Mineral Identification for Rock Stars

Every book and web site has its own theory on the best sequence of tools to use when trying to identify an unknown mineral. The goal of this article is to help you come up with a process that works well for you.

Mineralogical Society of America Mineral Identification Key @ http://www.minsocam.org/msa/collectors_corner/id/mineral_id_keyi1.htm

Location, location, location

Professional geologists working in mineral exploration quickly learn that the most important tool is knowledge. The geology and mineralogy of the location where the mineral was collected will help limit the possibilities even before you see the specimen.

Those of us who have been around for a while have collections of books, journals and other documents that describe areas we are interested in. This is, of course impractical for the mineral collector. Fortunately, we live in the internet age and there are many online resources that can be used to research mineral localities. The best one of these is the Mineral and Locality Database @ http://www.mindat.org/ which has a remarkably complete location database with a simple search engine. It includes detailed list of minerals at each location with picture galleries containing thousands of photographs.

Others internet resources include the Mineral and Gemstone Kingdom @ http://www.minerals.net/MineralMain.aspx and Web Mineral Mineralogy Database @ http://webmineral.com/

Always start with what you can see.

The three most obvious properties of a mineral are its color, transparency and shape.

Color : Color is determined by the wavelength of light that a mineral reflects. Think of a rainbow, each color is a different wavelength. So red minerals reflect red light, green minerals reflect green light, etc. Many minerals have distinctive colors … Pyrite is always gold, Galena is always silver gray. But there are also many minerals that come in a variety of colors … Calcite and Quartz can be pretty much any color. Plus, the same color can be seen in several different mineral species … Calcite, Quartz, Gypsum, Halite, Talc, Albite and a couple of hundred others can be white. So, color is a fairly poor mineral identifier unless it is used in combination with other properties.

Transparency : This property describes whether you can see through a crystal. It can have a dramatic affect on color. For opaque minerals, the color tends to be more consistent. On the other hand, translucent to transparent minerals usually have much more varied and less distinct colors. (see transparency for more information)

Shape : During the process of crystallization, minerals assume various geometric shapes dependent on the ordering of their atomic structure and the unique physical and chemical conditions under which they grow. For many minerals, like Quartz, crystal shape is distinctive. For others, it can vary greatly. For example, Calcite has more than 300 crystal forms and these forms can combine to produce over a thousand different crystal shape variations.

So, shape is very important in identifying a mineral. Unfortunately, the way shape is described in mineral identification literature is overwhelmingly complex. Shape is described by two related properties. The crystal system tells us the geometry (how many sides, angles between the sides, etc.) of a single crystal. The crystal habit describes the way in which crystals grow (how long they are, what the ends look like, how they group together, etc.).

You can try to learn all this in the sections below, but the best thing to do is get pictures of minerals that occur in the area you are exploring and compare the shape of your unknown to those pictures. Take a look at the Quartz ID article to get an idea of the kind of research you might want to do.

Luster : Describes how well the crystal faces reflect light. Seventy percent of all minerals have the same luster … vitreous (glass-like) so it can't be use to differentiate between them. On the bright side, if the mineral's luster is not vitreous you can eliminate a lot of possibilities.

Cleavage and **Fracture** : These two properties describe how a crystal breaks. If a crystal breaks along a smooth flat surface it has cleavage. Irregular breakage is caused by fracture.

At this point, we are still just looking at the specimen so don't try to break it. Instead, look for signs that it is already broken. Cleavage will show up as a smooth, flat surface that doesn't match up with the rest of the crystal's shape. Fracture will show up as a rough surface missed in among the smooth crystal faces.

Test Your Hypothesis

By now you should have a limited set of possibilities and may even have decided on an identity. It's time to perform whatever physical tests are necessary to eliminate "possibles" from the list until a positive ID can be made. Remember, physical tests are destructive and will do irreparable harm to the specimen. Always do physical tests on a part of the specimen that is already damaged.

The main physical properties to check are streak, hardness and tenacity. Each of these is more or less useful depending on the mineral, so, again it pays to have an idea of what you are looking for. Specific gravity is mentioned in all the text books, but is impractical in the field (see specific gravity).

If there was no visible cleavage or fracture, you can try to break the specimen. Only do this as a last resort because minerals have a tendency to break in unexpected ways that often ruin the specimen.

Then, of course, there a species-specific tests that can be done. For example, the taste test for Halite, the acid test for Calcite and the magnet test for iron minerals.

