

Lab- Rocks, Minerals, and Sediments

KEY WORDS: Biogenous, calcite, color index, crystal, diatoms, evaporitic, extrusive, feldspar, felsic, ferro-magnesian minerals, fluorescence, foraminifers, grain size, granite, gypsum, igneous, intrusive, lithogenous, magma, mica, microcline, minerals, mineraloids, obsidian, olivine, pegmatite, pelagic, phaneritic, provenance, pyroxene, quartz, rock, sand, sediment(ary), stratification, terrigenous, tourmaline, weathering.

Introduction

Minerals are naturally occurring, inorganic substances that have a crystalline structure defined by its chemical composition. Substances having crystalline structure are called **crystals**. Minerals also have specific and distinct physical properties (such as hardness, solubility, color, refractive index, etc.). A mineraloid is much like a mineral, but they are missing key characteristics, like obsidian (volcanic glass) which has no definite crystalline structure, or coal, which is organic.

Minerals are identified through a series of systematic steps. Some minerals are easy to identify, and a cursory look is all that is needed. However, often geologist must use multiple tools from a mass balance to look at the specific density to a piece of glass to see if the mineral is hard enough scratch it. Here are a few ways minerals are identified;

Luster – How the surface of the mineral looks.

Hardness – Each mineral has a specific hardness. Geologists use the Mohs Hardness scale from 1 to 10. A diamond is the hardest mineral, 10, and talc or chalk can be scratched with a finger nail, less than 2.

Streak – Some minerals have a very distinct streak when drawn across a ceramic plate, sometimes it is even different from the apparent color of the mineral

Cleavage – How the mineral will break, or cleave, if dropped. Some minerals have distinct planes of weakness in their crystalline structure and will break in a regular, predictable way for example mica comes off in sheets.

Specific Gravity – The density of the mineral can tell you a lot. Does it look heavier than it should? Lighter?

Habit - How the mineral grows.

Color - Color is hard because a lot of minerals can be multiple colors but for some, color is distinct. Sulfur is always yellow, and gold is always gold.

Fluorescence – Whether mineral fluoresce under UV light is a helpful tool.

Magnetism – Only a few minerals are magnetic, hematite and magnetite are two common ones.

Rocks are natural aggregates of **minerals** and mineraloids. They can be composed of one mineral solely, or of multiple different types. Rocks are divided into three classes on the basis of their origin. The three rock groups are **igneous rocks, sedimentary rocks** and **metamorphic rocks**. In this laboratory you will examine only the first two groups (igneous and sedimentary).

Igneous Rocks

Igneous rocks form when molten rock cools. They can form underground from cooling **magma**, or molten rock under the earth's surface or at the surface of the Earth from cooling **lava**, or molten rock above the earth's surface. Ocean spreading centers and volcanoes are the most well known source of igneous rocks, but, keep in mind that igneous rocks also form in continental settings, from magma cooling below the continents. Common igneous rocks are basalt, gabbro, andesite and granite.

Igneous rocks formed from magma are called **intrusive** rocks, whereas those formed from lava are called **extrusive** rocks. The sizes of mineral crystals that form in igneous rocks indicate the rate at which the magma or lava cooled. Lava cools very fast because it is exposed to the atmosphere, which is significantly colder than the melting point of a rock. Magma, on the other hand, is underground in a heated environment and therefore has a much slower cooling rate. The slower the cooling rate the bigger the individual crystals will grow. A good example of this is gabbro or granite. You can see the large crystals with your naked eye. For rocks that have cooled much faster, the crystals are too small to see, and require a microscope. An extreme example of rapid cooling is **obsidian**. In this case, the lava cooled so fast (it was "quenched") that crystals did not have enough time to form, and the resulting glass (obsidian) is amorphous.

The percentage abundance of three principal rock forming minerals, **quartz, feldspar, and iron-magnesium minerals** in igneous rocks is the most important criterion used to name igneous rocks. Igneous rocks with a very high abundance of quartz (SiO_2), potassium feldspar, and plagioclase are classified as **felsic**. They are always light in color from white to tan to red. Red is considered felsic. On the other hand, if the rocks are composed mostly iron-magnesium minerals they are labeled as **mafic**, these rocks are dark in color and range from dark grey to black to green. Green is considered mafic. Rocks that are composed exclusively of iron-magnesium minerals are called ultra-mafic, these rocks will be entirely black or green. There are, of course, intermediate rocks that are composed of both felsic and mafic minerals. These general igneous rock classifications can be approximated by using a **color index**, which is simply a visual estimate of the percentage of light versus dark minerals that comprise the rock.

