Name: ______________________________

Determining the relationship between the summit and Pu‘u ‘Ō‘ō on Kilauea

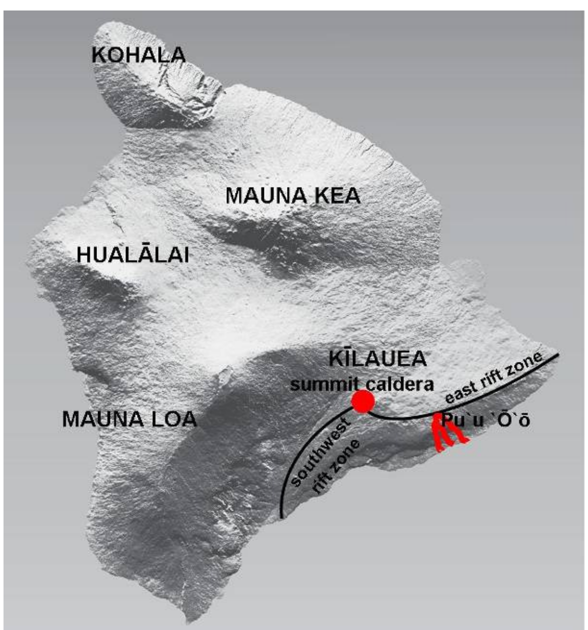
After completing this activity, you will be able to:
1. summarize the physical events that produce the data volcanologists use to understand volcanoes
2. predict the physical response of the Kilauea system for each scenario given
3. test the given hypotheses and determine the most likely scenario based on the data

I. Introduction

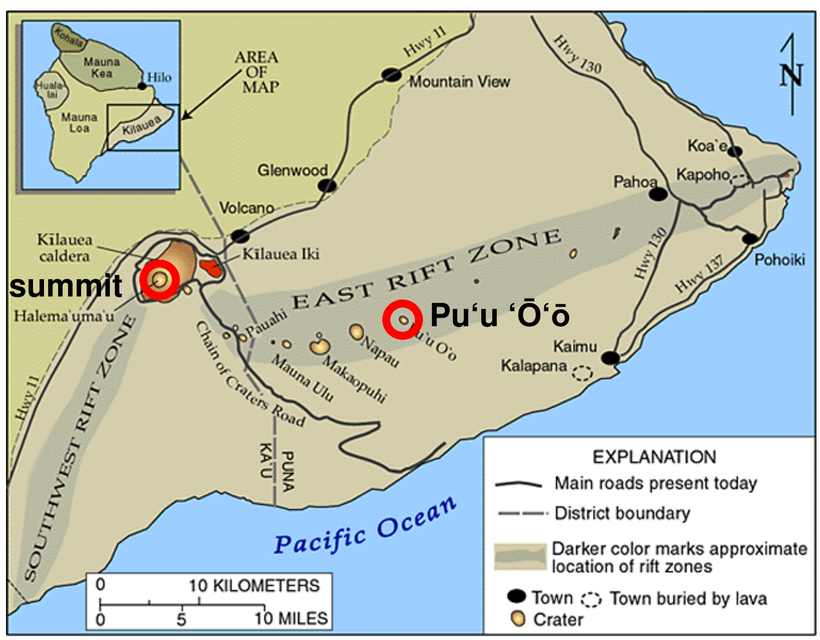
Kilauea is an active volcano on the Big Island of Hawaii. It exists because a hotspot under the Pacific tectonic plate causes rock to melt forming a deep magma chamber (2.5-3 km or 1.5-2 miles beneath the surface) beneath the summit. The magma in the deep magma chamber rises and stops in a more shallow magma chamber. The shallow chamber is roughly 1 km (half mile) beneath the summit and another one is likely even more shallow beneath Pu‘u ‘Ō‘ō.

The summit caldera and Pu‘u ‘Ō‘ō are located 20 km or 12 miles from each other as measured along the rift zone. Lava last erupted out of the summit on 1982, and it is currently (as of summer 2010) erupting ash and gas with lava visible deep in a volcanic crater in the summit caldera. Lava (as well as ash and gas) are currently (as of summer 2010) erupting out of Pu‘u ‘Ō‘ō, and has been since 1984.