Mineral Properties

Color

Color is determined by the wavelength of light that a mineral reflects. Think of a rainbow, each color is a different wavelength. So red minerals reflect red light, green minerals reflect green light, etc.

Many minerals have distinctive colors, but there are also many minerals that come in a variety of colors. Plus, the same color can be seen in several different mineral species. And transparency can have a dramatic affect on color.

So, color is a fairly poor mineral identifier unless it is used in combination with other properties. For example, use cleavage/fracture, hardness and crystal habit along with the color.

Cleavage

Cleavage occurs in minerals where the bonds between atoms aligned in certain directions are weaker than bonds between atoms in other directions. These minerals preferentially break along smooth, flat surfaces parallel to the weaker zones – known as the the cleavage plane. Not all minerals exhibit cleavage.

Cleavage is described by how easily a mineral breaks along the cleavage plane using the following terms:

- **Perfect** : cleavage happens along a very smooth plane
- **Exellent** : cleavage along a smooth plane
- **Distinct** : well defined, not so smooth
- **Good** : cleavage surface has some imperfections
- **Poor** (**Indistinct**, **Imperfect**) : a rough surface (close to irregular fracture)
- **None** : No cleavage … the mineral only fractures (see fracture)

Crystal Habit

In nature perfect crystals are rare. The faces that develop on a crystal depend on the space available for the crystals to grow. If crystals grow into one another or in a restricted environment, it is possible that no well-formed crystal faces will be developed. The term used to describe general shape of a crystal is ***habit***. Given room, most minerals will develop one crystal form more commonly than others, which makes habit a very powerful diagnostic tool.

Simplified Habits of Individual Crystals

- Cubic : cube shapes
- Tabular : rectangular shaped crystals.
- Equant : all 3 dimensions of the crystal are approximately equal.
- Octahedral : shaped like octahedrons (eight-sided polygons).
- Prismatic : main faces run parallel to an axis of the crystal.
- Acicular : long, slender prisms.

- Bladed : shaped like a wedge or knife blade.

Simplified Habits of Groups Crystals

- Dendritic : tree-like growths.
- Reticulated : lattice-like groups of slender crystals.
- Radiated : radiating groups of crystals.
- Fibrous : elongated clusters of fibers.
- Botryoidal : smooth bulbous or globular shapes.
- Globular : radiating individual crystals that form spherical groups.
- Drusy : small crystals that cover a surface.
- Stellated : radiating individuals that form a star-like shape.

Crystal System

A crystal is the solid form of a chemical compound that is bounded by flat planes (commonly called "faces"). All minerals are chemicals formed by and found in nature. A crystal normally forms during the change of matter from liquid or gas to the solid state. The solid mineral takes on a regular 3-dimensional form. These forms are grouped into seven groups (systems) based on similarities in geometry.

Crystal systems are very complex and the terminology can be very confusing, so we won't tackle the details here. If you want to know the details see the Wikipedia article @ http://en.wikipedia.org/wiki/Crystal_system or the "Introduction to Crystallography and Mineral Crystal Systems" @ http://www.rockhounds.com/rockshop/xtal/index.html

Everywhere else, follow the links to get more details.

Amorphous System

Amorphous minerals have no crystalline structure. The most common of these cooled down too quickly to form any distinct shape. Obsidian (volcanic glass), limonite, opal and mercury are examples of amorphous minerals.

Also, minerals containing radioactive uranium and thorium often devolve into amorphous forms (called metamict minerals) due to accumulated structural damage caused by radioactive decay.

Finally, some amorphous minerals are formed by the hardening of organic matter. Examples are amber, bitumen and pyrobitumen (found in as inclusions in "Herkimer Diamonds") .

Isometric (Cubic) Crystal System

The sides of minerals in the isometric system are all the same shape and size and are the same distance apart in all directions. Crystal shapes include cubes (Fluorite, Halite, Galena, Pyrite), octahedrons (Fluorite), rhombic dodecahedrons (Garnet) and icosi-tetrahedrons (Pyrite).

- Wikipedia has an article on the cubic system @ http://en.wikipedia.org/wiki/Cubic_crystal_system

- Rockhounds.com has a detailed explanation of the isometric(cubic) crystal system @ http://www.rockhounds.com/rockshop/xtal/part3.html
- Web mineral has illustrations of the shapes in the isometric crystal system @ http://webmineral.com/crystall.shtml#isometric
- See Mindat's list of minerals in the isometric system @ http://www.mindat.org/system_search.php?c=Isometric

Tetragonal Crystal System

Minerals in the tetragonal system have crystals that are longer in one direction than the other two (which are the same size). This results in 4-sided prisms and pyramids and 8-sided prisms, dipyramids (two pyramids stuck together) and trapezohedrons. Almost no common minerals are in this group, the exceptions being Pyrolusite, Rutile and Tin.

