

# Carbonates and Phosphates

A subset of the oxide group  
minerals?

# Carbonates

The carbonates make up the fourth largest subset of the general grouping of carbonates, nitrates, borates, sulphates, chromates, tungstates, molybdates, phosphates, arsenates and vanadates.

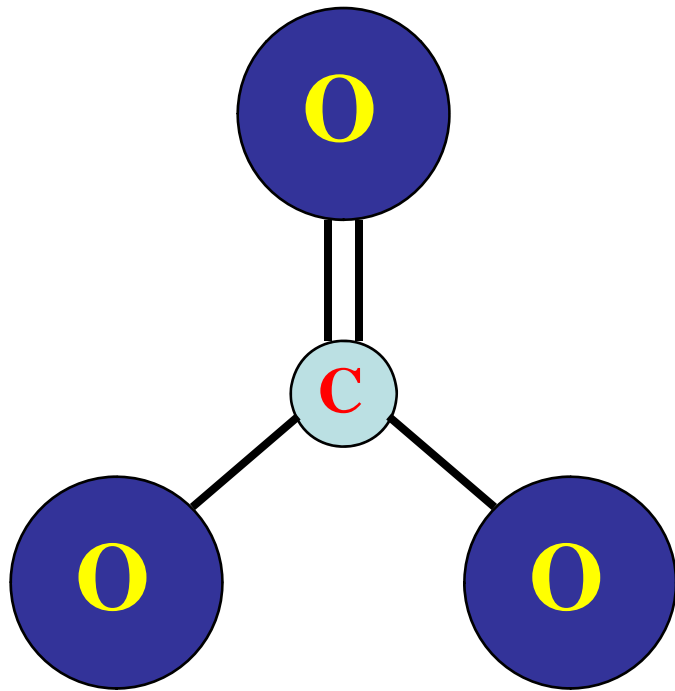
This general grouping comes from the Dana Classification system.

It is a well established classification methodology, commonly used by museum curators, and is based loosely in mineral composition.

These particular minerals, although chemically diverse, are treated together because they all contain a very strongly bonded anionic complexes.

# Carbonate Crystal Chemistry

The crystal chemistry of all carbonates is based around the anionic  $(\text{CO}_3)^{2-}$  unit.



This is a tightly bonded species, but when dissociated from its related cations is highly reactive.

There are multiple anhydrous species, but the most important ones are anhydrous:

- Calcite –  $\text{CaCO}_3$
- Aragonite –  $\text{CaCO}_3$
- Dolomite –  $\text{CaMg}(\text{CO}_3)_2$
- Ankerite –  $\text{CaFe}(\text{CO}_3)_2$
- Magnesite –  $\text{MgCO}_3$
- Siderite –  $\text{FeCO}_3$

