Mineralogy Boot Camp Session #20

Miscellaneous Mineral Classes: Part 2

This session of Boot Camp is the second of two sessions devoted to introducing some of the minerals found in a variety of mineral classes not already described. In many cases these classes have relatively few members, with only one or two being particularly well known. As in previous cases, specific cations combine with oxygen to form distinctive anionic complexes which give these classes particular physical and chemical properties.

Molybdates

Molybdenum (Mo) is an element already introduced in Mineralogy Boot Camp Session #15 in the description of the mineral molybdenite (MoS_2). When present as Mo^{+6}, this cation can coordinate with oxygen to form the $(MoO_4)^{-2}$ complex. The only common member of this class is where lead (Pb) joins with the molybdate complex to form *wulfenite* ($PbMoO_4$). This mineral has distinctive tabular crystals that are typically orange, red, yellow, or gray (Figure 1). With both lead and molybdenum present, the specific gravity of wulfenite is fairly high (6.5 to 7), but the crystals are usually too small and isolated in order to get an accurate judge of this property. The commonly translucent crystals have a vitreous luster, making it a popular selection for mineral collectors. It is far too rare to be a significant source of molybdenum like molybdenite.

Figure 1. This is a good example of orange-red platy wulfenite crystals. Long axis of specimen is 2.8 inches. Specimen is from Red Cloud Mine, La Paz County, Arizona. Image from *mindat.org*.

Vanadates

Vanadium (V) is a relatively common element in the Earth's crust, occurring at about the same abundance as chromium (Cr). The size of the vanadium ion is about the same as phosphorous, and with an identical charge (P^{+5} and V^{+5}), this element often replaces phosphorous forming a $(VO_4)^{-3}$ complex that can substitute into phosphate minerals such as apatite. The most well-known vanadate mineral is *vanadinite* [$Pb_5(VO_4)_3Cl$]. This mineral often occurs as tiny hexagonal red to orange-red to brown crystals (Figure 2). The high specific gravity (near 7) may be evident if the specimen is large enough. Vanadium has been used as an indicator element for uranium deposits since it also occurs in the yellow uranium (U) mineral *carnotite* [$K_2(UO_2)_2(V_2O_8)\bullet 3H_2O$].

