LESSON 3: IGNEOUS ROCKS – LAVA FLOWS AT PARASHANT

GEOLOGICAL ADVENTURES AT PARASHANT

EXPLORING THE GEOLOGY OF GRAND CANYON-PARASHANT NATIONAL MONUMENT

NATIONAL PARK SERVICE

THE GEOLOGICAL SOCIETY OF AMERICA®

SCIENCE ▪ STEWARDSHIP ▪ SERVICE

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Lesson 3 Guide: Igneous Rocks – Lava Flows at Parashant

OVERVIEW

Students look at samples of igneous rocks and sort the rocks by texture, color, and then by texture and color. Students then model the flow of lava at Parashant by pouring liquid soap onto the top of their clay models and observing the differences in the speed of the flow (slow, medium, fast) over slopes of different gradients. Students compare their models to surface and aerial photographs of lava flows at Parashant as they read about the main types of igneous rocks (extrusive versus intrusive) and the nature and timing of eruptions at the monument. Students are asked to design and conduct their own experiment into lava flows using one of six research questions.

Objectives After studying samples of igneous rocks, modeling the flow of lava on slopes of different gradients, and reading about the igneous rocks exposed at Grand Canyon-Parashant, students will understand:

- Igneous rocks cool and crystallize from magma.
- The composition of magma determines the chemical and physical properties of the igneous rocks.
- The distribution and thickness of lava depends upon the volume erupted, the topography of the land, and the composition of the magma.

Concepts Properties and types of igneous rocks; magma versus lava; cooling and crystallization; intrusive versus extrusive igneous rocks; gradient.

Duration Two to three 45-minute class periods

Audience Students in grades 6 to 9

Materials **Part A**

- Samples of igneous rocks. The rocks should be labeled with names (or numbered and a key given to students):
  - Intrusive: granite, diorite, gabbro
  - Extrusive: basalt, andesite, rhyolite, scoria, obsidian, pumice, porphyry
- Hand lens or magnifying glass
- Metric ruler
- Worksheet 3.1 – Classifying Igneous Rocks

Part B

- Clay model of rock layers and slopes (see Lesson 2).
- 10 ml of liquid soap
- Eye dropper (or small plastic squeezable dropper bottle filled with liquid soap)
- Stopwatch (or clock with seconds hand)
- Metric ruler
- See the **Elaborate** section of this guide for a description of materials

needed for experimental design activity.

Extensions **For all students**

- Add samples of local or regional igneous rocks to the collection in Explore, Parts A, B, and C.
- Arrange for a field trip to view local outcrops of igneous rocks.
- Incorporate photographs of local or regional igneous rocks into a slide show for comparison to igneous rocks (primarily volcanic rocks) at Parashant.

For gifted, honors, or higher grade-level students

- If you want to focus on identifying igneous rocks, provide students with an identification chart. A good source is Pamela Gore's igneous rock ID chart at gpc.edu/~pgore/geology/physical_lab/igneouschart.htm
- The Elaborate section of the lesson offers many options for tailoring the activity for students of different ability levels and for integrating mathematics (calculating slopes of best-fit lines) and technology (MS Excel). See the suggestions in the appropriate section of this guide.

ENGAGE — 10 minutes

The engage question explores student's observation and description skills, and their initial ideas about igneous rocks. If you have large (hand-sized) samples of granite and basalt, hold them up for comparison as you introduce the question (or put samples of the two rocks at each table – real objects will work better than the photographs). Basalt is a dark-colored, fine-grained igneous rock and granite is a light-colored, course-grained intrusive igneous rock. If you have students record their initial ideas before they discuss with others (i.e., without talking), you will gather more information about their ability to observe and describe.

Observations students might make are that the basalt in the photo is dark in color, does not appear to have crystals, and has holes (vesicles), whereas the granite has different colored crystals (four different colors are visible), the crystals are large enough to see, and the overall color is light. Ask volunteers to share ideas. Accept all reasonable ideas and write them on the board. Avoid providing the "right" answer – students will learn about how to classify igneous rocks in the explore phase of the lesson.

