Mineralogy Boot Camp Session #9

Silicate Minerals: Part 2

This session of Boot Camp is devoted to two important rock-forming silicate mineral subgroups. The *amphiboles* and *pyroxenes* are both names used to describe certain collections of silicate minerals based upon their respective atomic structures. Both of these subgroups are known as *chain silicates* because the silica tetrahedra join together in such a way to create endless chains. Together these two subgroups comprise about 16% of Earth’s crust, where pyroxenes are twice as abundant as amphiboles. Both mineral subgroups are most common in igneous and metamorphic rocks. In many cases, it is difficult to tell the specific mineral present without detailed optical or chemical investigations, so with hand specimens geologists may just use the subgroup name without specifying a specific mineralogical species.

**Amphiboles**

Amphiboles are the double chain example of the chain silicates. On an atomic level, the crystalline structure consists of two side-by-side chains which give such physical properties as the distinctive two directions of cleavage in amphiboles, where the angle between the cleavage planes is commonly either 60° or 120°.

The most common variety of amphibole is *hornblende* (See Figure 1). It usually occurs as elongate black crystals with a hardness of 5 to 6 and specific gravity of 3.0 to 3.4. Hornblende has a complex chemical composition where numerous elements can substitute in various atomic positions, creating the range of hardness and specific gravity listed above.
Figure 1. The dark crystals in this igneous rock are hornblende. (Total length of this specimen is about 7 inches.) Careful examination of numerous crystals shows that the crystal edges are not at right angles, but instead are about 60° or 120°. This same angular amount can be observed as cleavage in other specimens. Note that several hornblende crystals appear as elongate rectangles, which is a common habit. The green-gray groundmass of this specimen is relatively fine-grained, suggesting the magma sat for a while at depth growing the hornblende, and then moved closer to the surface causing it to cool faster and develop finer-grained crystals of feldspar and quartz.

An amphibolite is a higher-grade metamorphic rock composed almost exclusively of amphiboles, typically hornblende (See Figure 2). An igneous rock consisting of almost all amphibole is called a hornblendite. These two rocks would look so similar in hand specimen that it’s nearly impossible to tell them apart. There is no substitute for seeing rocks in the field, where outcrops can be traced and origin determinations (metamorphic vs. igneous) made based on the surrounding rocks.
Figure 2. This hand specimen consists of an amphibolite, where the dominant mineral is the amphibole hornblende that gives the overall black appearance to the rock. This rock is from Styria, Austria. Image from mindat.org.

A white to gray amphibole very similar to hornblende is *tremolite*. As shown in Figure 3, tremolite commonly consists of radiating blades, which in some cases may be fibrous.

Figure 3. Tremolite in this specimen exhibits a typical bladed mass of radiating crystals. This specimen is from Redwing Quarry, Litchfield County, Connecticut. Image from mindat.org.
As iron substitutes for magnesium in tremolite, the mineral takes on a green cast as shown in Figure 4 and is called actinolite. The more iron in the crystalline structure, the deeper the green color tends to develop. Outside of the color differences, the cleavage, hardness, and specific gravity is essentially the same between hornblende, tremolite, and actinolite.

Figure 4. The green bladed mineral in this amphibole specimen is actinolite. This specimen measures 4 inches by 3 inches and is from Tyrol, Austria. Image from mindat.org.

**Pyroxenes**

The single chain examples of chain silicates are the pyroxenes. Because the crystalline structure of pyroxenes consists of a single chain, there are some physical similarities and differences with the amphiboles. Pyroxenes also typically have two directions of cleavage, but have a nearly 90° angle between these cleavage planes.

The most common variety of pyroxene is augite, which typically ranges from black to greenish black to dark green stubby crystals. Usually augite occurs in igneous and metamorphic rocks as an essential mineral frequently associated with plagioclase feldspar. An igneous rock composed almost exclusively of augite is referred to as a pyroxenite (See Figure 5). Pyroxenites are most commonly found in rocks from Earth’s mantle that have been incorporated into the crust.
Figure 5. This specimen (which is about 4 inches by 3.5 inches) is composed almost exclusively of the pyroxene augite, and this rock is probably best classified as a pyroxenite. The variation in lighter to darker green is common in augite, and indicates slight changes in chemical composition. Examination of this specimen with a hand lens shows the frequent 90° angles between crystal faces and cleavage surfaces.

A relatively rare but interesting pyroxene mineral is *spodumene*, the lithium (Li) variety of augite. Spodumene (shown in Figure 6) is usually white to gray and exhibits the two strong directions of cleavage. It often will have a texture resembling wood, but with an ash color. Spodumene was historically mined as a source of lithium; current sources of lithium are mostly subsurface brines pumped from continental basins. Spodumene is the source of two gem materials; a clear emerald-green variety is called *hiddenite*, and a clear pink to lilac-colored variety is known as *kunzite*.
Figure 6. Spodumene is the lithium variety of pyroxene. The well-developed two directions of cleavage, characteristic color, and relatively high specific gravity (about 3.2) make it distinct from most other light-colored silicate minerals. The length of this specimen is 5 inches and is from the Etta Mine, Pennington County, South Dakota.

Another pyroxene of economic importance is jadeite, characterized by a strong green color. The presence of sodium (Na) gives this mineral its distinctive color. A note on nomenclature: the term jade is traditionally applied to two different materials. Nephrite jade is the name for a tough green variety of the amphibole tremolite, which has the hardness 5 to 6. Jadeite is the pyroxene form of jade, and is more valuable because of its higher hardness of 6½ to 7. The term jade has now expanded to include various hard green fine-grained materials based solely on the material’s color and ability to be carved and polished, regardless of its mineralogy.