

**Northwest
Micro Mineral
Study Group**



MICRO PROBE

FALL, 2015

VOLUME XII, Number 2

FALL MEETINGVANCOUVER, WASHINGTON

November 7, 2015

9:00 am to 5:00 pm

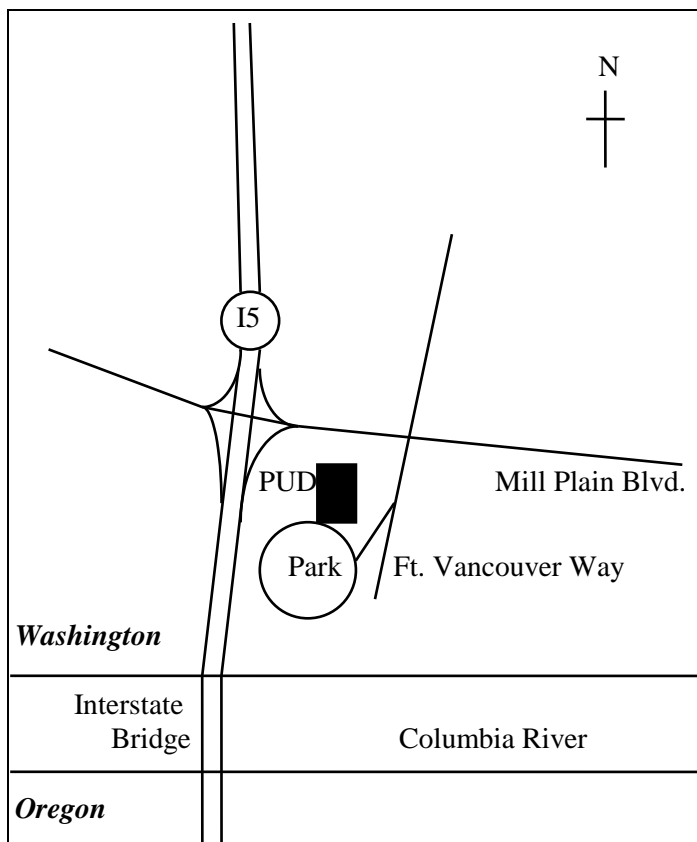
**Clark County P. U. D. Building
1200 Fort Vancouver Way
Vancouver, Washington**

We all will be glad to be able to meet again in our old haunts in Vancouver. Bring your microscopes and things to share with the group. The free table will have some extra goodies thanks to Beth (see the next page for details). Also bring some of your minerals that may fluoresce. We will have a few of the 405nm lasers for you to try out to see how they work in practice. There will be lots of time to go over the give-aways and to catch up on collecting with your friends.

As usual we will have a lunch potluck: The Club provides sandwich makings (bread, meat, lettuce, cheese, dressings, and coffee, tea, cocoa). Please bring salads, chips, pop, nuts, chili, cookies, pie, or cake to add to the lunch.

After lunch, we will have our usual business meeting and collecting location review, followed by a time for pictures. Bring what you have to share with the group.

We will start cleaning up around 4:00 pm. Dinner will be at the Country Buffet in Vancouver, where we continue to visit. Do plan to join us if you can.



Collections Need To Be Given a Second Life

Beth Heesacker

You never know what you are getting yourself into when you answer an ad on Craig's List. The ad was for a silent auction of minerals and fossils. The problem was that the auction was scheduled during the time we were going to be in Utah for the Northwest Federation of Mineralogical Societies (NFMS) meetings. I contacted the auctioneer and he let me come early to fill out my bid sheet. I found out that this was the collection of Tony Sobolik whom some of you might know.

The collection was housed in a shed and had been there for 10 years since Tony died. It had become the home for many, many critters over time. To make a long story short, I had to face many spiders, other bugs and even a mouse that ran up the side of my head as I pulled a box off of the shelves. By the way, I did not scream even though others around me did.

I ended up with a pickup load of flats and egg cartons of micro minerals, most unprocessed. According to the labels he had acquired them from the Northern and Southern Californian Mineral meetings along with the NWMM meetings. Most were dated in the 60s through 1990. All were well documented as to location, many as to mineral content and many as to the actual person he received the minerals from.

Because of the condition of the collection, I unloaded it and left it outside and did the first sort to remove mouse nests, mouse droppings, dead and live spiders, etc. outside. I carefully saved all documentation by transferring it to clean egg cartons, etc. with the labels. I then slowly went through all the specimens, sorting them by location and placing them in perky boxes or other small boxes and into trays labeled by location. Paul helped me build "mail sorters" by turning bookcases on their side and building small shelves in between the now vertical bookcase shelves for the trays. There are about 250 trays with specimens from about 130 locations around the world

There is still a lot of work to be done to bring this up to a first class collection but it is clean and safe from destruction. I do not plan on integrating the bulk of this collection with my main collection but keeping it separate. I will go through, and after identifying the minerals, pick out some specimens to integrate but this collection is so huge that it seems to want to stand on its own. It has a new second life.

Now to the reason I am letting you know about this. During the sorting into trays I selected out what I wanted to keep and put the rest back into the flats and egg cartons with their documentation (or my re-writing of the information).

At the November meeting I will have 50+ flats to place on the free tables. I am happy to share this wonderful collection with you.

Tony Sobolik's collection in its new home – my hallway.



A New Tool for Studying Fluorescent Minerals

Henry Barwood and Don Howard

Fluorescent minerals have been a fascinating sideline for many years. They have been fun to observe in a darkened room, but very hard to photograph adequately, especially for micro specimens under the microscope. But now there comes a cheap and easy alternative to the ultraviolet light that makes observing and photographing them much more feasible. We are referring to the 405nm laser.

In order to understand how this whole thing works, let us first examine how materials interact with light. When light strikes a material, several different things can happen. The most obvious is that it can be absorbed and the energy can be converted to heat. If that happens at all frequencies, the material will appear black. Alternatively, it can be readmitted at the same frequencies; if that happens at all frequencies, it will appear to be white. If only some frequencies are absorbed, say those in the blues and violet, while others are reemitted, the material will appear colored, in this case probably yellow. The color of the material will depend on what frequencies are remitted and what are absorbed.

A third possibility exists. If the material has a characteristic internal energy level below the energy of the incident light, some of that light can lose only part of its energy in the process of populating that internal level. The level can then emit light, but now at a new frequency that depends on the exact energy level. The light emitted will thus be at a different frequency than the original light that was absorbed, and it will therefore appear as a characteristic color for that material. This is the process of fluorescence.

In order for fluorescence to work, the exciting light must be at a higher frequency than the secondary light to be emitted. Traditionally, this has been light in the ultraviolet. However, it does not need to be that high a frequency. For minerals that fluoresce in the reds, yellows, or greens, violet light is at a sufficiently high frequency to excite the material. Recently, lasers have become available at a wavelength of 405nm, in the violet right at the edge of our normal vision. They come in a wide range of models. The more powerful of these can be rather dangerous. However, because all of the energy is contained in a narrow frequency range and is focused into a beam, even the least powerful is many times as efficient at producing a fluorescent response as their ultraviolet counterparts. The brightness of the beam leads to an amazingly intense response that does not require the normally darkened room to be observable.

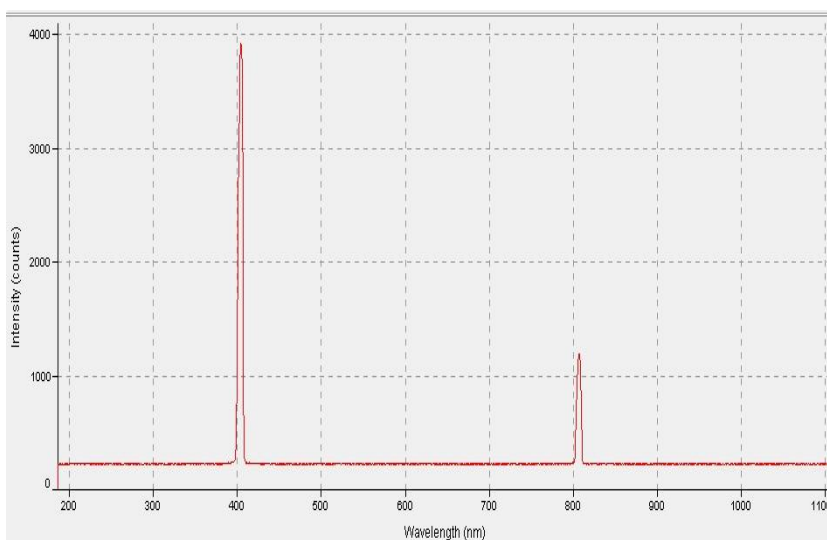


Fig. 1 *Emission spectrum of the 405nm solid state laser diode.*

The minimum tools necessary to begin to explore this new way to observe fluorescence are shown in fig. 2. The penlight is a 405nm laser rated at 5mw that can be obtained on eBay for a few dollars (beware, there is a rather long delivery time because it is shipped from China!). They operate off of two standard AAA batteries. The yellow glasses serve to block out the violet light so the other colors can be seen. Safety glasses of this type can be obtained from an industrial supply firm. The system is therefore very portable and fully useful in the field.