- Wikipedia has an article on the tetragonal crystal system @ http://en.wikipedia.org/wiki/Tetragonal_crystal_system
- Rockhounds.com has a detailed explanation of the tetragonal crystal system @ http://www.rockhounds.com/rockshop/xtal/part4.html
- Web mineral has illustrations of the shapes in the tetragonal crystal system @ http://webmineral.com/crystall.shtml#tetragonal
- See Mindat's list of minerals in the tetragonal system @ http://www.mindat.org/system_search.php?c=Tetragonal

Orthorhombic Crystal System

Like minerals in the tetragonal system, orthorhombic crystals form 4-sided prisms, pyramids and dipyramids (two pyramids stuck together), but no two directions are the same length. The most common orthorhombic minerals are Aragonite, Barite, Celestite and Topaz.

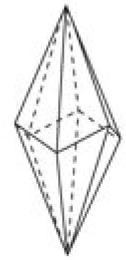
- Wikipedia has an article on the orthorhombic crystal system @ http://en.wikipedia.org/wiki/Orthorhombic_crystal_system
- Rockhounds.com has a detailed explanation of the orthorhombic crystal system @ http://www.rockhounds.com/rockshop/xtal/part5.html
- Web mineral has illustrations of the shapes in the orthorhombic crystal system @ http://webmineral.com/crystall.shtml#orthorhombic
- See Mindat's list of minerals in the orthorhombic system @ http://www.mindat.org/system_search.php?c=Orthorhombic

Hexagonal Crystal System

Minerals in the hexagonal crystal system for 6-sided and 12-sided prisms, pyramids and dipyramids (two pyramids stuck together). Six-sided trapzeohdrons are also possible. The most common orthorhombic minerals are **Ice**, Apatite, Graphite, Zinc and Beryl and its gem forms Emerald and Aquamarine.

- Wikipedia has an article on the hexagonal crystal system @ http://en.wikipedia.org/wiki/Hexagonal_crystal_system

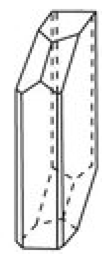
- Rockhounds.com has a detailed explanation of the hexagonal crystal system @ http://www.rockhounds.com/rockshop/xtal/part6.html
- Web mineral has illustrations of the shapes in the hexagonal crystal system @ http://webmineral.com/crystall.shtml#hexagonal
- See Mindat's list of minerals in the hexagonal system @ http://www.mindat.org/system_search.php?c=Hexagonal



Trigonal Crystal System

6-sided pyramids, rhombohedrons, trapezohedrons and scalenohedrons (see picture). Common trigonal minerals are Quartz, Calcite, Hematite, Tourmaline and Corundum and it's gem forms Ruby and Sapphire.

- Wikipedia has an article on the trigonal crystal system @ http://en.wikipedia.org/wiki/Trigonal_crystal_system
- Rockhounds.com has a detailed explanation of the trigonal crystal system as part of it's article on the hexagonal crystal system @ http://www.rockhounds.com/rockshop/xtal/part6.html
- Web mineral has illustrations of the shapes in the trigonal crystal system @ http://webmineral.com/crystall.shtml#trigonal
- See Mindat's list of minerals in the trigonal system @ http://www.mindat.org/system_search.php?c=Trigonal



Monoclinic Crystal System

Monoclinic crystals look like tetragonal crystals that have been bent to one side (see picture). About one third of all minerals are monoclinic. Common monoclinic minerals are Gypsum, Talc, the micas, Orthoclase feldspar, Diopside, Hornblende, Malachite and Azurite.

- Wikipedia has an article on the monoclinic crystal system @ http://en.wikipedia.org/wiki/Monoclinic_crystal_system
- Rockhounds.com has a detailed explanation of the monoclinic crystal system @ http://www.rockhounds.com/rockshop/xtal/part7.html
- Web mineral has illustrations of the shapes in the monoclinic crystal system @ http://webmineral.com/crystall.shtml#monoclinic
- See Mindat's list of minerals in the monoclinic system @ http://www.mindat.org/system_search.php?c=Monoclinic

Triclinic Crystal System

Minerals in the triclinic crystal system are unruly. Unlike crystals in the other systems, pairs of faces are usually not symmetrical from one side to the other which makes for some fairly strange shapes. Common triclinic minerals are the Albite-Anorthite plagioclase feldspar series, Microcline feldspar, Kyanite and Turquoise.

