A TERM-LONG MINERALOGY LAB PRACTICAL EXAM

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Overview

One of the hardest things to teach in mineralogy is the ability to identify minerals in hand sample. I think this is principally because mineral identification is a skill that, in large part, must be learned by long practice.

For several years I used the standard "rocks in a drawer" approach to teaching hand specimen identification. This involved handing out a list of important minerals and reviewing drawers of teaching samples in lab by going over the individual mineral properties and some aspects of their crystal chemistry and structure. For the lab exam at the end of the course students were required to identify a portion of the minerals seen in lab. This method was largely unsuccessful, in part I think because the students had no tangible goal to work toward. The goal of learning to identify the minerals on the list is too amorphous, since it does not refer to a specific set of specimens or properties but rather to an unknown set of test specimens that may differ widely from the practice specimens. As a result, students have no clear idea of what properties are important, and therefore don't know when they have studied enough or if they have studied the right things. When faced with such uncertainty, many students tend to do too little rather than too much. An additional problem with final exam-oriented teaching is that the students do not develop skill at using advanced methods of mineral identification such as X-ray diffraction and mineral optics. Although individual lab exercises can cover X-ray diffraction and other mineral identification techniques, it would be worthwhile for students to practice using them repeatedly as practical problem-solving tools.

To address the problems with final exam-oriented teaching of hand specimen identification, I decided to change my goals:

1) Mineralogy students <u>do not</u> need to be able to identify most minerals presented to them in classic mineralogy courses. A relatively small subset of minerals, including important rock-forming minerals, is sufficient for most geologically-related employment and graduate school. More obscure minerals can be learned on the job.

2) Mineralogy students <u>do</u> need to learn the tools and skills of mineral identification. These include determining the usual properties hardness, luster, color, streak, and so on, and more advanced techniques including density measurement, mineral optical properties, and X-ray diffraction.

3) Mineralogy students should practice these techniques many times on a variety of samples. I do not, however, require them to determine every property for every specimen, since this involves a lot of unnecessary repetition that annoys students.

4) Students should have an obvious goal for their mineral identification exercises and, at least minimally, to have a stake in reaching the goal other than their final grade. I hope that this increases student motivation.

On the first day of mineralogy class each student receives a box of 65 thumb-sized, numbered mineral specimens, which are theirs to keep. All of the minerals are described in their text (Klein and Hurlbut, 1993). At the end of the term students must turn in a list of their 65 identified minerals, with the properties they used for identification. Because students keep their samples, most really do want to learn what they are, and they have an incentive to test the samples carefully without destroying them, just like a geologist would (or should). One twist to letting the students keep the minerals, suggested by Michael Wolf, is to let students keep only samples they correctly identify. This apparently increases their incentive to work hard. Although the sample sets can be expensive (about $20 each), our teaching collection receives much less damage than previously.

I still go over the practice specimens in lab, but I dwell much more on common rock-forming minerals, the reasons for variability of mineral properties, and on crystal chemistry, crystal structure, and the origin and uses of minerals. I encourage students to bring their box of samples to lab to compare them with those in the teaching collection. After all, that is frequently what real geologists do. It is also a useful learning experience since relatively few of their samples really look like their counterparts in the teaching collection, and some specimens that look similar are actually completely different minerals. Students quickly learn that direct comparison is an easy way to identify a few samples, but does not work for many.

Discussion

In several respects my redesigned mineralogy lab has been extremely successful. Most students love their samples and work hard outside of class to identify them. They usually identify several within a few minutes of opening their box on the first day (e.g., quartz crystal, muscovite, biotite, and halite), based on previous geology classes and other experience. This gets them started and makes them realize that the goal of identifying all of them is attainable. Early in the term I review all the mineral identification techniques available in our department, including X-ray diffraction and basic practical optical mineralogy using grain mounts. By the middle of the term the students have all the necessary tools and they usually start working in earnest. It is wonderful to come in late in the evening and find several students working on their mineral sets; something I never saw with the old method. The students generally get quite skilled with the identification techniques that we cover, except, alas, for optical techniques. Students quickly learn that the flashy computer-controlled XRD can be a slow and tedious way to identify minerals, and so most use it as a last resort (I disable the automatic peak matching program to encourage students to use their brains rather than a machine, which in any case is often wrong).

Although I would never return to my old ways, there is a problem with the redesigned labs. Students become relatively skilled at mineral identification, but still do not really learn to identify mineral specimens by sight or with a few tests even for most of the common rock-forming minerals. I have partly remedied this problem by putting out a weekly "puzzle box", each of which includes, among other things, five unlabeled common rock-forming minerals that students will be expected to know for the final exam. Since these samples help them to identify their own samples, the fact that the "puzzle box" is optional does not seem to hinder the students from looking and learning from it.

