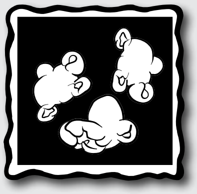
Tephra Popcorn



Grade Level: 6–9

Learner Objectives:

Students will:

- Understand meaning of the term "tephra"
- Observe that volcanic ash consists of rock fragments and not a burned substance
- Recognize that expanding gas bubbles can inflate and fragment magma explosively
- Understand that the volume of erupted bubble-filled tephra is greater than the original volume of magma because of the expansion of gas bubbles
- Recognize volcanic ash (grain size equal to or less than 2 millimeters, or 1/10 inch) as a common form of tephra
- Identify energy transformations that occur in popping corn and a tephra eruption
- Volcanic gases are an important driving force of volcanic eruptions

Setting: Classroom

USGS science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard- An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Students measure the volume and mass of popcorn before and after popping in an exploration of how expanding gas bubbles inflate and fragment magma during a volcanic eruption. They study the physical characteristics of tephra using samples or photographs.

Timeframe: 50 minutes

Comparing Tephra to Popcorn—30 minutes

Analyzing the Characteristics of Volcanic Ash—20 minutes

Materials:

Comparing Tephra to Popcorn

- Graphic *"Images of Popcorn—Up Close"*
- Graphic *"Soda Bottle Volcano"*
- Graphic *"Tephra Types"*
- Student pages *"Tephra Popcorn"*

One for each student group:

- Hot air popper or stove and pot for corn popping
- 2 1/2 cups unpopped kernels
- Graduated cylinder, beaker, or metric kitchen measuring cups (one liter or larger)
- Empty containers for popped kernels
- Scale or balance

continued.....

Activity last modified: November 21, 2014

Analyzing the Characteristics of Volcanic Ash

- Graphic *"Samples Collected by a Geologist"*
- Copies of student page *"Samples Collected by a Geologist"*

Vocabulary: Blocks, bread-crust bombs, conduit, eruption, eruption cloud, explosion, lava, lithic, magma, magma chamber, obsidian, Pele's Hair, pumice, scoria, spindle-shaped bombs, tephra, vent, vesicles, volcano, volcanic ash, volcanic gas, viscous

Skills: Comparison, describing, measurement, observation, prediction

Benchmarks:

See benchmarks in Introduction.

Teacher Background

Tephra—General term for fragments blasted into the air by a volcano

Tephra is a general term used for fragments of volcanic rock, regardless of size, that a ***volcano*** blasts into the air by an ***explosion*** or ***eruption***. Tephra is not a product of combustion like ash produced by burning wood or paper. Some tephra originates as local rock while other tephra consists of fresh ***magma*** that retains gases and is bubbly in appearance. The heat and expansion of ***volcanic gas*** can force tephra and steam to rise to high altitudes as part of a billowing ***eruption cloud*** that resembles a giant puff of smoke.

Tephra ranges in size from enormous blocks the size of small houses to ***volcanic ash*** (particles < 2 mm (1/10 inch) in diameter). Tephra comes in a variety of shapes and textures, such as masses of solid ***blocks,*** bubbly ***pumice***, ***bread-crust*** and ***spindle-shaped bombs***, fine dust, and at some volcanoes, of glass fibers called ***Pele's Hair***.

Gases are an important driving force of volcanic eruptions

The expansion and release of volcanic gases (principally water vapor) provide the energy for eruptions. Gas bubbles expand dramatically within the magma as they rise from a deep, high-pressure to a shallow, low-pressure environment. As they rise up the ***conduit***, the gas expands to the breaking point and explodes, causing the magma to break into fragments. Evidence of gas bubbles in magma is preserved as holes ***(vesicles)*** in tephra and lava rocks. See the Soda Bottle Volcano activity for further detail.

The expansion of magma during a volcanic eruption

During the journey from the ***magma chamber*** to the ***vent*** of a volcano, gas bubbles expand to a thousand times or so of their original size, which increases the volume of magma by three to four times. An inexact analogy can be made with the effect that baker's yeast has as it feeds on bread dough. The yeast produces carbon dioxide bubbles that expand and force the dough to rise in the bowl. The result is a highly porous loaf of bread.

By these volcanic processes described above, gases are added to the atmosphere and oceans. The activity below, "***Comparing Tephra to Popcorn***," addresses the evolution of bubble-filled tephra.

Sidebar 1 — The Texture of Tephra Particles Provides Clues to Their Origin

After a volcano erupts tephra into the air, large particles fall back onto the volcano's slopes, while finer particles are carried away from the volcano by the wind. The appearance of tephra tells us a lot about its origin and cooling history. Find a comprehensive list of tephra appearances on the Internet Resources Page.

Bubble-filled (Vesicular) Tephra and Pumice

Pumice is similar to the liquid foam produced during the opening of a bottle of pressurized soda. The gases can remain entrapped or can escape and leave behind foam that solidifies within a few seconds, locking in gas bubbles. We call these bubbly, light-colored rocks pumice. ***Scoria*** rock is bubbly, though usually darker and heavier than pumice.

Tephra with no Bubbles—(Lithic Tephra)

Some tephra contains few or no bubbles, either because it originated in gas-poor magma, or because the gases already escaped. Other bubble-poor tephra, called ***lithic*** tephra, consists of rock from the vent walls that was blasted into small pieces by eruptive forces.

