

Northwest  
Micro Mineral  
Study Group



# MICRO PROBE

SPRING, 2014

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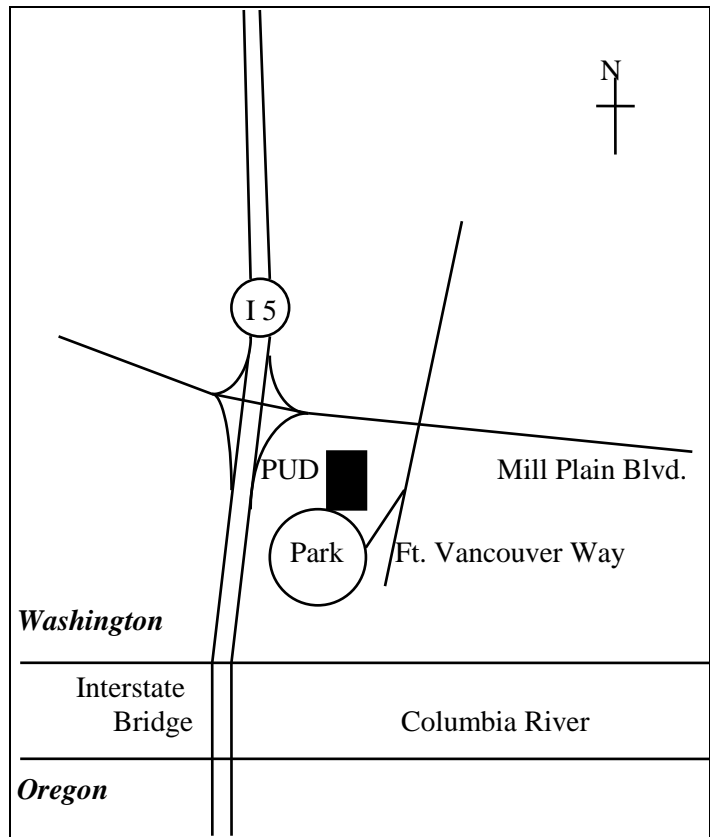
## SPRING MEETING . . . . .VANCOUVER, WASHINGTON

May 3, 2014                      9:00 am to 5:00 pm

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

### Schedule for the day;

- 9:00 am            Doors open at the PUD building for table set up. Helpers needed.
- 9:30 am            Meeting starts: (trading, selling, free tables, viewing specimens, and visiting). Bring your microscope and some material to share with others on the free table. Barry Murphy is promising to add some material from Mt. Ste. Hilaire.
- 10:30 am          Barry Murphy will present the things he has come up with for a possible website. The business meeting will follow (see the President's report for details).
- 12:00 noon        Lunch potluck: 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.
- 1:30 pm            Showing of pictures of minerals and collecting sites by members. Bring things to share. Rudy and Don will have pictures.
- 4:00 pm            End of meeting and clean up. Please stay to put away tables and help clean up.
- 5:00 pm            Dinner will be at the County Buffet in Vancouver. Please join us if you can.



Hello from your new President.



I would like to introduce myself and present an idea for the future. My husband, Paul, and myself have been active rockhounds for quite a few years, but just in the last few years I have been interested more and more in minerals. I consider myself very new at identifying minerals and at collecting them. I was told at the last meeting, when I was elected, that this beginner status was not a deterrent to being elected President, that I just was expected to lead the meetings. That suited me just fine. I hope that suits all of you too. I find that the more I get involved, the more I learn.

At the next meeting I would like to have a discussion on membership and educational opportunities. Does the group have an interest in increasing membership? If so, I believe that having some sort of beginning presentations on mineral identification (which can be advertised in rockhound club newsletters) would provide an avenue for adding to our membership. Even if we do not use it as a membership drive tool, maybe it still would be useful. This topic comes from my beginner status at identifying minerals mentioned earlier. I have been struggling with this and have really not seen the help that I had hoped for. You all seem so far ahead of me and I cannot seem to find a "bridge" across the huge chasm. I do not know what form this education might come in. Presentations, short hands-on help sessions during the meeting, list of reading resources (divided up by level of expertise), something during the symposium for beginners, etc. would all be useful.

I am willing to do a lot of the editing of any handouts, etc. that might be needed, but I need your expertise. I look forward to the next meeting and getting to know more of you. And to this discussion along with all of the other very wonderful slide presentations.

See you there.

Beth

## THE MICROPROBE

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## Mineralogy and Optical Mineralogy

In 2007, M. Darby Dyar and Mickey E. Gunter published Mineralogy and Optical Mineralogy. This has recently become available for Apple iBooks. It is available for download to an iPad or Mac computer from the iTunes Store. Currently, the first 12 chapters are available, with the remainder becoming available later this year. The price starts at \$3.99 per chapter. The hardcover book came with a DVD that included a mineral database of 600 minerals. This is available as a free download. The photos of mineral examples can be clicked to enlarge. There are many crystal structure diagrams that can be enlarged and rotated. These were produced using the Crystal Maker program. Many of the figures in the chapters are animated to illustrate the topic being discussed. At the end of each chapter, there is an interactive review section.

The following chapters are currently available;

1. The Essence of Mineralogy
2. Hand Sample Identification
3. Crystal Chemistry
4. Crystallography
5. Optical Mineralogy
6. Systematic Mineralogy
7. Chemistry of the Elements
8. Bonding and Packing in Minerals
9. Chemical Analysis of Minerals
10. Mineral formulas
11. Introduction to Symmetry
12. Symmetry

The following chapters will be available later this year;

13. Mathematical Crystallography
14. Representation of Crystal Structures
15. Diffraction
16. Introduction to Optics
17. Optical Crystallography
18. Optical Crystal Chemistry
19. Mineral Identification
20. Environments of Mineral Formation
21. Nomenclature and Classification
22. Silicate Minerals
23. Non-Silicate Minerals

The following link is to the page on the American Mineralogical Society website where information on this is available.

