

Lab 4: Rock-cycle and Igneous Rocks

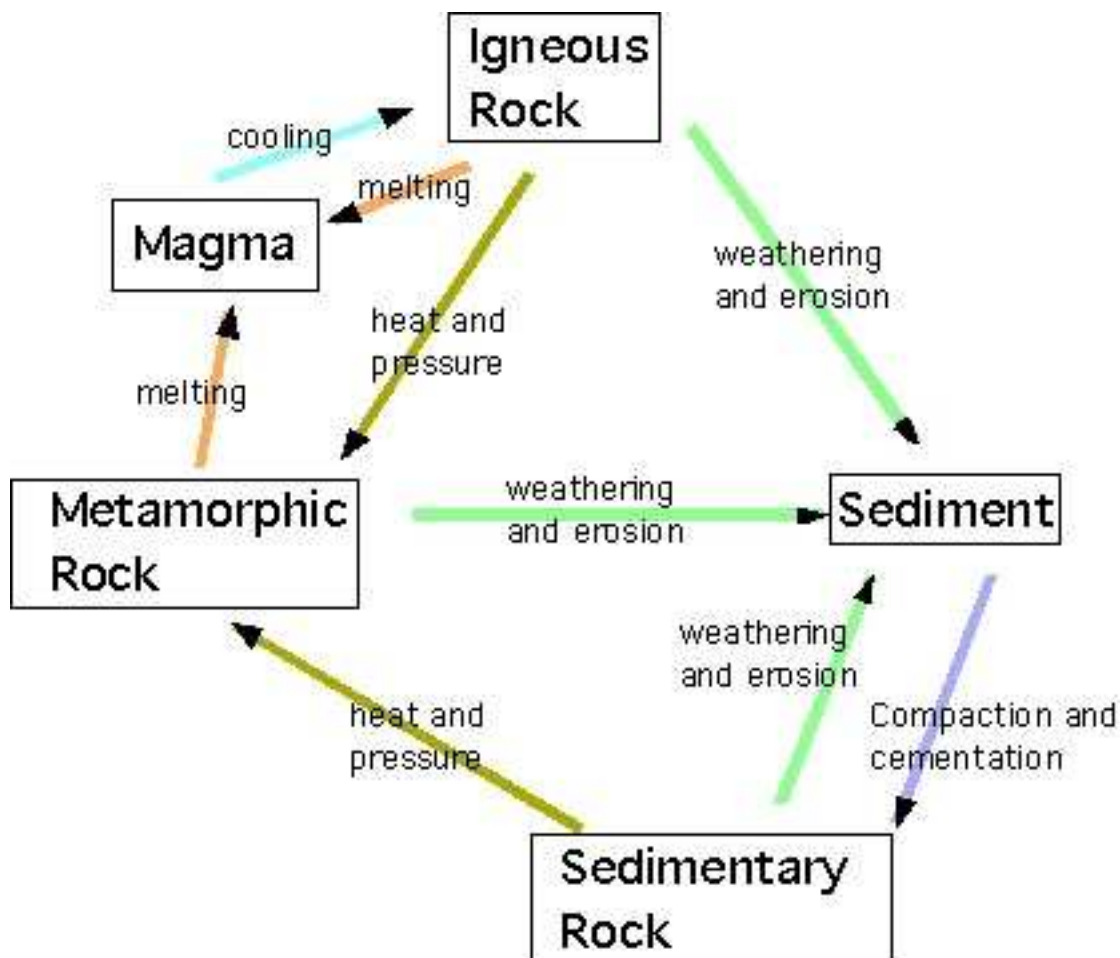
Earth 202: Earth's Interior

Introduction: The Rock cycle

As discussed previously, rocks are aggregates of one or more mineral. There are a few notable exceptions to this definition. (For example, the rock obsidian is volcanic glass, which is not a mineral because it does not have a definite crystal structure. Coal (*or peat*) and skeletal limestone are rocks which are made up of decayed organic matter, and therefore do not contain minerals).

