

Descriptive Mineralogy

Classification of Minerals

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- Native Elements
- Halides
- Sulfides
- Oxides
- Hydroxides
- Carbonates
- Sulfates
- Phosphates
- Silicates
 - Orthosilicates
 - Sorosilicates
 - Cyclosilicates
 - Chain Silicates
 - Layer Silicates
 - Tektosilicates

Native Elements

- Fe, Co, Ni: Meteorites
- Platinum Group: (Ru, Rh, Pd, Os, Ir, Pt): Mafic Igneous Rocks
- Coinage metals: Cu, Ag, Au
 - Cu, Ag: Supergene Enrichments (Sulfide Oxidation)
 - Au: Low Temperature Hydrothermal, Placer

Native Elements

- Carbon:
 - Graphite: Metamorphic Rocks
 - Diamond: Kimberlites
- Sulfur (+Se):
 - Salt Domes (Sulfate reduction),
 - Volcanos (H_2S oxidation)
- Tellurium (Te) Telluride oxidation

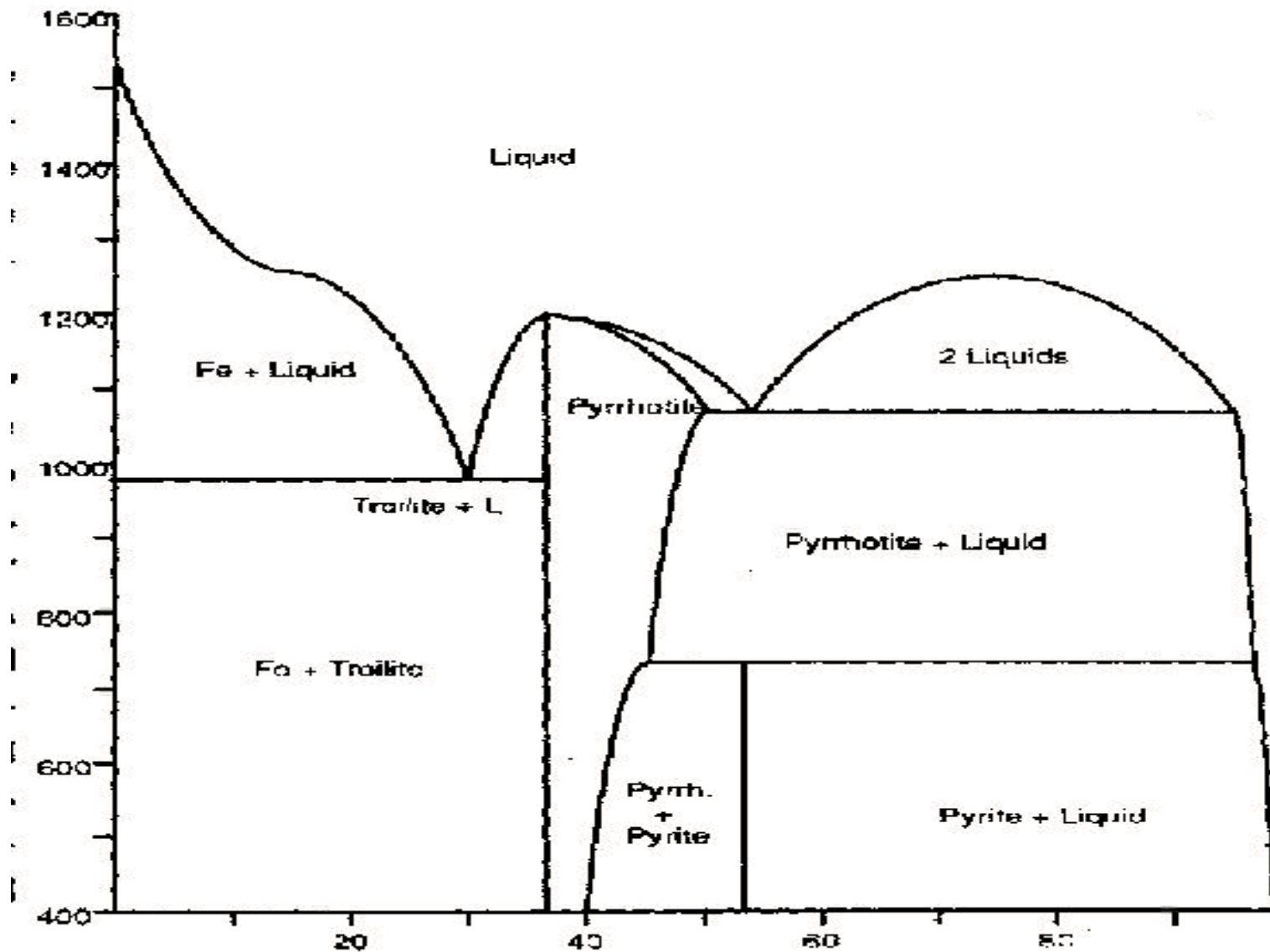
Halides

- Halite (NaCl) and Sylvite (KCl): Evaporites
- Fluorite (CaF_2) Low temperature hydrothermal
- Cryolite (Na_3AlF_6): Pegmatite