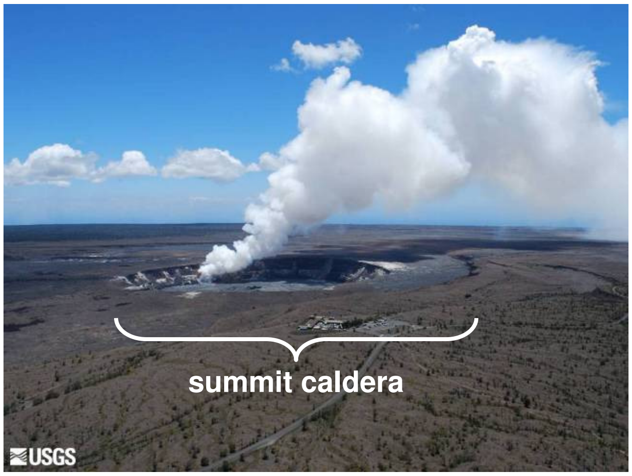
Volcanic plumbing is the way magma rises to the surface, like the plumbing in a house. Although Hawaii is often used as an example of typical hotspot volcanic islands, the volcanic plumbing beneath Kilauea is unusual. During this activity, you will explore the plumbing beneath Kilauea.



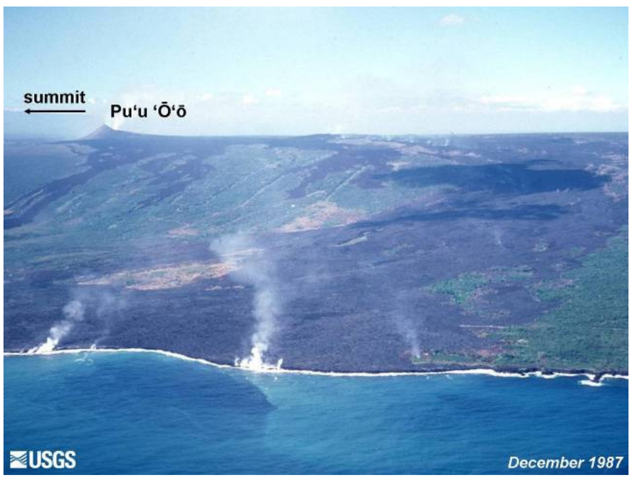
Map by Mike Poland

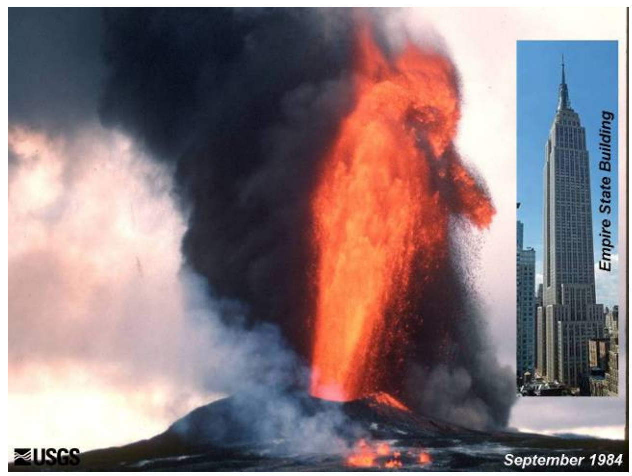


Map by J. Johnson 2000, from http://hvo.wr.usgs.gov/kilauea/Kilauea_map.html



These two images show the summit caldera of Kilauea with the smaller crater inside emitting ash and gas. In the right image, lava is visible deep within the crater in the larger caldera.





These two image show Pu‘u ‘Ō‘ō on the flanks of Kilauea. The left image shows Pu‘u ‘Ō‘ō in the distance with lava flow from it hitting the ocean, and the right image shows a period of time in 1984 when Pu‘u ‘Ō‘ō was fountaining lava (the empire state building is shown for scale).

In this activity, you will act like a geologist and examine three hypotheses about the volcanic plumbing beneath Kilauea:

Hypothesis #1: Magma first rises into the summit region and then travels underground to the Pu‘u ‘Ō‘ō magma chamber.

Hypothesis #2: Magma first rises beneath the Pu‘u ‘Ō‘ō region and then travels underground to the summit magma chamber.

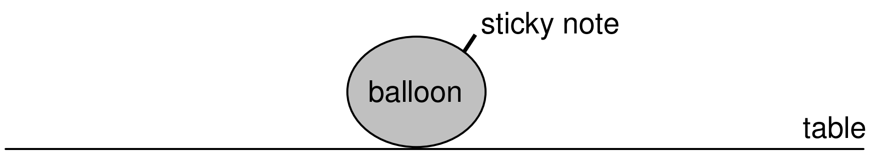
Hypothesis #3: Magma rises separately beneath both the summit and Pu‘u ‘Ō‘ō magma chambers.

