

Mineral Identification Lab: Oxides, Carbonates and Evaporites

Oxide Minerals

The oxides are compounds in which one or more metal cations bond with oxygen. The structures are relatively easy to describe; they have the metal cations packed into the interstitial positions between the oxygen atoms. Most common oxide minerals can be classified into three structural groups as shown in Table 1.

Oxide Minerals

<u>Spinel Group; $A_1B_2O_4$ (Cubic)</u>	<u>Hematite Group; A_2O_3 (Hexagonal)</u>	<u>Rutile Group; AO_2 (Tetragonal)</u>
Spinel (MgAl)	Hematite (Fe)	Rutile (Ti)
Magnetite (Fe)	Corundum (Al)	Cassiterite (Sn)
Franklinite (ZnFe)	Ilmenite (FeTi)	Pyrolusite (Mn)
Chromite (FeCr)	(Perovskite)* (CaTi)	Uraninite (U)

Most of these oxides are relatively hard, often very dark in color, and can be difficult to identify. They are typically quite refractory (difficult to melt or corrode) and are found as accessory minerals in Igneous and Metamorphic rocks. Some of the chemically stable oxides, such as magnetite, ilmenite, and cassiterite persist through the weathering process and are concentrated in sands and gravels as economically important deposits.

The prominence of iron (and steel) as a construction material used in such a variety of ways in industrial societies should be emphasized. Its importance is reflected in the great tonnages produced annually by most all major industrial powers; Russia produces approximately 180 million tons annually, Japan 110 million, and the U.S. about 90 million.

The most prolific ore bodies for principle iron ores, hematite and magnetite are found in some unusually Pre-Cambrian sedimentary rocks called banded iron formations (B.I.F.s) or taconites which date typically about 1.5 to 2.0 billion years old. The reason why these types of deposits are so widespread and formed at such a specific time in geologic history is still debated by sedimentologists and geochemists.

A few less common oxides are worth mentioning as we may find it useful to identify them. Cuprite and zincite are both secondary minerals associated with copper and zinc deposits respectively. Both tend to be softer than many of the other oxides and also contrast by being reddish in color. Chrysoberyl is a beryllium aluminum oxide particularly known from its gem variety alexandrite.

Two minerals related to oxides but typically formed from weathering of primary minerals are the hydroxides, goethite (Fe) and Gibbsite (Al). Most people are more familiar with their common names, limonite and bauxite respectively. These minerals are soft and earthy and easily distinguished from oxide minerals.

Carbonate Minerals: CO₃⁻²

Most all carbonates can be grouped into one of two structural groups the rhombic and the orthorhombic as shown in Table 2.

The Carbonates

<i>Rhombic</i>	Cations	<i>Orthorhombic</i>	Cations
Calcium	Ca	Aragonite	Ca
Magnesite	Mg	Strontianite	Sr
Sederite	Fe	Witherite	Ba
Rhodochrosite	Mn	Cerussite	Pb
Dolomite	CaMg	Malachite, Azurite	Cu Carbonates:

Calcite is by far the most common carbonate mineral and is found in all types of rocks. It is particularly common, of course, as the sedimentary rock limestone, Calcite crystals are known to occur in a tremendous variety of forms a few of which are shown in fig. 1.

Since the rhombic carbonates cleave so readily in the rhombic shape as in fig 1a (see below) it is worth the effort to remember this shape as an aid in identification. Complex geometric variations of this crystal form include the “negative” rhombohedron (fig. 1b) and the rhombic scalenohedron (fig 1c). These last two forms are also a common and produce pointed crystals referred to a "Dog Tooth Spar" because of its resemblance to a canine tooth. Clear, optical quality calcium is referred to as Iceland spar.

