Lab 10 - Rock Identification

A rock is a substance made up of one or more different minerals. That is why an essential part of rock identification is the ability to correctly recognize the major (or most abundant) minerals within a given rock sample. This is often described as the rock's *mineralogy*. Another important component in rock identification is to correctly interpret the rock texture. Technically, *texture* is the size, shape, and grain-to-grain relationships between minerals in a rock. For the purposes of this lab, texture really implies genesis, or how the rock formed. All rocks can be placed into one of three major rock groups based on their texture; igneous, sedimentary or metamorphic rocks. Recognition of the texture of a rock allows one to properly place the rock into its appropriate rock group.

Separating the Three Rock Groups

Igneous rocks form from the cooling and crystallization of molten rock. When minerals grow directly from a liquid the boundaries between adjacent minerals tend to penetrate each other, forming a very strong, interlocking pattern similar to that of pieces in a jigsaw puzzle. Given this and the fact that igneous rocks are composed of relatively hard (for the most part) silicate minerals, igneous rocks are very hard rocks that have been used as major building materials by people for 1000s of years.

Sedimentary rocks form from either pieces of preexisting rocks or the hard parts of once-living plants and animals. These loose materials, called *sediment*, are then either compacted or cemented in order to *lithify* them (turn them into a sedimentary rock). Thus these rocks have the overall appearance of particles or bits of plant or animal material that are held together by some kind of binding agent, called a *cement*. Cements are, generally, soft minerals, such as gypsum, calcite or iron rust (hematite or limonite) and, hence, sedimentary rocks are not as hard as igneous rocks and appear to be 'pieced together' from previous materials.

Metamorphic rocks are formed either under intense heat and pressure (called regional metamorphism) or by intense heat and volatiles escaping from an ascending magma body (called contact metamorphism). Because pressure is a key component in regional metamorphic rocks, these rocks generally show a strong alignment of platy or sheet-like minerals (mostly clays and micas). This alignment of minerals create a weakness in regionally metamorphosed rocks such that most will tend to break into thin sheets (a property known as *rock cleavage*) or will form in light and dark bands. Because pressure is largely absent from contact metamorphic rocks, these rocks do not display rock cleavage. Instead the heat and volatiles cause a recrystallization or a distinct increase in mineral size and create a strong, interlocking fabric between minerals similar to that found in many igneous rocks. But most of the common contact metamorphic rocks are composed of only one major mineral, whereas most igneous rocks are made up of two or more different minerals or of rock glass (see further readings).

Identification of Igneous Rocks

Igneous rocks may form from *magma*, molten rock that never makes it to the earth's surface or from *lava*, molten rock that either flows onto or explodes onto the earth's surface. If the rock forms from magma, it may have stayed in a liquid state for 1000s or tens of 1000s of years. This means that minerals that grow out of a magma have had a long time to grow and, thus, tend to be large enough to be visible with the naked eye. An igneous rock that is composed of large, visible minerals is said to have a *phaneritic* texture.

All igneous rocks originally form from partial melting of the earth's crust, or even, the earth's upper mantle. Since both crust and upper mantle are composed largely of *silicate minerals* (minerals that contain both silicon and oxygen) igneous rocks also consist mostly of silicate minerals. In the early 1900's a Canadian Petrologist by the name of N. L. Bowen first published the sequence of silicate minerals and the order in which they crystallize from a magma. This sequence of minerals is now referred to as *Bowen's Reaction Series* (Figure 1). Bowen also proposed that a single magma body (a single liquid) may be capable of producing different types of igneous rocks through a process called fractional crystallization. As a magma body raises towards the surface minerals that crystallize from the magma may sink to the bottom of the magma chamber (or fractionate) and be left behind by the raising liquid. This would change the chemistry of the raising liquid causing it to crystallize different minerals on its way toward the surface. In this way a very hot, very deep magma body would first crystallize olivine, which would sink to the bottom and be left behind. The raising and cooling magma body would then crystallize augite and calcium-rich plagioclase, which would sink and be left behind. Next would come hornblende and calcium-sodium plagioclase, then biotite and sodium-rich plagioclase and finally, as the magma nears the surface, the last minerals in Bowen's sequence would crystallize out from the, largely cooled and solidified magma body.