- Wikipedia has an article on the triclinic crystal system @ http://en.wikipedia.org/wiki/Triclinic_crystal_system

- Rockhounds.com has a detailed explanation of the triclinic crystal system @ http://www.rockhounds.com/rockshop/xtal/part8.html
- Web mineral has illustrations of the shapes in the triclinic crystal system @ http://webmineral.com/crystall.shtml#triclinic
- See Mindat's list of minerals in the triclinic system @ http://www.mindat.org/system_search.php?c=Triclinic

Fracture

Fracture describes how a mineral breaks when the bonds between atoms in a mineral are the same (or almost the same) in all directions. All minerals will fracture when put under stress, even if they have a perfect cleavage. So, in minerals with cleavage, fracture describes how a mineral breaks in a direction other than the direction of the cleavage.

Fracture is described by the character of the fracture surface :

- Conchoidal : smoothly curved breakage that resembles the concentric ripples of water
- Subconchoidal : similar to conchoidal fracture, but not as curved.
- Splintery : results in sharp elongated points, particularly seen in fibrous minerals
- Granular : surface looks like group of grains or granules
- Even : flat surfaces (not cleavage) fractured in an even pattern.
- Uneven : rough or irregular surface
- None : mineral does not fracture under normal conditions

Hardness

Hardness is the ability of a mineral to resist scratching. It is measured using the Mohs scale which is based on the hardness of ten minerals that are readily available :

Mohs Hardness Scale		
Hardness	**Mineral**	**Absolute Hardness**
1	Talc	1
2	Gypsum	3
3	Calcite	9
4	Fluorite	21
5	Apatite	48
6	Orthoclase Feldspar	72
7	Quartz	100
8	Topaz, Emerald, Aquamarine	200
9	Corundum (Ruby, Sapphire)	400
10	Diamond	1600

The Mohs scale (left column in the table) is a relative scale. This means that Gypsum is not twice as hard as Talc, nor is Fluorite twice as hard as Gypsum. These types of "absolute" hardness can only be measured using sophisticated (and expensive) scientific equipment. Using the right column in the table, we can see that Gypsum is in fact 3 times harder than Talc and Fluorite is 7 times (21 / 3) harder than Gypsum.

The hardness of a material is measured by finding the hardest material that the given mineral can scratch, and/or the softest material that can scratch the mineral. For example, if some material is scratched by Apatite but not by Fluorite, its hardness on the Mohs scale would fall between 4 and 5.

When testing an “unknown” mineral specimen, you need to find a good surface or edge to scratch, one that you can easily access with your “standard” (the material that you know the hardness of). In some cases it is easier to scratch the “unknown” across the “standard” (e.g. the point of a unknown mineral grain across a calcite cleavage). In other cases it is easier to test the “standard” across the “unknown” (e.g the edge of a piece of Quartz across the cleavage surface of the unknown). In most cases, you should do both, to double check your findings. You need to press hard enough to good effect, but not so hard as to fracture either sample.

A successful scratch test will leave a mark ! *Don’t scratch test any part of a sample that is important to its beauty or value as a mineral specimen.*

As a result of your test, you will look for a scratch. Rub aside any powder to see if a distinct scratch has been left. Calcite will leave a trail of powder across quartz. Rub away the powder and you'll see the quartz is unharmed. A hand lens will help you see the scratch. In this way you can bracket the hardness of your unknown between two of your standards (harder than a fingernail, softer than a penny). The ease with which one substance scratches another is also useful. Quartz easily scratches calcite, telling you of a large hardness difference. Quartz will scratch feldspar with much more difficulty. When testing a standard against an unknown that is of equal hardness, both substances will leave shallow scratches on each other.

The hardness of a particular mineral may vary with direction within the same grain. Kyanite is a good example. Kyanite generally occurs in long bladed crystals. The hardness taken the short way across the blade has a hardness of 7 the hardness taken the long way along the same grain will be 4.0. Muscovite is another good example of this. Its hardness is 2.5 when taken across a the flat surface of a cleavage sheet, but 4 when taken across the grain of a book. The reason hardness varies in this way is that the phenomenon depends on the strength of the bonds holding the mineral together. The bond strength can be significantly different in different directions in the mineral, giving the different hardness. In most minerals this difference with direction is minor and doesn't affect the test. In the case of kyanite, this difference in hardness is a confirming test by itself.