In summary, giving students their own box of minerals to identify during the entire term gives them a clear and tangible goal, motivation to work and learn, lots of practice looking at samples using various identification techniques, and practice interpreting diverse and sometimes conflicting data. In addition, students develop a camaraderie as they voluntarily work during evenings and weekends. Since students do this willingly, they really have fun even if they do complain a bit. Most students end up successfully identifying about 80% of their samples, 90%

if you include identifications that are wrong but are very similar to the actual minerals. I admit that many of the minerals I give them are quite difficult to identify, but that's fine.

My favorite mineral in the set is romanechite (formerly psilomelane), a hydrated Ba-Mn oxide. It looks rather like an iron oxide or dense hydroxide, but the various basic properties are conflicting when one tries to identify it as an iron mineral. As a last resort, students try X-ray diffraction and find out, to their horror, that it is X-ray amorphous! However, when they read their book carefully, they do indeed find that romanechite is X-ray amorphous, and most identify correctly.

Mineral List

The following is the list of minerals that we currently use. The list changes yearly as different minerals become more or less expensive or available. Some minerals are present in two or more varieties. The samples are numbered differently for each class, and the students do not get this list.

Actinolite
Alabaster
Albite
Amblygonite
Anorthoclase
Apatite (chunk)
Apatite (crystal)
Asbestos
Barite
Bauxite
Beryl
Biotite
Calcite
Celestite
Chalcopyrite
Chert
Chrysocolla
Chromite
Corundum
Diopside
Dolomite
Dumortierite
Enstatite
Epidote
Fluorite
Galena
Garnet
Glauconite
Goethite
Graphite
Halite
Hematite
Hornblende
Jasper
Kaolinite
Kyanite
Labradorite
Lepidolite
Limonite
Magnesite
Magnetite
Microcline
Muscovite
Olivine
Opal
Phlogopite
Pyrite
Quartz crystal
Romanechite
Rose quartz
Nepheline
Satin spar
Selenite
Serpentine
Siderite
Sillimanite
Sodalite
Sphalerite
Spodumene
Talc
Tiger eye
Topaz
Tourmaline
Travertine
Wollastonite

Reference

Klein, C., and Hurlbut, C.S. Jr. (1993) Manual of Mineralogy (21st edition). John Wiley and Sons, Inc., New York, 681 p.

TAKE HOME LAB EXAM: INSTRUCTIONS TO STUDENTS

You have been given a box of 65 mineral specimens, and these are yours to keep as a souvenir of this course. These specimens are the take-home part of your lab practical final exam. You are to identify all 65 specimens. Some of the specimens are pure minerals, others are impure minerals, and others are mineraloids or even rocks. There may even be a few duplicated minerals. All of the minerals are in your text.

I will not give any help identifying these specimens, except to clarify the instructions, to help with analytical and identification techniques, and to point out which mineral is the important one in a sample. You are to work independently and may not help each other except with identification techniques. You can use any of the mineral identification techniques available in the Geology Department (except ICP-MS analysis) including:

- Hardness
- Color
- Cleavages and cleavage intersection
- Stereo microscope or hand lens
- Taste
- Mineral optics in immersion oil
- Radioactivity (Geiger counter)
- Reaction with acids
- Streak
- External crystal form
- Density
- X-ray diffraction
- Fluorescence under U.V. light
- Comparison with known minerals

I recommend against relying heavily on visual comparison of your unknown minerals with specimens in lab or in the display cabinets. Outward appearances can and will be misleading! It is more reliable to base your identification on several properties. Full credit will be given only for properly identified minerals with a sufficient and accurate set of identifying characteristics. Extra credit will be given for chemical and structural data that *you* determine (give data), for variety names, and for any other pieces of interesting information that you can determine. Feel free to use any resources in the lab, in the library, or on the Internet.

Hand in the following information in table form:

Mineral Name: The basic mineral name and/or variety. This is the name of the most abundant or prominent mineral in the specimen.

Distinguishing Characteristics: Give the characteristics of this specimen that you determined and used to identify this mineral and its variety. This can be just a few properties if it is that obvious, or several properties such as hardness, color, streak, X-ray pattern (give specific peaks and positions used for identification), crystal form, mineral optics (give refractive indices, optic sign, 2V, etc.), density (give measured value), and anything else.

Other Information: Give any other information that is important, including other minerals that occur in the specimen, other properties not listed under Distinguishing Characteristics, chemical composition as derived from X-ray pattern, density, or mineral optics, crystal form, twinning, etc.