

Name(s) _____

Hot Spots and Plate Movement exercise

Two good examples of present-day hot spot volcanism, as derived from mantle plumes beneath crustal plates, are Kilauea, Hawaii (on the Pacific oceanic plate) and Yellowstone (on the continental North American plate). These hot spots have produced a chain of inactive volcanic islands or seamounts on the Pacific plate (Fig. 1) and volcanic calderas or fields on the North American plate (Fig. 2) – see the figures below.

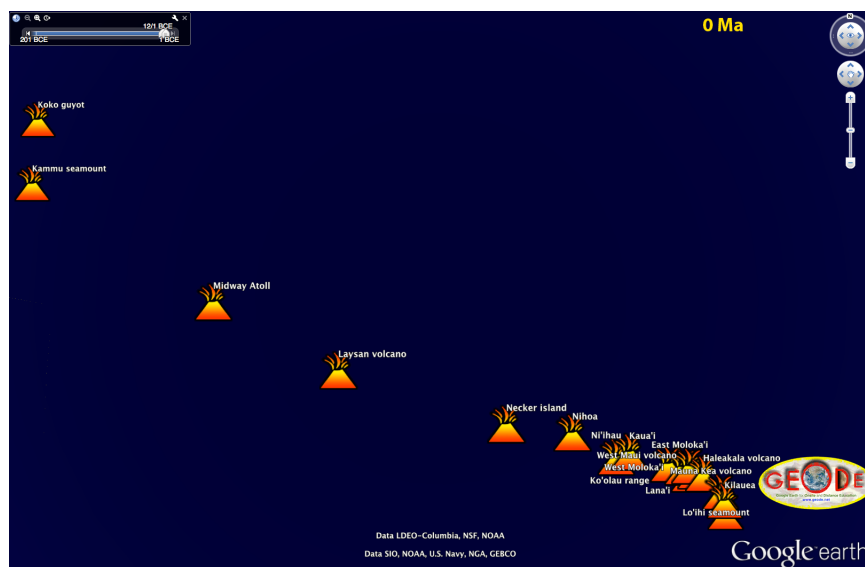


Figure 1. Chain of islands and seamounts produced by the Hawaiian hot spot.

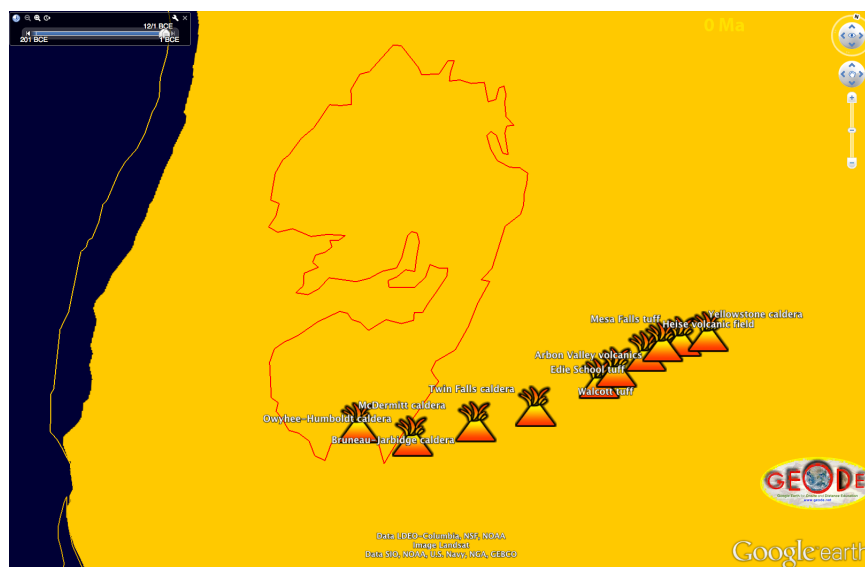


Figure 2. Chain of volcanic fields produced by the Yellowstone hot spot.

The purposes of this exercise are to use locations, ages, and displacements 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. Whether the rates and directions of the movement of these two plates have been the same or different over the past 16 million years.


