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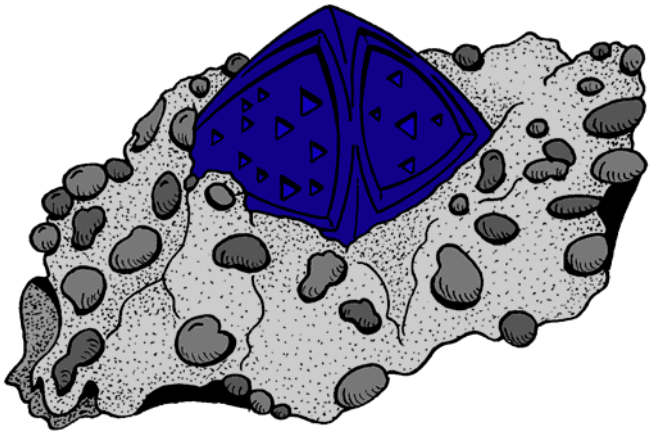
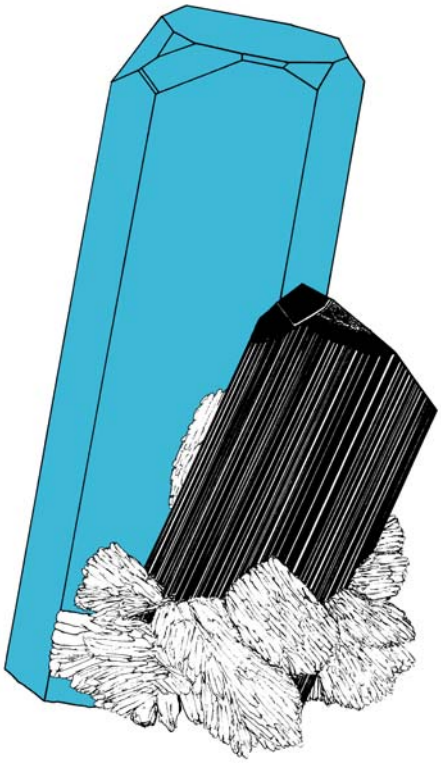
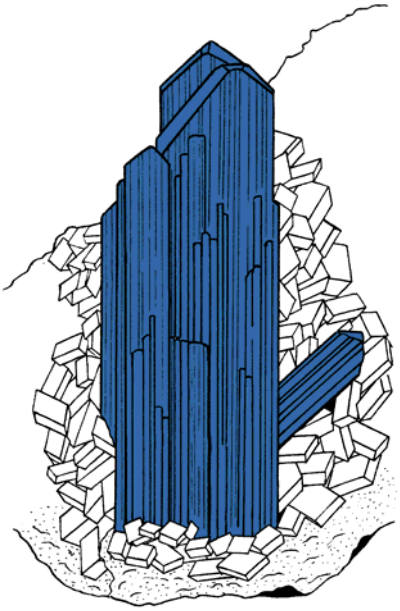




Shades of Blue: Minerals of the World



Shades of Blue: Minerals of the World

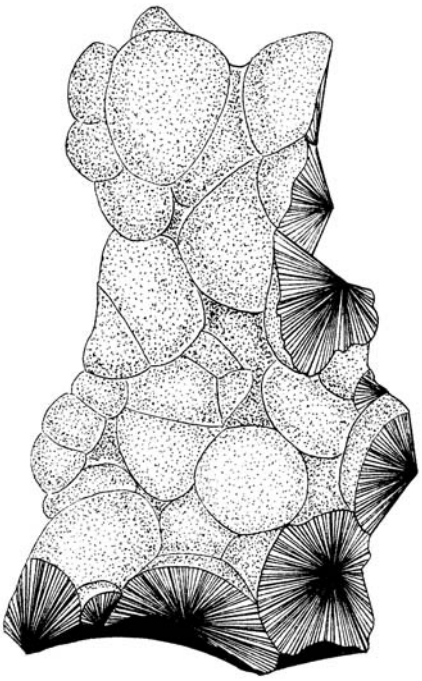
Light blue, dark blue, sky blue, navy blue, sapphire blue and many more. "Singing the blues" means that you are sad and depressed. You certainly will NOT be depressed when you see the awesome blue mineral specimens here in this book, in great mineral picture books and magazines, and on the internet. You probably didn't know there could be so many different shades of blue!

Colors and how they are created in minerals involves understanding a little science. You will encounter words that describe how minerals get their color (idiochromatic, allochromatic and pseudochromatic). You will also see the chemical formulas of all of the minerals presented here, so there are some words from the field of chemistry to learn, too. And, you will be introduced to very rare minerals that you probably have never heard of before.

If at first this seems too complicated, don't worry. By reading these words over and over again, and by seeing actual mineral specimens you will begin to learn and understand. The most successful mineral collectors are the ones who learn more and more about minerals and mineralogy as they get older.

This book (drawings and text) was created by Darryl Powell at Diamond Dan Publications www.diamonddanpublications.net ~ powellpublicationsgroup@gmail.com

What is "Blue"?

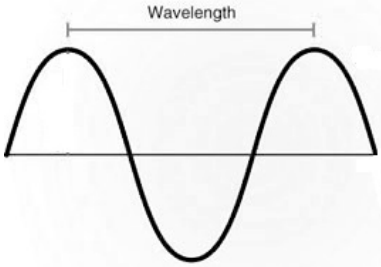


Most people will say that blue is their favorite color. Maybe that's because the sky, the ocean and our planet are blue. Maybe it's because blue makes people feel cool and calm. Maybe it's because there are so many different shades of blue: dark blue, light blue, sky blue, navy blue, sapphire blue, midnight blue, Prussian blue, ice-blue, robin's egg blue, electric blue, slate blue and more.

Artists will tell you that blue is one of the three primary colors. The other two are yellow and red. You can mix these primary colors together in different amounts to create most other colors. For example, red and yellow create orange, blue and yellow create green and red and blue create purple.

It is interesting that there aren't many fruits and vegetables that are blue. There are blueberries, of course, and blue Hubbard squash (which some would say is more gray-green than blue), but that's about it. However, when you check out the world of minerals you will discover that there are a lot of minerals that are some shade of blue. You are about to discover some of them in this book.

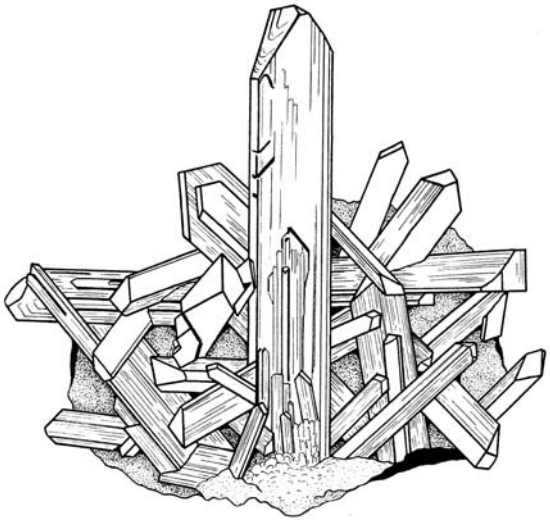
Scientifically-speaking, blue is the color that is between violet and green on the optical spectrum of visible light. Light energy can be described to move like a wave and it is known that each color of light has its own wavelength. The distance from the highest point of the wave to the next highest point is called the "wavelength." The wavelengths for blue are between 450 and 495 nanometers (a "nanometer" is one billionth of a meter...that's very, very, very small).



You may ask, why does my eye see the color blue (or any color for that matter)? Let's say the sun or a lamp shines its light on a mineral specimen. That light contains all the different wavelengths of light energy, all mixed together. The mineral specimen absorbs some of the light and it reflects the rest of the light. The light that it reflects travels to your eye is seen as a color. So, you are looking at a specimen of azurite crystals from Tsumeb, Namibia, in one of our display cases. The specimen absorbs the light from the light bulbs and reflects dark blue light energy back to your eye. You see the specimen as dark blue. As you visit the many display cases say to yourself over and over, "this specimen is light blue because it has absorbed all other wavelengths of light and has reflected light blue to my eye!"

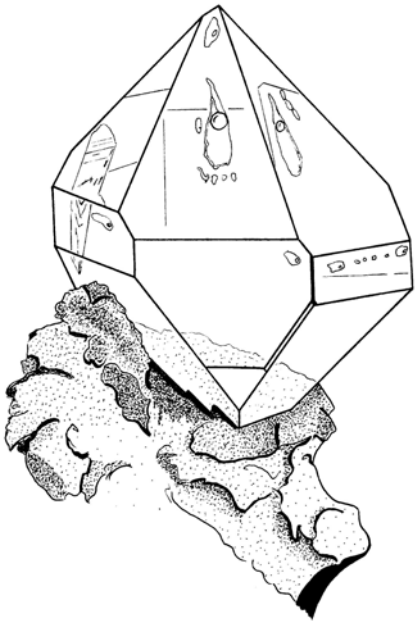
Why Are Some Minerals Blue?

Mineralogists use three special words to describe what causes color in minerals. The words are idiochromatic, allochromatic, and pseudochromatic.



Idiochromatic minerals are described as "self-colored." This means that the elements that make up the mineral create the color. Azurite is a great example. Azurite is copper carbonate ($Cu_3(CO_3)_2(OH)_2$). This combination of elements gives its blue color.

Allochromatic minerals are "other-colored" minerals. One way allochromatic minerals get their color is from very, very small amounts of impurities (called "trace" impurities) that are trapped in the crystal structure. The impurities can be tiny amounts of elements that are not part of the crystal structure. Impurities can also be very small amounts of another mineral. This is called an inclusion. Even trapped air in a crystal is an inclusion, like the air bubbles in this specimen of quartz from Herkimer, New York (right).



Allochromatic minerals can also get their color from defects in a mineral's crystal structure. One example of this is called a "color center." Blue topaz is blue because of a defect, or color center, in its crystal structure. Another example is called "charge transfer." In some minerals two or more of the elements that make up the mineral pass an electron from one element to the other. Charge transfers absorb certain wavelengths of light and reflect others. The blue color in sapphire, aquamarine and tourmaline is created by charge transfer.

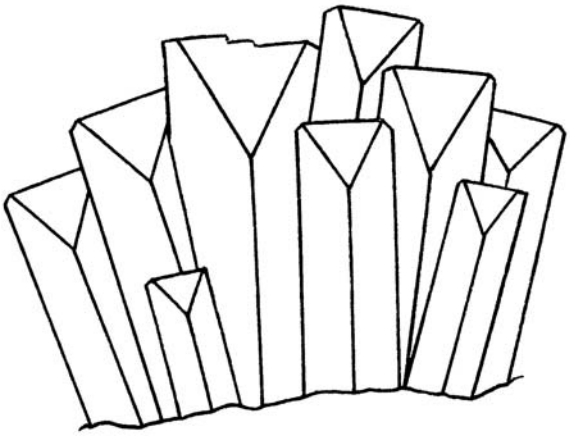
Pseudochromatic minerals are "false-colored." Their color is created by the way the mineral bends (scientifically-speaking "diffracts") the light. A great example is labradorite. Labradorite breaks light into blues, greens, and purples.

Adamite

$Zn_2(AsO_4)(OH)$ (Hydrous zinc arsenate)

Adamite is popular with mineral collectors because of its crystal form and bright colors. It can be dark yellow to greenish yellow, green, sky blue, pink, purple and even orange. Pure adamite is colorless. However, it is commonly yellow. This color comes from iron compounds mixed in with the adamite. When there is copper in the crystal structure, it is green. When manganese is in the crystal structure adamite is purple. Copper is also the element that gives some adamite specimens a beautiful blue color.

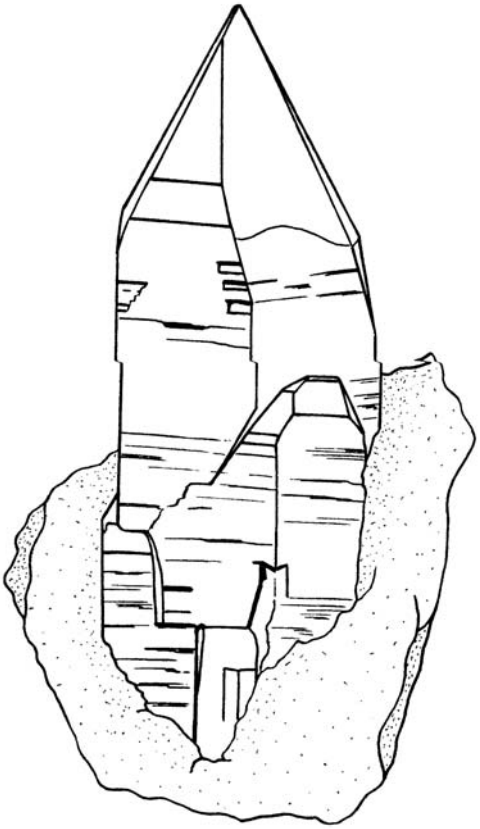
Pictured to the right is a small cluster of adamite crystals from the Ojuela Mine, Mapimi, Durango, Mexico.



Afghanite

$(Na,Ca,K)_8(Al_6Si_6O_{24})(Cl_2,SO_4,CO_3)_3 \cdot 0.5H_2O$

(Hydrous sodium calcium potassium sulfate chloride carbonate alumino silicate)



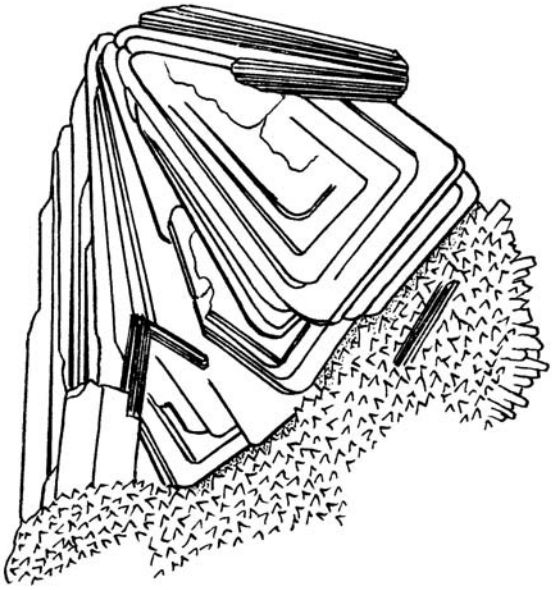
Afghanite was first discovered in 1968 in the famous Lapis-lazuli mine in Sar-e-Sang, Badakhshan Province in the country of Afghanistan. You can easily see that it was named after the country in which it was first discovered.

Afghanite can be colorless or light blue to dark blue. The specimen pictured here is dark blue and was discovered at Sar-e-Sang, Afghanistan.

When afghanite is seen under longwave ultraviolet light, it is not blue, but fluorescent orange-brown. Some mineral collectors specialize in fluorescent minerals. Fluorescent minerals are those that display a fluorescent color when viewed under shortwave or longwave ultraviolet light.

Andyrobertsite

$KCdCu_5(AsO_4)_4(H_2AsO_4) \cdot 2H_2O$
(Hydrated potassium cadmium copper arsenate)



Andyrobertsite is a very, very rare mineral. Pictured here is a drawing of the only known specimen of this mineral. (To be accurate, this specimen contains both andyrobertsite and calcioandyrobertsite which has calcium instead of cadmium in its chemical formula.) It was discovered at the famous Tsumeb Mine, Tsumeb, Namibia. It has a vitreous luster (glassy), is bright blue and forms thin, flat, bladed crystals. The blue color is created by the copper in its chemical formula. Therefore, this is another example of an idiochromatic mineral species.

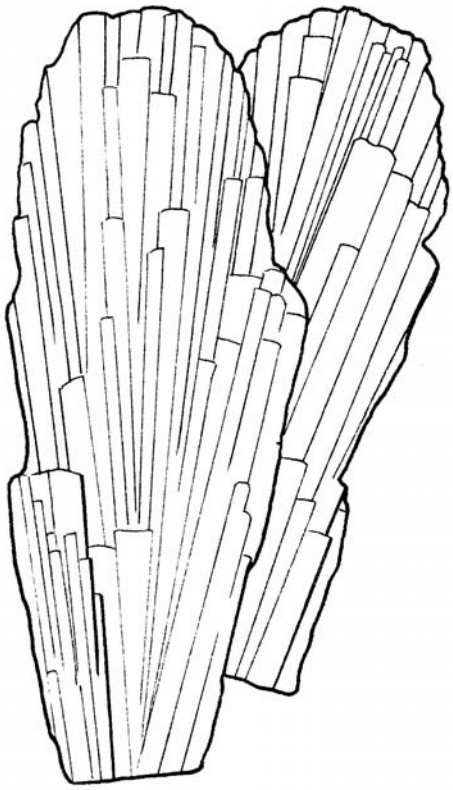
Anhydrite

$CaSO_4$ (Calcium sulfate)

The chemical formula for gypsum is $CaSO_4 \cdot 2H_2O$ (hydrated calcium sulfate). Notice that anhydrite has the same formulas gypsum but is *without the water molecules!* The name anhydrite comes from the Greek word anhydrous which means without water.