There are three main rock groups:

- **Igneous Rocks** are formed by cooling magma or *lava* (*magma which cools on Earth's surface*).
- **Sedimentary Rocks** are formed by the chemical precipitation of mineral grains; or by the sedimentation and cementation of fragments of plants, animals or other rocks, transported by water, wind or ice to a site of deposition.
- **Metamorphic Rocks** are formed after a rock is subjected to intense temperatures and/or pressures, resulting in the transformation of original compounds (minerals) and/or textures (crystal size).



All rock types are connected by the *rock cycle* model, first recognized by James Hutton. In this model, all rocks can be formed, transformed, destroyed and re-formed from one type to another, over and over again. For example, a cooling magma forms an igneous rock. This igneous rock can be uplifted, exposed on Earth's surface, and subjected to erosion or chemical decay. The rock is broken down into fragments, or sediments, which are transported away and eventually deposited. The sediments become lithified either by compaction, or natural cementation from crystals precipitated in the water, and form a sedimentary rock. If the sedimentary rock is then subject to intense pressures and temperatures, it will become transformed (in shape, color, density, composition) into a metamorphic rock. If this rock is then subjected to even more intense heating, it will melt, forming another body of magma.

Questions

i. Use the rock cycle model to explain how a metamorphic rock could become a sedimentary rock. Likewise, explain how a sedimentary rock could become an igneous rock.

Igneous Rocks

Crustal rocks on Earth are formed from material which comes from Earth's mantle, in addition to smaller fractions coming from space (as meteorites), living organisms, or as fragmented pieces of other rocks. Igneous rocks make up 95% of Earth's crust, sedimentary and metamorphic rocks are derived by various methods of reworking igneous rocks. Therefore, since we are interested in the gross properties of Earth's interior, to understand the composition of Earth's crust we will focus our attention on igneous rocks.

Igneous Rocks are classified primarily on the basis of their texture (crystal sizes) and composition (mineral content).

Cooling Rate and Crystal Size: Before we learn how to identify igneous rocks, we will first demonstrate how the rate of cooling affects the size of mineral crystals. We will use a heated mixture of Epsom Salts and water (representing magma) and cool samples of this solution at three different rates.

ii. Predict how crystal size relates with the rate of cooling. By cooling our melt in a bath of warm tap water, do you expect the rate of cooling to be faster or slower? Compared to cooling our melt in water with ice cubes, and water at room temperature, which process do you expect to generate larger crystals?

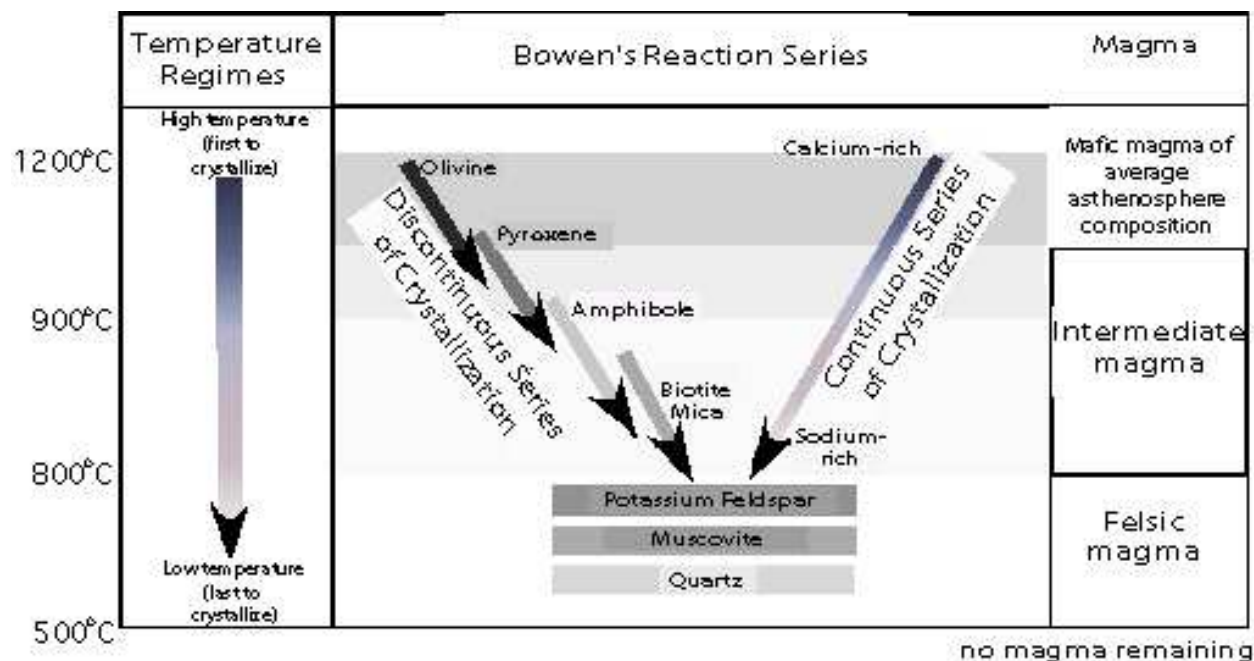
Experiment: Using three beakers, fill one with warm tap water, one with room temperature water, and the last with ice water. To create the "magma", mix Epsom Salts with an equal volume of warm water. Mix the solution so that salts are completely dissolved. Using three test tubes, pour in each an equal volume of the "magma" mixture. Next, place a test tube in one of each of the beakers.