Thus igneous rocks that form from a magma always have a coarse-grained, phaneritic texture (Figure 2a) and are named for the silicate minerals that they contain . Phaneritic, olivine-rich rocks are fairly uncommon owing to the fact that they originate at great depth within the earth. The rest are more common and are present in your rock set. A helpful hint in recognizing the 3 major phaneritic igneous rocks is to look at their overall color. Gabbros are very dark-colored phaneritic rocks because both augite and calcium-rich plagioclase are dark-colored minerals. Diorites are often described as 'salt and pepper' in appearance, since hornblende is black and Ca-Na plagioclase is light gray. Granites are composed of light-colored minerals with a small sprinkle of dark biotite flakes in them (Figure 1).

As magma raises to the surface some minerals will crystallize out of the liquid and may grow quite large over time, but if a portion of that magma reaches the surface and flows out as lava, the liquid component of that lava will cool very quickly (in a matter of hours or days depending on the quantity of lava that makes it to the surface). An igneous rock that is composed of both large visible minerals that formed in the magma (called phenocrysts) and very tiny invisible minerals that formed when the magma became lava (called groundmass) is said to have a *porphyritic* texture (Figure 2b). The different sizes of the minerals in a porphyritic igneous rock reflect the two-stage cooling history of the rock; slow-cooling, visible minerals while it was a magma and

<table>
<tr><th>Rock Color</th><th>Bowen's Minerals</th><th>Phaneritic texture</th><th>Porphyritic texture</th><th>Glassy texture</th></tr>
<tr><td>very dark</td><td>olivine</td><td>RARE</td><td>RARE</td><td>RARE</td></tr>
<tr><td>dark</td><td>augite, Ca-rich plagioclase</td><td>gabbro</td><td>basalt</td><td rowspan="3">obsidian</td></tr>
<tr><td>medium</td><td>hornblende Ca-Na plagioclase</td><td>diorite</td><td>andesite</td></tr>
<tr><td>light</td><td>biotite
Na-rich plagioclase
orthoclase
muscovite
quartz</td><td>granite</td><td>rhyolite</td></tr>
</table>

Figure 1. Classification of common igneous rocks.

fast cooling, invisible minerals when it became a lava.

Recognition of the three common porphyritic igneous rocks can also be tied to the overall color of the rock (Figure 1). A gabbro magma that makes it to the surface will produce a basalt lava. Thus basalts, like gabbros, contain all dark-colored minerals. The difference between a gabbro and a basalt is in their rock textures (phaneritic gabbros and porphyritic basalts). Likewise a ‘salt and pepper’ diorite magma will produce a light- and dark-colored lava rock; an andesite. And a light- colored granite magma will form a light-colored rhyolite lava rock.

The upper few inches of a lava flow may cool off and solidify extremely fast, so fast that no minerals get a chance to form. This is what is called rock glass. It has all of the appearance, hardness and sharpness of manufactured glass, but is naturally occurring. Igneous rocks made up of rock glass are said to have a vitreous or glassy texture. An igneous rock composed of dense rock glass is called obsidian.