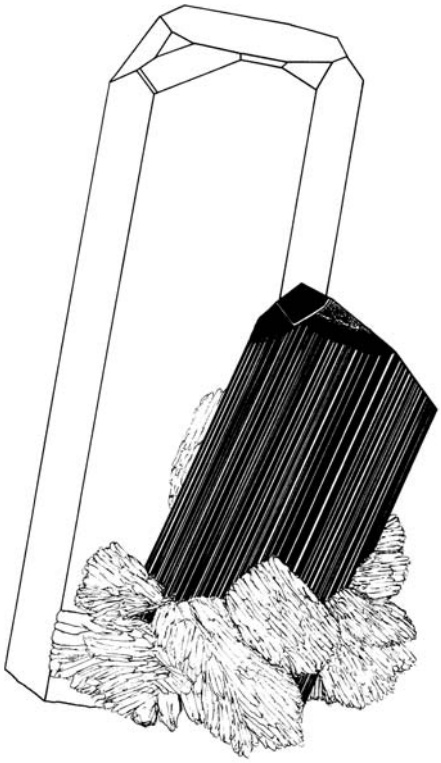
Like many other minerals, anhydrite is colorless or white. But when there are impurities trapped in the crystals, they can be rose pink, gray or pale brown. Some specimens are light blue. Wing-shaped crystal groups of light blue anhydrite are found in Chihuahua, Mexico.

Anhydrite can be found both as mineral specimens and as a sedimentary rock. It is found in huge sedimentary deposits in Texas and Louisiana, for example, where it occurs with sulfur and halite.



Aquamarine

$Be_3Al_2Si_6O_{18}$ (Beryllium aluminum silicate)



Aquamarine is the blue to blue-green variety of the mineral beryl. It is named from the Latin words aqua and marinus which mean water and sea. In other words, "water of the sea." This is a reference to the blue to blue-green color of ocean water. When it is truly blue, aquamarine is a beautiful, light blue. Clear crystals are cut and polished to make gemstones and jewelry.

Aquamarine is another allochromatic mineral. It gets its color from traces (very, very small amounts) of iron that has taken the place of some aluminum atoms in the beryl crystal.

Natural aquamarine can be light blue. Gemologists have discovered that if aquamarine is heated, the blue color gets stronger. In addition, once it is heated and the color changes, it does not change back to its original color. It remains strong blue.

In the past, people believed that because of its color, aquamarine could protect sailors while they were out at sea and then bring them home safely. Folklore like this has been passed on for hundreds of years.

Left: A superb, perfectly clear aquamarine with black tourmaline and white cleavelandite from Shigar, Northern areas, Pakistan.

Aurichalcite

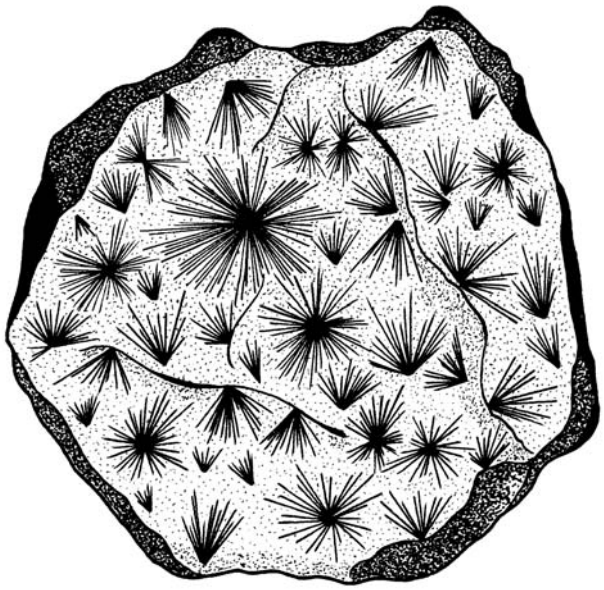
$(Zn,Cu)_5(CO_3)_2(OH)_6$

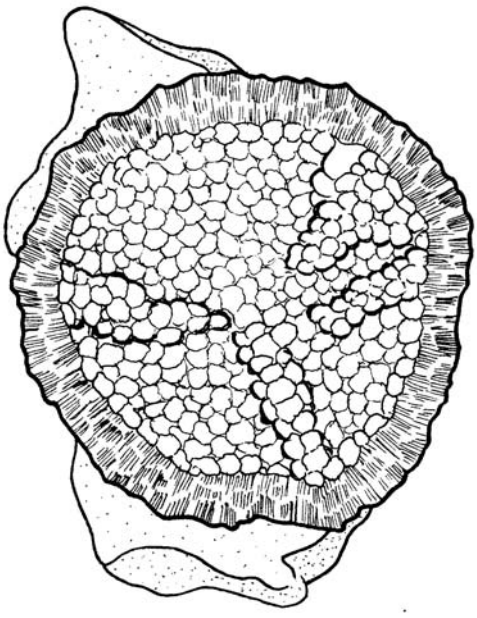
(Hydrous zinc copper carbonate)

Aurichalcite is usually found as very tiny, blue (and sometimes blue-green) tufts of crystals, like the specimen pictured here. The crystals are like needles and are very delicate. Therefore, collectors have to be very careful when handling aurichalcite specimens or the crystal groups can be easily damaged or broken.

The blue color comes from the copper in the mineral. This means that Aurichalcite is idiochromatic.

The specimen pictured here is from the 79 Mine, Hayden, Arizona. The light blue crystal sprays are sitting on a reddish matrix.





Azurite

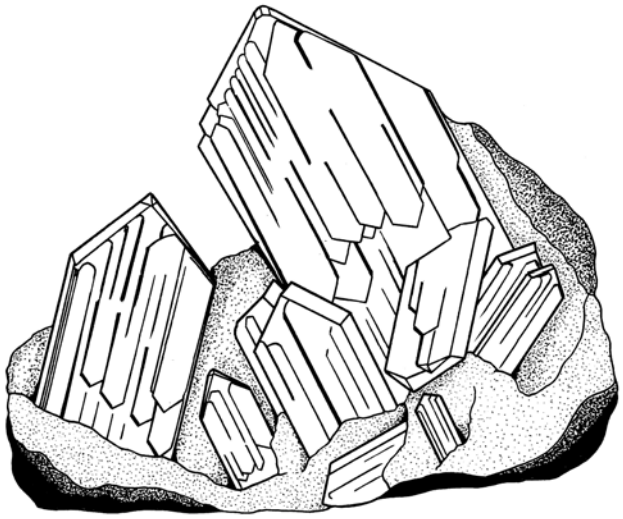
$Cu_3(CO_3)_2(OH)_2$ (Hydrous copper carbonate)

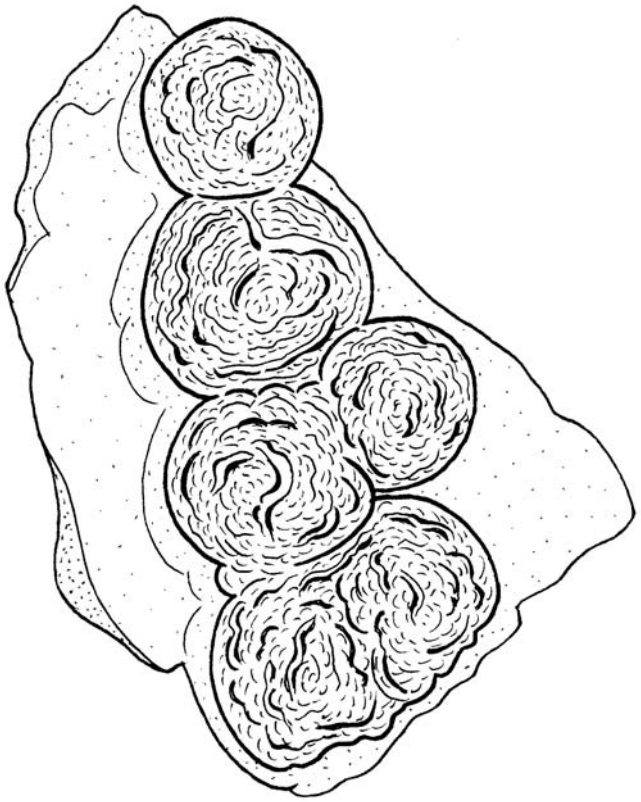
Azurite is an idiochromatic mineral: the copper in azurite's crystal structure creates its blue color. Azurite is also known as a monochromatic mineral. This means that it occurs only in one color - blue. You can find yellow quartz (citrine), black quartz (smoky) and pink quartz (rose), but you can never find green azurite. Azurite is always a shade of blue.

The name *Azurite* comes from the ancient Persian word lazhward which means blue. Azurite can be a light, powder blue, like the azurite "discs" or "suns" pictured on this page. On the other hand, azurite can be deep blue, so dark, in fact, that the crystals can appear to be nearly black. The crystal group on the next page from Tsumeb, Namibia, Africa are very dark blue.

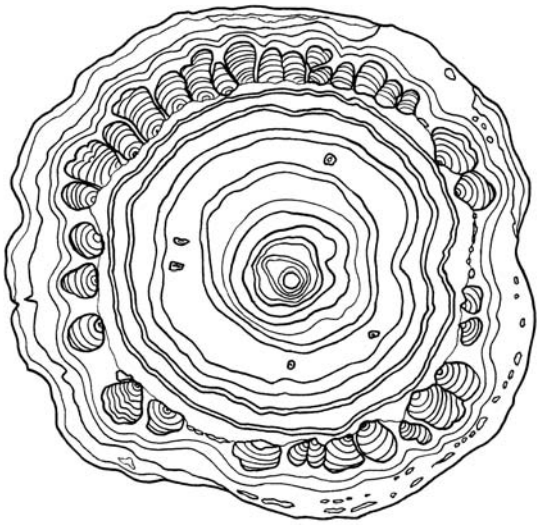
For many centuries azurite was used as a pigment for paint. A piece of azurite would be crushed to powder and added to other paint ingredients to give the desired color. A light blue piece would give a light blue color. A very dark blue piece of azurite would give a dark blue color. Artists also discovered that other hues could be created by mixing the crushed azurite with other materials. For example, if you mix crushed azurite with egg yolk, the color becomes gray-green. When it is mixed with oil it is blue with a slight hint of green.

Mineralogists know that over a long period of time, a chemical change in azurite will cause it to change into the green copper mineral, malachite. There are many mineral specimens of azurite that have the form or shape of azurite crystals but have the green color of malachite. Such specimens are called pseudomorphs which means false form. Pictured below left is a pseudomorph of malachite after azurite from Arizona.





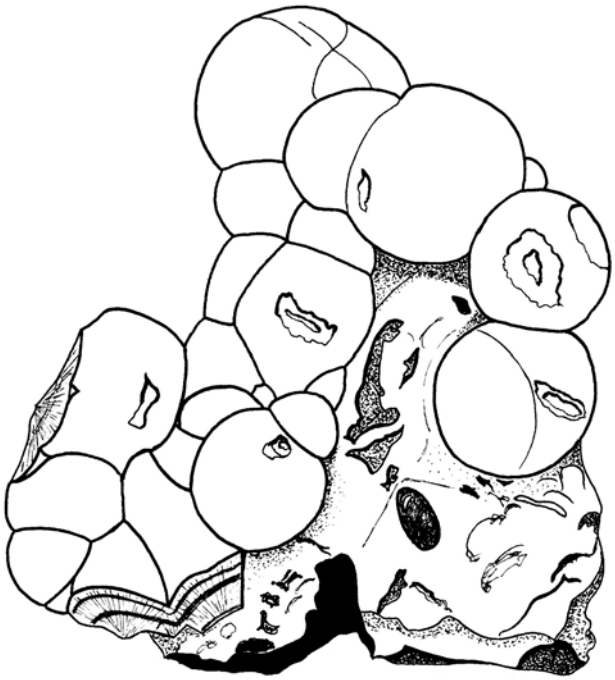
Azurite



Some very, very old paintings have green skies, green clothing and other items that are green. Some of these items were truly meant to be green. However, others were originally painted *blue*, like the blue sky. They were painted using paint that was colored blue with crushed azurite. Over the centuries, the blue azurite changed into green malachite and the color of the paint changed with it!

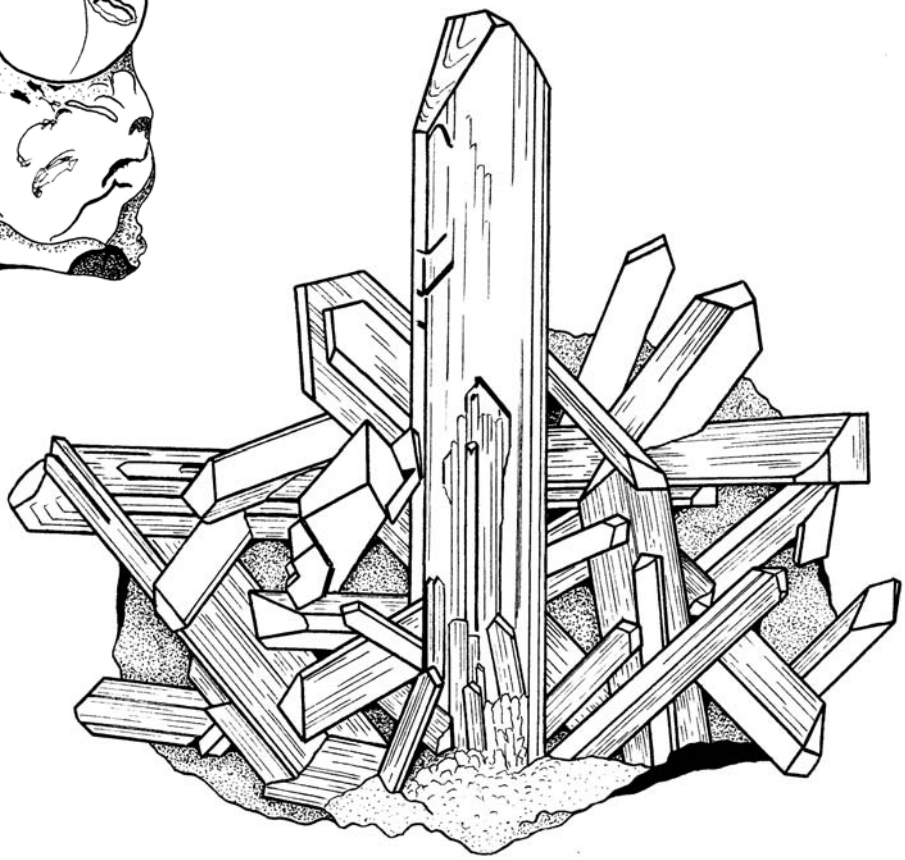
Pictured here are three outstanding azurite specimens.

Top Right: A slice of a stalactite this is blue azurite and green malachite. The central section is green malachite. The little "blobs" are also green malachite. The rest is dark blue azurite. This specimen is from Bisbee, Arizona.



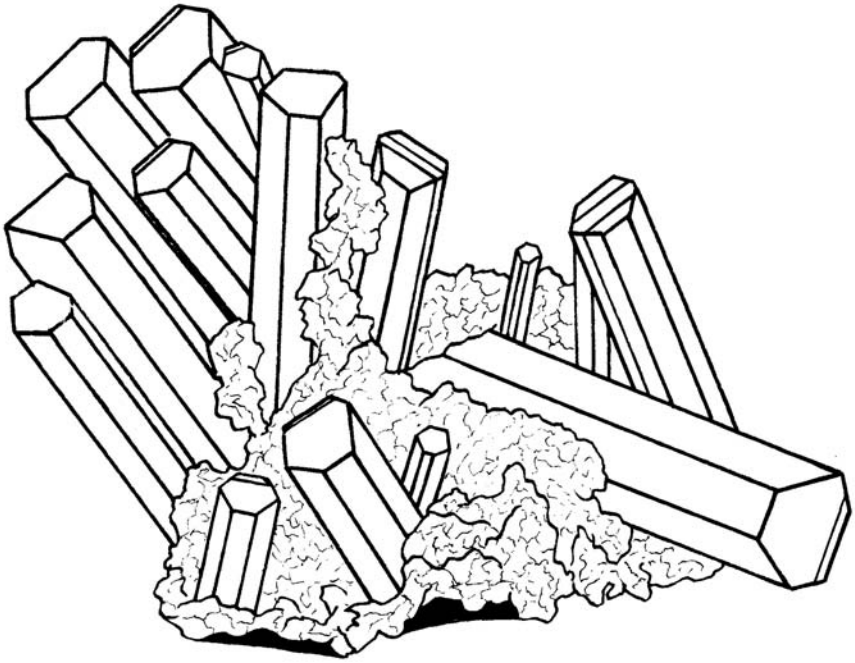
Left: A famous specimen of powder blue (light blue) botryoidal azurite from the Copper Queen mine, Bisbee, Arizona.

Below: Dark blue azurite crystals from the famous deposits of Touissit, Morocco.



