

Identify Your Mineral Treasures Part Three: Physical Mineralogy

Picking up where we left off last issue, determining as best as possible the physical characteristics of your recently collected or acquired specimen will help to narrow the field of likely candidates. If you collected the specimen yourself, and did your research beforehand, then you know the location, geologic environment, and mineral suite known from that locale. Not that other species won't be present, but at least you have a solid start. Once you have a list of contenders, the process that follows will help you make a final determination by either eliminating from the list, or confirming identification.

Color

This series began by covering the basic qualities of all the chemical classes of minerals, from native elements and sulfides to the various silicate groups. Such knowledge of *descriptive mineralogy*, combined with research, experience, and consulting determinative tables helps significantly in narrowing the field of candidates when the collector is faced with identifying an unknown specimen.

Determinative tables, however, have limited usefulness without competent familiarity of the various physical and optical properties that are distinctive—and sometimes uniquely characteristic—of all minerals. These properties include such common features as hardness, luster, color, streak, tenacity, fracture, cleavage, diaphaneity; plus more exotic ones as specific gravity, fluorescence, magnetism, refractive index, twinning, and crystal class (this last characteristic will be expounded upon in the future section covering crystallography). In this issue we will focus on the most conspicuous of mineral characteristics... *color*.

Almost invariably, the first thing we usually notice when examining a specimen is its color. At one end of the spectrum color is a distinctive and constant quality that serves as an important means of identification. All azurite specimens are blue (though the shade can vary from vibrant royal to nearly black). Likewise, the golden-yellow of pyrite, the steel blue-gray of galena, the black of magnetite, and the green of malachite are striking properties of those minerals. However, environmental exposure can alter the surface color of any specimen; when noting the color of a mineral, a fresh surface should always be examined.

GML Publishing

a division of the

Mojave Natural Resources and

Lithologic Survey

Las Vegas, NV 89107

www.discover-minerals.com

gmlslehman@gmail.com

Discover Minerals

Copyright 2016

a mineralogy journal reviewing the
mines, mineral resources, and
geological history of the Mojave
Desert region

Regular Components Features

Mine of the Month

Element of the Month

Mineral Showcase

Articles

Guest Contributor

Publisher

G. Miles Lehman

View N of the Clark Mountain Range
from Cima Road



Conversely, quartz is inherently colorless, but impurities can bestow any color to the mineral, and thus is not a diagnostic trait. The same is true for fluorite, another mineral that can be found in a very large range of colors. Such extensive variations in color in one species is rather rare, however. Nevertheless, these two minerals serve as examples where color cannot be relied upon to identify the specimen. Since Nature rarely produces anything in purity, this latter likelihood is more often the case.

But what exactly *is* color? In the science of physics, color is a specific wavelength in a narrow range of the electromagnetic spectrum that eyes have evolved to perceive. But those wavelengths often occur blended together. Rainbows are Nature's prisms, separating those wavelengths into their individual bandwidths. But the colors we see are not always a result of direct, radiating light, as from a star or laser beam, but rather are reflections of what's left over after light strikes an object and other wavelengths have been absorbed. This is more often the case when we say that something is of a certain color. For our purposes, the above question can be rephrased as what *causes* color in minerals?

There are a number of agents responsible for producing color in minerals. First, the way the atoms are arranged causes the absorption and transmission of incident light specific to the **crystal structure** of the mineral. Diamond, the hardest of minerals, is famous for this trait. Its atoms are arranged in such a way that most light simply passes through the crystal, thus it appears colorless, with the exception of some dispersion of individual wavelengths of light known as "fire" in the jewelry trade. This high color dispersion makes diamond one of the most valued of all gemstones. Compare this to a mineral of the exact same composition, but with a significantly different crystal arrangement: graphite, among the softest of minerals.

The **chemical composition** creates inherent color in many mineral species. In compounds containing transition metals, the *d* orbitals are commonly split into sets separated by energies that correspond to wavelengths of electromagnetic radiation in the visible region (4×10^{-5} cm to 7×10^{-5} cm). The absorption of visible light causes electronic transitions between orbitals in those sets. Color arises as electrons undergo transitions from one *d* orbital to another. When certain visible wavelengths are absorbed from incoming "white" light, the light not absorbed appears to have the complementary color of the light absorbed. It is this reflected light that we see. For instance, a compound that absorbs yellow light (5.5×10^{-5} cm) will appear blue.