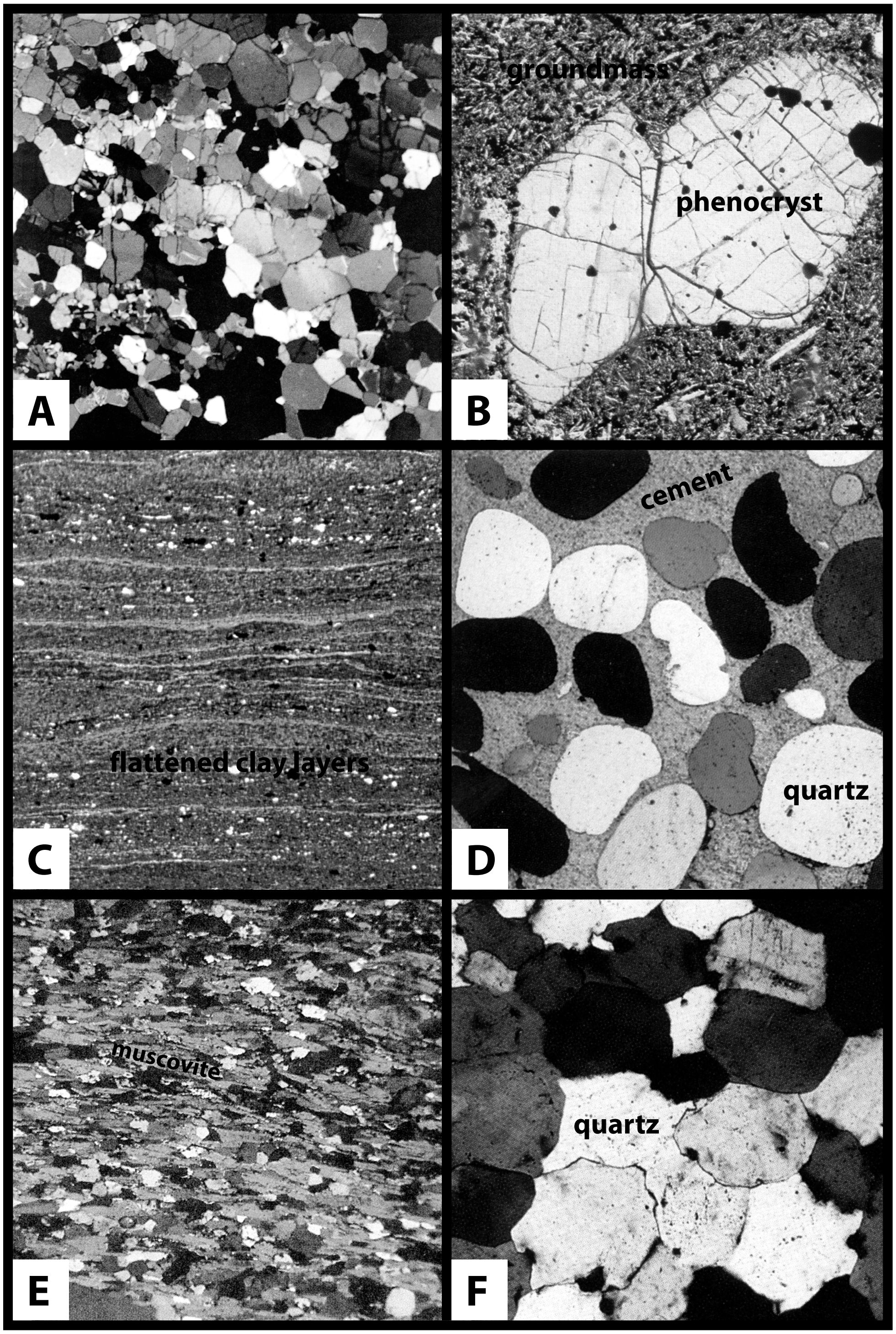

Figure 2. Common textures in the 3 major rock groups as seen in highly magnified, thin slices of rocks. A. A coarse-grained phaneritic ganite with quattz, muscovite and feldspars. B. A porphyritic igneous rock with large phenocrysts surrounded by very fine-grained groundmass. C. Thin layers of compacted clays in a detrital sedimentary shale. D. Rounded quartz sand grains with soft, white calcite cement filling the pores in between the sand creating a detrital, sedimemtary sandstone. E. Large, aligned muscovite flakes in a foliated metamorphic schist. F. Recrystallized quartz showing the strong, interlocking, nonfoliated texture in a metamorphic quartzite.