In summary, three characteristics are used to classify igneous rocks:

- Their composition or the minerals they contain
- Their texture, the shape and size of the crystals
- Their color index, % light versus dark minerals

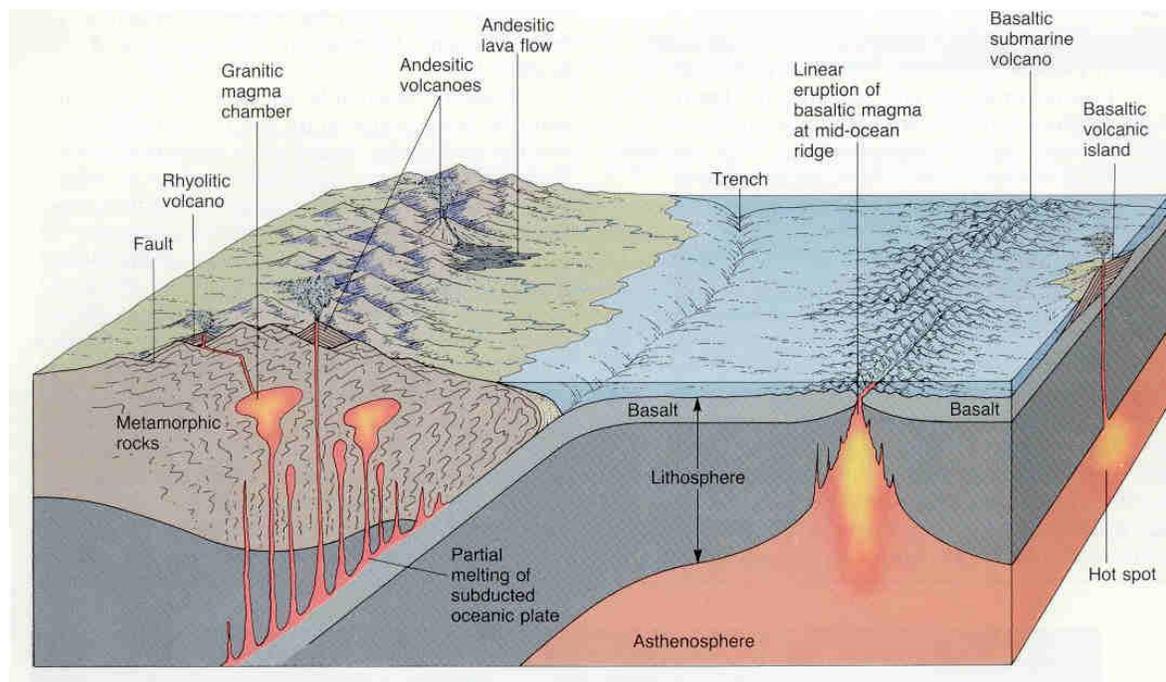
As you know, the interior of the Earth is molten to semi-molten, and upwelling of magmas in the plate tectonic system leads to formation of the various types of igneous rocks. The property that determines what types of minerals form under given conditions

and a given chemical composition of a magma, is principally the temperature of crystallization. This is really the same thing as the freezing point (which is the opposite of the melting point); it is the transition between liquid and solid state.

The composition of magma is also important in determining which minerals will crystallize. Hence, terms such as “mafic” or “felsic” are typically used to describe magmas. In summary, Bowen’s Reaction Series provide a relationship between composition of magmas, temperature and resulting rocks.

For example, **peridotite**, a rock type that you studied in the previous laboratory, is an intrusive rock (large crystals) having a very high color index (>95% dark ferro-magnesian minerals). It is composed primarily of green **olivine**. If the rock has large abundance of (black) **pyroxene**, rather than olivine, it is called a pyroxenite. Pyroxene forms from magma at lower temperatures than olivine, but it is possible to have both olivine and pyroxene in a single rock. You will see in the laboratory specimens of the mantle xenoliths from Hualalai volcano on the Big Island (Hawai`i) that contain both olivine and pyroxene.

When magma intrudes country rock (often sedimentary rocks) in continental settings but does not break the surface it has the opportunity to cool very slowly and form very large crystals. This type of rock is known as **granite pegmatite**, which has large crystals of quartz, feldspar, and mica. Quartz is the most common mineral in the crust of the earth; but feldspars and mica are also common. Depending on the abundance of minerals other than quartz and feldspar (and the type of feldspar) the color of the granite can vary. Pink granites are rich in potassium feldspar, but those rich in sodium feldspar (NaSi_3O_8) are either gray or white. In the laboratory you will examine pegmatite minerals from Lake Tahoe, Nevada and complex granite pegmatites of San Diego County. The latter are called “complex” because when magma intrudes country rock it often incorporates other elements, which remain in the magma as it cools and crystallizes. Near the end of the crystallization sequence when quartz and (microcline and orthoclase) feldspars and mica form, a “soup” of exotic elements remains, which leads to the formation of complex minerals such as tourmaline. The high abundance of lithium in complex pegmatites causes formation of lepidolite (a Li-rich mica) rather than muscovite, the common form of mica in pegmatites. Examples of tourmaline and lepidolite minerals are shown in next page.



