Mineralogy Boot Camp Session #8

Silicate Minerals: Part 1

Silicate minerals, those using the anion complex $(SiO_4)^{-4}$ as a basic building block, are the most important minerals in Earth's crust. Recall from Session #2 that nearly 95% of all the minerals in the crust are in the silicate group, and estimates have been made that about one-quarter of all known minerals are silicates. In addition to their sheer abundance, silicates compose the majority of what we call soil, and also compose much of the construction materials used in modern society (brick, stone, concrete aggregate, glass, and ceramics to name a few).

Feldspars

Feldspar minerals altogether compose 51% of the Earth's crust, far more than any other mineral group. Feldspars are subdivided by their chemistry into two major collections. The *plagioclase feldspars* consist of a mixture of calcium (Ca) and sodium (Na) whereas the *potassium feldspars* are characterized by the presence of potassium (K). Because of this difference in chemistry, each type has a different atomic structure and thus is a separate mineral. Plagioclase tends to be found more abundantly in rocks created from higher-temperature magmas that produce the intrusive igneous rock *gabbro* and its equivalent volcanic counterpart *basalt*. Potassium feldspars are commonly the most abundant mineral found in the intrusive igneous rock *granite* and its volcanic counterpart *rhyolite*.

Feldspars can have a range in colors (Figure 1), but tend to be mostly gray to white. Impurities in potassium feldspar may frequently give it shades of pink or green. Hardness of feldspars is reliably around 6 on Mohs scale. Two directions of good cleavage at nearly right angles are characteristic of feldspars, as shown by the blocky habit of all three specimens in Figure 1. Telling plagioclase and potassium feldspars apart may be difficult in hand samples, but the best indication is the presence of *striations* on cleavage surfaces of plagioclase (Figure 2). Striations are the result of mineral twinning within the crystal and can be best observed by reflecting light off the cleavage surface. They appear to be tiny parallel grooves that have been machine-cut into the surface. Another method to help identify the type of feldspar relies on mineral associations: if olivine is abundant, the dominant feldspar is likely to be plagioclase, and if quartz is abundant the dominant variety is more likely to be potassium feldspar. Most igneous rocks consist of a combination of the two feldspars.

Industrial uses of feldspar are mostly in glassmaking, where it is used as a flux to lower melting temperatures of the ingredients. Cations such as potassium and sodium from the feldspar promotes chemical bonding within the glass melt, while calcium and aluminum help increase the resistance to chemical and physical breakdown of the finished glass products. It is used for similar properties in the manufacturing of ceramics.

Figure 1. These are various examples of potassium feldspar. Larger white-gray specimen (from Boise County, Idaho) in upper left is hosting small gray blobs of quartz. Pinkish color of the specimen on right (collection location unknown) is caused by tiny dispersed grains of the iron oxide mineral hematite. The long axis of this pink specimen is 6.5 inches. The green variety of potassium feldspar (from Morefield Gem Mine, Amelia, Virginia) is called *amazonite*, caused by the presence of fluorine (F^{-1}) substituting in the crystalline structure for oxygen (O^{-2}).

Figure 2. This is a crystal of plagioclase with well-developed *striations* on the lower half of the specimen. These are observed as very fine dark lines as light is reflected off this cleavage surface. Length of crystal is 1.6 inches.

Quartz

Quartz is probably the most familiar mineral to people. Sand beaches throughout the world (and most sandstones) consist primarily of quartz grains. (Realize that *sand* is a particle size name, not a mineral name. Sand grains range in diameter from 2 mm to 1/16 mm.) Quartz is a very durable mineral commonly found in igneous, sedimentary and metamorphic rocks. Two physical properties make quartz this durable: it is a relatively hard mineral (7 on Mohs scale) with no cleavage. These two properties allow quartz form smooth outer surfaces that resist destruction better than most other minerals. In addition, the mineral is chemically resistive at Earth's surface because of the stability of the simple SiO_2 structure.

