ESS 403- 2010
LAB 1- HOT SPOTS

OBJECTIVES:

Investigate the ‘Hot Spot” hypothesis by determining rates of motion and pole(s) of rotation that match volcano and seamount age-location data for Hawaii and other Pacific ocean island chains

BACKGROUND:

THE CURIOUS CASE OF THE HAWAIIAN ISLANDS

During the nineteenth century, American geologist James Dwight Dana (1813-1895) observed that the age of extinct volcanoes in the Hawaiian Island chain increases as one gets farther away from the active volcanoes on the "big island". The age increases from the contemporary, active underwater volcano Loihi (southeast of the big island of Hawaii) to nearly 60 million years at the Suiko Seamount 1300 km distant. The only active volcanoes are at the southeast end of the island chain, and the seamounts to the northwest are long extinct. Earthquakes occur only near the active volcanoes.

As the theory of plate tectonics took shape in the 1960s, Tuzo Wilson, the Canadian scientist who named transform faults, pointed out that Dana's observation about the progressively aged islands in the chain provided a possible test of the plate hypothesis. Wilson proposed that a long-lived hot spot lies anchored deep in the mantle beneath Hawaii. A hot, buoyant plume of mantle rock continually rises from the hot spot, partially melting to form magma at the bottom of the lithosphere-magma that feeds Hawaii's active volcanoes.

If the seafloor were stationary over the deep mantle, an active volcano would just sit above the hot spot and erupt for as long as heat in the deep mantle could maintain the plume. But if the seafloor moves over the mantle plume, an active volcano could remain over the magma source only for about a million years. As the plate moved, the old volcano would pass beyond the plume and become dormant. A new volcano would sprout periodically through the plate above the hot spot, fed by plume magmas. Then the next volcano would emerge, and so on. Eventually a chain of volcanoes would form, lined up in order of increasing age away from the hot spot.

The Hawaiian Islands connect with a chain of seamounts to the northwest. These are underwater mountains formed from dormant seafloor volcanoes that have sunk below the sea surface by a combination of erosion and isostasy. By taking the ratio of distance (from an extinct volcano to the active volcanoes on the big island of Hawaii) and time (the age of an extinct volcano), you can compute the average speed of the Pacific Plate. Further, the orientation of the island/seamount chain, also known as a hot spot track, indicates the direction of plate motion.

In the case of Hawaii and the Emperor Seamounts, where the seamounts are about 40 million years old, the Hawaii hot spot track changes direction on the Pacific sea floor. It has been suggested that the bend in the hot spot track indicates that the Pacific lithospheric plate changed its direction of motion at this time.

EXERCISES:

1. Using m_map, create a map of the Pacific Ocean.
    a. Include bathymetric contours
    b. Plot the prominent volcanoes and sea mounds of the Hawaiian-Emperor chain listed in Table 1.
    c. Identify characteristics of the chain, visible in the map, that support the hot spot hypothesis.
    d. Identify other potential hot spot tracks in the Pacific including Line Islands, Louisville, Marquesas, and Pitcairn.
2. Make an age-distance plot using data in Table 1.
    a. Determine apparent plate velocities based on your plot.
    b. Is a single line through all data appropriate?
    c. What are the sources of error in your interpretation?
3. Estimate a pole of rotation for the Hawaiian chain and other linear island chains using a “trial and error” approach.
    a. Does a single pole of rotation “fit” all data?
        i. What judgment/assumptions are needed?
        ii. What criteria could you use to determine a “goodness of fit”?
    b. What rotation rate(s) emerge from your analysis? How does this compare with answers to (2) and data from other sources (see text discussion).
    c. Are other volcanic chains consistent with the plate motion of the Hawaiian chain?
4. What additional information can be inferred from the apparent bend in the Hawaiian – Emperor chain?
5. Consider your work and the ideas expressed in the “background” section of this lab.
    a. Do your results and interpretations validate ideas based on the hot-spot hypothesis within the framework of plate tectonics?
    b. Are hot spots fixed relative to one another?
    c. Are you completely satisfied or have you identified any problems or additional questions that need consideration?

Organize material to write your abstract. Refer to the guide and class discussion to determine what should be included.

Always – Always for every lab!!

1. Make sure that all figures (plots, graphs, maps, etc.) are appropriately titled, labeled, and if necessary have keys and scales.
2. Discuss the accuracy/uncertainty of your measurements and results.
3. Identify the source of all data.

