Painted Canyon: A New Frontier (Lab 1)

Synopsis

You have been stranded in a remote, but beautiful, desert canyon on a distant planet. In this lab, you will begin investigating this canyon and its exquisite. Each of the teams will investigate the earth materials to better understand the processes that are occurring or have occurred in the past. The goal is to figure out the sequence of geologic events in this strange, new world.

The reconnaissance team that explored Painted Canyon brought back samples of minerals and rocks for you to investigate and use to unravel the geologic history of Painted Canyon. There are four main exercises: (A) learning how to distinguish different minerals and using these criteria to identify some mineral samples from Painted Canyon, (B) identifying some minerals in coarse-grained rocks from Painted Canyon, (C) learning how to classify and identify igneous rocks by using a reference collection, and (D) examining the samples of igneous rocks from Painted Canyon and identifying them.

Painted Canyon, looking to the north.

Introduction

Due to a strange sequence of events, you and your team became stranded in a vast desert near a lone, mountainous region on a newly discovered planet. As you hiked to these mountains, you discovered a special place, which you named Painted Canyon for its brightly colored rocks. This seems like the only possible place in which to build a settlement and survive the desert heat. To survive, you need to understand the landscape and its underlying geology so that you will know where to safely build your settlement and where to find natural resources for cement and other essentials.

You sent a reconnaissance team of rock climbers and photographers into the region to collect samples of rocks and minerals they encountered and to take photographs of where they collected the samples. You will use this information to begin to reconstruct the geologic history of this place and figure out where it is safe to live.

Introduction

There was great excitement in camp when the reconnaissance team displayed their collection of rocks and minerals, most of which came from the deeper parts of the canyon. These collections included such unique and attractive minerals as garnet and olivine. The solid parts of the Earth (and other planets) are composed of **minerals**, which are naturally occurring solids with a definite crystalline structure. Minerals are distinguished by properties, such as hardness and crystal form, which can readily be observed. Minerals occur together to form **rocks**, the building blocks of the landscape. Most minerals form from the cooling and solidification of molten rock and many others are precipitated from water. Once formed, minerals can be eroded into grains of sand, silt, and clay, deposited along beaches and rivers, and incorporated into other rocks. Understanding minerals and rocks is the first step in unraveling the geologic history of Painted Canyon.

Goals for This Week

- ♦ Observe and recognize properties of minerals.
- ♦ Observe and recognize important minerals.
- ♦ Identify unknown minerals.
- ♦ Classify rocks formed from magma by their textures.
- ♦ Observe and characterize igneous rocks.
- ♦ Describe and identify unknown samples of igneous rocks from Painted Canyon.

Exercise 1A: Observing Minerals and Their Properties

To help you identify the minerals collected by the reconnaissance team, you first need to learn how to recognize some physical properties of minerals that help in mineral identification. Then, you will observe examples of the most common minerals. Next you will observe and describe samples of some unidentified minerals collected by the reconnaissance team, and use their physical properties to identify each mineral and evaluate their potential uses as mineral resources. Follow the steps below.

- ☐ Examine *Table 1-1* and *Box 1-1*, which summarize some useful physical properties of minerals and how to observe or test them. For example, some minerals can be scratched with your fingernail, but most cannot.
- ☐ On the side counter are small boxes, each containing several minerals and labeled with the name of a physical property (e.g., hardness). The different minerals in each box vary in the physical property named on the box (minerals in the "hardness" box, for example, vary in hardness). For each box, examine the minerals, noting how the physical property differs in each sample. Record your observations in ***Worksheet 1A*** as to how the minerals in the box differ in this property. **You do not have to identify these minerals yet (but you will).** Refer to *Table 1-1* as you observe the samples.

> *Because the number of samples is limited, please use only one to three boxes at a time and return each box back to the counter as soon as you are finished with it.* ***PLEASE WORK AT YOUR TABLE, NOT THE COUNTERS***.

- ☐ After you have completed a box for each physical property, get from the counter a table listing the names of the minerals in each physical property box. Armed with this list, go through the boxes again, this time using your knowledge of all the physical properties to determine which mineral is which within each box. To do this, compare each mineral with the physical properties listed for various minerals in *Table E-1* in Appendix E.

Exercise 1B: Identifying Minerals from Painted Canyon

- ☐ When you are finished observing each mineral in *Table E-1* in Appendix E, your team should get a box containing a Painted Canyon sample. You may use *Table 1-1, Table E-1* in Appendix E, and your own notes – but NOT the boxes with the physical property reference minerals – to help identify the minerals. Write a brief description of each unknown mineral and identify the mineral by name in ***Worksheet 1B***. Please do not take more than two minerals at a time.
- ☐ On the computer, examine where the samples were collected by opening the SES123 home page and clicking on the appropriate link. You do not have to do anything with this location, but it's always best to know where samples were collected so you can consider their geologic context.