Schematic diagram of igneous features of the plate tectonic system.

Mafic (basaltic) magmas commonly erupt at the seafloor along mid ocean ridges, and above hot spots (see last week's laboratory). When oceanic crust, its sediment load, and water are subducted, partial melting occurs because the melting point of the rocks is lowered by the presence of subducted water. This produces intermediate (diorite) to felsic (granite) magmas, along with andesitic (e.g., Mount Saint Helens) and rhyolitic eruptions.

A few examples of minerals...

Mineral collectors prize the tourmaline and the blue lepidolite crystals. Tourmalines are particularly sought out by jewel enthusiasts, as very well formed tourmaline crystals can take on a variety of beautiful colors, be perfectly clear (no flaws), and can thus be cut into gemstones.



Tourmaline and smoky quartz on cleavelandite (bladed Na-rich feldspar) with feldspar. Himalaya Mine, San Diego County, California

Smoky quartz crystals collected from a pegmatite at the Ocean View Claim, on Chief Mountain in Pala, San Diego County, California. Note the quarters at the bottom of the photograph for scale.





Amazonite, a blue-green variety of microcline feldspar found in pegmatites, among other locations, from Colorado and Nevada. This specimen is from Teller County, Colorado.

Sedimentary Rocks

Sedimentary rocks are rocks that have formed by any of the following:

- compaction of sediments
- cementation of sediments
- direct formation of crystal aggregates during evaporation of water (also known as evaporites)

Common sedimentary rocks include sandstone, limestone and shale (mudstone).

Sediment, by definition, is any loose or fragmented material. Hence, loose sand, shells and their fragments, dead leaves, and mud can all be categorized as sediment. All sediments have a source from which they originate. The source of sediments can involve the life cycle of plants or animals (i.e., leaves, logs, shells), or chemical **weathering** (such sediments are reaction products) or physical weathering (mechanical breakdown) of rocks. Sediment always has a parent material, the weathering of which creates the sediment. Sediment is typically eroded and transported from its source, most usually by water or wind, but also by ice.

Sand, which is a type of sediment, can be compacted into **sandstone** under high pressure. It is also possible for grains of sand to be cemented by the growth of **calcite** (CaCO_3) in the interstitial (void) space between the individual grains of sand to also form sandstone. Evaporation of water can lead to the formation of minerals by direct precipitation, when the concentration of the constituents of minerals exceeds its solubility in the (remaining) water. Rock salt and **gypsum** (also known as selenite) are examples of evaporitic minerals. You will examine examples of calcite and gypsum in the laboratory.

Transportation of sediment sorts the materials by size and by density. Sediment with material of many different sizes (or densities) is known as “**poorly sorted**”, whereas sediment composed primarily of material of very similar size (or density) is called “**well sorted**”. The processes of transportation and sorting also mechanically weather material so that well sorted sediments are typically composed of well-rounded grains (they were abraded during transport), whereas poorly sorted sediments will have more angular (sharp corners) shapes.

Grain size is also used to describe sedimentary rocks. The most commonly used grain-size classes used by sedimentologists are:

- Gravel: grains larger than 2 mm diameter
- Sand: grains from 1/16 mm to 2 mm diameter
- Silt: grains from 1/256 mm to 1/16 mm in diameter
- Clay: grains less than 1/256 mm

In summary, characteristics such as mineralogy (mineral composition), grain size and grain shape, and grain sorting (poorly-sorted versus well-sorted) are commonly used to describe sedimentary rocks.

Marine Sediments

Because this is an oceanography class, we will now turn our attention to marine sediments. Marine sediments, just as their continental counterparts are typically mixtures, although in some cases one particular component can dominate. Sedimentologists classify marine sediments by a variety of methods.

A way to classify marine sediments is by their origin:

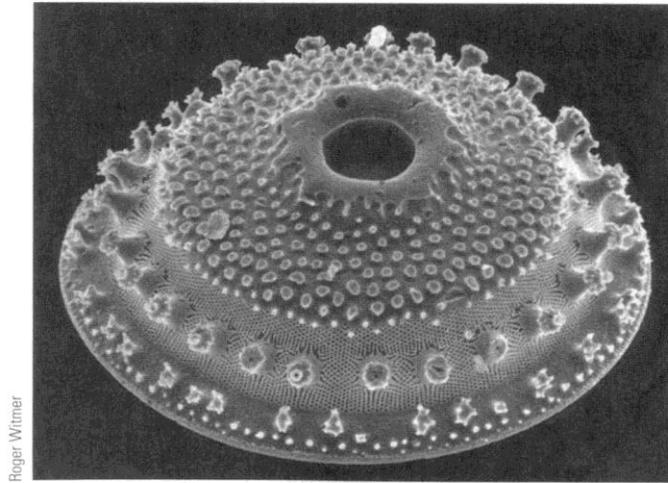
Terrigenous sediments are those whose origin is traceable to a specific land (terra) area. They are the most abundant type and include a series of variously colored muds, volcanic debris, coral muds, and turbidity flow deposits. They are dominant on continental margins and abyssal plains.