Volcanic Glass

Some ***viscous lavas*** do not allow growth of minerals, and instead form glass. ***Obsidian*** is one example of volcanic glass.

Mineral-Rich Tephra

Magma that cools slowly underground (days to centuries) can grow large minerals that give pumice and scoria a speckled appearance.

Bread-Crust Bombs

Fragments cool faster on the outside and more slowly inside. When the interior vesicles expand, the surface cracks. The result is a rock with a crusty surface like baked bread.

Tephra with a Streamlined Appearance such as Spindle Bombs

Molten lava is twisted and smoothed as it falls through the air to the volcano slopes below.

Tephra Popcorn-continued . . .

Sidebar 2 — Tephra as a Hazard

Tephra can be a hazard, a nuisance, or a harmless substance, depending on its size and distribution. While large blocks of tephra can crush structures, it usually falls back to the ground within 1.2 kilometers (2 miles) of the crater where human populations are generally sparse. Volcanic ash is fine-grained and its movement is influenced by wind direction and speed. Volcanic ash can disrupt daily life for people hundreds of miles from a volcano for long periods of time.

Envision a cloud of fine particles that covers the sky over a town and deposits a layer of dust everywhere. Fine particles of volcanic ash can be easily breathed into lungs and cause respiratory problems for people and animals, in addition to irritating eyes and skin. The ash itself is not toxic, but high amounts of fluorine and chlorine on ash surfaces from a few volcanoes in the world have caused livestock deaths and contaminated human water supplies. Volcanic ashfall can strip leaves from crops and trees and disrupt pollination of flowers.

Volcanic ash can severely impact transportation systems. Ash reduces driver visibility. It can disrupt vehicle operation and impede traffic flow. Volcanic ash clouds can pose a serious hazard to aviation. Engines of jet aircraft have failed after flying through clouds of ash. Roads, highways, and airport runways can be treacherous or impassable because ash is slippery. Wind and vehicle movement often resuspends ash for months after an eruption. Billowing ash can reduce driver and pilot visibility to near zero.

Ash can collapse building roofs when they are burdened by 10 centimeters (approximately 4 inches) or more of wet ash. When people use high volumes of water, they can dramatically reduce the community's water supply. Volcanic ash clogs drains; it damages sewer systems, which can require expensive repair. Use Internet Resources as a guide to current information about how to plan and respond before, during, and after an ashfall.

Teacher Tips

Use of the term "Mass and Weight on Earth"

Students often have difficulty understanding the difference between mass and weight because in everyday use, people use weight as a synonym for mass. You might want to remind students that we define mass as the amount of matter in an object. The weight of an object is defined as the force of gravity upon that object, and is calculated as the mass times the acceleration of gravity, $w = mg$. The difference between mass and weight would become more apparent if students spent time on multiple planets where gravitation attractions are different. This activity uses "mass." For younger students, teachers can substitute "weight on earth" for "mass" if it helps students conduct the activity with greater understanding.

Teacher Tips

Optionally, conduct the Soda Bottle Volcano activity in Chapter 1 prior to this activity.

Procedure

What to do Before Class Begins:

Comparing Tephra to Popcorn

- A few days before conducting this activity, ask students to bring in hot air poppers from home or arrange to use local stove facilities where kernels can be popped in an ungreased pot.
- Assemble graphics "***Soda Bottle Volcano***," "***Types of Tephra***" and "***Images of Popcorn—Up Close***."
- If using real samples, assemble one each of fireplace ash, volcanic ash, and small stones for each group.
- If using real samples, set up the microscope and (or) hand lens for students.

Comparing Tephra to Popcorn

For this activity you and (or) the students will pop popcorn kernels in an air popper or in an ungreased pot on the stove. Students examine changes in the volume and mass of unpopped and popped kernels and hypothesize how these results apply to actual tephra deposits. Look for evidence of gas bubbles using microscopes or microscope images of popcorn and relate this to characteristics of real tephra. Use this activity in small student groups or as a teacher demonstration.

1. Use the graphic "***Soda Bottle Volcano***" to review the role of gases in production of a volcanic eruption. See information in the teacher background.

2. Define the word tephra and show the graphic "***Tephra Types***" to provide examples of a variety of tephra types. Emphasize that tephra can be big or small and can greatly vary in texture.

3. Provide each student with a "***Tephra Popcorn***" student page.

4. Divide the class into groups of 4 or 5 students.

5. Give each group a hot air popper, container for popped kernels, graduated cylinder, metric measuring cup or beaker, 100 milliliters of unpopped kernels.

6. Point out the location of the scale or balance in the classroom, and note whether your scales allow students to "zero" automatically.