Fe Sulfides

- Fe:
 - Pyrite FeS_2
 - Marcasite FeS_2
 - Pyrrhotite Fe_{1-x}S
 - Troilite FeS
 - Arsenopyrite FeAsS

Fe-S Diagram



Cu Sulfides

- Cu Sulfides
 - Chalcocite Cu_2S
 - Covellite CuS
- Cu-Fe Sulfides
 - Chalcopyrite CuFeS_2
 - Bornite Cu_5FeS_4

Other Sulfides

- Sphalerite ZnS
- Molybdenite MoS_2
- Galena PbS
- Realgar AsS and Orpiment As_2S_3
- Arsenopyrite FeAsS
- Stibnite Sb_2S_3
- Cinnabar HgS

Simple Oxides

- Hemioxides
 - Cuprite (Cu_2O)
 - Ice (H_2O)
- Monoxides
 - Periclase (MgO)
 - Wüstite (FeO)
 - Manganosite (MnO)
 - Lime (CaO)
 - Zincite (ZnO)
 - Bromellite (BeO)
 - Tenorite (CuO)
- Sesquioxides
 - Corundum (Al_2O_3)
 - Hematite (Fe_2O_3)
 - Bixbyite (Mn_2O_3)
- Dioxides
 - Rutile (TiO_2)
 - Anatase (TiO_2)
 - Brookite (TiO_2)
 - Cassiterite (SnO_2)
 - Pyrolusite (MnO_2)

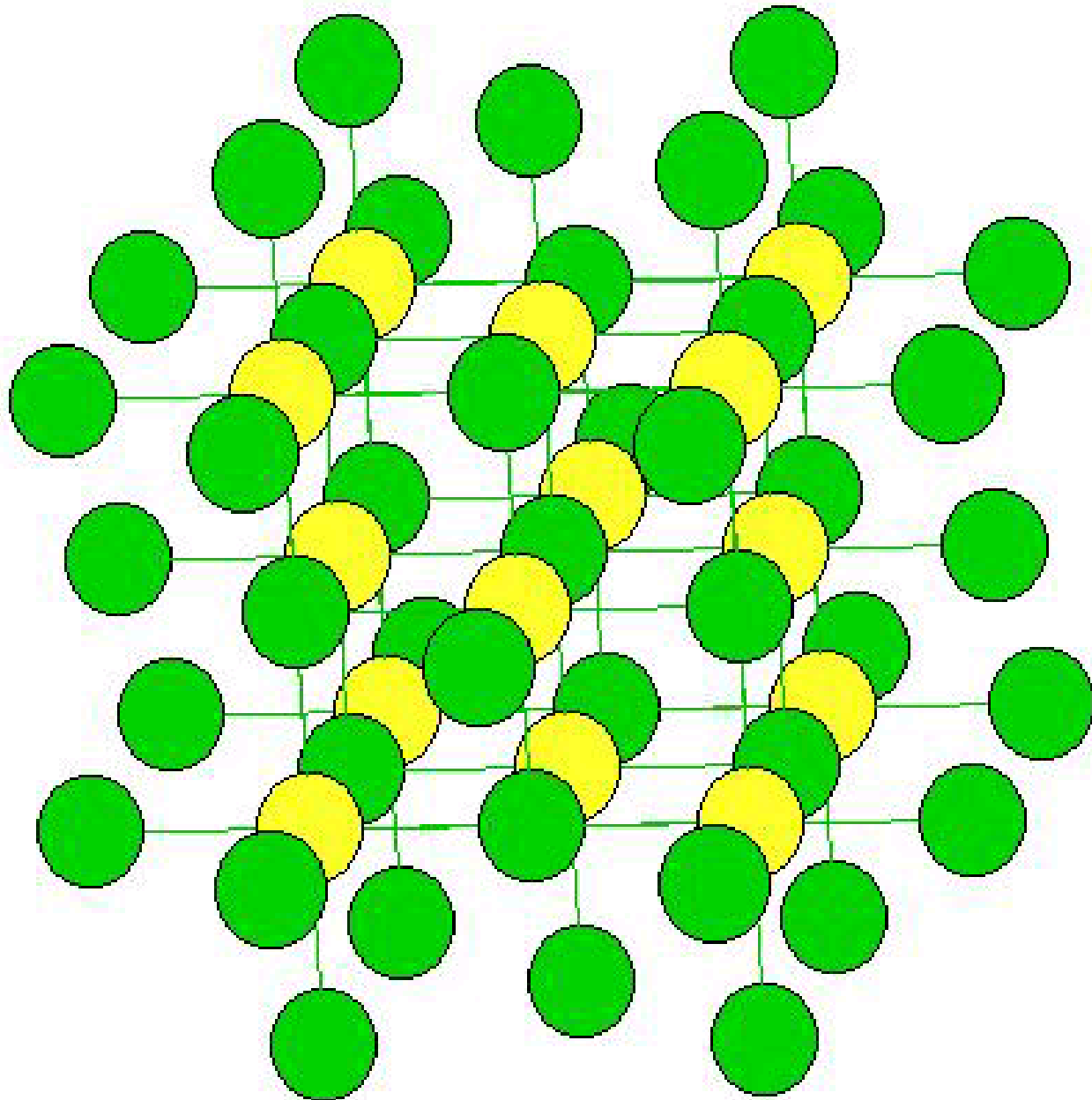
Hemi-Oxides (M_2O)

