Paleo Lab 2 - 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 1000's 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).

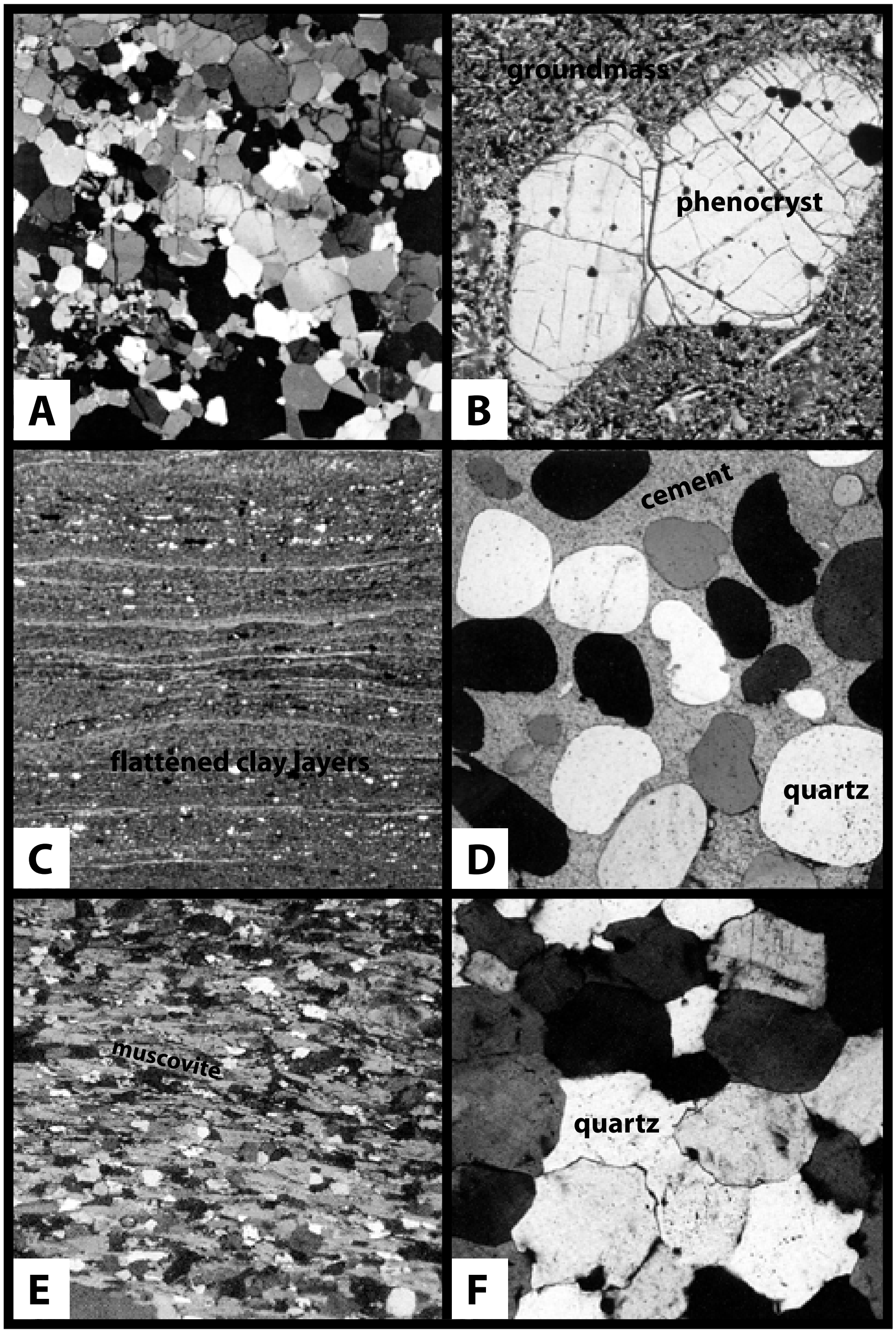

Figure 1. Common textures in the 3 major rock groups as seen in highly magnified, thin slices of rocks. A. A coarse-grained phaneritic ganite with quattz, muscovite and feldspars. B. A porphyritic igneous rock with large phenocrysts surrounded by very fine-grained groundmass. C. Thin layers of compacted 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 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 1000's or tens of 1000's 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 1a) 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 2).

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 1b). 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 fast cooling, invisible minerals when it became a lava.

<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 2. Classification of common igneous rocks.

Recognition of the three common porphyritic igneous rocks can also be tied to the overall color of the rock (Figure 2). 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.