Baryte

$BaSO_4$ (Barium sulfate)

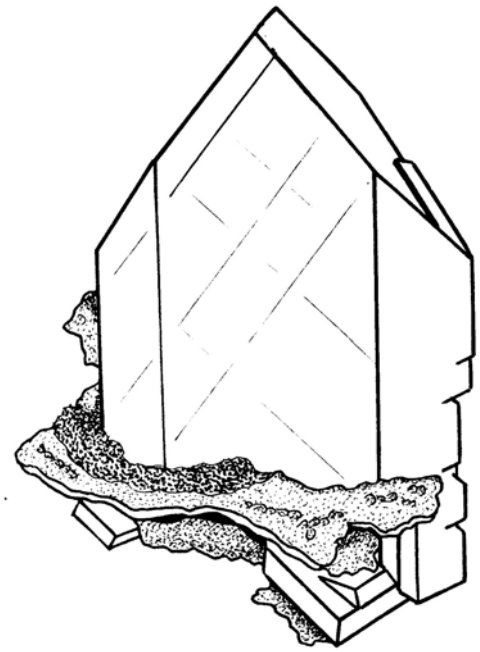


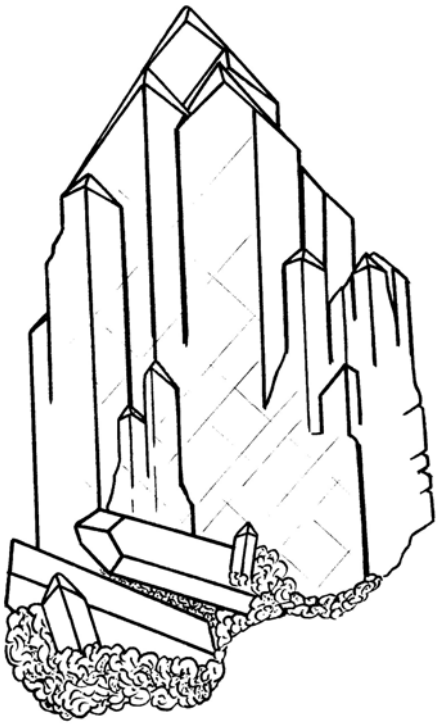
Baryte can be found in an amazing rainbow of colors. As you look around the Show, you will find white, yellow, light green, red, colorless, brown, golden brown and, yes, various shades of blue.

Pictured to the left is a cluster of light blue baryte crystals on white calcite matrix from Stoneham, Weld County, Colorado. Pictured below are two baryte specimens from Frizington, Cumbria, England. They are gray-blue with red staining (from iron) around the edges of the crystals.

Some scientists say that the blue color is due to radiation from surrounding rocks that damage centers in the crystal structure. This means that baryte is allochromatic.

Baryte has the highest specific gravity of all the non-metal minerals. When you pick up a piece of baryte you will notice that it feels heavier than you would expect. Baryte is the main ore of the element barium. It has many uses including the manufacture of paper and rubber.



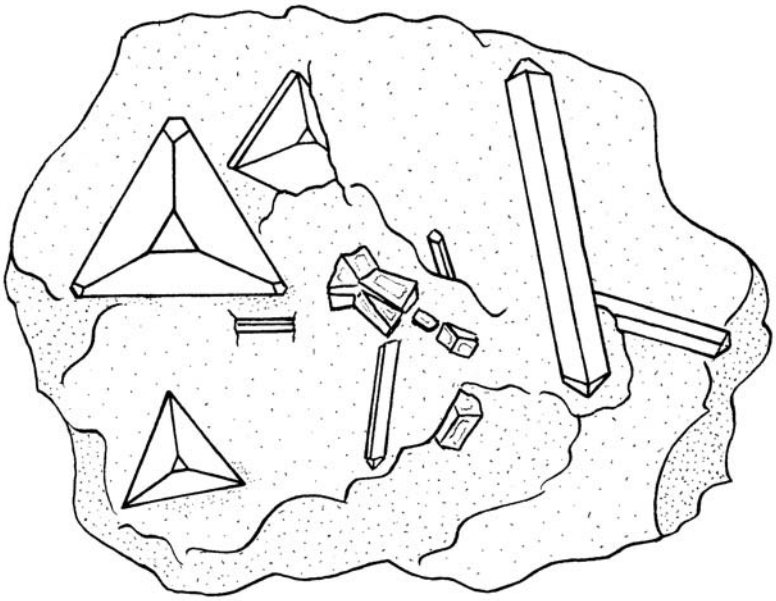


Benitoite

$BaTiSi_3O_9$ (Barium titanium silicate)

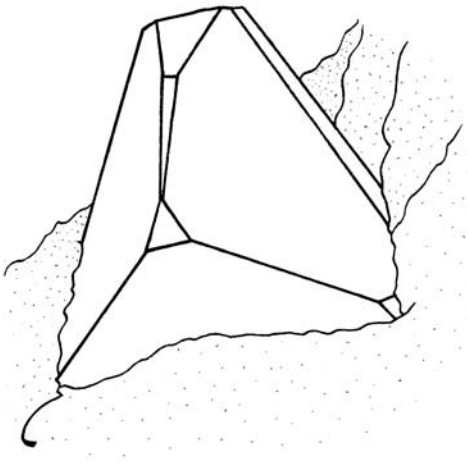
Benitoite was first discovered in San Benito County, California in 1907. Before it was studied in the laboratory, it was thought to be sapphire. Dr. George Louderback from the University of California at Berkeley studied this new mineral and discovered that it was a species that had never before been known. He named it "benitoite" after the locality where it was discovered. Another new mineral discovered from this same locality is joaquinite.

Some of the benitoite crystals from San Benito County are gem-quality and have been cut and polished to make beautiful jewelry. Since California is the only place in the world that has produced gem-quality benitoite, the California State Assembly voted to proclaim benitoite as the official gemstone of the State of California. On October 1, 1985 benitoite became California's official gemstone.

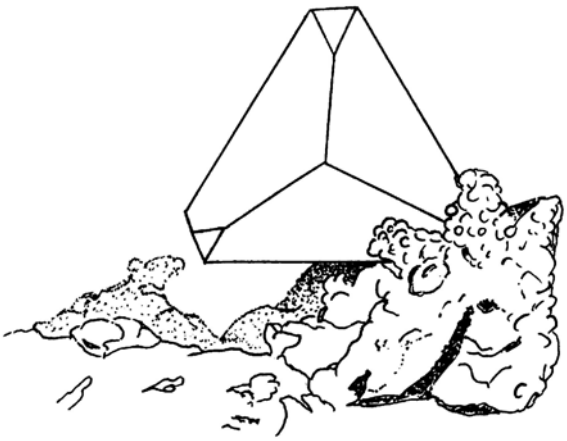


The blue color of benitoite is described as "sapphire blue." As you study benitoite specimens you will see that its color can be light blue to dark blue and, in some cases, gray-blue. The best gemstones are medium to dark blue.

Pictured is a specimen of benitoite crystals with neptunite and joaquinite crystals from the Benitoite Gem mine, San Benito County, California. Color the triangular-shaped crystals of benitoite light to dark blue. The long, thin crystals of neptunite are black. The small "boxy" crystals are joaquinite. They are orange-tan. In the middle of the specimen is a rare twinned crystal of joaquinite. Also notice that the largest Neptunite crystal has terminations on both ends of the crystal. Mineralogists call this "doubly terminated." Benitoite is the only mineral found to crystallize in this habit.

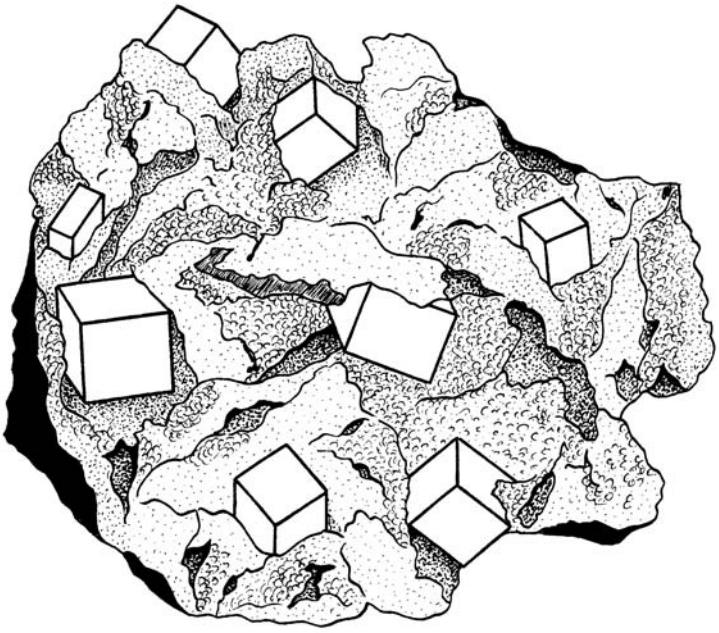


Left and Right: Large benitoite crystals from the Dallas Gem Mine, San Benito County, California.



Boleite

$KPb_{26}Ag_9Cu_{24}(OH)_{48}Cl_{62}$
(Hydrous potassium lead silver copper chloride)

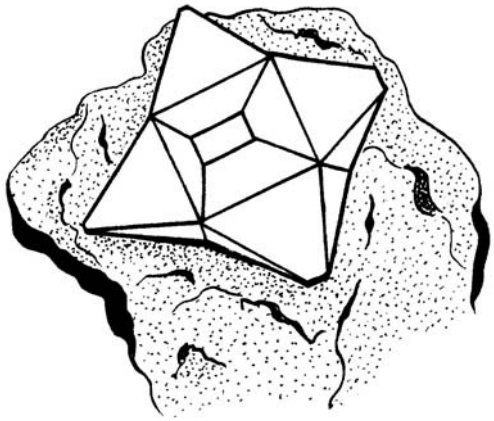


Boleite was named after the place it was first discovered, Boleo, near Santa Rosalia, Baja California. Its color is described by mineralogists as deep Prussian blue to indigo. The crystals are especially beautiful when they sit on the orange-tan to light brown matrix.

Looking at the specimen pictured here, you would think that boleite crystallizes in the isometric or cubic crystal system. Actually, it crystallizes in the tetragonal crystal system. What we see as simple cubes are actually three rectangular crystals that have intergrown with each other. These are properly called pseudocubic crystals. Pseudo- means "fake."

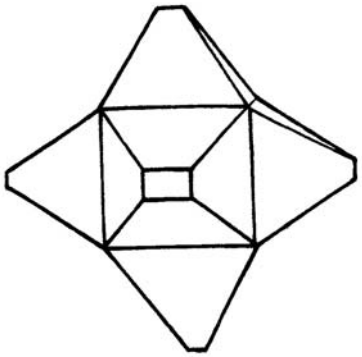
Cumengeite

$Pb_{21}Cu_{20}Cl_{42}(OH)_{40} \cdot 6H_2O$
(Hydrated lead copper chloride)



Cumengeite is a rare halide mineral that is closely related to boleite, described above. Notice how similar their chemical formulas are. Notice that cumengeite does not contain silver, as boleite does. Like boleite, cumengeite is also dark, indigo blue. It was named after Edouard Cumenge (1828-1902). He was the Mining Engineer at Boleo, Baja California, where this mineral was first found.

Cumengeite forms on boleite crystals. When it does, it doesn't grow randomly. Instead, it always grows on the cubic faces of the boleite. This relationship is known as epitaxial overgrowth. You can see it in these drawings: each of the six boleite faces are topped with 4-sided cumengeite pyramids. The result is a 6-pointed, deep blue "star!"

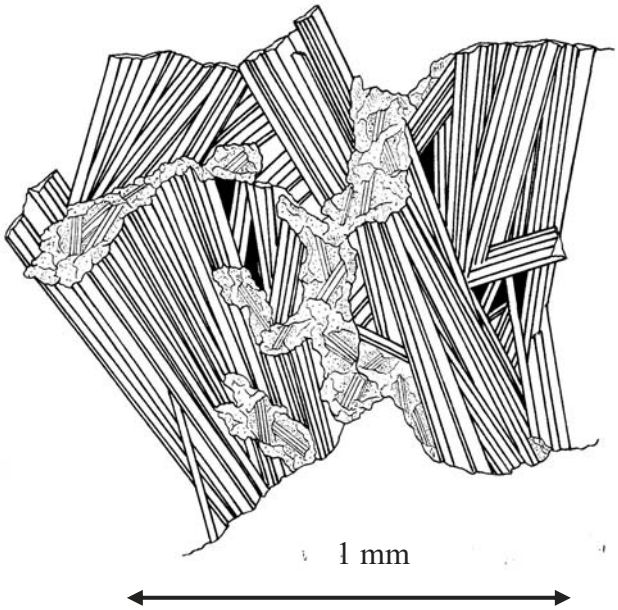


Buttgenbachite

$Cu_{19}Cl_4(NO_3)_2(OH)_{32}\bullet 2(H_2O)$
(Hydrated copper chloride nitrate hydroxide)

As you develop more interest in mineralogy, you will discover rare minerals that most people have never heard of before. Buttgenbachite is one of those minerals. These beautiful, translucent, deep blue, needle-like crystals are very rare. They are also very small. The specimen pictured here is actually only 1 millimeter across! You would need a microscope to see it well.

Buttgenbachite was named in honor of the Belgian mineralogist, Henri J. Buttgenback (1874-1964). It is related to the mineral connellite.



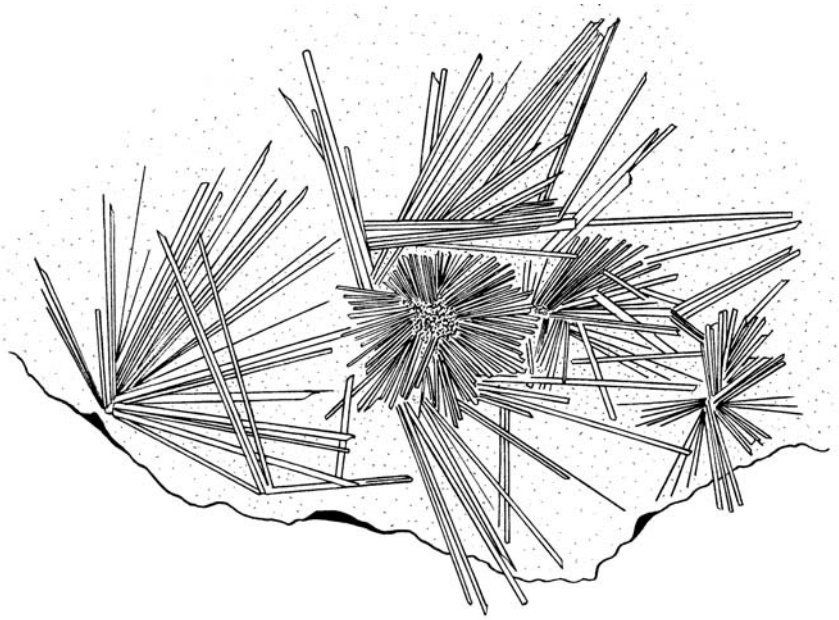
Connellite

$Cu_{19}Cl_4(SO_4)(OH)_{32} \cdot 3H_2O$ (Hydrated copper sulfate hydroxide chloride)

Connellite is another rare mineral species. It has copper in its crystal structure and is found with other copper minerals. It was first discovered in Cornwall, England. Pictured here is a specimen of very thin, needle-like connellite crystals from the Ingadanais Mines, Vila Velha de Rodal, Portugal.

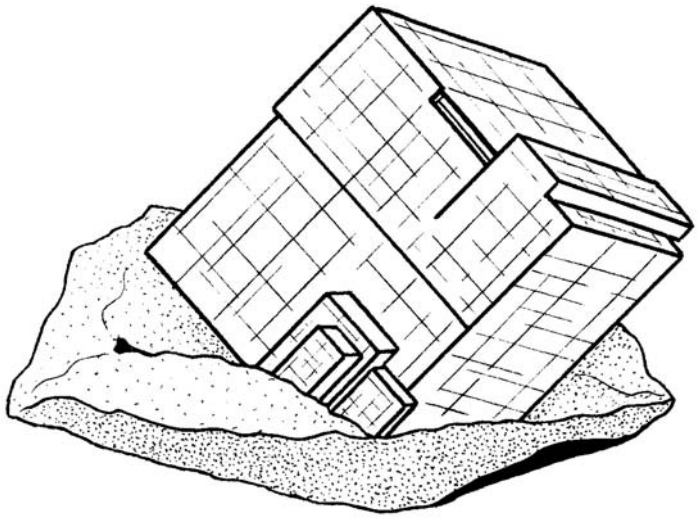
Don't be fooled by the size of this drawing. The actual crystals are very small. You need a microscope to see them clearly. This specimen is what mineral collectors call a micromount specimen.

Also see buttgenbachite because they have very similar chemical formulas. Buttgenbachite is deep blue. Connellite is powdery light blue.



