The previous session of Boot Camp described some of the most common sulfide minerals, and this session will discuss some additional sulfide that are less common, but nonetheless important minerals. Like the previous group, this set of minerals consists of metal (or semimetal) ions combining with sulfur, resulting in relatively simple chemical formulae and distinctive physical characteristics. [Semimetals are those elements which have some properties of both metals and nonmetals.]

Molybdenite

Molybdenum (Mo) is a frequently-used element in metallurgical applications, and is derived solely from the mineral molybdenite (MoS$_2$). It is a typical sulfide mineral in that it shows a strong silvery metallic luster (Figure 1) with a greenish to grayish-black streak. The hardness is exceeding low (1 to 1.5 on Mohs scale). Molybdenite commonly occurs as massive or foliated masses, although it does have one direction of perfect cleavage. It might be mistaken for graphite, but has a higher specific gravity (about 4.5, as compared to 2.2 for graphite). Molybdenite lacks the cubic cleavage characteristic of galena.

Figure 1. Molybdenite occurs within gray quartz veins in this specimen, which is a frequent mode of occurrence in some molybdenum mines. Length of specimen is about 5 inches. Specimen is from the Henderson Mine, Clear Creek County, Colorado.
Molybdenite is actively mined from two mines in the U.S., both of which are in Colorado. It is also recovered as a byproduct from several large copper mines in the western U.S., where the molybdenite is found associated with chalcopyrite.

**Chalcocite**

While chalcopyrite is the main ore mineral of copper, *chalcocite* (Cu$_2$S) can be an important source of copper in some mines based on its mode of occurrence. Chalcopyrite (and some other copper sulfides) are unstable close to the Earth’s surface, and will breakdown during weathering when exposed to an oxidizing environment. The acidic conditions produced (due to water combining with sulfur to create sulfuric acid [H$_2$SO$_4$]) will mobilize the Cu$^{+2}$ ion and transport it downward to the water table, where it will redeposit in a reducing environment as the copper-rich sulfide chalcocite. An extensive chalcocite “blanket” may thus develop at the top of some copper deposits, giving the mine an economically important copper-enriched layer early in the production history.

Chalcocite typically occurs as a sooty mass (Figure 2), often lead-gray which may tarnish to a dull black. It is relatively soft (2.5 to 3 on Mohs scale).

![Figure 2. The gray metallic mass toward the center of this specimen is chalcocite. Note the host rock (which was originally an igneous rock) has been extensively leached to a light gray spongy appearance. The leaching is due to near-surface weathering and breakdown of the original sulfide minerals, resulting in acidic fluids that carry the copper downwards. Long axis of specimen is 3.8 inches. Specimen is from the Morenci Mine, Greenlee County, Arizona.](image)
**Arsenopyrite**

The semimetal element arsenic (As) can occur in sulfides in either the cation (metal) position or as a substitute for sulfur. The most common arsenic-containing mineral is arsenopyrite (FeAsS), where arsenic is replacing half of the sulfur. Arsenopyrite is typically found associated with other more common sulfide minerals such as pyrite. This mineral may be an important host in many gold deposits, because the gold occurs as microscopic blebs within the arsenopyrite grains.

Arsenopyrite (Figure 3) has a silver-white color with a black streak. Like many sulfides, it has a relatively high specific gravity (about 6) but unlike many sulfides, it is relatively hard (5.5 to 6 on Mohs scale). It exhibits a distinctive elongated prismatic crystal form which makes it recognizable from the cubic form of pyrite.

![Figure 3. Elongate crystals of arsenopyrite, like in this specimen, are a common form for this mineral. Long axis of specimen is 2.2 inches. Specimen is from Huanzala, Peru.](image)

**Stibnite**

The semimetal element antimony (Sb) is also not common in minerals, but its most frequent occurrence is as the mineral stibnite (Sb$_2$S$_3$). This mineral has a metallic luster (Figure 4) and one direction of perfect cleavage like molybdenite, but most commonly occurs as elongate blades.
making it distinctive from both molybdenite and galena. Certain types of gold deposits will frequently contain small amounts of stibnite, so this mineral can be an important indicator used during exploration activities.

