Space Photography Laboratory
Arizona State University
Tempe, AZ 85287-1404

Planetary Geology Group
http://europa.la.asu.edu

Pudding Volcanism: Exploring Lava Flows

Instructor Notes:

Estimated Time: 1 hour- 1 1/2 hours

Time Required for Preparation: 30-40 minutes

Purpose:

To examine the influence of viscosity on a material flow in order to understand some of the factors which determine the size and shape of volcanic flow fields.

Suggested Correlation Of Topics:

- types of volcanoes
- characteristics of different lava types
- environmental effects on volcanoes
- structures associated with volcanic activity, such as calderas, geysers, and lava tubes
- historical and environmental effects of volcanoes on humans
- igneous rocks
- fluid properties, such as rheology
- thermal evolution and heat loss mechanisms of planets and satellites
- plate tectonics

Materials:

For each group of 4 to 6 students:

- Needed for pudding:
  - 2 Tbsp+1/4 tsp regular instant chocolate pudding mix. (one box will yield enough for 4 groups with approximately 1 tsp extra)
  - 1/2 cup+1 Tbsp+1 tsp regular instant vanilla pudding mix. (1 box will yield enough for 1 group with approximately 3 Tbsp+1 tsp extra)
  - 2 cups milk (regular or low fat; be sure that the same type is used throughout)
  - 5 large containers with lids to mix pudding in
  - 2 tablespoon and 2 teaspoon measures
- 1/4 cup chopped nuts

- 10 8" or larger cake decorating or pastry-fill bags (only 2 are necessary if sinks are available in the room)
- 10 tips for decorating bags, preferably metal, with widest opening possible (2 if sinks are available)
- 2 small metric rulers
- 1/4 cup, 1/3 cup, and 1/2 cup capacity dry measures.
- 1 measuring cup or wide graduated measure with a capacity of at least 1.5 cups

- 2 rubber spatulas
- 10 plates, preferably styrofoam
- 6 rubber bands
- masking tape
- paper towels for cleanup
- scissors (if a metal tip is not used on decorator bag or if plates are not styrofoam)

Teacher Recommendations:

Variations: It may be easier, especially if working with a small group, to have a select group of students prepare and measure all flows in front of the class. Have students individually answer questions based upon their observations. As a demonstration the flows can be prepared and then compared to the photographs used in part 3. Give an oral explanation of viscosity, have students examine the pudding flows compared to the terrestrial flows (photos A & B), then the terrestrial flows compared to the others (photos C & D).

A Note on Advance Preparation and Set-Up: Some preparation before class is necessary for this exercise. The pudding should be prepared in advance so that the students will not know the mixtures and cannot guess their relative viscosities. Other ingredients should be prepared in advance to save time and avoid mess. Pudding can be mixed by hand or by using an electric mixer, but pudding mixed by hand will be slightly thicker. Therefore, whichever method is used should be used consistently to avoid textural variations. Instant pudding will set in 5 minutes but can be prepared up to a few days in advance, provided that it is kept tightly covered and refrigerated. It is very highly recommended that additional pudding be prepared for at least one extra group to avoid shortages and prepare for potential spills.

It would be a good idea to have paper towels on hand around the room. Allow a full 1 1/2 hours if students will be rinsing and drying decorator bags rather than using a new bag for each flow.

Preparation: (**Estimated Time**: 30-40 minutes)

For each student group, mix each of the following:

- 1/2 cup vanilla pudding mixed at ratio of 1 part pudding to 2 parts milk. Label this 1A.
  (2 Tablespoons+2 teaspoons of mix; 5 Tablespoons+1 teaspoon of milk per group)
- 1/2 cup vanilla pudding mixed at a ratio of 1:6. Label this 1B.

(approximately 1 Tbsp+1/2 tsp of mix; approximately 3 oz+2 1/2 tsp of milk per group)

- 3/4 cup vanilla pudding mixed at a ratio of 1:3. Label this 2A.
  (3 Tbsp of mix+1/2 cup+1 Tbsp of milk per group)
- 3/4 cup chocolate pudding mixed at a ratio of 1:4. Label this 2B.
  (2 Tbsp+1 1/4 tsp of mix; approximately 1/2 cup+1 Tbsp+1 3/4 tsp of milk per group)

The nuts will also require advance preparation. Nuts which are not ground into small enough pieces will become lodged in the tip of the decorator bag, and may lead to a very explosive eruption! Place nuts in a bag or wrap in paper and hammer (a rubber mallet will work best) to the texture of large grains of sand or very fine gravel.