Calcite

$CaCO_3$ (Calcium Carbonate)

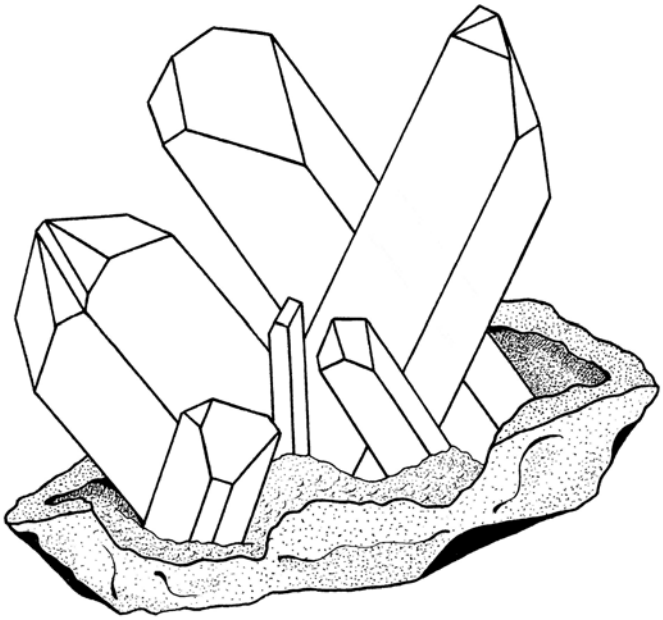


Like fluorite, calcite can be found in a rainbow of colors, including colorless, white, green, brown, red, orange, golden brown, yellow, black and blue. Blue is not a common color for calcite. Excellent masses and cleavage rhombs of blue calcite have been found in the Adirondack Mountains of Northern New York, specifically in the town of Pitcairn. Pictured here is cleavage rhomb from Pitcairn. The blue color is caused by iron trapped in the calcite crystal structure. Therefore, it is an allochromatic mineral.

Celestine

$SrSO_4$ (Strontium sulfate)

When pure, celestine is colorless. It can be many other colors, however, including shades of light blue, white, pale red, pale green, pale brown, or grey. The first specimen studied was faint blue. It was named celestine in 1799 by the "Father of German Geology" Abraham Gottlieb Werner. Its name comes from the Greek word coelestis which means celestial (to make us think of heaven or the blue sky). Celestine is also known by the name Celestite.

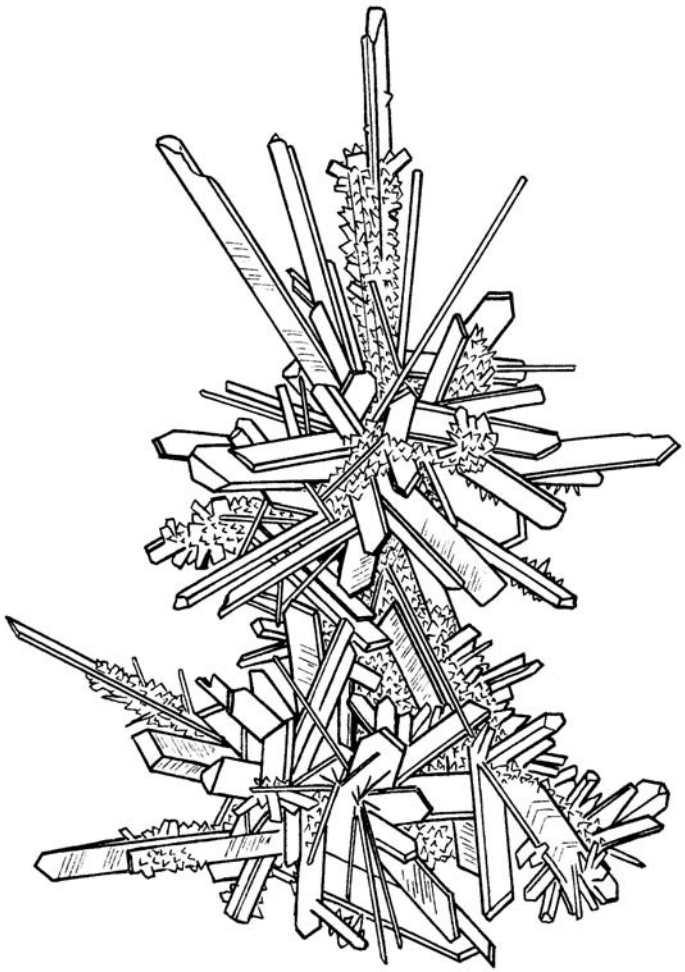


Celestine has been studied very carefully to try to determine what causes the common pale blue color. Some thought that the color comes from inclusions of another mineral, like vivianite. Some thought the color comes from the inclusion of gold trapped in the crystal. Others suggested the blue color comes from heat or irradiation. These are just a few theories. Further studies will some day unlock the mystery of what causes the "heavenly blue" color in celestine.

If left in direct sunlight, light blue celestine will slowly lose its color and become colorless.

Cavansite & Pentagonite

$Ca(VO)Si_4O_{10} \cdot 4H_2O$ (Hydrated calcium vanadium silicate)



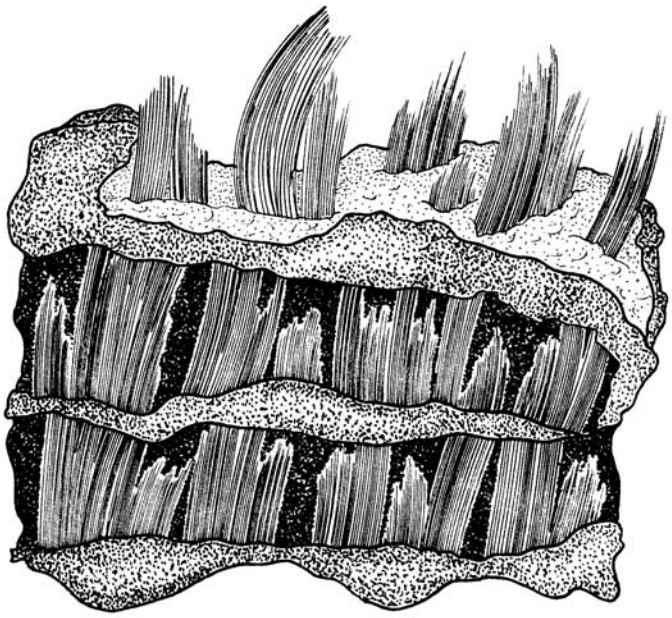
Notice that the chemical formulas of Cavansite and Pentagonite shown above are the same! Why, then, do they have different names? Mineralogists call Cavansite and Pentagonite dimorphs. Dimorph literally means two forms. Both Cavansite and Pentagonite crystallize in the orthorhombic crystal system. However, Cavansite crystallizes in the orthorhombic dipyramidal class and Pentagonite crystallizes in the orthorhombic pyramidal class. (The subject of crystallography can be difficult to understand. It takes a lot of study to learn and remember crystal systems, crystal classes and all the names and shapes that go with them. If you are interested in crystallography, you can do some research to learn more about it.)

Cavansite was first discovered in 1967 in Lake Owyhee State Park, Malheur County, Oregon. The most famous occurrence of Cavansite, however, is in the basalt known as the Deccan Traps in Poona, India. Cavansite and Pentagonite crystals are very small and almost always grow in groups, often groups that look like small balls. Because their crystals are about the same size, and because they are both a bright, electric blue, it was assumed that all bright, electric blue crystal groups were Cavansite. A close-up examination of different "Cavansite" specimens from Lake Owyhee State Park revealed that there is a difference in the crystallography. In 1973 the name Pentagonite was given to the orthorhombic pyramidal class in order to show that it is actually different than the very similar mineral, Cavansite.

Pictured above is a group of Pentagonite crystals from the Wagholi quarry complex, Ahmadnagar, Poona, Haharashtra, India. It is presented as a very large picture here so that you can color it. The actual specimen is only 4 centimeters high. It is pictured to the left in its actual size so you can see just how small the specimen is. Notice that very small specimens can actually have very well-formed crystals. Collectors call these very small specimens thumbnail specimens. Many collectors specialize in thumbnails because the crystals can be nearly perfect.

Chalcanthite

$CuSO_4 \cdot 5H_2O$ (Hydrated copper sulfate)

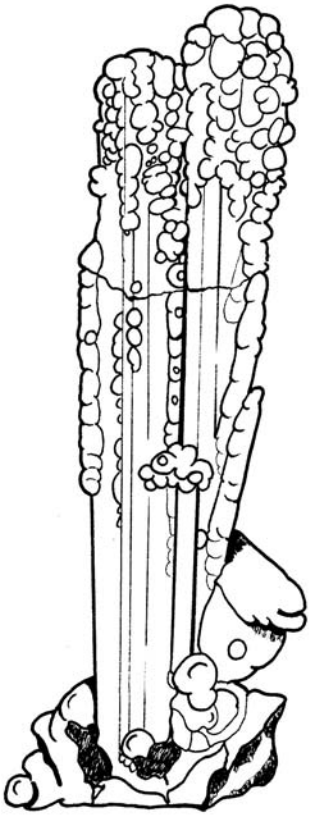


Chalcanthite is a bright blue copper mineral that can be dissolved in water. As a result, natural chalcanthite crystals are very rare. Bundles of parallel chalcanthite crystals have been found at The Planet Mine, La Paz Co., Arizona, like the specimen pictured here. Its bright blue color is the result of the copper in its crystal structure. Therefore, chalcanthite is idiochromatic.

Because chalcanthite can be dissolved in water, people have been making chalcanthite crystals which are very well-formed, large and quite beautiful. Be aware, however, that they are not made in nature and, therefore, are not technically considered a mineral. A mineral, by definition, is made by nature without human help. When made other than by nature this should be identified as a copper sulfate not chalcanthite.

Chrysocolla

$(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$
(Hydrous copper aluminum silicate)



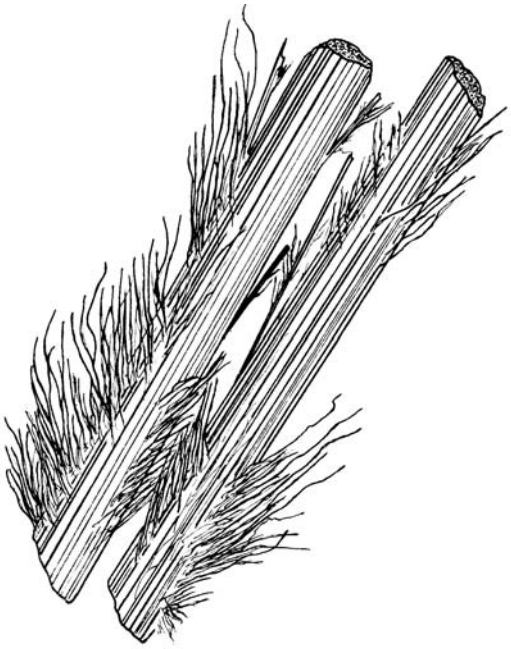
Chrysocolla is a minor copper ore mineral. It is light blue to blue-green. The specimen pictured here had an interesting history. Originally, the mineral was azurite. But due to chemical changes in the geologic environment, the azurite was transformed into chrysocolla. Mineralogists call this a pseudomorph. You have seen other pseudomorphs in this book. It has the form of azurite but the chemical composition of chrysocolla.

Chrysocolla is idiochromatic. Remember that this means that its color is created by the elements of which it is composed. In this case, copper gives it its light, powdery blue color.

The specimen pictured here is from the Ray mine, Pinal County, Arizona.

Crocidolite

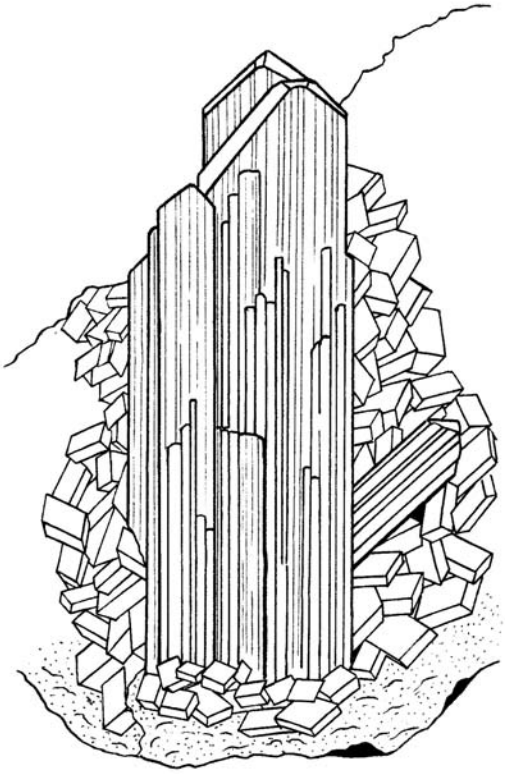
$Na_2(Fe^{2+}{}_3Fe^{3+}{}_2)Si_8O_{22}(OH)_2$ (Hydrous sodium iron silicate)



Crocidolite is a fibrous form of the mineral riebeckite. Fibrous minerals are referred to by the common name asbestos. Crocidolite is sometimes referred to as blue asbestos because of its dark blue color.

Asbestos minerals are minerals that break into very fine fibers. They were once used for many purposes because asbestos does not burn. However, it was discovered that when people breath asbestos into their lungs, it can cause cancer. Crocidolite is considered the most dangerous of the types of asbestos.

In the right geologic situation, Crocidolite fibers are altered and become quartz. The blue color and the fibrous form, however, remains. This is called a pseudomorph. The specimen looks like crocidolite but does not have the fibrous form or the same chemical composition. Mineral enthusiasts call this "Falcon's Eye" or "Hawk's Eye." It is similar to brown "Tiger's Eye" in which the crocidolite fibers have altered to limonite and then intergrown with quartz. Tiger's Eye and Falcon's Eye are used as semiprecious stones to make jewelry. Pictured here is a specimen of Crocidolite from Carn Brea Mine, Prieska District, Cape Province, South Africa.



Euclase

$BeAl(SiO_4)(OH)$
(Hydrous beryllium aluminum silicate)

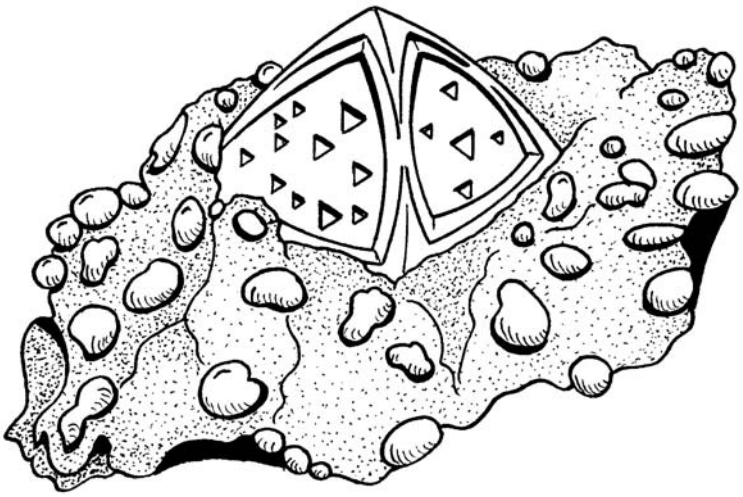
Euclase forms when beryl breaks down in pegmatite deposits. A pegmatite is an igneous deposit that is notable for the rare minerals that form in it. They are also known for containing very large crystals.

Euclase is most often found as masses or in fibrous masses. However, beautiful, slender, glassy, gemmy crystals of euclase are found and are eagerly sought out by collectors.

Its color can range from light blue to dark blue. Colorless and light green euclase crystals have also been found. Pictured here is a grouping of dark blue euclase crystals from the Gachala Mine, Boyaca Department, Colombia.

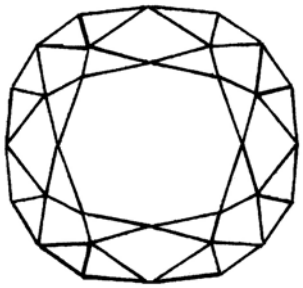
Diamond

C (Carbon)



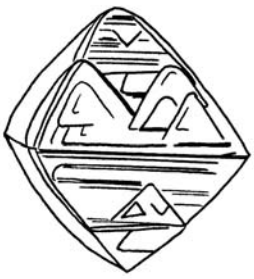
Diamond is carbon that has crystallized deep in the mantle of the earth where pressures and temperatures are extremely high which causes carbon atoms to crystallize in the isometric (or cubic) crystal system. The result is a mineral that is the hardest substance on earth.

Pure diamond is colorless. Impurities can create colors in diamonds. A colored diamond is known as a "fancy diamond." Yellow and orange diamonds have nitrogen trapped in them which absorbs blue light and reflects yellow light. Purple diamonds are colored by a distortion of the crystal structure (also called a lattice distortion. Do you remember another mineral with lattice distortion in this book?) Pink and red diamonds are also created by lattice distortion. This happens when they are still very deep in the earth's mantle. Blue diamonds are colored by the inclusion of boron in the crystal. You can see from these descriptions that fancy, colored diamonds are allochromatic minerals.



