Mineralogy Boot Camp Session #14

Sulfide Minerals: Part 1

The next two sessions of Mineralogy Boot Camp involve the broad category of sulfide minerals, where a metal cation (like iron, copper, lead, or zinc) combines with the anion sulfur (typically as S\(^{-2}\)). These are an economically important group of minerals, because we obtain the vast majority of the metals we use (except iron) by mining and processing deposits of sulfide minerals. [Iron is obtained from oxide deposits.] Although there are over 80 different sulfide minerals known, only those containing iron, copper, lead, or zinc are relatively common. These are the sulfides discussed in this session.

Some physical characteristics of sulfide minerals as a whole make them fairly easy to identify. In general, the sulfides are relatively soft (hardness of 4 or less) compared to other minerals, particularly silicates. They are often heavy, with specific gravities near 5. Sulfides often have distinctive colors combined with a characteristic streak and a metallic luster (looks like a metal in reflected light).

Pyrite

The iron sulfide *pyrite* (FeS\(_2\)) is the most abundant sulfide mineral at Earth’s surface. It can be found in all three rock types (igneous, metamorphic, and sedimentary) and can form in high temperatures (such as a magma) and in low temperatures (such as a swamp). Regardless of the temperature, pyrite requires abundant iron and sulfur with very little oxygen in order to precipitate.

Pyrite has a pale brass-yellow color (Figure 1), although it’s not uncommon for it to appear darker because of surface tarnish. [Old-timers often referred to pyrite as “fool’s gold” because of the similar color to gold. Using other physical properties allow you to make this determination without being fooled.] The streak ranges from a greenish black to brownish black. Hardness is around 6, making it harder than most other sulfides. Pyrite crystals are usually found as cubes or *pyritohedrons* (12-sided crystals, where each face has 5 sides, as shown in Figure 2). Fine-grained massive to globular bunches occur commonly. In oxygen-rich environments with water, such as Earth’s surface, pyrite eventually breaks down into an iron oxide residue (reddish-brown “rust”) and sulfuric acid (H\(_2\)SO\(_4\)) which is flushed out with the water during the weathering process. Pyrite frequently occurs with other sulfide minerals such as chalcopyrite, galena, and sphalerite.
Figure 1. The characteristic cubic form of pyrite (brass-yellow) is abundant in this specimen. Also present are dolomite (white to faint pink), fine-grained galena (silver-gray) and a small amount of chalcopyrite (tiny blebs of deeper-brass color present along the left central side of the figure). Photo long axis field of view is about 3 inches. Specimen is from Reynolds County, Missouri.

Figure 2. Pyrite on this specimen occurs as both cubes and pyritohedrons, and in some cases the crystal appears to be a combination of both forms. Several of the crystal faces have striations (fine parallel grooves), which is characteristic of pyrite. The elongate cloudy crystals are quartz. Photo long axis field of view is 1.5 inches. Specimen is from Peru.
Marcasite

Another iron sulfide is the mineral *marcasite*, which has the same chemical formula (FeS$_2$) as pyrite but a different atomic structure. [Just like calcite and aragonite described in the carbonate session (#12), pyrite and marcasite are *polymorphs* of each other.] Although the hardness (6) and specific gravity (about 5) are nearly the same as pyrite, the different atomic structure gives it different crystal shapes such as tabular prisms (Figure 3) rather than cubes. Marcasite usually has a bronze-yellow hue rather than the brass-yellow of pyrite. A very common habit of marcasite is to form fine-grained botryoidal masses, often coating other minerals (Figure 4). Deposition of marcasite seems to be limited to lower temperature, near-surface environments. Marcasite is less stable at Earth’s surface and decomposes more readily than pyrite.

