

Hot Spots and Plate Movement exercise

Koko guyot

Kammu seamount

Midway Atoll

Laysan volcano

Necker island

Nihoa

Ni'ihau Kaua'i

East Molokai'

West Molokai' Haleakala volcano

West Molokai' Maui Haleakala volcano

Kō'olau range Lana'i Kilauea

Lo'ihi seamount

0 Ma

1201 BCE

201 BCE

Google earth

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Yellowstone National Park

Map of Yellowstone National Park showing volcanic features.

Labels on the map:

- Owyhee-Humboldt caldera
- Bruneau-Lakeview caldera
- McMurtry caldera
- Yarns Falls caldera
- Arbon Valley volcano
- Edie Shoof tuff
- Walden vent
- Mesa Falls tuff
- Heise volcanic field
- Yellowstone caldera

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Google Earth

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://csmgeo.csm.jmu.edu/Geollab/Whitmeyer/geode/pangaeaBreakup/PangaeaBreakup.kml>

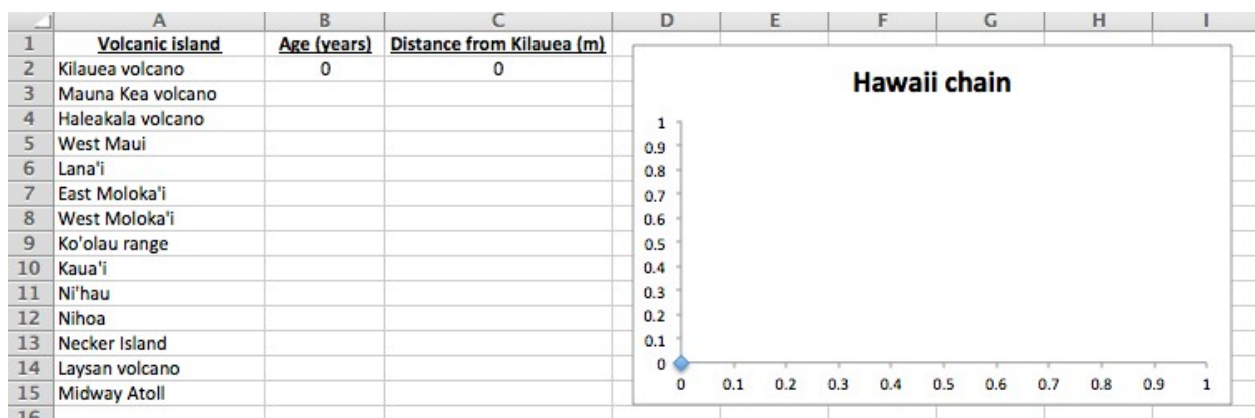
To download Google Earth for your computer, go here:

<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 movement of Pacific and North American plates

7. Compare the movement rates and directions of the Pacific plate and the North American plate during the past 16 million years. Are they the same or different? Explain.

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.