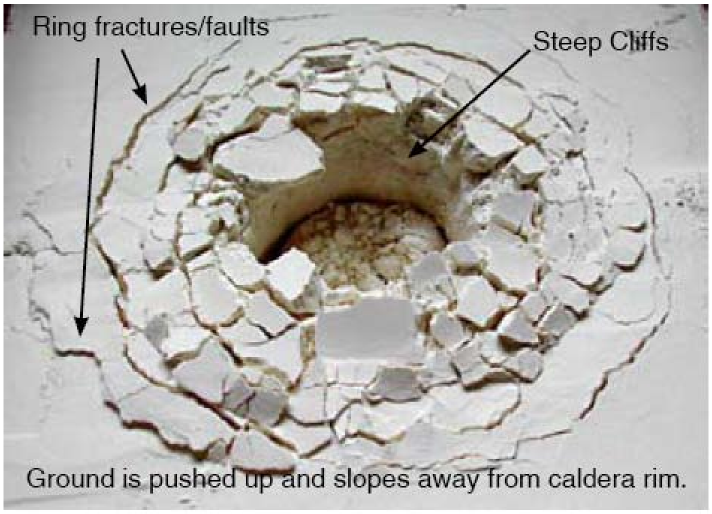
Activity—Flour box volcano deformation model

A balloon and a box of flour model a magma chamber and overlying rock



Some volcanic craters form by the violent expulsion of magma (liquid rock) when it reaches Earth's surface where liquid rock is referred to as "lava". However, many volcanic craters form by collapse of the rock near the summit of the volcano. When magma pushes up through Earth's crust, it must displace the surrounding and overlying rocks as it works its way toward the surface. When magma enters a shallow reservoir beneath a volcano, the ground above that magma chamber can "inflate," pushing the ground upward and outward away from the center of the volcano.

Although we use a balloon to model a magma chamber, this is a very simplistic model. Magma chambers are more often a system of inter-connected dikes and sills that may or may not coalesce as magma pushes up through cracks in the volcano.

Science Standards

- Systems
- Inquiry
- Evidence of Change
- Forces and Motion
- Energy & Matter: Transformation and Conservation
- Cycles in Earth Science
- Predictability & Feedback

Additional Resources relevant to this activity

Gelatin Model of Magma Intrusion: **http://orgs.up.edu/totle/index.php?q=node/407**

Watch "*Measuring Deformation & Tilt with GPS*" to learn about changes in volcano**:** **http://www.iris.edu/hq/programs/education_and_outreach/animations/16**

Note: The activity on the following pages (used with permission) is from **Volcano Video Productions**, from their ***Teachers Guide*** to the award-winning DVD: **Lava Flows and Lava Tubes; What They Are, How They Form (http://volcanovideo.com/index.html)**.

3-5: Volcano Deformation and Caldera Collapse

Grade Level: 5-12
NSC Standards: A, B, D
Science, inquiry, observation, materials process.

Introduction

How do calderas form in the top of volcanoes?Some form by the violent expulsion of material. But most crater structures on volcanoes form by collapse. When magma pushes up through the crust it fractures and displaces the country rock. When magma forcefully enters shallow reservoirs in a volcano the ground above it will "inflate," pushing the ground upward, or "deflate" when the magma leaves. The inflation-deflation process deforms and weakens the ground surface.

This demonstration consistently gets an "Aha!"-type response from participants as it takes you through the step-wise process of "predicting" what you might see before and after a caldera collapse.

Objectives—Students will:

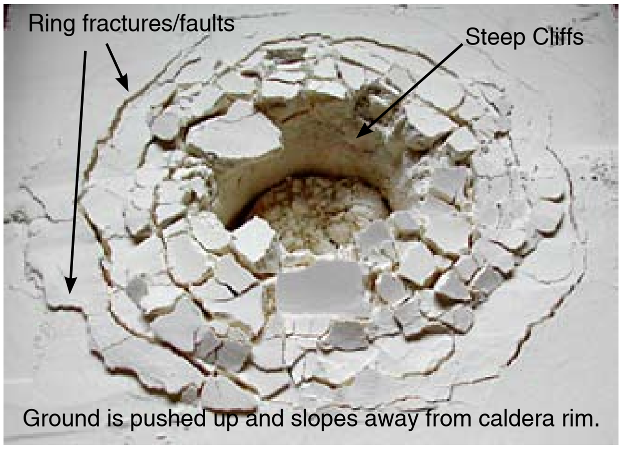
- Describe step-by-step process of ground deformation;
- Describe how calderas can collapse.