Geologists often have multiple working hypotheses. This means that we have several ideas about what is happening (or what happened), and by collecting data, we can narrow it down, hopefully to one hypothesis. Therefore, you will use data from multiple sources (ground tilt, ground movement, and lava composition) to test each hypothesis to see which one the data best support. You will use some of the same data scientists use to answer this question.

II. Ground Tilt

When magma enters a shallow magma chamber it will cause the magma chamber to inflate. When monitoring volcanoes, geologists look for and measure this tilt on the surface of Earth. First, we will examine the inflation of the magma chamber with a balloon.

Blow up the balloon so it is approximately full. Hold the balloon closed, and do not tie a knot in it. On the side of the balloon, bend a sticky note and stick it to the balloon so it is sticking up away perpendicular (at a right angle) to the balloon. Set the balloon the table so the piece of paper is at approximately the angle shown (see diagram below).



1) Examine the angle of the sticky note relative to the table. Slowly deflate the balloon and observe what happens to the angle of the sticky note. As the balloon deflates, what happens to the tilt of the sticky note?

   It becomes more tilted   It becomes less tilted   The tilt stays the same

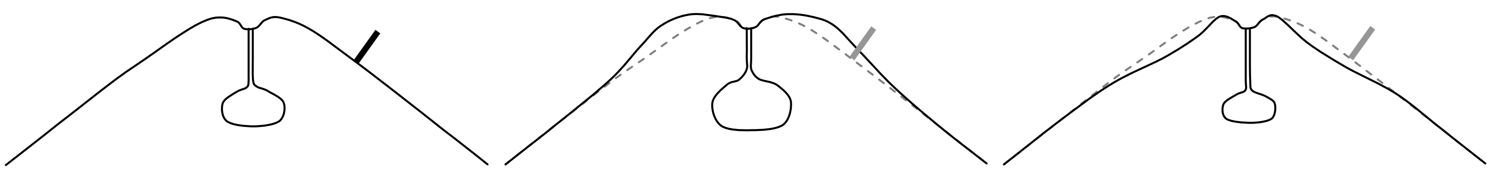
   Explain your answer by drawing sketches of before, during, and after your experiment. (You may need to repeat the experiment and pause the balloon deflation as necessary)

2) Predict what will happen to the tilt of the sticky note if you inflated the balloon. Explain your prediction by drawing sketches as above.

3) In your experiment, the balloon represents the magma chamber. Generate some ideas as to how your experiment is similar to and different from a volcano and what geologists measure?

The inflation of the magma chamber will cause the ground above it to move as well. Below is a series of three figures. The first is the initial volcano and magma chamber. The second shows an inflated magma chamber with more magma than the initial chamber, and the third shows a deflated magma chamber with less magma than the initial chamber. This profile of the initial volcano is shown with a dashed line on the second and third volcanoes. Please note that the drawing is exaggerated on all three figures. Actual tilts and movements are generally not visible to the naked eye and can only be measured by precise instruments. On the figure of the initial volcano, a large pole is sticking out of the ground, perpendicular (at a right angle) to the ground.

4) For the second and third figures, draw how the location and tilt of the pole will change as the magma chamber inflates and deflates.

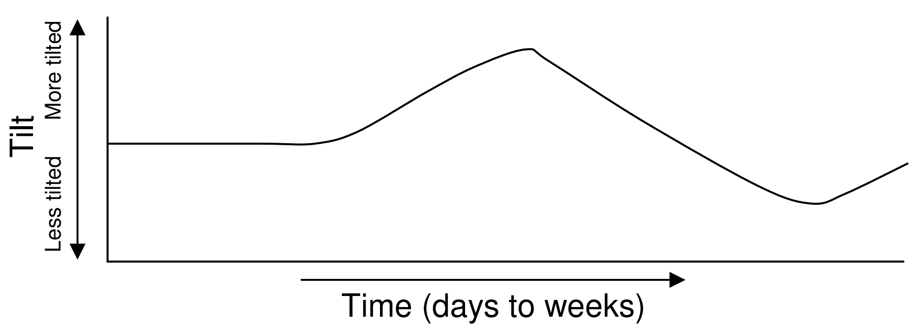


5) When the magma chamber inflates (gets larger), what will happen to the tilt of the slope?