<http://www.minsocam.org/msa/DGTtxt/>

## Hexagonal and Rhombohedral Crystals

Donald Howard

### Introduction: the other five crystal systems

One of the primary ways that minerals are classified is by their crystal structure. The most symmetric of these structures is the *cubic* system, represented by three axes of equal length that are mutually perpendicular to each other. To further define the structure of a particular mineral, it is only necessary to specify one additional parameter, in this case the length of the repeat distance along any one of the axes. Many common minerals have this sort of cubic structure, such as pyrite, fluorite, garnet, cuprite, halite, and analcime. These minerals are relatively easy to pick out, since normally they are pretty much the same size in all directions. The details of the faces, however, can be anywhere from simple to elaborately complicated. Still, they reflect the overall symmetry of the system.

In order to define other systems, it is necessary to relax one of the conditions: either the axes are allowed to be different, or the angle between the axes is allowed to be something other than  $90^\circ$ . If we keep the requirement of mutually orthogonal axes ( $90^\circ$ ) but let one of the axes be a different length than the other two, we have the *tetragonal* system. Apophyllite and wulfenite are common examples of tetragonal mineral. If all three axes are allowed to be different, we have the *orthorhombic* system. Enstatite, barite, and olivenite are examples of orthorhombic minerals. Note that if only the six prism faces are present, minerals of all three of these systems appear the same. That is because the external shape of a crystal depends more on the rate of growth of each face than it does on the size of the repeat distance along the individual axes. The clue as to whether a crystal is cubic, tetragonal or orthorhombic comes from the additional faces that modify the corners and edges.

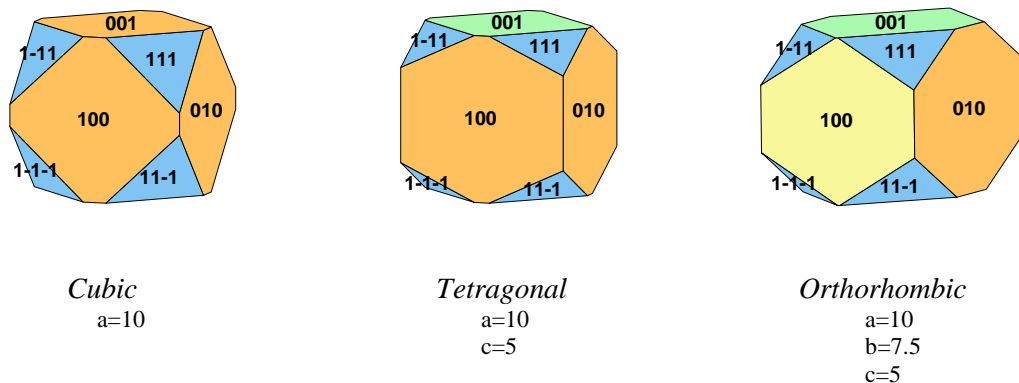


Fig. 1. Comparison of an equant prism modified by an octahedron in each of 3 crystal systems.

In order to proceed farther to successively less symmetric system, the next step would be to relax the condition on the right angles between axes. If one angle is different from  $90^\circ$ , we have the *monoclinic* system, requiring four parameters, three axis lengths and one angle (traditionally tanked between *a* and *c*). Numerous common minerals, such as orthoclase, titanite, and the amphiboles, are monoclinic. Finally, if all the angles are different than  $90^\circ$ , we have the least symmetric system of all, the *triclinic* system. All three axis lengths and all three angles will be necessary to specify the structure. There are a number of triclinic minerals; most are rather unusual. Turquoise and rhodonite are probably the best known. The mineral axinite is a very obviously triclinic

## Rhombohedral versus hexagonal representation

One other possibility exists. Going back to the original definition of the cubic system, we could have left all three lengths the same and kept all the angles the same, but allowed them to be something other than  $90^\circ$ . This choice leads directly to the *rhombohedral* system. The shape of the prism would be a rhombohedron – like a cube pushed over, with each side a similar parallelogram whose acute angle would be the characteristic angle between the axes. In a cube, the body diagonal (from one corner to the opposite corner) is a three-fold axis of rotation. In the rhombohedral system, that three-fold axis is preserved. Just as with the tetragonal system, only two numbers are required to describe a particular crystal shape, but in this case they are an axis length and the angle. Since the three axes come together at the three-fold axis, the



Fig. 3 *Cleavage rhomb of calcite*

Now this is the way a Physicist would define the sixth major crystal system, in order to maintain the same overall pattern of description. This is NOT the way the system has been defined historically by mineralogists. Most mineralogy texts define the *hexagonal* system instead. This is easily related to the rhombohedral system, as shown in the diagram in fig. 5. The three axes marked  $s_1$ ,  $s_2$ ,  $s_3$  are the three vectors of the rhombohedral representation, and the vertical line is the three-fold symmetry axis. In the hexagonal representation, the projection of  $s_1$  onto the three-fold axis is taken as the  $c$  axis. Projections of the three  $s$  axes onto a plane perpendicular to the  $c$  axis are taken as new vectors  $a_1$ ,  $a_2$ ,  $a_3$ . The set of vectors ( $a_1$   $a_2$   $a_3$   $c$ ) now become the basic hexagonal representation.



Fig. 2 *Rhombs of calcite on siderite  
Clackamas River, Oregon*

angle can be anything from  $0^\circ$  to  $120^\circ$ , excluding  $90^\circ$ .

Just as cubic minerals often are found as cubes (like some pyrite and fluorite crystals), rhombohedral minerals are often found as simple rhombs. Calcite and siderite are excellent examples of this. Though calcite occurs in many other forms as well, the cleavages in calcite are along directions that yield these same rhombohedral faces, so cleaved pieces also are in the form of rhombs (see fig. 3). When calcite vein material is broken, the rhombohedral cleavage faces generally are easily discernible on the fractures (see fig. 4).