7. Instruct students to follow directions on their student pages. Students will develop a method to obtain the percent change in mass and the expansion factor for volume.

$$\% \text{ Change in Mass} = \frac{\text{Mass of popped corn} - \text{Mass of unpopped corn}}{\text{Mass of unpopped corn}} \times 100$$

Expansion factor = (Final volume/Initial volume)

8. After students conduct the experiment, lead a class discussion. Ask students what they observed in their experiments. Ask students why the volume of popcorn increased while the mass might have decreased. Ask what factors might lead to a decrease of mass (as with magma, loss of water from the popcorn by heating will cause some decrease in mass). Discuss how expanding gases provide the energy for an eruption. Note that volcanic gases disperse in Earth's atmosphere. Ask how the popcorn expansion is similar to, or different from, processes at an actual volcano. The volume of actual erupted tephra is commonly 3 to 4 times the volume of the original magma. ***The popcorn generally increases to 10 to 20 times or more of its original volume.*** As you discuss the popcorn images, project the graphics "***Images of Popcorn—Up Close***" and "***Types of Tephra***" (optional).

Instruct students to list potential sources of error such as inaccurate measurements of popped and unpopped corn and some unpopped kernels.

9. Finish your discussion with a dialogue about energy transformation. Students should comprehend that the unpopped kernel gains thermal energy during heating, which changes water to steam. Steam expands and increases pressure in the kernel until the kernel pops, and the expanding steam converts thermal energy to kinetic energy.

Analyzing the Characteristics of Volcanic Ash

Discover the difference between volcanic ash and fireplace ash by analyzing the characteristics of several samples. This is done most effectively when actual samples are used.

1. Give each student "***Samples Collected by a Geologist***" student page.

2. Divide the class into 6 to 8 groups.

3. Display the graphic "***Samples Collected by a Geologist***" or distribute samples of volcanic ash, river sediment, and fireplace ash to each group.

4. Without divulging the sample origins, direct students to answer questions on their student pages and identify the volcanic ash sample.

5. Lead a class discussion. Ask the class how they reached their conclusions.

Adaptations

- ***The Foil-Wrapped Popcorn Experiment***
  Use foil pan-wrapped popcorn (available at most grocery stores) to demonstrate how volume changes when kernels pop. Hold the popcorn over a stove burner to pop the kernels. Point out how kernels pop and release steam. Discuss how this is similar to expulsion of gases in a volcanic eruption.

- ***Analyzing the Characteristics of Volcanic Ash***
  As an alternative to providing all the samples, ask students to collect ash from a fireplace at home, and sediment from a streambed. Instruct students to devise classification categories for the samples or photos.

Extensions

◆ ***Expansion of Magma***

Direct students to use library and Internet resources to collect additional estimates of tephra volume for observed volcanic deposits. Some tephra volumes they can use are as follows: for a 2,200 year old tephra fall at Mount Rainier the volume was 0.2 cubic kilometers; for the May 18, 1980 Mount St. Helens the volume was 1 cubic kilometer; 1883 Krakatau tephra fall deposit has a volume of 10 cubic kilometers; the 1812 Tambora deposit had a volume of 100 cubic kilometers. Students divide the volume of the deposit by four to obtain the volume of the preeruptive magma. Students can create innovative ways to depict this expansion graphically, on paper or with use of a computer-based graphics program. Another follow-up activity is for students to depict the relative sizes of eruptions graphically.

◆ ***Pumice Demonstration***

Demonstrate to students that pumice contains holes and ask students how the holes formed. Ask students to predict what will happen when the samples are placed into a water-filled bucket. When the samples are placed into the bucket, most pumice floats. Ask students to hypothesize about why pumice floats. Encourage discussion about how pumice floats because the air-filled holes are isolated from one another. Some other bubbly rocks such as scoria are denser than water, or have holes that are interconnected so that water travels through these spaces and replaces the air, making them heavy and sinkable.

◆ ***Tephra Poster and (or) Computer Research***

Assign students one of the following types of tephra to research using a computer: volcanic block, volcanic bomb, lapilli, pyroclastic rock deposits, volcanic ash, pumice, or scoria. Instruct students to find a definition for their type of tephra. Make a poster with the definition on it. Students can print images from the computer to use on their poster.

Assessment

For assessment, instruct students to show results of calculations and other answers on the student pages. Use the questions in “Analysis and Conclusions” (question 8) and “For Further Thought” (question 9) to assess students’ understanding of the comparisons of popcorn and tephra. Students should demonstrate ability to follow instructions on the student page, record results and make calculations. Look for evidence that students understand the following concepts: tephra consists of rock fragments and not burned material; that expanding gas bubbles can inflate and fragment magma; that the volume of erupted tephra is greater that the original volume of magma because of the expansion of gas bubbles; that volcanic gases are an important driving force for volcanic eruptions. Assess application to real-world situations by assigning one or more of the extension activities.

References

Frances, P., Oppenheimer, C., 2004, Volcanoes: New York, N.Y., Oxford University Press, 521 p.

Kenedi, C.A., Brantley, S.R., Hendley, J.W., II, and Stauffer, P.H., 2000, Volcanic ash fall—A hard rain of abrasive particles: U.S. Geological Survey Fact Sheet 027–00, 2 p.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

Images of Popcorn—Up close and Microscope images of popcorn. (U.S. Geological Survey photography by Robert Oscarson)

A. Tephra in eruption column at Mount St. Helens on May 18, 1980, Photo by Austin Post, USGS.

B. Hand sample of tephra erupted by Mount St. Helens on May 18, 1980, Photo by David Wieprecht, USGS.

C. Microphotograph of tephra erupted by Mount St. Helens on May 18, 1980, Scanning Electron Microscope (SEM) image provided by Andre M. Sarna-Wojcicki, USGS.