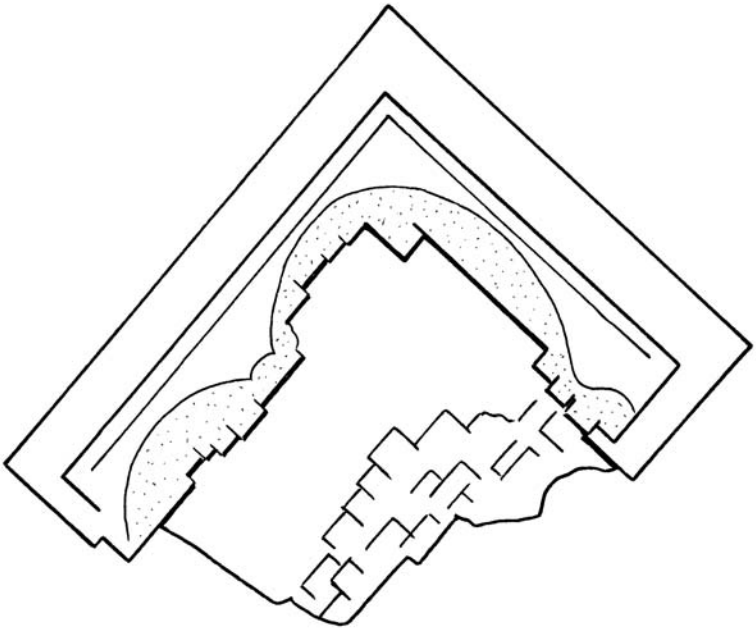
One of the most famous fancy diamonds ever found is the Hope Diamond. Today you can see the Hope Diamond in the Smithsonian Institution National Museum of Natural History in Washington, D.C. It is a large diamond, weighing in at 95.52 carats (this is equal to 0.3211 ounces or 9.104 grams). It is about the size of a walnut. Its color is described by some as "fancy dark grayish-blue." Others describe it simply as "dark blue."

No one knows for certain where the Hope Diamond was originally found. Its first owner, Jean-Baptiste Tavernier claimed it was found in India in the 1600s. When he obtained it, it was an even larger stone, much larger than the finished Hope Diamond we can see today. After a very long and interesting history, it was given to the Smithsonian Institution in 1958 by famed jeweler, Harry Winston, where it would be kept at the National Museum of Natural History. It would be the centerpiece for a new national gem collection. Winston mailed this fabulous stone to the Smithsonian in a box wrapped in brown paper. He insured it for $1 million!



Fluorite

CaF_2 (Calcium fluoride)

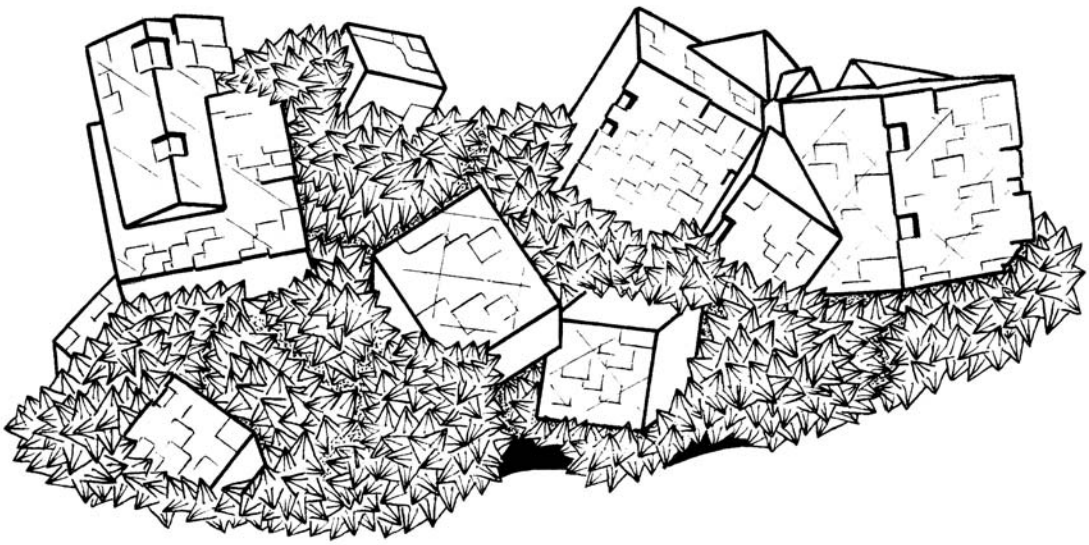


Fluorite can be found in a rainbow of different colors. Colorless, white, light purple, dark purple, yellow, black, pink, green, and shades of blue. It is not unusual for a single fluorite crystal to have two or more colors within it.

Pictured to the right is a portion of a fluorite cube. The outer edge of the upper portion is light blue. The section from the inner double line to the smaller, central portion is purple. The central, lower portion is yellow. This amazing, multi-color specimen is from the Cave-in-Rock region of Illinois.

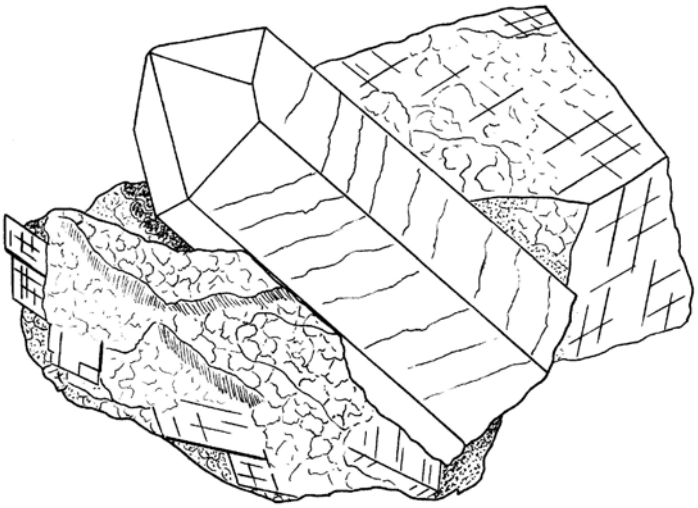
Below is a group of light blue fluorite crystals sitting on a matrix of small quartz crystal points. (When small crystals grow together like this, mineralogists describe them as "drusy".) This stunning specimen is from Spain.

The blue color in fluorite is caused by a defect in the crystal. Mineralogists call this a lattice defect. If the number of lattice defects increases, the blue color gets stronger. Mineralogists say that blue color in fluorite can also be due to the presence of Rare Earth Elements (REE's) like cerium, europium, gadolinium, lanthanum, yttrium and others.



Fluorapatite

$Ca_5(PO_4)_3F$ (Calcium phosphate fluoride)

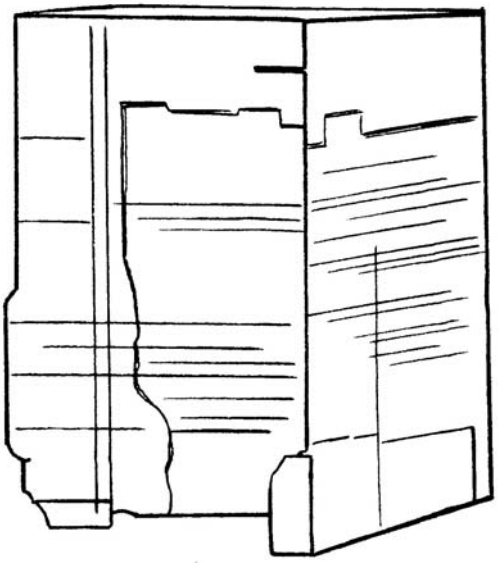


Apatite is the most common phosphate mineral. The name Apatite is not for a single mineral species. It refers to a group of minerals which have similar physical properties as well as similar chemical formulas. Fluorapatite has fluorine in its crystal structure. Chlorapatite has the element chlorine in its crystal structure (Ca5(PO4) 3Cl).

Apatite is found in a number of different colors. It can be brown, white, gray, green (a variety that is sometimes called Asparagus Stone), yellow, deep purple, violet and reddish, and light blue to dark blue. Pictured here is a large blue fluorapatite in salmon-orange calcite from the famous mineral region of Bancroft, Ontario, Canada. Fluorapatite is an allochromatic mineral. The blue color is created by the exchange of electrons from the element oxygen to the element manganese that is trapped in the apatite crystal. (This may sound very confusing. When you study chemistry in school, this will all begin to make more sense to you!)

Halite

NaCl (Sodium Chloride)

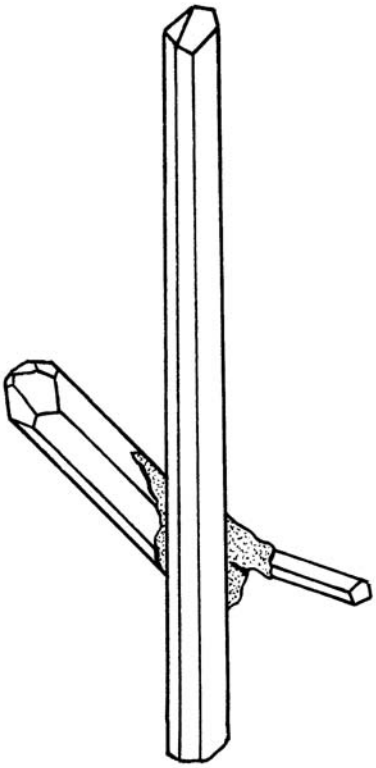


Pure halite is colorless. Impurities can color halite black. At Searles Lake in Trona, California, the halite crystals are light pink. The pink color is created by the inclusion of bacteria in the crystals. Remember that this is called allochromatic because its color comes from the inclusion of another element or material.

Blue halite, like this specimen from Carlsbad, New Mexico, is also allochromatic. In this case, it gets its color from defects in the halite crystal lattice caused by natural radiation. Irradiated halite can also be deep purple.

Jeremejevite

$Al_6(BO_3)_5(F,OH)_3$
(Aluminum borate with fluoride and hydroxide)



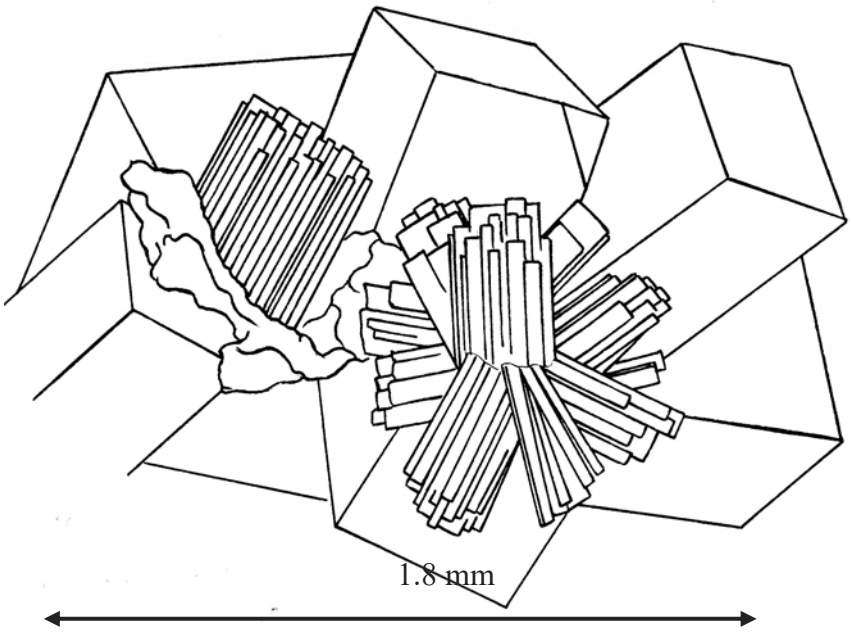
Jeremejevite is colorless when pure. However, it can be a light yellow-brown color. It can also be light blue, similar to aquamarine. Usually it forms very small crystals. However, it has been found in crystals that are both gemmy and large enough to allow them to be cut into gemstones.

Blue jeremejevite is considered one of the rarest gem minerals. Gem-quality crystals were found in the African nation of Namibia in 1973. Pictured here is one of those very rare jeremejevite specimens.

Kinoite

$Ca_2Cu_2(H_2O)_2(Si_3O_{10})$
(Hydrated calcium copper silicate)

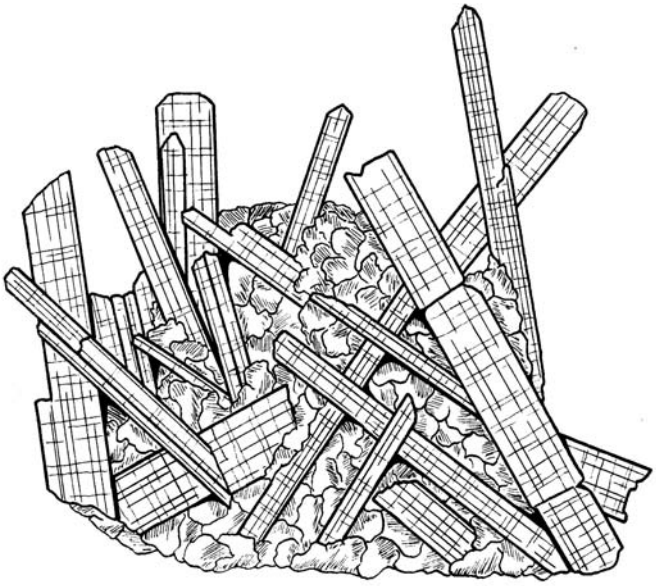
Kinoite is a rare copper silicate mineral that has only been found in three localities in the world. One of those localities is the Christmas Mine, Christmas, Gila County, Arizona. The specimen pictured here is from the Christmas Mine. What you see here is what mineralogists call a micromount specimen. Though it is a large drawing, the actual specimen is only 1.8 millimeters long!



Like many other minerals in this book, kinoite is idiochromatic: it gets its color from the copper in its chemical formula. Kinoite is transparent and deep blue.

Kyanite

Al_2SiO_5 (Aluminum Silicate)



Kyanite can be found in a variety of different colors. It can be white, pink, green, black and even orange. The most common color for kyanite, however, is blue. In 1789, the famous German mineralogist, Abraham Gottlob Werner, named this mineral after the Greek word kyanos which means deep blue.

Kyanite is an allochromatic mineral. Its common blue color is created by a transfer of an electron between atoms of iron. Remember that this is called a "charge transfer."

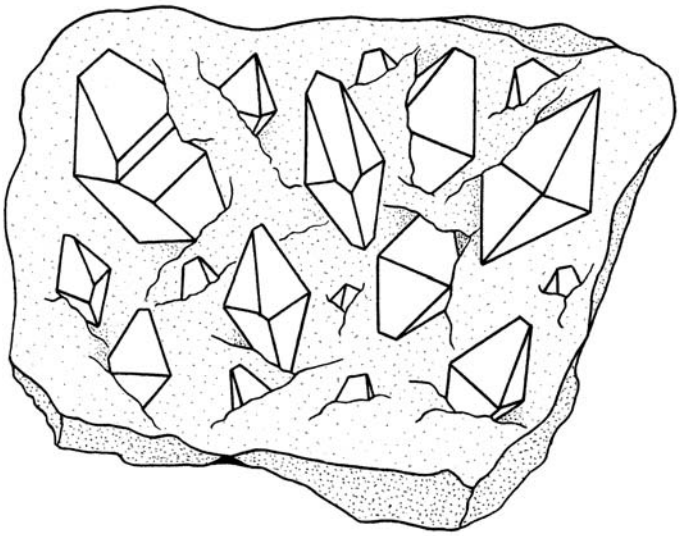
Kyanite has an interesting and unique physical property. If you test its hardness across the crystal you will discover it is 6.5 to 7. However, if you measure its hardness along the length of the crystal, you will discover it is 4.5 to 5.

Pictured here is a group of blue kyanite crystal "blades" on white to tan quartz from Barra de Salinas, Minas Gerais, Brazil.

Lazulite

$(Mg,Fe)Al_2(PO_4)_2(OH)_2$

(Hydrous magnesium iron aluminum phosphate)



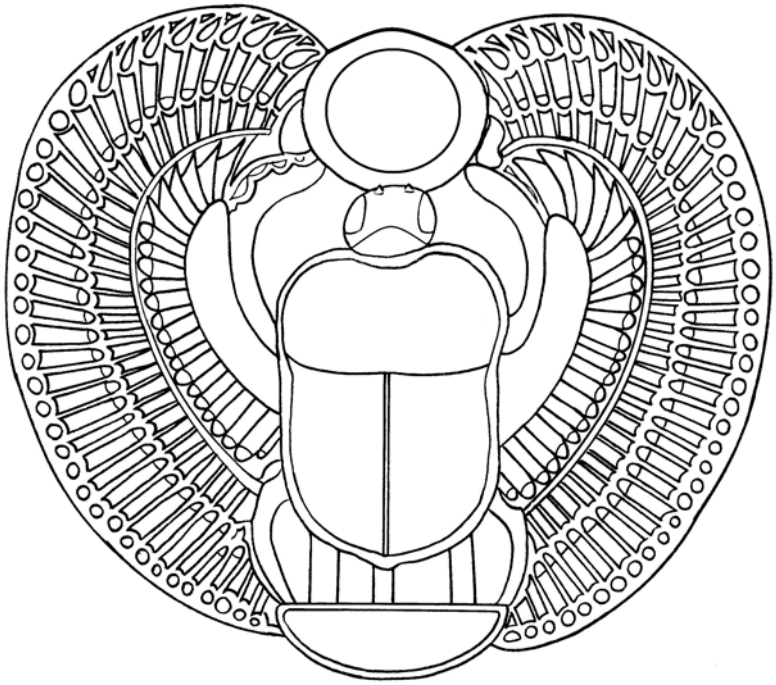
Lazulite contains the elements magnesium and iron. Its light to dark blue color comes from the iron in its crystal structure. Therefore lazulite is idiochromatic. Beautiful, large crystals of lazulite (up to 2 inches long) are found at Graves Mountain, Georgia, where they are found in the metamorphic rock, quartzite.