Fig. 2 A 405nm laser penlight and yellow safety glasses

In order to use the laser with your microscope, some other equipment and modifications will be necessary. The most obvious (and probably the most expensive) is a yellow filter to view through. I managed to find a used one at a photographic supply store in Portland. This is best rigged to be able to swing under the objective lens of the microscope, and then out of the way when you wish to use ordinary illumination, as shown in the two views below.

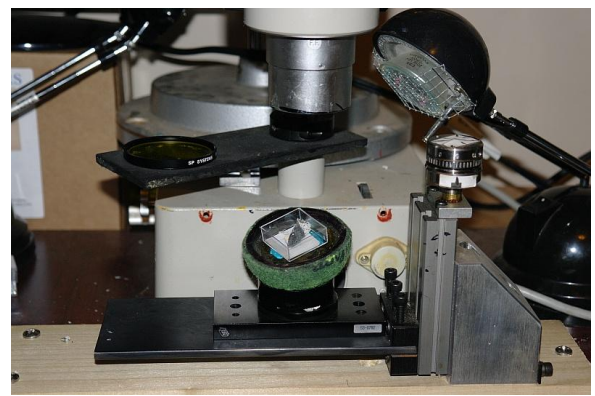
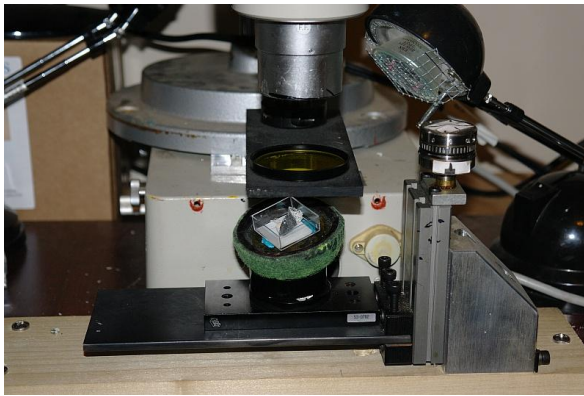


Fig. 3 Two views of Henry's microscope with a yellow filter, swung in on the left picture and out on the right.

The other piece necessary is the 405nm laser itself. The 5mw penlight will work, but it has a small spot size, and spreading the beam or using a higher magnification makes the intensity of the fluorescence barely bright enough for picture taking. Focusable 405nm diode lasers are available with higher power ratings. Ones in the 50 to 150mw range are most useful for microscope imaging. Lasers with higher power ratings than this are very dangerous and should be avoided. There are a wide variety of ways to mount the laser in some manner similar to your ordinary light source so that you have your hands free for adjustment and picture capture operations.



Fig. 4 Don's microscope, including illuminator light-pipes, with the laser pen mounted to the right and the yellow filter swung out of the way on the left.

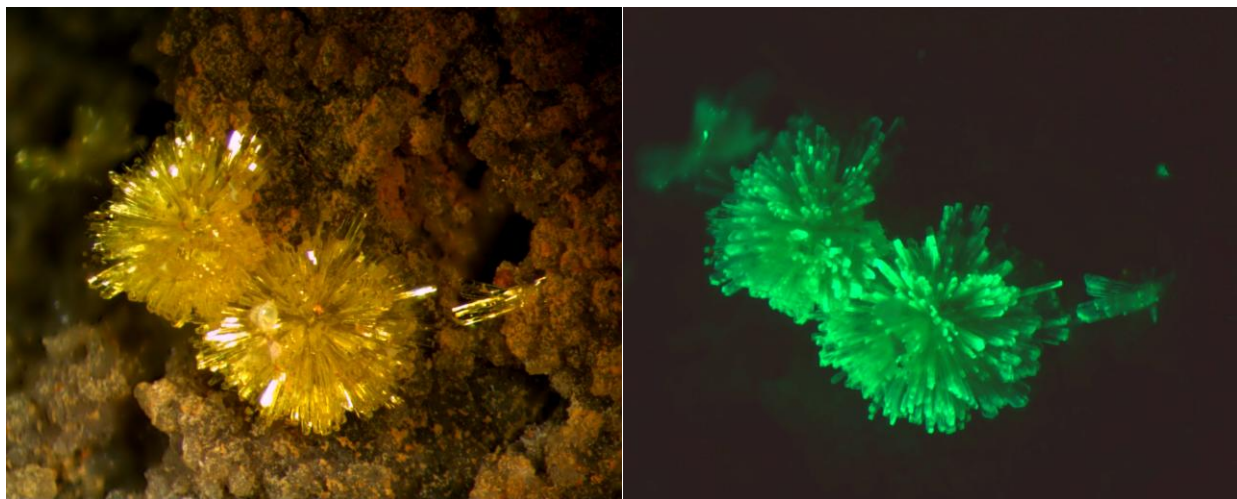


Fig. 5 A specimen of uranophane from Valentine, Texas, in ordinary light (left) and 405nm light (right). The only other adjustment made between pictures was to swing the yellow filter in place, and refocus.

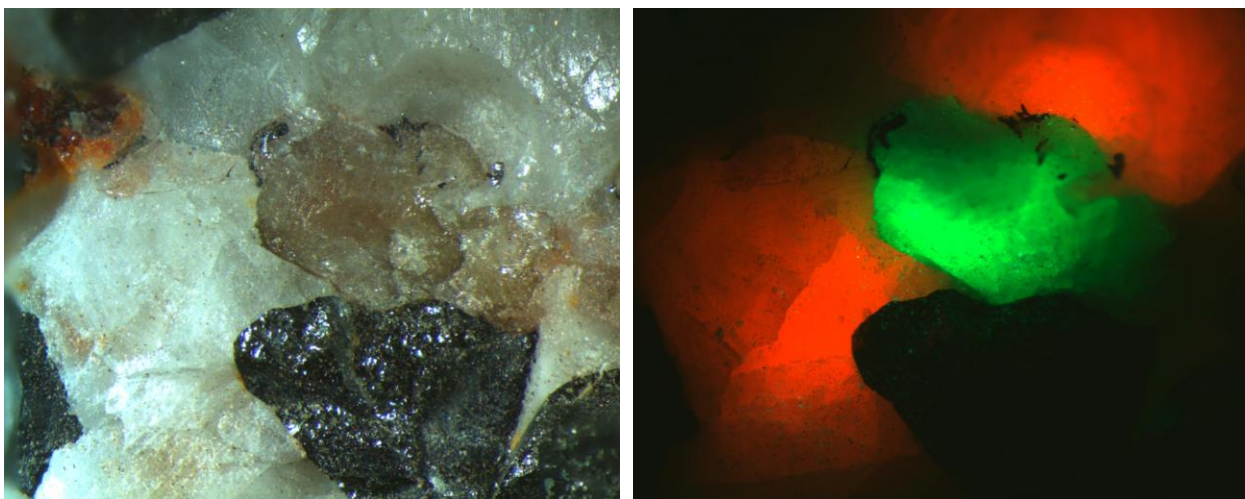


Fig. 6 Willemite (tan) and franklinite (black) in calcite from Franklin, New Jersey, taken as in fig. 5.