Identification of Sedimentary Rocks

Detrital sediment is derived from the physical and chemical weathering of pre-existing rock. Ultimately, much of that pre-existing rock started out as igneous rock, meaning rock whose mineralogy begins with Bowen's reaction series. Bowen's reaction series is more then the sequence of minerals and the order in which they form in igneous rock. It has also been described as a chemical stability series. Because of the high temperatures in which they form, most silicates are unstable when exposed to the earth's surface and will decompose to clay. The higher a mineral's position is on Bowen's reaction series, the higher the temperature that it formed and the more chemically unstable it is. Thus olivine, the highest mineral on Bowen's reaction series, is extremely chemically unstable and, under the right conditions, will begin to convert to clay within a few years of its exposure to the earth's surface. Whereas, the silicate mineral quartz, the lowest mineral on Bowen's reaction series, is the only chemically stable silicate mineral; the only silicate mineral that will not convert to clay. Thus, the mineralogy of detrital sedimentary rocks depends on it's degree of weathering. It can contain some unstable minerals if the degree of weathering is low; but if the degree of weathering is high it will consist only of quartz and/or clay.

To make a detrital sedimentary rock the detrital sediment from which it is composed must be **lithified** or turned into a sedimentary rock. For silt and clay-sized sediment this is a simple matter of compacting the sediment and drying it out (**dehydration**). For coarser-sized sediment compaction and dehydration alone will not lithify the rock. Coarser sediment requires exposure to air and then allowing chemical-rich surface water to flow between the grains and evaporate. This water will leave behind the chemicals it contained in the open spaces between the sediment grains and these chemicals will acts as natural cements to hold the sediment grains together. This is a process known as **cementation**. Naturally occurring cements are all minerals that you are familiar with. Hematite, limonite, calcite, gypsum and, in rare cases quartz (quartz will not convert to clay but can be dissolved and most surface water contains a small portion of dissolved quartz) all can act as natural cements to lithify a detrital sedimentary rock.

A detrital sedimentary rock is named primarily for the size of its clasts:

- lithified angular gravel-sized clasts	= **breccia**
- lithified rounded gravel-sized clasts	= **conglomerate**
- lithified sand-sized clasts	= **sandstone**
- if sand is pure quartz	= the sandstone is called "**arenite**"
- if sand contains unstable silicates	= the sandstone is called "**arkose**"
- lithified silt-sized clasts	= **siltstone**
- lithified clay-sized clasts	= **shale**

Nondetrital sediment consists of the hard parts of either dead animals or dead plants. Most marine life extracts the mineral calcite from sea water to make their hard shells or skeletons. Calcite is a mineral that dissolves fairly readily in the presence of fresh water. Exposure to a large quantity of this material, say on a beach, and over a period of time, rainwater trickling through the shells will dissolve a portion of these shells and evaporate and leave the calcite behind. Thus, seashells and other marine hard parts are said to be “self-cementing”.

A third type of limestone consists of little sand-sized spheres of calcite called ooids. Ooids form in warm tropical waters that contain large amounts of dissolved calcite. Here waves can move around small bits of sand and pieces of seashells while the calcite forms when the waters evaporate and coat the sand grains with concentric layers of calcite. Ooids, like seashell, can get washed onto a beach where they can become cemented and turned into a rock

- very old broken seashells cemented by calcite = **fossil limestone**
- calcite ooids cemented by calcite = **oolitic limestone**

Normally when plants die they are decomposed by bacteria or eaten by various organisms, or both happens, and the plant is totally destroyed. But in swamps and lagoons where plants die and are buried under protective layers of mud, they will slowing became compacted over time and will be slowly converted to a form of carbon called **coal**. Coal is classified according to its **rank**, or amount of carbon it contains:

- lowest rank ---> a mass of plant plant pieces, very little carbon = **peat**
- higher rank ---> a few plant bits remain, about 50% carbon = **lignite**
- higher rank ---> no plant remain, layered, mostly carbon = **bituminous coal**
- highest rant ---> pure carbon, has distinct conchoidal fracture = **anthracite**

Rock Texture	Mineralogy	Useful Characteristics	Rock Name
detrital	angular gravels of quartz or broken rock cemented together	>2 mm angular gravels (usually quartz) cemented by quartz, calcite, limonite or hematite	breccia
	rounded pebbles of quartz or broken rock cemented together	>2 mm rounded pebbles (usually quartz) cemented by quartz, calcite, limonite or hematite	conglomerate
	mostly quartz, but may have small flakes of muscovite or pieces of orthoclase	2 to 1/16 mm quartz sand grains cemented by gypsum, calcite, limonite or hematite	sandstone
	mostly quartz, but may contain some fine clays	1/16 to 1/256 mm quartz silt grains cemented by gypsum, calcite, limonite or hematite, silt grains are too small to be visible but feels gritty	siltstone
	mostly very fine-grained clay	< 1/256 mm clays, generally thinly layered, often colored dark gray to black by organic material, but may be green or red due to other impurities	shale
nondetrital	carbon, with occasional plant fragments	very soft, marks on paper, light weight, usually black, often in compacted layers	coal
	calcite fossils in a calcite cement	either whole or broken fossils that are the hardparts of ancient marine life, mostly shell fragments	fossil limestone
	calcite ooids in a calcite cement	sand-sized round balls of calcite deposited concentrically around a sand grain or fossil fragment, cemented by calcite	oolitic limestone

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 1e).

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 1f). 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 Group	Rock Texture	Mineralogy	Other Characteristics	NAME