The lack of cleavage makes it fairly easy to tell quartz from the feldspar minerals. When given the opportunity to grow well-formed crystals, quartz reliably develops a six-sided (hexagonal) form when viewed down the axis of the specimen (Figure 3). Although pure quartz is colorless, the mineral is found with a variety of colors, such as purple (amethyst), pink (rose), yellow (citrine), and white (milky).

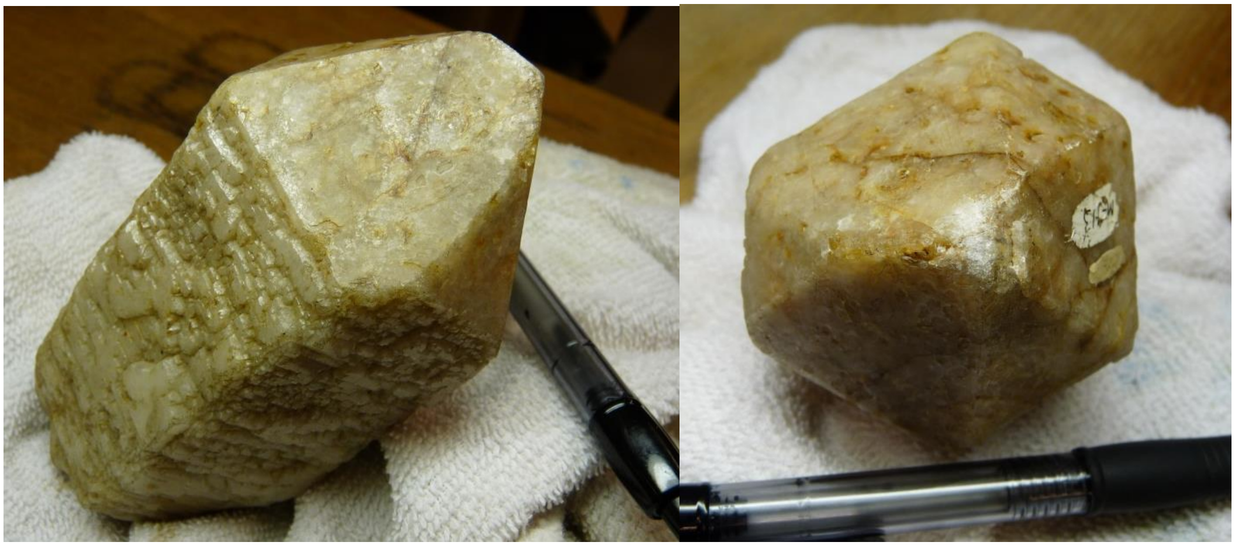

Figure 3. This is an excellent example of a hexagonal quartz crystal showing the characteristic six-sided form when viewed along the long axis. Note that not all crystal faces have to be the same width in order to create the hexagonal shape.

Quartz has a wide range of industrial uses, including as frac sand in hydraulic fracturing (helps hold open the cracks), glassmaking, fillers for building products such as bricks and cement, abrasives (sand blasting), water filtration, and foundry sands for steelmaking.

Olivine

While olivine composes about 5% of Earth's crust, the abundance in the upper mantle likely rises to over 50%. Igneous rocks with upper mantle origins are typically the host rock for olivine, either as granular masses or as individual grains. The volcanic rock basalt often contains visible olivine grains (Figure 4). The well-known green sands of Hawaii consist of olivine grains weathered from basalt flows.

The lack of cleavage and irregular outline may cause olivine to look like quartz, but the pale green to brownish-green color is usually enough to tell the difference. If the olivine is a single crystal free from any rock matrix, the significantly higher specific gravity (about 3.5) can also aid in differentiating it from quartz (S.G. about 2.7). The clear gem variety of olivine is known as *peridot*.

Figure 4. Sand-sized green crystals of olivine are present in this exposure of Hawaiian basalt. These basalt flows are from an upper mantle source, which is where olivine is most stable.

Olivine is another industrial mineral used extensively in blast furnaces, where it helps lower the viscosity of the slag and captures unwanted oxides and sulfur in the metals. Because of its great heat resistance, olivine is also an additive to other materials used in very high-temperature environments, such as furnace bricks and molds.