EXPLORE — 60 minutes

Materials for Parts A, B, and C: These three activities involve sorting samples of igneous rocks into groups and should take a total of about 35 minutes. Students can work in pair or groups, depending upon how many rock samples you have available.

- You will need a set of labeled samples of igneous rocks. Students need to have the names of rocks available in order to put rock names in the data tables and to facilitate discussion. If your rock samples lack numbers (with a key that shows the name of each numbered rock), then you can put them in small, labeled trays and ask that students move the trays around the table during the sorting process.

- A few hand lenses or magnifying glasses per group
- A metric ruler for each group (for measuring grain size)
- Photocopy and distribute Worksheet 3.1 – Classifying Igneous Rocks to each student so that they do not have to spend time making up data tables.
- Students begin by observing the texture of igneous rocks. They then move to observing and sorting igneous rocks by color (chemical composition). Finally, they combine the two criteria and sort the rocks by texture and color. Set a timer and give students a set amount of time for each sorting activity. The point is not to memorize the names of rocks, but to focus on the process of classification.

Part A. Sorting Igneous Rocks by Texture **10 minutes**

1. Distribute materials and worksheets to groups at tables. Inform students how much time they have to sort the rocks by texture.

2. Students will have lots of questions about what constitutes coarse texture versus fine texture, what to do with obsidian (Is it one large crystal? Is it a crystal?), and so on. Remind them that they are welcome to make up new categories, so long as they can describe and defend their choices.

3. Save a class discussion of the results of sorting for later (see Part C, question 5). As you circulate, you will see that students will make "mistakes". Keep in mind that the point is not for them to sort or group rocks as well as geologists do (besides, geologists sometimes argue about how to classify rocks).

Part B. Sorting Igneous Rocks by Color **10 minutes**

1. Inform students how much time they have to complete part B. In this part of the activity, students put the rocks back into the center of the table and focus on a second criterion for sorting igneous rocks – color. It might be helpful to point out to students that "light" and "dark" are relative terms. Dark does not mean black, and light does not mean white. A helpful hint that you can provide students is that an example of mixed color is roughly equal amounts of salt and pepper. You might want to show them a small sample of mixed salt and pepper.

2. As you circulate, review students' sorting of rocks and remind them that they can make new categories if they wish (and remind them to describe their new categories). Rather than coaching students into making a perfect sorting, encourage group discussion and provide feedback on their ability to defend their choices.

Part C. Classifying Igneous Rocks by Texture and Color 15 minutes

1. Again, it is helpful to set a timer or remind students about time remaining to classify the rocks. At this stage, students are technically classifying the igneous rocks into specific groups using the same two criteria that geoscientists use – texture and composition.
2. Table 3 is very close to a standard igneous rock identification chart. If students wish to use their own chart with their own categories, that's okay. Table 4 in the Explain section provides a scientific classification scheme (but you should avoid pointing Table 4 out to students during the activity to lessen the likelihood that they will simply copy rock names into Table 3).
3. The concept underlying the question is that classification schemes do not exist in nature – they are made by people. It often takes a lot of discussion, debate, and revision to decide where things belong in a classification scheme.
4. The long debate about what constitutes a planet in the solar system is a good analogy to raise in the discussion. In the end, scientists prefer to have a standard classification scheme and appreciate the benefits of grouping similar objects into categories. It is part of defining the order and organization of nature.
5. If you have circulated and monitored student's progress, you should be able to have a brief discussion about the results of Table 3. At this point, you can refer students to Table 4, and ask if they have specific questions about how they classified rocks compared to what is shown in Table 4. Depending upon your district or state standards, discussing the process and benefits of classification schemes may be more important than making sure that every student has the correct rock name in each cell on the data table.
6. It is advisable to have students wash their hands after handling rock samples.