Identification of Sedimentary Rocks

All rocks that form at higher than normal surface temperatures and pressures are both chemically and physically unstable when exposed to the earth's surface. A series of chemical and physical processes collectively known as *weathering* will begin to slowly break these rocks down into their constituent minerals. All silicate minerals, except for quartz, will eventually break down into a very fined-grained material known as *clay*. One of the major forces of weathering is surface water (rivers and streams). These pieces of preexisting rock are called detrital (meaning pieces) sediment (meaning 'to settle'). Detrital sediment is transported in hugh volumes by rivers and streams as load. Stream load may be deposited on a floodplain if the river floods or left behind in a river channel (if the river dries up) or may, eventually, make it to the ocean and be collected along the shore lines as beaches and at the river's mouth as deltas. Clays that are deposited along floodplains or swamps or lagoons by rivers may dry up and harden over time to produce a detrital sedimentary rock called a shale (Figure 2c). Shales often contain small amounts of plant debris because the quiet, often stagnant regions that they are deposited in are places where plant life also flourishes.

Sand that are deposited by rivers in their channels, at deltas or along beeches may also be converted into a sedimentary rock. Most sand is made up of quartz, but is not pure. Along with the sand are loose chemical ions that formed as unstable silicate minerals are converted to clay by various weathering processes. If this mixture of sand and loose ions is deposited at a place where they can accumulate, groundwater may eventually percolate through pore spaces in the material and selectively dissolve and reprecipitate the loose ions that are mixed with the quartz sand. This will fill the pores in between the sand grains with minerals they can act as a natural cementing agent, thus binding the quartz sand grains into a detrital sedimentary rock called a sandstone (Figure 2d). Minerals that can act as *cements* to form a sandstone can include calcite, gypsum, hematite and/or limonite.

Sediment may consist of weathered pieces of preexisting rocks (*detrital* sediment) or the hard parts of preexisting animal or plant life (*nondetrital* sediment). The largest concentration of animal life on our planet lives just offshore in the shallow water of the earth's oceans. Here, animals such as clams, snails, oysters. etc., extract chemicals (mostly the mineral calcite) from sea water to build their hard shells. These shells are washed up onto beaches in vast quantities and, over time, may be compacted and cemented together to form a rock called a limestone. Many limestones still retain remnants of the shells that formed them and are readily recognizable for the 'fossil' animal life that they contain.

Swamps, lagoons and river deltas are environments that can support hugh amounts of plant life. In these quiet, often stagnant areas plants live, die and accumulate in vast quantities. Over geologic time this accumulated plant material may become slowly compacted and converted into a soft, black material called carbon. A rock that consists of the 'carbonized' remains of ancient plants is called coal.

Texture	Mineralogy	Other Characteristics	NAME
Detrital	very-fine clays	flat gray to black rocks plant fossils common	**shale**
	quartz 'sand' grains with various cements	cements are usually soft so quartz easy to remove	**sandstone**
Nondetrital	calcite 'fossils' with calcite cement	very old-looking 'sea shells' are common	**limestone**
	compressed layers of carbon	soft, easily marks on paper and very light in weight	**coal**

Figure 3. Classification of common sedimentary rocks.

Identification of Metamorphic Rocks

Metamorphic rocks form from a preexisting rock (called the *protolith*) that has been subjected to intense heat, pressure, or chemically active fluids and gases (such as volatiles from a magma body). These three forces are said to metamorphose the protolith; or to change the protolith's original texture and mineralogy. All rocks (igneous, sedimentary and, even other metamorphic rocks) may serve as the protolith for metamorphism . Metamorphic processes take place in the solid state, that is, no melting may occur. If the pressures and temperatures become high enough to partially or completely melt the rock, then magma and igneous rock are formed.

Metamorphism that is driven by increasing heat and pressure is called *regional metamorphism*. Regional metamorphism occurs at a depth of a few miles or greater anywhere in the earth's crust and is a consequence of the fact that the deeper you descend into the earth's crust the higher the temperatures are and the greater the pressure created by the weight of the overlying rock. How rocks react to increasing heat and pressure depend largely on what the original protolith was before it was metamorphosed. If you start out with a shale, a detrital sedimentary rock composed largely of clay, increasing heat and pressure causes to tiny, microscopic clay plates to recrystallize or grow in size to become large, visible micas (either muscovite or biotite or both). In addition, increasing pressure will cause the micas to rotate and become strongly aligned in a direction perpendicular to the direction of the pressure. This will create a rock that can be easily broken into flat sheets parallel to the direction of alignment of the micas. Such a rock is called a schist and is said to have a *foliated* texture, because the aligned micas have the appearance of a pile of compressed leaves or 'foliage' (Figure 2e).