iii. Compare the crystals sizes in all three samples.

iv. How would you change this experiment to generate even larger crystals?

The size of crystals in an igneous rock is an important indicator of the conditions where the rock formed. If the magma cools *extrusively*, or near the surface of the Earth, this process occurs at lower temperatures. In this situation, the crystals do not have much time to form, so they are very small. If the magma cools *intrusively*, or deep inside the Earth, the temperature is much warmer. The cooling process takes place more slowly, and the crystals have time to grow and become large. When magma flows on the surface of the Earth, this lava cools suddenly, or is *quenched*, and there is no time for crystals to form (*this is how obsidian, volcanic glass, develops*).

Bowen's Reaction Series and Composition: When magma cools, crystals form because the melt is supersaturated with respect to a particular mineral. A scientist by the name of Bowen noticed that there was a particular order in the succession of mineral crystallization, where different crystals form from the melt at different temperatures. He devised *Bowen's Reaction Series*, which is a representation of this order of crystallization and how it depends on the temperature within the magma. Dense, "mafic" minerals, rich in Mg and Fe, would crystallize first, at the highest temperatures. Later, at lower temperatures, less dense "felsic" minerals could crystallize. This reaction series is also reversible, so if a rock is subject to extreme temperatures, the first minerals to melt are the felsic ones.



Mafic minerals, such as olivine and pyroxene, are also referred to as ferromagnesians based on their composition. Since these minerals are darker in color, igneous rocks containing them will be darker. Likewise, felsic minerals such as quartz, alkali feldspar and muscovite, are referred to as non-ferromagnesians. Rocks containing nonferromagnesians are more silica-rich and lighter in color.

Using a color index, such as the one below, it is possible to identify igneous rocks based on their relative abundance of silica and dark colored minerals.



Rock Identification

In the next part of this lab, we will use a color index, to quantify the amount of silica in various samples of igneous rocks. We will then classify rocks as either felsic (acidic), intermediate, mafic (basic), and ultra-mafic (ultra-basic). Next, we will look at the crystal size and determine if the rock formed intrusively, or extrusively. Last, we will assign rock names to the samples.

Sample #	Main Minerals	Color Index	Intrusive or extrusive	Rock Name
	Quartz, Alkali feldspar, Plagioclase (minor: biotite, hornblende)	acidic	Intrusive	Granite
	Quartz, Alkali feldspar, Plagioclase (minor: biotite, hornblende)	acidic	Extrusive	Rhyolite
	Plagioclase Feldspar (minor: quartz, biotite, hornblende)	intermediate	Intrusive	Diorite
	Plagioclase Feldspar (minor: quartz, biotite, hornblende)	intermediate	Extrusive	Andesite
	Plagioclase feldspar, Pyroxene (minor: olivine)	basic	Intrusive	Gabbro
	Plagioclase feldspar, Pyroxene (minor: olivine)	basic	Extrusive	Basalt
	Pyroxene, Olivine	ultra-basic	Intrusive	Peridotite
	Olivine	ultra-basic	Intrusive	Dunite

v. Can you think of a scenario in which both large and small crystals can be formed in an igneous rock?