Part D. Modeling Lava Flows 15 Minutes

There are some 213 volcanic vents on the Uinkaret Plateau on or near Parashant that have erupted ash, cinders, and lava during the past 3.6 million years. The most recent eruption on the monument was the Little Springs Volcano near Mt. Trumbull, which erupted less than 1000 years ago. Lava from at least 13 eruptions of various volcanoes flowed into the Grand Canyon. Most common are basalt flows topped by pyroclastic (cinder) cones which blast rock and cinders out during the dying stages of gaseous vents. Many of the basalts at Parashant have inclusions of peridotite (olivine-rich igneous rock), which suggests that the magmas are derived from the upper mantle.

Materials: In this activity, students use their model of sedimentary rock layers and slopes to model the flow of lava across the Earth's surface (see Figure 1). Each group will need:

- The clay model of rock layers on a Styrofoam plate. The Styrofoam plate will prevent soap from running on tables and desks.
- Liquid soap. Choose a liquid soap with some viscosity (not too runny). To get a sense of the viscosity, turn the bottles upside down where you are at the store, and watch how quickly bubbles rise to the surface. The slower the bubbles rise, the more viscous the soap is.
- A small cup (to hold the liquid soap) and an eye dropper (**or** a small squeezable dropper bottle of liquid soap). Dropper bottles work best because they minimize spillage and mess, but a small plastic cup of liquid soap and an eye dropper will work, too.
- Paper towels.
- A metric ruler (to measure the distance lava travels)
- A stopwatch (or clock with seconds hand) to measure how long flows take to stop moving.

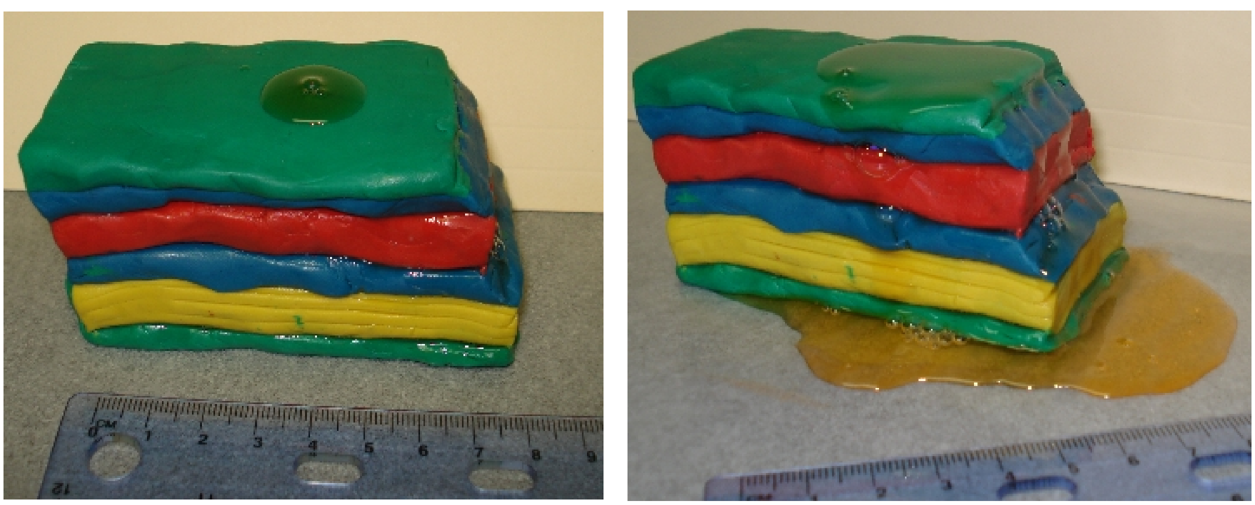

FIGURE 1 Clay model showing small lava flow and large lava flow. Have students level the top of the model by gently pressing down on it with a flat object, like a textbook. Drop soap towards one end.

1. Have students read through all of the steps before starting.
2. Students should predict that the larger volume will cover a greater area (flow down the slope). Liquid soap serves as the lava in the model. Point out that in the real world, lava is erupted from vents and fissures from below. Dropping liquid soap onto the model does not simulate the eruption process, just the flow of lava.
3. The activity refers to ml of liquid soap. If you use dropper bottles, measure how many drops of soap there are in 0.5 ml, and provide

students with this number. They can multiply by six to estimate how many drops will be in 3 ml of soap for step 4.