Biogenous sediments are the next most abundant marine sediments. They are of biological origin (i.e. organic material and hard parts of some marine organisms). Common examples include calcareous and siliceous oozes found in the deep-floor.

Hydrogenous sediments are minerals that have precipitated directly from seawater such as manganese nodules. They represent less than 1% of total marine sediments.

Cosmogenous sediments are the least abundant and are of extraterrestrial origin. Examples include meteorite debris and dust from space.

Important contributors to marine **biogenous** sediments are two plant-like organisms and two simple animals. One plant and one animal produce tests (shells) made of calcium carbonate (CaCO_3), the other plant and animal produce tests of silica (SiO_2). Coccolithophores and foraminefera produce CaCO_3 and diatoms and radiolarians produce SiO_2 . The coccolithophores and the diatoms are the plants (and photosynthesize); the foraminefera and the radiolarians are the animals. Images of these microorganisms tests are shown on next page. You will also examine mounted slides of these marine microorganisms in the laboratory.



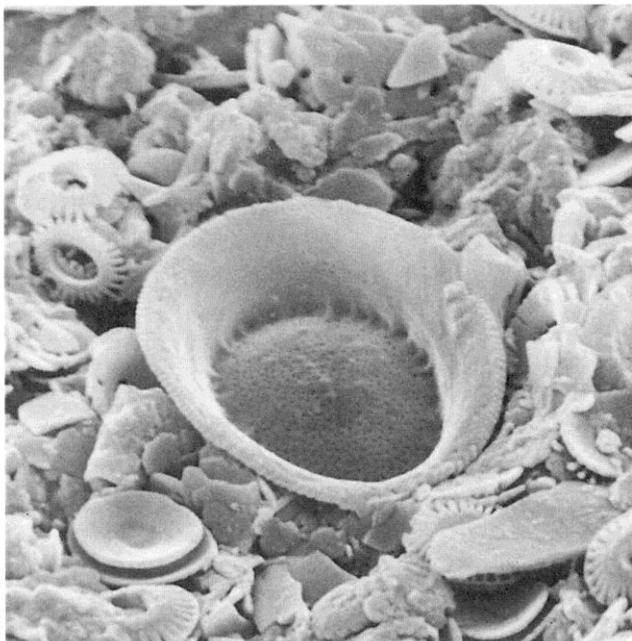
Roger Witmer

Electron micrograph of a diatom test (shell). Diatoms are single celled algae that grow in high latitude high productivity waters. They produce silica skeletons.

Micrographs of radiolarian tests. Radiolarians are amoeba-like animals, which flourish in the high productivity zones of the Equatorial Pacific Ocean.



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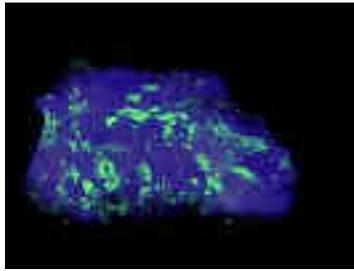
Electron micrograph (enlarged 2000 times) of the surface of a fecal pellet produced by a marine planktonic animal. The pellet is composed primarily of tests of coccolithophores, along with some other plant-like organisms.

Fluorescent Minerals

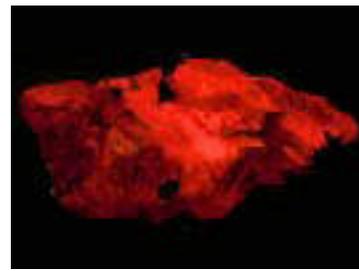
The last part of this laboratory is designed to demonstrate another method to identify certain minerals and enjoy unusual visual effects at the same time. There are many minerals that fluoresce when exposed to ultra-violet (UV) light. Not all minerals, however, fluoresce. The fluorescence that rocks emit when excited with UV light depends on the chemical composition of their mineral constituents. Fluorescence is a process whereby a substance emits light after its electrons have been excited to a higher energy state and drop back down to the “ground state” (i.e., unexcited state). In this process electrons of the atoms in the mineral initially absorb the energy associated with UV light and then release some of the energy in the form of visible light (red, orange, yellow, blue, green, or blue).



Chalcedony seen under short-wave UV-light (fluoresces bright green)



Willemite (fluoresces green) and **fluorite** (fluoresces blue) seen under short-wave UV light



Calcite seen under long wave UV-light (fluoresces red)