- Ice (H_2O) Hexagonal
- Cuprite (Cu_2O)
- Why not Na_2O ?
 - (Na radius too large)

Monoxides (MO)

- Rocksalt oxides MgO, FeO, MnO, CaO, NiO
 - Periclase MgO - Wuestite FeO
 - Manganosite MnO
 - Lime CaO
 - Bunsenite NiO
- Zincite oxides: zincite ZnO, bromellite BeO
- Other monoxides:
 - Tenorite CuO, Montroydite HgO

Periclase Structure



Sesquioxides (M_2O_3)

- Corundum Group
 - Corundum Al_2O_3
 - Hematite Fe_2O_3
 - Karelite V_2O_3 and Eskolaite Cr_2O_3
- Other Sesquioxides
 - Bixbyite Mn_2O_3

Dioxides

- Rutile Group
 - Rutile TiO_2 ; Anatase; Brookite
 - Cassiterite SnO_2
 - Pyrolusite MnO_2
 - Stishovite SiO_2
- Uraninite (UO_2) and Thorianite (ThO_2)
- Baddeleyite ZrO_2

Complex Oxides

- Two or more different cations
 - Spinel Group: M_2TO_4
 - Ilmenite Group : $FeTiO_3$
 - Pseudobrookite Group : A_2BO_5
 - Perovskite Group : $CaTiO_3$
- High Pressure silicate analogues

Spinel Group

- Spinel MgAl_2O_4
- Hercynite FeAl_2O_4
- Chromite FeCr_2O_4
- Magnesiochromite
 MgCr_2O_4
- Magnetite $\text{Fe}^{2+}\text{Fe}^{3+}_2\text{O}_4$
- Magnesioferrite MgFe_2O_4
- Gahnite ZnAl_2O_4
- Ulvospinel TiFe_2O_4
- Ringwoodite Mg_2SiO_4