Background

The rise of magma beneath a volcano forces the ground surface upward and is accompanied by ground deformation and earthquakes (seismicity). The earthquakes result as rocks at depth are shifting, grinding, and bumping past each other. The flour model differs in several key ways from nature.

(1) Although it fractures and collapses properly, the flour is a poor substitute for a solid substrate. (A room-scale model using solids is impractical).
(2) the balloon contains all the "magma," whereas in a volcano, the magma squeezes into nooks and crannies and can escape.
(3) magma is hot and melts the wall rock.

Caldera collapse without explosion in part requires the volume of rocks be pushed up and out. (See #6 next column.)



Oblique view of photo ***D*** next page. The "ground" slopes away from the pit and is riddled with ring fractures, similar to many real calderas; the volume of the hole is equal to the upward displacement of the "rocks" surrounding it. [Concept from USGS *Volcano Watch*.]

Activity Length

5-15 minutes to demonstrate.
30 minutes to construct when you have the materials.

Materials

- 12" x 12" x 5"-deep box (or equivalent size).
- 5-8 pounds of baking (all purpose) flour.
- 18-24" plastic tubing to blow through.
- Sturdy 6-8" balloon, not inflated.
- flexible tape, electrical tape works great.

Instructions

(1) Describe the model. Explain that the box of flour represents the bedrock of a volcano. It has a balloon in it—a magma chamber—that will inflate and deflate as "magma" is forced up into it from great depth, pushing the ground (flour) up, thereby fracturing and deforming it. Make it clear that magma chambers aren't really like big empty balloons but more like a big chamber full of rocks and the magma infiltrates the spaces. When magma rises in a volcano it "inflates" and pushes up on the overlying ground.

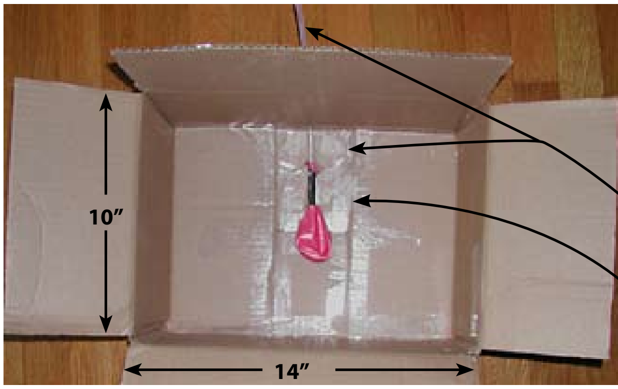
(2) Before doing it, tell the students they will see three things (read captions to photos ***A-D*** on next page: (***A***) When the "magma" pushes the flour up, the first evidence is radial fractures (like bike spokes). *Why does this happen?* [Because of round discrete source of inflation.] (***B***) Continued on/off influx of magma (inflation/deflation) results in ring fractures, discontinuous arcs of weakness. (***C***) The rise and displacement of the ground above the magma chamber leaves a void that the ground collapses in to.

(3) First blow gently into the balloon to get radial fractures.

(4) Blow the balloon enough so that you begin to get the ring fractures develop in semi-circles around the radial pattern.

(5) Blow more into the balloon and suck the air back out, over and over, until you see the caldera collapse. Carefully examine the flour crater and the surrounding "ground." Like a real caldera, it has steep cliffs. The ground slopes away from the crater and is riddled with ring fractures.

(6) Ask: *How there can be a deep hole if there is no drain at the bottom of the box to let the flour out?* They can address this in small groups or write their own answer on paper. Answer: When the rocks are pushed up they shift and can't settle back down into their original position. So with each inflation the overlying ground rock rises higher above the original elevation. The volume of rock above ground level is equal to the volume of the caldera.

