

Name: \_\_\_\_\_

## Using Google Earth to Explore Plate Tectonics


*Adapted from the GIS-based Exploring the Dynamic Earth series of Saquaro exercises authored by Michelle K. Hall, Science Education Solutions, Los Alamos, NM (<http://www.scieds.com/>), and Laurel Goodell, Department of Geosciences, Princeton University, Princeton, NJ 08544 [laurel@princeton.edu](mailto:laurel@princeton.edu)*

In order to understand “how the earth works,” it is important to understand plate tectonics - 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. If it is not already installed on your computer install Google Earth from <http://earth.google.com/>
2. Open a browser (preferably Chrome or Firefox - do not use Internet Explorer!) and download to your desktop the Google Earth file “**Dynamic\_Earth.kmz**” from the lab website: <http://www.grossmont.edu/people/gary-jacobson/geology-111.aspx> , then open the file.
3. 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 or reduce the Dynamic\_Earth files by clicking on the tiny triangles. 
  - Turn the various layers on and off by clicking and un-clicking the boxes. You might want to turn off the “Primary Database” under “Layers” and then minimize the entire “Layers” section to keep your display free of clutter.
  - 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 Search window and click search or hit enter.

**B. Topographic Patterns** Turn-off (uncheck) **ALL** of the layers and focus on the topographic features of the earth. Your cursor's elevation/depth and latitude/longitude is displayed at the bottom right.

#### Topography of the earth ABOVE sea level

4. Type Cowles Mountain, CA into the Search window and click search (or hit enter). Find the exact elevation, latitude and longitude of the very top of Cowles Mountain: \_\_\_\_\_ feet \_\_\_\_\_ lat. \_\_\_\_\_ long. Notice that the largest canyons that cut across the Cowles-Fortuna Mountain Range are roughly parallel to each other. Use the compass in the upper right corner to determine in what average direction they align (e.g. north-south, east-west, northwest-southeast, northeast-

southwest). \_\_\_\_\_

5. Navigate to Mt. Everest and give the elevation (in feet), latitude and longitude of the highest point on earth: \_\_\_\_\_ft \_\_\_\_\_lat. \_\_\_\_\_long.

### **Topography of the earth *BELOW* sea level**

6. 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. Make sure the water surface is unchecked in Google Earth so you can see the sea floor (look under "VIEW").

Examine the Atlantic Ocean floor near 15°S;13°W. Find the top of the Mid-Atlantic Ridge closest to that point and, using the **line tool**, draw a 1000-mile long line from that point perpendicular to the ridge towards the west. Find the depths at either end of the line and calculate the slope gradient of the Mid-Atlantic Ridge in feet per mile. (*show your work*)

Examine the Pacific Ocean floor near 17°S;113°W. Find the top of the East Pacific Rise closest to that point and, using the **line tool**, draw a 1000-mile long line from that point perpendicular to the rise towards the west. Find the depths at either end of the line and calculate the slope gradient of the East Pacific Rise in feet per mile. (*show your work*)

7. The deep linear features, the lowest points on Earth, are called *ocean trenches*. Using Google Earth, "fly to" the Challenger Deep, the deepest place on Earth (once Google Earth gets you there, you may have to zoom out to see where you are). What island is a little more than 200 miles northeast of the Challenger Deep? \_\_\_\_\_ Describe the general shape of the ocean trench along which the Challenger Deep is located (e.g. line, arc, zigzag etc.) \_\_\_\_\_

8. What is the maximum depth of the Marianas Trench at the Challenger Deep? \_\_\_\_\_feet. Which is greater, the elevation of Mt Everest (see question 5) above sea level, or the depth of Challenger Deep below sea level, and by how much? \_\_\_\_\_