Lazulite was named in 1795. Its name comes from an Arabic word which means heaven. This was chosen because of the light blue color of some lazulite crystals.

Notice that the name lazulite is very similar to the mineral species called lazurite. Look at their chemical formulas. You will notice that they are very different mineral species. Lazulite is a phosphate mineral; lazurite a sulfate. Lazulite crystallizes in the monoclinic crystal system; lazurite in the isometric (cubic).

Lapis Lazuli

The Mineral Famed for its Color



Lapis Lazuli (also called Lapis) is a metamorphic rock that is composed of the minerals lazurite, sodalite, calcite and pyrite. It has been mined in Afghanistan for thousands of years. Cultures from all over the world have sought out Afghan Lapis because of its deep blue color which is decorated with white calcite and flashes of brassy-yellow, metallic pyrite.

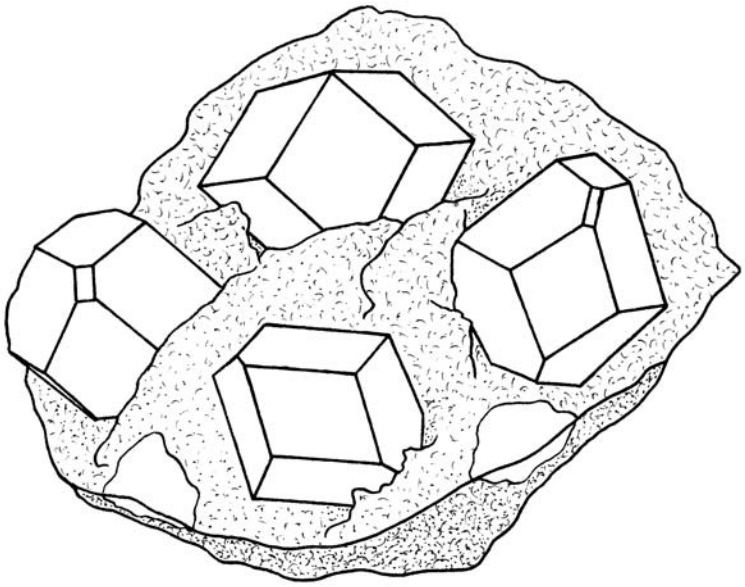
The ancient Egyptians made carvings out of Lapis Lazuli from Afghanistan. Pictured here is a beautiful winged scarab from ancient Egypt. The large scarab in the middle (a scarab is a carving of a beetle) is deep blue Lapis Lazuli. The other minerals in the wings are red carnelian, green turquoise and feldspar. All these semiprecious stones are set in pure gold. This famous work of art was discovered in King Tutankhamun's Tomb in the Valley of the Kings in Egypt and was created for his burial and was placed on his chest.

Europeans brought Lapis Lazuli to Europe in the Middle Ages. It was ground into a fine powder and mixed with other materials to make a very special and expensive paint called ultramarine. Ultramarine paint was used by the master painters like Vermeer. It was often used to paint the clothing of Aristocracy.

The name Lapis is the Latin word for stone. The word Lazuli can be traced all the way back to an ancient Persian word lāžavard which is the name for this stone in Persian. Words for "blue" in many different languages come from this ancient Persian word. For example, the English word azure, the French word azur, and the Italian word azzurro all come from the Persian word lāžavard (notice that they all look alike!)

Lazurite

$(Na,Ca)_8(Al,Si)_{12}O_{24}(S,SO_4)$
(Sodium calcium aluminum silicate sulfate)



Lazurite is the blue mineral in the rock known as Lapis Lazuli (which also contains calcite and pyrite). It belongs to a group of similar minerals that are called the Sodalite Group. Other minerals in this group are sodalite, hauyne, nosean, tsaregorodtsevite, and vladimirivanovite. You may not have heard of these minerals before. Look them up in a good book or on the internet to learn more about them. Look carefully around the Tucson Show® and you might spot specimens of these rare minerals.

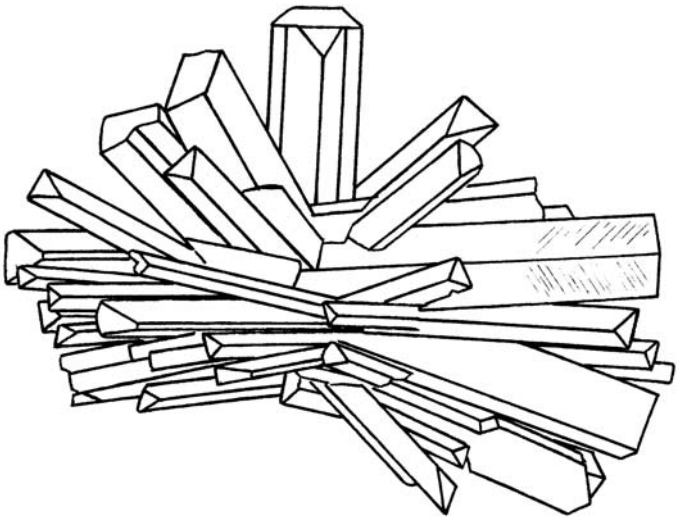
Lazurite is named from the Persian word lazhward which means blue, because lazurite is dark blue.

Linarite

$PbCu(SO_4)(OH)_2$ (Hydrous lead copper sulfate)

Linarite has been described as having an "intense, pure blue color." It looks a lot like bright blue azurite. A simple chemical test can distinguish linarite from azurite: azurite reacts with dilute hydrochloric acid where linarite does not.

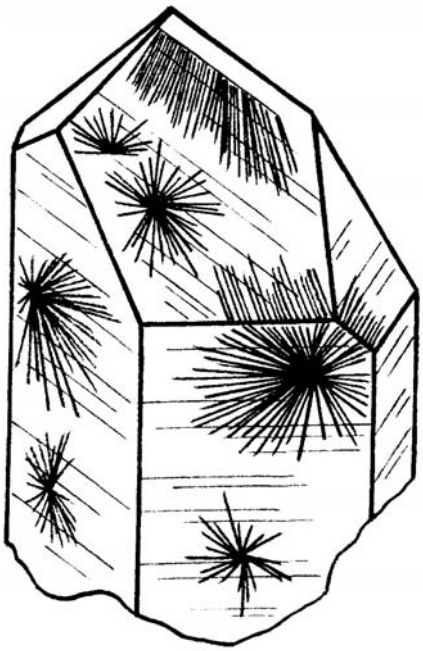
Linarite crystals up to 2 inches long have been found. Quite often, though, it is found as microscopic crystals. There are other mineral species that are found only as microscopic crystals, some of which are described in this book. Mineral collectors who specialize in microscopic crystals are known as Micromounters.



Pictured here is a linarite crystal group from the Monte Trisa Mines, Mercanti Valley, Veneto, Italy.

Papagoite

$CaCuAlSi_2O_6(OH)_3$
(Hydrous calcium copper aluminum silicate)



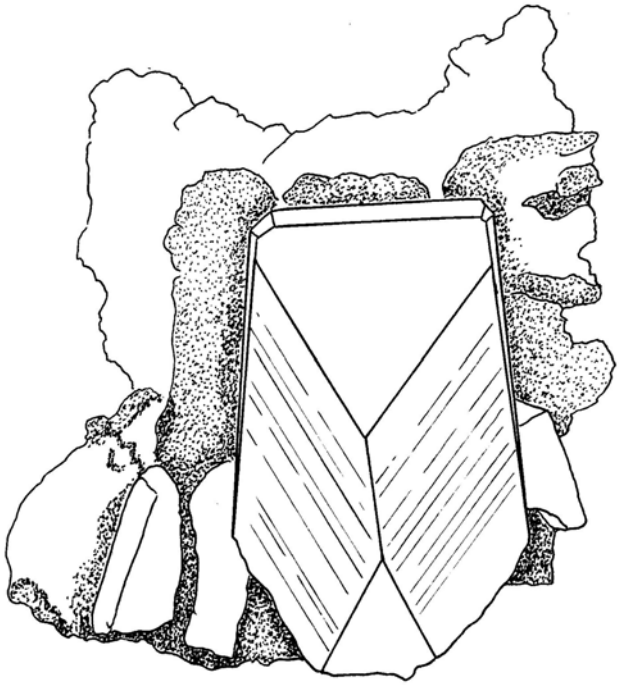
Papagoite is a rare silicate mineral. It was first discovered in 1960 in Ajo, Arizona. It was named after the Native American peoples who live in that area, the Sand Papago peoples. (Today they are known as the Tohono O'odham peoples.) The only locality where papagoite has been found in the United States is Ajo. However, it has also been found in Slovakia, Namibia and South Africa.

Papagoite's bright blue color is its most notable feature. The copper in its crystal structure creates this color. Therefore, it is an idiochromatic mineral.

It is found with other interesting copper minerals such as aurichalcite, shattuckite, and ajoite. In South Africa, delicate sprays of papagoite have been found inside clear quartz crystals, like the specimen pictured here. This specimen came from the Messina Mine, Musina, Vhembe District, Limpopo Province, South Africa.

Phosphophyllite

$Zn_2Fe(PO_4)_2 \cdot 4H_2O$ (Hydrated zinc iron phosphate)

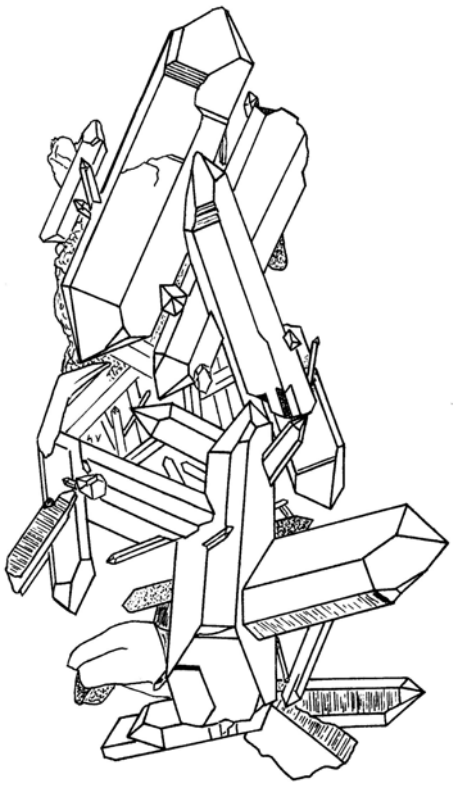


Phosphophyllite is a beautiful, rare blue to blue green mineral. The best phosphophyllite crystals were found in Unificada Mine, Cerro de Potosí, Potosí Department, Bolivia, like the one pictured here. They are large, well-crystallized and gemmy. It has been found in other localities (Germany and New Hampshire, USA) but not in crystals as large, or as well-formed and clear as those found in Bolivia.

Phosphophyllite was named after the fact that it is a phosphate mineral (phosphor-) and the Greek word phyllos which means leaf. This is a reference to its perfect cleavage.

Quartz

SiO_2 (Silicon dioxide)



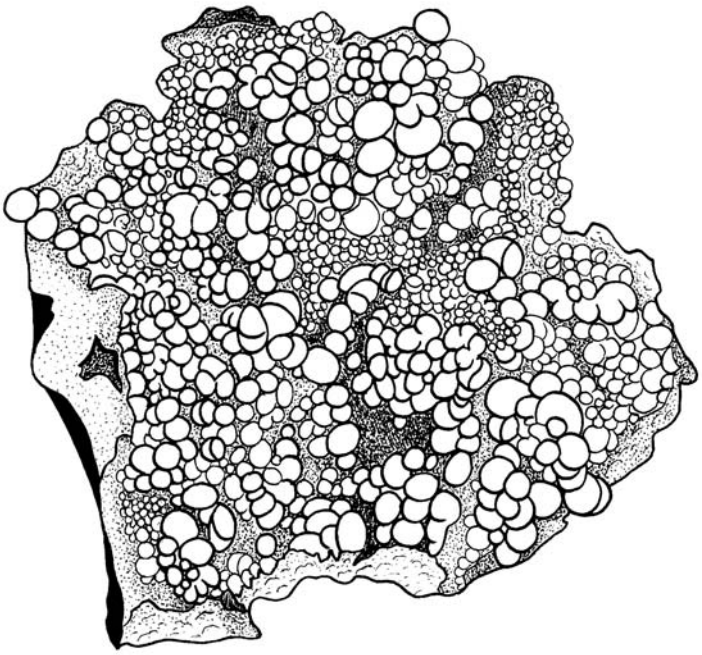
Quartz is the second most common mineral in the Earth's continental crust. (The first most common is feldspar.) Pure quartz is colorless. However, inclusions of compounds and other minerals can color quartz almost any color of the rainbow including white, green, red, brown, yellow, orange, black, pink, purple and blue. For example, very fine rutile inclusions can create the lovely pink of rose quartz. Iron can color quartz brown. Iron oxide can color quartz bright red.

Compared to the other color varieties of quartz, blue quartz is very rare. The blue color is created by the inclusion of tiny particles of other minerals like dumortierite or fibrous riebeckite (also known as crocidolite). Because the color is created by the inclusion of other minerals, quartz is an allochromatic mineral.

Rosasite

$(Cu,Zn)_2(CO_3)(OH)_2$ (Hydrous copper zinc carbonate)

Rosasite contains the metals zinc and copper. When it is found in large enough quantities, it could be a minor zinc and copper ore. It was first discovered in 1908 in the Rosas Mine, Sardinia, Italy. It was clearly named after this locality. Rosasite looks a lot like aurichalcite but is harder.

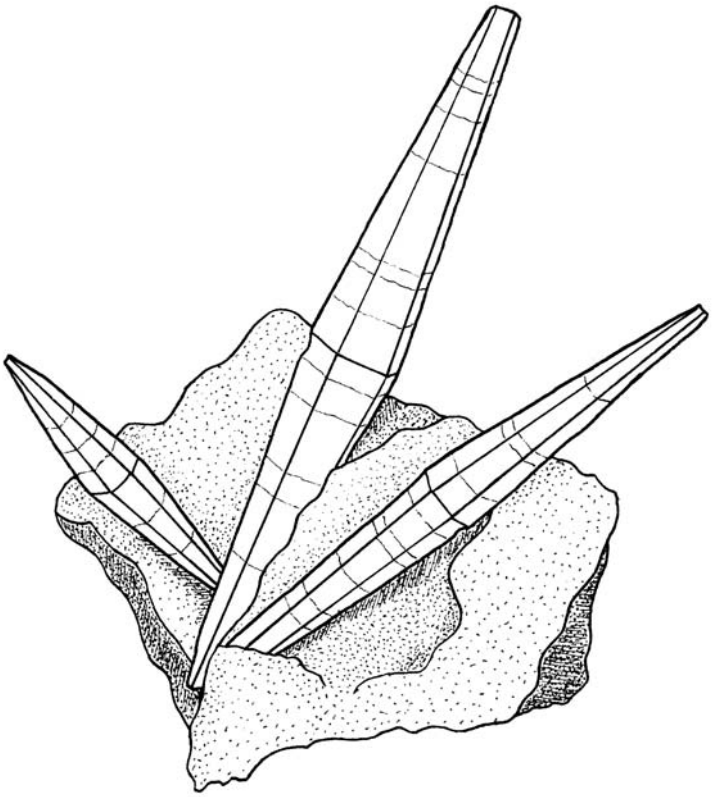


Its color can be blue, blue-green to green, and even sky-blue. It is found as groups of rounded balls like the specimen pictured here. Mineralogists call this form botryoidal which means grape-like because it can obviously look like a bunch of grapes.

The specimen pictured here was found in the Silver Bill Mine, Cochise County, Arizona.

Sapphire

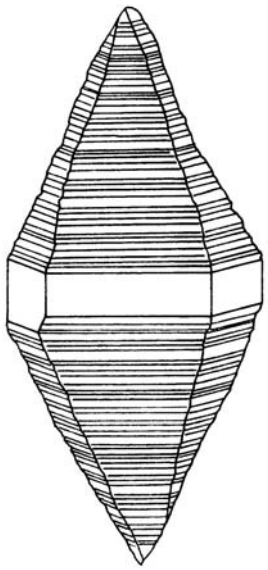
Al_2O_3 (Aluminum oxide)



Sapphire is used to refer to colorful, blue corundum crystals. The name sapphire is from the Greek word sappheiros which means blue stone. The shade of blue can range from greenish-blue to deep blue to purple-blue.