4. It is important the students drop the soap towards the carved end of the model, but not directly on the slope. Students should measure the distance traveled and measure and record how long it takes for the flow to stop moving. Students may have difficulty noting how the steepness of the slope affects the speed of the flow, but if they look carefully, they should see that soap travels faster on the steep slopes (especially if the soap goes over the straight edge of the model, not the carved slope).

5. The greater the volume of lava erupted, the larger the area it covers.

6. Put the models away for use in Lessons 4-6.

EXPLAIN

Assign the reading either during class or as homework (even if the entire activity has not yet been completed). You can supplement the explanation phase of the lesson with a discussion or lecture. Photographs of outcrops of igneous rocks, samples of igneous rocks, diagrams of igneous intrusion structures (batholiths, laccoliths, dikes, sills,), diagrams or photos of types of volcanoes (cinder cones, stratovolcanoes, and shield volcanoes), and photos erupting volcanoes would be most relevant to the lesson. Photographs of local or regional outcrops would increase the relevance to students.

ELABORATE

45 minutes

In this activity, students design an experiment to investigate a factor that might affect the flow of lava. You can use the description below to create your own worksheet to tailor the activity to the needs of your students and your school or district requirements for writing up laboratory investigations. This would enable you to provide as little or as much structure to experimental design as you think your students require.

Note: Because it requires only simple materials, this activity is well-suited for an at-home assignment to be done with parents or guardians. If you choose the at-home option, have students work on their investigation designs in class to ensure safe and valid procedures.

Materials: For all six of the research questions, students will need liquid soap, dropper bottle(s) or eye droppers, and an overhead transparency of cm-square graph paper. The grid allows them to measure distances (for students who are calculating lava speed) and area (for those doing experiments about surface area covered). Have students use the grid square transparency upside-down so that the squares do not wash away. The transparency is easy to clean up – just rinse and dry gently with a paper towel. Table 1 (next page) shows additional materials needed to test each research question.

Note that each question follows the form "What is the relationship between X and Y?" This allows students to easily identify the independent variable (the "X") and dependent variable (the "Y"), and produce a graph of results (independent variable "X" on the X-axis and dependent variable "Y" on the Y-axis).

Table 1. Guidelines for Designing Experiments Into Lava Flows

Research Question	Suggestions	Additional Materials
1. What is the relationship between the volume of lava erupted and the surface area it covers?	Control the slope angle by doing the tests on a flat surface. Allow students to test multiple volumes simultaneously by dropping soap on different parts of the transparency. Graph volume (cm^3) versus area (cm^2), determine a best-fit line, and calculate the slope of the line.	None
2. What is the relationship between the temperature of magma and the speed of lava flow?	Control the slope angle and volume of liquid soap used in each test. Heat soap in hot water bath, keep one at room temperature, and cool one bottle of soap in ice bath. Use 0.5 ml soap for each test. Graph results as a bar graph with temperature descriptors on X axis: cold, room temperature, warm and speed of the flow in cm/s on the Y axis.	3 dropper bottles of liquid soap at three temperatures Materials for heating soap and cooling soap Clipboard (to attach transparency grid to). Books to make a slope, Stopwatch Calculator
3. What is the relationship between the temperature of magma and the area of a lava flow?	Control the volume of liquid soap "erupted" and control slope by doing tests on a flat surface. Use 2 ml soap for each test Allow students to perform multiple trials simultaneously by dropping different soaps on different parts of the transparency. Graph results as a bar graph with qualitative temperature descriptors on X axis: cold, room temperature, warm, and quantitative data (area in sq. cm) on Y axis.	3 dropper bottles of liquid soap at three temperatures Materials for heating soap and cooling soap