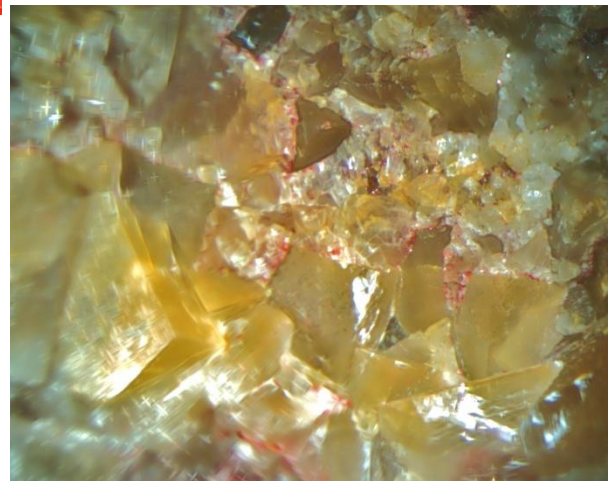
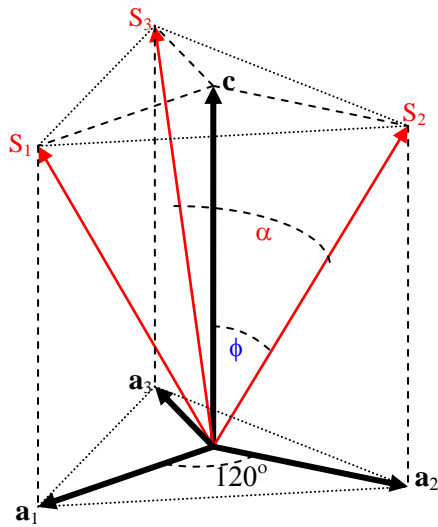


Fig. 4 *Fracture face of the calcite/cinnabar vein  
at the Kiggins Mine, Clackamas River, OR  
showing rhombohedral cleavage of calcite.*



$$a = S \sin \phi$$

$$c = S \cos \phi$$

$$\text{where } \sin \phi = 1.1547 \sin (\alpha/2)$$

or the inverse:

$$S = [a^2 + c^2]^{1/2}$$

$$\sin (\alpha/2) = 0.866 [1 + (c/a)^2]^{-1/2}$$

Fig. 5 The relationship between the hexagonal system ( $a_1 a_2 a_3 c$ ) shown in black and the rhombohedral system ( $S_1 S_2 S_3$ ) shown in red. The angle  $\phi$  shown in blue relates the two systems. These vectors (shown as arrows) define the edges of a unit cell for each representation.

We then recognize that the  $c$  axis may indeed be a six-fold symmetry axis instead of a three-fold axis. (Of course, we could have done that just as easily in the rhombohedral system.) So the hexagonal system does seem to be a more intuitive way to represent minerals that naturally form hexagonal prisms. Having several right angles has the advantage of making the algebra of figuring out facial angle considerably easier. The disadvantage, of course, is that now we have four numbers to represent points in three-dimensional space, so one is obviously superfluous.

Clearly the Miller indices representing any particular face will be different in the two systems. Consider one of the faces of the rhomb formed by  $S_1 S_2 S_3$  above:

Rhombohedral system: (001)

Hexagonal system: (11-21)

Notice that the first three indices in the hexagonal representation add to zero. *This is always true!* So we can treat one of the three as unnecessary. Traditionally, this is the third number. So this same face is often written simply as (11.1). But be careful. The other five faces are (-21.1), (1-2.1), (-1-1.-1), (2-1.-1) and (-12.-1). [Note: the minus sign is usually written **above** the number rather than in front, but I don't have the capability to be able to do that on my computer.]

## Hexagonal minerals

Having thus settled the way things are represented, we can now go on and talk about the minerals involved. Let's start with hexagonal minerals – that is, ones that possess a six-fold symmetry axis. The apatite group is the biggest set of hexagonal minerals. In addition to the various forms of apatite, it includes such common and important minerals as vanadinite, mimetite, and pyromorphite. All the minerals of this group form hexagonal prisms. Most also have a  $c$ -face (00.1) also prominent. Since the forms are pretty much the same, identification of which member of the group you are dealing with can be difficult. Sometimes looking up what minerals occur at a given location narrows the choices. However, these minerals often occur together. In the worst cases, determining the chemical content may be necessary for a definitive identification.

The color range of the various minerals can help. Vanadinite is generally red to orange in color, though it can be nearly colorless. Pyromorphite is often green, though that can be pale to nearly colorless, and orange pyromorphite also occurs. Mimetite ranges from nearly colorless to orange.



Fig. 6 *Vanadinite*  
*Apache Mine, Globe, Arizona.*

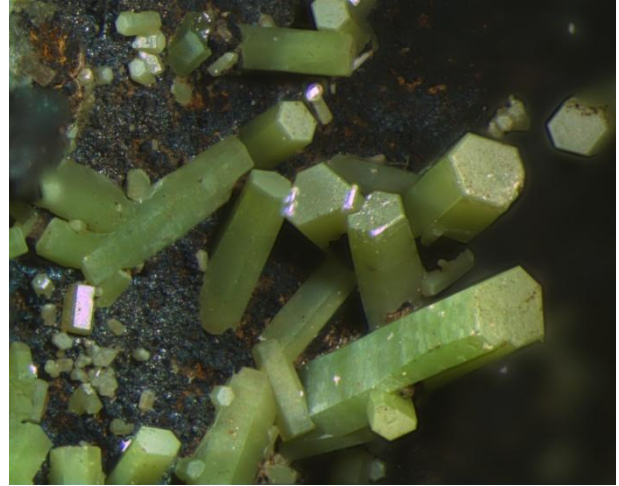


Fig. 7 *Pyromorphite*  
*Mullen, Spokane Co., Idaho.*

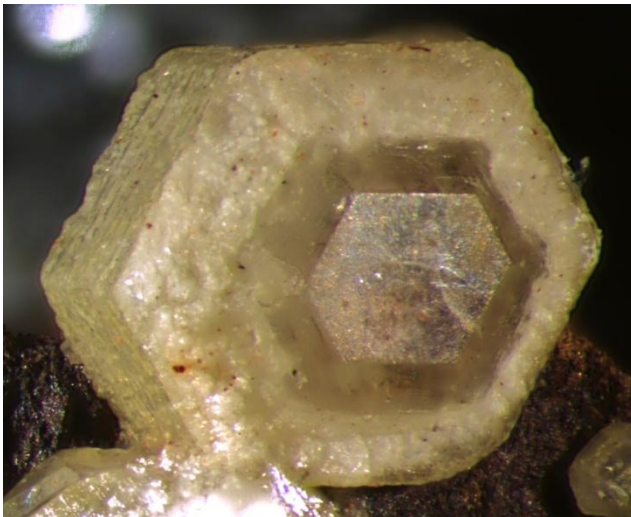


Fig. 8 *Mimeticite*  
*Bagdad-Chase Mine, California.*



Fig. 9 *Mimeticite*  
*San Francisco Mine, Sonora, Mexico.*

Green and dark red hexagonal prisms from known lead-producing mines can be identified pretty confidently. Orange crystals will be much harder to determine with any confidence short of chemical tests.