![Image of stibnite specimen](image)

**Figure 4.** Blades of stibnite such as in this specimen frequently occur with other sulfide minerals. Here it is occurring with pyrite (brassy fine-grained growth on right side of specimen). Long axis of specimen is 2.6 inches. Specimen is from China.

**Realgar**

Arsenic does occur bonded with just sulfur as two distinctive sulfide minerals. The first of these is *realgar* (AsS), a soft (hardness of 1.5 to 2) consistently red to orange-red mineral found usually in the presence of the arsenic sulfide *orpiment* (Figure 5). Although it is found occasionally as prismatic crystals, realgar is frequently observed as a fine-grained crust. Both small amounts of realgar and orpiment are also frequently associated with particular gold deposits, so just like stibnite, they can be a useful indicator of nearby gold mineralization.
Figure 5. Red realgar crystals are shown with a light dusting of yellow orpiment. Fine-grained mixtures of these two minerals may appear somewhat orange. Underlying sulfide mineral of this specimen is chalcopyrite. Long axis of this specimen is 1.6 inches. Specimen is from Quiruvilca Mine, Santiago de Chuco, Peru.

**Orpiment**

The close associate to realgar is the other arsenic sulfide mineral *orpiment* (As$_2$S$_3$). While it has quite similar hardness and specific gravity to realgar, the reliable difference between the two is the striking lemon-yellow to dark-yellow color of orpiment (Figure 6). These two minerals occur together so often that if one is suspected, the confirmation is usually in finding the other present also (Figure 7).
Figure 6. Fine-grained orpiment coats this rock, although close examination in the center of this specimen suggests some foliated crystal habit developed. There are only a few tiny blebs of realgar present. Long axis of specimen is 4.2 inches. Specimen is from the Getchell Mine, Humboldt County, Nevada.

Figure 7. This specimen represents a common occurrence for the arsenic sulfides, where both realgar and orpiment are intermixed as a fine-grained coating. Despite the mixing, the distinctive red and yellow colors are still obvious. Photo long axis field of view is 1.7 inches. Specimen is from the Getchell Mine, Humboldt County, Nevada.
Cinnabar

Mercury (Hg) commonly occurs in only one sulfide mineral: *cinnabar* (HgS). The color of this mineral (Figure 8) is often described as “blood red”, although the term *vermilion* is a better descriptor because the original vermilion pigment was made from powdered cinnabar (after a while they learned about the toxicity of the contained mercury and quit using it). Impurities in the cinnabar may make it appear more brownish-red. The mineral itself is relatively soft (hardness about 2.5 on Mohs scale) and unusually high specific gravity (around 8), although it is usually present in such small amounts that the specific gravity is hard to determine. Cinnabar commonly occurs as fine-grained coatings (Figure 9), often associated with other sulfide minerals. Like the antimony and arsenic sulfides, cinnabar is frequently found associated with gold mineralization and thus can be an important indicator mineral.

![Image of cinnabar](image.jpg)

Figure 8. Vermilion cinnabar is present in this specimen, along with quartz (clear to light gray terminated crystals visible in lower left of photo) and dolomite (rectangular to rhombohedral pale brown to cream crystals particularly above and to the left of the largest cinnabar occurrence). Photo long axis field of view is 0.9 inches. Specimen is from Tongren Mine, Guizhou, China.
Figure 9. This is a typical occurrence for cinnabar, as a fine-grained mass coating quartz-rich volcanic rocks. The brownish-black material to the left of the cinnabar is oxidized pyrite. Long axis of specimen shown is 2.7 inches. Specimen is from McDermitt, Humboldt County, Nevada.

Cinnabar used to be the main source of mercury, although it hasn’t been mined as an ore in the U.S. since the early 1990s. Most newly-mined mercury is recovered as a byproduct from several gold mines, primarily in Nevada, but the majority of mercury used in industry is recovered from recycled items like batteries and medical devices. The main use for mercury is in dental amalgam and in sensors, switches and relays in the electrical industry. Small amounts of mercury are used in conventional fluorescent bulbs, but with the increased utilization of LED lights, this usage is diminishing.