Answer Key:

Note: Please be aware that measurements of flows may vary from one trial to another. However, the differences between flows in the same trial will remain consistent. Measurements will reflect viscosities which contrast one another in a manner consistent enough for demonstration purposes.

Part One:

1. **length**: (will vary) approximately 80mm, will be less than length in answer 3.
   width: (will vary) approximately 70mm, will be less than width in answer 3.
   height: (will vary) approximately 30mm, will be greater than height in answer 3.

2. sketch of tall, rounded mound, possibly pointed on top, not very wide at base.

3. **length**: (will vary) approximately 150mm, will be greater than length in answer 1.
   width: (will vary) approximately 150mm, will be greater than width in answer 1.
   height: (will vary) approximately 10mm, will be less than height in answer 1.

4. sketch of low round puddle, covering much surface area; possibility of small crater present in middle of flow.

5a. 1B.
 b. 1B.
 c. 1B.

6a. 1A.
 b. Flow 1A is taller than flow 1B.

7. 1A.

8. 1C.

Part Two:

9. **length**: (will vary)
   "mafic"/chocolate (m/c): approximately 140mm.

"felsic"/vanilla (f/v): approximately 100mm.
will be greater than length in answer 12.

width: (will vary)
m/c: approximately 140mm.
f/v: approximately 100mm.
will be greater than width in answer 12.

height: (will vary)
m/c: approximately 5mm.
f/v: approximately 15mm.
will be less than height in answer 12.

10. m/c: sketch of low, round puddle, flat on top; possibility of small crater present in middle of flow.

    f/v: sketch of short, rounded mound, tallest in center.

11. 50%.

12. **length:** (will vary)
    m/c: approximately 90 mm.
    f/v: approximately 75mm.
    will be less than length in answer 9.

    width: (will vary)
    m/c: approximately 90mm.
    f/v: approximately 75mm.
    will be less than width in answer 9.

    height: (will vary)
    m/c: approximately 12 mm.
    f/v: approximately 30 mm.
    will be greater than height in answer 9.

13. m/c: sketch of short, lumpy flow, flat on top.
    f/v: sketch of tall, lumpy mound, possibly pointed at center.

14. 1A.

15. flow #2, the one with nuts in it.

16. felsic.

17. a. "mafic"/chocolate #1
    b. "mafic"/chocolate #2 (with nuts)
    c. "felsic"/vanilla #1
    d. "felsic"/vanilla #2 (with nuts)

Note: Answers b & c occasionally will be reversed; it is possible for these pudding mixtures to have similar viscosities.

Part Three:

18a. A.
b. B.
c. The important factors to consider are the heights relative to the widths. A is tall and doesn't cover a large surface area. It is shaped similarly to the vanilla flows. B is not very tall and its base is spread wide. It is shaped similarly to the chocolate flows.

19a. B.
b. A.

20a. D.
b. C.
c. C.
d. Volcano C resembles the low viscosity terrestrial volcano. It is spread over a large surface area. Its crater is obvious (as was seen in the low viscosity pudding flows). The volcanoes in photograph D cover less surface area, and are more mound-shaped, similar to the high viscosity terrestrial volcano. They don't have obvious craters.

Note: Although it is possible to determine relative viscosities from these pictures, the volcanoes in photographs C and D should not be assumed to be simply mafic or felsic. Although viscosity is an important clue, more detailed information is important for positively determining mineral content. Other types of flows besides mafic and felsic flows, such as sulphur flows, ice flows, etc., occur on non-terrestrial bodies.

The craters that can be seen on some of the volcanoes in photograph D are believed to be impact craters.

Name_____

Effect of Viscosity on Lava Flows: Volcanism with Pudding

Purpose:

In this experiment you will investigate the influence of viscosity on lava flows and examine some of the factors which determine the size and shape of volcanic flow fields.