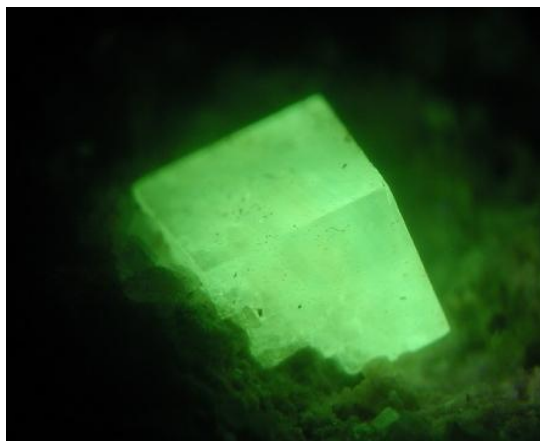


Fig. 7 Fluorite, from Bedford, Indiana

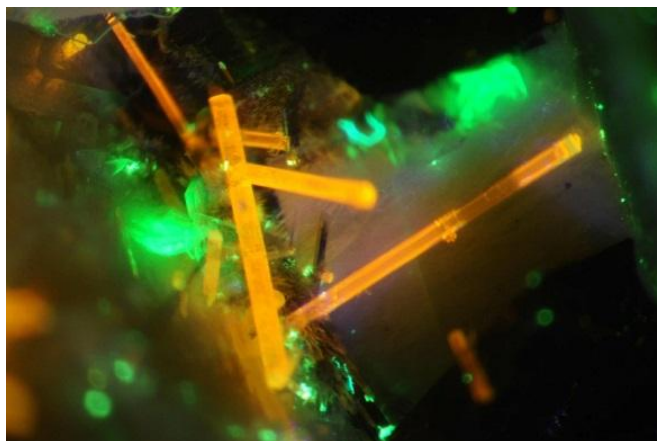


Fig 8 Fluorapatite (orange) from Little Rock, Arkansas

The fluorescent response of a mineral is much more dependent on the energy level structure of the material than it is in the nature of the radiation exciting it. Thus the colors observed with the 405nm laser are very much the same as those obtained with an ultraviolet light. Thus, many uranium minerals give a very strong green emission characteristic of the uranyl ion, as is seen in fig. 5. Many calcites, such as the one in Fig. 6, give a red fluorescence that is attributable to manganese impurities. These particular characteristic responses of impurities can be observed through a range of different minerals. In other cases, the impurity or configuration responsible for the given color has yet to be determined.

Just as with the long and short wave ultraviolet, the ability of the fluorescence to be excited may be different for the 405nm light than it is for the ultraviolet. Some minerals may respond more and some may respond less or none at all. Minerals that fluoresce in the blue region, like scheelite, benitoite, and zektzerite/sogdianite have very little response to the 405nm light. This is exacerbated by the need to use the yellow filter for viewing, which also filters out a portion of the blue light.

At any rate, here is a new tool to experiment with. Since it is very inexpensive, we hope that many of you will try it out and share what you learn with the rest of us.

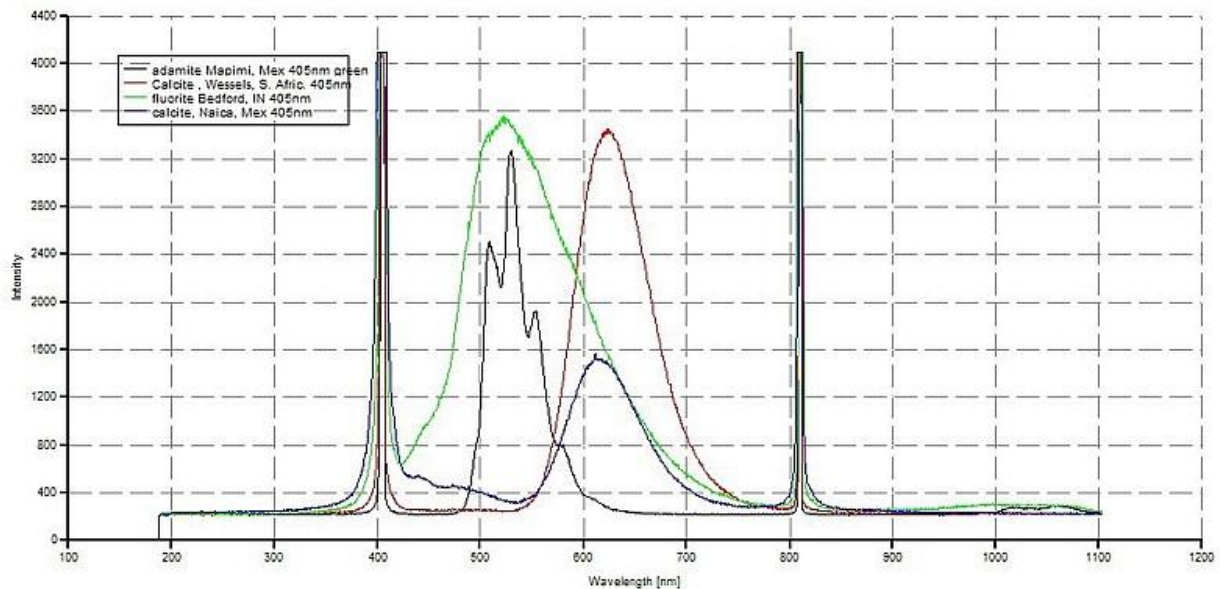


Fig. 9 Spectrographic response of several minerals to exposure to 405nm radiation. The red and black traces on the right are from calcite with manganese impurities, such as is shown in fig. 6. The black curve on the left is from adamite with a green fluorescence characteristic of uranium impurities. The trace shown in green is from fluorite with unknown impurities, shown in fig.7.

Minerals Forming Tetragonal Crystals

Don Howard

In recent issues, we have explored the systematics of cubic crystals extensively. In cubic crystals, we have all three axes of equal length situated at 90° to each other. Prior to that, we looked at rhombohedral crystals, in which all three axes were equal, but we had relaxed the condition that they had to be at right angles. In this article we wish to retain the requirement that the axes all be at right angles, but relax the condition that all axes must be equal. If we let just one of the three axes be longer or shorter than the other two, we come up with the Tetragonal system.

Traditionally, we call the different axis the *c*-axis, and the unit cell we pick is a rectangular prism with a square base. So let us begin with examining the full symmetry of such a system. In the Cubic system, you may recall that we named full symmetry as $4/m\text{-}32/m$. Now we must modify that downward in light of the fact that the *c*-axis is different. We still have a fourfold axis along the *c* direction with a mirror plane perpendicular to it: $4/m$. However, the threefold axes are no longer present. The *a* and *b* axes have been reduced to twofold axes with a mirror plane perpendicular: $2/m$. The diagonal axes along the $[110]$ directions are still twofold symmetry axes and they still have their perpendicular mirror planes: $2/m$. So full symmetry in the Tetragonal system becomes: $4/m2/m2/m$.

Numerous minerals have point groups consistent with full tetragonal symmetry, some with the *c*-axis longer than the *a*-axes and some with it shorter. As an example, let us consider zircon, with an axis ratio $c/a = 0.91$. The most common form of zircon, and the form seen most often at Washington Pass, is a prism capped by pyramidal faces. This can be accomplished in two different ways, as shown in fig. 1. The two differ in the steepness of the termination, since the $\{011\}$ faces are less steeply inclined than the $\{111\}$ faces. Of course, we could correct that by reducing the *c/a* ratio, but that parameter is determined independently by crystallographic data, as is obtained for instance through X-ray diffraction measurements.

By comparing to an actual zircon crystal, such as the one from Washington Pass shown in fig. 2, we can see that the upper representation using $\{100\}$ and $\{011\}$ faces is the proper set to use for zircon crystals from Washington Pass.

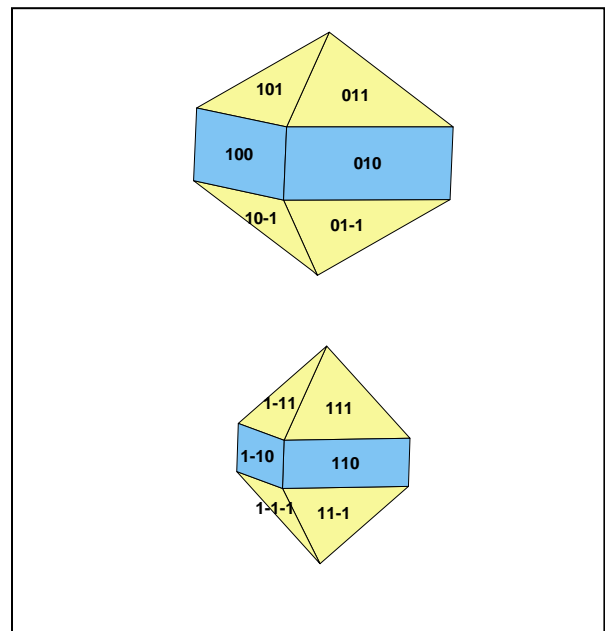


Fig. 1 Two representations of a prism with bipyramid

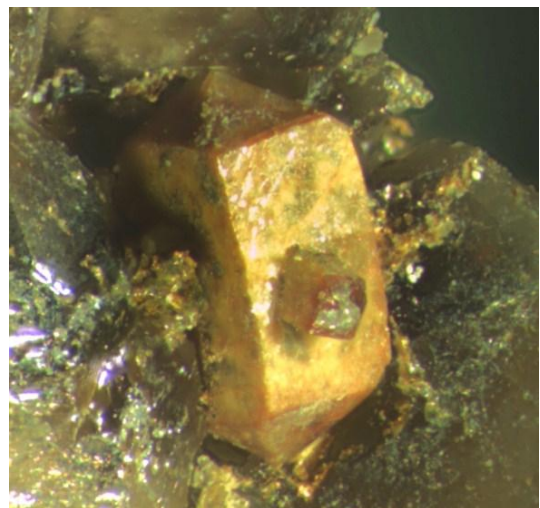


Fig 2 Terminated prism of Zircon
Washington Pass, Okanogan Co., Wash.