Research Question	Suggestions	Additional Materials
4. What is the relationship between the angle of a slope and the speed of a lava flow?	Control the volume used for each test. Graph results as a bar graph with qualitative temperature descriptors on X axis: cold, room temperature, warm, and quantitative data (speed) on Y axis.	Clipboard (to attach transparency grid to). Books to make a slope, Stopwatch Calculator
5. What is the relationship between the composition of magma and the speed of a lava flow?	Vary composition (which will alter the viscosity) by adding different amounts of water to two of the three bottles of one brand of liquid soap. Create a 50% soap mix (50 parts water to 50 parts soap), a 75% soap mix (75 parts soap to 25 parts water), and a 100% soap (pure). Graph composition as percentage soap on x axis, and speed (cm/s) on Y axis.	Three dropper bottles of liquid soap – 50%, 75%, 100% (pure). Clipboard (to attach transparency grid to). Books to make a slope, Stopwatch Calculator
6. What is the relationship between the composition of magma and the area of a lava flow?	Vary composition (which will alter the viscosity) by adding different amounts of water to two of the three bottles of one brand of liquid soap (OR use three different brands of liquid soap). Create a 50% soap mix (50 parts water to 50 parts soap), a 75% soap mix (75 parts soap to 25 parts water), and a 100% soap. Graph composition (% soap) on x axis, and area covered (sq cm) on Y axis.	Three dropper bottles of liquid soap: 50%, 75%, 100% (or three different brands of soap).

EVALUATE

1.

a. Granite forms slowly underground (coarse crystals) whereas rhyolite forms at the Earth's surface in a volcanic eruption (fine crystals)

b. Both granite and rhyolite are similar in chemical composition (felsic). They are both rich in silica and low in iron and magnesium.

2. A magma that produces rhyolite magma will erupt more explosively than a magma that produces basalt lava because rhyolite has a higher percentage of silica. The higher the silica content, the more explosive the eruption is.

3. The correct order from smallest to largest area covered is c, a, and b. Rhyolite does not flow far due to its high silica content. Basalt flows more easily, and the more basalt that erupts, the greater the area it will cover.

Challenge Question

a. The texture is porphyritic (large-grained crystals surrounded by fine-grained crystals). The chemical composition is mafic because the overall color is dark.

b. The olivine crystals formed underground as the magma began to cool slowly, then a volcanic eruption occurred and made the fine-grained basalt lava with crystals of olivine inside it.

WORKSHEET 3.1 – CLASSIFYING IGNEOUS ROCKS

Table 1. Sorting Igneous Rocks by Texture.

Texture	**Igneous Rocks**
Coarse (crystals > 1mm)	
Fine (crystals < 1mm)	
Mixed (fine and coarse)	
Other – Describe:	
Other – Describe:	

Table 2. Sorting Igneous Rocks by Color (Chemical Composition).

Color	**Igneous Rock Names**
Dark (mostly dark minerals or overall dark color)	
Intermediate (mixed light and dark)	
Light (mostly light minerals or overall light color)	

WORKSHEET 3.1 – CLASSIFYING IGNEOUS ROCKS

Table 3. Classifying Igneous Rocks by Texture and Color

Texture	**Color**		
	Light	**Intermediate**	**Dark**
Fine			
Coarse			
Mixed			
Glassy			
Holes			
Other – Describe:			
Other – Describe:			

LESSON 3: IGNEOUS ROCKS - LAVA FLOWS AT PARASHANT

ENGAGE

Look at the photos of basalt and granite in Figure 3.1.

⇒ What differences do you see between the two rock samples?

Record your ideas, then discuss your answer with a partner.


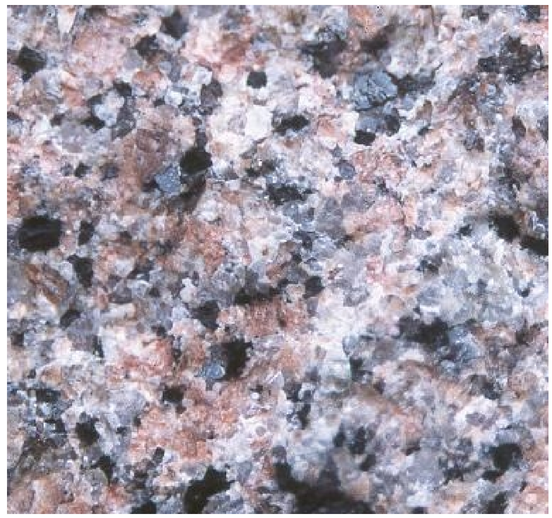

FIGURE 3.1 Left: Basalt, Black Rock Mountain at Parashant. Right: Granite, location unknown (credit: R.A. Busch).

