The Lunar and Planetary Institute
Department of Education and Public Outreach
3600 Bay Area Boulevard, Houston, Texas 77058
Draft

Cooling Planets

Overview

The students compare the cooling rates of large and small containers of hot water as a model of the terrestrial planets of our inner solar system to develop an understanding of cooling histories of these planets.

Objectives

The students will:

- predict the outcome of an experiment, test their hypothesis, observe, measure, record, organize and graph data, interpret the experimental results, and communicate results
- develop an understanding of the role of heat loss in shaping the planetary bodies of the inner solar system using a model
- determine that smaller planets cool faster than larger planets because smaller planets have a larger surface area to volume ratio
- understand that size and cooling history has implications for currently observed geologic activity on the planets

Science Standards

Scientific processes.

The student uses scientific inquiry methods. The student is expected to: collect data by observing and measuring using appropriate tools (e.g., thermometers); analyze and interpret information to construct reasonable explanations from direct and indirect evidence; communicate valid conclusions; and construct graphs, tables, maps, and charts using tools including computers to organize, examine, and evaluate data.

The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to: analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information; represent the natural world using models and identify their limitations.

Fifth Grade Science Concepts
The student is expected to interpret how land forms are the result of a combination of constructive and destructive forces.

Sixth Grade Scientific Concepts
The student is expected to identify forces that shape features of the Earth including uplifting, movement of water, and volcanic activity.

Eighth Grade Scientific Concepts
The student knows that natural events and human activities can alter Earth systems. The student is expected to: predict land features resulting from gradual changes such as mountain building, beach erosion, land subsidence, and continental drift

Time Requirements

45 minutes

Materials

For each group of three to four students:

- Images of volcanos on the inner planets. Some Internet sites for such images include:

Planetary Photojournal: http://photojournal.jpl.nasa.gov/index.html
Solar System Forum:
http://solarsystem.nasa.gov/multimedia/gallery.cfm?Category=Planets
Solar Views: http://www.solarviews.com/eng/solarsys.htm;
http://www.solarviews.com/eng/earth.htm

- One large (20 oz or larger) and one small (8 oz or smaller) container –cardboard cups, milk cartons, plastic drink bottles, etc. The two containers must be the same shape, thickness, material, but of substantially different sizes.
- Warm and very hot water (to fill both containers)
- Two thermometers that measure from boiling point to room temperature
- Watch or clock
- Graph paper and paper for recording
- Safety goggles (for each student is best)
- Clear tape

Activity

Invite the children to examine the images of planetary surfaces. What features do they observe?

Volcanos (yes, this is how we spell it at the LPI!) are one feature that may indicate that a planet is geologically active. Geologically active planets are still hot inside – hot enough to produce magma that makes volcanos (or lava flows) at the surface.

Of course, we have not witnessed a volcanic eruption on another planetary body (except on Jupiter's moon Io!) – so scientists must examine the volcanos and interpret if they are recent or not. How might a scientist figure this out? (*Is the volcano worn down by erosion or does it have steep sides and well defined features – in other words, is it "fresh?"*)

Invite the students to discuss which of our inner solar system terrestrial planets might be geologically active, based on the images of volcanos and their knowledge of the planets.

Is Earth geologically active? *(Yes! Earth is very active with volcanos and earthquakes)*
Our Moon? *(No, volcanos on our Moon are present but weathered; there are large areas of ancient lava flows – the Maria)*
Mars? *(Probably; Mars has evidence of volcanos that have not weathered very much)*
Venus *(Probably; the Magellan spacecraft revealed volcanos on Venus)*
Mercury *(No, there are no active volcanos on Mercury)*

Are there any patterns that the students can recognize? Distance from the Sun and volcanic activity? *(Nope; Venus is closer to the Sun and geologically active – it lies between two geologically inactive bodies, the Moon and Mercury)* Size and volcanic activity? *(Hmmmmm…… maybe!)* What reasons do they pose for why some planets are volcanically active and some are not?

Invite the students to view the experiment materials. What experiment might they do to test their ideas? What might the small and large containers represent *(small and large planets)*.

If both of the containers were filled with hot water, which would cool down faster? Invite them to test their hypothesis.