Calcite Crystal Forms

Rhombohedron

“Negative” Rhombohedron

Scalenohedron

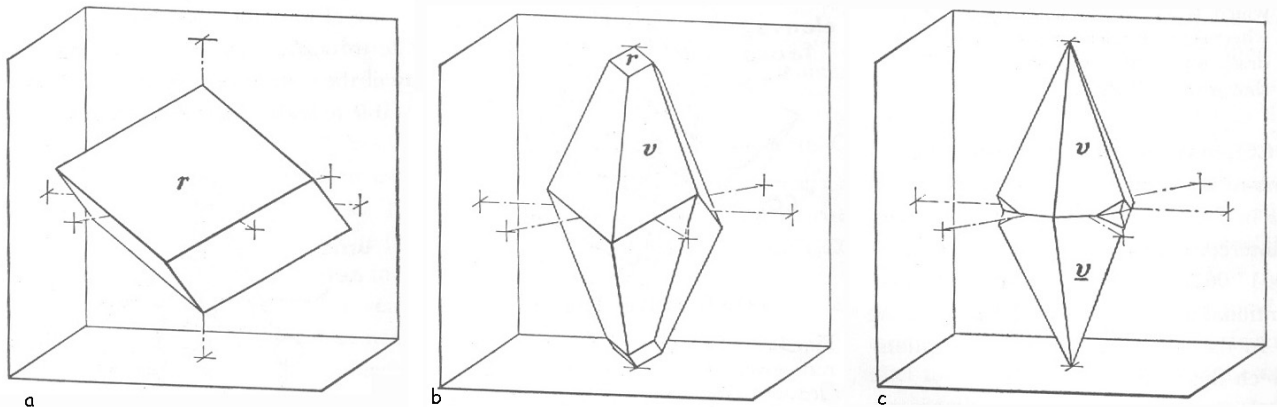
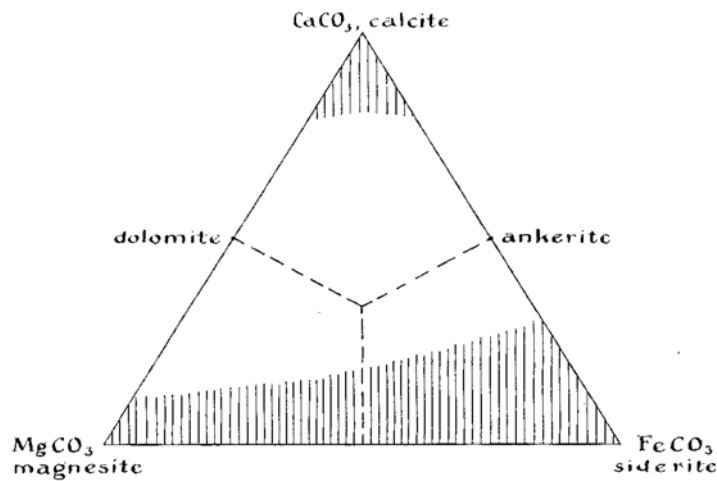


Figure 1

There are many other terms applied to natural occurrences of CaCO_3 as illustrated in the following list.