Spinel Structure

Space Group $Fd3m$

Edge sharing octahedra

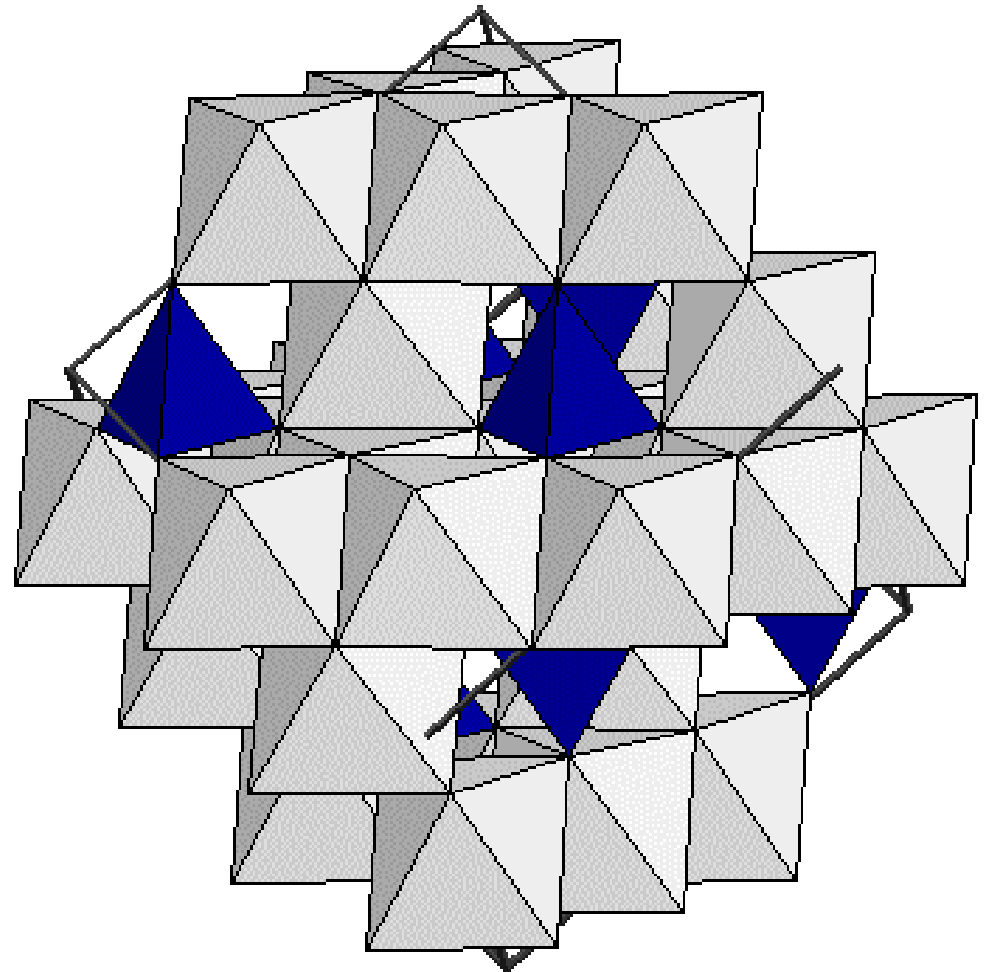
Cell edge $\sim 8.5\text{\AA}$

Two octahedra per

Tetrahedron

Mg Al₂ O₄ (Normal) or

Al (MgAl) O₄ (Inverse)

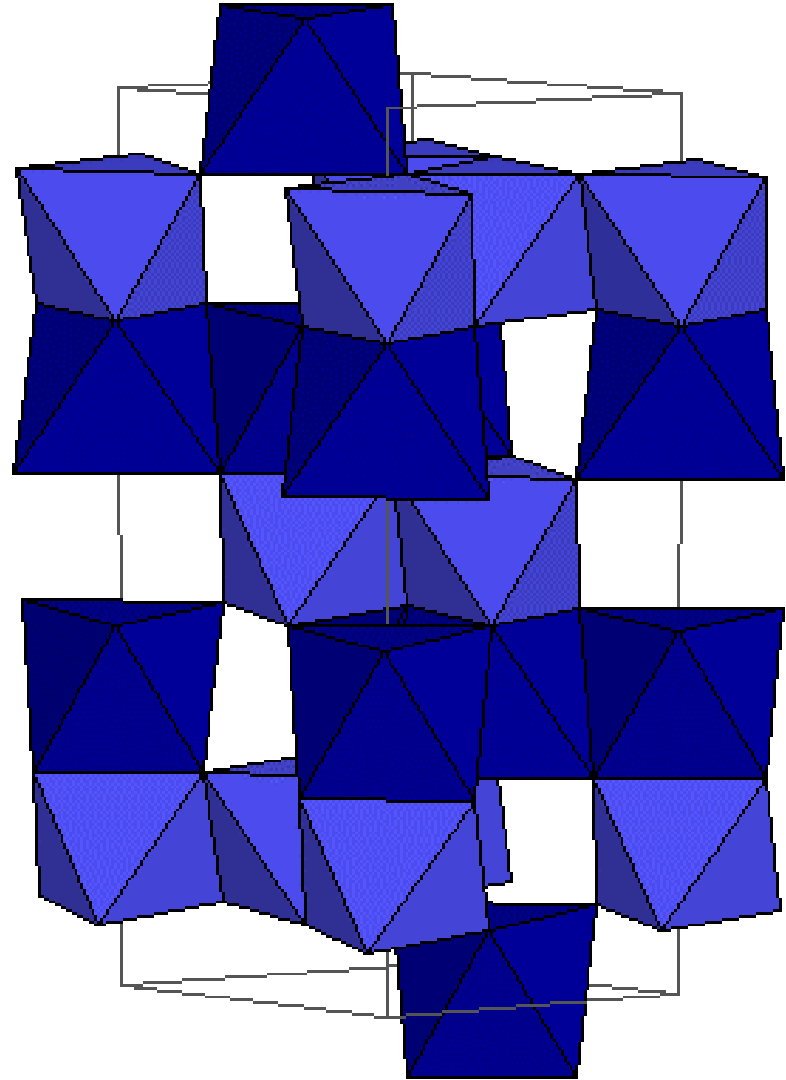


Ilmenite Group

- Ilmenite FeTiO_3
- Geikielite MgTiO_3
- MgSiO_3

Ilmenite Structure

- Corundum Structure
- Space Group R-3
- Alternating layers of Fe and Ti Octahedra
- Face-sharing Octahedra
- Dense