So as to form a closed solid, it has been necessary to include two different sets of symmetrically related faces. This will always be the case when a prism is involved. In order to have a set of faces that completely enclose a shape, it will be necessary to have at least one non-zero index in one of the two first positions, and another non-zero number in the third position. For instance, the set $\{011\}$ will form a closed figure with eight faces. The $4/m$ part of the symmetry designation is sufficient to generate this shape; the fourfold axis makes (011) , (-101) , $(0-11)$ and (101) , while the mirror plane produces $(01-1)$, $(-10-1)$, $(0-1-1)$ and $(10-1)$. Many of the zircon crystals from Washington Pass do indeed have such a simple shape, as shown in fig. 3.

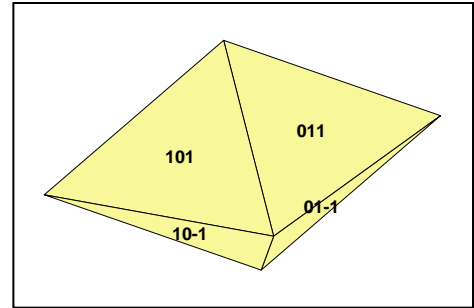
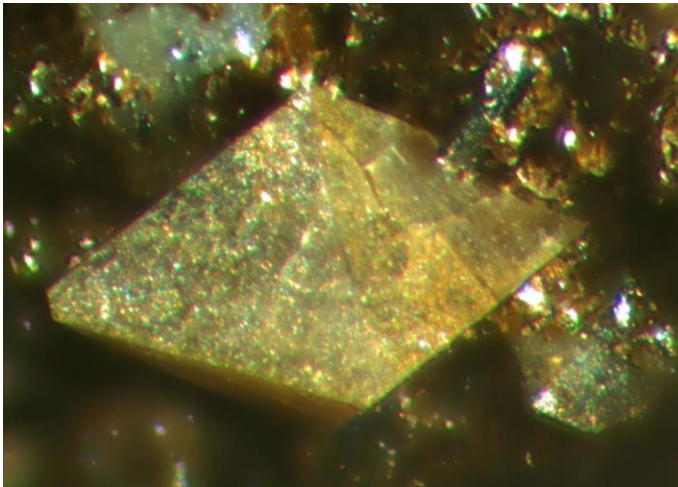


Fig. 3 A simple bipyramidal zircon crystal
Washington Pass, Okanogan Co., Wash.

In the atomic structure of the unit cell, the zirconium and silicon alternate in chains parallel to the c -axis. Each silicon atom is, of course, surrounded by four atoms of oxygen in tetrahedral arrangement. Since the tetrahedron does not possess fourfold rotation symmetry, the overall symmetry along the c -direction is maintained by having every other chain rotated by 90° and displaced upward or downward in such a way that the zirconium atoms are surrounded by eight oxygen atoms, two above and two below as members of their own chain and one laterally from each of the four neighboring chains. (For an illustration of this arrangement, see Gaines *et. al.*, *Dana's New Mineralogy*, 8th ed., page 1055.)

Several other minerals have this same structure. They all involve a large high- z atom and either SiO_4 or PO_4 tetrahedra. These include Hafnon, Hf SiO_4 , Thorite, Th SiO_4 , Coffinite, U SiO_4 , and Xenotime-(Y), Y PO_4 . A tiny, pale yellow crystal of Thorite growing epitaxially on a colorless Zircon crystal is shown in the SEM micrograph, fig. 4. Notice that the steeper bipyramidal faces on the Zircon means that it is of the type shown in the lower diagram in fig. 1. The Thorite, adopting this shape, is therefore composed of a short $\{110\}$ prism terminated by $\{111\}$ bipyramids that are themselves capped by $\{001\}$ faces.

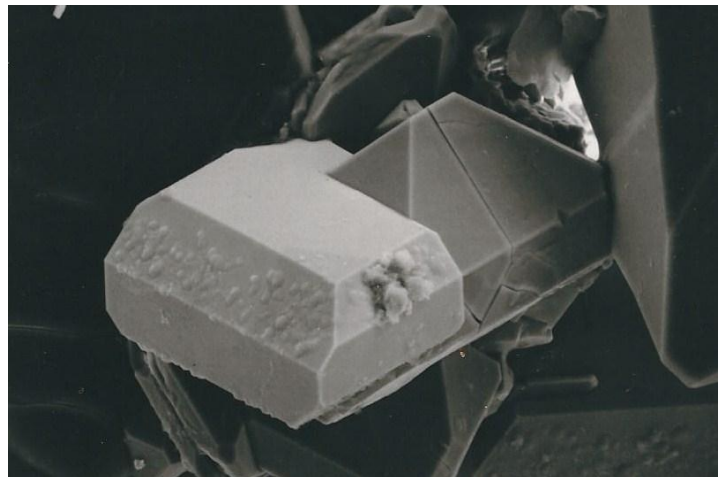


Fig. 4 Thorite epitaxial on Zircon (x500)
Lookout Prospect, Thomas Range
Juab Co., Utah

An example of a mineral with c larger than a is apophyllite. Actually, apophyllite is now a family of three minerals:

Apophyllite-(KF)	$\text{K Ca}_4 \text{Si}_8 \text{O}_{20} (\text{F}, \text{OH}) \cdot 8\text{H}_2\text{O}$
Apophyllite-(KOH)	$\text{K Ca}_4 \text{Si}_8 \text{O}_{20} (\text{OH}, \text{F}) \cdot 8\text{H}_2\text{O}$
Apophyllite-(NaF)	$\text{Na Ca}_4 \text{Si}_8 \text{O}_{20} \text{F} \cdot 8\text{H}_2\text{O}$

Only the two containing potassium are actually tetragonal, with $c/a = 1.76$. The structure is that of sheets containing SiO_4 tetrahedra arranged in groups of four oriented perpendicular to the c -axis, with the potassium, calcium and water located between the sheets binding them together.

The simplest crystals of apophyllite are rectangular prisms composed of $\{100\}$ and $\{001\}$ faces. In addition, they tend to be colorless and water clear, so they can easily be confused for a cubic mineral, especially similar to some fluorite crystals. One clue as to their tetragonal structure is that they often show small $\{111\}$ faces on their corners, as shown in the crystal illustrated in fig. 5. These extra faces are not equilateral triangles, as would be the case with a cubic crystal. The steepness of these faces in fig. 5 indicates that we are looking directly at the $\{100\}$ face and that the c -axis is vertical.

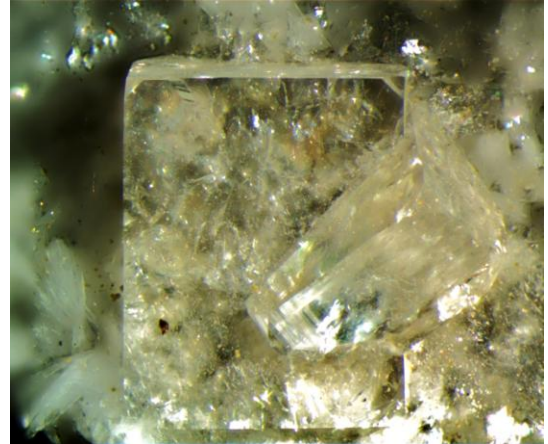


Fig. 5 Simple prisms of Apophyllite
Monument, Grant Co., Oregon

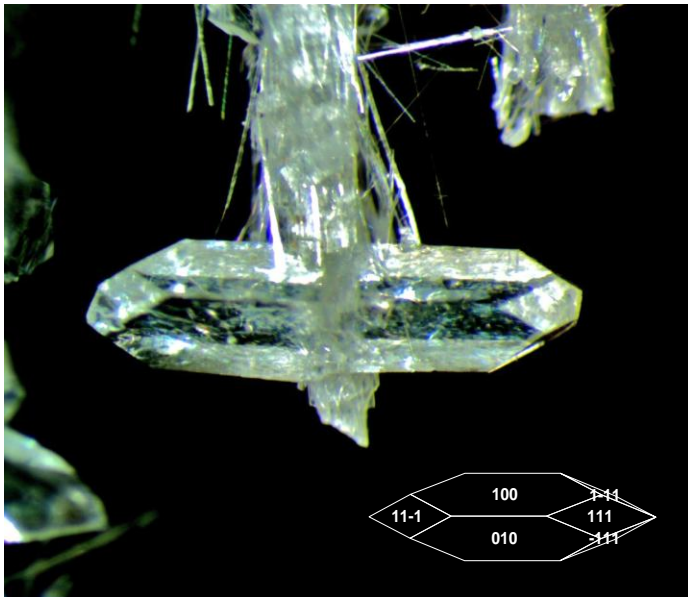


Fig. 6 Apophyllite on fibrous Natrolite
Lincoln Creek Quarry, Lewis Co., Washington

Often the $\{111\}$ faces can be much more fully developed, as in the crystal shown in fig. 6. This crystal is elongated along the c -axis; in examples with less elongation, the prism faces may be entirely lacking, leaving only a steep bipyramid composed of a total of 8 faces, as shown below.