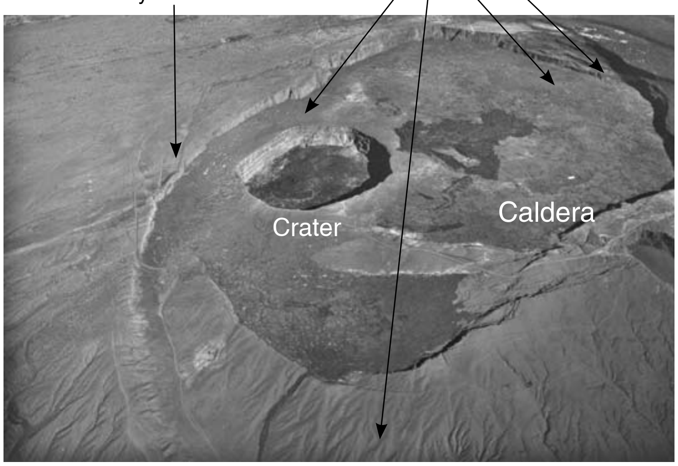


Pre-class Construction of Cardboard Caldera Box

1. If the box is deep, cut it to about 7 inches in height (so students can all see the top of the flour that will be added.) Tape bottom of box to keep flour from leaking.
2. Slip a balloon over the end of the tubing until tubing is inside the large part of the balloon. Tightly wrap electrical tape around the stem of the balloon, stretching it as you go, so that no air will leak out of the balloon from the sides when inflated.
3. Poke a tube-diameter hole in the side of the box near the bottom. Feed the tube from inside to outside until the balloon lies in the middle of the bottom of the box.
4. Tape the tubing along the black electrical tape to the bottom of the box in several places to keep it from rising up through the flour as you blow the balloon later. (You don’t want your magma chamber floating to the surface.)
5. Fill box to a depth of at least 6 inches (7–10 pounds flour). If it is too shallow, the caldera doesn’t collapse very well. Compact the flour with a flat block or the cover of the DVD, then smooth the top. If there isn’t enough flour, mound it up above the balloon.

Ground slopes away in all directions away from caldera

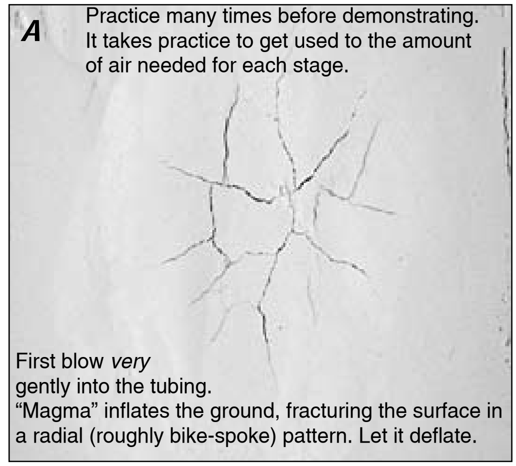
Ring fractures



CALDERA vs. CRATER?

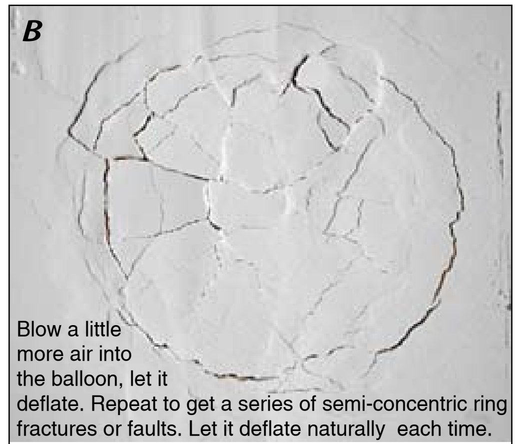
A *caldera* is a basin-shaped volcanic depression that formed from explosion or collapse and is more than a mile in diameter. A *volcanic crater*, can form the same way, but is less than a mile across.

Summit caldera of Kīlauea Volcano on the Island of Hawai‘i. The caldera formed by combinations of explosive eruptions and collapse by magmatic withdrawal. In the 1800s, Kīlauea caldera was several hundred feet deeper than it is now. Summit eruptions filled it to its current depth by 1919. The magma chamber is 1/4 to 2 miles underground near the vicinity of Halema‘uma‘u Crater. That crater formed by an explosive eruption in 1924. The walls of the caldera and crater are steep and unstable, and landslides can occur at any time, particularly during strong earthquakes. This points out the changing nature of calderas.