Figure 3. Blades of marcasite are occurring along a crack in this specimen of dolomite. Note the small reflective cube face of pyrite in the lower center of the figure. Marcasite will frequently also form radiating masses of tiny crystals. Photo long axis field of view is about 1 inch. Specimen is from the Indian Creek Mine, Washington County, Missouri.
Chalcopyrite

The most important source of copper for our society is the mineral *chalcopyrite*, which is a combination of copper, iron, and sulfur (CuFeS$_2$). This mineral is softer than pyrite (hardness ranges from 3.5 to 4) with a lower specific gravity (about 4). The easiest way to distinguish between these two minerals is by the deeper brass-yellow color of chalcopyrite (Figure 5) which can tarnish to a bronze or even iridescent. [The term “peacock ore” is often applied to this tarnished version of chalcopyrite (see Figure 6), as well as the iridescent version of the sulfide mineral *bornite* (Cu$_5$FeS$_4$).] Unlike pyrite, chalcopyrite does not occur as cubes. It is frequently associated with sphalerite, galena, and pyrite.

Copper is the most widely-used base metal in the world, mostly because of its ability to easily transmit electricity. The U.S. Geological Survey estimates that U.S. mines produced $12$ billion of copper in 2021, which amounted to $1.2$ million metric tons. Despite that staggering production amount, we still needed to import nearly $45\%$ of the copper consumed last year to meet the demand.
Figure 5. The massive chalcopyrite in this specimen is accompanied by quartz (white). Long axis of specimen is about 3.5 inches. Specimen is from Reynolds County, Missouri.

Figure 6. Chalcopyrite (brassy yellow) will often tarnish to a bluish iridescence (present in the left central part of this specimen). Sometimes this is referred to as “peacock ore” because of the iridescent splay of colors. Photo long axis field of view is about 2 inches. This specimen is from Reynolds County, Missouri.
Galena

The lead sulfide mineral *galena* (PbS) is probably the easiest sulfide to identify (Figure 7). It has a silver-gray to lead-gray color and streak, relatively low hardness (2.5, soft enough to leave a mark on cardboard) and unusually high specific gravity (7.5). Galena has three directions of perfect cleavage, giving it the characteristic cubic appearance as cleavage fragments as illustrated in Boot Camp Session #5. This mineral can often occur with other sulfides, as shown in several figures in this session.

Galena is the main source of lead, a metal most of us use nearly every day. [There are about 19 pounds of lead in your car battery.] The U.S. Geological Survey reports that America consumed about 1.6 million metric tons of lead in 2021, approximately two-thirds of which was from recycled automotive batteries. The 2021 value of newly-mined lead ore was about $750 million. Locally galena is also an important host of silver, containing enough such that silver is the primary ore metal mined and lead is recovered as a secondary product.

Figure 7. Three directions of perfect cleavage give galena its characteristic cubic form. Even when it occurs in massive form, the very high specific gravity is also an important clue to its identification. Specimen is from the Fletcher Mine, Reynolds County, Missouri.
Sphalerite

Zinc is a widely used element, and *sphalerite* (ZnS) is the main source of this metal. This mineral is different from most other sulfides in that it does not have the strong metallic luster like so many others (Figure 8). Sphalerite is commonly dark yellowish-brown to almost black. [Iron can substitute for zinc in low concentrations; the higher the iron content, the darker the color.] The specific gravity is about 4, making it unusually heavy for a non-metallic mineral. Although often too fine-grained to show cleavage, occasional large sphalerite crystals may show the one direction of perfect cleavage characteristic of this mineral. Sphalerite is commonly found with chalcopyrite, galena, and pyrite (Figure 9).

The U.S. Geological Survey estimates the value of the 740,000 metric tons of zinc mined in the U.S. during 2021 to be about $2.4 billion. Most of this zinc is used in galvanizing of iron, and in making *brass* (alloy of copper and zinc) and *bronze* (alloy of copper and tin, with some zinc added).

Figure 8. This specimen consists of sphalerite (dark, nearly black) with pyrite (note cube on left side) and minor quartz (elongate gray-white crystals). The uncommon sulfide mineral *jamesonite* (Pb₄FeSb₆S₁₄) is present in the center of this specimen, occurring as aciculic (hair-like) crystals. This specimen (from Nevada) is 2.7 inches by 1.8 inches.
Figure 9. In this specimen the sphalerite (steel-gray) is accompanied by chalcopyrite (both upper right and lower left) and dolomite (white). The association of sphalerite and chalcopyrite is exceedingly common. Specimen is from Reynolds County, Missouri.