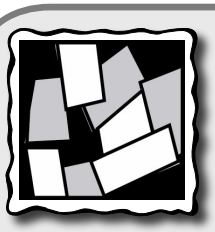
# Magma Mash







**Grade Level: 4-8**

## Learner Objectives:

Students will:

- Recognize and record differences and similarities of rock samples with similar chemical compositions
- Hypothesize about methods of rock formation
- Understand the effect of cooling rates the appearance of igneous rocks

**Setting:** Large open area and classroom lab

**Timeframe:** 20 minutes; 30 minutes

*"Discovering How Magma Makes Rocks"*

*"Making Observations Using Mount Rainier Rock Samples"*

## Materials:

*Discovering How Magma Makes Rocks*

- Colored tokens (poker chips, craft sticks, etc.) [For a class of thirty students (twelve each of two different colors and six of a third color]

USGS science for a changing world

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

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## Overview

In an exploration of magma behavior, students role play minerals that are cooling at different rates, and then examine rock samples

## Teacher Background

### *Upward Ho!–Magma Ascent*

All ***igneous*** rocks originate underground in the molten state as magma. ***Magma*** is hot molten rock containing chemical elements from melted ***mantle*** rock and ***oceanic plate***. Magma contains dissolved gases such as water, carbon dioxide, sulfur dioxide, and possibly a few crystals.

Magma forms in the mantle where the subducted plate has sunk to great depths. At Mount Rainier, magma forms from rocks about eighty kilometers (fifty miles) below Earth's surface. Temperatures and pressures at such depths are sufficiently high to cause water within the oceanic plate to sweat into the mantle rock. The addition of water to hot mantle rocks causes rock to melt and form magma. This magma begins to rise because it is less dense than surrounding solid mantle rock.

### *Rock flows at great pressure and temperature*

Rock flows like putty in this inhospitable environment of great pressure and temperature. Rock that surrounds rising magma deforms, allowing passage of the magma. This partially molten magma eventually rises to the base of the ***continental crust.*** The upper continental crust is more rigid than the mantle, so the magma must force its way upward through cracks or by melting surrounding crustal rocks. The magma creeps upward like giant

- Colored pencils (three for each student)

*"Making Observations Using Mount Rainier Rock Samples"*

- Sample of andesite and granodiorite or graphic *"Mount Rainier Rock Photos"* for each student or small student group
- Graphic *"Magma Cooling Rates"*
- Graphic *"Elements to Rocks"*
- Copies of *"Rock Sample Observations"* student page
- Colored pencils (three for each student)
- Ruler
- Hand lens (one for each student, or per class)
- Sample of obsidian (optional)

**Vocabulary:** Andesite, chemical elements, continental crust, extrusive, granite, granodiorite, igneous, intrusive, lava, magma, magma chamber, mantle, mineral, obsidian, oceanic plate, plutonic, solidus, tephra

**Skills:** Classifying, comparing, demonstrating, describing, listing, sketching

**Benchmarks:**

*Science:*

**1– The student understands and uses scientific concepts and principles**

**1.1– Use properties to identify, describe, and categorize substances, materials, and objects, and use characteristics to categorize living things**
**Classify rocks and soils into groups based on their chemical and physical properties; describe the processes by which rocks and soils are formed**

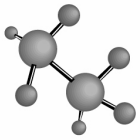
fingers. By the time magma reaches Earth's crustal rocks, its density often is comparable to that of the surrounding crustal rock. Here the ascent of magma ceases. This stagnant mass of magma forms a reservoir called a ***magma chamber.*** From here, magma may cool and solidify in place, or continue its ascent to erupt eventually onto Earth's surface through a volcano. Once magma reaches Earth's surface, it is known as ***lava.***

### What Happens Inside the Magma Chamber?

Magma resembles the texture of hot oatmeal because chemical elements in the cooling magma start to combine to form minerals. You may have heard the expression that "birds of a feather flock together." In a similar way, individual ***chemical elements*** combine and form distinct minerals. They bond to each other and form complex structures with specific chemical patterns or crystalline structures known as ***minerals*** (see the table below).

Minerals often look like small cubes, spheres and many-faced crystals. The longer it takes for magma to cool, the more time is available for crystals to grow and become larger mineral grains. Eventually, magma cools and crystallizes completely and becomes solid rock. Most magma cools slowly enough that all the liquid is used to form minerals. Some magmas cool so fast that the liquid hardens into glass. The ***solidus*** is the temperature at which all liquid in the magma becomes completely crystalline.