As can be seen above, the relative dimensions of the crystals can range from short fat prisms to long thin acicular rods. The length and diameter of a crystal are not a good way to determine the ratio of  $c$  to  $a$ ; crystal dimensions depend much more on the relative growth rates of different faces than they do on axis ratio. Faces such as  $(00.1)$  and  $(10.0)$  can tell you nothing about  $c/a$ . Sloping faces are the key. Notice that in fig. 8, the edges of the prism are beveled. In fig. 9, the terminations are complete hexagonal pyramids. These terminal  $(10.1)$  faces are short and stubby, because for mimeticite,  $c/a < 1.0$ . With  $c = a$ , these sloping faces would be at  $45^\circ$ .

Apatite is almost always white to clear in color. It can vary from hexagonal plates short in the  $c$ -direction to long thin needles. There is no way short of performing chemical tests to differentiate between Apatite-(CaOH), Apatite-(CaF), and Apatite-(CaCl), so unless you know from the literature for a given site which must be present, just labeling the mineral Apatite without the suffix is the safest bet.

In the zeolites, gmelinite, erionite, and offretite are hexagonal minerals. Gmelinite crystals generally show a short hexagonal prism capped on each end with a simple pyramidal termination. In this case,  $c/a > 1.0$ , so the pyramid is much steeper. The tops of the pyramid are often flattened by a (00.1) c-face. For material from the North Fork of the John Day River, such as the crystal shown in fig. 10, the prism faces are usually smooth and distinct, but the terminations are often hidden by gyrolite, or by epitaxial chabazite. Gmelinite from Boron, California usually has very short prisms and a well-developed c-face, so they appear lens-shaped; they are often twinned into complex groups.

Erionite is much more common than offretite. It is the white coating on many of the blades of levyne, growing as fine hairs perpendicular to the levyne surface. In fact, erionite commonly forms as tufts of fine, hair-like crystals. Even in cases where there are fairly sturdy prisms, the prism faces may look fibrous. The fibers occasionally form rather dense balls that look something like fish-eyes, with a smooth surface comprised of the ends of the fibers. Both kinds of habit are shown in fig. 11. At a few locations, discernable crystals are found, such as at Twig Creek, British Columbia and at Moeraki, New Zealand (fig. 12). In both places, the form is of simple prisms terminated by c-faces.

Molybdenite forms as sheets, normally with hexagonal symmetry. Thin hexagonal crystals of molybdenite are shiny metallic and flexible, whereas thin hematite and ilmenite crystals are blackish, rhombohedral, and brittle.

Osumilite forms short inky-blue hexagonal prisms with large c-faces similar in shape to those of vanadinite shown in fig. 6.

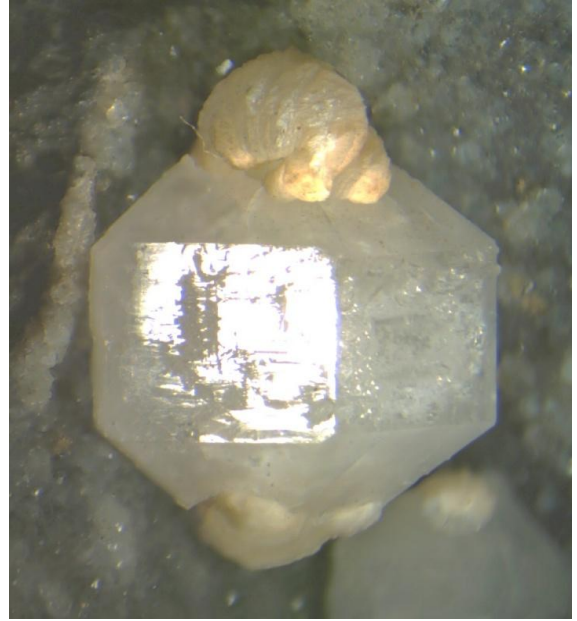


Fig. 10. *Gmelinite with Gyrolite on the caps*  
*N. Fk. John Day R., Grant Co., OR.*

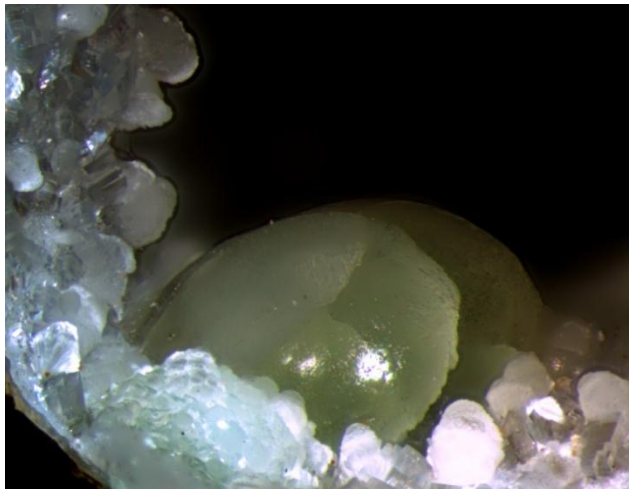


Fig. 11. *Two forms of Erionite, as bundles of white needles and as greenish 'fish-eyes'.*  
*Oceanside, Tillamook Co., Oregon.*

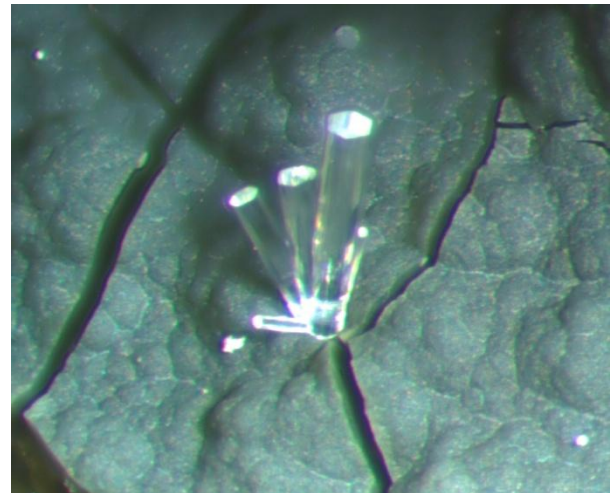


Fig. 12. *Clear, simple prisms of Erionite on a dark, cracked clay base.*  
*Moeraki, New Zealand.*