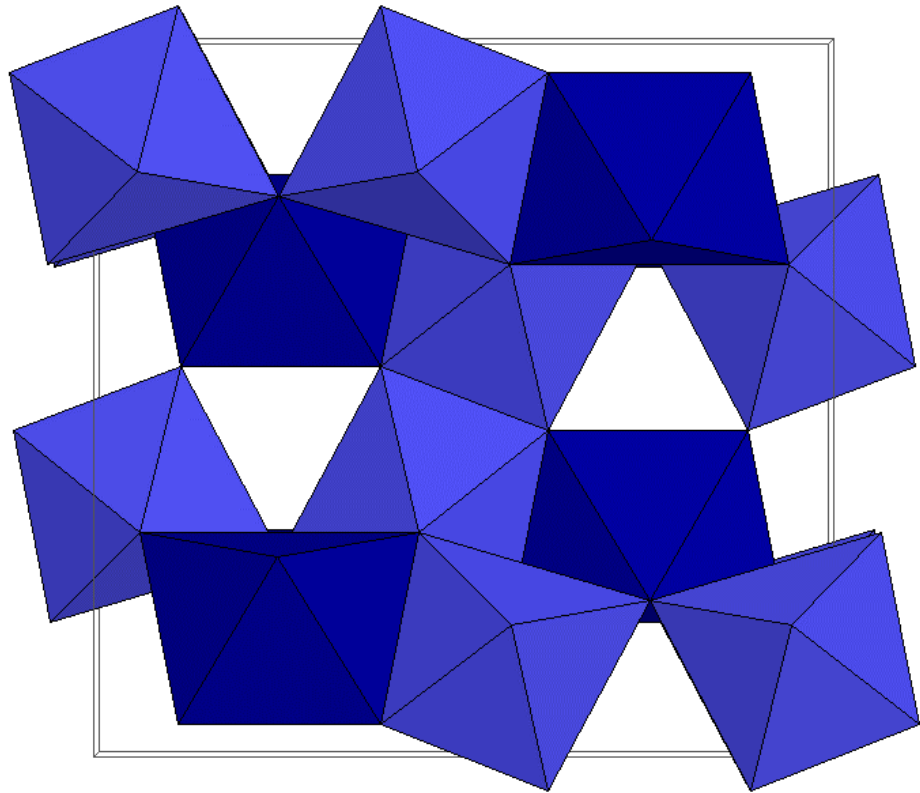


Pseudobrookite Group

- Pseudobrookite $\text{Fe}^{2+}\text{Ti}_2\text{O}_5$
- Ferro-pseudobrookite $\text{TiFe}^{3+}_2\text{O}_5$
- Armalcolite $(\text{Mg},\text{Fe}^{2+})\text{Ti}_2\text{O}_5$

