Introduction to Minerals

- Introduction and Definitions
- Chemical Classification
- Diagnostic Properties
- Some Common Minerals

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The word *mineral* is used in a variety of ways.

- any valuable material extracted from the Earth like coal, gravel, and even groundwater.
- by nutritionists for elements metabolized by the body
- as anything that isn't *animal* or *plant*

Over 4,000 minerals have been identified in the scientific literature - Approximately 40 - 50 new ones are discovered every year!

Luckily, there are relatively few (10-15) common rock-forming minerals.

DEFINITIONS

A *rock* is any solid mass of mineral (or mineral-like) matter that occurs naturally. A few rocks may be composed of only one mineral, but most are an aggregate of several minerals.

A *mineral* is any naturally occurring inorganic solid that possesses an orderly internal structure and a definite chemical composition.

1. naturally occurring (concrete, synthetic diamonds, etc. are excluded).
2. inorganic (teeth, seashells, trees, etc. are excluded)
3. solid (gases and liquids are excluded)
4. orderly internal structure (amorphous solids like glass are excluded)
5. definite chemical composition

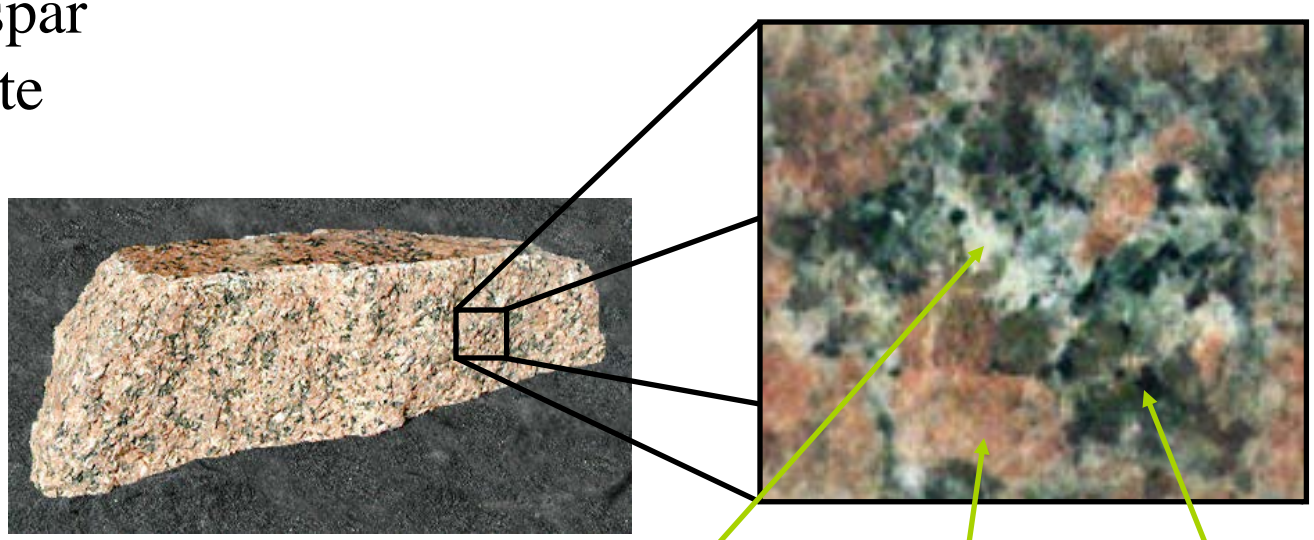
   examples: C Diamond

   NaCl Halite

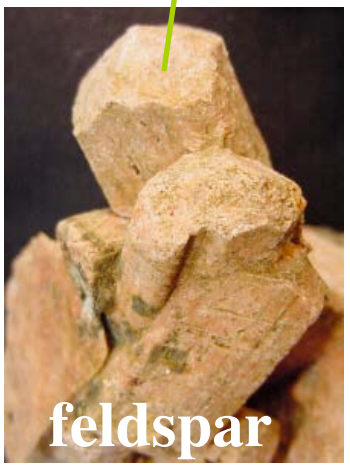
   $(Na,Ca)Al(Si,Al)Si_2O_8$ Plagioclase

One way that rocks are characterized is by their mineral content.
For example, the rock *granite* commonly contains the three minerals:

- quartz
- feldspar
- biotite



Luckily, most rocks are composed of a few common rock-forming minerals.