### Table 1–Elements to Rocks

| Building Blocks | Mount Rainier Examples |
|---|---|
| **Chemical Elements**  | Si, Na, Ca, Al, Ti, K, O, Fe, Mg |
| *Bond to become* **Minerals** | **Olivine** $(Mg,Fe)_2SiO_4$<br>**Pyroxene** $(Ca,FeMg)Si_2O_6$<br>**Feldspar** $(Ca, Na, K)\ AlSi_3O_8$<br>**Amphibole** $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$<br>**Magnetite** $Fe_3O_4$<br>**Quartz** $SiO_2$ |
| *Become* **Rocks** | **Andesite** 60% $SiO_2$: fine-grained<br>**Granodiorite** 60% $SiO_2$: coarse-grained |

### Cooling Rates of Magma

Magma that cools slowly over thousands of years develops minerals throughout its entire mass. These minerals continue to grow larger until all liquid has changed to crystal. We call these igneous rocks ***intrusive,*** or ***plutonic***, in commemoration of Pluto, the Greek god of the Underworld. ***Granite*** and ***granodiorite*** are common plutonic rocks.

Some magma ascends through cracks and breaks through the surface during a volcanic eruption. The resulting ***extrusive*** rock, called ***lava*** cools quickly, providing little or no time for chemical elements to group together and form minerals. Volcanic rocks form in this way. Minerals in some volcanic rocks can be so small they are difficult to identify without magnification. These miniature mineral grains form the background, groundmass, or matrix that creates the principal color of a rock. Magmas that cool before chemical elements bond to form minerals solidify to a glass. ***Obsidian*** is one example of a volcanic glass.

***Before class begins, assemble samples of andesite and granodiorite or make copies of the graphic "Mount Rainier Rock Photos" for each student or small student group. Learn more about andesite and lava flow features in Lava: Building Blocks of a Volcano activity; see Soda Bottle Volcano and Riding the Magma Elevator for more information about eruption dynamics.***

## Sidebar 1 The Magma Chamber Beneath Mount Rainier

This magma chamber occupies part of a zone a few kilometers wide and eight to ten kilometers (five to six miles) beneath the volcano. How do we know this? Seismologists measure the velocity of earthquake waves passing through the Earth below Mount Rainier. These waves travel slower through molten rocks and hot fluids than through solid rock. Seismologists found that earthquake waves slowed beneath Mount Rainier. The magma chamber occupies part of this zone.

## Sidebar 2 Rocks Made from Magma at Mount Rainier

Granodiorite and andesite are common rocks found at Mount Rainier. Both rock types originated from magmas with similar chemical composition; however, each has a very different appearance. They appear dissimilar because they cooled at different rates and the rate of cooling controls crystal sizes and, hence, rock textures.

Andesite is a common volcanic rock at Cascade volcanoes, formed by magma that ascended to Earth's surface and cooled quickly. At Mount Rainier, andesite erupted as thick lava flows and tephra. The matrix of andesite is made of microscopic minerals and some glass and usually appears gray. Andesite typically contains a sprinkling of small rectangular black or white crystals of minerals that can be seen without magnification. The light–colored minerals are feldspar and the dark minerals are pyroxene and/or amphibole (see Table 1, Elements to Rocks for chemical formulas). In Mount Rainier andesite, these black and white crystals are usually smaller than five millimeters (0.2 inches) and make up thirty percent of the rock. Andesite that cools quickly often traps bubbles of volcanic gas.

Granodiorite, a plutonic rock, is formed by magma that cooled slowly below the surface of the Earth. The crystals in granodiorite, the bubbles have been squeezed out. These black and white crystals are commonly five millimeters (0.2 inches) across and make up one hundred percent of the rock.The Tatoosh Range, a neighbor to Mount Rainier, is composed of granodiorite. The magma that formed the Tatoosh Range solidified 13 to 16 kilometers (eight to ten miles) below the surface. Subsequent erosion of overlying rocks has exposed this granodiorite at the surface. Slow cooling allowed the minerals to grow large.

Granodiorite has a black and white speckled appearance. The minerals in granodiorite include: quartz (clear to light gray), feldspar (white to pink), and pyroxene or amphibole (black) (see table for chemical formulas).