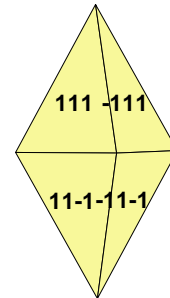


Fig. 7 Simple tetragonal bipyramid

The crystals shown above are elongated more or less along the c -axis. Crystals from other locations can be shorter to much shorter in the c direction. Such a crystal is shown in two views in fig. 8. Apophyllites of this type generally show large $\{001\}$ faces and relatively small $\{100\}$ faces. The major edge faces are $\{111\}$, and there is often a small $\{310\}$ face present. This ends up giving the shape an overall rounded look.

The particular atomic structure, as mentioned above, gives us some insight into the processes leading to these particular shapes. Since the silica forms in sheets perpendicular to the c -axis, we would

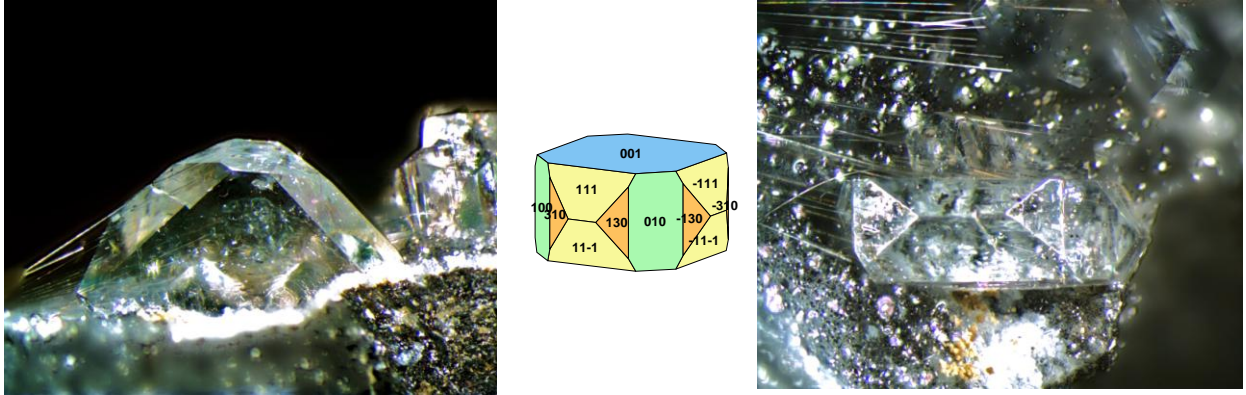


Fig. 8 *Apophyllite with Natrolite on Phillipsite. Two views of the same water-clear crystal. Devil's Backbone, North Fork of the John Day River, Grant Co., Oregon*

expect that excess silica in solution would favor more rapid growth on the $\{100\}$ faces, leaving major $\{001\}$ faces and a rather disc-like shape. On the other hand, excess calcium would favor growth of the $\{001\}$ faces and create crystals elongated in the c direction. This means that the possibility exists that conditions can change over time at a given location. An example of this is shown in the illustrations of fig. 9. An early form of apophyllite crystallized as thin plates with large $\{001\}$ and $\{111\}$ edges. After that, natrolite, harmotome, and hyalophane formed. By the time a secondary crystallization of apophyllite occurred, the solution had changed enough that these later crystals are formed almost entirely of $\{111\}$ faces of the type shown in fig. 7.

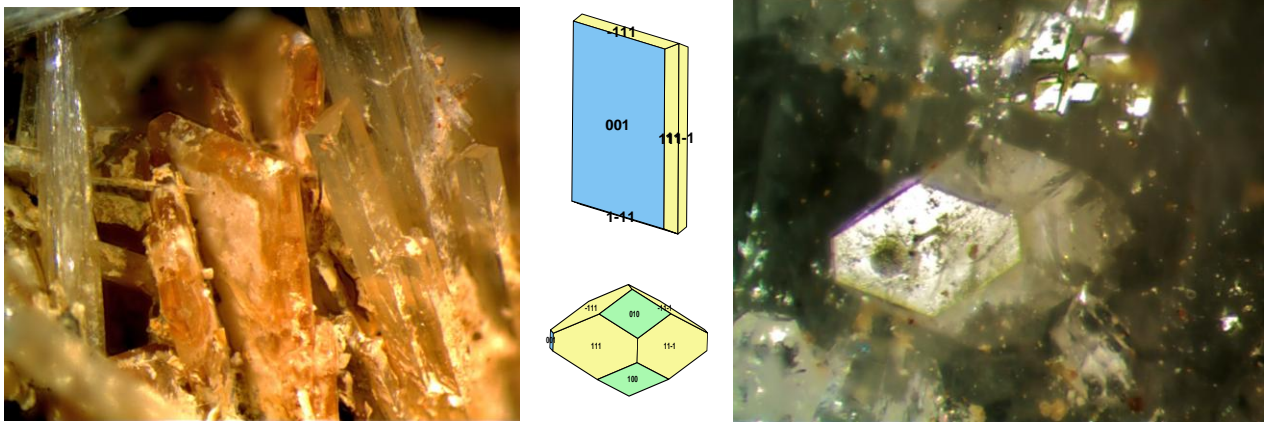


Fig. 9 a. *Natrolite on Apophyllite*

b. *Apophyllite on Hyalophane*

Two generations of Apophyllite from the same location.

The Grampians, Pahau River, South Island, New Zealand.

Another mineral with $4/m2/m2/m$ symmetry is Anatase, TiO_2 , with a $c/a = 2.51$. The unit cell is fairly large, containing four titanium atoms and eight oxygen. The predominant form for anatase is the $\{101\}$ set of faces, which tend to be striated perpendicular to the c -axis.

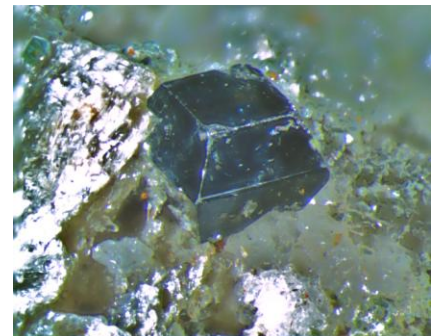
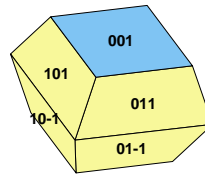


Fig. 10 *Anatase on Quartz Binntal, Switzerland*

Anatase when pure is a clear transparent mineral with a very high refractive index. Impurities tend to color it various shades of orange (iron) or blue. Relatively high impurity levels render it almost black, such as the one pictured in fig. 10. There, the (001) face is particularly well developed. Often, the 001 is lacking, as in the crystal shown in fig. 11. That crystal is clear and colorless, so the striation pattern perpendicular to the c-axis has been emphasized using reflected light. Though most anatase crystals are similar to the ones shown here, complicated crystals with very many faces do occur. The combination of color (either very dark or very clear) and the high reflectivity make taking good pictures of anatase quite difficult.