Exercise 1C: Minerals in Rocks of Painted Canyon

The reconnaissance team brought back some coarse-grained rocks, in which the individual minerals are quite large, and want you to identify them.

- ☐ On the side counter are samples of coarsely crystalline rocks, each of which contains several minerals. For one rock determine how many minerals are present and describe the general characteristic of each mineral present (color, presence of cleavage, etc.). Then, try to identify each mineral. Write your results in ***Worksheet 1C***.

Exercise 1D: Examining and Classifying Rocks Formed from Magma

Your team has acquired a collection of rocks that your reconnaissance team says formed from the cooling and solidification of molten rock (magma). Rocks formed in this way are called **igneous rocks**. There is a reference suite of rocks to help you recognize different types of igneous rocks, so that you can identify some unknown samples from Painted Canyon. Do the following with these rocks:

- ☐ The first thing you should do is read the information in *Box 1-2* about how to observe rocks so that you know what to look for in each different rock type.
- ☐ Now, observe each of these rocks briefly, without writing anything down. Focus on identifying the main *attributes* of each rock (e.g., crystal size) and how these attributes vary from rock to rock.
- ☐ With your laboratory partner, discuss these attributes and some ways to classify igneous rocks (those formed from magma). See *Table 1-2* for a classification of igneous rocks and *Box 1-3* for a discussion of igneous rocks and how they form.
- ☐ On the side counter are labeled boxes, each containing several samples of a single kind of igneous rock, such as granite. Take only one or two boxes at a time from the counter and carefully observe the samples in the box. If you want, you may use magnifying glasses and other diagnostic tools. Identify the main physical characteristics of each sample, writing your observations in the appropriate place in ***Worksheet 1D***.

Exercise 1E: Observing Igneous Rocks from Painted Canyon

Use the table you developed (***Worksheet 1D***), in addition to the rock names in *Table E-2* in Appendix E, to identify the rock samples collected by the reconnaissance team in Painted Canyon.

- ☐ On the computer, examine where the samples were collected by opening the SES123 home page and clicking on the appropriate link. You do not have to do anything with this location, but it's always best to know where samples were collected so you can consider their geologic context.

- ☐ Compare your descriptions in ***Worksheet 1D*** with those in *Table E-2* in Appendix E, which also lists the geologic setting and uses for each kind of rock.
- ☐ Samples from Painted Canyon are in boxes on the side counter. Get one sample at a time, carefully observe it, and circle the best answer for the physical characteristics of each sample using ***Worksheet 1E***. Assign a name to this sample based on your description, your knowledge from the reference suite, and the rock names in *Table E-2* in Appendix E.
- ☐ Based on your identification of the rock, circle the best answer in ***Worksheet 1E*** about environment (geologic setting) in which the rock formed (see *Table E-2* in Appendix E). By environment, we mean whether the rock was formed by a volcanic eruption (explosive or nonexplosive) or solidification of magma at depth.
- ☐ Repeat this, one at a time, with all the samples from Painted Canyon.

Table 1-1. Properties of minerals and tools used in mineral identification.

Property	How to Observe	Example
Hardness	Scratch mineral with a fingernail, copper penny, carpenter's nail, or glass plate.	Calcite can be scratched by your fingernail, but will be scratched by a copper penny or nail. It has a hardness of 3 (see *Box 1-1*).
Streak	Rub mineral against a streak plate (porcelain tile).	Hematite can be either red or silver in color, but most has a red-brown streak.
Luster and Transparency	Observe whether the mineral is transparent, translucent, or how it interacts with light.	Pyrite has a metallic luster because it reflects light like a metal (it shines like gold). Biotite-mica has a nonmetallic luster because it is shiny but *not* metallic. Muscovite-mica generally is translucent.
Color	Observe color.	Olivine is always olive-green. Color is not a reliable diagnostic aspect for many other minerals that vary greatly in color.
Cleavage	Observe broken faces of mineral and see shape of break and how it reflects light.	Biotite-mica has a single very well-developed direction of cleavage and so breaks into sheets or flakes oriented parallel to the cleavage. Other minerals have more than one direction of cleavage.
Shape of Unbroken Crystals	Observe form of any crystals present, including number of sides.	Quartz crystals commonly are six sided and terminate in sharp points.
Specific Gravity	Pick up sample and feel how heavy it is for its size.	A sample of galena will feel heavier than expected, thus having a high specific gravity.
Reacts to Acid	Place a small drop of dilute HCl acid on rock.	Calcite fizzes when dilute HCl is dropped on the surface of mineral.
Magnetic	Place small magnet against mineral and observe if it is attracted to mineral.	Magnetite will attract a magnet, but most other minerals will not.
Lines (striations) on the Mineral Feldspar	Observe feldspar with a hand lens.	Plagioclase feldspar commonly has straight, parallel lines (striations) on the cleavage faces, whereas potassium feldspar has wavy lines.