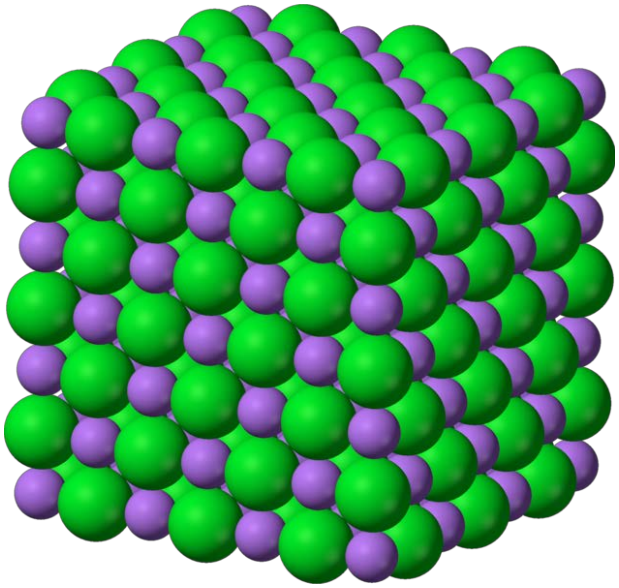
Part of the definition of a mineral is that it has an orderly internal structure, i.e. crystal structure.

The top image shows the crystal structure of halite (common table salt) NaCl (Na = purple, Cl = green).

The bottom image shows a halite crystal.

It is clear that the crystal structure of a mineral may control important mineral properties such as its form (crystal shape) and cleavage.

Some materials are mineral-like but lack crystal structure and are known as *mineraloids* (ex. amber, obsidian, etc.)



Wikipedia contributor: Benjah-bmm27

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Part of the definition of a mineral is that minerals have a definite chemical composition.

The composition or chemistry of a mineral is an important property that may control geologic process such as weathering, melting, metamorphism, etc.

Some minerals have a simple chemical formula

examples: diamond C

halite NaCl

quartz SiO_2

Other minerals have chemical formulas that vary between very specific limits. This is because some elements are similar and may substitute for others within the crystal structure.

examples: plagioclase $(Na,Ca)Al(Si,Al)Si_2O_8$

olivine $(Mg,Fe)_2SiO_4$

Question

Graphite and diamond are pure carbon have the same chemical formula:

C (pure carbon)

But,
diamond is the hardest substance know

Wikimedia: Mario Sarto

Rob Lavinsky, iRocks.com – CC-BY-SA-3.0

and,
graphite is one of the softest minerals.

If they have the same chemical formula, why are they different minerals?

Chemical Classification of Minerals

Minerals are classified based on their (anion) chemistry:

- minerals that contain silica (SiO_2) are silicates ex. quartz SiO_2
- minerals that contain carbonate (CO_3^{2-}) are carbonate ex. calcite $CaCO_3$
- minerals that contain sulfur (S) are sulfides ex. pyrite FeS_2
- minerals that contain oxygen (O) are oxides ex. magnetite Fe_3O_4

Silicates are the most common minerals and the properties of silicate minerals significantly control geologic processes. For example,

- silica-rich magma and lava is more explosive or violent when it erupts. The amount of silica affects the mode of eruption.
- silica-rich minerals tend to be more resistant to chemical weathering than silica-poor minerals

Diagnostic Properties of Minerals

Minerals may be identified by different physical and chemical properties. It is important to understand that a minerals is usually identified by a variety of properties. No single property is diagnostic for all minerals. Common diagnostic properties include:

- Color
- Streak
- Luster
- Hardness

Other properties that may be diagnostic for a mineral may include:

- Crystal form
- Cleavage/fracture
- Magnetism
- Reaction to acid
- Density
- Smell/Taste and many more.