Regional metamorphism of an igneous rock, such as a granite, also creates a metamorphic rock with a foliated texture. This is because most igneous rocks contain micas and other elongate or sheet-like minerals which will become aligned by increasin g pressure. In addition to aligning certain minerals, some minerals in an igneous rock will physically separate from others during the metamorphic processes. Usually the light colored minerals will separate from dark colored ones, producing a rock with very distinct light- and dark-colored bands. The resulting rock will break readily in between the bands and, hense, is also described as a foliated rock. Such a rock is called a gneiss (pronounced 'nice').

Contact metamorphism occurs when a hot, volatile-rich magma body comes in contact with colder surrounding crust. This normally takes place close to the earth's surface where pressure is not an important process. Therefore contact metamorphic rocks lack the distinct alignment of minerals found in the high-pressure processes of regional metamorphism. Contact metamorphic rocks are said to have a *nonfoliated* texture, a texture resulting from an absence or pressure and, hense, an absence or any mineral alignment or banding. Contact metamorphism does, however, drastically alter the texture of the rock that is in contact with the magma body. The intense heat and chemically-reactive volatiles act to recrystallize the mineral components in the cooler protolith, making them grow in size and destroying the original texture of the protoliths. If the original protolith was a sandstone, the detrital quartz grains of the sandstone will grow in size and literally weld themselves together at their grain boundaries. This will produce an incredibly hard rock (remember quartz has a hardness of 7) that, unlike the original sandstone, will not readily break across the softer cementing mineral. Such a rock is a nonfoliated metamorphic rock called a quartzite (Figure 2f). If the original protolith was a limestone, recrystallization of the original calcite fossils by contact metamorphism will cause the calcite to grow in size, destroying the original calcite fossils and creating a rock that is made up of coarse, blocky-looking calcite called a marble. Marbles are also nonfoliated metamorphic rocks, as the coase calcite crystals will not desplay any form of mineral alignment. Like quartzites, they appear to be hard, strong rocks but are composed entirely of calcite (which has a hardness of 3 and can easily be scratched by a steel nail).

Texture	Mineralogy	Other Characteristics	NAME
Foliated	layers of muscovite and biotite with quartz common	muscovite often gives the rock a silver, glittery look	**schist**
	biotite, quartz orthoclase	thin, alternating light- and dark-colored bands	**gneiss**
Nonfoliated	calcite	often sugary-looking, calcite hardness = 3	**marble**
	quartz	quartz breaks across grains, quartz hardness = 7	**quartzite**

Figure 4. Classification of common metamorphic rocks.

Rock Table

Rock Group	Rock Texture	Mineralogy	Other Characteristics	NAME

Lab 10 - Homework

There are 15 samples of igneous, sedimentary and metamorphic rocks to identify in this lab. Your mission is to determine whether your rocks are igneous, sedimentary, or metamorphic by their mineralogies and textures. Be sure to refer to both your textbook and this lab for the definitions of these three rock groups.

NOTE FOR THE LAB FINAL: Not only will you have to know the rock name of these 15 specimens but you will also need to learn their rock group and rock texture.

Igneous Rocks: If you examine page 3 (Figure 1) you will notice that there are seven different igneous rocks. These igneous rocks have three distinct textures.

Glassy
Fine-grained (Porphyritic)
Coarse-grained (Phaneritic)

Additionally, based on the mineral composition your porphyritic and phaneritic rocks can be divided based on color into dark, medium, and light. First you should pull the seven rocks to the side that you think are igneous. **Your instructor will check your selections and once you have choosen correctly, only then can you proceed with the questions.**

Select the one igneous rock that has a glassy texture. Place this rock on the appropiate location on your handout sheets.

1. Comment on the validity of the following statement. Glassy igneous rocks form so quickly that they do not have mineral crystals?

Separate your porphyritic and phaneritic rocks into two piles of three each. Then place your porphyritic and phaneritic rocks into three columns based on color into dark, medium, and light. Your instructor will check your selections.