Note: Safety goggles are needed for this experiment!

1. Split the students into groups of 4 and explain that duties will include data collection, time management, measurement reading, and graphing. Groups should select one person for each aspect of the experiment.
2. Have the students put on safety goggles.
3. Have the students place a thermometer in each of the containers (the thermometer for the large container may need to be taped to the inside).
4. Have the groups practice taking and recording measurements at intervals of three minutes using the warm water.
5. Pour out the warm water and refill each container with very hot water. Have the students immediately take the water temperatures (the water in both containers should start at about the same temperature). For safety purposes it is not necessary for the water to be at the boiling point but it should read at least 170°F.
6. Record the temperature and time every three minutes.
7. Once a few measurements are taken, invite the students to brainstorm with you how to best graph the data. What are they graphing? *(change in temperature with time)* What is the total possible temperature interval? Time interval? What kind of graph is appropriate? What are the axes?

   The graph should have a minimum of 30 minutes along one axis and the temperatures shown along the other axis should be 200° F maximum and 80°F minimum.
8. Have the students begin to graph their results. After six or seven readings, ask the children what they are observing about the temperatures of the two containers. Are they heating up, staying the same, cooling? Is one cooling differently from the other?
9. After 30 to 45 minutes, have the teams wrap up their measurements and graphing. Invite them to share their observations. Why might the smaller container have cooled faster than the large container? The smaller container has as smaller volume, but a greater surface area to volume ratio. The bigger container has a greater volume and is slower to cool.
10. Invite the students to brainstorm how they might apply this model of cooling containers to the planets. What did they observe/learn about volcanic activity on the different sized planets?

    The smaller planetary bodies – Mercury and the Moon are no longer geologically active inside, they have no evidence of young volcanos; the few volcanos observed are eroded.

The largest planet – Earth – is still geologically very, very active!

Venus is close in size to Earth and has volcanos across its surface that appear to be fairly young (uneroded). In addition, much of Venus' surface has been smoothed over by lava flows in the last several hundred million years (somewhat recent to a geologist!).

Mars …. Mars has few volcanos that are concentrated in one large region and these appear to be young and not very eroded. Scientists think that these have been geologically active fairly recently (perhaps within the last million years). Mars is in the middle of the planets in size and seems to have cooled more than Earth and Venus (planets with volcanos scattered across their surfaces), but not as much as the Moon and Mercury.

The cooling containers are models for the cooling planets. The larger the planet, the slower it cools. Small planets or moons, like Mercury and our Moon, have cooled to the point that they are no longer hot enough to melt rock. Larger planets, like Earth and Venus, are still hot and still have active volcanism.

Some Background

What is volcanism?

Volcanism is the eruption of molten rock (magma) onto the surface of a planet. Magma and gases erupt through a break in the surface – a vent. The vent can be a long linear feature – a fissure. Vents also can be marked by volcanos - conical features that form from ejected magma. Magma that reaches the surface is called "lava." Volcanos are named for Vulcan – the Roman god of fire!

Why and where do volcanos form?

Volcanism is the result of a planet losing its internal heat. Volcanos can form where rock near the surface becomes hot enough to melt. On Earth, this often happens in association with plate boundaries. Where two plates move apart, such as at mid-ocean volcanic ridges, material from Earth's interior slowly rises up, melts when it reaches lower pressures, and fills in the gap. Where one plate is being subducted under another, chambers of magma may form. These magma bodies feed the volcanic islands that mark subduction zones.

Although most volcanic activity takes place at plate boundaries, volcanism also can occur within the plate interiors at hotspots. Hotspots are thought to be from large "plumes" of extremely hot material rising from deep in Earth's interior. The hot material rises slowly, eventually melting as it reaches lower pressures near Earth's surface. When the material erupts it forms massive lava flows of fine-grained dark volcanic rock - basalt. The broad, gentle shield volcanos of Hawaii come from a hotspot.

What do Earth's volcanos tell us?