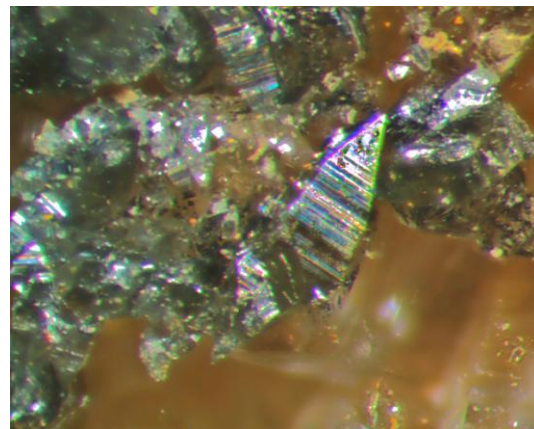


Fig. 11 *Anatase crystal striated laterally*
Lehmann Prospect, Mono Co., Calif.

These have been examples of the full symmetry tetragonal group $4/m2/m2/m$. But we can also have point groups that have a lower symmetry than the full tetragonal lattice. If the point group is such that both rotational and mirror symmetry no longer exist along the a-axes, we then have the lower symmetry $4/m$ group. Wulfenite, $Pb MoO_4$, a popular mineral because of its outstanding color, is an excellent example of this symmetry class. The structure of the mineral is as sheets where the Pb and Mo atoms alternate in a square array. However, the molybdenum is surrounded by four oxygen atoms arranged in a tetrahedron. In order to accommodate this, the subsequent layers above and below are staggered in such a way that the fourfold axis with its perpendicular mirror plane is retained, but the symmetry operations along the a-axes are lost. The resultant $c/a = 2.23$.

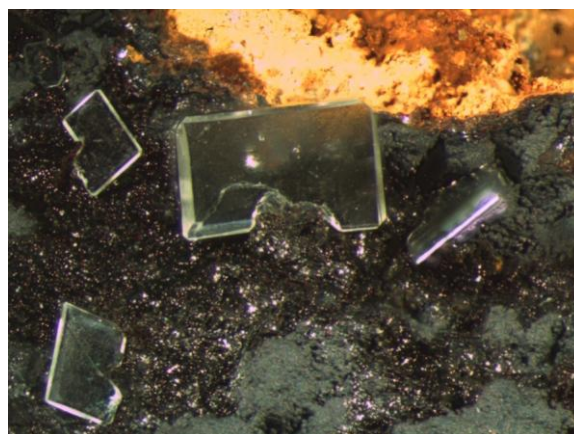


Fig. 12 *Wulfenite*
San Rafael Mine, Nye Co., Nevada

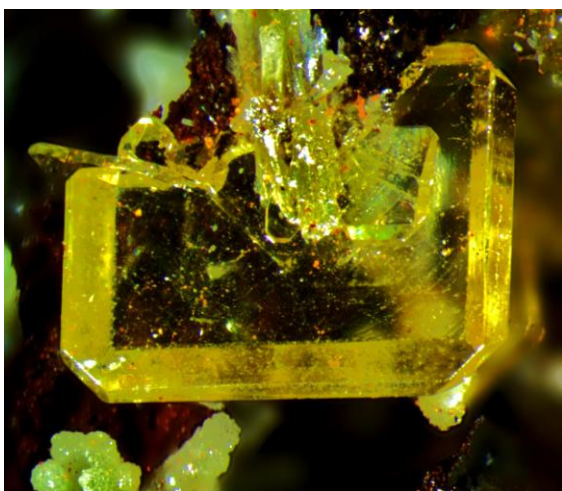
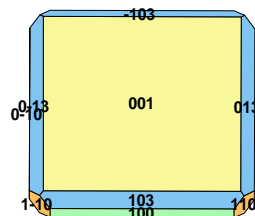


Fig. 13 *Wulfenite on Mimetite*
Mapimi, Durango, Mexico



Actually wulfenite when pure is colorless and transparent. It often forms as thin square platelets with beveled edges, such as those shown in fig. 12 and 13. The color comes from impurities that produce yellow, orange and eventually red as concentrations increase. The most common bevel to the edges of the plates are $\{103\}$ faces, and the corners if beveled could be either $\{110\}$ as shown or $\{113\}$ faces.



Fig. 14 *Blocky Wulfenite on Quartz*
Los Lamentos, Chihuahua, Mexico



Fig. 15 *Blocky Wulfenite on Mimete*
Mapimi, Durango, Mexico

Another common form, quite different from the blade, is that of a rectangular box, as illustrated in fig. 14 and 15. The thickness in the c-direction may be either less than (fig. 14) or greater than (fig. 15) the length in the a-directions. Notice the banding in fig. 15, showing clearly which direction the square sheets are oriented.

A third form, different from both of the above, is based on the bipyramid {101} with or without accompanying prism faces. These are often slender and elongated in the c-direction. An example with considerable prism is shown in fig. 16. Very often the faces of this type of crystal are rounded, so that the transition edge is not evident. Wulfenite does occur as very fine needles along the c-axis, but such crystals do not have distinct faces or a very characteristic cross-sectional shape.



Fig. 16 *Bipyramidal Wulfenite on Mimete*
Mapimi, Durango, Mexico

These are the basic forms of wulfenite. There are no faces present in these simple examples that would not have been present in the full symmetry group $4/m2/m2/m$. We can only begin to see the effect of the lower symmetry when we look in detail at the small faces located along the edges and corners. A particularly striking example of the effect of lower symmetry is shown in fig. 17. The top (001) face appears to be twisted about 8° with respect to the bulk of the crystal. This is because of the presence of $\{8\ 1\ 20\}$ faces around the edges. The fourfold symmetry axis requires the four faces $(8\ 1\ 20)$, $(-1\ 8\ 20)$, $(-8\ -1\ 20)$, and $(1\ -8\ 20)$ and the perpendicular mirror plane requires the four matching faces with -20 , but there are no mirror planes perpendicular to the a-axes to generate the other eight faces. Those other eight faces belong to a different group $\{1\ 8\ 20\}$. In this case, that other group is not developed at all.

There are cases, however, where two groups unrelated by symmetry can be nearly equally developed. Consider the blocky crystal with numerous faces on each edge shown in fig. 18. The

Fig. 17 *Wulfenite on Mimetite*

A blocky crystal with small {8 1 20} faces (in blue) that give the top (001) face a twisted look.

The diagrams show two views for clarity.

from Mapimi, Durango, Mexico.

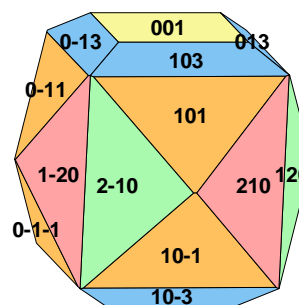
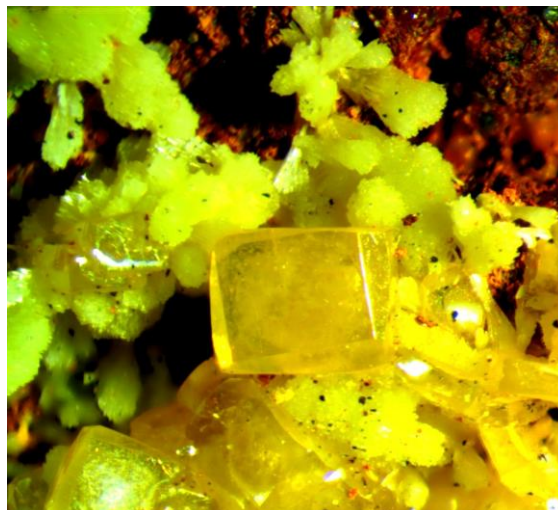
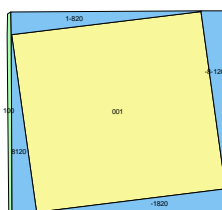
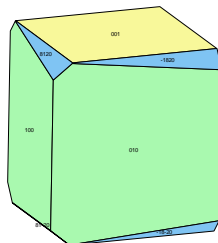


Fig. 18 A rather rounded crystal of Wulfenite
Glove Mine, Santa Cruz Co., Arizona

combination of {103}, {101}, {210} and {2-10} faces give the crystal a rather rounded appearance. But notice that the green (210) and pink {2-10} are members of different symmetry groups but have been developed very similarly. In the $4/m2/m2/m$ symmetry class, these would be part of the same group.