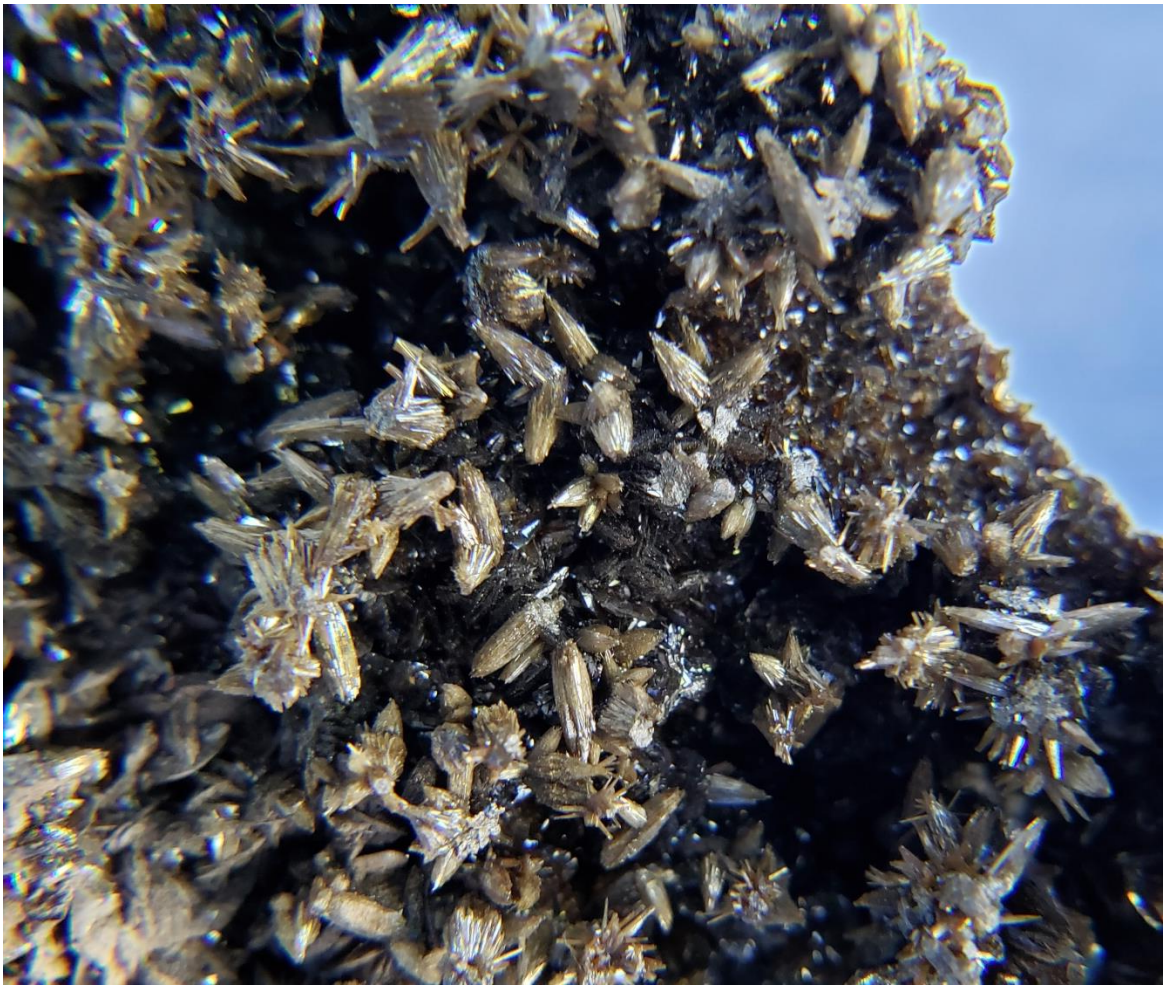

Figure 2. Close up view of vanadinite crystals grown along a crack surface in quartzite from New Mexico. Horizontal field of view is 0.8 inches.

Vanadium is used in the production of iron and steel, where it contributes to the hardening of these commodities. According to the U.S. Geological Survey, in 2021 the U.S. consumed about

4,500 metric tons of vanadium, commonly expressed as V_2O_5. Nearly this entire amount was imported. China is the world's largest vanadium producer, most of which is consumed by the steel-producing industry in that county.

Borates

The element boron (B) is present in the crust in about the same abundance as copper (Cu) and lead (Pb). Because the B^{+3} ion is so small, it can occur in a variety of configurations with oxygen, forming either $(BO_3)^{-3}$ or $(BO_4)^{-5}$ as well as more complex anionic groups with oxygen and $(OH)^{-1}$. This leads to over 100 different borate minerals, most of which are very rare. Three of the more common borates are described here, all of which are deposited in closed continental basins with arid conditions, leading to high evaporation rates. Most borate minerals are soluble in water, so they are only found in the field in arid regions.

The best known and most widespread borate mineral is *borax* [$Na_2B_4O_5(OH)_4 \bullet 8H_2O$]. It has long been used in soaps and detergents, which contributes to its name recognition. Borax crystals are commonly prismatic (some examples are shown in Figure 3) and some shade of white because the original borax and been altered to *tincalconite,* where the eight water molecules have been reduced to three molecules due to atmospheric exposure. It is a soft mineral (about 2 on Mohs scale) with a low specific gravity (1.7).

Figure 3. These borax crystals are undergoing alteration to *tincalconite*. The base of this specimen is about 4 inches long. Specimen is from Boron, Kern County, California. Image from *mindat.org*.

A similar borate mineral related to borax is *kernite* [$Na_2B_4O_6(OH)_2 \cdot 3H_2O$]. It is rarely found in individual crystals, but rather as crystal aggregates and masses (Figure 4). Slightly harder than borax (3 on Mohs scale) with slightly higher specific gravity (2) is how kernite usually occurs. Colors are commonly white also due to the development of tincalconite on its surface. Locally it appears to have developed from the recrystallization of borax during sediment burial.

Figure 4. Masses of kernite crystals such as these are common in the borax mine in Boron, Kern County, California. This specimen is 14.5 inches long and 9 inches wide. Image from *mindat.org*.