Box 1-1. Physical Properties of Minerals

Crystal Form

When allowed to grow unobstructed, crystals will form into smooth, planar faces with perfect geometric form. The internal arrangement of atoms in a mineral determines the shape of its crystal. Certain minerals commonly grow into well-developed crystals, and their crystal forms are diagnostic. Some of the common minerals in which crystal form is especially diagnostic are quartz, garnet, fluorite, pyrite, and galena.

Cleavage

Cleavage is the tendency of a mineral to break along definite planes of weakness that exist in the internal (atomic) structure of the mineral. The bonds that hold the atoms together in a crystalline structure are not equally strong in all directions. If definite planes of weakness exist, the mineral will cleave, or break, along the planes of weakness much more easily than in other directions.

Crystals may cleave in one, two, three, four, or six directions. Perfect cleavage displays a smooth, even surface that reflects light. Cleavage planes, however, can occur in small segments arranged in a step-like manner. This step-like arrangement may appear initially as an irregular fracture, but if the sample is rotated, light will reflect just as it would on single large, smooth cleavage surfaces. If the surface were an irregular fracture, the light would not concentrate in any particular direction.

Cleavage surfaces may be confused with natural crystal faces, but there are several ways to distinguish them: (1) although crystal faces and cleavage planes are both normally smooth, cleavage planes commonly are broken in a step-like fashion; (2) some crystal faces have fine grooves or ridges on their surfaces; most cleavage planes do not; and (3) unless crystal faces happen to correspond with cleavage planes, the mineral will not break parallel to them. Cleavage results from planes of weakness within the crystal structure along which the crystal breaks. Crystal faces reflect the geometry of the crystal's growth.

Fracture

When minerals break along random, irregular surfaces, it is called fracture. Some minerals break only by fracturing, while others both cleave and fracture. The best everyday example of fracture is broken glass, which fractures into smoothly curved fracture surfaces, called *conchoidal* fracture. Because fractures are random, they will not concentrate light reflections in any particular direction. Fracture surfaces, like cleavage surfaces, are only produced because of breaking the mineral.

Hardness

The hardness of a mineral is its resistance to abrasion. Hardness is measured according to Mohs scale of hardness, where 1 is the softest mineral (talc) and 10 is the hardest mineral (diamond). All other minerals have a hardness between 1 and 10. Each number in the Mohs hardness scale is represented by one mineral (calcite is 3 and quartz is 7). Because it is not practical to have a set of Mohs index minerals with you at all times, a scratch test is used to determine a mineral's hardness using several common objects in place of index minerals. Common objects used in this lab, and their relative hardnesses, include your fingernail (2-2.5 for real fingernails), a copper penny (3.5), a glass plate (5-5.5), a steel nail (5.5), and a streak plate (6.5-7).

Hardness is generally a reliable diagnostic physical property of a mineral, but be aware that variations in composition may make some minerals harder or softer than normal. Weathering can also affect hardness, so make sure to test your sample on a fresh mineral surface.

Box 1-1 (continued).

Color

Color is the most obvious physical property of a mineral, and for some minerals, such as galena (gray), azurite (blue), and olivine (green), it is diagnostic. Other minerals, however, may contain slight impurities or defects within the crystal structure that give the mineral a variety of colors. Quartz, for example, can be a colorless, clear crystal or white, pink, green, purple, red, and black. Although color may be diagnostic for a few minerals, especially minerals with a metallic luster, it is almost without diagnostic significance in minerals of nonmetallic luster. Color should be considered in mineral identification, but other properties should also be considered before making identification.

Streak

Streak is the color of the mineral when powdered, and the color of the streak may differ considerably from the color of the mineral. Streak is obtained by rubbing the mineral across an unglazed porcelain plate. Streak is more helpful for identifying minerals with a metallic luster because minerals with a nonmetallic luster will usually have a light-colored streak or no streak at all. Minerals with hardness greater than that of porcelain will scratch the plate and will not produce streak. Because the streak of a mineral is usually the same, no matter what color the mineral, streak is generally more diagnostic than color. Hint – place the streak plate on the table, rather than holding it in your hand where it can break under the pressure.

Luster

Luster describes the general appearance of a mineral surface in reflected light. Most minerals are either metallic or nonmetallic. Minerals, such as pyrite or galena, that have a metallic luster look like metal. There are a variety of nonmetallic lusters, including glassy, silky, dull or earthy (not bright or shiny). Also, minerals can be transparent (you can see through them, like window glass), translucent (they transmit light but no clear image, like frosted glass), or opaque (don't let any light pass through them, like a brick wall).

Other Properties

Specific Gravity. The specific gravity of a mineral is a number that represents the ratio of a mineral's weight to the weight of an equal volume of water. For purposes of general laboratory work, you can estimate specific gravity simply by lifting a mineral specimen in your hand and making an estimate: relatively heavy or relatively light.