# Procedure

## *Discovering How Magma Makes Rocks*

This activity illustrates how the sizes of mineral grains increase with cooling time. Students role play as minerals that have already formed from elements, and now move within a magma chamber. They "search" for like minerals during teacher-designated short, medium, and long "cooling periods." At the end of each cooling period, students drop colored tokens (colored craft sticks, or other colored tokens) to the ground, and then map positions of the tokens on the ***"Magma Mash"*** student page.

1. Designate an area, six-meter-by-six-meter (twenty-feet-by-twenty-feet), as a "magma chamber." Students stand in a circle that outlines the magma chamber as you provide instructions. Inform students that they will now simulate the process of rapid cooling of magma from molten to solid rock. When called upon, they will enter the magma chamber, and when told to do so, will move randomly within the circle. Over the next two cooling periods, they will search and stand beside other minerals of same type.

2. Provide each student with a copy of the ***"Magma Mash"*** student page. Then, distribute colored tokens, one per student, in the following approximate ratios: feldspar-50%; pyroxene—30%; olivine—20%; magnetite—10%. Provide each student with colored pencils—one color for each mineral assigned (matching colored pencils work best). Encourage students to draw a legend that correlates mineral to color of token. Be sure that each student knows the name of the mineral that they represent.

3. Introduce each "mineral" that enters the magma chamber. Once in the magma chamber, each student "mineral" should remain in place until you have given instructions to "mingle" in search of students with like token color. Optional: Enhance your introduction. Olivine, a green-colored silicate mineral is first to crystallize because it "freezes" as a solid at high temperatures. It is followed by pyroxene, a dark-green or brown colored silicate, then by feldspar, a common mineral that can be white or pink in color. Finally, magnetite, a black or metallic iron-oxide mineral that is naturally magnetized, is one of the last minerals to crystallize from the magma.

4. Follow the cooling period instructions below. Remember to begin each cooling period by shouting "mingle," end each cooling period with "freeze."

***Cooling Period #1 (Rapid Cooling)***

- ✘ Lasts for a few seconds (or when students have had time to disperse).
- ✘ Students step back and map the position of all colored tokens on ***"Magma Mash"*** student page.
- ✘ Students look for patterns in the distribution of each mineral. Minerals will be randomly distributed with little recognizable pattern.

***Cooling Period #2 (Medium-length Cooling)***

- ✘ Lasts for ten to fifteen seconds (or when some "minerals" have assembled beside one another).
- ✘ Students step back and map the position of all colored tokens on ***"Magma Mash"*** student page.
- ✘ Students look for patterns in the distribution of each mineral. Minerals will be show some clumping into groups.

***Cooling Period #3 (Slow Cooling)***

- ✘ Lasts for 20 seconds or more (give all minerals time to associate with one another).
- ✘ Students step back and map the position of all colored tokens on ***"Magma Mash"*** student page.
- ✘ Students look for patterns in the distribution of each mineral. All like minerals should be grouped together.

**5**. Assemble students so that they can analyze their diagrams on the ***"Magma Mash"*** student page. Instruct students to look for patterns in the distribution of each mineral.

**6.** Did this rock cool slowly enough to allow time for mineral growth?

- ✘ Is it possible for rocks of the same composition to have different crystal sizes?
- ✘ Which cooling period produced the largest mineral groupings?
- ✘ Which cooling period produced the smallest mineral groupings?
- ✘ How is cooling rate related to the size of minerals?
- ✘ What characteristics would you expect of a rock that has cooled in just a few hours? For thousands of years?

## Making Observations Using Mount Rainier Rock Samples

Examine similarities and differences in samples or photos of an extrusive rock (andesite) and an intrusive rock (granodiorite), two rock types commonly found at Mount Rainier National Park. These rocks are similar, though not identical in chemical composition (granodiorite cooled over a longer time, allowing the formation of crystals of quartz and two dark-colored minerals called biotite and hornblende).

1. Direct small groups of students to observe samples of andesite and granodiorite from your school collection. You can use the ***"Mount Rainier Rock Photos"*** graphic provided in this activity if rock samples are unavailable.

2. Instruct students to compare the two rock samples using a ruler and hand lens. On the ***"Rock Sample Observations"*** student page, direct students to draw and describe each sample with enough detail that they could locate the sample in a box of rocks. Instruct students to observe the overall texture and appearance of the mineral crystals.

3. Next, instruct students to record the similarities and differences between these rocks on the student page. Provide enough time for observation of the finer details of each rock.