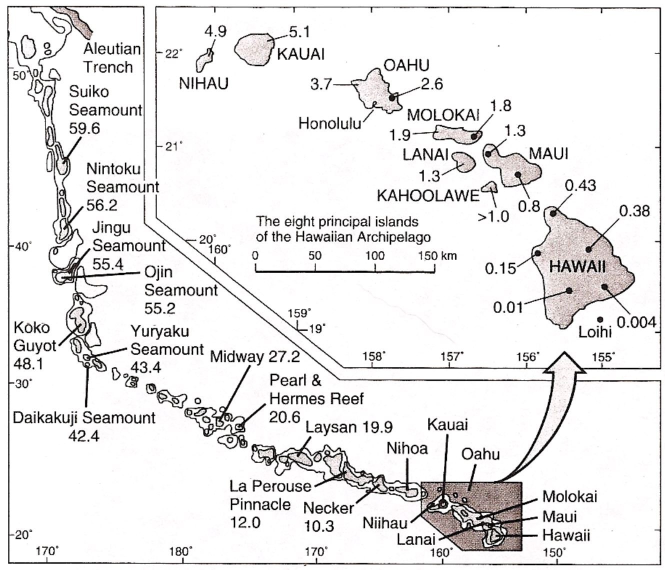

Figure 2.20 Chain of Hot Spot Volcanoes The Hawaii-Emperor chain of volcanic islands and seamounts. The oldest reliable age of rocks associated with particular volcanoes is listed in millions of years (Myr). Note the steady progression of ages from recent to ancient volcanic activity as one progresses down the chain.

Table 1. Location and ages of volcanoes along the Hawaiian-Emperor chain from Clouard and Bonneville 2004

Long.	Lat.	Age(Ma)	Uncertainty	island/seamount dating method original source
174.30	31.80	38.70	0.90	%Abbott Hawaii-Emperor K/Ar [20]
175.90	30.90	38.60	0.30	%Colahan Hawaii-Emperor K/Ar [20]
172.30	32.10	42.40	2.30	%Daikakuji Hawaii-Emperor K/Ar [21]
203.80	20.60	0.75	0.04	%Haleakala Hawaii-Emperor K/Ar [22]
171.20	38.40	55.40	0.90	%Jingu Hawaii-Emperor K/Ar [23]
203.40	20.50	1.02	0.18	%Kahoolawe Hawaii-Emperor K/Ar [22]
200.50	22.00	5.10	0.20	%Kauai Hawaii-Emperor K/Ar [24]
204.75	19.40	0.00	0.00	%Kilauea Hawaii-Emperor observation
171.60	33.70	39.90	1.20	%Kimmei Hawaii-Emperor K/Ar [21]
204.25	20.10	0.43	0.02	%Kohala Hawaii-Emperor K/Ar [25]
171.67	35.10	48.10	0.80	%Koko Hawaii-Emperor K/Ar [21]
193.70	23.60	12.00	0.40	%La PÈrouse Pinnacle Hawaii-Emperor K/Ar [26]
203.00	20.80	1.28	0.04	%Lanai Hawaii-Emperor K/Ar [27]
188.00	25.70	0 19.90	0.30	%Laysan Hawaii-Emperor K/Ar [28]
204.74	18.93	0.00	0.00	%Loihi Hawaii-Emperor observation
204.50	19.75	0.38	0.05	%Mauna Kea Hawaii-Emperor K/Ar [29]
182.70	28.30	27.70	0.60	%Midway Hawaii-Emperor K/Ar [30]
203.30	21.20	1.83	0.07	%Molokai Hawaii-Emperor K/Ar [22]
195.50	23.50	10.30	0.40	%Necker Hawaii-Emperor K/Ar [26]
198.00	23.00	7.20	0.30	%Nihoa Hawaii-Emperor K/Ar [26]
170.20	41.20	56.20	0.60	%Nintoku Hawaii-Emperor K/Ar [23]
188.00	25.30	26.60	2.70	%Northampton Bank Hawaii-Emperor K/Ar [28]
202.20	21.40	2.60	0.10	%Oahu Hawaii-Emperor K/Ar [31]
170.30	37.50	55.20	0.70	%Ojin Hawaii-Emperor K/Ar [23]
184.10	27.90	20.60	0.50	%Pearl and Hermes reef Hawaii-Emperor K/Ar [32]
170.00	44.00	64.70	1.10	%Suiko Hawaii-Emperor K/Ar [23]
204.00	20.80	1.32	0.04	%West Maui Hawaii-Emperor K/Ar [31]
172.00	32.70	43.40	1.60	%Yuryaku Hawaii-Emperor K/Ar [32]