THE USE OF NATURAL CRYSTALS IN THE STUDY OF CRYSTALLOGRAPHY

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INTRODUCTION

I use single, euhedral, natural crystals of minerals extensively when teaching basic concepts of crystallography. Wooden or paper models, showy museum-quality crystal clusters, colorful pictures in a book, or even computer images simply cannot compete with the beauty, awe-inspiring mystery and educational value of genuine, individual mineral crystals when held in your (or your students'!) hands.

Most Mineralogy courses include lecture material and lab exercises on crystallography. Why not have students work with real crystals as much as possible? From my experience, this can be a lot of fun for everyone and seems to effectively engage the students in the learning process. Students think natural crystals are very cool as they explore crystallographic topics.

In my Mineralogy course I use single, well-formed crystals in all aspects of basic crystallography including measurement of interfacial angles, determination of symmetry elements, recognition of crystal system and class, determination of forms, stereographic projections and stereograms, recognition of common twins and pseudomorphs, and even SHAPE plots. These are just some of the possibilities.

This approach has a very practical value as well, considering my student population. The mineralogy students I teach are primarily environmental science and education majors, with a few geology majors usually interested in working in the south Texas oil patch. Identifying minerals in hand specimens, aided by a comfortable knowledge of how to recognize crystal system and characteristic crystal shapes, may be one of the most useful crystallographic skills for these students in their later careers.

ACQUISITION OF CRYSTALS

In just the last four years I have purchased euhedral, single crystals of approximately 50 different minerals which I've incorporated into labs and quizzes. I only buy samples whose crystal system and forms can be determined. Most specimens were acquired from dealers at Gem and Mineral shows and rock shops throughout south Texas. (I have been disappointed with specimens purchased sight-unseen through the mail.) If I can assemble a fairly extensive, useful collection of crystals in south Texas, it should be possible to build a similar collection anywhere in the United States.

Many of the best specimens I've purchased are referred to as "thumbnail" size and come in small, clear plastic cases. Some dealers have hundreds of these for sale, often including several of the same mineral from which to choose. Most dealers are also fairly knowledgeable about specific locales of their specimens. Cost varies from a few dollars to a few tens of dollars for larger, more euhedral or less common crystals. Interestingly, single crystals in matrix are also usually more expensive. Many dealers give discounts for college and university purchases. You could start a collection for an investment of just a few hundred dollars, which is less expensive than most other mineralogical supplies and equipment.

COMMONLY AVAILABLE CRYSTALS

All of my crystallography labs are too specific to my collection for reproduction here. Instead, I'll list some crystals you should be able to find, and their commonly available forms:

Isometric System

Garnet. (Various species, including Uvarovite)
- Trapezohedron
- Dodecahedron
- Trapezohedron /Dodecahedron combinations (either one dominant)

Galena.
- Cube
- Cube modified at corners by octahedron

Magnetite.
- Octahedron

Diamond.
- Cube
- Octahedron

Halite.
- Cube (including hopper crystals)

Fluorite.
- Cube
- Octahedron (less common)

Pyrite.
- Cube (with and without striations)
- Cube/Octahedron combinations (either one dominant)
- Pyritohedron

Apophyllite. (Pseudo-isometric)

Hexagonal System

Beryl. (Aquamarine and Emerald)
- Prism with pinacoid

Molybdenite.
- Prism with prominent pinacoid

Vanadinite.
- Prism with prominent pinacoid

Corundum.
- Prism with pinacoid

Calcite.
- Rhombohedron
- Scalenohedron

Dioptase.
- Rhombohedron

Quartz.
- Assorted varieties and forms including scepter crystals, doubly-terminated crystals and enantiomorphic pairs (less common)

Tourmaline.
- Trigonal prism/Hexagonal prism combinations (either one dominant)
- Trigonal dipyramid with prism

Benitoite. Less common, various forms. (Benitoite is the only mineral in the $\bar{6}m2$ class.)

Aragonite. (Pseudo-hexagonal cyclic twin)

Muscovite. (Pseudo-hexagonal)

Tetragonal System

Vesuvianite.

Dipyramids with prisms and pinacoid

Zircon.