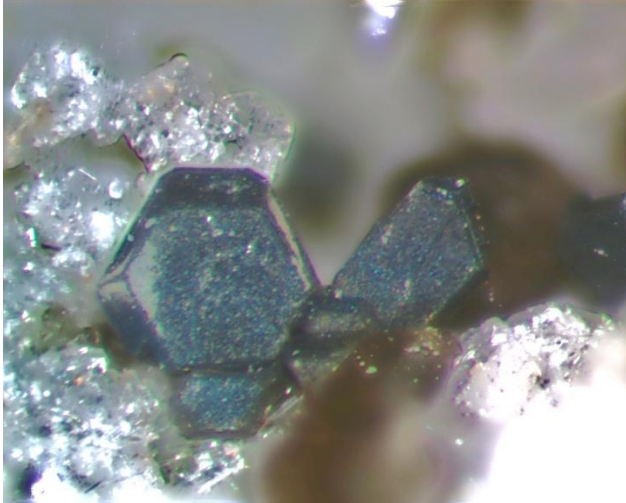


Fig. 13. *Ilmenite, with alternating edges*  
*Summit Rock, Klamath Co., Oregon.*

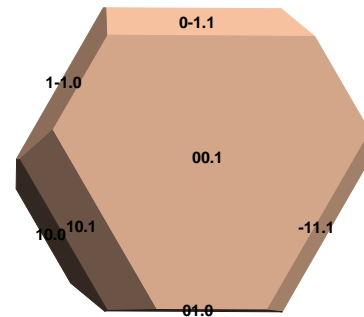


Fig. 14. *Diagram of fig. 13, showing alternating (10.1) edges, along with (01.0) prism faces.*

### Rhombohedral minerals

Ilmenite,  $\text{FeTiO}_3$ , and Hematite,  $\text{Fe}_2\text{O}_3$ , are two relatively simple rhombohedral minerals. Their structures are closely related, and they differ primarily in that half of the iron in hematite has been replaced in an ordered way by titanium. They are both shiny black platelets that tend to form blades thin in the  $c$ -direction. Visually, they cannot be distinguished, and are identified by detecting the presence or absence of titanium, usually using x-ray fluorescent studies in a microprobe or SEM.

Both minerals show very large (00.1) faces. One of the things that distinguish them as rhombohedral minerals is the alternating bevels where the rhombohedral (10.1) faces intersect the large  $c$ -face. As shown in fig. 14, prism faces (01.0) may also be present alternating with the rhombohedral faces, as is the case of the crystal shown in fig. 13. Hematite (fig. 15) shows similar variety in alternating edge faces. Both minerals have a ratio  $c/a \gg 1.0$ , causing the edge bevels to be quite steep.

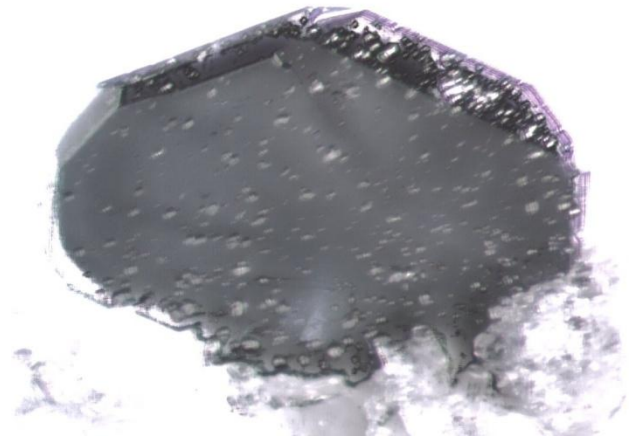


Fig. 15. *Hematite on Tridymite*  
*Mt. Ngongotaha, New Zealand.*

Levyne is another rhombohedral mineral that commonly forms very thin plates with very large  $c$ -faces. In this case, the crystals are quite clear unless there is an overgrowth of erionite. The arrangements of atoms on the  $c$ -face of each mineral is similar enough that the erionite grows in fine hair-like crystals out perpendicular to the blade of levyne. This may be anywhere from a fine dusting, as in fig.17, to layers many times the thickness of the original levyne blade, as in fig. 18.

The levyne blades may appear hexagonal. The edges are usually so thin that it is hard to observe the alternating slopes mentioned for hematite and ilmenite. You may notice that in fig. 17, the blades show re-entrant angles (notches), a sure sign of twinning, in this case on (11.0). For hexagonal

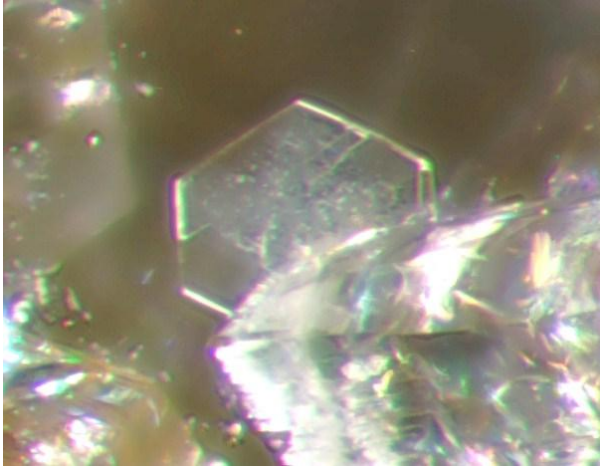


Fig. 16. *Levyne on Heulandite*  
4-mile Quarry, Porter, Washington



Fig. 17. *Levyne coated with Erionite*  
Beech Creek Quarry, Grant Co., OR.

symmetry, twinning on that plane (a mirror plane) is not possible, so its presence here is a direct indication that levyne is indeed a rhombohedral mineral.