Color

Color seems like an easy property but it is risky to identify a mineral by its color alone.

Most minerals can have a wide range of colors due to small amounts of impurities in them such as these examples of quartz.

Smokey Quartz

Amethyst Quartz

Citrine Quartz

Rose Quartz

Another example, rubies and sapphires are the same mineral, corundum, and have a wide range of colors! So color alone is not very diagnostic.

Corundum

Streak

A mineral's streak is the color of a powdered mineral on a streak plate (unglazed porcelain tile).

This property can be diagnostic for a small number of minerals (usually those with a metallic luster).

Although the color of a mineral may vary, the color of the streak remains surprisingly constant.

harmonscieince6

Luster

Luster describes the way that the surface of the mineral reflects light. There are many types of lusters but the common ones are:

- Metallic
- Nonmetallic
  - glassy
  - brilliant
  - dull

Wikimedia: CarlesMillan

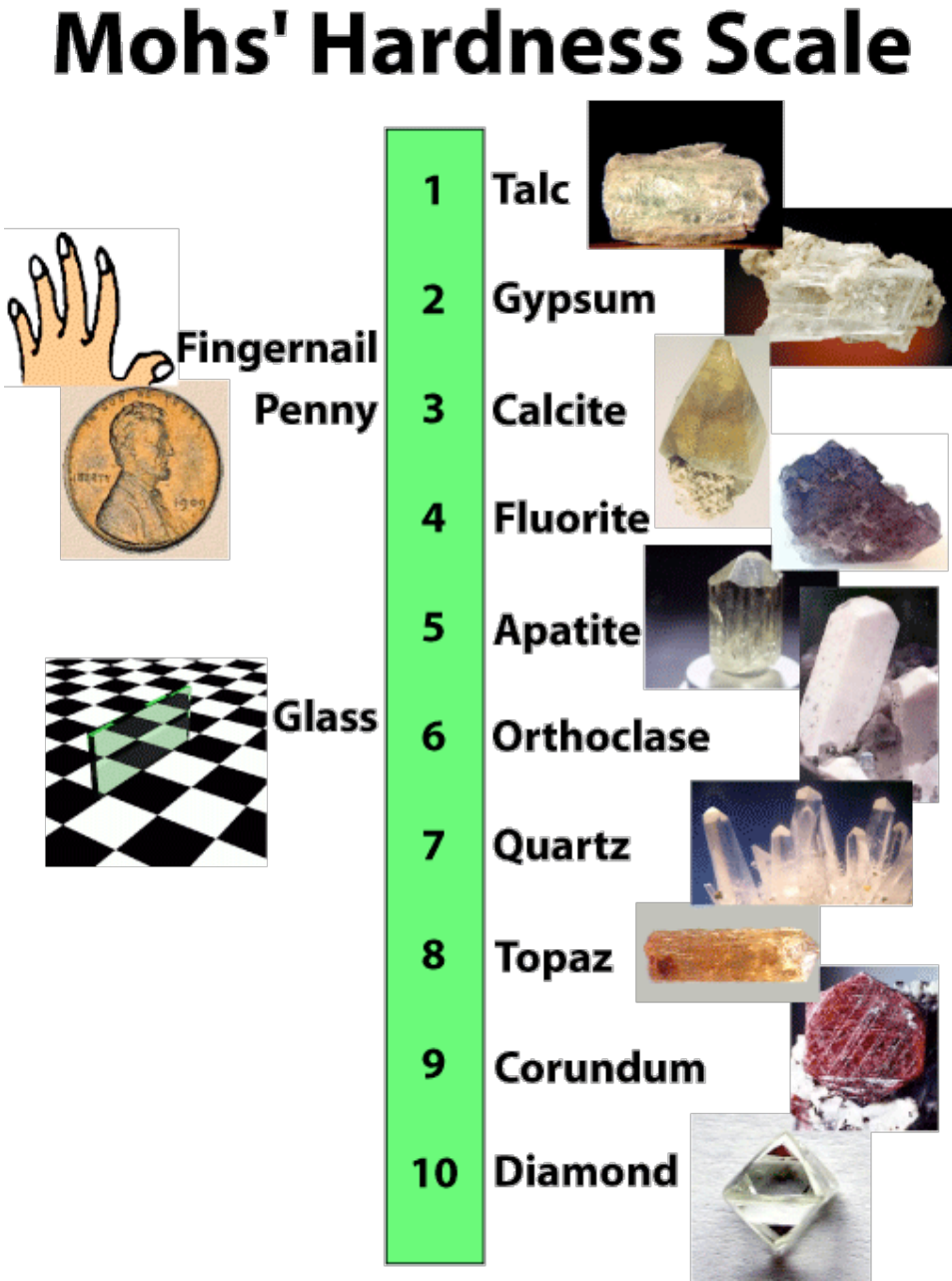
Wulfex India

Hardness

Hardness is a mineral's ability to resist being scratched.

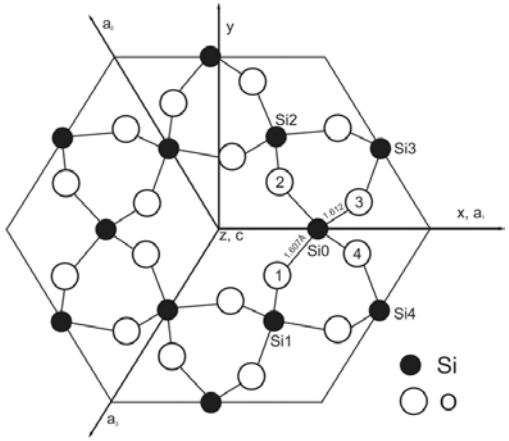
The Mohs hardness scale is a unitless 10-point scale with each hardness value represented by a common mineral. The Mohs' hardness scale is not linear!

