

Article

The BIG Four



Pyrite

Casapalac Mine, Peru

Alteration of the four primary base-metal minerals, pyrite, galena, sphalerite, and chalcopyrite, leads to an enormous suite of minerals that are favorites of mineral collectors the world over.

While all collectors appreciate the beauty of such specimens, it is likely that those without a chemistry or geology background don't fully



Galena

Sweetwater Mine, Missouri

understand how oxidation, and the ensuing sequence of events, is the mechanism by which these minerals are produced. Environmental conditions need to be just right for this process to proceed. This means *water* and *time*.

First, water is the key ingredient, specifically, *rainwater*. Without water, ore veins will simply corrode and wear away. Rainwater percolating down through the surface layers picks up and carries the components that interact with local elements to form the secondary minerals, but too much water will dissolve and wash away the minerals too quickly to allow for the slow steady reactions that are necessary to convert the sulfides in the vein into the secondary specimens.

Secondly, the reactions must have time to progress. Thus, the local water table must not be too close to the surface, or the process will end before it ever gets started. With the water table near the surface, no reaction at all will take place, as rainwater will not travel very far for very long. Rainwater needs someplace to go and time to get there.

One region where conditions have been just right for millions of years is the southwestern United States, home of the Mojave Desert. Here, the water table is deep, there is just enough rainwater available, and, of course, there has been significant igneous activity in the past to emplace ore deposits. With every rainfall since the deposits were emplaced, the process was set and maintained in motion.



Chalcopyrite

Unknown location

Atmospheric water claims and dissolves gases from the air, particularly carbon dioxide and oxygen. These make the water a weak acid, a potent chemical agent capable of dissolving minerals in the ground faster than pure water. Once it hits the ground, it immediately goes to work and gains in potency as it dissolves additional acids



Sphalerite

Paloma Mine, Peru

All specimens from the G. Miles Lehman Collection

from decaying vegetable matter and other sources. When this water contacts a mineralized vein, the real action begins.

Of the primary sulfides found in base-metal ore deposits, pyrite is the most abundant by far. Being also the most easily affected, pyrite reacts with the oxidizing water to produce iron sulfate and sulfuric acid (anyone who has worked with sulfuric acid knows what a powerful, insidious acid this is!). At the same time, huge quantities of iron oxides and hydroxides, mostly hematite and goethite, are generated to form a spongy yellow, red, or brown “gossan” of mixed oxides called *limonite*, the matrix of many minerals coveted by collectors.

Once the iron sulfide is converted to iron sulfate and sulfuric acid, a chemical chain reaction with the remaining sulfides is set in motion to produce the corresponding sulfates; galena to lead sulfate, sphalerite to zinc sulfate, chalcopyrite to copper sulfate. With the exception of lead sulfate, these dissolve easily in water. As the solutions contact other minerals in the ambient rocks, further reactions lead to the formation of new minerals.

Copper sulfate reacts with calcite in limestone to form malachite, azurite and other copper carbonates; it also reacts with chalcopyrite to form bornite, which in turn transforms into chalcocite. If the copper sulfate is produced in a silica-rich environment (shales, sandstones, etc.), copper silicates are formed, predominantly chrysocolla.

Zinc sulfate reacts in a similar, but less spectacular, way with limestone to form the carbonates smithsonite and hydrozincite, or hemimorphite if silicate rocks are present. Lead sulfate, though less soluble in water, is still present in enough quantity to form cerussite in carbonate rocks, but is less compatible with silicates (lead silicates are very rare). One of my favorites is plumbophyllite from the **Blue Bell Mine** near Baker, CA.

A host of more exotic minerals that are combinations of all these ingredients are also produced when conditions of temperature, pressure, concentration, and pH are just right, such as mottramite and descloizite, aurichalcite, caledonite, linarite, and leadhillite, to name just a few.

One would like to think that all this was accomplished for one grand purpose: to create spectacular specimens to be eventually unearthed and proudly displayed in future mineral collections!



Linarite

3 x 2.25 inches

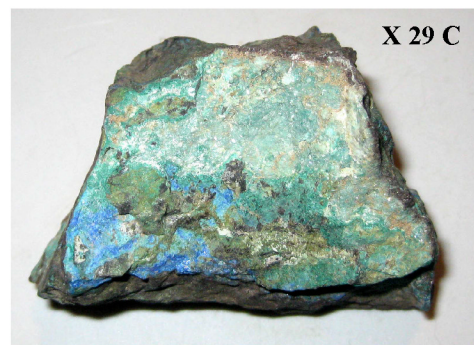
Blue Bell Mine



Chalcanthite

1 x 2.75 inches

Antler Mine



Caledonite

2.5 x 2 inches

Blue Bell Mine



Leadhillite

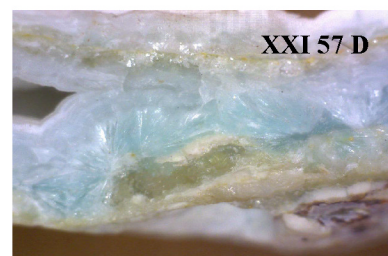
2.25 x 1.25 inches

Blue Bell Mine

Plumbophyllite

2.38 x 30 inches

Blue Bell Mine



All specimens from the G. Miles Lehman Collection