There is another group of minerals, the autunite group, whose structure is very much like that of wulfenite. These are phosphates and arsenates of uranium with a positive divalent ion and water of crystallization. The uranium is in a uranyl ion, UO_2 , that is linear and oriented along the [001] direction. These uranyl ions alternate in a square array with the tetrahedral phosphate or arsenate ions. The divalent metal ion and the water are located between layers to hold them together. There is room for twelve water molecules per unit cell. In this arrangement, the minerals belong to the full tetragonal symmetry class $4/m2/m2/m$. Examples of this arrangement are:

$4/m2/m2/m$

Torbernite

$Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$

Uranospinite

$Ca(UO_2)_2(AsO_4)_2 \cdot 12H_2O$

Zeunerite

$Cu(UO_2)_2(AsO_4)_2 \cdot 12H_2O$

However, several of the water molecules are not tightly bonded and can easily be removed without seriously altering the structure of the uranyl-phosphate/arsenate sheets. The fourfold axis usually remains, so the members with less water are usually tetragonal, but the rearranged bonding between sheets affects the symmetry present along the a-directions and results in structures of lower symmetry



Fig. 19 *Torbernite*
Musonoi, Katanga, Zaire

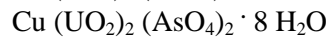
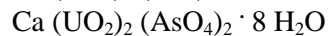
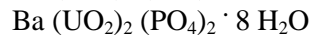
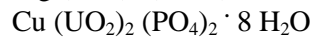


Fig. 20 *Zeunerite*
Tyrone, Grant Co., New Mexico

classes. The most common of these is the group to which wulfenite belongs, **4/m**. These are called the meta-autunite subgroup. Among its members are:

4/m

Metanovacekite
Metatorbernite
Metauranocircite
Metauranospinite
Metazeunerite



However, one appears to have a different symmetry:

4mm

Metaheinrichite



So here we have yet another symmetry class, **4mm**. Notice that the mirror planes are not perpendicular to the fourfold symmetry axis, but are instead perpendicular to [100] and [110]. This means there is no symmetry operation that links the top and bottom of the crystal; such a situation is called hemimorphism. The two end terminations can potentially be quite different. However for metaheinrichite, the crystals tend to be thin square platelets, as shown in fig. 21. The place that this limited symmetry is most likely to appear is at the edges and corners of the plates. In fig. 21, edges appear to be {100} faces, but there is one corner, indicated by the arrow, formed by a (111) face without any (11-1) face to balance it. That is consistent with **4mm** symmetry.

There are several other classes that do not possess mirror symmetry perpendicular to the c-axis. One such class is **422**, where in addition to the fourfold axis along the c-direction, we have twofold axes along the a-directions and along [110]. Wardite, $\text{Na Al}_3 (\text{PO}_4)_2 (\text{OH})_4 \cdot 2 \text{H}_2\text{O}$, belongs to this symmetry class, with $c/a = 2.71$.

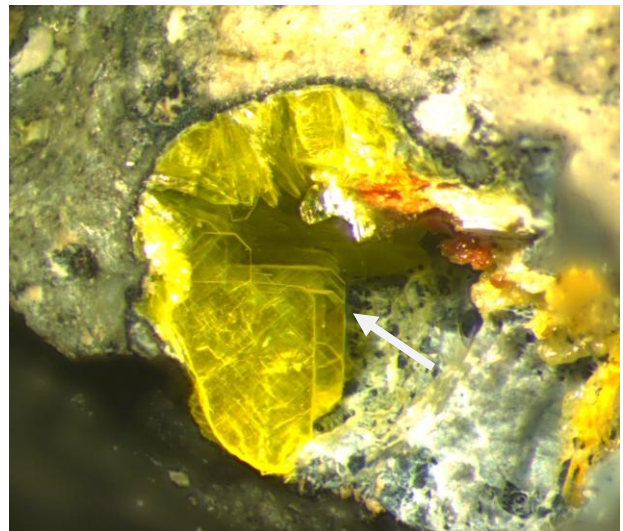


Fig. 21 *Metaheinrichite*. The arrow points to a small (111) face at a crystal corner.
White King Mine, Lake Co., Oregon

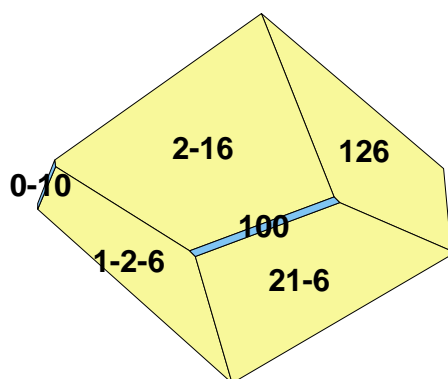


Fig. 22 Diagram of a possible crystal composed primarily of $\{126\}$ faces, with the c -axis vertical and the a -axis horizontal.



Fig 23 Wardite crystals
Rapid Creek, Yukon Territory, Canada

Because of the twofold symmetry, the top and bottom resemble each other, but they are not always mirror images, as the diagram in fig. 22 illustrates. The result of this is to form rather complex crystals that do not particularly look tetragonal unless they can be viewed directly down the c -direction. Such clear, complex crystals of wardite are shown in fig. 23.

There is a final symmetry class that needs mentioning, $-42m$. This is the class to which chalcopyrite belongs. Though there is a type of fourfold symmetry here, the minus sign means that inversion is involved. So each time you make a 90° rotation, you simultaneously make an inversion (that is $x \leftrightarrow -x$, $y \leftrightarrow -y$ & $z \leftrightarrow -z$). The result is similar to the $-43m$ crystal class of cubic crystals, to which sphalerite belongs. And that is no coincidence. The arrangement of atoms in the two minerals is closely related. In both cases, the placement of the sulfur atoms is identical. In the chalcopyrite structure, the zinc atoms are replaced by copper and iron atoms that alternate. The resultant tetragonal unit cell is essentially two sphalerite cells stacked one atop the other. This makes the $(1-12)$ face in chalcopyrite equivalent to the (111) face in sphalerite. Fig. 25 shows chalcopyrite growing epitaxially on a (111) face of sphalerite.

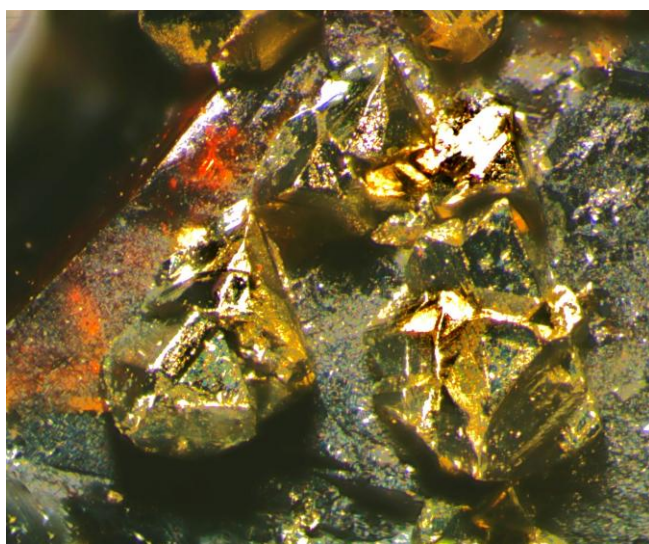


Fig. 25 Chalcopyrite epitaxial on a sphalerite (111) face.
Casapalca, Peru

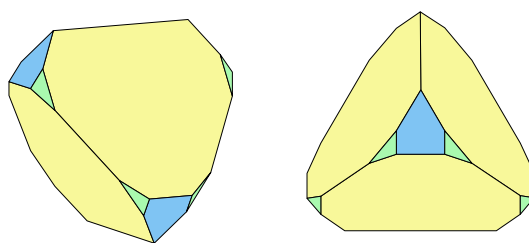


Fig. 24 Two views of the type of crystals shown in fig. 25. The colors represent:
yellow $\{112\}$
blue $\{1-12\}$
green $\{101\}$
The view at left has the c -axis vertical.
The view at right is looking down $[1-12]$.

Though probably the most common copper mineral, chalcopyrite is only very rarely found in good crystals. Most of the time, it is embedded in the matrix as shiny, irregular masses. The crystals when present tend to be rather complex, with many faces, and the lower symmetry makes them hard to identify as a tetragonal mineral. The members of the stannite group also possess this structure.

All told, there are seven symmetry classes that belong to the tetragonal system. We have featured four of them. As a final example, we show in fig. 26 the result of a hypothetical crystal exhibiting each of the seven classes. We have chosen a simple example with $c/a=0.83$ and faces $\{100\}$, $\{001\}$, $\{111\}$, and $\{123\}$. Hopefully, this will give you some final insights into what different classes may look like.