Chemical Reaction. Some minerals, especially carbonate minerals, react vigorously with dilute hydrochloric acid (HCl) by effervescing (bubbling) to release carbon dioxide. Calcite, a common carbonate mineral, will readily bubble when HCl is applied. This simple chemical test is very diagnostic and can be used to distinguish calcite from most of the other common minerals.

Magnetism. Some minerals are magnetic, to varying degrees. The test for magnetism requires a common magnet. Magnetite is the only common mineral actually attracted by a small magnet.

Double Refraction. If an object appears to be double when viewed through a transparent material, the material is said to have double refraction. Calcite is the best common example.

Taste and Odor. Some minerals have a distinctive taste or odor. The salty taste of halite is a definite and unmistakable property of that mineral. We do not recommend tasting minerals in this laboratory.

Lines on Feldspar. Plagioclase feldspar contains distinctive tiny, straight, parallel lines, called striations, that appear on some of the cleavage surfaces. Potassium feldspar may have crooked lines, which help distinguish it from plagioclase feldspar.

Box 1-2: How to Observe Rocks

Rocks are naturally occurring aggregates of minerals. Sandstone, for example, is composed of sand grains, each of which is a rounded piece of a mineral like quartz. To identify a rock and use it to interpret an area's geologic history, we need to understand the geological significance of the rock's physical characteristics and mineral assemblages.

Texture (the size, shape, and arrangement of minerals within a rock) and **composition** (which minerals make up the rock) can tell us a great deal about the processes by which a rock formed. Texture and composition, along with observations about the rock's appearance in outcrop and its local geologic setting, allow us to interpret whether the rock has an igneous, sedimentary, or metamorphic origin. For example, a rock that is coarsely crystalline, composed mostly of the light-colored minerals quartz and feldspar, and forms rounded, nonlayered outcrops is granite. Our interpretation of the origin of a rock will further influence what other things we look for, to continue to evaluate our interpretation.

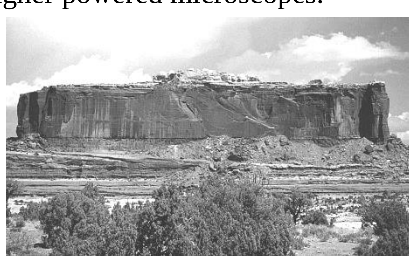
Observing Rocks at Different Scales

We can observe rocks at various scales, each of which provides us with different types of information to help us identify and interpret a rock. When observed from a *distance*, nearly all we can tell about a rock is its color, whether it occurs in layers, whether it erodes into cliffs or soft-appearing slopes, and any internal features, such as fractures and small-scale layers. With experience, you can make some good educated guesses about what the rock is from a distance. For example, a red, cliff-forming layer is nearly always sandstone, whereas red, slope-forming, layered rocks are usually mudrocks. In both cases, the red color indicates that the rocks were deposited on land or in very shallow water where the rocks could be oxidized.

At the *outcrop scale*, where we observe a rock exposure the size of a car, we can see features not visible from afar. We can observe whether the rocks are layered on a fine scale, whether they are homogenous or vary in size of crystals or clasts, how they weather and erode, and if they contain small-scale features, such as mud cracks, ripple marks, and fossils.

When we look closely at a rock in *hand specimen*, we can often see that it is made up of many small components (crystals, grains, and cement), but not all rocks have components large enough to see clearly without the aid of magnification. By looking at the rocks with a hand lens or other type of magnifying glass, you can make more detailed observations of the rock's composition and texture. We can see the size and shape of individual crystals and grains, and how they are arranged. We commonly can tell what mineral each crystal or grains is, and whether the minerals are interlocking (see *Box 1-1*). We can tell if the minerals have some preferred orientation, like parallel mica crystals in schist.

For those samples whose components are too small to see even with the aid of a hand lens, a *binocular microscope* may aid in determining the mineralogy and texture. At this scale, individual crystals and grains are clearly visible, and their size, shape, and relation to one another are usually obvious. Some rocks, however, are very fine grained and individual crystals and grains can't be seen with the binocular microscope. In this case, geologists cut very thin slices of the rocks and look at them under higher powered microscopes.



Sedimentary rocks from a distance

Hand sample of sedimentary rock

Table 1-2. Classification of Igneous Rocks.