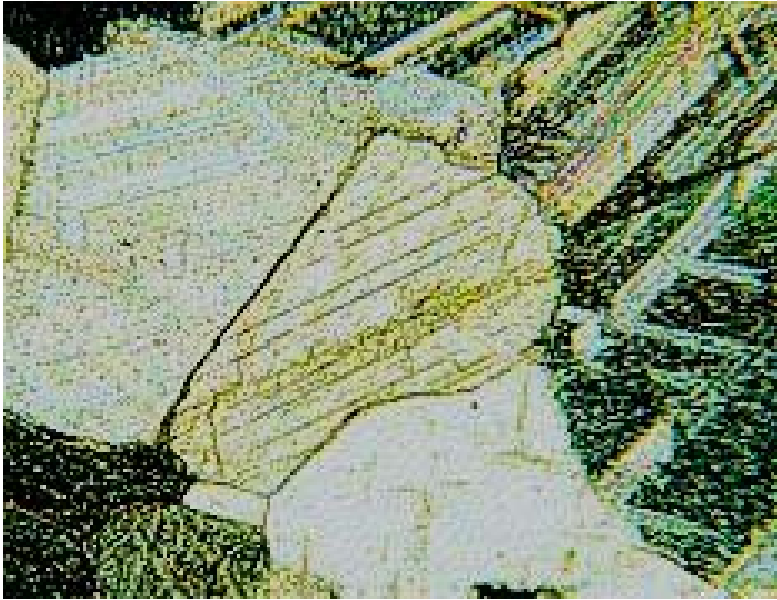
# Calcite – $\text{CaCO}_3$ – limestone

Calcite also lends its name to a group of isostructural minerals (Ca, Mg, Fe, Mn and Zn carbonates), which are hexagonal ( $R\bar{3}c$ )

The triangular nature of the  $(\text{CO}_3)^{2-}$  group results in rhombohedral, rather than isometric (NaCl structure), crystals which have perfect cleavage  $\{10\bar{1}1\}$ .



While rhombs are common, calcite has one of the greatest ranges in morphology of all known mineral species.



Calcite, being a hexagonal (trigonal) mineral, is uniaxial (- ve)

It has very distinctive cleavage and twinning, with very high birefringence, which differentiates it from the amphiboles.

Differentiating calcite from other members, optically, is difficult, but it can be accomplished by using interference figures and relief.

Calcite (limestone) is the major ingredient in cement. Different quantities of siliceous minerals leads to different qualities and strengths of cement.



# Dolomite – $\text{MgCa}(\text{CO}_3)_2$

Hexagonal (trigonal) mineral = uniaxial (- ve).

Dolomite has a slightly lower symmetry space group, but displays all the expected features of the carbonates.

Rhombohedral cleavage, high birefringence, twinned.

Structure consists of ideally sorted Mg and Ca sheets, with a high degree of order.

Differentiation may be achieved by measuring RI, heating samples to form brucite, or staining.







# The dolomite problem!

What is the “dolomite problem”?

The dolomite problem is best defined as, “how does dolomite form”?

How does calcite form?

How do we go from one to the other?

Organisms do not precipitate dolomite?

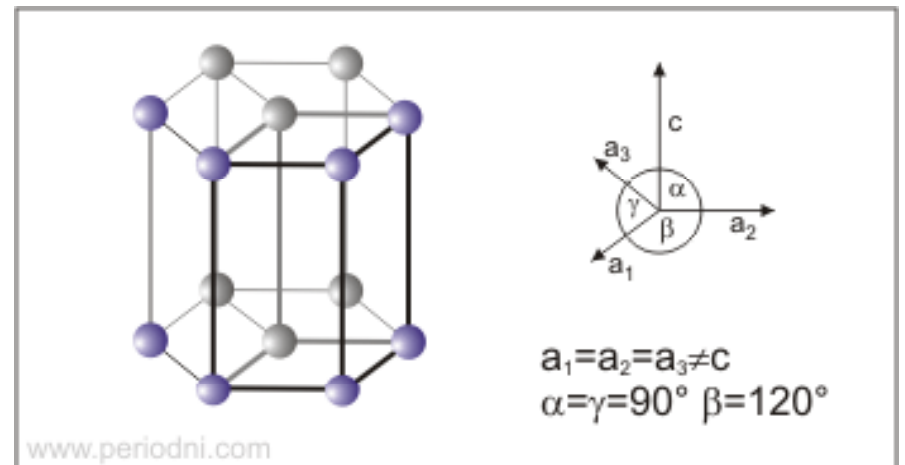
Dolomite does precipitate as a primary mineral phase in Shark Bay, Australia.

Most dolomite is believed to form by alteration, recrystallisation, or fluid activity.

# Bastnäsite-(Ce)-(La)-(Y)

(LREE,Y)[F|CO<sub>3</sub>], is also hexagonal, and therefore uniaxial.  
However, it is (+ ve).

It is colourless to yellow in thin section, with poor cleavage. Commonly has a pearly lustre, is transparent, with a reddish-brown colour.