Jarosite, a basic sulfate of ferric iron, is found commonly crystallized in the form of rhombohedrons, often truncated by a large c-face. As seen in fig. 19, these flattened crystals show edges that have alternating slopes, as described above. Jarosite is a secondary mineral of ore deposits that contain a considerable amount of iron. Jarosite belongs to a large group of sulfates, arsenates, and phosphates that all have a similar crystal structure and similar habit.



Fig. 18. *Thick Erionite overgrowth on Levyne*  
Adel, Lake Co., Oregon

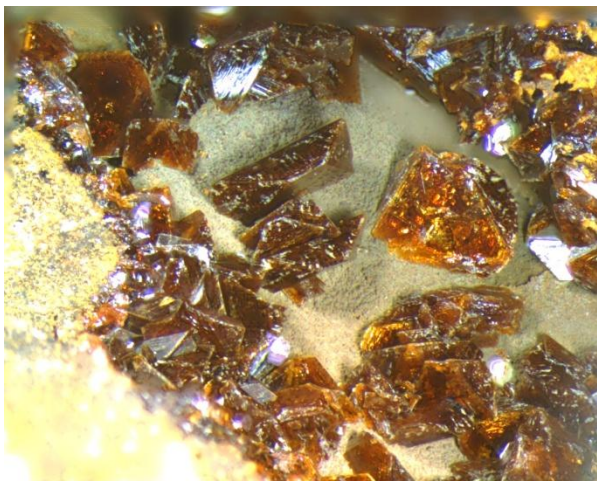


Fig. 19. *Truncated rhombs of Jarosite*  
Santa Fe Mine, Mineral Co., Nevada



Fig. 20. *Quartz on Calcite*  
Houdaille Quarry, Passaic Co., N. J.



Fig. 21. *Quartz on Stilbite*  
*Mill Creek Quarry, Polk Co., Oregon.*



Fig. 22. *3-sided termination on Amethyst*  
*Vera Cruz, Mexico.*

It may come as a surprise, but quartz is actually a rhombohedral mineral rather than a hexagonal one. For quartz,  $c/a = 1.10$ , so the usual terminal faces are close to  $45^\circ$ . Quartz crystals typically have six well-developed prism faces  $\{10.0\}$  and  $\{01.0\}$ . The common six-sided pyramidal termination is composed of two sets of rhombohedral faces,  $\{10.1\}$  and  $\{01.1\}$ . Such a 'normal' quartz crystal is shown in fig. 20. However, all of these faces in a given crystal may not be developed to the same extent. In some cases, one of the terminal rhombohedrons may be completely absent, leaving only three triangular faces on the termination. The quartz crystals in fig. 21 and the amethyst in fig. 22 have this sort three-sided ends. Notice also that the two sets of prism faces in fig. 21 have a different appearance caused by horizontal striations.

It is very common for quartz crystals to have only the six prism and six terminal faces. Occasionally, a few other faces may be present, but these are usually very small. The presence of  $c$ -faces is not common but does rarely occur, as shown in fig. 23 below.

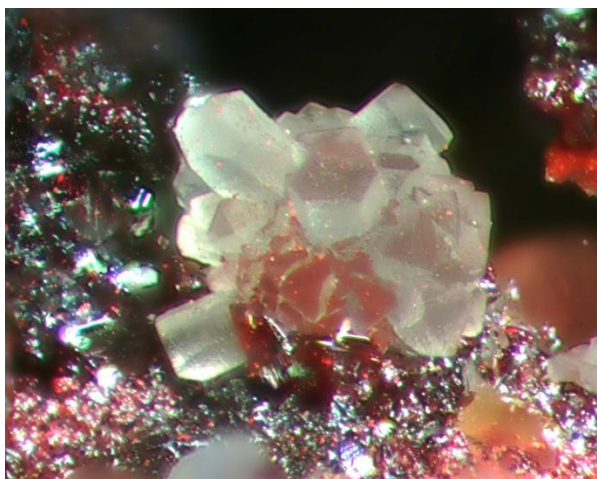


Fig. 23. *Quartz, showing large c-faces, on cinnabar*  
*Red Bird Mine, Churchill Co., Nevada.*



Fig. 24. *A Brazil twin of quartz*  
*Zaca Mine, Alpine Co., California.*

Twinning does happen in quartz, and several types are recognized. Twins on (10.0), such as the one shown in fig. 24, are called ‘Brazil twins’. They clearly illustrate the rhombohedral nature of quartz, since the (10.0) plane is a mirror plane in hexagonal symmetry, and therefore cannot be a twin plane. The atomic arrangement in quartz forms a spiral structure along the c-axis. This means that circularly polarized light traveling along the c-axis will have a different interaction depending on whether it is right-handed or left-handed. This causes the plane of linearly polarized light to be rotated. In a Brazil twin, the two members will rotate the plane of polarization in opposite directions. In this way, transparent quartz can be sorted into right-hand and left-handed crystals. This is important in studying quartz optically, and makes quartz a useful optical material.

