Stories of the Present

How Does it Work?—Volcanos and Geysers with Syringes Lab Walk Through

Earth Science Essentials-Advanced

by Russ Colson

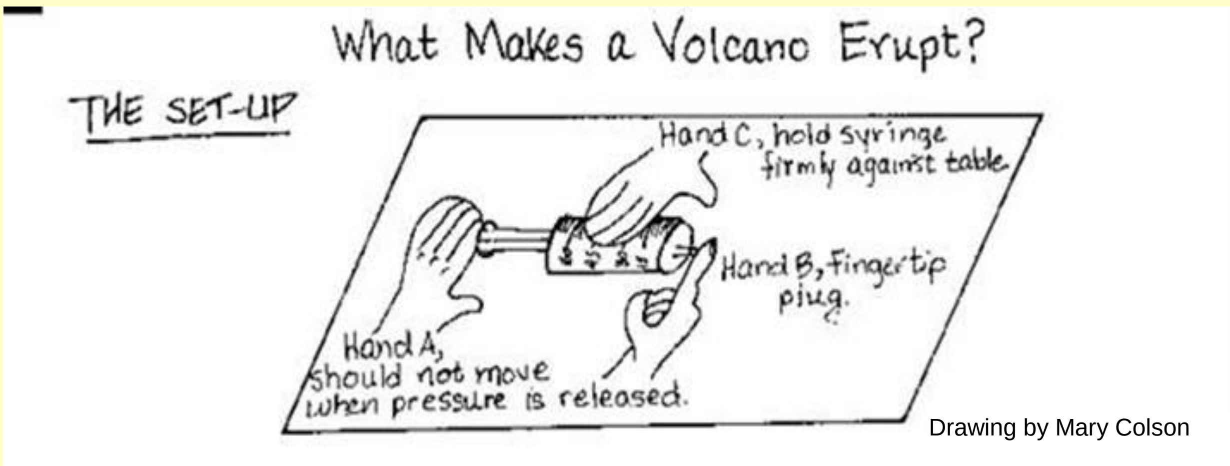
The walk-through is given below.

Volcanos

The baking soda and vinegar volcano is, for many young students, a memorable demonstration of how expanding gases can drive lava from a volcano. Here is an inquiry activity originally developed for 8th graders to expand that demonstration into an experiment that encourages a student to figure out how a volcanic eruption works. How is a baking soda volcano like a real volcano and where does a real volcano get its oomph?

This activity is modified from "Spirit of the Volcano" by Russ and Mary Colson, published in the Journal of Geoscience Education, November 2000.

Your goal is to measure, quantitatively, how gas in a magma chamber affects energy of an eruption. You will do this by measuring how far water squirts from your 60cc syringe, given a fixed starting pressure, as a function of how much air is in the syringe.



Drawing by Mary Colson

Trials:

Trial 1: fill the syringe ¾ full of water (45cc)
Trial 2: fill the syringe ¾ full of water (45cc) plus some air (15cc)
Trial 3: After looking at your results, decide on a third experiment that will give you important information. (For example, you might change the amount of water present instead of changing the amount of air (remembering that if the syringe is less than half full of water, no water can come out because it doesn't reach the spout of the syringe). Or, you might make a prediction from your previous results—

e.g. will doubling the amount of air double the increase in distance the water goes—and then test that prediction. Your report should specify what you did. For the example data table below, the amount of air was the same as in Trial 2, but the water was decreased to half—an experiment with ambiguous results because the water drops below the outlet of the syringe.)

For each trial, compress the plunger in the syringe with hand A, keeping pressure equal for each experiment. Release hand B finger, keeping other hands stationary. Measure how far the liquid shoots.

Some things to consider:

- Repeat all measurements at least 3 times. Report your results neatly and clearly! (See table below.)
- Figure out a way to control the pressure in the syringe so that you have the same initial pressure for each different experiment. (If the same person pushes against the syringe from the same position and in the same way, the pressure will be roughly constant. Be sure to then brace your hand on the table so you don't change the amount of force or 'keep pushing' after the end of the syringe is opened. It's also possible to be creative and push the plunger with a scale of some sort, like a bathroom scale, and make sure the same amount of force is added each time.)
- Notice that there are two different ways to measure how far the water shoots: The continuous stream and the discontinuous stream. Measure and record both and include in a data table. Note that data tables should include all measurements, not only the final average. (Usually the discontinuous stream is less reproducible than the continuous stream. This is especially true if you do an experiment in which the syringe is close to half full of water, which makes the eruption 'sputter' as the water is mostly below the spout of the syringe.)