<table>
<tr><th rowspan="2">Texture</th><th colspan="4">Composition</th></tr>
<tr><th></th><th>Felsic (light colored)</th><th>Intermediate</th><th>Mafic (dark colored)</th></tr>
<tr><th>Coarsely Crystalline</th><th>Intrusive</th><td>Granite
mostly light-colored crystals</td><td>Diorite/Granodiorite
dark and light-colored crystals</td><td>Gabbro
mostly dark crystals</td></tr>
<tr><th>Finely Crystalline</th><th>Volcanic</th><td>Rhyolite
light-colored, small crystals</td><td>Andesite
medium-colored, small crystals</td><td>Basalt
dark-colored, small crystals</td></tr>
<tr><th>Glassy</th><td colspan="2">Obsidian
dark glass</td><td>No special name</td><td>No special name</td></tr>
<tr><th>Vesicular (has holes)</th><td colspan="2">Pumice</td><td>No special name</td><td>Scoria</td></tr>
<tr><th>Pyroclastic</th><td colspan="2">Tuff
light-colored with fragments of pumice, obsidian and/or crystals</td><td>Tuff
light- to medium-colored with fragments of pumice, obsidian and/or crystals</td><td></td></tr>
</table>

Box 1-3. Igneous Rocks and How They Form

Where and How Magma Solidifies

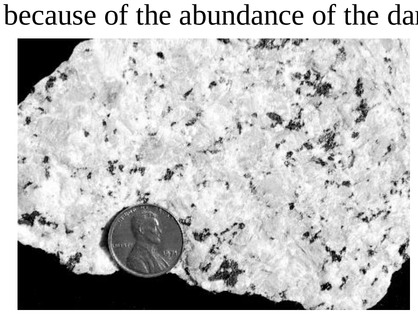
Volcanic eruptions are one of the most spectacular natural exhibitions on Earth. They occur when magma (molten rock) forms at depth and rises through the crust and reaches the surface. Rocks formed when magma cools and solidifies are called **igneous rocks**. Igneous rocks formed from volcanic eruptions are called **volcanic rocks**. Magma can be erupted as molten lava flows or more explosively as volcanic ash and fragments.

Volcanic eruptions are impressive, but most magma crystallizes *beneath* the surface of Earth, in which case it forms **plutonic rocks** (an igneous rock that solidifies at depth), like granite. Such magma can solidify in large magma chambers, forming large irregular rock bodies called **plutons**. Or, it can force open and inject into fractures, forming a sheet-like rock mass called a **dike** if it has a steep orientation or a **sill** if it is nearly horizontal and between layers of rock. Sometimes, the outer parts of a volcano are eroded away, exposing the vertical, pipe-shaped, magma conduit, forming a **volcanic neck**.

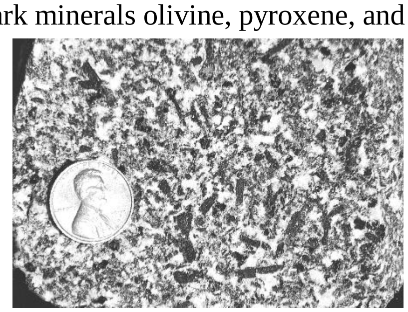
As magmas cool and solidify, at temperatures of 700 to 1200°C (depending on their composition), the minerals do not all crystallize at the same time, because they have different temperatures at which they form. Instead, minerals commonly crystallize in a specific sequence, with the higher temperature minerals forming first, followed by those that only crystallize at lower temperatures. Those minerals that crystallize at high temperatures develop well-formed crystal faces, whereas those that crystallize at lower temperatures are forced to grow between the earlier formed crystals, causing them to be irregular in shape with few well-developed crystal faces.

Photograph of well-formed dark crystals in a very coarsely crystalline igneous rock. Rocks with crystals that are this size or larger are called *pegmatite*, and form when water dissolved in magma permits crystals to grow to relatively large sizes.

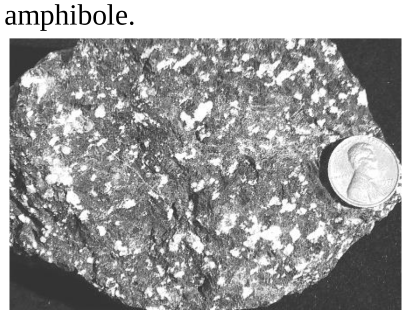
Six minerals make up nearly all the volume of all common igneous rocks: feldspars, olivine, pyroxenes, amphiboles, quartz, and mica. Magmas rich in silicon and aluminum are referred to as **felsic** and tend to form light-colored rocks, like granite and rhyolite, composed mostly of quartz and feldspar. Magmas rich in iron, magnesium, and calcium are called **mafic**, and produce rocks that are dark colored because of the abundance of the dark minerals olivine, pyroxene, and amphibole.



Felsic igneous rock, composed of mostly light-colored minerals



Intermediate igneous rock, composed of dark- and light-colored minerals



Mafic igneous rock, composed of mostly dark-colored minerals

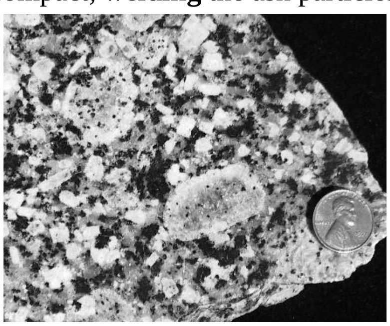
Box 1-3. Igneous Rocks and How They Form (continued)

Crystallization of Magma and the Resulting Textures

As magmas cool and solidify, at temperatures of 700 to 1200°C (depending on their composition), the minerals do not all crystallize at the same time, because they have different temperatures at which they form. Instead, minerals commonly crystallize in a specific sequence, with the higher temperature minerals forming first, followed by those that only crystallize at lower temperatures. Those minerals that crystallize at high temperatures develop well-formed crystal faces, whereas those that crystallize at lower temperatures are forced to grow between the earlier formed crystals, causing them to be irregular in shape with few well-developed crystal faces.