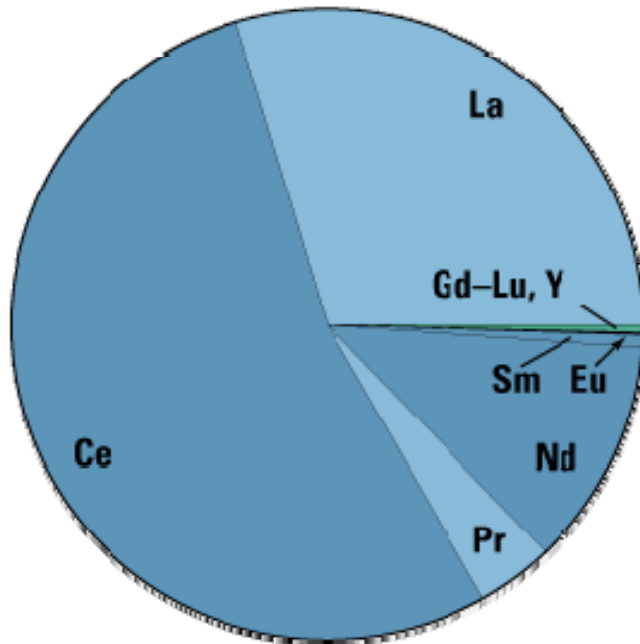


It is a carbonate mineral, but rather than occurring in oceanic environments, crystallises in very special magmatic rocks – carbonatites.

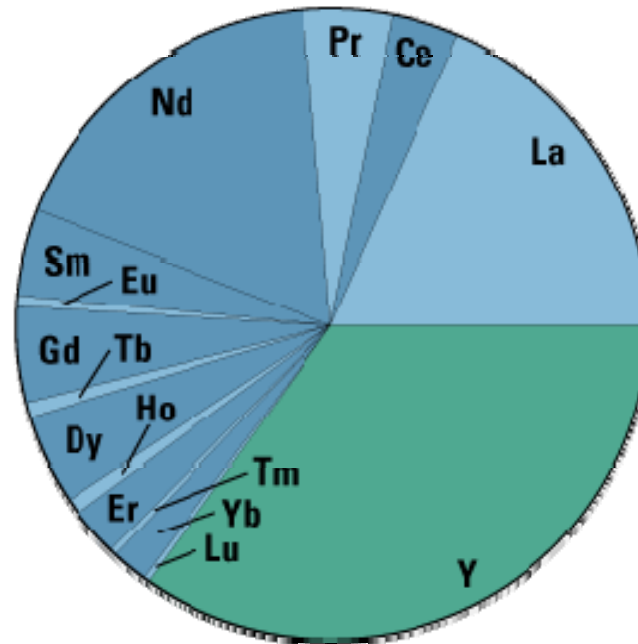
World's premier source of rare earth elements.

Used in high brightness filaments, lighting, catalysis, glasses, and influencing metal properties.

**Bastnaesite ore, Mountain Pass, California**



**Lateritic ore, southern China**



# Phosphates: Apatite and Monazite

$P^{5+}$  in these minerals forms a tetrahedral anionic group  $(PO_4)^{3-}$ .

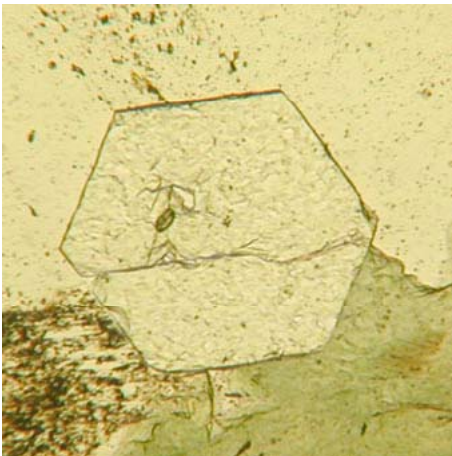
Apatite has three end-members, defined by the volatile species (F, Cl or OH).