D. Block was ejected into the air by an explosion at Kilauea Volcano, Hawai`i on January 26, 1988, Photo by Christina Heliker, USGS.

E. Spindle-shaped bombs erupted by Mauna Kea Volcano, Hawai`i, on July 10, 1992, Photo by Jack Lockwood, USGS.

F. Gas-rich pumice fragments erupted by Mount Pinatubo, Philippines on June 15, 1991, Photo by Willie Scott, USGS.

G. Bread-crust bomb erupted from the lava dome at Mount St. Helens, Washington, in March, 1997, Photo by David Wieprecht, USGS.

Name ____________________________

Tephra Popcorn

Instructions: *Follow the procedure and answer the questions.*

1. ***Before Popping the Popcorn:*** Measure the mass of the container, then add 100 ml of popcorn kernels. Subtract the values to obtain mass of the kernels. Note that some scales allow you to "zero" automatically.

   Measured Volume of Popcorn:

   Initial Measured volume of unpopped kernels ____________________

2. ***Initial Measured Mass of Popcorn:***

Measured mass of unpopped kernels + container ________	-	Measured mass of container ________	=	Initial measured mass of unpopped kernels ________

3. ***Your Prediction***:
   Write down your hypothesis about potential changes in mass and volume of the popcorn. Will they increase, decrease or remain the same? Then predict the mass and volume of the popped kernels.

   Predicted mass of popped kernels: ___________________________

   Predicted volume of popped kernels: ______________________________

Student Page

Name ______________________________

Tephra Popcorn-continued

4. ***Pop the Popcorn:***
Plug in the air popper and turn it on. Set a container in front of the popper to catch the popped kernels. Add the unpopped kernels to the popper and watch the corn pop. Or, pop the popcorn in a pot on a stove **without the oil**.

5. ***After Popping the Popcorn:***
Measure the volume, then measure the mass of the popped kernels using a scale or balance. Obtain the volume using a measuring cup or graduated cylinder. Calculate the percent change in mass and the expansion factor in volume.

Final Measured Volume of Popped Popcorn:

Measured volume of popped kernels ______________________

Final Measured Mass of Popped Popcorn:

Measured mass of popped kernels + container ________ - Measured mass of container ________ = Measured mass of popped kernels ________

Calculations:

Change in Volume:

Change in volume = (Final volume/Initial volume) = __________________

Change in Mass:

Change in mass = [(Final mass - Initial mass) / Initial mass] x 100 ________________

Name ______________________________

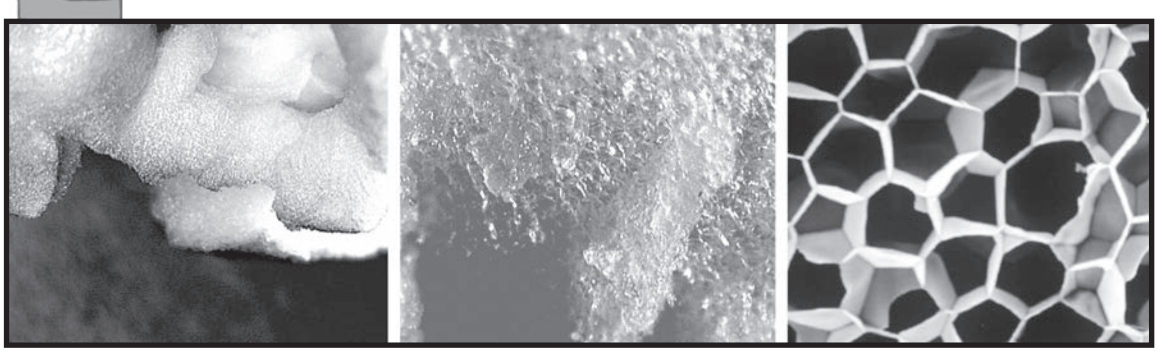
Tephra Popcorn-continued

6. ***Read the information about why popcorn pops.***

Why Does Popcorn Pop?
Inside the hard, outer shell of a kernel of corn is a starchy middle that contains water. As the kernel warms, the water within it changes into steam, which is the gaseous form of water. The steam expands. Eventually, the pressure inside the kernel exceeds the strength of the hard, outer shell and the kernel explodes with a pop!

7. ***Examine popcorn under a microscope below.***
These microscope images show popped kernels at different magnifications. Compare the size and shape of the popped kernels to unpopped kernels. List some characteristic features of the popped kernels.

Popcorn magnified 10 times, 70 times and 250 times



10 mm — 1.5 mm — 0.05 mm

Name ______________________________

Tephra Popcorn-continued

8. ***Analysis and Conclusions:*** *Answer the following questions.*

a. Explain the origin of holes in the popcorn.
(Review the box on **“Why Does Popcorn Pop?”**)

b. How did the mass and volume change during popping?

c. Imagine that the unpopped kernels represent magma inside a volcano and that the popped kernels are tephra erupted from a volcano. Do you think the preeruptive magma and erupted volumes of tephra are the same? Explain your answer.

d. Based on your observations of popcorn microscope images, what common features might be shared by both popcorn and tephra?

e. Explain the origin of holes in real tephra.