Hardness can be directly related to bond strength – hardness is an expression of the weakest bond. Compare the hardness of graphite (H=1) and diamond (H=10); they have the same chemical composition but different bonds/structures.



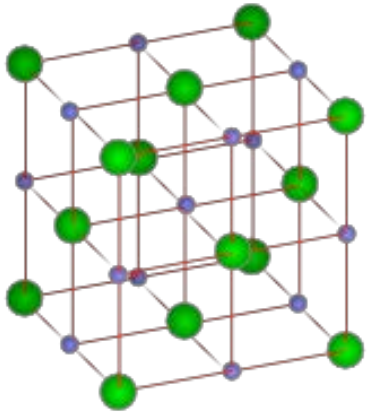
Crystal Form

Some minerals that grow without being impeded by their environment develop characteristic crystal shapes or crystal form that represents the symmetry of the crystal structure. Crystal form can be a diagnostic property for some minerals.



Quartz has an internal structure that has a 6-sided (hexagonal) symmetry. As a result, quartz crystals commonly are 6-sided.

Halite has an internal structure that has a cubic (4-sided) symmetry. As a result, halite crystals commonly are cube shaped.



Wikimedia: Piotr Sosnowski

Cleavage

Cleavage is the tendency of minerals to break parallel to crystallographic planes along which chemical bonds are weaker than others.

Cleavage surfaces are not necessarily parallel to crystal faces.

It may be difficult to distinguish between cleavage planes and crystal faces.

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Mica has one direction of cleavage and breaks into flat sheets.

MacMaster Virtual Geology Museum: Lisa Leoni

Halite has three directions of cleavage breaks to form cubes.