2. What type of silicate minerals do your dark colored rocks have?

Ferromagnesium Dominated or Non-Ferromagnesium Dominated or Both

3. What type of silicate minerals do your medium colored rocks have?

Ferromagnesium Dominated or Non-Ferromagnesium Dominated or Both

4. What type of silicate minerals do your light colored rocks have?

Ferromagnesium Dominated or Non-Ferromagnesium Dominated or Both

5. What does the texture of an igneous rock indicate about the location in which it was crystallized from molten rock?

6. One of your igneous rocks actually has a glassy texture. Where did this glass solidify, deep below the surface or at the surface?

7. Compare the eruptive nature (gentle vs. violent) for the volcanic (porphyritic) rocks you have identified.

8. Compare the chemistry of a gabbro and granite. Specifically, which of these rocks is most likely to have abundant Na, Al, and K in it? Explain.

Now you can fill out the table on page 8 for your seven igneous rocks. Be sure to select one good other characteristic that will help you identify these rocks on the lab final.

Sedimentary Rocks: If you examine pages 5 and 6 (Figure 3) you will notice that there are four different sedimentary rocks. These sedimentary rocks have two distinct textures.

Detrital
Non-Detrial

You should pull the four rocks to the side that you think are sedimentary. Y**our instructor will check your selections and once you have choosen correctly, only then can you proceed with the questions.**

9. Your two detrital rocks consist of what sized material?

Coarse-sized = pebbles to boulders
Medium-sized = sand
Fine-sized = can only see grains with a microscope.

See if you can identify the main mineral in each of your sedimentary rocks. Note: that one of your sedimentary rocks does not have a mineral.

10. What mineral(s) dominate dominate in your two detrial sedimentary rocks? Hint test the hardness of these two rocks.

    Sandstone ______________________ Shale __________________________

11. Name an environment where the sediment that makes up each of your detrital rocks could have been deposited? You need to indicate two answers.

    Sandstone ______________________ Shale __________________________

12. Note that the red color in one your detrital rocks is derived from hematite that finely coats the individual grains that make up this rock. Do you think that this coating may be responsible for the transformation of loose sediment into a detrital sedimentary rock. Elaborate!

13. What types of biological materials are present in the two nondetrital sedimentary rocks in your rock set? Indicate on the composition column on the Rock Table.

14. One of these nondetrital sedimentary rocks actually is not made up of minerals. What is it and why is it not a mineral? (Refer to your notes on the precise definition of a mineral).

Now you can fill out the table on page 8 for your four sedimentary rocks. Be sure to select one good other characteristic that will help you identify these rocks on the lab final.

Metamorphic Rocks: Metamorphic rocks form at high temperatures and pressures in the earth that change one rock type into another rock. These rocks have two types of textures (foliated and non-foliated). Separate your metamorphic rocks based on texture. **Your instructor will check your selections and once you have choosen correctly, only then can you proceed with the questions.**

15. In your own words describe the difference between a foliated and non-foliated texture.

16. Identify the dominant minerals in your four metamorphic rocks.

Schist ____________________________

Gniess ____________________________

Marble ____________________________

Quartzite ____________________________

17. What were the protoliths of each of your metamorphic rocks?

Schist ____________________________

Gniess ____________________________

Marble ____________________________

Quartzite ____________________________

Finally, pick one key characteristics that can help you identify the rocks of this exercise on the upcoming lab final and record those characteristics on the Rock Table.

Igneous Rocks

Rock Color	Phaneritic Texture	Porphyritic Texture	Glassy Texture
Dark Color	GABBRO	BASALT	
Medium Color	DIORITE	ANDESITE	OBSIDIAN
Light Color	GRANITE	RHYOLITE	

Sedimentary Rocks	**Detrital Texture**	**SHALE**	**SANDSTONE**
	Nondetrital Texture	**LIMESTONE**	**COAL**

Metamorphic Rocks	**Foliated Texture**	**SCHIST**	**GNEISS**
	Nonfoliated Texture	**MARBLE**	**QUARTZITE**