Name ______________________________

Tephra Popcorn-continued

9. ***For Further Thought:***

a. Describe how the expansion of gases in magma contributes to the energy of the volcanic eruption.

b. Describe the energy transformations that take place in popping kernels, and in erupting magma.

c. The volume expansion factor for erupted tephra is commonly three to four times the volume of the original magma. Is this magma expansion factor greater or less than that for popcorn? Explain how Earth's landscape would appear different if magma showed the same expansion factor as popcorn.

d. Popping kernels may lose mass due to water loss. The same can be said of rising magma. Explain what happens to excess water expelled from rising magma.

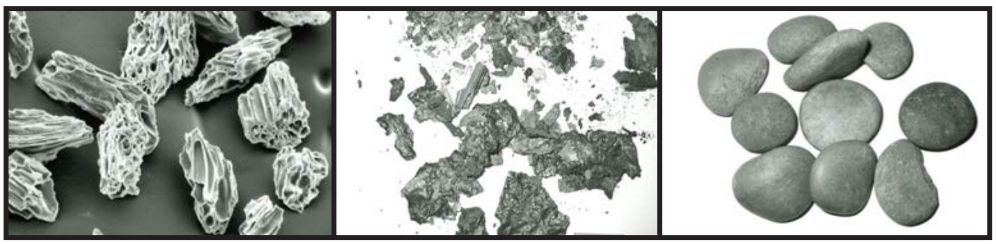
e. Describe how the presence of bubble-filled tephra on Earth's surface can affect the ecology of a landscape.

Name ____________________________

Samples Collected by a Geologist

Instructions: *These samples are similar to those a geologist would collect while working in the field. One sample is volcanic ash, one is ash from a fireplace, and the other is river sediment. Determine which sample is volcanic ash by answering the following questions.*

Sample A | Sample B | Sample C



—— 0.6mm —— | —— 100mm —— | —— 200mm ——

1. Predict which sample you think is volcanic ash, fireplace ash, or river sediment.

Volcanic Ash ______________ Fireplace Ash ______________ River Sediment ______________

2. List three adjectives that describe each sample.

Sample A	1		1		1	
Sample B	2		2		2	
Sample C	3		3		3	

3. Which sample contains bubbles? ________________________________

4. Hypothesize about the origin of these holes.

5. Based on your descriptions of the three samples, which sample is volcanic ash? How did you reach this conclusion?

6. Which sample is most likely the fireplace ash? Describe how it differs from volcanic ash.

Teacher Page

Tephra Popcorn—Answers

Instructions: *Follow the procedure and answer the questions.*

1. ***Before Popping the Popcorn:*** Measure the mass of the container, then add 100 ml of popcorn kernels. Subtract the values to obtain mass of the kernels. Note that some scales allow you to "zero" automatically. *Note to teacher: Values listed are examples. Your values and answer will vary, and depend in part upon use of fresh or stale popcorn.*

   Measured Volume of Popcorn:

   Initial Measured volume of unpopped kernels *100 ml*

2. ***Initial Measured Mass of Popcorn:***

Measured mass of unpopped kernels + container	*133 grams*	-	Measured mass of container	*41 grams*	=	Initial measured mass of unpopped kernels	*92 grams*

3. ***Your Prediction***:
   Write down your hypothesis about potential changes in mass and volume of the popcorn. Will they increase, decrease or remain the same? Then predict the mass and volume of the popped kernels.

   ANSWER: Students might predict that the mass remains unchanged. A correct hypothesis is that the mass of the popcorn decreases because the popping process releases water, in a similar way that magma releases water during a volcanic eruption. Volume of popcorn increases.

   Predicted mass of popped kernels:

   ANSWER: <120 grams

   Predicted volume of popped kernels:

   ANSWER: 1,000 ml

Teacher Page

Tephra Popcorn—Answers -continued

4. ***Pop the Popcorn:***
Plug in the air popper and turn it on. Set a container in front of the popper to catch the popped kernels. Add the unpopped kernels to the popper and watch the corn pop. Or, pop the popcorn in a pot on a stove **without the oil**.

5. ***After Popping the Popcorn:***
Measure the volume, then measure the mass of the popped kernels using a scale or balance. Obtain the volume using a measuring cup or graduated cylinder. Calculate the percent change in mass and the expansion factor in volume.

Final Measured Volume of Popped Popcorn:

Measured volume of popped kernels *2300 ml*

Final Measured Mass of Popped Popcorn:

Measured mass of popped kernels + container	*336 grams*	-	Measured mass of container	*255 grams*	=	Measured mass of popped kernels	*81 grams*

Calculations:

Change in Volume:

Change in volume = (Final volume/Initial volume) = *23 times initial volume*

Change in Mass:

Change in mass = [(Final mass - Initial mass) / Initial mass] x 100 *11%*

Tephra Popcorn—Answers
-continued

6. ***<u>Read the information about why popcorn pops.</u>***

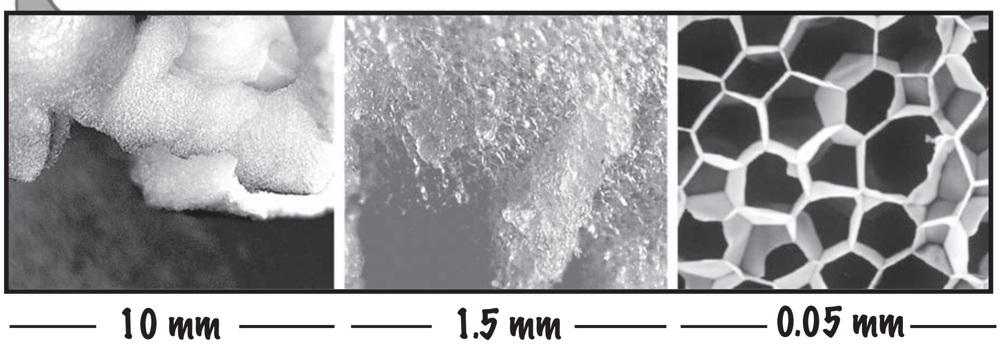
Why Does Popcorn Pop?
Inside the hard, outer shell of a kernel of corn is a starchy middle that contains water. As the kernel warms, the water within it changes into steam, which is the gaseous form of water. The steam expands. Eventually, the pressure inside the kernel exceeds the strength of the hard, outer shell and the kernel explodes with a pop!

7. ***<u>Examine popcorn under a microscope</u>*** or the "***Images of Popcorn—Up Close***" below. These microscope images show popped kernels at different magnifications. Compare the size and shape of the popped kernels to unpopped kernels. List some characteristic features of the popped kernels.

<u>ANSWER: On the 10 mm image, students might note that the popped kernel is rounded and appears pitted, foamy, puffed up, inflated, bubbly or frothy. These same descriptions also might be used in the 1.5 mm image, with the addition of the words fragile, delicate, shiny, or sparkling. The 0.05mm image shows a clear honeycomb structure within the popcorn. Students might use that term in addition to hollow, fragile, flimsy, or note that the popped kernel is of low density</u>

Tephra Popcorn—Answers -continued

Popcorn magnified 10 times, 70 times and 250 times



8. ***Analysis and Conclusions:*** *Answer the following questions.*

a. Explain the origin of holes in the popcorn. (review the box on "**Why Does Popcorn Pop?**")

ANSWER: As the kernel is heated, water changes to steam, which is a gas. The steam expands. Eventually, pressure inside the kernel is so great that the gas escapes in a small explosion that "pops" the kernel.

b. How did the mass and volume change during popping?

ANSWER: Mass decreased and volume increased

c. Imagine that the unpopped kernels represent magma inside a volcano and that the popped kernels are tephra erupted from a volcano. Do you think the pre-eruptive magma and erupted volumes of tephra are the same? Explain your answer.

ANSWER: No, magma expands as it rises from the volcano. Water within the kernels expands when heated, expands the corn, and pops the outer shell.

d. Based on your observations of popcorn microscope images, what common features might be shared by both popcorn and tephra?

ANSWER: bubbles, gases, water contained within the magma

e. Explain the origin of holes in real tephra.

ANSWER: Bubbles enlarged as steam expanded

Tephra Popcorn—Answers -continued

9. ***For Further Thought:***

a. Describe how the expansion of gases in magma contributes to the energy of the volcanic eruption.

ANSWER: During an eruption, gases (principally water vapor) within the magma expand and escape, and force magma to the surface. Gases are an important driving force of volcanic eruptions.

b. Describe the energy transformations that take place in popping kernels, and in erupting magma.

ANSWER: The unpopped kernel gains thermal energy during heating, and the water inside changes to steam. Pressure in the kernel increases until the kernel pops. Expanding steam converts thermal energy to kinetic energy. In a volcanic system, magma and the water molecules within it gain thermal energy while confined within the earth. The magma and water within it expand and the pressure within increases. During a volcanic eruption, magma rushes up the conduit and explodes into the atmosphere. Thermal energy converts to kinetic energy.

c. The volume expansion factor for erupted tephra is commonly three to four times the volume of the original magma. Is this magma expansion factor greater or less than that for popcorn? Explain how Earth's landscape would appear different if magma showed the same expansion factor as popcorn.

ANSWER: Popcorn generally increases to 10 to 30 times its original volume. If magma had the same expansion rate as popcorn, Earth's surface would be covered with thicker (and less dense) accumulations of tephra.

d. Popping kernels may lose mass due to water loss. The same can be said of rising magma. Explain what happens to excess water expelled from rising magma.

ANSWER: Steam from rising magma adds water vapor to Earth's atmosphere.

e. Describe how the presence of bubble-filled tephra on Earth's surface can affect the ecology of a landscape.

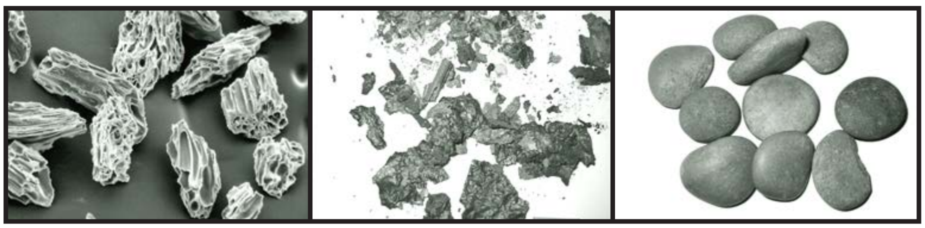
ANSWER: Bubble spaces allow for movement of air and groundwater. Tephra layers are unconsolidated and easily penetrated by plant roots and burrowing animals.