Fracture

Fracture is the way a mineral breaks in the absence of a cleavage plane. In some crystals, the strength of bonds is approximately equal in all crystallographic directions. Several types of fracture can be described:

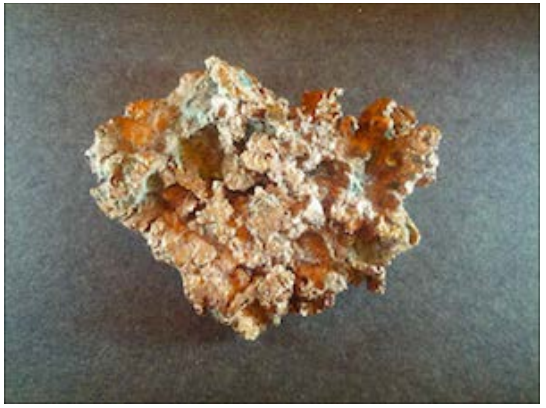
conchoidal – smooth curved surfaces resembling shells
fibrous – common with asbestos
hackly – jagged fractures with sharp edges
irregular or uneven – rough or irregular surfaces

Conchoidal fracture in obsidian.

Siim Sepp

Fibrous fracture in chrysotile.

USGS



Hackly fracture in native copper.

Wikimedia: John Mortimore

Magnetism

Magnetism in minerals results from atomic properties of certain metal atoms in minerals.

This property is diagnostic for a few minerals such as magnetite.

Herschel Friedman

Guillermo Rocha/Brooklyn College

Reaction to Acid

Minerals that contain the chemical component carbonate (CO_3^{2-}) react to acid by effervescing.

The mineral calcite effervesces by the reaction:

$$CaCO_3 + 2HCl \longrightarrow CO_2 + Ca^{2+} + 2Cl^- + H_2O$$

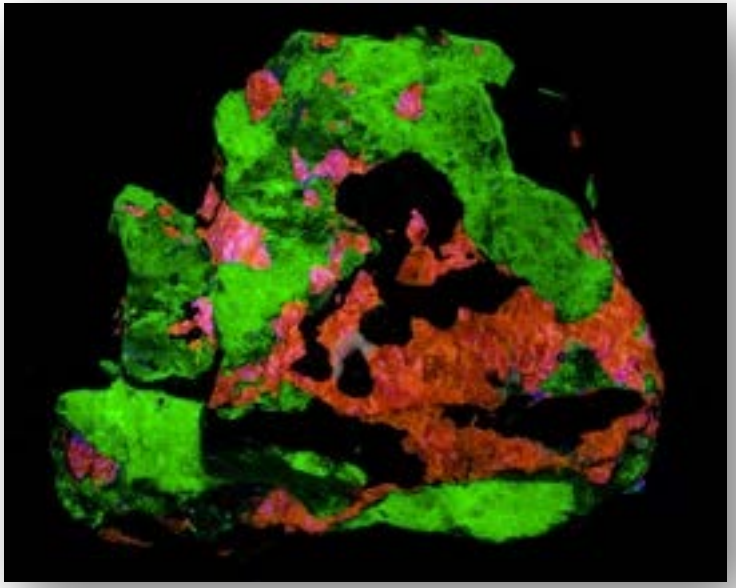
Other Properties

There are many other physical properties that may be diagnostic for some minerals.

- Play of color
- Smell/Taste
- Luminescence

It is important to understand that not all properties are diagnostic for all minerals.

Wikimedia User: Mitchell Gore



Nature's Rainbows

Let’s look at some minerals.

Quartz SiO_2

Quartz is a silicate mineral and is the second most common mineral in the Earth's crust.

It is usually white or colorless but has a wide range of colors; some of its colored varieties are semi-precious gems such as *amethyst* and *citrine*.

Quartz is used to make glass and computer chips.

Quartz commonly forms nicely shaped 6-sided crystals that are widely available.

Quartz is common in igneous and metamorphic rocks. It is resistant to chemical weathering and is a common constituent of sediments such as sand and sedimentary rocks because it is resistant to weathering.