Fluorapatite:  $Ca_5(PO_4)_3F$

Chlorapatite:  $Ca_5(PO_4)_3Cl$

Hydroxyapatite:  $Ca_5(PO_4)_3OH$

Apatite is a very common mineral in many Ca-rich rock assemblages.



Apatite often takes on the hexagonal form of its crystallographic system.

It is uniaxial (- ve).

Often grows are large euhedral crystals, especially in pegmatites, and also in carbonatites.



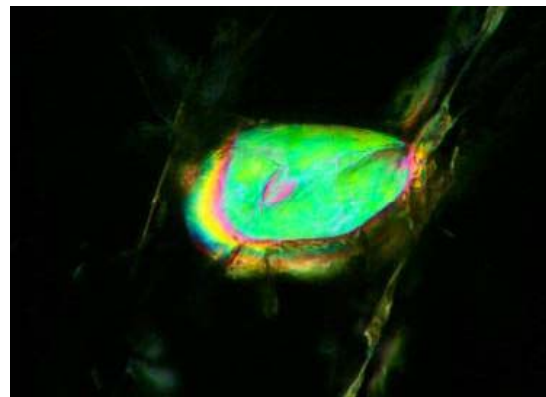
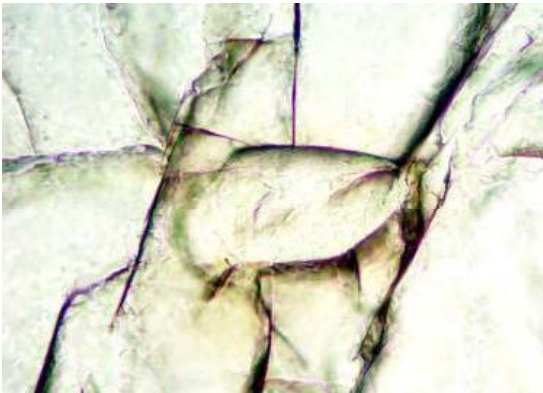
It is of historical importance, because it was a primary source of P for fertilizers for a long time, but is only mined for such purposes today on the Kola Peninsula.

# Monazite (Xenotime) – (LREE,Y)PO<sub>4</sub>

Monazite is a ubiquitous accessory phase mineral, especially in metamorphic rocks. It is less common in igneous rocks, particularly those rich in CaO.

Monoclinic, with crystals often being small, flattened and elongate.

Being rich in REE it has a high relief and high birefringence, but its crystal shape makes it easily distinguishable from zircon.



# The frontiers of monazite research.

Integrating accessory phase composition and geochronology into rock-forming processes.

Using combinations of common rock-forming minerals (i.e. garnet-biotite) Geologists can estimate the pressure and temperature at which mineral assemblages formed.