4. Students and teacher compile a list of students' observations, then review results.

5. Review the composition of igneous rocks from Mount Rainier using ***"Table 1–Elements to Rocks."*** Explain that andesite and granodiorite have similar chemical compositions and mineral assemblages, yet they look distinctly different. Allow students to hypothesize why this may be true based on what they learned from first part of the activity.

6. Show the graphic ***"Magma Cooling Rates"*** to show actual cooling times for volcanic rocks, and to summarize what students learned.

## Adaptations

- Examine, compare and classify other igneous rocks in your school's rock collection.

- Direct younger students to assemble a four-page book called "How a Rock Forms." On page one, students draw a picture of magma inside a volcano. On page two, write "Magma that cools fast has small minerals," and have students draw a rock with small minerals. On page three, write "Magma that cools slowly has large minerals" and have students draw a rock with large minerals. Page four, is a drawing by students of their favorite rock.

- For younger students, instruct them to make rocks from construction paper. Draw two rock outlines on a piece of paper. On one rock, students glue small pieces of colored construction paper so that the paper pieces are separated by some space. This represents a rock that was cooled quickly, so only small minerals formed. On the other rock, students glue larger pieces of paper, until no blank paper is showing. This represents a rock that cooled slowly and has large minerals.

- For younger students, have them do the "Magma Mash" to music. Use slow music for slower cooling and fast music for faster cooling.

## Extensions

- ***The Rock Candy Experiment***. Make rock candy to demonstrate how crystals develop in magma. To show how rapid cooling effects the development of crystals, spoon some of the hot candy mixture into cold water before dispensing the remainder into the container for cooling. The candy mixture that cooled quickly should show no crystal development, while the slowly cooled mixture will create rock candy crystals.

- ***Rock and Mineral Classification***. This activity can be used as part of a unit on rocks and minerals or to prepare students for scientific observations during a planned visit to Mount Examine and interpret five Native American stories about geologic events at Mount Rainier by making a storyboard.
  1. Take students on a field trip to a local streambed to collect a variety of different rocks.
  2. Instruct students to make up classification categories for the collected rocks. With a grid on the floor or on a large sheet of paper, ask students to arrange the rocks into different categories based on the classification system they developed. Afterwards, instruct students to arrange the rocks using the rock classification system commonly used by geologists.

- ***Shoe Classification.*** Students learn about classification systems by sorting shoes. Each student takes off one shoe and places it in a pile with their classmates' shoes. Students then define categories to sort the shoes into different piles (smelly vs non-smelly, white vs. other colors, big vs. little, etc.). Once the shoes are sorted, they make up subcategories to sort them even more. Continue to do this until each shoe has been sorted into its own pile and can be identified as one particular person's shoe. This is similar to how geologists sort rocks into categories and eventually identify the rock and give it a name.

- ***Rock Stories.*** Ask students to write a creative story illustrating the formation of a rock from magma to a solid.

## Assessment

As this activity progresses, pay attention to student's understanding of the effect of cooling rates on the appearance of igneous rocks. Note how students' thinking progresses from basic observations of appearance to the causes of appearance and how the causes are related to volcanic processes. Use students' results on student pages ***"Magma Mash"*** to assess their ability to observe and record experimental results; use "***Rock Sample Observations"*** to assess ability to apply the concepts to identifying the source of igneous rocks in the real world.

## References

Francis, P., and Oppenheimer, C., 2003: Volcanoes: Oxford University Press, 536 p.

Harris, S. L., 2005, Fire Mountains of the West: The Cascade and Mono Lake volcanoes. Mountain Press Publishing Company, 3rd edition, 454 p.

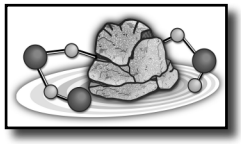
Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

## Credits

Photos by U.S. Geological Survey

Name _____





# Magma Mash

***Instructions:*** *Use colored pencils or crayons to draw the arrangement of the colored tokens after each period of movement.*

| Freezing Point | Diagram of Colored Tokens |
|---|---|
| Cooling time #1 | |
| Cooling time #2 | |
| Cooling time #3 | |