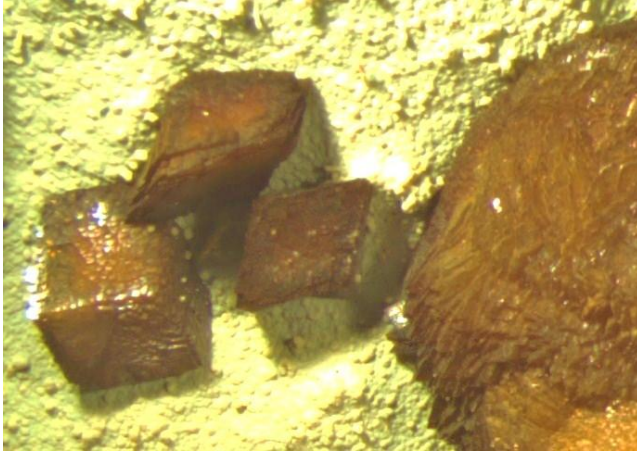


Fig. 25. *Rhombohedral Siderite*  
*Clackamas River, Oregon.*

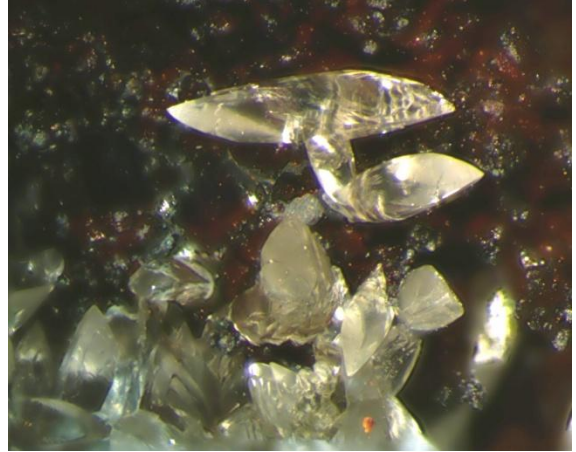


Fig. 26. *Smithsonite with rounded faces*  
*Santa Eulalia, Chihuahua, Mexico.*

The carbonates contain several common rhombohedral minerals. We have already mentioned that calcite forms rhombs. Actually, it forms a variety of several rhombs of varying steepness. Other members of the same group include siderite, smithsonite, and rhodochrosite, are often found as rhombs. Siderite rhombs, such as those shown in fig. 25, are usually rather equant and in a shape similar to the cleavage rhomb of calcite, fig. 3. Smithsonite rhombs can be more acute, such as those shown in fig. 26. The faces of smithsonite are often curved, giving the crystals a rounded appearance. Rhodochrosite is often in simple rhombs (fig. 27) but can also be found in six-sided elongated crystals with complicated terminations based on multiple rhombohedrons.



Fig. 27. *Rhodochrosite on quartz*  
*Silverton, Colorado*



Fig. 28. *Rhodochrosite*  
*El Potosi, Mexico*

The two pictures of rhodochrosite above give an indication of the wide range of forms this group can take. Calcite has probably more forms than any other mineral. It varies from flattened, plate-like disks to greatly elongated needles. The Goldschmidt Atlas lists 148 different sets of identified faces. There are many examples of one form growing on or around a completely different form. I know that many times I have put an unusual-looking crystal into the SEM only to discover that it is *just* calcite. Below we show a few examples of the many shapes calcite can take.

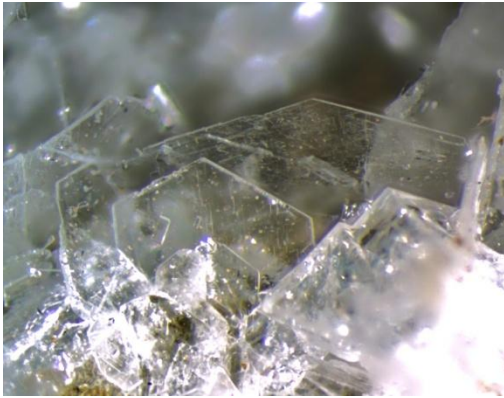


Fig. 29. *Paper-thin plate of calcite with stilbite  
Shellrock Mtn., Hood River Co., OR..*



Fig. 30. *Equant calcite with flattened cap  
Houdaille Quarry, Passaic Co., N. J.*



Fig. 31. *Steep rhombs of calcite with phantoms  
Boron, Kern Co., California.*



Fig. 32. *Calcite crystals on stilbite  
Mill Creek Quarry, Polk Co., Oregon.*



Fig. 33. *Calcite needle on heulandite  
Rock Creek, Stevenson, Washington*



Fig. 34. *Levyne on calcite rhomb with an  
enclosed needle-like phantom  
Baird Creek Q., Cowlitz Co., Wash.*

Dolomite is another carbonate mineral that commonly forms rhombohedral crystals. The faces are often curved, and that and low-angle twinning leads to complicated, saddle-shaped forms. Dolomite and calcite resemble each other, but dolomite is a little harder and does not react nearly as strongly to acid, while calcite rapidly releases bubbles of  $\text{CO}_2$ .

### Trigonal minerals

There are a few other minerals that fall into the hexagonal classification, but that do not have a six-fold symmetry axis and do not form as rhombohedrons. The tourmaline group is one of these, including minerals such as elbaite, dravite, and schorl. Tourmalines generally form long, often very slender crystals mainly comprised of three prism faces. These faces tend to be curved and therefore not very distinct. Terminations are very rare. Since there is no cleavage, the ends are rather rough and irregular as a rule. Tourmaline can be in the form of long, fine filaments that are sometimes grouped into bundles. Tourmalines come in a wide variety of colors, sometimes several colors zoned into a single crystal.

In general, we have tried to restrict the range of examples cited to rather common minerals. However, in this category we need to include benitoite despite its rarity because of the popularity of the rather large, well-formed, distinctive blue crystals. Benitoite forms as trigonal bipyramids. The top has the same three sloping faces as a rhombohedron, but there is a mirror plane perpendicular to the c-axis, so the bottom three faces are mirrored instead of rotated  $60^\circ$ . There is usually a small c-face and minor prism faces present as well. Add to that the fact that the mineral is fluorescent, and it is something we all want to include in our collection. And it is uniquely a West Coast mineral.



Fig. 36. *Benitoite and neptunite in natrolite*  
Gem Mine, San Benito Co., California



Fig. 35. *Quartz on rhombohedral dolomite*  
Livingstone Q., Los Angeles, Calif.

### Imposters

There are several minerals that have a structure close to being hexagonal, but have slight distortions. These can look hexagonal to the naked eye, but optical and x-ray crystal studies reveal that the necessary symmetry is lacking.

Chabazite is *nearly* a rhombohedral mineral. It is listed as triclinic; all three angles are slightly different, but none exceed  $90^\circ$  by more than  $2^\circ$ . All three axes are also only slightly different from each other. Chabazite crystals are therefore nearly cubes, but appear slightly distorted into almost rhombohedrons, the corner angles being around  $92^\circ$ . Close examination of



Fig. 37. *Pseudocubes of chabazite*  
Goble, Columbia Co., Oregon



Fig. 38. *Phlogopite on cristobalite*  
Obsidian Cliffs, Lane Co., Oregon

the striations on the faces in reflected light will usually disclose several twinned regions making up the rhombohedron. Chabazite (*variety phacolite*) can also form complex twins, and likes to grow epitaxially on the terminations of gmelinite. In an epitaxial overgrowth, the crystal structures of the two minerals in contact form a relationship to each other. In this case, the c-axes of the minerals are parallel.