Technically, the name sapphire is used to refer to any corundum specimen that is not red. Red corundum is called ruby. Yellow, blue, green and pink sapphires are also known. As a group, colorful sapphires are called fancy sapphires. (See the section on Diamond. Colorful diamonds are called fancy diamonds.)

The blue color in sapphire is caused by the addition of the elements titanium and iron to the corundum crystal. The red color in rubies is caused by the inclusion of the element chromium.



Like so many other minerals you have encountered in this book, sapphire and ruby are allochromatic.

Scientists discovered that when sapphire is heated to very high temperatures, the color will become deeper blue. As a result, many average sapphires are heat treated to make them more desirable as gemstones.

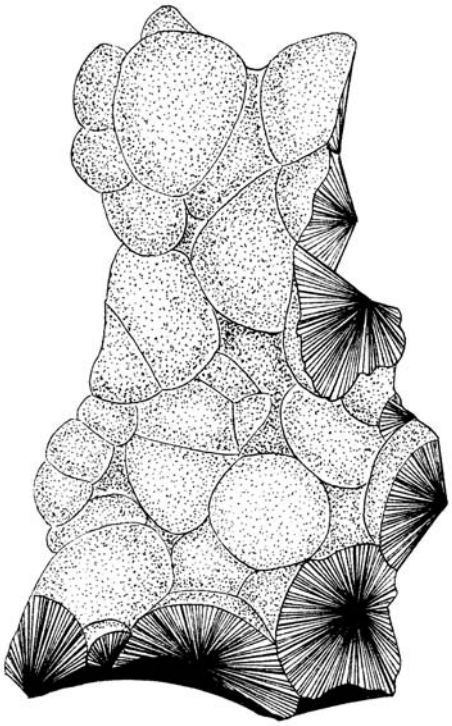
Sapphire and ruby were among the very first gemstones that were created artificially in a laboratory. Synthetic sapphire may have been made in the laboratory, but it has the same chemical, physical and optical properties as natural sapphire.

Pictured above: Natural sapphire crystals on matrix from San Jacinto Mountains, Riverside County, California.

Left: A single, doubly-terminated sapphire crystal from Sri Lanka. A "doubly-terminated" crystal is a crystal that has well-formed faces at both ends of a single crystal.

Shattuckite

$Cu_5(Si_2O_6)_2(OH)_2$
(Hydrous copper silicate)



Shattuckite was first discovered in 1915 in the Shattuck Mine, Bisbee, Arizona. The Shattuck Mine was named after Lemuel C. Shattuck, a Pennsylvania businessman who moved to Arizona where he founded a bank, ran a beer hall, and had business in cattle and water rights, to name a few of his varied business interests.

The locality where a mineral is first discovered is called its type locality. So, the Shattuck Mine is the type locality of shattuckite.

Shattuckite is an uncommon, vivid light-blue mineral species. It is idiochromatic: it gets its color from the copper in its crystal structure.

Shattuckite frequently forms in rounded masses like this specimen. When the "balls" are broken open, you can see that they are made of thousands of individual, needle-like crystals that grow out from a central point. These are called radiating crystals.

The specimen pictured here is from the Tantara mine, Shinkolobwe, Kanga, Republic of the Congo.

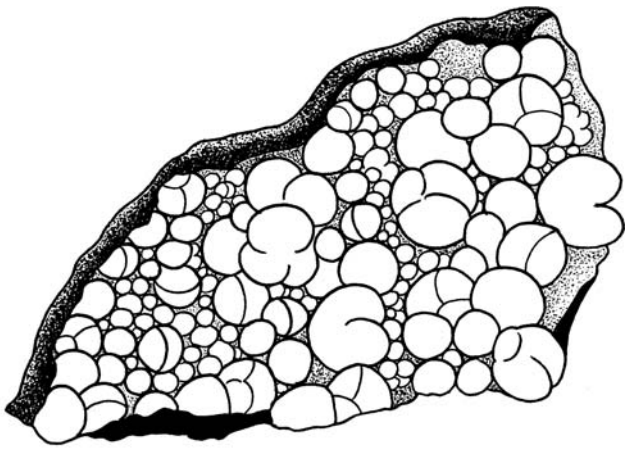
Smithsonite

$ZnCO_3$ (Zinc carbonate)

Smithsonite was named after James Smithson, the English scientist who donated his fortune to the United States to establish our national museum, The Smithsonian Institution. Smithsonite can be found as rounded, botryoidal masses like the specimen pictured here. It can also be found in excellent, well-formed crystals.

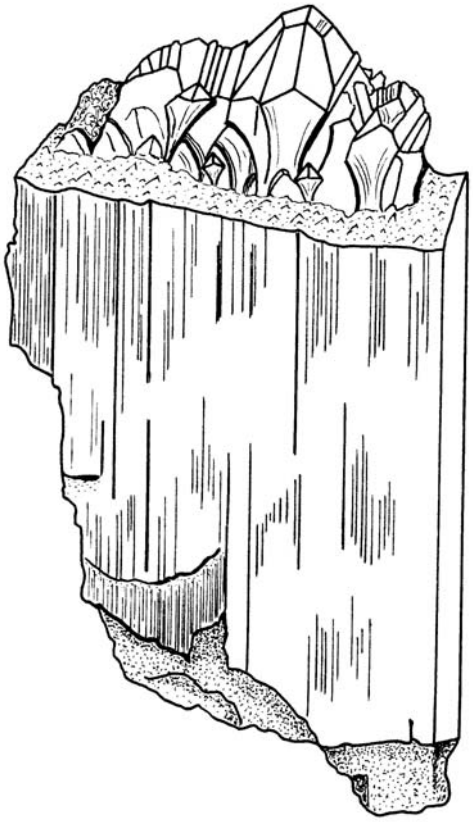
At one time mineralogists thought that smithsonite and hemimorphite were the same mineral. It was eventually discovered that smithsonite is a zinc carbonate mineral while hemimorphite is a zinc silicate mineral. Smithsonite is also known as zinc spar. Spar is the word used to describe glassy minerals that break easily on cleavage planes.

Pictured here is a smithsonite specimen from the Silver Bill Mine, Cochise County, Arizona. Smithsonite can be pink to purple, yellow, green and blue. This specimen is light blue, a rare color for smithsonite.



Tanzanite

A gem variety of Zoisite.



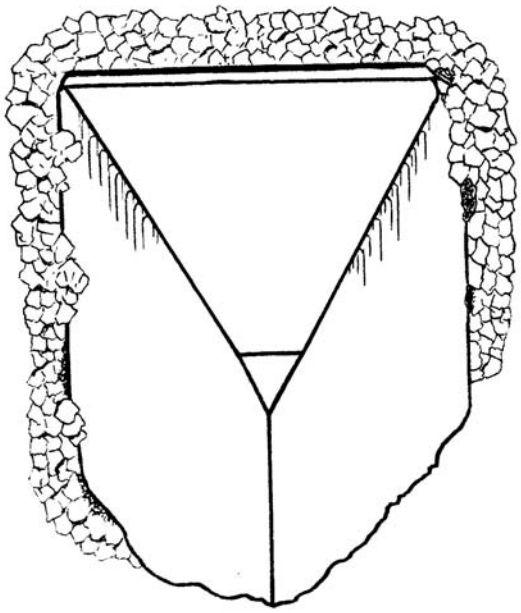
$Ca_2Al_3(Si_3O_{12})(OH)$
(Hydrous calcium aluminum silicate)

When it comes to color, tanzanite is a unique mineral. A single tanzanite crystal can have up to three different colors, depending on which way you look at it. In the world of mineralogy, this is called trichroism which means, literally, three colors. Look at a tanzanite crystal from one direction and it is violet. Look at it from another and it is burgundy (a deep red). Look at it from another and it is sapphire blue!

Tanzanite was first discovered in Tanzania, East Africa in 1967. The story goes that tanzanite was first discovered by local Masai tribesman cattle herders. Lightning strikes from a thunder storm started fires that burned the area. When the fires were burned out, the Masai discovered that the brown Zoisite had become purple-blue.

Pictured to the right is a large, deep blue, single tanzanite crystal topped with numerous smaller, fully faceted tanzanite crystals. This specimen, like all others, is from Tanzania. To date, tanzanite is found nowhere else in the world.

Topaz



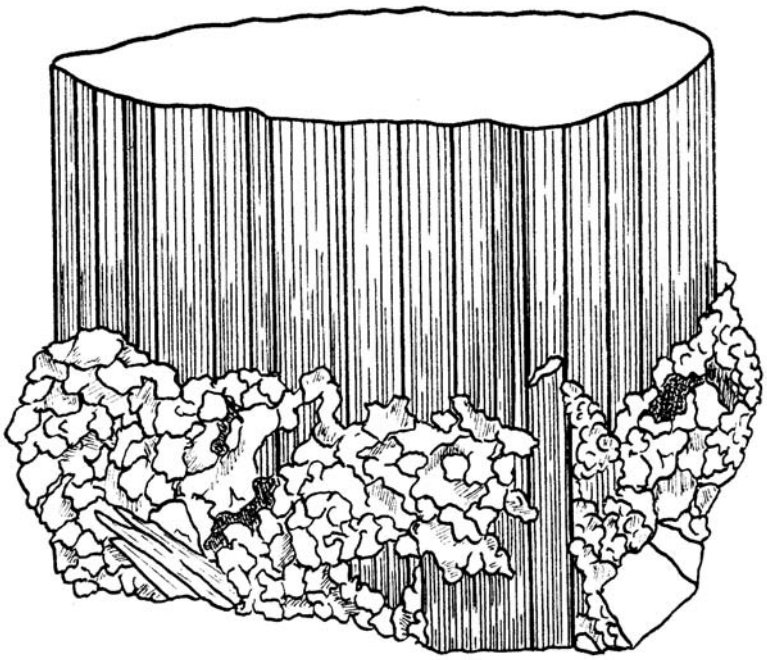
$Al_2(SiO_4)(F,OH)_2$ (Hydrous aluminum silicate)

Pure topaz is colorless. Like many other minerals, topaz is allochromatic. That is, impurities create different colors in topaz crystals. For example, when the element chromium is trapped in the crystal, topaz can be pink, red or purple. When there are imperfections in the crystal structure, topaz can be yellow, brown or blue. Scientists discovered that when colorless topaz is irradiated (that is, exposed to radiation) and then heated, it will become blue.

Tourmaline

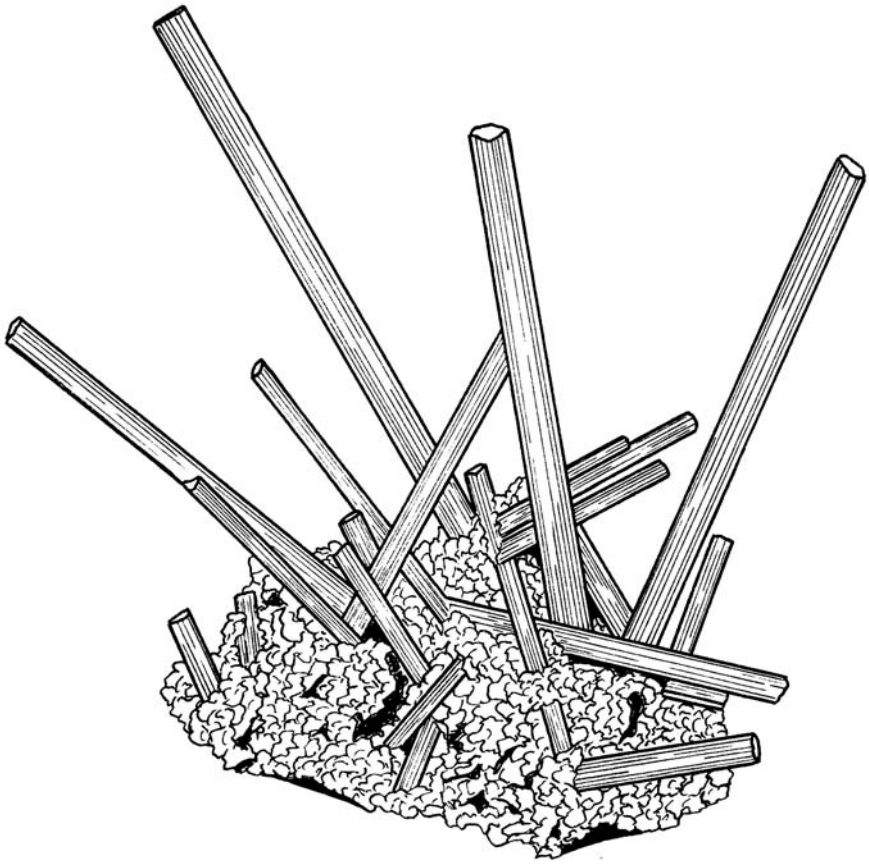
$Na(Li,Al)_3Al_6Si_6O_{18}(BO_3)_3\ (OH)_4$

(Sodium Lithium Aluminum Boro-Silicate Hydroxide)



The Tourmaline Group of minerals is rather complicated. Tourmalines are silicate minerals. Like many silicates they are hard (7 on the Hardness Scale). They form prismatic crystals which are often very thin and long, although they can also be short like the one pictured to the right.

Different elements in the crystal structure of tourmaline can give the crystals different colors. Colorful varieties of tourmaline are, as a group, called elbaite. Blue elbaite is known as indicolite. The name "indicolite" comes from the earlier name "indigolite." "Indigo" is very dark blue.

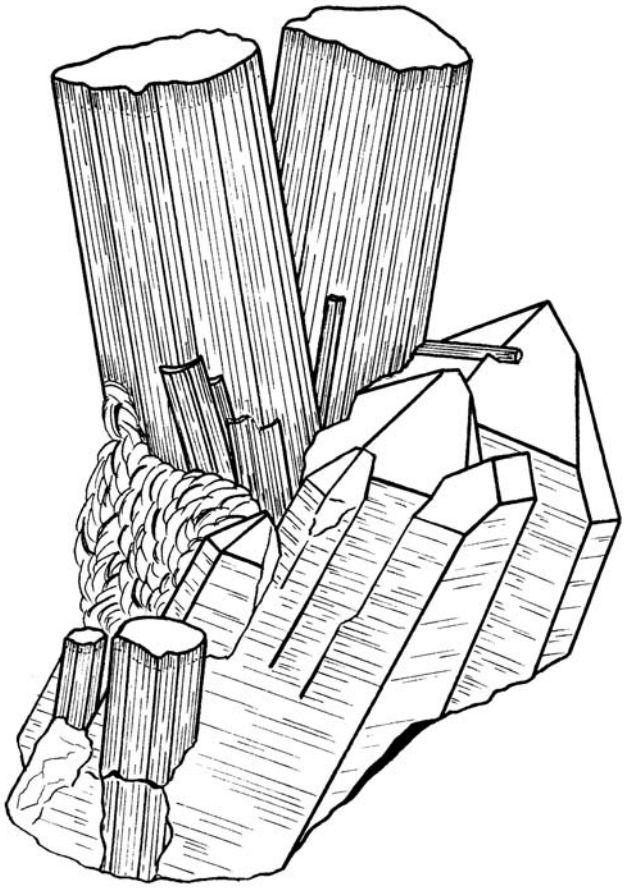


Indicolite is an allochromatic mineral. Its deep blue color is created by the inclusion of iron in the crystal.

Above: A deep blue indicolite crystal on pink lepidolite from Paprok, Nuristan, Afghanistan.

Left: Blue tourmaline "rods" on pink lepidolite from the Porcupine Pocket, Pederneira Mine, Minas Gerais, Brazil. This specimen was named "The Porcupine" by the people who collected it. It is 37 spectacular centimeters tall.

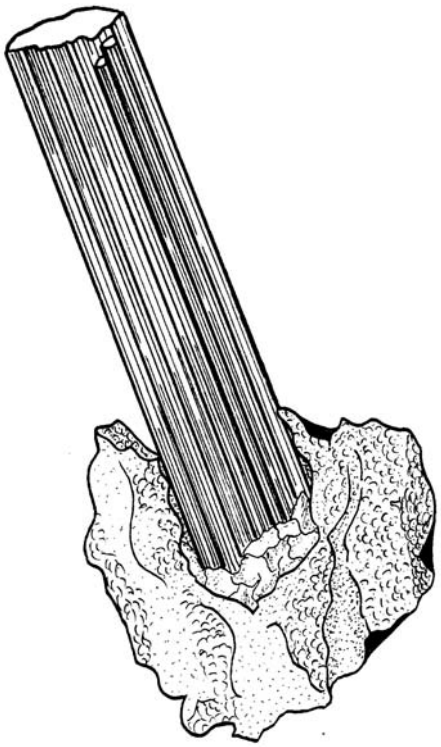
Tourmaline



Elbaite tourmalines can have two or more colors within the same crystal. Pictured here (right) is a very famous tourmaline and quartz specimen from the Tourmaline Queen Mine, San Diego County, California. This specimen has been nicknamed "The Rabbit Ears" tourmaline because of the two large tourmaline crystals that stick up a bit like rabbit ears.