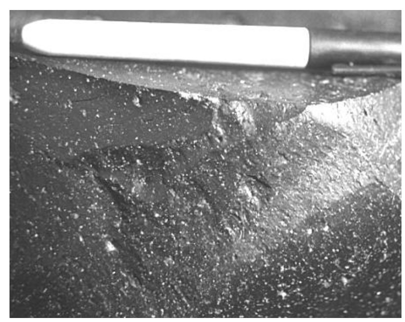
The size, shape, arrangement of minerals, and how the minerals fit together controls the overall appearance of a rock, or its **texture**. In most igneous rocks, texture primarily reflects the magma's composition and rate of cooling. Magmas trapped deep in Earth's crust cool slowly, thereby growing *larger crystals*, locally more than an inch in diameter. If magma rises higher, reaching shallower levels of the crust, it cools more quickly, leaving only a short time for *small crystals* to grow. And if the magma is erupted onto Earth's surface, such as in a lava flow, it cools so rapidly that there is no time to form crystals. Instead, it chills rapidly to form volcanic **glass**, which has no crystalline structure. Some magma has had a complex cooling history – slow and then fast. This forms rocks containing large crystals imbedded in a matrix of finer crystals or glass. This is known as **porphyritic** texture, and the resulting rock is called simply **porphyry**. The larger crystals are called **phenocrysts**.

Other textures of igneous rocks include vesicular and fragmental. **Vesicular** texture forms in fast-cooling magma that traps gas bubbles, forming holes and a sponge-like appearance upon cooling. A vesicular rock is **pumice** if light colored, or **scoria** if dark colored. **Fragmental** or **pyroclastic** texture displays countless fragments, both small and large, of volcanic glass, pumice, and angular rocks fragments. It forms when gas-charged magma bursts apart into volcanic ash and is ejected into the air. Depending on how hot the ash is when it comes to rest, it may still be partially molten, and will flow or compact, **welding** the ash particles together, forming a **welded tuff**.

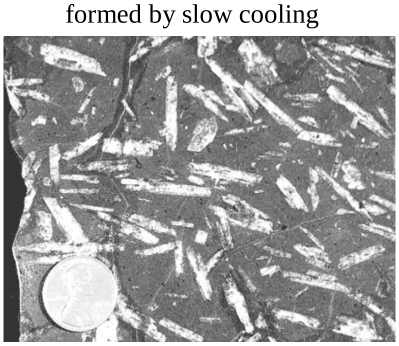


Coarsely crystalline igneous rock, formed by slow cooling

Finely crystalline igneous rock, formed by fairly fast cooling

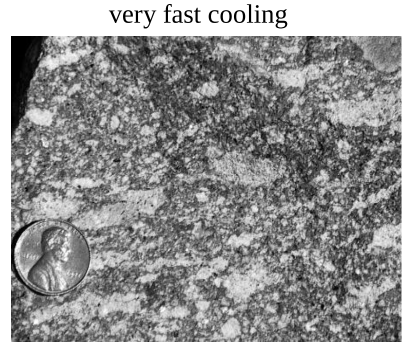


Glassy igneous rock, formed by very fast cooling



Porphyritic igneous rock, with phenocrysts in finer matrix

Igneous rock with relict gas bubbles (vesicles)



Pyroclastic igneous rock, composed of flattened pumice.

APPENDIX E: Minerals and Rock Identification Tables

Table E-1. Minerals for This Lab and Some Physical Properties They Possess.

An asterisk (*) means the rock contains only minor amounts of the mineral.