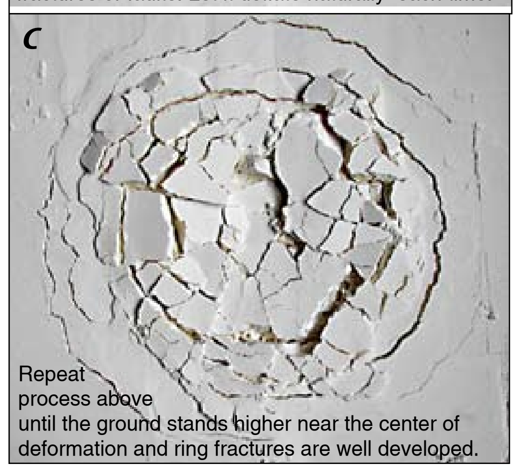


A Practice many times before demonstrating. It takes practice to get used to the amount of air needed for each stage.

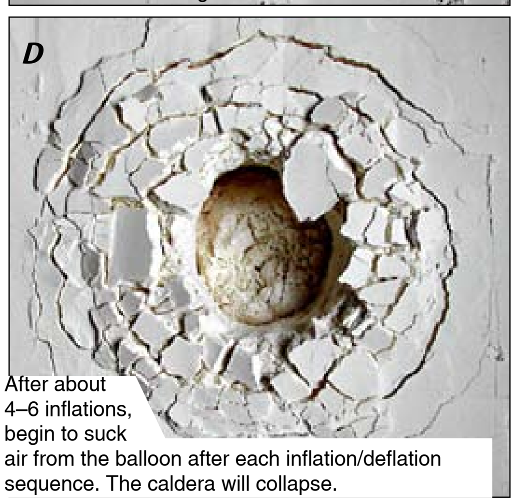
First blow *very* gently into the tubing. “Magma” inflates the ground, fracturing the surface in a radial (roughly bike-spoke) pattern. Let it deflate.



B Blow a little more air into the balloon, let it deflate. Repeat to get a series of semi-concentric ring fractures or faults. Let it deflate naturally each time.



C Repeat process above until the ground stands higher near the center of deformation and ring fractures are well developed.



D After about 4–6 inflations, begin to suck air from the balloon after each inflation/deflation sequence. The caldera will collapse.

Volcano Monitoring: Deformation, Seismicity & Gas*

Background pages to accompany: **IRIS' Animations: Volcano Monitoring**

The animations in this set were done in collaboration with the US Geological survey & Mount St. Helens Institute. Most of the information and graphics for this document comes from **www.usgs.gov**

How do you know a volcano could erupt?

Precursory seismicity, deformation of the crater floor and the lava dome, and, to a lesser extent, gas emissions provided telltale evidence of forthcoming eruptions, which is why we selected these three monitoring methods for our first animations.

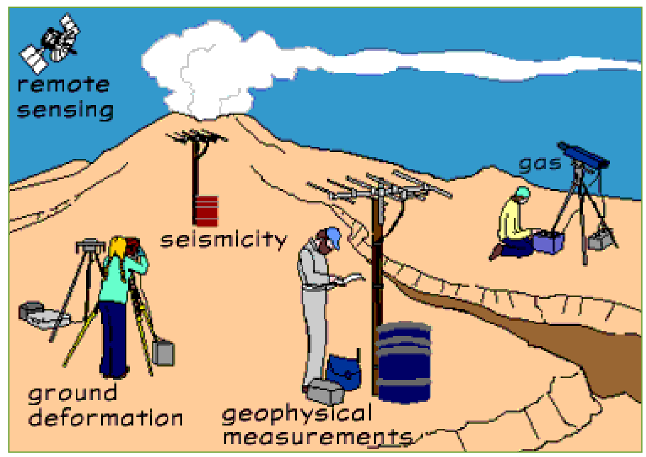
When a volcano begins to show new or unusual signs of activity, monitoring data help us answer critical questions necessary for assessing and then communicating timely information about volcanic hazards. Seismicity and ground deformation, in concert with past geologic history, helped forecast the 1980 eruption of Mount St. Helens and helped save 10's of thousands of lives prior to the 1991 eruption of Mount Pinatubo, Philippines, among others.