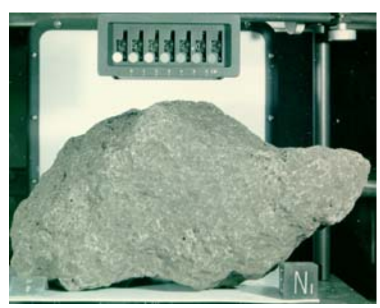
The fact that Earth has volcanos tells us that Earth's interior is circulating and is hot. Hot material rises very slowly from the deep interior of the Earth. When it gets close to the surface, where the pressure is less, this material melts, forming pools of magma. This magma feeds Earth's volcanos. Earth is cooling; volcanos are one way to lose heat. The pattern of distribution of volcanos on Earth gives us a clue that Earth's outer surface is divided into plates; the chains of volcanos associated with mid-ocean ridges and subduction zones mark the plate edges. Other planets have volcanic features – some recently active – telling geologists that they, too, are losing heat from their interiors and that there is circulation. However, these planets do not display the pattern that Earth's volcanos do.

What evidence is there of volcanism on other planets?

Moon: Our closest neighbor has small volcanos, fissures (breaks in the crust) and extensive flows of basalt, a fine-grained dark volcanic rock. The large dark basins that you can see on the Moon are the maria – areas of these lava flows. However, all of these volcanic features are old. There are no active volcanic features on the Moon. Most of the volcanic activity took place early in the Moon's history, before about 3 billion years. The most recent lava flow occurred about 1 billion years ago.

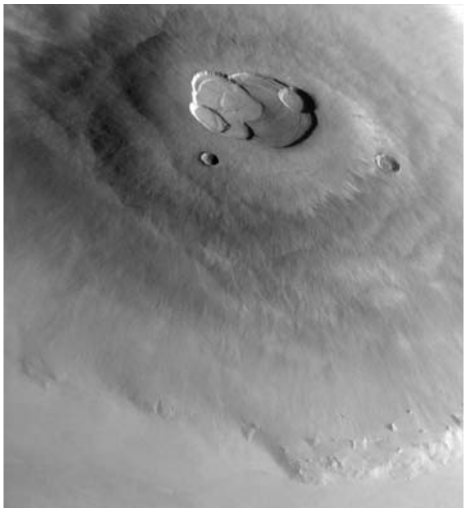
Dark regions on the Moon are lunar maria. These are low, smooth regions of dark, fine-grained volcanic rock – basalt. While the maria infill large, old impact basins (created when an asteroid struck the Moon), the basalts are from lava flows that are younger than the impact.

Galileo spacecraft image (PIA00405) produced by the United States Geological Survey, courtesy of NASA and the Jet Propulsion Laboratory.



This rock sample was collected by the Apollo 15 mission in 1971. It is a basalt, a type of rock that solidifies from a volcanic lava. This particular basalt formed 3.3 billion years ago and is similar to basalts formed at volcanos such as Hawai'i on Earth.

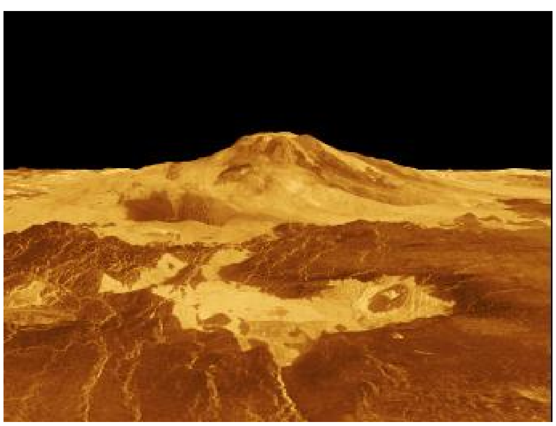
Mars: Mars has volcanic features that are similar in shape to those on Earth, though much larger. There are large shield volcanos – like those in Hawaii - that contain 100 times more mass that those on Earth. Olympus Mons is the tallest volcano in our Solar System. It is 22 kilometers tall (14 miles), compared to Mauna Loa's 9 kilometers (almost 6 miles), and would fill the state of Arizona. Several of the volcanos on Mars, including Olympus Mons, occur in the Tharsis region; the magma for the volcanos may come from hot material welling up in plumes from deep in Mars' interior. Many scientists consider Mars to be volcanically active, even if we have not observed an eruption. Basalt meteorites from Mars indicate that volcanism has occurred in the last 150 million years. Very few impact craters occur on the lava flows of Olympus Mons, suggesting that this volcano probably has erupted in the last few million years.