Materials:

For each student group:
- 1/2 cup of pudding labeled 1A and 1B
- 3/4 cup each of pudding labeled 2A and 2B
- 1/4 cup chopped nuts (2 oz)
- 10 8" or larger cake decorating or pastry-fill bags (only 2 are necessary if sinks are available in the room)
- 10 tips for decorating bags (2 if sinks are available)
- 2 small metric rulers
- 1/4 cup, 1/2 cup, and 1/3 cup capacity dry measures
- 1 measuring cup or wide graduated measure with a capacity of at least 1 cup
- 2 Tablespoon and 2 teaspoon measuring spoons
- 2 rubber spatulas
- 10 plates (preferably styrofoam)
- rubber bands
- masking tape
- paper towels for cleanup
- scissors (if a metal tip is not used on decorator bag or if plates are not styrofoam)

Introduction:

Volcanism is a geologic process leading to distinctive landscapes. Volcanoes and lava flows are found on Earth, the Moon, Venus, Mars, and moons of the outer planets such as Jupiter and Neptune. On Earth, volcanism is often associated with active plate boundaries. New material for Earth's crust is created at mid-ocean ridges, while large volcanoes such as Mt. St. Helens are found near subduction zones. However, volcanism occurs far from plate boundaries as well. For example, hot spots form where hot magma rises from the mantle and erupts through the crust (e.g. the Hawaiian Islands). On Venus, the Moon, and Mars, volcanic materials and processes are thought to be similar to those on Earth. On some moons of the large gas planets, which are further from the sun, icy materials such as slush can erupt onto surfaces in a type of volcanism, called cryovolcanism.

Lavas and volcanic rocks are classified by their texture and mineral content. All rocks that crystallize from magma (molten rock) are called igneous rocks. Igneous rocks are broadly classified as **felsic** (containing abundant silica (SiO_2) and the minerals quartz, feldspar, and mica) or **mafic** (containing abundant magnesium and iron, and the minerals pyroxene, olivine, and biotite). Felsic magmas usually melt at lower temperatures than than mafic magmas.

The size and shape of a lava flow is controlled partly by the viscosity of the magma being erupted. Viscosity is determined by several factors, including the temperature, chemical composition, crystal content, and gas content of the magma. Felsic lavas tend to have a high viscosity (that is, they do not flow readily) , while mafic lavas have a low viscosity (they are "runny"). The rate and environment of the eruption, along with other factors determines the final form of the lava flow.

By studying photographs of volcanoes and lava flows on different planets and moons, geologists can estimate the mineral make-up of their crusts. Scientists do this by examining the dimensions, shapes, and other characteristics of these flows. They compare their observations with information gathered from terrestrial flows or laboratory models.

Procedure And Questions:

Part One: Comparison of Viscosity

One person should use a dry measure cup to measure 1/2 cup of the pudding labeled **1A** and level it off with a rubber spatula. Meanwhile, another person should prepare the "volcano" plate.

To prepare the plate: If a metal tip is used, remove it from decorator bag. With one finger inside the tip, firmly and carefully push and twist it up through the middle of the bottom of the plate, to create a small hole. If the tip is not metal or if the plates are not styrofoam, cut a small hole in the center of the plate with scissors, approximately the same size as the small end of the tip. Replace the tip on the bag and gently push through the hole so that the tip points up through the plate no more than 1cm. Tape all around the tip on the top of the plate, so that the crack between the plate and the tip is completely covered and the tip is securely held in place. Be sure the tape lies as flat as possible along the tip and against the plate. Add extra tape underneath the plate to further stabilize the bag. Place **2 pieces of tape** securely over the opening of the tip. This is your "volcano".

One person should hold the bag open while another fills it with the pudding. Push it as far down in the bag as possible. Twist the top of the bag and wrap a rubber band around the twist. Push two desks or tables together so that they are about 6-8cm apart. If this cannot be done, stack 2 piles of thick textbooks of equal height about 6-8cm apart. Tape the plate down so that the bag hangs between the tables or books. Remove the tape from the opening and squeeze the pudding from the bag, moving from bottom to top. Squeeze until no more pudding will come out.

Carefully measure, in millimeters, the length, width, and height of the highest point of the flow.