Of course we don’t always have all these minerals with us when we are in the field (and those used to test hardness 8 and above are way too expensive to be used in scratch tests). Fortunately, there are more common things when can use in their place :

Hardness	Mineral	Alternatives
1	Talc	
1.5	Graphite	#2 pencil “lead”
2	Gypsum	zinc penny
2.5		fingernail
3	Calcite	
3.5		copper penny
4	Fluorite	
5	Apatite	
5.5		window glass, obsidian, knife blade, steel nail

Be Aware

Most sources report that a copper penny is 3.2–3.5; this is true BUT since 1982 pennies are 97.5% zinc with a very thin copper plating and zinc has a Mohs hardness of only 2 (soft like Gypsum). So make sure you don’t use the same zinc penny too many times or you might get a bogus test result.

A good knife blade has a hardness of 5.5, but some cheaper pocket knives are 5.1 or less.

6	Orthoclase	
6.5		steel file
7	Quartz	chert, streak plate
8	Topaz	
9	Corundum	
10	Diamond	

Luster

Luster describes how well the surface of a mineral reflects light. Therefore, the luster of a mineral is affected by the brilliance of the light used to observe the mineral surface. The words used to describe luster were chosen so that they would describe what the reflection reminds you of :

- **Adamantine :** very high reflectance … looks sparkly and brilliant like diamond
- **Dull :** plain looking surface that is lacking in richness or intensity of color
- **Earthy :** looks like soil or clay
- **Glassy** or **Vitreous :** high reflectance … looks like glass … 70% of all minerals have a vitreous luster.
- **Greasy** or **Oily :** looks like oil floating on water
- **Metallic :** opaque and reflects light like metal polished metal
- **Pearly :** appears iridescent like a pearl. Often found on the cleavage face of a mineral having perfect cleavage.
- **Pitchy :** tar-like appearance. Minerals with a pitchy luster are usually radioactive.
- **Resinous :** looks like hardened tree sap (amber) – not quite glassy
- **Silky :** fine parallel fibers with the look of silk
- **Submetallic :** looks like metal that is dulled by weathering or corrosion
- **Waxy :** looks like it is coated with wax.

Andradite can display adamantine luster in high-quality specimens, which led to its traditional name of demantoid (diamondlike) garnet.

Chrysocolla has a dull or earthy luster, even though it is vibrantly colorful, owing to its microscopic crystals.

There is a brief discussion of other optical phenomena near the end of the Wikipedia article on luster @ http://en.wikipedia.org/wiki/Lustre_%28mineralogy%29#Optical_phenomena

Specific Gravity (Density)

Most texts suggest using specific gravity (density) as an identifying property of a mineral. Most tables give very precise numbers for this property, but they can only be precisely measured in a laboratory. In the real world of mineral collectors, one can only guess relative differences in density. When comparing the weight of samples of two different minerals that are of approximately the same size, the heavier one will be more dense and have the higher specific gravity.

Even then, most non-metallic minerals have a specific gravity between 2.5 and 4. grams/cc. That’s not much difference when you are in the field weighing small specimens with your hands. And, while the metallic minerals are significantly heavier, they would have been identified by other means long before a specific gravity test was needed.

Streak

A mineral’s streak is obtained by rubbing it across the surface of a hard, unglazed piece of porcelain (a streak plate). The color of the powder left behind on the streak plate is the mineral's streak.

Tenacity

Tenacity is the resistance of a mineral to breaking, crushing, or bending. Tenacity can be described by the following terms.

- **Brittle** : breaks or powders easily.
- **Malleable** : can be hammered into thin sheets.
- **Sectile** : can be cut into thin shavings with a knife.
- **Ductile** : bends easily and does not return to its original shape.
- **Flexible** : bends somewhat and does not return to its original shape.
- **Elastic** : bends but does return to its original shape.

Transparency

Transparency describes a mineral’s ability to allow light to pass through it. Three degrees of transparency are described as follows:

- **Transparent :** the mineral is clear enough to see right through it
- **Translucent :** you can see shapes through the mineral specimen
- **Opaque :** no light gets through, most minerals are opaque

The degree of transparency may vary with the thickness of the mineral specimen.

Transparency can affect the usefulness of color as an identification aid. For opaque minerals, the color tends to be more consistent, so learning their colors associated can be very helpful in identification. On the other hand, translucent to transparent minerals usually have much more varied and less distinct colors due to the presence of trace minerals or other inclusions.