EXPLORE

Igneous rocks are rocks that cool and crystallize from molten rock (**magma**). For now, you can think of magma as being a little like cake batter. What you put into the batter and how hot the oven is controls how your cake turns out. In this activity, you will look at the relationship between magma (batter) and igneous rock (cake). By the end of the lesson, you will understand how igneous rocks form and how lava travels across the landscape.

Part A. Sorting Igneous Rocks by Texture

Can you sort the igneous rocks in your collection by texture? **Texture** refers to the presence, shape, arrangement, and size of mineral crystals in a rock. The texture of an igneous rock reveals whether the magma cooled below ground (slowly) or at the surface (quickly). Large crystals (easily visible to your eye) mean that the magma cooled more slowly.

1. From your teacher, obtain a set of labeled igneous rocks. Put the rocks on the table in front of your group.

2. Using Table 1 as a guide, sort the rocks into groups by texture. If you think that a fourth category of texture will help, add it under "Other" in the table and describe your new category.

3. When your group agrees on the sorting, write the name of each rock where you think it belongs in a copy of **Table 1**.

Table 1. Sorting Igneous Rocks by Texture.

Texture	Igneous Rocks
Coarse (crystals > 1mm)	
Fine (crystals < 1mm)	
Mixed (fine and coarse)	
Other (describe)	

Part B. Sorting Igneous Rocks by Color

Can you sort igneous rocks by their color? Color indicates the **chemical composition** of the igneous rock – the kinds of minerals that make it up. Think again about cake batter. Chocolate has a dark color, so it is no surprise that batter with chocolate in it makes a dark-colored cake. Magma behaves the same way. Magma that has a chemical composition rich in dark-colored minerals will cool to form a dark-colored igneous rock.

1. Put the rocks back into the middle of the table again. This time, sort the rocks by color.

2. When your group agrees on the sorting, write the name of each rock where you think it belongs in a copy of Table 2.

Table 2. Sorting Igneous Rocks by Color (Chemical Composition).

Color	Igneous Rocks
Dark (mostly dark minerals or overall dark color)	
Intermediate (mixed light and dark)	
Light (mostly light minerals or overall light color)	

Part C. Classifying Igneous Rocks by Texture and Color

1. Put the rocks back into the middle of the table for a final sorting. This time, sort the rocks by color and texture.

2. When your group agrees on how to sort the rocks, record your results in a copy of Table 3.

Table 3. Classifying Igneous Rocks by Texture and Color

Texture	Color		
	Light	Intermediate	Dark
Fine			
Coarse			
Mixed			
Glassy			
Holes			
Other (describe):			

3. Describe at least one disagreement that came up during the process of classifying igneous rocks.
4. Was the disagreement resolved? If so, how?
5. Share your group's classification scheme and responses to questions 3 and 4 above in a class discussion.
6. Put the rocks away and wash your hands as instructed by your teacher.

Part D. Modeling Lava Flows

When magma reaches the Earth's surface and flows on the ground, it is called **lava**. Several factors affect how fast the lava flows, how far it travels, and how large of an area it covers. In this part of the lesson, you will model and investigate these factors.

FIGURE 3.2 Eroded cinder cone and lava flow (horizontal ledge in foreground) at Parashant.

1. Place your clay model of sedimentary rock layers onto the Styrofoam plate on your table. Obtain a supply of liquid soap and an eye dropper (or a plastic dropper bottle filled with liquid soap). The liquid soap represents hot lava erupted from a volcano that forms at the top of your sedimentary rock layers.
2. Predict what will happen if you were to pour 0.5 ml of liquid soap (1 full eye dropper) versus 3 ml of liquid soap onto the top of your model. Record your predictions.
3. Pour 0.5 ml of liquid soap onto the top of your model. Measure and record what happens by answering the following questions:

a. How far does the soap travel?

b. How long does it take to stop moving?