Dipyramid

Dipyramids with prisms

Apophyllite.

Dipyramid with prism

Wulfenite.

Dipyramid with prominent pinacoid

Orthorhombic System

Barite.

Prisms with pinacoid

Danburite.

Prisms with pinacoid

Topaz.

Various combinations of dipyramids with prisms and pinacoid

Monoclinic System

Orthoclase.

Prism with pinacoids

Gypsum.

Prisms with or without pinacoid

Glauberite.

Prism with pinacoid

Triclinic System

These are not common. The only good crystal I have is of relatively rare axinite.

Some minerals, such as native copper, stibnite, smithsonite, wavelite, etc. are rarely found as individual crystals, but are commonly available in crystalline masses that exhibit good examples of habit (dendritic, acicular, botryoidal, radiating, etc.).

SAMPLE QUESTIONS

The number of possible laboratory and quiz questions you can create using real crystals is endless. Some questions are very similar to those you might ask using a good set of wooden or paper models. Other questions are uniquely possible with natural crystals. I also try to relate external crystallinity to atomic structure when possible. I also like to require some sketches of crystals, combining "left brain" and "right brain" activities. Sample questions include:

1. List all symmetry elements present in this crystal.
2. Give the crystal system and class for this crystal.
3. Give the Hermann-Mauguin symbol for this crystal.
4. Sketch the given crystal and list all forms present.
5. Give the form(s) and Miller indices for this crystal.
6. Sketch a face stereogram of this crystal.
7. What are the *general* characteristics of crystals that crystallize in this system?
8. (Various minerals possible)
    a. Explain the twin law by which this sample is twinned.
    b. Name the mineral.

9. (For Quartz)
    a. For each of the given crystals, measure and list the indicated interfacial angles.
    b. Do size, shape or color of the crystal influence your measurements?
    c. What is the significance of your measurements?
10. (For Quartz)
    a. Is this a right-handed or left-handed crystal?
    b. Give the space group of this crystal.
    c. Sketch this crystal and identify the trigonal trapezohedral face.
    d. Discuss the origin of "handedness" in quartz crystals.
11. (For a Quartz scepter crystal)
    Explain how this crystal could form.
12. (For Vesuvianite)
    a. Recreate this crystal using SHAPE and list the parameters.
    b. Change the parameters and explain how the crystal has changed.
13. (For Staurolite)
    Crystals of this mineral, like two of these, are often twinned. Note the third, untwinned crystal. Although actually monoclinic, it appears to be orthorhombic. Explain why.
14. (For cyclically-twinned Aragonite)
    a. Although aragonite crystallizes in the orthorhombic system, this crystal appears to have the symmetry of what other crystal system?
    b. Explain why.
15. (For Calcite rhombohedron and scalenohedron, plus several calcite cleavage rhombs)
    a. Two of these samples are crystals and the others are all cleavage fragments. Pick out the two crystals.
    b. Explain why this may be difficult.
16. (For Pyrite cube)
    a. Give the crystal system and class.
    b. Give the crystal form.
    c. Explain how this form, which has the symmetry of $4/m\ \bar{3}\ 2/m$, can exist in this crystal class of lower symmetry.
    d. Explain the signifance of the striations on crystal faces.
17. (For a variety of minerals)
    a. You have been given a collection of 15 mineral crystals of various shapes, sizes and colors. As an early crystallographer, your job is to create a logical, workable classification scheme for these crystals.
    b. You have been given 3 additional crystals. Can they be classified within your system, or do you have to modify it? If so, how?

Additional questions can be created for unusual crystals you may find. For example, I have several bixbyite crystals from the Thomas Range, Utah, which are cubes modified at the corners by a trapezohedron. The trapezohedron can only be identified by sketching a face stereogram, as the shape of the three faces at the corners superficially resemble faces of a trisoctahedron.

CONCLUSIONS

The extensive use of euhedral, single, natural mineral crystals is a very low-tech and low-cost approach to teaching basic concepts of crystallography. I have found that this approach makes the entire subject of crystallography much more real and accessible to students. Students prefer working with these crystals rather than the traditional wooden or paper models, an enthusiasm which seems to carry over into other classroom topics and laboratory exercises.