Pseudobrookite Structure

- Space Group
Bbmm
- M1 dark
- M2 lighter

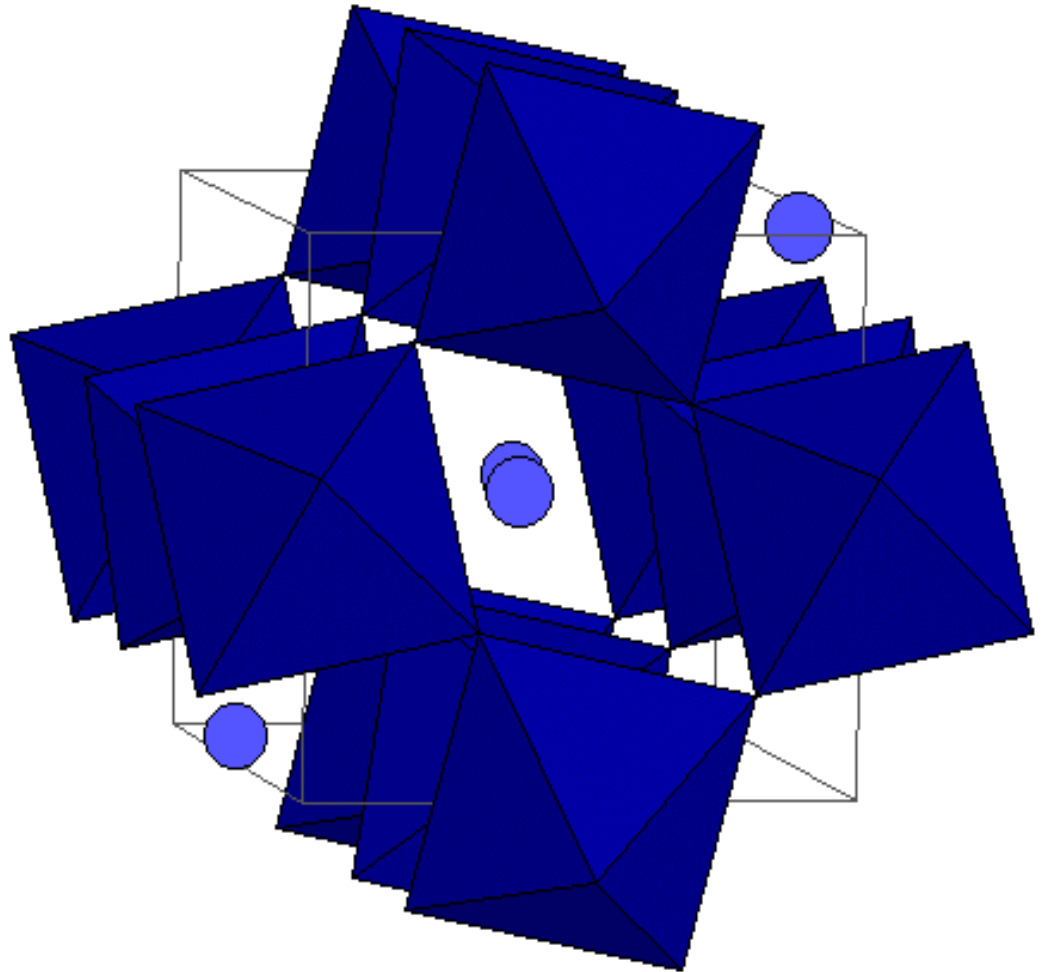


Perovskite

- Perovskite CaTiO_3
- MgSiO_3 (Lower mantle phase)