Teacher Page

Samples Collected by a Geologist

Instructions: *These samples are similar to those a geologist would collect while working in the field. One sample is volcanic ash, one is ash from a fireplace, and the other is river sediment. Determine which sample is volcanic ash by answering the following questions.*

Sample A | Sample B | Sample C



0.6mm | 100mm | 200mm

1. Predict which sample you think is volcanic ash, fireplace ash, or river sediment.

Volcanic Ash ***A*** Fireplace Ash ***B*** River Sediment ***C***

2. List three adjectives that describe each sample.

Sample A	1	***Bubbly***	1	***Fluted***	1	***Oblong***
Sample B	2	***Irregular***	2	***Flat***	2	***Fragile***
Sample C	3	***Smooth***	3	***Rounded***	3	***Solid***

3. Which sample contains bubbles?

ANSWER: Sample A

4. Hypothesize about the origin of these holes.

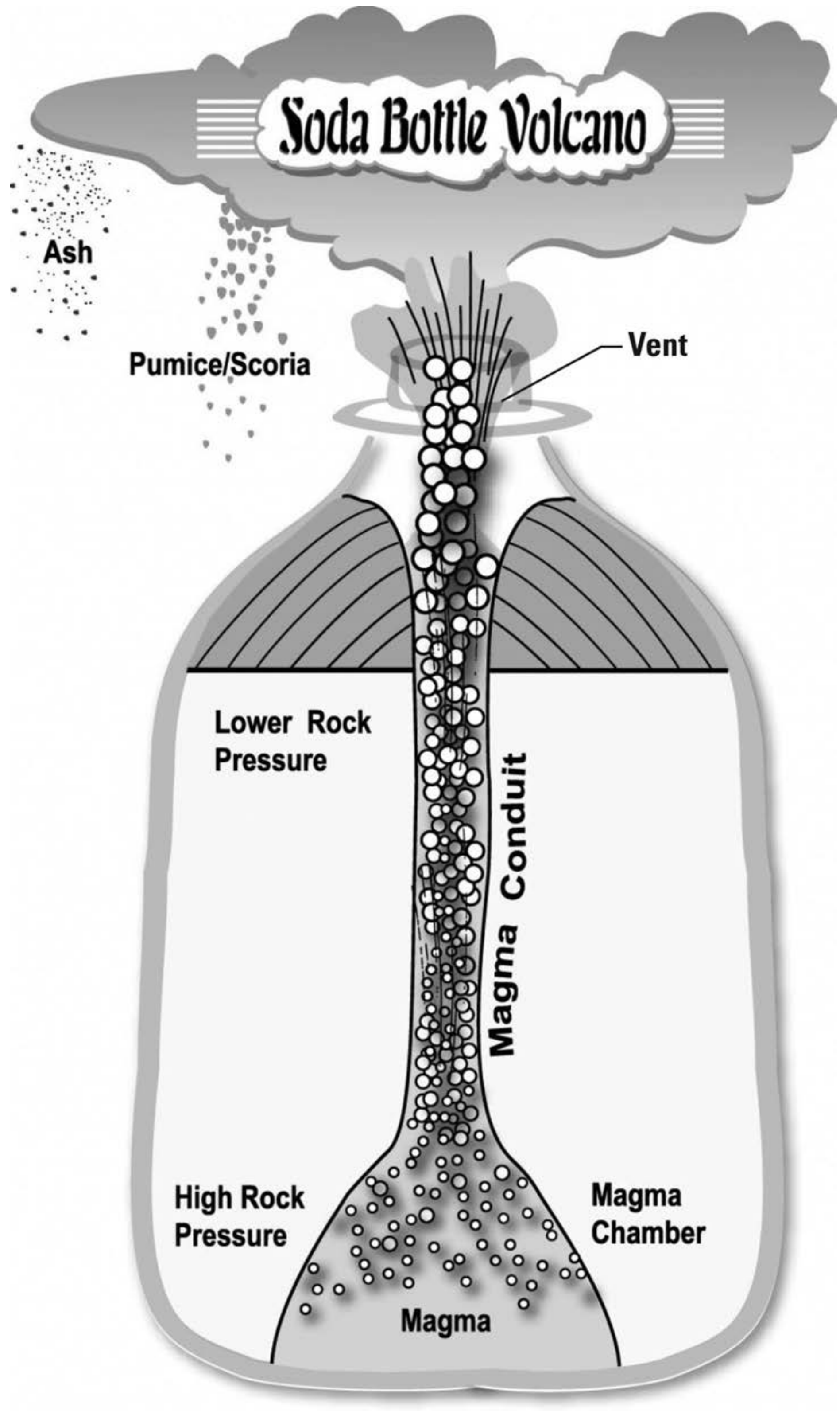
ANSWER: Expanding gases form bubbles.

5. Based on your descriptions of the three samples, which sample is volcanic ash? How did you reach this conclusion?

ANSWER: A

6. Which sample is most likely the fireplace ash? Describe how it differs from volcanic ash.

ANSWER: Fireplace ash is not bubbly. It is fragile and platy, and the skeleton of wood fiber is visible in some pieces. Volcanic ash is bubbly, fluted, and often sharp-edged.