Feldspar $NaAlSi_3O_8$ - $CaAl_2Si_2O_8$ - $KAlSi_3O_8$

Wikimedia: Rob Lavinsky

Feldspar is a large, complex family of silicate minerals and is the most common mineral in the Earth's crust.

Since it has a wide range of chemical compositions, its appearance may also vary widely.

Feldspar is commonly white to dark gray in color. Some common varieties are pink.

Feldspars are used in the manufacturing of specialized glasses and ceramics. It is commonly used in aggregate and, because it is so common, is commonly used in construction (building facing, etc.).

Univ. of Pittsburgh

Pyrite FeS_2

Pyrite is a sulfide mineral and is one of the most common of the minerals with metallic luster. It is also known as "fool's gold."

Although it usually forms massive groups of indistinct crystals, it may also form beautifully formed cubic and soccer ball-shaped crystals.

It also commonly replaces organic material and forms fossils.

It has little economic importance now, but in the past, it was an important source of iron and sulfur.

Magnetite Fe_3O_4

Magnetite is an oxide mineral and is a common iron ore mineral.

It is usually black in color and has a black streak. Its luster is commonly metallic but may appear submetallic.

Magnetite forms massive groups of small indistinct crystals, but may rarely form octahedral crystals.

The most distinguishing property of magnetite is that it is magnetic.

Herschel Friedman

Wikimedia: Rob Lavinsky

Talc $Mg_2Si_4O_{10}(OH)_2$

Talc is a silicate mineral and is commonly found in metamorphic rocks.

Although it is not a very common mineral, it is a good one to show to students because of its very low hardness. The extreme softness of the mineral gives it a slippery feel.

It is usually white to light green in color and may exhibit one-direction of cleavage. Its nonmetallic luster may appear glassy to pearly in appearance.

Talc is used as an industrial lubricant, as a filler in paints and plastic and commonly as a major ingredient in talcum powder and cosmetics.

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Wikimedia: Mattman723

Mica

Muscovite $KAl_2(Si_3O_{10})(OH,F,Cl)_2$

Biotite $K(Fe,Mg)_3AlSi_3O_{10}(OH)_2$

Muscovite and biotite are silicates and are two of the most common types of mica.

The micas are a complex group of minerals that are characterized by excellent cleavage in one direction - thus, it can be split into thin flexible sheets.

Muscovite and biotite can be distinguished from one another by color: muscovite is clear to tan-brown and biotite is dark brown to black.

The hardness of the micas ranges 2-3.

Wikimedia: Rob Lavinsky

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Hornblende $Ca_2(Mg,Fe)_4Al(Si_7Al)O_{22}(OH,F)_2$

Hornblende is a silicate and is the most common member of a complex family of minerals known as the amphiboles.

Hornblende is common in igneous and metamorphic rocks. It is uncommon in sedimentary rocks because it quickly alters to other minerals at the Earth's surface.

USGS

Hornblende has a Moh's hardness of 5-6 so that its hardness is approximately that of glass.

Hornblende has 2 directions of cleavage - thus it can be easily distinguished from biotite mica.

Fluorite CaF_2

Fluorite is a distinctive but relatively uncommon halide mineral mineral. It is most commonly associated with hydrothermal deposits.

It comes in a wide range of colors - clear, yellow, purple and green are common.

It has a Moh's hardness of 4 and has excellent cleavage in 4 directions.

Fluorite is our primary source for fluorine.

Calcite $CaCO_3$

Calcite is a common carbonate mineral, especially in sedimentary rocks. It is also associated with biological activity in the production of shells.

Calcite is usually colorless to white in color but may show a range of pale colors including yellow, pink and green.

It has 3 directions of cleavage - forming rhombohedra ("smooshed" cubes).

Calcite is most distinguished by its vigorous reaction to acid.

Calcite is used to manufacture cement and as a calcium dietary supplement.