Student Page

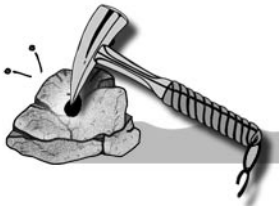
Name _____

# Rock Sample Observations

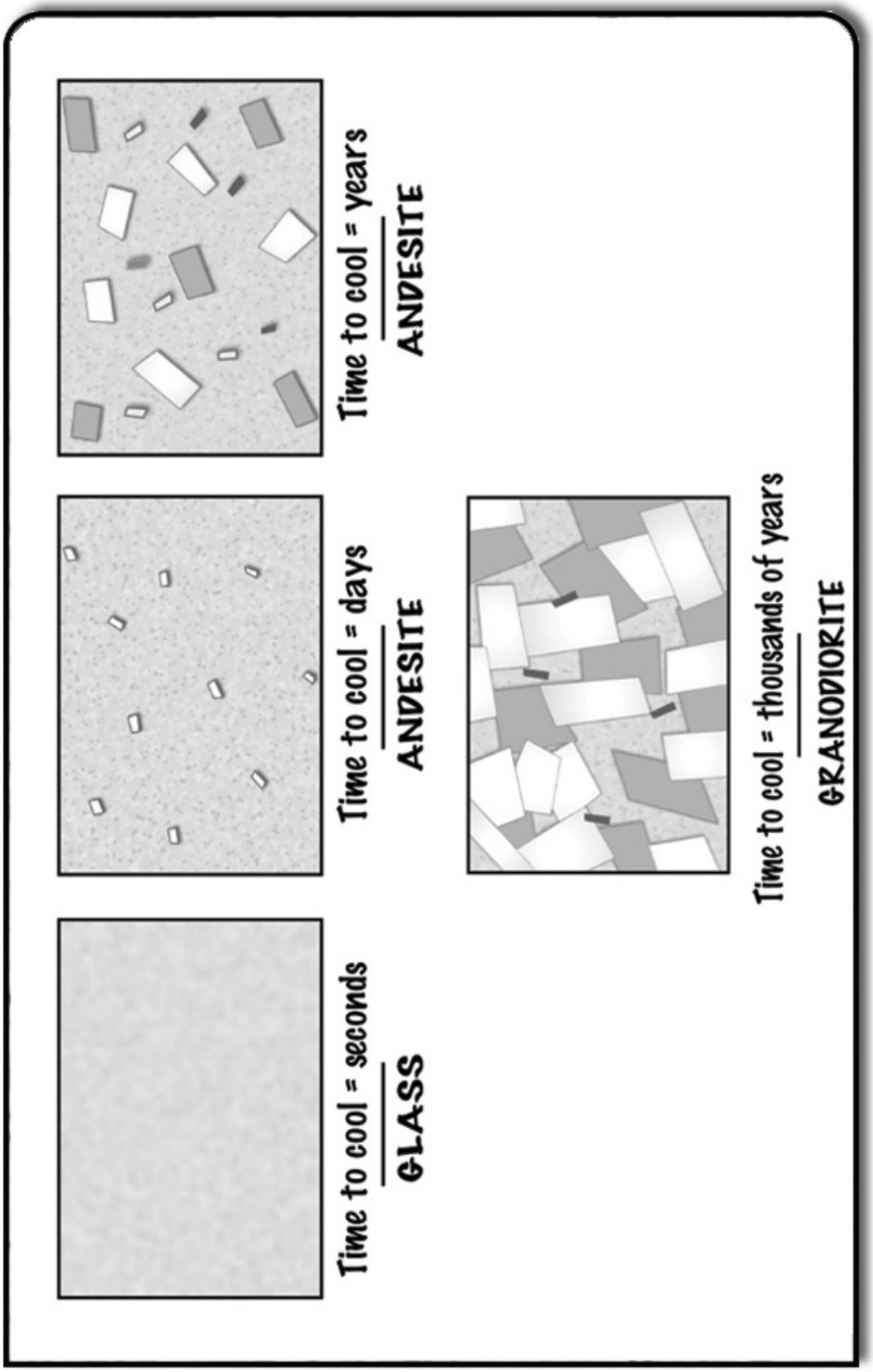
| Rock Sample #1 | Rock Sample #2 |
|---|---|
| **Draw, color and label sample #1** | **Draw, color and label sample #2** |
| **Using words, describe the characteristics of sample #1** | **Using words, describe the characteristics of sample #2** |

**Examine the rock samples. In the space below, list the characteristics that are similiar and different in each sample**

| Similarities | Differences |
|---|---|
| | |



# Mount Rainier Rocks

Graphic Page

# Magma Cooling Rates