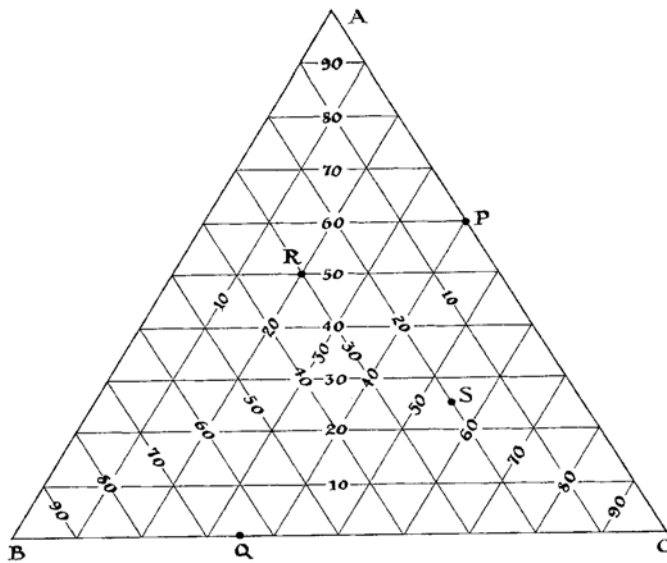
1. Chalk - made up of microscopic, calcareous plant shells (coccolithophores, “coccoliths”) (The White Cliffs of Dover in England are a well known chalk formation).
2. Marl - similar to chalk - often found in Glacial lake deposits.
3. Travertine - a finely layered deposit occurring at the mouths of mineral rich springs, sometimes the word "Tufa" is used to describe such deposits. Nicely colored travertine used for decorative carving is called onyx marble and/or Mexican onyx.
4. Stalactites and stalagmites - calcite deposited in caves.
5. Sand crystal - calcite can form sand crystals in a fashion similar to gypsum.
6. Marble - a limestone recrystallized as a result of metamorphism within the earth's crust.
7. Vein calcite - associated with metallic mineral deposits
8. Carbonatites - calcite as an igneous intrusion.

Calcite also has many important industrial uses such as decorative facing for buildings. The well known Indiana limestone is used for this purpose and it has been used on many monumental buildings in the United States. Some of WMU's older buildings have used it as decorative trim. Calcite is used as a flux in metal refining, as the principle ingredient in cement, as agricultural lime and as the source for quick lime mortar.



Triangular diagram showing the compositional variations of calcite, magnesite, and siderite. Shaded areas indicate the limits of solid solution observed in nature.

Figure 2. Compositional relationships among the common carbonate mineral species.



The representation of compositions in a three-component system. A represents 100% of component A, B 100% of component B, C 100% of component C. P represents 60% of A, 40% of C; Q represents 65% of B, 35% of C; R represents 50% of A, 20% of B, 30% of C; S represents 25% of A, 20% of B, 55% of C.

Figure 3. Explanations of a *Ternary Composition Diagram*

See figure caption (we will talk lots more about ternary composition diagrams!)

Evaporite Minerals (and other odds and ends)

There are a many minerals that form from hyper-concentrated waters and might be considered "salts". They occur in either marine (ocean basins) or terrestrial (on land) evaporite deposits. Evaporite minerals include those found in the Halides, Sulfates, Nitrates, and Borates mineral classes. Each group shall be discussed in brief.

1. Halides:

- a. **Halite (NaCl)** and **Sylvite (KCl)** are two very common evaporite minerals and both are produced in large amounts as important industrial minerals. Both are associated with thick and widespread salt deposits, well recognized in the sedimentary record. Silurian strata in the Michigan basin and else where in the northern Midwest are important examples of ancient evaporite deposits formed in isolated marine basins. Large amounts of halite are mined from these thick deposits. Underground storage in water-tight caverns dug in evaporite deposits in Michigan are of interest.
- b. **Fluorite (CaF₂)** is another common halogen (you should know what this reference means) compound but it is definitely not associated with evaporites but rather it is associated with hydrothermal vein deposits. It is frequently associated with sphalerite and galena and its octahedral cleavage is a useful property that is helpful in its identification. Fluorite is a **MUST KNOW** mineral!

2. Sulfates: The sulfates can be conveniently classified into two basic groups,

The **Gypsum group** (hydrous sulfates, that is with bond water in the crystal structure) and the **Anhydrite group** (anhydrous sulfates), see Table 3

TABLE 3

<u>Hydrous</u>	<u>Anhydrous</u>
Gypsum {CaSO ₄ 2H ₂ O}	Anhydrite {CaSO ₄ }
Antlerite {Ca ₃ SO ₄ (OH) ₄ }	Barite {BaSO ₄ }
Alunite {KAl ₃ (SO ₄) ₂ (OH) ₆ }	Celestite {SrSO ₄ }