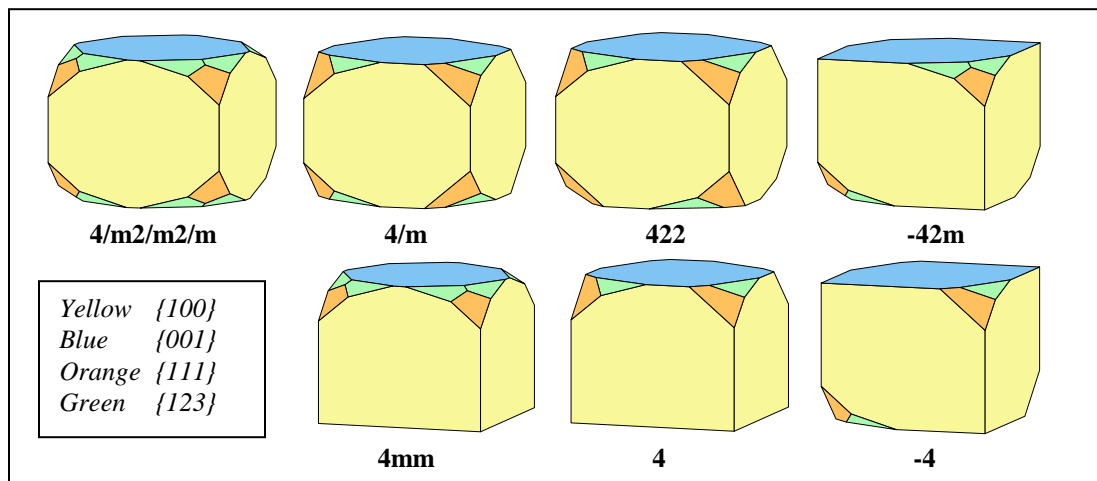


Fig. 25 A simple tetragonal shape, shown in each of the seven symmetry classes for comparison.

References:

Gaines, R.V., Skinner, H.C.W., Foord, E.F., Mason, B., & Rosenzweig, V.T., *Dana's New Mineralogy*, (John Wiley & Sons, New York), 8th edition, 1997.

Making Use of those Cursed Reflections

Don Howard

For anyone used to mineral photography through the microscope, it is common knowledge that the hardest part of setting up a picture is getting the lighting right. You twist and turn the specimen in order to get the shadows right and to be able to see the faces on the featured crystal. And then you mess endlessly with the lights to get rid of the reflection off the face of some other crystal that flares into the picture, because you know that the flare is going to mess up everything. And for samples with multiple crystals clustered together with lots of faces to reflect, there doesn't ever seem to be a right position, no matter how we shift the lights around. That is why we go to light diffusers and ringlights, just to avoid those sorts of problems.

But there can be advantages to reflection that we can use to our advantage. Take for example the thin, clear blades of wulfenite shown in fig. 12 of the preceding article. You would never notice the intricate pattern of faint striations on the face unless you got the reflection off the surface just right, as shown in fig. 1.

Often, the patterns on the faces can tell you about the way a crystal has grown. Consider the view of a face of chabazite shown in fig. 2. The striations in this case are a map of the twinned regions that make up in a complicated manner what otherwise would appear to be a simple pseudocube. Observing surface striations often can clarify the nature of twinning in a mineral. This can be particularly useful with the zeolites.

In practice, I have always been careful to get the crystal surface as nearly perpendicular as possible to the line of sight so that I would have everything in focus in a single frame and would not

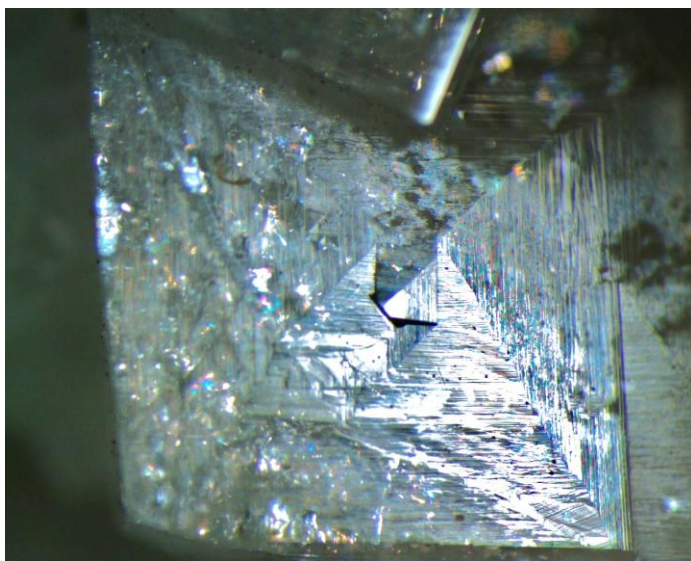


Fig. 2 *The surface structure of a crystal of chabazite from Burnt Cabin Creek, Spray, Wheeler Co., Oregon*

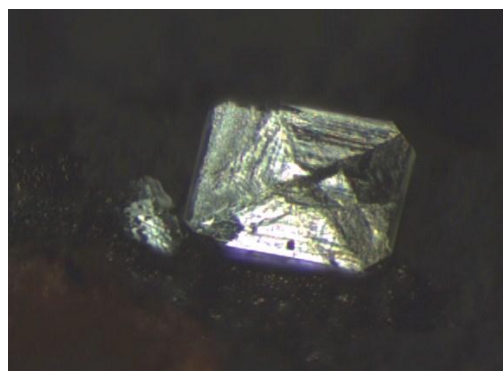


Fig. 1 *Striations on a clear wulfenite, one of the crystals from San Rafael mine shown in fig. 12 of the preceding article on tetragonal minerals.*

have to worry about stacking. Because the one thing that *really* messes up a picture is out of focus reflections. Out of focus reflections obscure the regions they border and introduce strange color banding that simply looks weird. Reflections do not behave well in stacking programs.

But I have discovered a slick trick to get around this problem in some cases. Consider the picture of the polybasite crystal shown in fig. 3. Mixed in with the acanthite, pyargyrite and other dark minerals that surround it, it is hard to make out in the stacked image on the left. But by adding a single additional frame to the stack where the light has been moved to reflect off of the c-face of the polybasite, and then rerunning the stacking program,

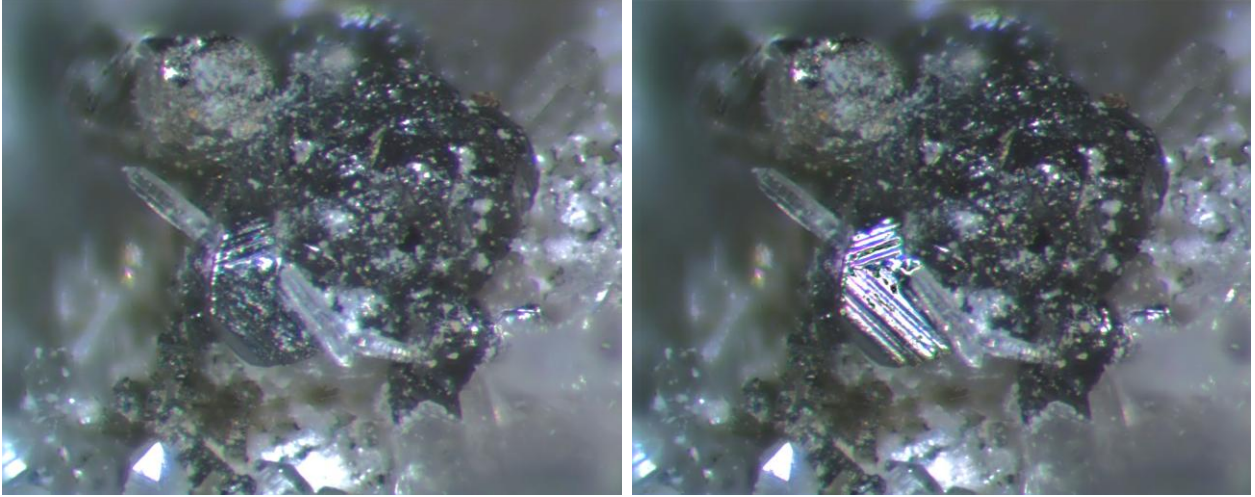


Fig. 3 *Two views of a polybasite crystal with acanthite on quartz from the Zaca Mine, Alpine Co., California. By adding a single additional frame to the stacking program, the surface striations are emphasized.*

the crystal of interest can be made to stand out. This technique was also used in the preceding article on tetragonal minerals to emphasize the {130} faces on the apophyllite crystal in fig. 8, the striations on the anatase in fig. 11, and the faces on the wardite crystal in fig. 23.

The stacking program I am using, Helicon Focus, will accept a variety of different kinds of changes to the members of the stack. Playing with changes in lighting instead of or in addition to the changes in focal plane can give a new dimension to the things we can do in our microphotography. I am anticipating trying new things, and look forward to hearing about your experiments and adventures in this fascinating aspect of our hobby.

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