## C. Earthquake Patterns

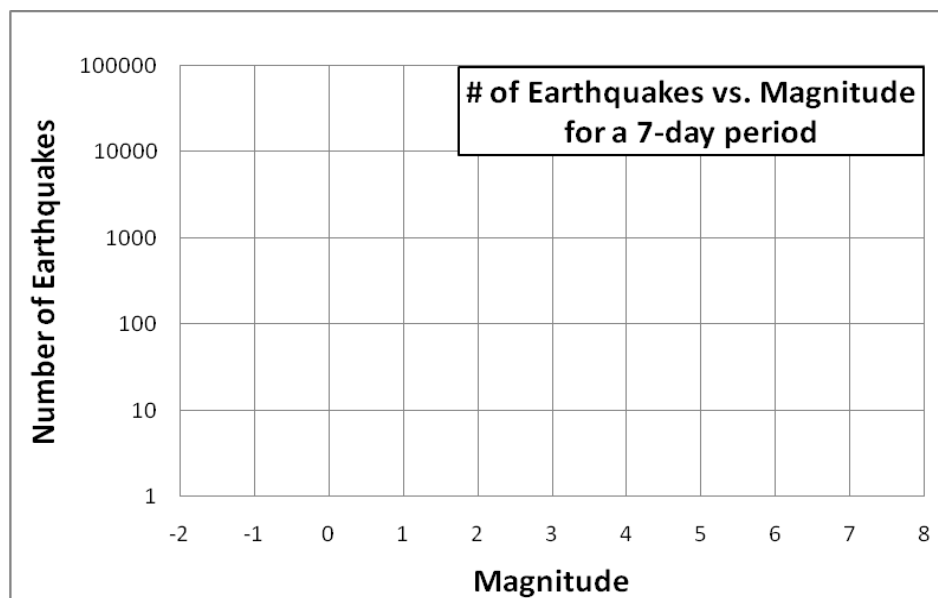
An earthquake is a vibration of Earth caused by the sudden release of energy, usually as an abrupt breaking of rock along planar fractures called *faults*. But only rocks that are relatively cold and brittle (i.e. lithosphere) can be broken in earthquakes. Rocks that are hot and ductile (i.e. asthenosphere) 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.

- Expand the “**Dynamic\_Earth.kmz**” file (it should be turned off), then expand the “**Dynamic Earth**” folder, and then expand the “**Earthquake**” folder by clicking the tiny triangle next to the folder.

Turn *on* the “**M1+, past 7 days, plotted by magnitude**” layer and turn *off* (if necessary) all other earthquake layer(s). Expand the “**M1+, past 7 days, plotted by magnitude**” folder 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:

Magnitude 7 \_\_\_\_\_  
Magnitude 6 \_\_\_\_\_  
Magnitude 5 \_\_\_\_\_  
Magnitude 4 \_\_\_\_\_  
Magnitude 3 \_\_\_\_\_  
Magnitude 2 \_\_\_\_\_  
Magnitude 1 \_\_\_\_\_

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



- 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 = \_\_\_\_\_

11. Turn *off* the “**M1+, past 7 days, plotted by magnitude**” layer, compress that folder, and then turn on the “**Twenty years of large earthquakes**” layer to show the locations of relatively large earthquakes (those with magnitudes  $\geq 6.0$ ) 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?

12. What color are the shallowest earthquakes? \_\_\_\_\_ The deepest? \_\_\_\_\_

13. Look closely at the ocean 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		

14. Is the Earth’s rigid outer layer (the *lithosphere*) deeper at ridges 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.

15. Leaving the “**Twenty Years of Large Earthquakes**” layer on, turn on the “**Volcanoes of the World**” 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 asserts that the Earth's lithosphere is broken into a finite number of jigsaw puzzle-like pieces, or *plates*, which move 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.

Turn on the “**Plate boundary**” layer (click the box to show it and click tiny triangle to expand the legend). Also turn on the “**Plate labels**” layer. Turn the other layers on and off as needed so that you can see the plate boundaries and their relationships to other features.

Double click on the **African - South American** plate boundary to fly to it.

16. Where is this plate boundary, relative to the coastlines of Africa and South America?
17. Turn on and explore the “**Seafloor age**” layer. Describe the pattern of ages associated with this plate boundary.
18. 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