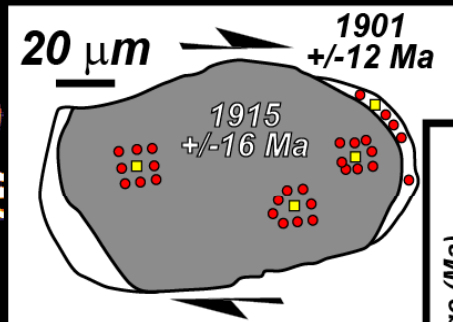
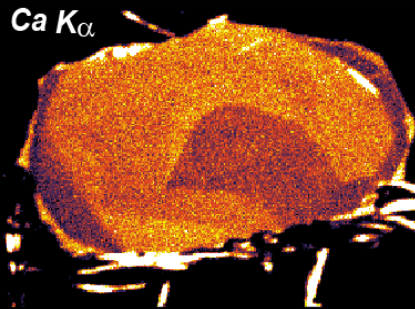
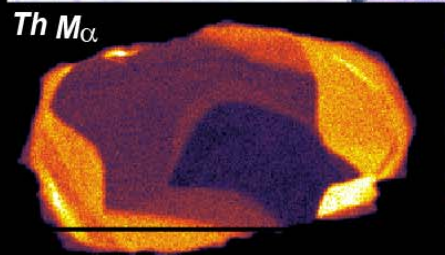
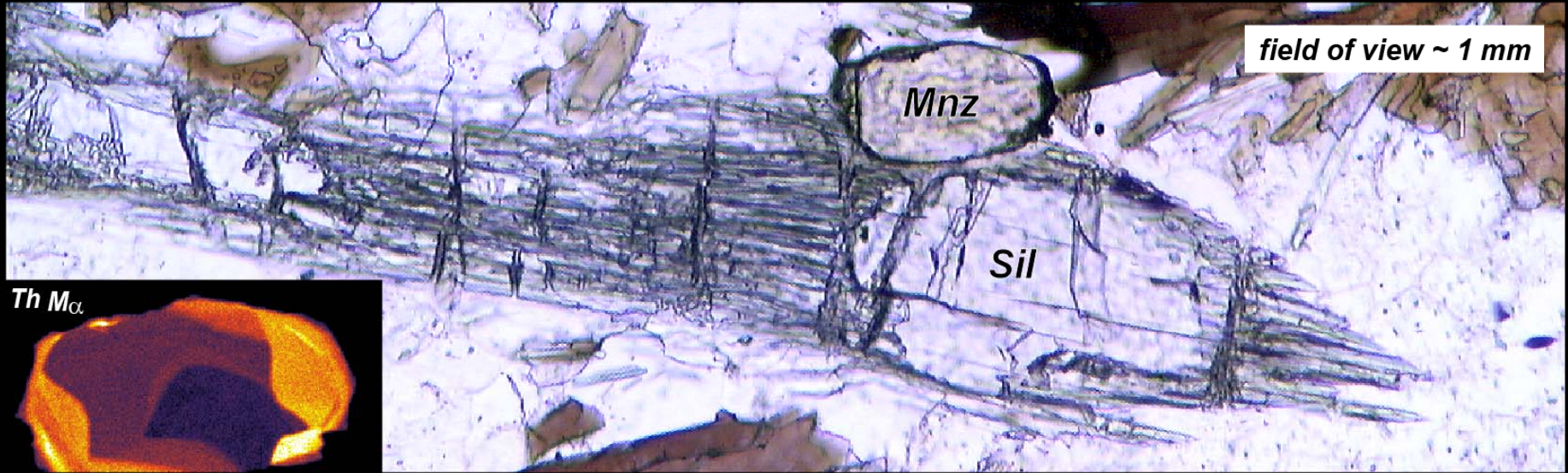
If we can incorporate chronologically important minerals (zircon, muscovite, biotite, or monazite) we can also constrain when the assemblage grew.

U-Th-total Pb chronology may be applied to monazite and xenotime.

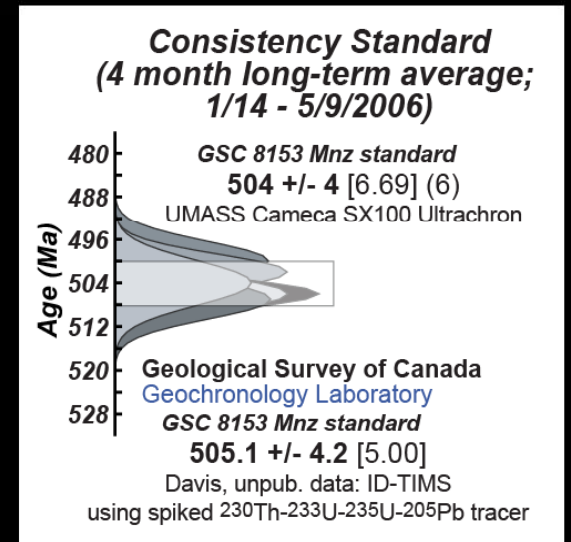
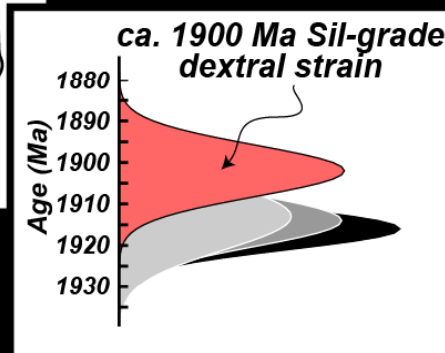
It is based on primarily on one assumption: that the crystallographic structure of these minerals does not incorporate Pb – Pb is incompatible.