Prior to the 2005 activity at Mount St. Helens monitoring equipment recorded a large increase in earthquake activity. Scientists quickly examined other monitoring data including ground deformation, gas, and satellite imagery to assess if a magma or fluid was moving towards the surface. Based on the history of the volcano and the analysis of the monitoring data they were able to determine what types of materials could be moving towards the surface.

HOT Links to Related Resources:

Animations: **Seismic Signatures**
(See "Rock break earthquake")

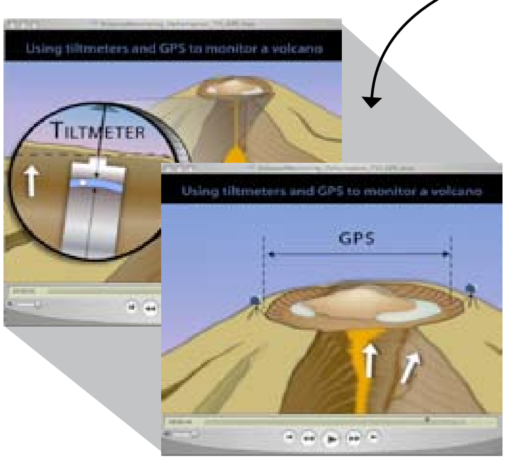
GPS—Measuring Plate Motion

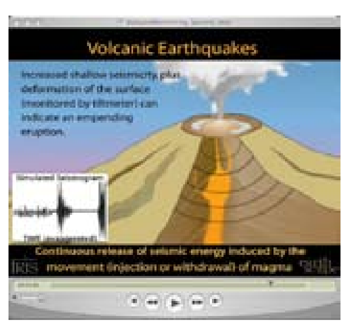


Some techniques used for monitoring volcanoes.

Volcano-monitoring techniques animated include:

- Ground deformation monitored by GPS and tiltmeters
- Earthquake monitoring & types of earthquakes
- Gas monitoring: aerial reconnaissance & land based.





*From USGS' **How We Monitor Volcanoes: http://volcanoes.usgs.gov/activity/methods/index.php**

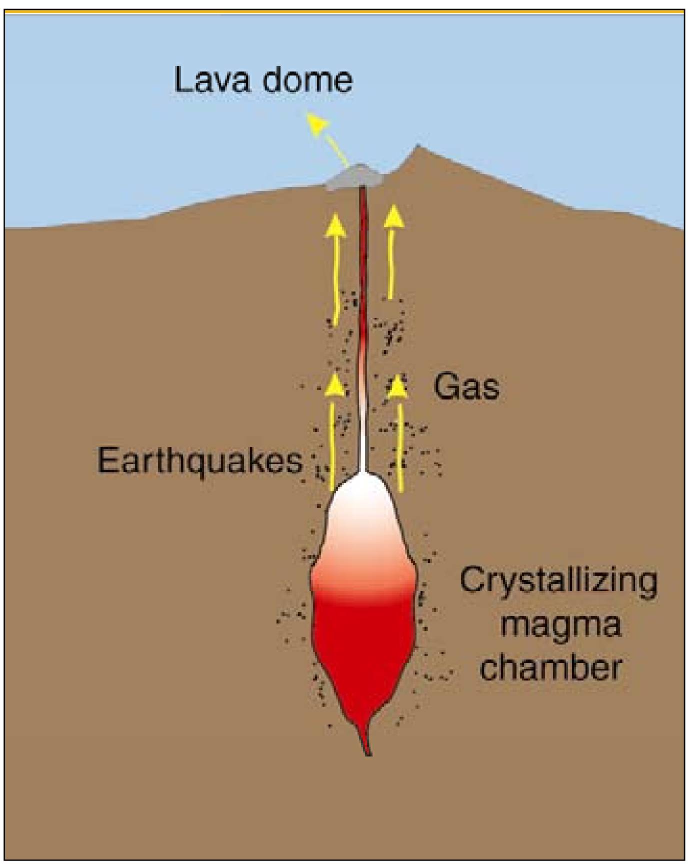
Deformation— GPS & Tiltmeters

Changes to the surface of a volcano (volcano deformation) can provide clues about what is happening deep below the surface. Most volcano deformation can only be detected and measured with precise surveying techniques. The Volcano Hazards Program has installed networks of sensitive deformation instruments around volcanoes to monitor changes over time. These instruments, along with satellite-based technologies help us to better understand the volcanoes we watch and allow us to provide eruption warnings.