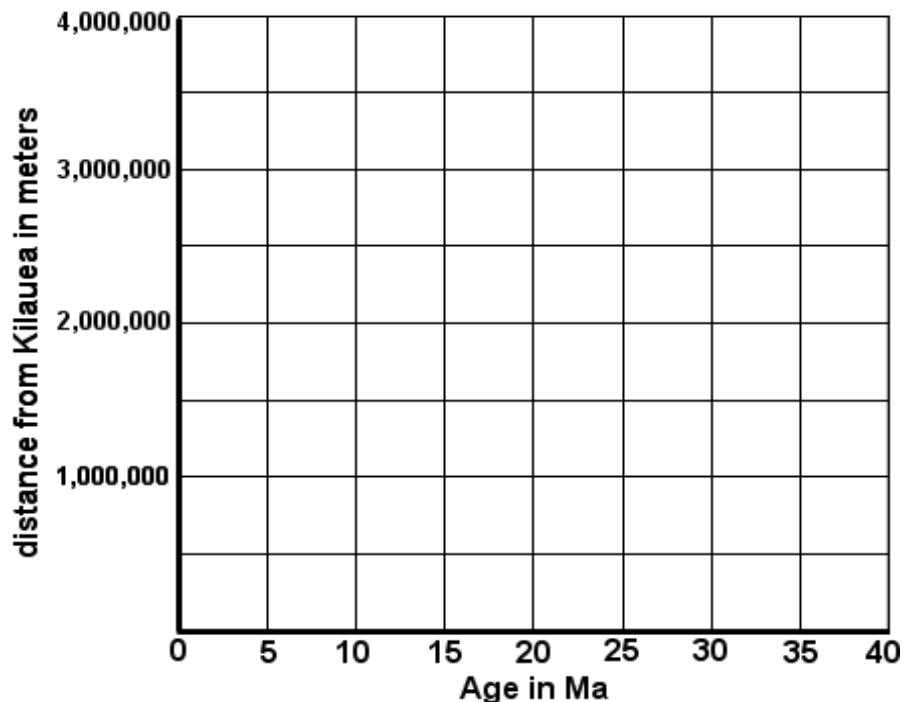
19. Where is this plate boundary, relative to South America?
20. If you did not have the “plate boundary layer” available to you, how could you determine where this plate boundary was? List several ways and be specific.

## G. Rate of plate motion from hot spots

Two good examples of present-day hot spot volcanism, as derived from mantle plumes beneath crustal plates, are Kilauea on Hawaii (on the Pacific oceanic plate) and the Yellowstone caldera (on the continental North American plate). Each of these hot spots has produced a chain of inactive volcanic islands and fields on the Pacific and North American plates, respectively. The purposes of this exercise are to use ages, locations, and distances for each of these hot spot chains to determine 1. Absolute movement directions; and 2. Movement rates for both the Pacific and western North American plates, and then to use this information to determine 3. The rate of relative movement along the transform boundary between these two plates in southern California (**San Andreas fault system**).

21. Collapse and turn off the “**Dynamic\_Earth.kmz**” layer you just worked with. Download to your desktop the Google Earth file “**Hawaii\_Chain.kml**” from the lab website: <http://www.grossmont.edu/people/gary-jacobson/geology-111.aspx> , then open the file in Google Earth. You will see a series of labeled white dots that mark significant volcanoes along the Hawaiian chain. If you click on each of these dots, you will get pop-up text boxes that indicate the age of each volcano or island (Ma = millions of years). By using the ruler tool in Google Earth, you can determine the distance from each of these volcanoes to Kilauea (on the big island of Hawaii). With this age and distance data for each volcano, construct a table and graph of distance (meters from Kilauea) on the y-axis and age of each volcano (in years) on the x-axis. Note that you don’t need to include Lo’ihi seamount on this graph; it is included in the KML file only to show where the next island in the Hawaii chain will be located. Draw a best-fit (linear) trend-line to the data points on your graph. The slope (distance/time) of this line is the average rate of movement of the Pacific plate (in meters/year) during the period of time represented by the age range of the volcanoes.