There will be more tilt   There will be less tilt   The tilt will not change

Explain your answer.

Geologists measure the tilt of the slopes of a volcano with precise instruments. For example, their instruments can measure if you put a dime beneath one end of a one-kilometer-long (half-mile-long) bar. Below is a graph showing the tilt on the slope of a volcano.

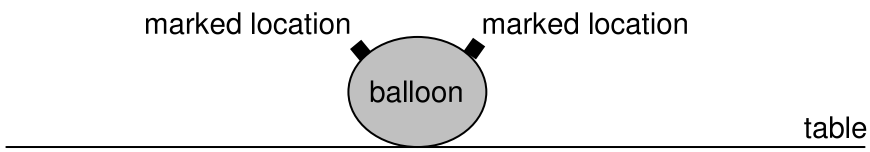


6) On the graph, label each place where the magma chamber is increasing, decreasing, or staying the same. All parts of the line should be labeled.

III. Ground Motion

We will use the balloon experiment to examine how the inflation of a shallow magma chamber affects the motion of the ground. When monitoring volcanoes, geologists look for and measure the distance between two points on opposite sides of a volcano.

Blow up the balloon so it is approximately full. Hold the balloon closed, and do not tie a knot in it. Mark two locations on different sides of the balloon (see diagram below) using markers. Place the balloon on the table with your two marked spots at the approximate locations as shown below.



7) Measure the distance between the two marked locations as seen from above the balloon. Slowly deflate the balloon and observe what happens to the angle of the piece of paper. As the balloon deflates, what happens to the distance between the marked locations?

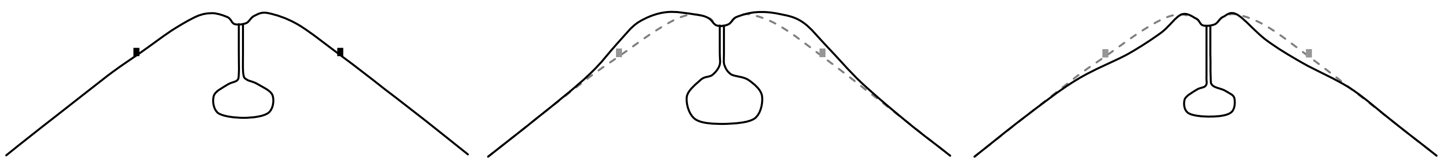
The distance increases The distance decreases The distance stays the same

Explain your answer by drawing sketches of before, during, and after your experiment. On your sketch, give the measurements between the two marked locations. (You may need to repeat the experiment and pause the balloon deflation as necessary to make your measurements)

8) Predict what will happen to the distance between the marked locations if you inflated the balloon. Explain your prediction by drawing sketches as above. (You do not need to include measurements for your predictions).

The inflation of the magma chamber will cause the ground above it to move as well. Below is a series of three figures. As below, the first is the initial volcano and magma chamber. The second shows an inflated magma chamber with more magma than the initial chamber, and the third shows a deflated magma chamber with less magma than the initial chamber. This profile of the initial volcano is shown with a dashed line on the second and third volcanoes. Please note that the drawing is exaggerated on all three figures. Actual tilts and movements are generally not visible to the naked eye and can only be measured by precise instruments. On the figure of the initial volcano, two points are located in the ground on opposite sides of the volcano.

9) For the second and third figures, draw how the new locations of the two points will change as the magma chamber inflates and deflates.

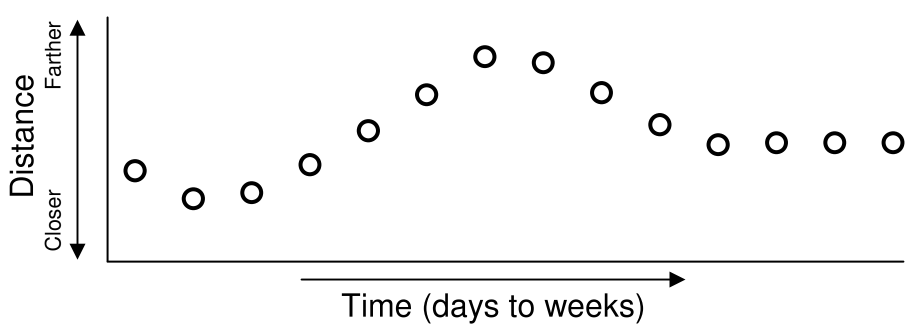


10) When the magma chamber inflates (gets larger), what will happen to the distance between the two points?