Example table:

	continuous stream (inches)				discontinuous stream (inches)			
	1rst	2nd	3rd	avg	1rst	2nd	3rd	avg
Trial 1	3	2.5	2.5	2.7	not seen	not seen	not seen	----
Trial 2	17	15	18	16.7	35	39	26	33.3
Trial 3	not seen	4	1	----	37	19	46	34

<u>The Analysis</u>

- Which trial shot water the farthest? Why do you think this was? (the one with more air, because the air is compressible, stores energy, and then ejects the water when it expands during decompression)
- What is the dependent variable (the response variable)? (distance water shoots)
- What is the independent variable (the causative variable)? (proportions and amounts of air and water)
- What are the constants in your experiment (the variables whose values you hold constant) (Many—for example, pressure, composition of gas and liquid,

geometry of magma chamber and orientation of liquid, distance that the water falls before its travel distance is recorded (liquid will travel farther if it is allowed to fall a greater distance, etc.)

- How are these experiments like a real volcano? (Gases are compressible and provide the oomph that propels magma from a volcano.)
- How are these experiments like a baking soda and vinegar volcano? (In both cases, gases expel the 'lava'.)

Geysers

Following a recipe that someone else has provided you is very little like doing real science. Real science happens when you invent the recipe.

Design an experiment to measure the pressure at which water boils at room temperature. Your materials are a weight scale, a piece of string, your 60cc syringe, a balloon (to protect your finger), a ruler, a bucket with a handle, water, and plenty of sand. You do not need to do this experiment—only design it.

Your grade will depend on your report of the following (listed in order of decreasing emphasis):

1) inclusion of all important steps in your experimental plan
2) experimental design to make all needed measurements
3) calculations needed to get the boiling pressure from your measurements

<u>Experimental plan (50 points):</u>
Measure the amount of force pulling down on the syringe plunger to cause the water inside to start to boil with only water inside the syringe and the end of the syringe plugged. Measure how much force it takes to move the plunger with the end of the syringe not plugged (the friction that needs to be overcome). Calculate the pressure inside the syringe that results from these forces.

<u>Experimental design (35 points):</u>
Tie one end of the string to the plunger and the other end of the string to the bucket. Fill the plunger about half full of water. Hold up the plunger, with the bucket dangling from it, and add sand to the bucket slowly until the plunger starts to move. Weight the bucket with the scale. Repeat this several times.

Again, fill the syringe about half full with water, make sure that all air is removed from the syringe, and close it up by holding the balloon tightly over the end with your finger. Again lift the empty bucket off the floor with the syringe and add sand slowly to the bucket until you see the water start to boil. Weigh the bucket full of sand with the scale. Repeat several times. There are two important points in marking the moment of initial boiling—when you see the water first start to boil (bubbles form) and when the water is actively boiling (in which case the plunger will keep sliding down without adding any more water). These two measurements will bracket the true value of the boiling pressure.

Measure the inside diameter of the syringe.

<u>Calculation (15 points):</u>
Pressure inside the syringe = atmospheric pressure – pressure applied by the weight of the bucket of sand

Pressure applied by the bucket of sand = force of sand/cross-sectional area of the syringe – friction effect.

Friction effect = force of sand when the syringe isn't closed/cross-sectional area of the syringe.

If we let P_{atm} = atmospheric pressure (about 14.7lbs per square inch), B1 = weight of bucket of sand when the syringe moves with the end open (say in pounds), B2 = weight of bucket of sand that causes water to start to boil with all air removed from the syringe (in pounds), and A = cross-sectional area of the inside of the syringe (say, in square inches, remembering that area = 2πr).

Then the boiling pressure = P_{atm} - (B2/A – B1/A) (in pounds per square inch)
To convert to atmospheres of pressure, we can divide by 14.7 pounds per square inch/atm-pressure.

The pressure at which water boils at room temperature is quite low—about 0.0245 atm or 0.36 pounds per square inch. Based on my experience with students who actually do this experiment (instead of design it), the uncertainty in the measurements above are likely to be in the range of half a pound per square inch, which means that you can only get a maximum pressure value.