04G-029B Grease River shear zone tectonite, kinematic section parallel to  $L_2 : 16 \rightarrow 235$   
 $S_2 : 229, 70$

NE SW



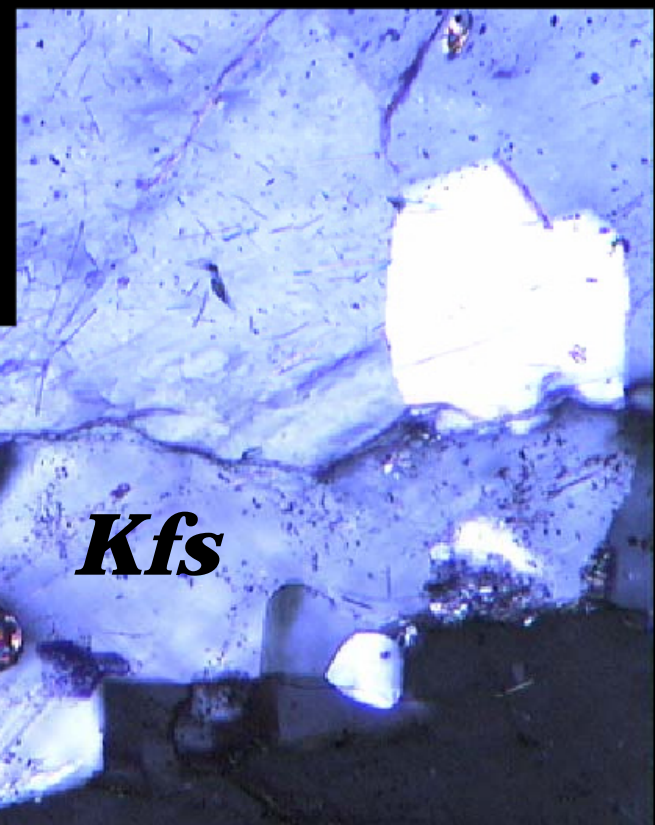
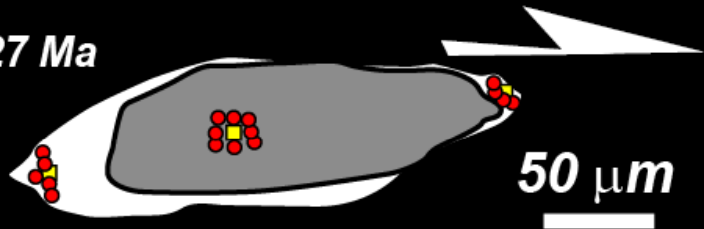
■ = background collection point  
 ● = trace element analysis point



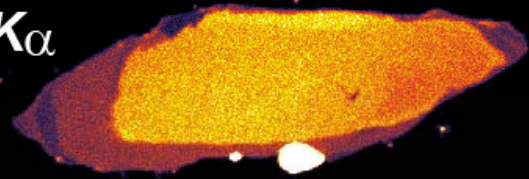
Williams et al. (2006) *Chemical Geology*  
 Jercinovic and Williams (2005) *American Mineralogist*

Core = 1927 +/- 27 Ma

Rim = 1850 +/- 28 Ma



Ca  $K_{\alpha}$



U  $M_{\beta}$