4. Pour 3 ml more liquid soap onto the top of your model close to the end that has a slope carved into it. Describe what happens by answering the questions below.

a. How far does the soap travel?

b. How long does it take to stop moving?

c. How does the slope of the rock layers affect how fast the soap moves?

5. Consider how what you have learned might apply to a real volcano by making a prediction. What is the relationship between the volume of lava erupted and the size of the area it covers?

6. Clean up. Wash the soap off the modeling clay and Styrofoam plate, and dry gently with a paper towel. Put the materials away and wash your hands.

EXPLAIN

Just as you could make hundreds of kinds of cakes by changing the ingredients, hundreds of kinds of igneous rocks are possible. Fortunately, scientists have devised a system to put all these different kinds into a few basic groups. The system they use follows what you did in your exploration activity.

Igneous means formed by fire. Igneous rocks form from the cooling and crystallization of molten rock material. Underground molten rock is called **magma**. Rocks that form from magma (beneath the surface) are called **intrusive** igneous rocks (see Figure 3.3). Magma that reaches Earth's surface through a vent or fissure is called **lava**. Igneous rocks that cool and crystallize at the surface are called **extrusive** igneous rocks. Intrusive and extrusive are thus the two basic types of igneous rocks.

FIGURE 3.3 Two different intrusive igneous rocks. The darker granodiorite formed first and was intruded by magma of a different chemical composition, which cooled to form the light-colored pegmatite (credit: Larry Fellows).

Table 4. Basic Classification Scheme for Igneous Rocks

Texture	Composition			
	Felsic	**Intermediate**	**Mafic**	**Ultramafic**
Coarse	Granite	Diorite	Diabase Gabbro	Peridotite
Fine	Rhyolite	Andesite	Basalt	
Porphyritic Coarse – Fine	Porphyritic - Granite Porphyritic Rhyolite	Porphyritic – Diorite Porphyritic – Andesite	Porphyritic - Gabbro Porphyritic - Basalt	Porphyritic – Peridotite --
Vesicular	Pumice	Pumice	Vesicular Basalt Scoria	--
Glassy	Obsidian	--	--	--
Fragmental	Tuff (ash) Volcanic breccia	Tuff (ash) Volcanic breccia	--	
Color Index (% dark minerals)	0-15	20-40	50-60	95-100

(after P. Gore. http://gpc.edu/~pgore/Earth&Space/GPS/Igneous.html)

The rate at which molten rock cools affects the texture of the igneous rock. Intrusive igneous rocks cool slowly beneath the surface where the temperature is high (like letting your cake cool inside the oven). The slower cooling gives crystals time to grow, so intrusive rocks are coarse grained. In contrast, molten rock that reaches the surface cools quickly. Crystals of extrusive igneous rocks have less time to grow and are fine-grained or glassy. Some volcanic rocks have holes (vesicles) due to trapped gases. Others have a fragmental texture because the explosive nature and heat of a volcano can weld together pieces of volcanic rock and ash. Sometimes, magma starts to crystallize underground, and large crystals start to form. Then the magma is erupted in a volcano. The lava cools quickly, producing a rock with coarse crystals surrounded by fine crystals. This texture, a mix of coarse and fine crystals, is called porphyry.

FIGURE 3.4 This igneous intrusion is a volcanic neck - the remains of a conduit that fed a volcano near Pakoon Springs at Parashant.

Now that you know how texture tells you whether a rock formed below or at Earth's surface, let us look at color, the other main property used to group igneous rocks. Color reflects the chemical composition of an igneous rock. If we return to our cake analogy, chocolate cake batter has a dark color and vanilla batter has a light color. The finished cake reflects the "chemical composition" of the batter. Similarly, light-colored igneous rocks have a higher percentage of light colored minerals in them, and dark igneous rocks have a higher percentage of darker minerals.