LOCATION	AGE (Ma)	DIST. FROM KILAUEA (m)
Kilauea	0	0
Mauna Kea		
Haleakala		
West Maui		
Lanai		
East Molokai		
West Molokai		
Ko’olau		
Kauai		
Niihau		
Nihoa		
Necker Island		
Laysan		
Midway		



22. What is the average rate of movement of the Pacific plate (in meters/year):

\_\_\_\_\_

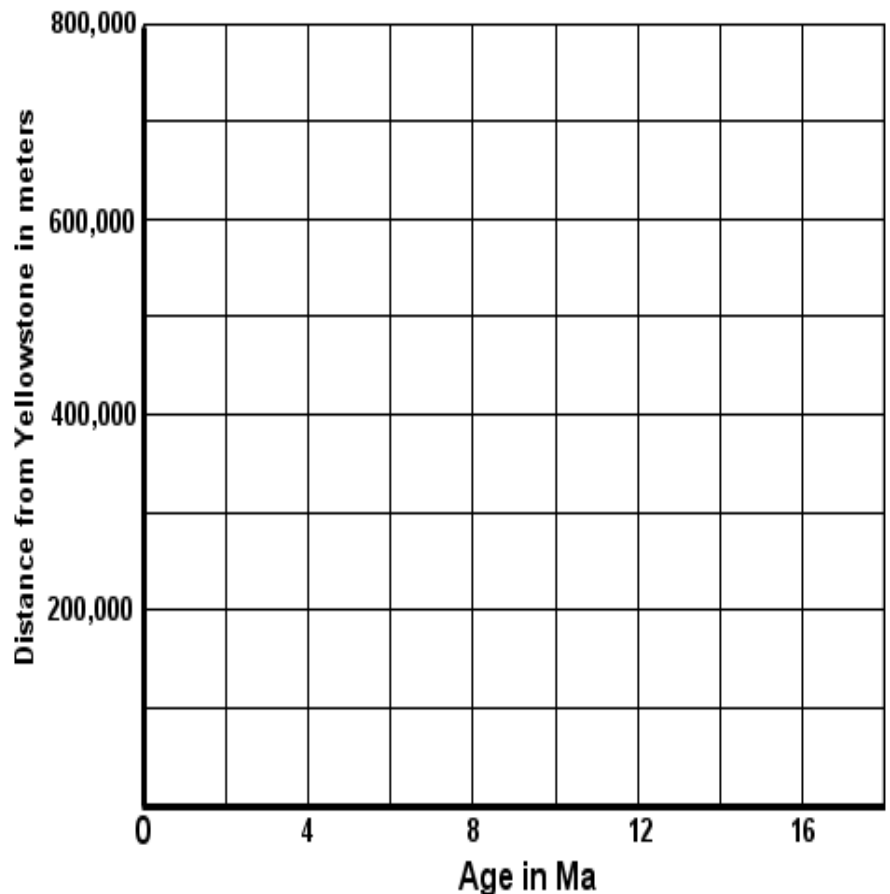
23. In what direction has the Pacific plate been moving (to the nearest degree):  
 \_\_\_\_\_ (Hint: the ruler tool in Google Earth will also give you the heading (angle clockwise from North) of the measuring line.)

24. Note the dogleg change in orientation of the seamount chain to the northwest of the Hawaiian island chain. Based on your calculated rate of movement in question 25, approximately when (in Ma) did the Pacific plate change its direction of movement? \_\_\_\_\_

25. Zoom in close enough to Mauna Kea and West Maui volcanoes to see the canyons carved into these volcanoes. What is the relationship between volcano age and canyon depth/development?

26. Load the file **Snake\_River\_Plain.kml** in Google Earth. You will see a series of labeled white dots that mark the major volcanic fields in southern Idaho and northeastern Oregon that lead to the Yellowstone caldera. If you click on each of these dots, you will get pop-up text boxes that indicate the approximate age of each volcanic field (Ma = millions of years). By using the ruler tool in Google Earth, you can determine the distance from each of these volcanic fields to the Yellowstone caldera. With this age and distance data for each volcanic field, construct a table and graph of distance (meters from the Yellowstone caldera) on the y-axis and age of each volcanic field (in years) on the x-axis. Draw a best-fit (linear) trendline to the data points on your graph. The slope (distance/time) of this line is the average rate of movement of the western part of the North American plate (in meters/year) during the period of time represented by the age range of the volcanic fields.