Examples of Colorizing Ions

Transition Metal	Color of Aqueous Solution
Cr^{2+}	Deep Blue
Mn^{2+}	Pale Pink
Fe^{2+}	Pale Green
Fe^{3+}	Red Brown
Co^{2+}	Pink
Ni^{2+}	Green
Cu^{2+}	Blue

A change in composition can also affect the color of a mineral when one element substitutes for another. For example, the progressive replacement of zinc by iron in sphalerite will change its color from white to yellow, red, brown, and ultimately black. Emerald (a variety of beryl) and ruby (a variety of corundum), both owe their color and value to the presence of trivalent chromium (Cr^{3+}) replacing aluminum (Al^{3+}) in the molecular structure of both minerals, producing a vibrant green and blood red color respectively. Such ionic substitutions are common in many minerals.

A phenomenon called a *color center* (or *F-center* from the original German word Farbzentrum) is a crystallographic defect in which an anionic vacancy in the crystal's structure is filled by one or more unpaired electrons. Such electrons tend to absorb light in the visible spectrum in a way that imparts color to an otherwise colorless, transparent compound. The process can occur naturally when a compound is heated to a high enough temperature that the ions in the compound become displaced from their normal positions in the crystal, leaving behind free electrons in the vacated spaces. The halite specimens from Strassfurt and Mexico are often colored blue from irradiation and heat of burial that causes an excess of sodium atoms that generate chlorine vacancies. Natural irradiation is the culprit responsible for coloring the varieties of quartz called *smoky quartz* and *amethyst*, though the latter involves the presence of trace amounts of ferric iron and other elements. Color can also be produced artificially by heating susceptible specimens. In this way, amethyst is converted to citrine. Citrine is rare in nature; most, if not all, citrine specimens made available to collectors is actually heated amethyst.

Possibly the most common cause of color in minerals is due to *impurities*. Usually this means one mineral is incorporated into another during

their formative stages. In this regard, the red cryptocrystalline variety of quartz known as jasper is colored by small amounts of included hematite. Likewise, the highly prized chrysoprase, another chalcedonic quartz related to jasper, is green due to the presence of garnierite (a general term for a mixture of hydrous nickel silicates). In some cases, however, the impurity is simply an element trapped within the mineral without involvement in the chemical makeup of the specimen. For example, trace amounts of nitrogen is the architect that colors some diamonds yellow.

Coloring agents is one thing, but interpreting color is an entirely different matter. Color is also defined by hue, saturation, and tone. In short, *hue* is essentially the degree of the color as it can be described as similar to or different from other colors, i.e. red, orange, yellow, green, blue, and purple. Thus a mineral can be described as greenish blue (rosasite), bluish green (caledonite) yellowish red (crocoite) or purplish red (erythrite). *Saturation* is the colorfulness of a color relative to its own brightness. The colorfulness can be intense and vivid, or muted and grayish. *Tone* is the variation in perception of a color's brightness relative to a similarly illuminated area. For a painter, this means how much white or black is added to change a color's value.

The problem is, these are all highly intuitive qualities. People see and interpret color distinctive to their own specific genetic characteristics of their eyes. What looks olive green to one person may look gray green to someone else. Plus there are uncountable shades of green, from the dull earthy of epidote to the vibrant lime green of molybdoferite. A mineral's color can be one of its important physical properties, but is not always constant and definitive. For the amateur and professional alike, color must be used with caution in the identification of mineral species.

Typical Colorizing Ions

Copper



VII 143 D

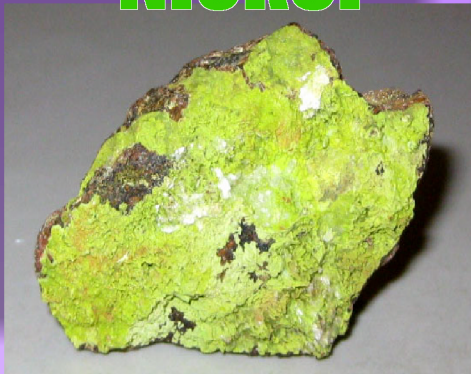
Malachite



VII 84 C

Azurite

Nickel



VII 125 D

Gaspeite

Manganese



VII 98 D

Rhodochrosite

Cobalt



VII 62 D

Sphaerocobaltite

Chromium

XIX.149 C

Emerald



IV 59 D

Ruby



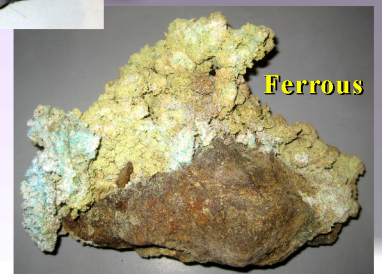
IV 22 D

Hematite

Iron

X 90 C

Copiapite



Ferrous

all specimens from the

G. Miles Lehman Collection