Mineral Name	Physical Properties	Geologic Setting	Industrial Uses
Biotite-mica[1] *(K, Mg, Fe, Al Silicate)*	Luster nonmetallic. Color dark green, brown, or black. Hardness 2.5-4. **Platy cleavage (sheets)**. Streak white to gray.	Schist, gneiss, granodiorite, granite*, rhyolite*.	Used as an insulator and in electrical devices.
Calcite *($CaCO_3$)*	Luster nonmetallic. Colorless and transparent or white when pure; wide range of colors possible. **Hardness 3**. **Cleavage rhomb shaped**. Streak white to gray. **Reacts with dilute HCl acid**.	Limestone, marble, caliche, veins of calcite, hard-water deposits on plumbing fixtures.	Chief raw material for cement, wide variety of other uses.
Galena *(PbS)*	**Luster bright metallic**. **Color lead-gray**. Hardness 2.5. **Cubic cleavage**. Streak lead-gray. High specific gravity.	Veins and other ore deposits.	Lead ore.
Garnet *(Fe, Mg, Ca, Al Silicate)*	Luster nonmetallic. **Color varies but dark red and reddish brown most common**. **Hardness 6.5-7.5**. **Cleavage none**. Streak white or shade of mineral color. Common 12- or 24-sided crystals.	Schist, gneiss, metamorphic rocks near intrusions, pegmatite*, light-colored granites*.	Commercial abrasive. Gemstone varieties are red and green.
Gypsum *($CaSO_4$*H_20)*	Luster nonmetallic; vitreous to pearly. Colorless to white, gray, yellowish orange, light brown. **Hardness 2**. **One primary direction and one less defined direction of cleavage**. Streak white.	Salt deposits from evaporation of lakes and seas.	Wallboard (sheet-rock), plaster, filler in paper products.
Halite *(NaCl)*	Luster nonmetallic. **Transparent to translucent**. Colorless, also white, gray, yellow, red. **Hardness 2.5**. Three directions of cleavage at 90° angles. Streak white. Characteristic taste of salt.	Salt deposits formed from evaporation of lakes and seas, salt domes.	Widely used as source of both sodium and chlorine and as table salt.
Hematite *(Fe_2O_3)*	Luster metallic in form known as specular hematite; submetallic to dull in other varieties. Color steel gray in specular hematite, dull to bright red in other varieties. Hardness 5-6. Cleavage none. **Streak red-brown**.	Red sedimentary rocks*, ancient iron-rich sedimentary rocks, soil, zones of weathering, veins.	Iron ore and red pigment in paints.
Mafic Minerals *(Na, Ca, Mg, Fe, Al Silicates)*	Luster nonmetallic. Color dark green to black. Hardness 6. Cleavage 2 directions at nearly 90º (**pyroxene**) and 2 directions at 60º and 120º (**amphibole**).	Dark-colored igneous rocks and gneiss.	Some amphibole minerals formerly used as asbestos; some pyroxene minerals used as source of lithium.

Table E-1 (continued)**.** Minerals for This Lab and Some Physical Properties They Possess.

An asterisk (*) means the rock contains only minor amounts of the mineral.

Mineral Name	**Physical Properties**	**Geologic Setting**	**Industrial Uses**
Magnetite *(Fe_3O_4)*	Luster metallic. Color black. Hardness 6. Cleavage none. Streak black. **Strongly magnetic**.	Igneous rocks*, ancient iron-rich sedimentary rocks, near intrusions.	Iron ore.
Muscovite-mica[1] *(K, Al Silicate)*	Luster nonmetallic. Colorless to shades of green, gray, or brown. Hardness 2.5-4. **One cleavage forming platy sheets**. Streak white. Flakes apart easily.	Schist, gneiss, pegmatite, veins, marble*, light-colored granite*.	Variety of industrial uses.
Olivine *($(Mg, Fe)_2SiO_4$*	Luster nonmetallic. **Color olive-green to yellowish**. Hardness 6.5-7. Cleavage indistinct. Streak white or gray. Usually granular masses.	Basalt and dark-colored intrusive rocks, inclusions in basalt; forms most of upper mantle.	Gemstone variety is peridot.
Plagioclase Feldspar *(Na, Ca, Al Silicate)*	Luster nonmetallic. Color white or gray. Hardness 6. Cleavage 2 planes at close to right angles, **twinning striations**. Streak white.	Most igneous and metamorphic rocks; volcanic-derived sandstone.	Sodium-rich varieties mined for use in ceramics.
Potassium Feldspar *(K,Al Silicate)*	Luster nonmetallic. Color varies white, cream, or **pink**. Hardness 6. **Two directions of cleavage at right angles**. Streak white. Has glossy appearance and may display wavy lines.	Most igneous and metamorphic rocks; sandstone derived from granite.	Commonly used in ceramics, glassmaking, and in scouring and cleansing products.
Pyrite *(FeS_2)*	Luster metallic. **Color brass-yellow**, may be iridescent if tarnished. Hardness 6-6.5. Cleavage none, conchoidal fracture. **Streak greenish or brownish black**. Crystals common, usually cubic with striated faces.	Veins, some granites*, slates*, schists*, and some unoxidized sedimentary rocks*.	Known as “fools gold.” Source of sulfur for sulfuric acid.
Quartz *(SiO_2)*	Luster nonmetallic. Typically colorless or white, but almost any color may occur. **Hardness 7**. **Cleavage none, conchoidal fracture**. Streak white but difficult to obtain on streak plate.	Sandstone, mudrocks, granite, granodiorite, quartzite, schist, gneiss, veins.	Electronics and glassmaking. Color variations include amethyst, smoky, rose, and milky quartz.
Talc *(Mg Silicate)*	Luster nonmetallic, pearly to greasy or dull. Usually pale green, also white to silver-white or gray. Hardness 1. Streak white. **Greasy or soapy feel**. Platy.	Some metamorphic rocks.	Commercial uses in paints, ceramics, roofing, paper, and talcum powder.