VOLCANIC FIELD	AGE (Ma)	DIST. FROM YELLOWSTONE (meters)
Yellowstone		
Heise		
Edie School		
WAlcott		
Arbon Valley		
Twin Falls		
Brunea-Jarbidge		
McDermitt		
Owyhee-Humboldt		



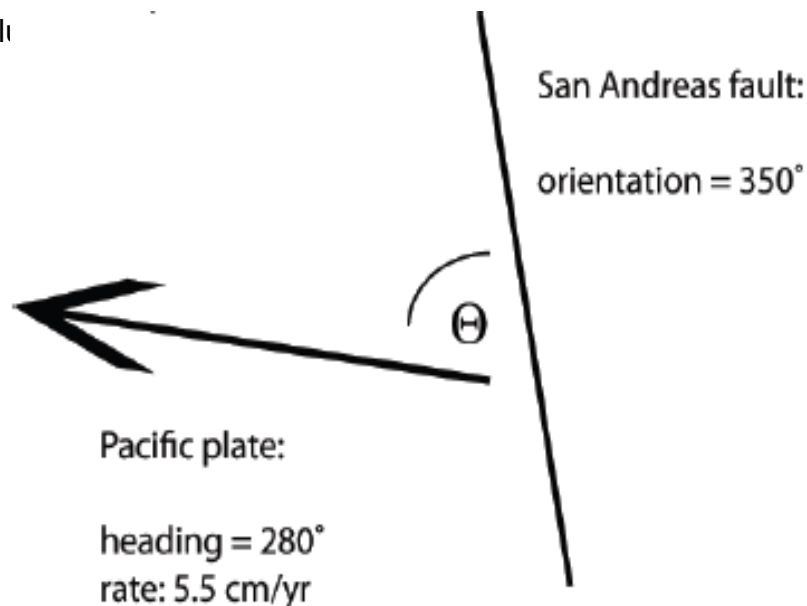
27. What is the average rate of movement of the western part of the North American plate (in meters/year): \_\_\_\_\_

28. In what direction has the western part of the North American plate been moving (to the nearest degree): \_\_\_\_\_

29. Does your graph suggest that the movement rate may have changed at some point during the past 16 million years? Explain.

30. The San Andreas fault system along the southern coast of California represents the transform boundary between the North American and Pacific plates. This is indicated by the thick blue line in the file **Tectonic\_Plates.kml** (open in Google Earth). In order to determine the relative rate of movement along this boundary, where the Pacific plate moves approximately northward relative to the North American plate, you will need to separate the movement vectors (rate and direction) for each plate that you calculated in parts 1 and 2 into components parallel to the San Andreas fault and components perpendicular to the San Andreas fault. In actuality, we are only interested in the components parallel to the San Andreas fault system. You already know the rates (magnitudes) and directions for the vectors that represent the movement of the Pacific and North American plates. Now all you need is the orientation (direction) of the San Andreas fault, and you can use trigonometry to calculate the movement rates along the fault.

Example (value)



Since you know the rate of the Pacific plate and the angle between the Pacific plate direction and the orientation of the San Andreas fault, you can use trigonometry to find the rate along the San Andreas fault. Use the same process to find the vector component for North American plate movement that is parallel to the San Andreas fault. Add the two vector components that parallel the San Andreas fault to get the relative plate movement along the fault.

31. What is the rate of movement of the Pacific plate relative to the western part of the North American plate along the San Andreas fault system? \_\_\_\_\_



32. What is the relative sense of movement along the San Andreas fault system?

a. Left-lateral (sinistral: Pacific plate moves south relative to North American plate)



b. Right-lateral (dextral: Pacific plate moves north relative to North American plate)



33. Is there compression or extension perpendicular to the San Andreas Fault?

Explain:

#### References

Anders, M.H., 1994, Constraints on North American plate velocity using the Yellowstone hotspot deformation field, *Nature*, vol. 369, p. 53-55.

Clague, D. A. and Dalrymple, G. B., 1989, Tectonics, geochronology, and origin of the Hawaiian-Emperor Chain, *in* Winterer, E. L., Hussong, D. M., and Decker, R. W., eds., *The Eastern Pacific Ocean and Hawaii*, Boulder, Geological Society of America, p. 188-217. (including references therein)

Pierce, K. L. and Morgan, L. A., 1992, The track of the Yellowstone hot spot: Volcanism, faulting, and uplift, *in* Link, P. K., Kuntz, M. A., and Platt, L. B., eds., *Regional Geology of Eastern Idaho and Western Wyoming*, *Geological Society of America Memoir* 179, p. 1-53.