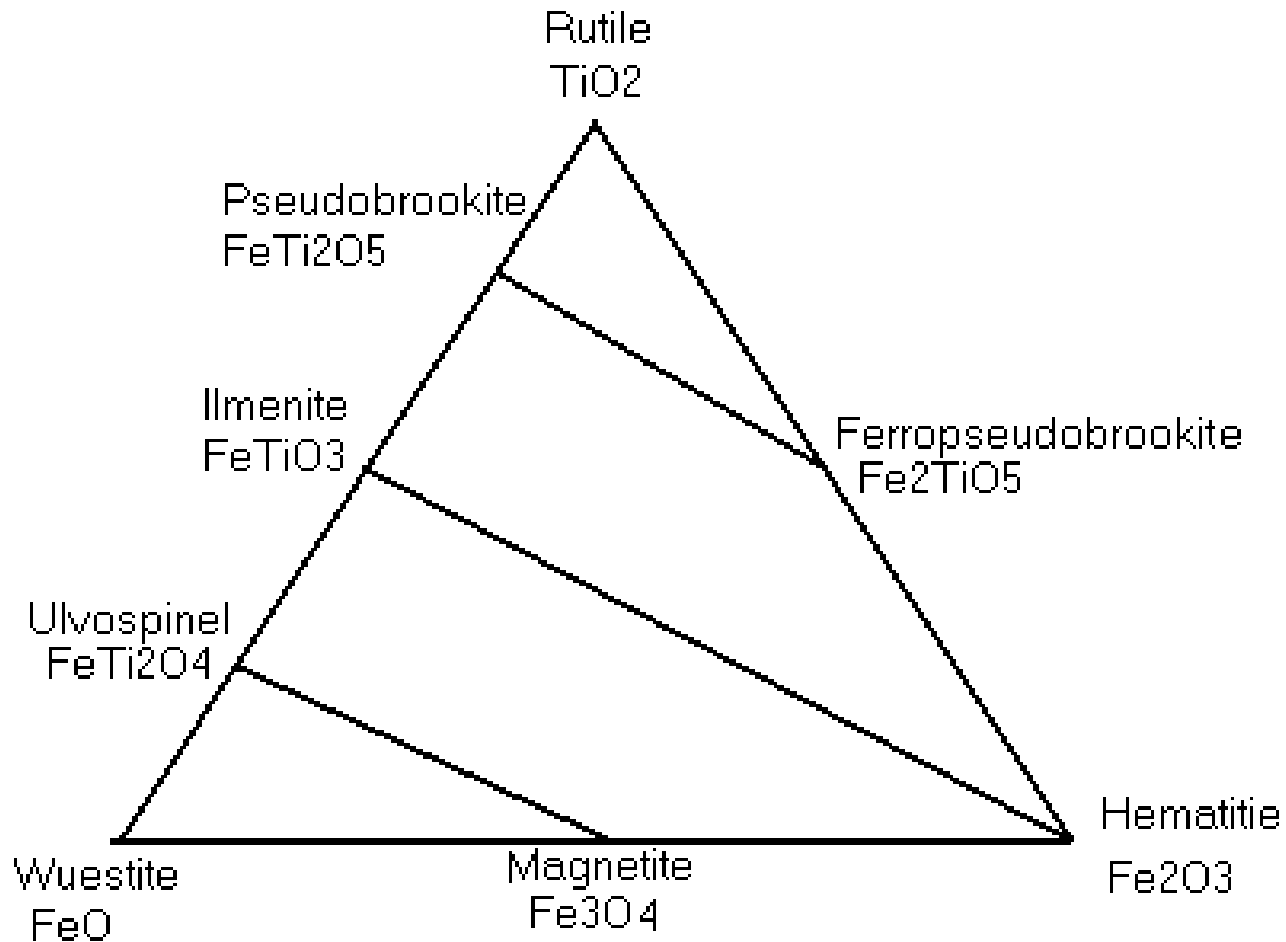
Perovskite Structure

- Pseudo-cubic
- Orthorhombic
- Space Group
Pbnm



Accessory Oxides

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Hydroxides

- Brucite $\text{Mg}(\text{OH})_2$
- Gibbsite $\text{Al}(\text{OH})_3$
- Boehmite and Diaspore $\text{AlO}(\text{OH})$
- Bauxite (Mixed Al hydroxides)
- Goethite $\text{FeO}(\text{OH})$ (+Lepidochrosite)
- Limonite $\text{Fe}(\text{OH})_3$

Carbonates

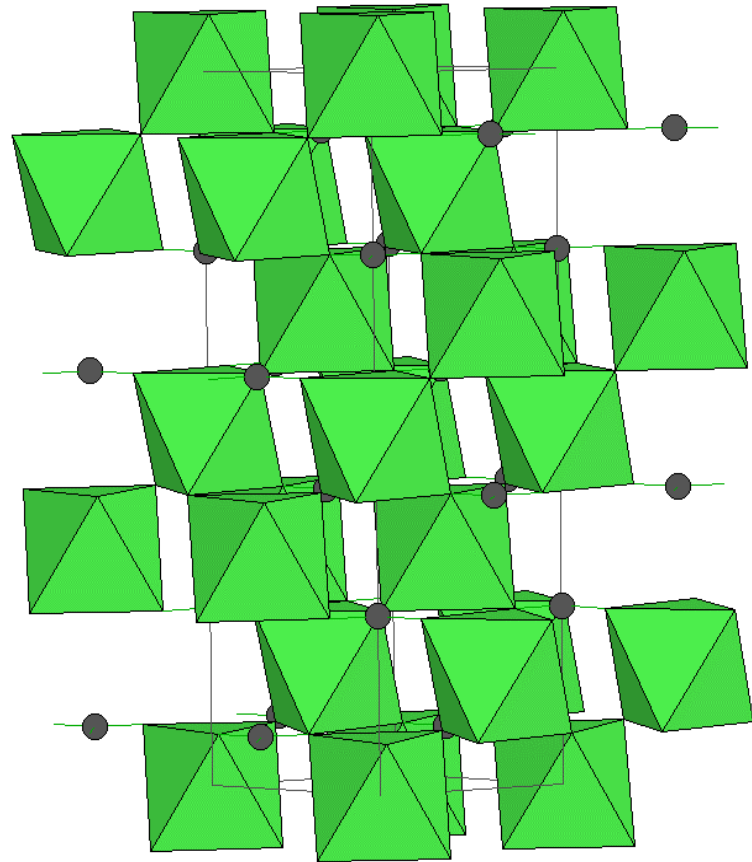
- Calcite Group
- Aragonite Group
- Dolomite Group
- Other carbonates

Calcite Group

- Calcite CaCO_3
- Magnesite MgCO_3
- Siderite FeCO_3
- Rhodochrosite MnCO_3
- Smithsonite ZnCO_3