The distance increases   The distance decreases   The distance stays the same

Explain your answer.

Geologists measure the location of points on the sides of a volcano using GPS. The GPS data are usually averaged over the course of a day. Below is a graph showing the distance between two points on opposite sides of a volcano.



11) On the graph, label each place where the magma chamber is increasing, decreasing, or staying the same. All parts of the graph should be labeled.

IV. Lava Composition

Magmas that rise from deep magma chambers have distinct compositions. Geologists tend to report compositions of lava as elements combined with oxygen (for example SiO_2 shows how much silicon is in lava). Geologists express the lava to be made up of elements combined with oxygen because this is how they combine to form minerals.

12) What type of rock forms from the lava that erupts from hot spot volcanoes in oceans?

basalt   andesite   rhyolite   granite

Within each rock group, the composition can vary a little. For example, the amount of SiO_2 in basalt can range from 45% to 55% of the total weight of the rock. The amount of some of the major elements for different rocks is given in the table below.

13) Circle the rocks listed below that are basalt, based on their composition.

	Rock A	Rock B	Rock C	Rock D
SiO_2	45%	70%	48%	58%
Al_2O_3	9%	15%	14%	16%
FeO	12%	2%	10%	7%
CaO	10%	1%	11%	7%
MgO	18%	0%	15%	4%
Other	6%	12%	2%	8%

14) Do all basalts have the exact same composition or can the composition vary within limits? Explain your answer.

15) What might explain a variation in two basalts that are near each other but have different compositions?

V. Predictions

You performed a couple experiments where you changed the size of the magma chamber, with a balloon as a model for a magma chamber.

16) In a volcano, what do you think could cause the magma chamber to increase in size?

17) In a volcano, what do you think could cause the magma chamber to decrease in size?

18) For each of the three hypotheses given in the introduction, fill in the table by making predictions about the timing and pattern of magma chamber inflation and deflation between the summit and Pu‘u ‘Ō‘ō. For example, would the summit magma chamber inflate before, after, or with an unknown relationship to the Pu‘u ‘Ō‘ō magma chamber? Would you expect the overall pattern to be similar or different for each location? Explain your predictions.

Hypothesis	Prediction: Timing of Deflation/Inflation	Prediction: Overall Pattern of D/I
#1		
#2		
#3		

19) For each of the three hypotheses, make predictions about the composition of lava erupting from the summit and Pu‘u ‘Ō‘ō. For example, would the composition of the lava be different or the same? Explain your predictions.

Hypothesis	Prediction: Composition
#1	
#2	
#3	

VI. Analyzing Data

Geologists are constantly monitoring Kilauea in order to learn more about the volcano, especially since people on Hawaii are directly affected by the eruption. Geologists use the data to try to answer questions and test hypotheses about the volcano. Given to you on another handout are data collected by geologists for Kilauea. Use the knowledge you learned about each of the monitoring techniques and analyze the data on the attached sheets.

20) Examine the handout called “DATA: Ground Tilt.” Which hypothesis(es) do the ground tilt data best support? Explain your answer. Convince your instructor that this hypothesis is supported by including specific times and numbers in your explanation.

21) Examine the handout called “DATA: Ground Movement Using GPS.” Which hypothesis(es) do the ground motion GPS data best support? Explain your answer. Convince your instructor that this hypothesis is supported by including specific times and numbers in your explanation.

22) Examine the handout called “DATA: Lava Composition.” Which hypothesis(es) do the lava composition data best support? Explain your answer. Convince your instructor that this hypothesis is supported by including times and numbers in your explanation.

23) If the data support hypothesis 1 or 2, how long would it take for lava to flow from the summit to Pu‘u ‘Ō‘ō or the other way? As with the previous questions, support your answer with numbers from the data.

VII. Drawing Conclusions

After analyzing the data, you are now ready to draw some conclusions about the plumbing beneath Kilauea.

24) Do all three lines of data support the same hypothesis? Yes No

25) Why do scientists use more than one source of data to test their hypotheses?

26) In your own words, summarize the relationship between the summit and Pu‘u ‘Ō‘ō on Kilauea.

27) The diagram below is a cross section showing beneath Earth’s surface between the summit and Pu‘u ‘Ō‘ō. Please note this cross section is not to scale. On the cross section, sketch the movement of magma from the deep magma chamber to where it is currently erupting at Pu‘u ‘Ō‘ō.