The minerals that make up all igneous rocks come from a group called **silicates**. Each silicate mineral has a unique percentage of silica in it. In general, minerals rich in silica and low in iron and magnesium are lighter in color than minerals that are low in silica and high in iron and magnesium. We call these compositions **felsic** and **mafic**, respectively. Of course, it is a continuum. A cake batter can be 100% chocolate and 0% vanilla on one end of the continuum, or 100% vanilla and 0% chocolate on the other end, and any combination in-between. Igneous rocks that have close to equal amounts of felsic and mafic minerals in them are intermediate in composition. Table 4 summarizes how to classify igneous rocks by texture and composition. If you find any part of the table confusing, go back and re-read this section.

The chemical composition of magma not only affects the color of the igneous rock, but also affects the nature of volcanic eruptions. The higher the percentage of silica in magma, the more explosive the eruption will be. That is because high silica (felsic) magma forms lavas that are cooler, more viscous (they do not flow freely), and more likely to trap gases. When enough gas pressure builds up behind the viscous magma…boom! A violent eruption occurs. In contrast, low silica (mafic) magmas produce lava that is hotter, flows more easily, and create gentler volcanic eruptions. An analogy is that of old toothpaste being squeezed from a tube (silica-rich magma) versus liquid soap or warm pancake syrup (low-silica lavas). Figure 3.5 shows a recent flow of basalt lava at Parashant. The lava flowed for some distance down a gentle slope.

FIGURE 3.5 Eruption of basaltic lava near Mt. Trumbull at Parashant some 1,000 years ago produced the Little Springs flow (credit: D. Mosby).

FIGURE 3.6. How many of the volcanic centers at Parashant can you find in this photo? (credit: D. Mosby)

The Uinkaret volcanic field at Grand Canyon-Parashant has some 200 volcanic vents. The vents erupted basaltic lava and cinders during the past 3.6 million years (Figure 3.6). On more than 13 occasions in the last one million years, basaltic lavas flowed down canyons that lead to the Grand Canyon. The lava flows built huge dams across the Colorado River. Eventually the dams failed, creating massive outbursts of floodwaters. Evidence shows that some of the floods reached 200 meters above the present level of the Colorado River. Blocks of basalt nearly 40 meters in diameter have been found downstream and traced to these lava dams.

ELABORATE

Design an Experiment into Lava Flows

Some lava flows move more quickly than others. Some flows cover a greater area than others. What causes one flow to behave different than another?

Choose one of the six questions in Table 5 below. Develop a hypothesis, identify the independent and dependent variables, design an experiment (using liquid soap as your lava source), and draw conclusions. Be sure that your design allows you to gather **quantitative data** (numerical data that comes from measuring something) rather than **qualitative data** (e.g., "the liquid soap flowed faster"). Graph your results.

Table 5. Research Questions about Controls on Lava Flows

1. What is the relationship between the volume of lava erupted and the surface area it covers?

2. What is the relationship between the temperature of lava and the speed of a lava flow?

3. What is the relationship between the temperature of lava and the area of a lava flow?

4. What is the relationship between the angle of a slope and the speed of a lava flow?

5. What is the relationship between the composition of lava and the speed of a lava flow?

6. What is the relationship between the composition of lava and the area of a lava flow?

EVALUATE

1. Refer to Table 4 to answer these two questions.

a. Describe the difference between how granite forms versus how rhyolite forms.

b. Describe how granite and rhyolite are similar.

2. Which magma is more likely to form the most violent volcanic eruption – one that produces rhyolite lava or one that produces basalt lava? Why?

3. Three situations that produce lava flows are described below. Put them in order from smallest area covered to largest area covered. Explain.

a. A small volume of basalt magma erupted onto a flat slope

b. A large volume of basalt magma erupted onto a gentle slope

c. A small volume of rhyolite magma erupted onto a flat slope

Challenge Question

Figure 3.7 shows an olivine basalt from Parashant. The olivine is visible as large green crystals.

a. Describe the texture and the chemical composition of the rock

b. Explain how the rock formed.

FIGURE 3.7 Olivine basalt from Whitmore Wash at Parashant. The large crystals are olivine, an iron-magnesium silicate mineral.