This exercise uses the Pangaea Breakup animation, which is a KML file that runs in the standalone Google Earth application. To download the Pangaea Breakup KML file, go here:

<http://geode.net/pangaeaBreakup/PangaeaBreakup.kml>

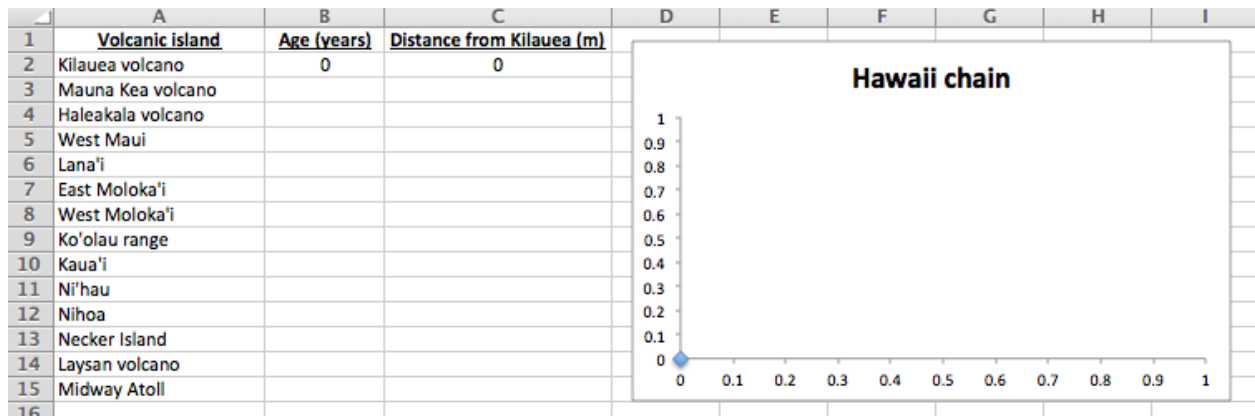
To download Google Earth for your computer, go here:

<https://www.google.com/earth/download/ge/agree.html>

Part 1. Hawaiian Island Chain

Load the **PangaeaBreakup.kml** file in Google Earth. Make sure the time period in the upper right of the screen says “0 Ma” and then select “Hot Spot Volcanos” under “Features” in the Places menu on the left of the screen. Rotate the globe until you see a string of volcano icons in the middle of the Pacific ocean. Zoom in until you see the text labels for the volcanoes (like Fig. 1 above). If you click on each of these volcano placemarks, 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  located at the top of the Google Earth window, 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, use Microsoft Excel to construct a chart of distance (meters from Kilauea) on the y-axis and age of each volcano (in years) on the x-axis (see screenshots of Excel below). 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 in the future.



Now, in Excel, fit a best-fit (linear) trendline to the data points on your graph. The slope 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.

Print out your spreadsheet and graph to turn in, and answer the following questions:

1. What is the average rate of movement of the Pacific plate (in meters/year): _____
2. 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 of the measuring line)
3. Note the dogleg change in orientation of the seamount chain to the northwest of the Hawaiian island chain (upper left region of Fig. 1 at the location of the Kammu seamount). Based on your calculated rate of movement in question 1, approximately when (in Ma – millions of years ago) did the Pacific plate change its direction of movement?

Part 2. Yellowstone Volcanic Fields

Now rotate the globe until you see a string of volcano icons in western North America. Zoom in until you see the text labels for the volcanic fields in northeastern Oregon and southern Idaho that lead to the Yellowstone caldera (like Fig. 2 above). If you click on each of these placemarks, 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, use Microsoft Excel to construct a chart of distance (meters from the Yellowstone caldera) on the y-axis and age of each volcanic field (in years) on the x-axis.

Now, in Excel, fit a best-fit (linear) trendline to the data points on your graph. The slope 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.

Print out your spreadsheet and graph to turn in, and answer the following questions:

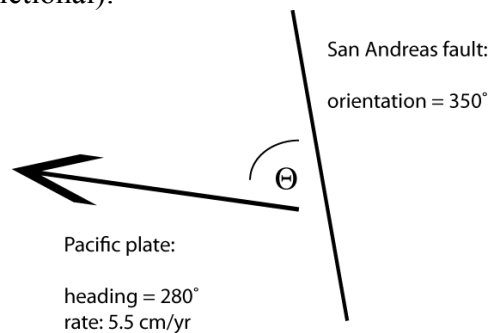
4. What is the average rate of movement of the western part of the North American plate
(in meters/year): _____
5. In what direction has the western part of the North American plate been moving
(to the nearest degree): _____

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

Part 3. Relative plate movement in Southern California

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 (values are fictional):



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.

7. What is your calculated rate of movement of the Pacific plate relative to the western part of the North American plate along the San Andreas fault system?

8. 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)



9. The published rate of movement along the San Andreas fault system is 33-37mm per year (Wallace, 1990). How does your calculated rate compare to this published number? Why might your calculated rate be different from the published rate?

Selected 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.

Wallace, R.E. (ed), 1990, *The San Andreas fault system, California*, U.S. Geological Survey Professional Paper 1515, 304 p.