Another set of near-hexagonal minerals are the micas, which include biotite, muscovite, phlogopite and polyolithionite. All the micas form large c-faces and have good cleavages perpendicular to the c-axis. Often they are strongly embedded, but when free they show a hexagonal outline, much like the phlogopite crystal illustrated in fig. 38. The structure is really monoclinic, because the c-axis is a few degree off of  $90^\circ$ . The plates happens to be very close to perfect hexagons, but they are not stacked up exactly one upon another.

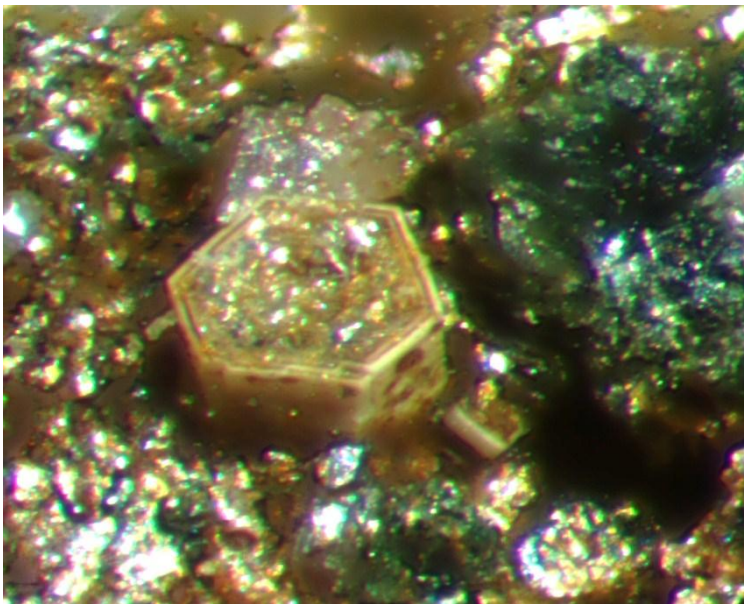


Fig 39. *Synchysite-(Y) / synchysite-(Ce) composite crystal*  
Washington Pass, Okanogan Co., Washington.

In the rare-earth fluorocarbonates, bastnasite is hexagonal and parasite is rhombohedral, but the mineral in between in composition, synchysite, is neither. It has a monoclinic distortion that is too small to be easily visible except in x-ray diffraction studies. Synchysite-(Ce) and synchysite-(Y) are the most common fluorocarbonates at Washington Pass, forming stubby, flat-ended pseudo-hexagonal prisms such as the one shown in Fig. 39.

There are also numerous minerals that form elongated crystals with six-sided prisms, such as the amphiboles. Included in that group are arfvedsonite from Washington Pass and fluoro-edenite from Summit Rock. Close examination will show that the

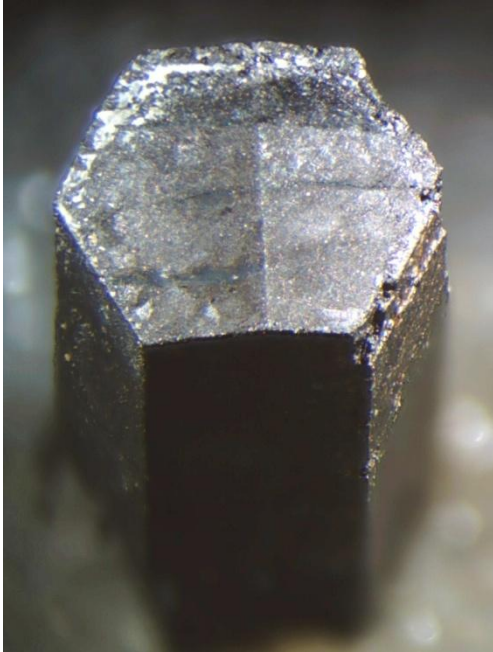


Fig. 40. *Arfvedsonite*  
Washington Pass, Wash.

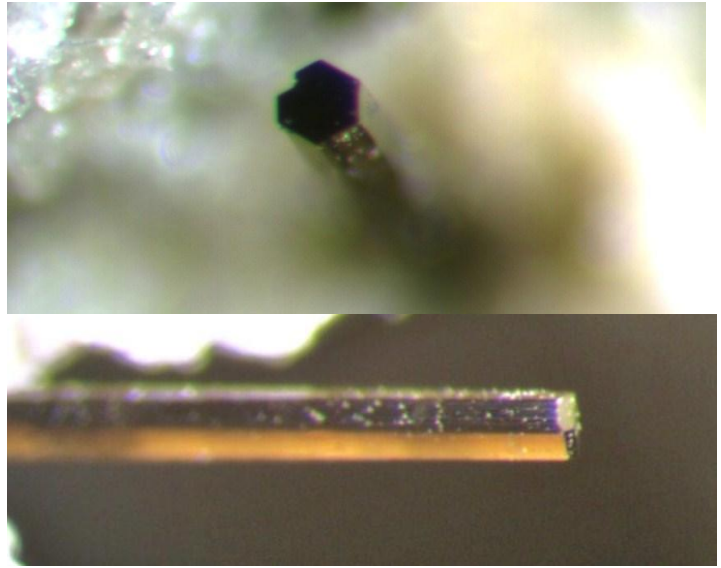


Fig. 41. *Two views of fluoro-edenite, showing both the six-sided cross-section and the bilateral termination.*  
Summit Rock, Klamath Co., Oregon

cross-section in an amphibole is not quite a regular hexagon in that some angles are larger than  $120^\circ$  and some are smaller. Moreover, the terminations are sloping and have bilateral rather than three-fold symmetry, as shown clearly in fig. 40. Amphiboles are monoclinic minerals, with the *b*-axis horizontal in fig. 40.

Hopefully, this article has given you some ideas on what to look for when examining crystal form. The best way to learn to identify minerals is by collecting and carefully observing them. That is the value of having a reference collection. On the preceding pages, we have tried for the most part to cite commoner minerals that you may already have in your collection, or that you may be able to pick up on the free table or at minimum cost from a dealer.

Studying crystals and collecting different forms of the same mineral can be a specialty in your collection. May you have many happy hours learning about the nearly endless forms minerals can take.

Good collecting to you!

This year's Symposium of the **Northern California Mineralogical Association** is scheduled to be held May 30 through June 1 at the El Dorado Community Hall in El Dorado, California.

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