Oblique view of the Olympus Mons volcano on Mars. The large depression in the upper center of the image is the caldera. The caldera is located near the summit of the volcano and is 65 × 80 kilometers (40 × 50 miles) across — about the size of Rhode Island. When magma erupted out of vents on the side of the volcano, the rock near the summit collapsed, producing the caldera.

Viking Orbiter image (641A52) courtesy of NASA.

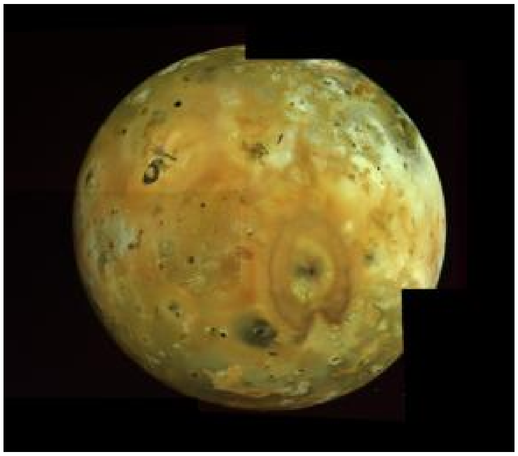
Venus: Venus has more than 1700 volcanic features and many of these look fresh - unweathered. Much of the surface of Venus has been covered by huge flows of basalt lava, probably in the last five to eight hundred million years. This blanket of lava completely covered surface features, such as impact craters. The fact that only a few craters dot the surface provides evidence of the recent nature of this resurfacing.



Computer-generated view of Maat Mons on Venus. This image is from Magellan spacecraft radar data; the atmosphere of Venus is too thick for telescopes to see through. Dark areas are smooth, interpreted to be older lava flows. Bright areas are rough, interpreted to be young lava flows.

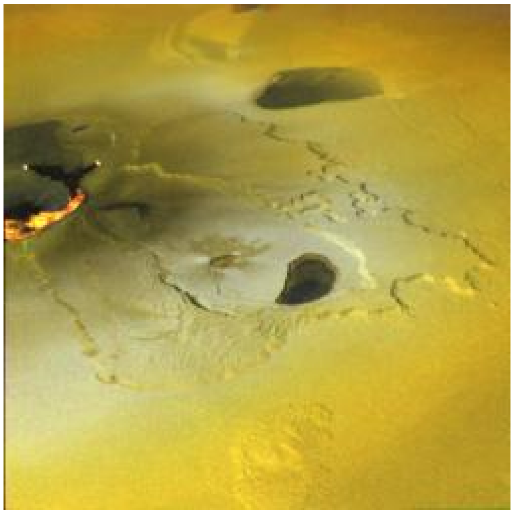
Image courtesy of NASA and the Jet Propulsion Laboratory.

Io: Jupiter's innermost moon, Io, is the most volcanically-active body in our entire Solar System! NASA missions imaged massive plumes shooting 100's of kilometers (miles) above the surface, active lava flows, and walls of fire associated with magma flowing from fissures. The entire surface of Io is covered with volcanic centers and lava flows, which have covered all of its impact craters. Io, however, is fairly small – about the size of our Moon. If Io is so small, why has it not already cooled? Io gets "tugged on" by Jupiter and its moons, Europa and Ganymede. This causes the crust of Io to flex – bend back and forth – and heats the interior of Io.



Voyager image of Io. The dark spots mark volcanos.

Image courtesy of NASA and the Jet Propulsion Laboratory.



The Galileo spacecraft captured this image of an active volcanic eruption on Io in 2000. This false-color picture is about 250 kilometers (about 155 miles) across.

Image produced by the University of Arizona, courtesy of NASA.

Why don't we find active volcanos on all planets and moons?

Active volcanos occur on planets that are still hot. In general, the larger the planet, the slower it cools. Small planets or moons, like Mercury and our Moon, have cooled to the point that they are no longer hot enough to melt rock. Larger planets, like Earth, Venus, and Mars, are still hot and still have active volcanism.