Another common borate mineral is *ulexite* [$NaCaB_5O_6(OH)_6 \cdot 5H_2O$]. It is distinctive by commonly occurring as fine acicular balls of crystals (sometimes called "cotton balls") or in masses of closely-packed parallel fibers (Figure 5). These parallel fibers have curious fiber optic properties when both ends have been polished, leading to the name "television rock". Like the other borates, ulexite is also quite soft (hardness of about 2) with a low specific gravity (about 2). The silky luster of ulexite is distinctive.

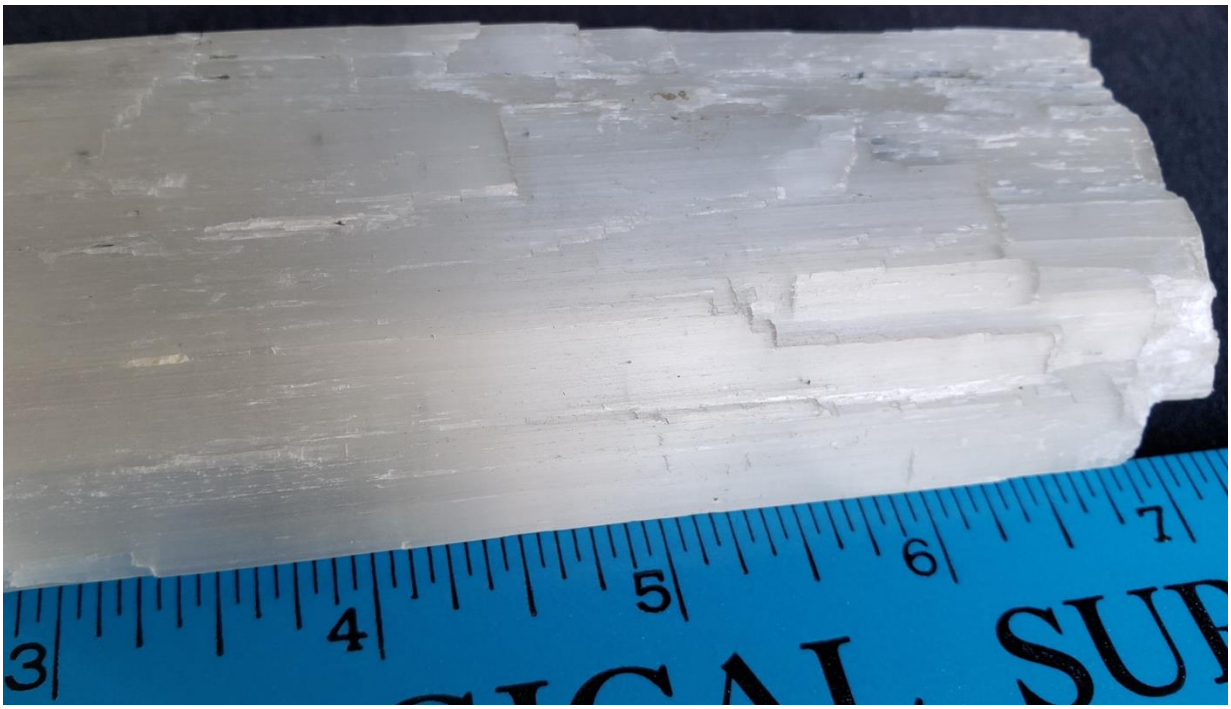

Figure 5. This ulexite specimen from Boron, Kern County, California exhibits the typical silky luster of this mineral when it occurs in masses of parallel fibers.

Borate minerals are mined and processed to produce the boron used in industry. The most common of these mined minerals are borax, kernite, ulexite, and colemanite (a calcium borate). According to the U.S. Geological Survey, the U.S. produces enough to meet all its domestic needs and is a net exporter of boron. While total production in the U.S. is not given because of company proprietary data restrictions, in 2021 it appears at least 340,000 metric tons were consumed at an average price of $390 per ton. Glass and ceramic industries were the leading domestic users, which accounted for 65% of the consumption. The remaining amount was used in making abrasives, cleaning products, insecticides, and insulation.