than 0).

Predicted number of earthquakes of magnitude 0 = _____

- 14. Click on the "Twenty years of large earthquakes" layer in Google Earth to show the locations of relatively large earthquakes (those with magnitudes >= 6.0) during a 20 year period. Describe any patterns you see in the distribution of earthquakes over the Earth's surface do they form lines, arcs, circles or clusters? Are patterns connected or disconnected?
- 15. What color are the <u>shallowest</u> earthquakes? _____ The <u>deepest</u>?_____
- 16. Look closely at the Earth's ridges and trenches. The earthquake depth patterns associated with these two types of features are different. Complete the chart below:

	at ridges	at trenches
Depth or range of depths or earthquakes		

17. Is the Earth's rigid outer layer (the *lithosphere*) thicker at riches or at trenches? Justify your answer.

D. Volcano Patterns

A *volcano* is an opening in the Earth's surface through which melted rock (*magma*), volcanic ash and/or gases escape from the interior of the Earth.

18. Leaving the "Twenty Years of Large Earthquakes" on, click on the Active Volcanoes layer in Google Earth. Describe the relationship between the locations of most active volcanoes and locations of earthquakes.

E. Plate Boundaries

The theory of plate tectonics posits that the Earth's lithosphere is broken into a finite number of jigsaw puzzle-like pieces, or *plates*, which more relative to one another over a plastically-deforming (but still solid) *asthenosphere*. The boundaries between plates are marked by active tectonic features such as earthquakes, volcanoes, and mountain ranges and there is relatively little tectonic activity in the middle of plates.

Click on the "plate boundary" layer (click the box to show it and click the + sign to expand the legend). Click the other layers on and off as needed so that you can see the plate boundaries and their relationships to other features.

Boundary between the African and South American plates

- 19. Where is this plate boundary, relative to the coastlines of Africa and South America?
- 20. Click on and explore the "Seafloor age" layer. Describe the pattern of ages associated with this plate boundary.
- 21. If you did not have the "plate boundary layer" available to you, how could you determine where this plate boundary was? List several ways and be specific.

Travel westward across the South American plate to its boundary with the Nazca plate

- 22. Where is this plate boundary, relative to South America?
- 23. If you did not have the "plate boundary layer" available to you, how could you determine where this plate boundary was? List several ways and be specific.

F. Putting it all together

- 24. On a separate sheet of paper, sketch a cross-section along approximately 10°S latitude that starts in Africa and goes westward across the southern Atlantic Ocean, across South America, and ends in the middle of the Pacific Ocean around 130°W longitude. (Plate-wise that would be from the middle of the African plate, across the South Atlantic plate, across the Nazca plate, and ending in the middle of the Pacific Plate.) You will end up crossing 3 major plate boundaries (African-South American, South American-Nazca, Nazca-Pacific). Use the Google Earth imagery and layers to give you the necessary detail so that you include and label the following on your sketch:
 - Sea level
 - Significant topographic features of the continents and sea floor (e.g. mountain ranges, ocean ridges, ocean trenches).
 - Earthquake hypocenters (indicating depth from epicenter)
 - Volcanoes
 - Plate names and plate boundary locations