- a. Both **Gypsum** and **Anhydrite** are abundant in sedimentary evaporite sequences and are found in Michigan. The other sulfates are less common and occur as secondary minerals (formed from weathering, metamorphism, or solution of primary minerals). Gypsum is also known by other names such as satin spar, selenite and alabaster (Used for sculpture) depending on its habit of occurrence. Gypsum is mined in large amounts for the production of plaster of Paris and the ubiquitous plaster board "sheet rock". It must be roasted in a kiln to partially dehydrate and when water is then mixed with the plaster, it "sets."
- b. **Barite** (BaSO₄) is well known to many geologists in the oil industry because it's used as a weighting material added to drilling muds to help prevent blowouts. Its specific gravity of 4.5 makes it noticeably heavy for a non-metallic mineral and helps to distinguish it from similar sulfates and carbonates.

3. **Nitrates**: There are only two nitrates we will consider here as they are not common minerals and are found only in vary arid climates because they tend to dissolve in moist air.
 - a. ***Nitratite*** or soda niter (NaNO_3) has a structure similar to calcite and **niter** (KNO_3) has a structure similar to aragonite. Both are mined as sources of nitrates used for fertilizers and for the manufacture of explosives. **NOTE**: You should be able to explain the relationship amongst chemical formulas of these two, uncommon minerals to their structural relationships with the more common calcium carbonate minerals mentioned here.

4. **Borates**: Borates are typically found in arid-salt lake deposits plentiful in the south western part of the U.S. They are light in weight and color, very hydrous and very soft. Some of the common ones are Borax (of Twenty Mule Team fame, an effective cleanser and surfactant, ***what is a surfactant?***),
 - a. ***Ulexite*** ($\text{NaCaB}_5\text{O}_9 \cdot 8\text{H}_2\text{O}$) and ***Kernite*** ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 4\text{H}_2\text{O}$) are used for the manufacture of specialty glass, as a flux (***what is a flux?***) for the production of porcelain enamels, for soap and as herbicides.

5. Although not usually considered evaporite minerals the ***Phosphates*** are briefly described here because they share some chemical and structural similarities to the sulfates and carbonates. The most common phosphate is the mineral
 - a. ***Apatite*** ($\text{As}(\text{XO}_4)_3(\text{F},\text{Cl},\text{OH})$) is a calcium phosphate and one of the principle constituents of bone. Some minor phosphates include wavellite, amblygonite and turquoise. Some of these phosphates are associated with pegmatite deposits and others are secondary in occurrence.

Non-Silicate Minerals {**BOLDCAPS**; you must know for lab exam}

<u>Native Elements</u>	<u>Sulfides</u>	<u>Oxides/Hydroxides</u>	<u>Carbonates</u>	<u>Sulfates</u>	<u>Halides</u>	<u>Phosphates</u>
COPPER	Chalcocite	Cuprite	CALCITE	GYPSUM	HALITE	APATITE
Silver	BORNITE	MAGNETITE	DOLOMITE	ANHYDRITE	SYLVITE	TURQUOISE
Gold	SPHALERITE	SPINEL	Magnesite	BARITE	FLOURITE	Wavelite
GRAPHITE	GALENA	Franklinite	Siderite	Celestite		
Diamond	CHALCOPYRITE	CHROMITE	Rhodocrosite	Epsomite		
SULPHUR	Pyrrhotite	HEMITITE	ARAGONITE	Chalcanthite		
	Covellite	Ilmenite	Smithsonite	Monazite		
	Cinnabar	CORUNDUM	Strontianite			
	PYRITE	RUTILE	Malachite		<u>Nitrates</u>	
	MARCASITE	Cassiterite	Azurite		Niter	
	Molybdenite	Psilomelane			Soda Niter	<u>Borates</u>
	Realgar/Orpiment	Uraninite				Borax
	Niccolite	Goethite (limonite)				
	STIBNITE	Gibbsite (bauxite,				
	Pentlandite	boehmite, diaspore)				