[1] Biotite and muscovite belong to a family of platy minerals called “mica”. All have one strong cleavage and form sheets that you can pick apart with a knife or your fingernail. Micas strongly reflect light and appear shiny. Muscovite is also called “white mica” and biotite is sometimes called “brown mica” or “black mica”.

Table E-2. Common **Igneous Rocks** and Their Properties.

Rock Type	Rock Name	Physical Properties	Geologic Setting	Industrial Uses
Felsic	**Granite** *(Intrusive; rhyolite is extrusive equivalent)*	**Coarsely crystalline, light-colored** rock consisting primarily of quartz, potassium feldspar, and sodium plagioclase; commonly contains biotite-mica or muscovite-mica. Granite can have a wide range of crystal size; mineral crystals are intergrown tightly. Many granites are gray, but may be pink or red. The term **pegmatite** is used for granite composed of very large crystals (mostly more than 2 to 5 cm in diameter).	Found only on continents; generally is the result of partial melting of the continental crust near subduction plate margins.	Facing stones on buildings; crushed granite and granite boulders used as ornamental stone.
	Rhyolite *(Extrusive; granite is intrusive equivalent)*	**Finely crystalline, light-colored** volcanic rock, usually massive and structureless, but may contain flow banding. Generally white, gray, or pink and commonly contains a few phenocrysts of feldspar or quartz.	Found only on continents at or near subducting plate margins.	Few known uses.
	Obsidian *(Similar in composition to granite and rhyolite)*	Massive volcanic **glass**, usually **jet-black**. Typically breaks with a conchoidal fracture and has a bright glassy luster. May be flow banded or contain small phenocrysts of feldspar or quartz.	Forms when lava erupts into the air or flows into a body of water causing it to cool instantly.	Used primitively as arrowheads and tools. Used today in some surgical instruments.
	Pumice *(Similar in composition to granite and rhyolite)*	Porous, **very light weight**, volcanic glass with a texture consisting of glass fibers tangled together or **holes**. Usually cream to gray colored. May float on water.	Forms when bubbling, high gaseous, silica-rich magma cools instantly after being erupted into the air.	Pumice is used as an abrasive cleaning agent, in concrete to make it lighter, and in “stone washing” jeans.
	Tuff *(Generally similar in composition to granite and rhyolite)*	Volcanic rock composed of a **volcanic ash, possibly with scattered crystals and/or rock fragments** and has a fragmental texture. Can be solid if densely welded or soft and somewhat porous if poorly welded. Strongly welded tuff has dark-gray, brown, or cream-colored lenses of flattened pumice fragments.	Common at convergent plate margins. Forms when volcanic fragments and ash erupt from volcanic vents and are trans-ported through the air.	Few known uses but may be enriched in gold, silver, copper, iron, and other minerals.

Table E-2 (continued). Common **Igneous Rocks** and Their Properties.

Rock Type	Rock Name	Physical Properties	Geologic Setting	Industrial Uses
Intermediate	**Diorite** *(Intrusive; andesite is extrusive equivalent)*	**Coarsely crystalline**, intermediate- to light-colored rock ("**salt-and-pepper**" appearance) consisting primarily of approximately equal amounts of plagioclase feldspar, potassium feldspar, and quartz, along with as much as 10% each of biotite-mica and mafic minerals.	Occurs in island arcs and continental volcanic chains; large intrusive bodies like stocks or batholiths.	Decorative stone for landscaping. Most major copper deposits are associated with this type of rock.
	Andesite *(Extrusive;diorite is intrusive equivalent)*	**Finely crystalline, intermediate-colored** (dark gray, green, brown, or red) volcanic rock composed of plagioclase and mafic minerals with some biotite-mica but little or no quartz. Commonly contains elongated black phenocrysts of mafic minerals.	Originates in subduction zones by partial melting of the oceanic crust, and in volcanic island arcs.	Few known uses.
Mafic	**Gabbro** *(Intrusive; basalt is extrusive equivalent)*	**Coarsely crystalline, dark-colored** rock composed almost entirely of mafic minerals and plagioclase. Characteristically dark green, dark gray, or almost black.	Produced at divergent plate margins and forms the bottom layer of the oceanic crust.	Many uses in construction.
	Basalt *(Extrusive; gabbro is intrusive equivalent)*	Finely crystalline volcanic rock composed primarily of calcium-rich plagioclase, mafic minerals, and commonly some olivine. It is characteristically **black to dark brown,** dense, and massive. Commonly contains **holes**.	Forms the upper layers of oceanic crust; oceanic volcanoes; basaltic lava on continents.	Often used as construction material in road building.