Calcite Structure

- Space Group
 $R-3c$
- Divalent cation
radius $< 1.00\text{\AA}$

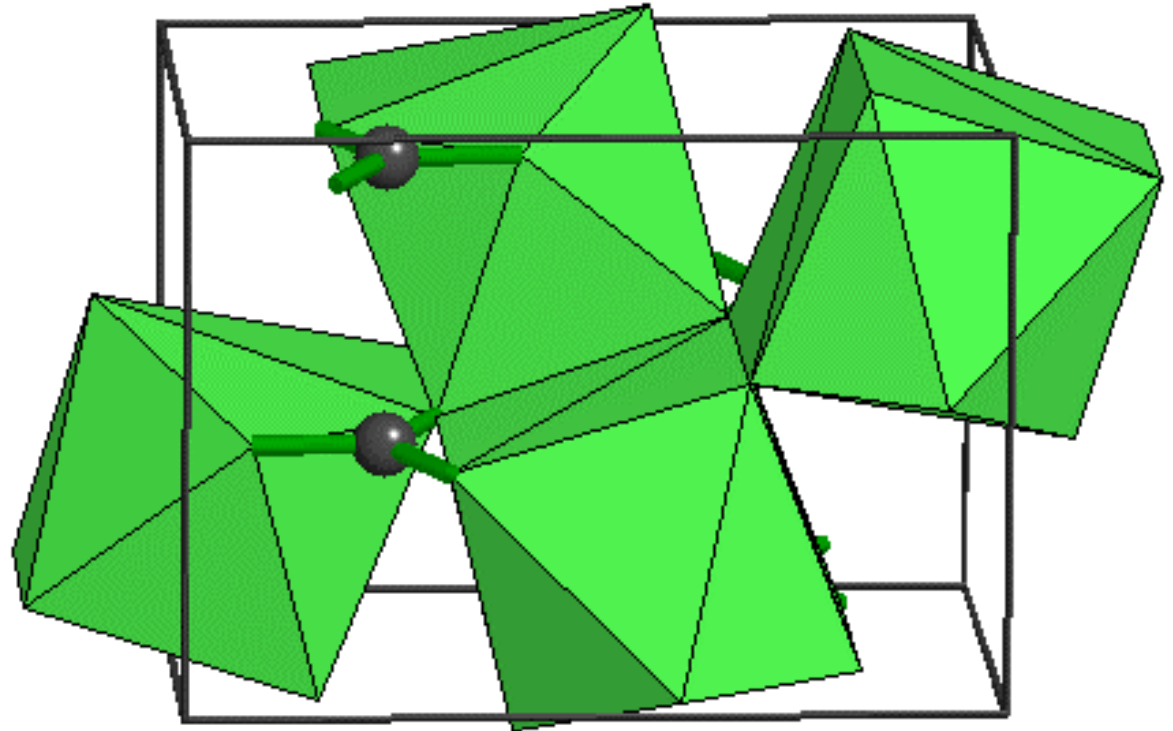


Aragonite Group

- Aragonite CaCO_3
- Strontianite CaCO_3
- Witherite BaCO_3
- Cerussite PbCO_3

Aragonite Structure

- Space Group
Pbnm
- Cation Radius :
1.00Å



Dolomite Group

- Dolomite $\text{CaMg}(\text{CO}_3)_2$
- Ankerite $\text{CaFe}(\text{CO}_3)_2$

Other Carbonates (+Nitrates)

- Malachite (Green) $\text{Cu}_2(\text{OH})_2\text{CO}_3$
- Azurite (Blue) $\text{Cu}_3(\text{OH})_2(\text{CO}_3)_2$
- Cu^{1+} or Cu^{2+} ?
- Niter KNO_3
- Soda Niter NaNO_3

Sulfates

- Gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
- Anhydrite CaSO_4
- Celestine SrSO_4
- Barite BaSO_4
- Anglesite PbSO_4
- Alunite $\text{KAl}_3(\text{OH})_6(\text{SO}_4)_2$

Gypsum

- $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
- Hardness 2
- Evaporite Mineral
- Contains molecular water

Anhydrite

- CaSO_4
- Hardness 3-3.5
- Evaporite Mineral
- Contains no molecular water

Celestine

- SrSO_4
- Hydrothermal
-

Barite

- BaSO_4
- Hydrothermal

Anglesite

- PbSO_4
- OxHydrothermal

Phosphates, Tungstates, Vanadates

- Phosphates are based on $P^{5+}O_4$ tetrahedron.
- By far the most important one is apatite.
- $Ca_5(PO_4)_3(OH,F,Cl)$
- Tungstates and Vanadates are based on $W^{6+}O_4$ and $V^{5+}O_4$ tetrahedra. Some are isostructural with apatite and so included in the same group, but they are usually considered oxides.

Apatite

- $\text{Ca}_5(\text{PO}_4)_3(\text{OH}, \text{F}, \text{Cl})$
- Hydroxy- Fluor-, and Chlor- apatites
- Major component of teeth and bone
- Common accessory mineral in igneous and metamorphic rock.
- Some sedimentary phosphates (phosphate sands).