1. What are the measurements of the flow?
   length:
   width:
   height:

2. In the space below, sketch the top view and side view of the flow:

Carefully pull the bag and tip out of the bottom of the plate by twisting gently. Place a piece of tape over the hole underneath the plate. Very carefully put this plate aside and label it "A". Scrape out the 1/2 cup measure with a rubber spatula and wipe clean with a paper towel. If a sink is available, rinse and dry the decorator bag. If not, begin with a new bag. Construct a new

"volcano", with 2 pieces of tape over the opening, and fill it with 1/2 cup of pudding **1B**. Tape the plate down in the same manner as before, and squeeze pudding onto the new plate.

Carefully take the measurements of this new flow.

3. What are the measurements of this flow?
   length:
   width:
   height:

4. In the space below, sketch the top view and side view of this flow:

Carefully remove the bag from the plate, tape over the bottom of the hole, put the plate aside and label it "B".

Compare the 2 plates.

5a. Which pudding flowed out of the bag more easily?

b. Which pudding spread out to cover more surface area?

c. Which flow has less height?

6a. Which pudding covers less surface area?

b. How does the height of this flow compare to the height of the other?

7. Which pudding had the higher viscosity (was more resistant to flow)?

8. In which flow is the "crater" or "vent" (where the pudding flowed up through) more evident?

Throw away both plates when you are done, and clean the bag if a sink is available.

Part Two: Simulated Lava Flows

For part two, split into 2 subgroups. One subgroup will work with the "mafic" chocolate pudding and one will work with the "felsic" vanilla pudding. Both subgroups will work independently and then compare results at the end.

Circle one of the following to indicate your subgroup:

"MAFIC"/CHOCOLATE "FELSIC"/VANILLA

Select the pudding that your subgroup will work with (2A for “felsic”/vanilla or 2B for “mafic”/chocolate). One person should measure 1/2 cup of pudding while another person prepares the "volcano" plate.

Place 2 pieces of tape over the opening of the tip, fill the bag as before and twist and seal the end with a rubber band. Tape the plate down between 2 tables or stacks of books, and squeeze the pudding out onto the plate.

9. What are the measurements of the flow?
length:
width:
height:

10. In the space below, sketch the top view and side view of the flow:

Carefully pull the tip out from the bottom of the plate and place a piece of tape over the hole under the plate. Carefully put this plate aside, label it "1", and clean and dry the bag or get a new one. One person should set up another "volcano" in the same manner, with tape over the hole in the tip, while the other person measures 1/4 cup of pudding. Measure 1/4 cup of nuts. In the measuring cup, mix the nuts with the pudding and place the mixture in the bag. Seal with a rubber band.

11. If the nuts represent mineral crystals which form as a magma cools, what percentage of crystallization is present in this mixture?

Squeeze the mixture onto the plate. Measure.

12. What are the measurements of this flow:
length:
width:
height:

13. In the space below, sketch the top view and the side view of the flow:

14. Which flow from part one was comparable to this one?

Remove the bag and tape over the bottom hole. Label this plate 2. Compare the 2 plates.

15. Which has the higher viscosity?

Now both subgroups should compare the "mafic" (chocolate) flows with the "felsic" (vanilla) flows.

16. Which have a higher viscosity, "mafic" or "felsic"?

17. List all 4 flows in order from lowest to highest viscosity:

a. (lowest) c.

b. d. (highest)

Part Three: Photographs

For this section, refer to the photographs at the end of this exercise.

Look at the pictures labeled "A" and "B". Both of these are terrestrial volcanoes.

18a. Which volcano was the result of high viscosity flows?

b. Which was the result of low viscosity flows?

c. What factors did you consider in determining your answers to 18a and 18b?

19a. Which terrestrial volcano, A or B, is probably more mafic in composition?

b. Which is more felsic?

Now examine the pictures labeled "C" and "D". Photograph C is of a volcano on Io, and photograph D shows part of the surface of Venus. Be aware that the craters that can be seen on some of the volcanoes in photograph D are believed to be impact craters, not volcanic vents.

Compare these with photographs A and B.

20a. Which picture (C or D) appears to be more similar to A?

b. Which appears to be more similar to B?

c. Which resulted from low viscosity flows?

d. What factors did you consider in answering these questions?

Note: Although it is possible to determine relative viscosities from these pictures, the volcanoes in photographs C and D should not be assumed to be simply mafic or felsic. Although viscosity is an important clue, more detailed information is important for positively determining mineral content. Other types of flows besides mafic and felsic flows, such as sulphur flows, ice flows, etc., occur on non-terrestrial bodies.