Soda Bottle Volcano
Ash
Pumice/Scoria
Vent
Lower Rock Pressure
Magma Conduit
High Rock Pressure
Magma Chamber
Magma

Graphic Page

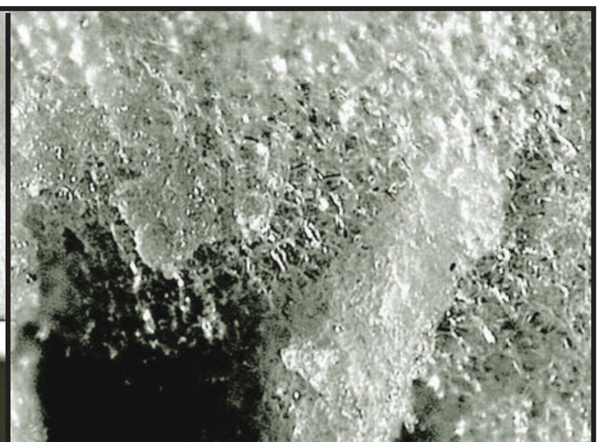
Images of Popcorn—Up Close

90mm

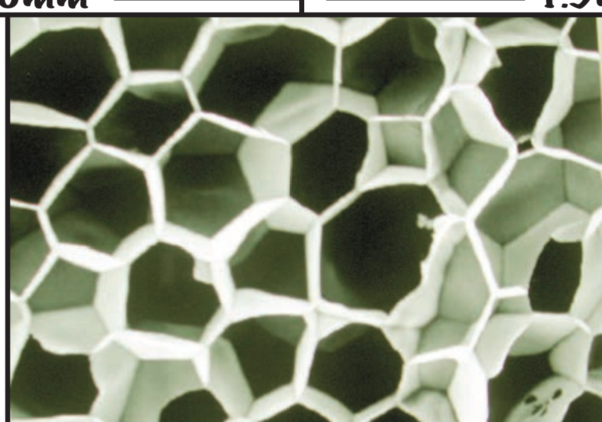
30mm

Microscope Images of Popcorn Kernels

10mm

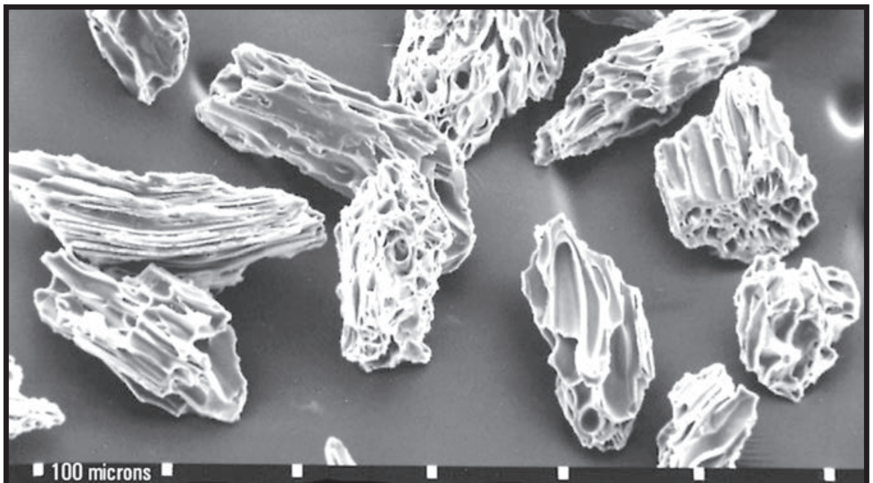


1.5mm



0.05mm

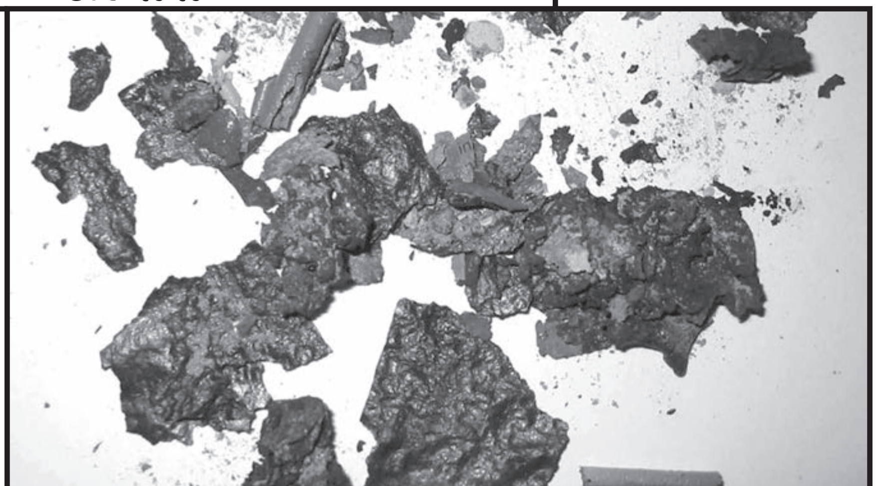
Samples Collected by a Geologist



0.6mm

Sample A

Sample B



100 mm

200 mm

Sample C

Tephra Types