The tourmaline crystals in this specimen are mostly pink, from the base right up to near the top of the crystal. However, the top of the crystals (which are drawn a bit darker here) are deep blue!

In 1972, a spectacular tourmaline pocket was discovered in the Tourmaline Queen Mine. The tourmalines were all bright pink and each was capped by a deep blue. This pocket is still known today as "The Blue Cap Pocket." Dr. Vincent Mason, who was the Director of the American Museum of Natural History in New York City at the time called this discovery, "the find of the century." A number of world-class specimens were recovered from this pocket. Others that you must look up in books or on the internet are "The Candelabra," and the "The Postage Stamp Tourmaline." The tourmalines are sitting on a matrix of light yellow-tan quartz crystals.

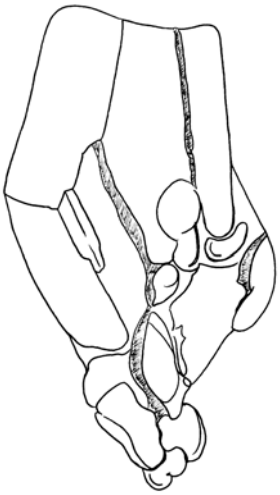


To the left is a single, deep blue indicolite tourmaline on matrix from Karibib, Namibia.

Notice that all of the indicolite specimens pictured in this book have fine lines running up and down the length of the crystal. Mineralogists call these striations. Striations can also occur in other minerals (like the quartz pictured above). You can also find striations in pyrite and apophyllite crystals.

Turquoise

$Cu(Al,Fe)_6(PO_4)_4(OH)_8 \cdot 4H_2O$
(Hydrated copper aluminum iron phosphate)



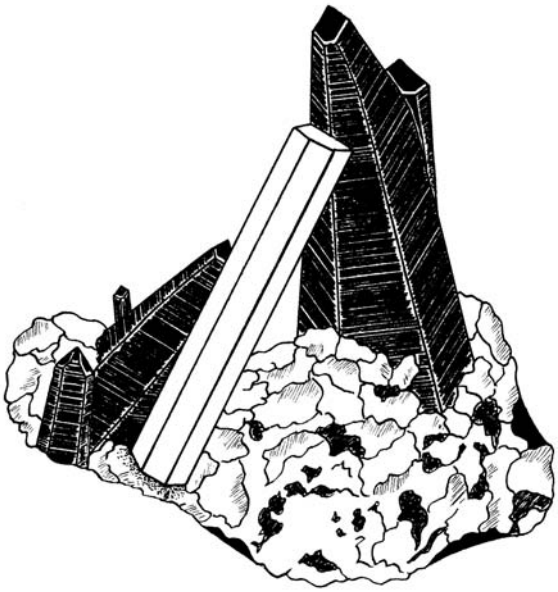
Turquoise has been valued by people all over the world as a gem and an ornamental stone for many centuries. It is blue to blue-green. It is used by Native Americans in beautiful silver jewelry. In Arizona gem-quality turquoise comes from the world famous Sleeping Beauty Mine in Globe, as well as from Kingman and Bisbee.

Turquoise is almost always found as nugget-like masses. It rarely occurs as crystals. In the United States turquoise crystals are found in the Bishop mine, near Lynch Station, Virginia. Turquoise crystals have also been found in Nevada, New Mexico and Pennsylvania. They are almost always microscopic.

The name turquoise comes from the French word for "Turkish" because it was believed turquoise was mined in the country of Turkey. History has shown that turquoise was not mined in Turkey, but it was traded in Turkish markets.

Pictured right: A turquoise pseudomorph after apatite from the Dusty Tim #1 Mine, Mina, Mineral County, Nevada.

One More Colorful Fact

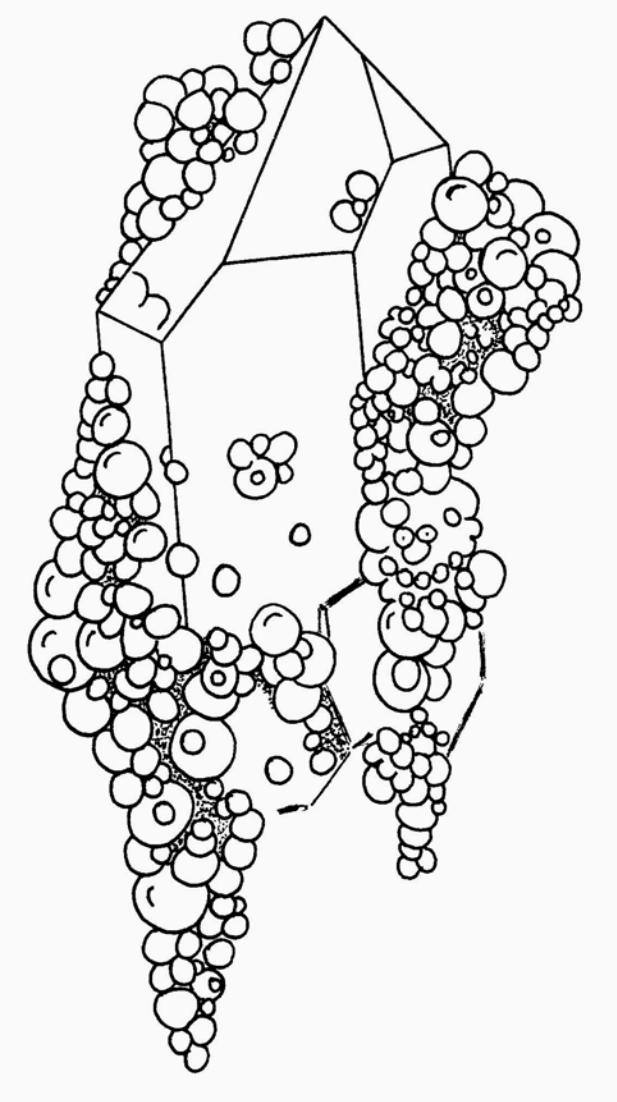


Minerals are identified by their physical properties. If you find a piece of an unknown mineral you can test its hardness, streak, cleavage, fracture, and specific gravity. You can also note its color. The combination of these physical properties will help you identify the mineral. Of all of the physical properties, color can be the least helpful. This is because many minerals can be found in a variety of different colors. Others occur in only a single color.

Some minerals, like quartz, fluorite and calcite, can be found in a number of different colors. When a mineral can occur in different colors it is described as polychromatic. When a mineral occurs in only one color, like blue azurite or green malachite, the mineral is described as monochromatic.

Pictured above: A large aquamarine crystal with smoky quartz from Mount Antero, Colorado.

Iridescent Minerals



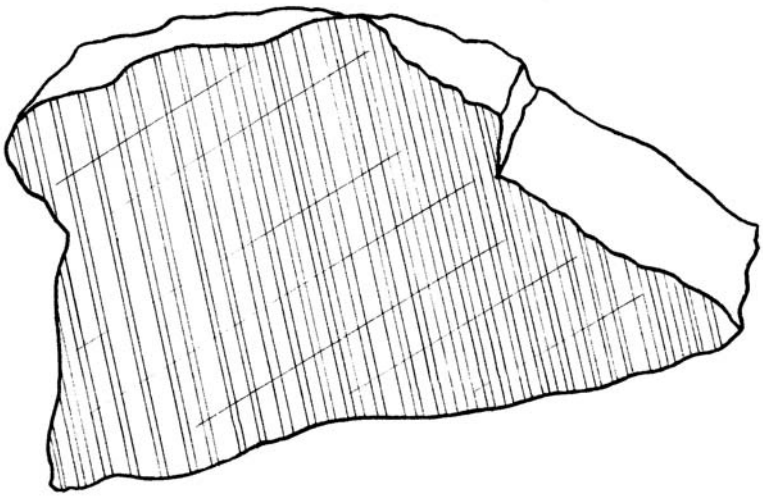
Iridescence is the property that some materials have to break light into a rainbow of many colors. Soap bubbles, oil floating on water, butterfly wings and seashells display iridescence. As you move around a soap bubble, you will see flashes of different colors of light...blue, purple, yellow, red. Scientifically speaking, this "splitting" of light into colors is called refraction. The scientific word for iridescence is goniochromism.

There are a number of minerals that also show this property of iridescence. When light bounces off of their surfaces, the light is broken (refracted) into its colors. You can see iridescence on some specimens of hematite, on bornite, pyrite, covellite, labradorite, goethite and bismuth.

Pictured to the left is a quartz crystal from Graves Mountain, Georgia that has been covered by bubbly, iridescent hematite. Color it a variety of bright colors including blue, purple, orange, yellow and green.

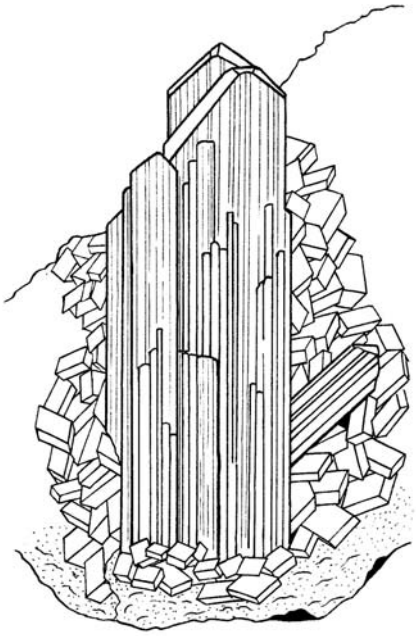
Pictured below is a specimen of the feldspar mineral labradorite. When you look very closely at the surface of labradorite, you can see hundreds of very fine, parallel lines, very, very close to one another. These lines are created by the labradorite twinning as it grew. Mineralogists call this polysynthetic twinning. A piece of labradorite is not very pretty. It is grayish and usually massive. But when the light bounces off of its surface (especially a polished surface) the specimen comes alive with a vivid rainbow of colors.

Throughout this book you have discovered minerals that are idiochromatic or allochromatic. Minerals that show iridescence are pseudochromatic minerals.



Blue Trivia

Did you ever think there could be so much to know about blue minerals? Let's see what you discovered today reading this book and looking at the beautiful blue minerals at the Tucson Gem and Mineral Show®.



A mineral whose color comes from the elements in its chemical formula is called _____.

A mineral whose color comes from inclusions of other minerals or compounds is called _____.

The scientific word for iridescence is _____.

Aquamarine gets its beautiful blue color from the inclusion of very small amounts of this element. _____

Blue is created in fluorite by a _____ in its crystal structure.

_____ is considered one of the rarest gem minerals.

Name three minerals whose names come from a word that means "blue."
_____, _____, _____

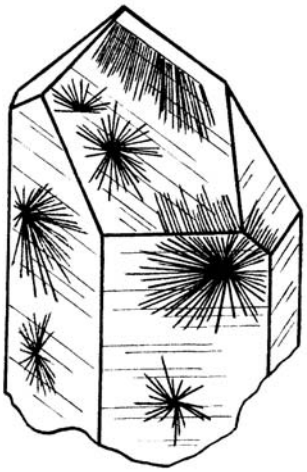
Colorful diamonds are known as _____ diamonds.

Name two blue minerals that have the exact same chemical formula.
_____, _____

Crystal specimens that can only be seen with the help of a microscope are collected by mineral collectors who call themselves _____.

Blue (and purple) color in halite is caused by natural
_____.

The light blue color in celestine might be caused by the inclusion of very small amounts of which valuable metal?
_____.



The Blue Mineral Matching Game

Match the statement in the left column with the mineral picture on the right.

A mineral that displays the property called iridescence.

A mineral that was named after the word for dark blue, indigo.

The red variety of this mineral is called ruby. The blue variety is called sapphire.

This mineral is now the official gemstone of the State of California.

A blue mineral that has two different hardnesses in the same crystal.

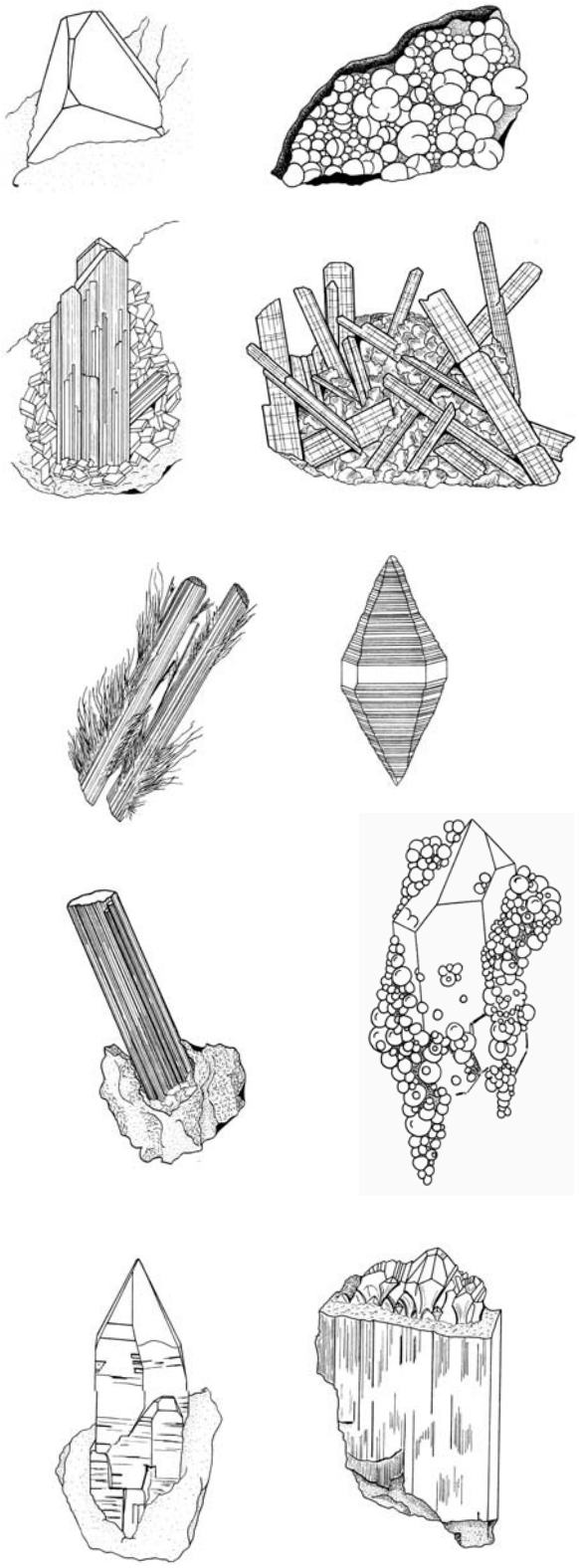
This mineral is known for its property of trichroism.

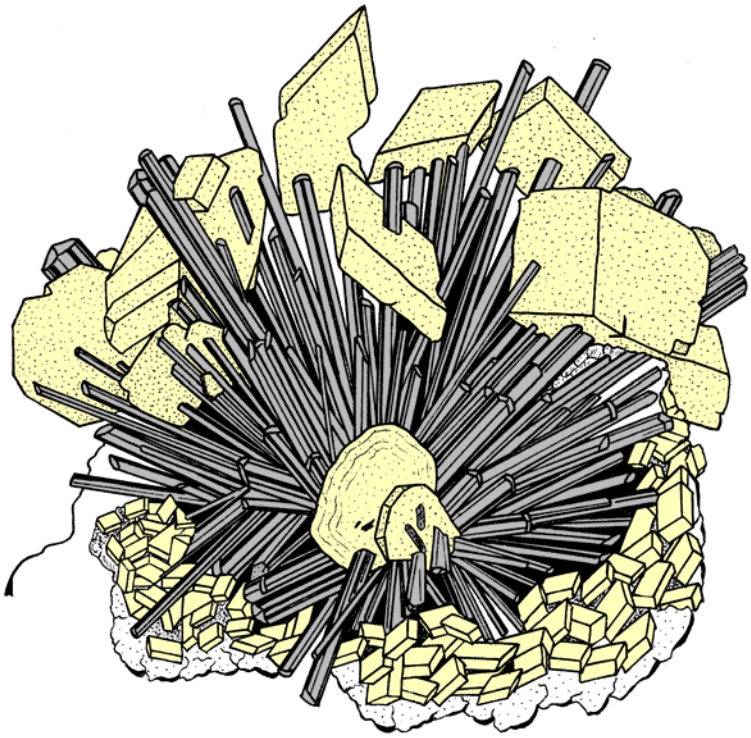
This blue mineral forms in pegmatite deposits.

This blue mineral was discovered in the famous Lapis Lazuli mines in Afghanistan.

The blue mineral that breaks into fine fibers.

A mineral named after James Smithson.





Please visit the Diamond Dan Publications website where you will find many fun and interesting books about minerals, crystals and fossils.

www.diamonddanpublications.net