GPS

The current constellation of satellites provides the GPS user with 5 to 8 satellites in view from anywhere on Earth, if one has an unobstructed view of the sky in all directions. With this much information, a GPS receiver can very quickly determine its position to within a matter of meters. On volcanoes, however, an accuracy of a few centimeters or less is extremely important for detecting the build up of stress and pressure caused by magma rising toward the ground surface. To obtain this kind of accuracy in our measurements, we need to take other factors into account, including the variation in the speed of the signal transmitted from the satellite as it travels through the atmosphere and the uncertainty in the position of the satellite.

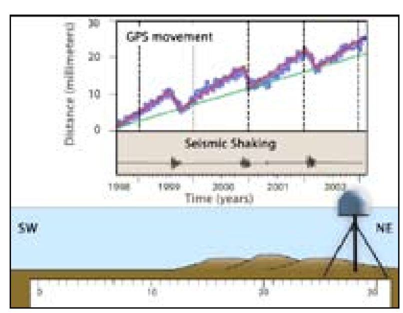
A common way of eliminating these potential errors is to set up GPS receivers over several volcano benchmarks at the same time so that we can simultaneously collect data from the same satellites. Since most of the error associated with the delay of the signal through the atmosphere and the location of the satellites becomes the same for all sites, we can determine their positions relative to one another to less than a centimeter. For the greatest accuracy, we collect GPS data for 8 to 24 hours and then calculate the position of the benchmark utilizing more precise satellite locations and modeling the atmospheric delay.



Left: (Image from U.S.G.S.)

Prior to a volcanic eruption, intrusion of magma will cause pressurization by:
- Increasing volume
- Heating of ground water
- Release of gas

This results in:
- Earthquakes
- Ground deformation
- Gas emission



Right: GPS shows change in position over time. See GPS animations on IRIS' Animations Page: **GPS—Measuring Plate Motion**

Living on an Active Volcano

Questions about Tilt, Eruptions, and Earthquakes

1. Is there a correlation between tilt and eruptions?

2. In terms of tilt, what happens at the summit before eruptions?

3. Does the summit inflate to the same tilt angle prior to each eruption?

4. Do short-period caldera earthquakes correlate with tilt and/or the eruptive episodes?

5. Do long-period caldera earthquakes correlate with tilt and/or the eruptive episodes?

6. Does summit tremor correlate with tilt and/or the eruptive episodes?

7. Based on the data presented in the graphs, outline the geologic events leading up to, during, and after an eruptive episode.

Questions & Answers from: http://volcano.oregonstate.edu/vwdocs/vwlessons/atg.html *

Answers About Tilt, Eruptions, and Earthquakes

1. Is there a correlation between tilt and eruptions?

Yes. Each eruption is marked by rapid subsidence of the summit.

2. In terms of tilt, what happens at the summit before eruptions?

The summit of the volcano gradually inflates between eruptions.

3. Does the summit inflate to the same tilt angle prior to each eruption?

No.

4. Do short-period caldera earthquakes correlate with tilt and/or the eruptive episodes?

Yes. During the eruptive episodes, the number of short-period caldera earthquakes is low. As the summit inflates after each eruption, the number of short-period caldera earthquakes gradually increases.

5. Do long-period caldera earthquakes correlate with tilt and/or the eruptive episodes?

Yes. Large numbers of long-period caldera earthquakes occur during rapid summit deflation and eruptive episodes. Long-period caldera earthquakes are rare between eruptive episodes.

6. Does summit tremor correlate with tilt and/or the eruptive episodes?

Yes. Summit tremor increases during rapid summit deflation and eruptive episodes. Summit tremor is rare between eruptive episodes.

7. Based on the data presented in the graphs, outline the geologic events leading up to, during, and after an eruptive episode.

- Magma accumulates in the summit reservoir, causing the volcano to inflate and tilt to increase.
- As more magma accumulates and the volcano continues to inflate, the rocks above and around the magma reservoir deform and create short-period caldera earthquakes.
- At the onset of the eruptive episode, magma leaves the summit reservoir causing the summit to rapidly deflate. Summit tremor indicates that the magma is moving. Long-period caldera earthquakes indicate that magma is rising from deep beneath the volcano to resupply the summit reservoir.
- After the eruption, the cycle, with some minor variations, is repeated.