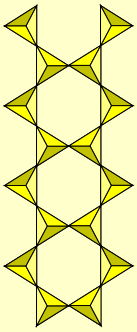
Biaxial Minerals Descriptions

- Olivine
- Pyroxenes
  - Orthopyroxene
  - Clinopyroxene
- **Amphibole**
  - **Hornblende**
  - **Actinolite**
- Micas
  - Biotite, muscovite, chlorite
- Feldspars
  - Plagioclase
  - Microcline, orthoclase, sanidine

Amphiboles

- Two groups to consider:
  - orthoamphiboles
  - clinoamphiboles
- Similar to pyroxenes (single chain) but have a double chain of silica tetrahedra elongated ⊥ to c axis
- Exhibit a range of compositions with a corresponding range of optical properties. (p. 201 - compositional range)
- Compositions can not accurately be determined based on optical properties.



Classification of Amphiboles

Fe-Mg Amphiboles
- Anthophyllite (O) $(Mg,Fe)_7Si_8O_{22}(O\ H)_2$
- Gedrite (O) $(Mg,Fe)_5Al_2\ (Al_2Si_6)O_{22}(O\ H)_2$
- Cummingtonite-grunerite (M) $(Fe,\ Mg)_7Si_8O_{22}(O\ H)_2$

Calcic Amphiboles (M)
- **Tremolite-actinolite** $\mathbf{Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2}$
- **Hornblende** $\mathbf{(Na,K)_{0-1}Ca_2(Mg,Fe^{2+},Fe^{3+},Al)_5(Si,Al)_8O_{22}(OH)_2}$
- Oxyhornblende $(Na,K)_{0-1}Ca_2(Mg,Fe^{2+},Fe^{3+},Al)_5(Si,Al)_8O_{22}(O,OH)_2$
- Kaersutite $NaCa_2(Mg,Fe^{2+})_4TiSi_6Al_2O_{22}(OH)_2$

Sodic-calcic amphiboles (M)
- Katophorite $Na(Na,Ca)(Mg,Fe^{2+},Fe^{3+},Al)_5(Si_7AlO_{22}(OH)_2$
- Richertite $Na(Na,Ca)(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$

Sodic Amphiboles (M)
- Glaucophane $Na_2(Mg,Fe^{2+})_3Al_2Si_8O_{22}(OH)_2$
- Riebeckite $Na_2(Mg,Fe^{2+})_3Fe^{3+}{}_2Si_8O_{22}(OH)_2$
- Arfedsonite-eckermanite $NaNa_2(Mg,Fe^{2+})_4(Fe^{3+},Al)Si_8O_{22}(OH)_2$

Orthoamphibole

Orthorhombic amphibole

- Anthophyllite $(Mg,Fe)_7Si_8O_{22}(O\ H)_2$
- Restricted to metamorphosed basaltic rocks
- Because it is orthorhombic it exhibits ‖ extinction in elongate sections
- All remaining amphiboles are monoclinic and exhibit inclined extinction in elongate sections

Amphibole

Monoclionic Amphiboles or Amphiboles

- most common
- all monoclinic
- generally all optically -ve
- 2 major ones to be familiar with:
  - Tremolite - Actinolite
    - $Ca_2Mg_5Si_8O_{22}(OH)_2$ - $Ca_2Fe_5Si_8O_{22}(OH)_2$
  - Common Hornblende
    - $Ca_2(Mg,Fe,Al)_5Si_8O_{22}(OH)_2$
- Variable compositions = variable optical properties.

Hornblende

Refractive Index

n_α = 1.60 - 1.70
n_β = 1.61 - 1.71
n_γ = 1.62 - 1.73

Relief, Birefringence, Retardation

- Exhibits moderate to high relief
- Birefringence 0.014-0.034
- Interference colours vary from 1st order orange to upper 2nd order - lower 3rd order colours
  - Average 2nd order blue-green interference colours

Hornblende

Optic Sign

- Optic sign either +ve or –ve
- $2V_X$ angle varies from 35 to 130°, depending on composition
- Generally $2V_X$ = 52 - 85° therefore optically -ve

Hornblende

Colour

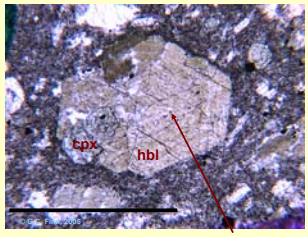
- Hornblende is distinctly coloured and pleochroic in thin section. Shades of green, yellow-green, blue-green and brown.

Pleochroism

X	Y	Z
yellow-green olive	green	dark green
pale brown	greenish	dark green
greenish-brown	reddish-brown	red-brown

- variety of pleochroic colours.

Hornblende Pleochroism



cleavage

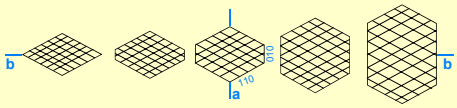
Hornblende

- Exhibits good amphibole cleavage on 110 plane at 56° and 124°
- Grain shape is controlled by cleavage and are usually elongated ‖ to c axis

Hornblende

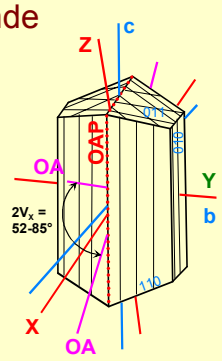
Form

- Occurs as:
  - slender prismatic to bladed crystals
  - with a 4 or 6 sided cross section which exhibit amphibole cleavage at 56 and 124°
  - also as anhedral irregular grains



Hornblende

- Monoclinic
- Optic orientation:
  - **X**^**a** = +3 to -19°
  - **Y** = b
  - **Z**^c = +12 to +39°
  - **OAP** is ‖ to 010



Hornblende

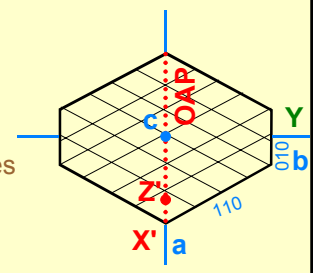
- Basal sections exhibit symmetrical extinction, slow ray ‖ to long diagonal between cleavages
- Elongated sections are length slow, and the Z^c extinction angle is used to identify hornblende

Hornblende

Basal Section

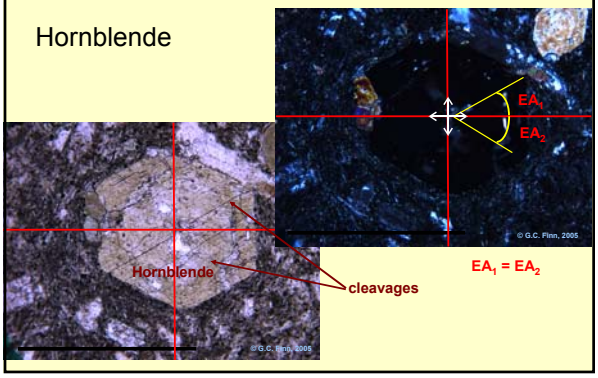
⊥ to c axis

- 4 to 6 sided grain
- and/or 2 cleavages at 56-124°
- Symmetrical Extinction
- ~ Bxo Figure



Symmetrical Extinction

Hornblende

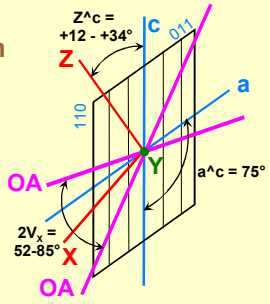


$EA_1 = EA_2$

Hornblende

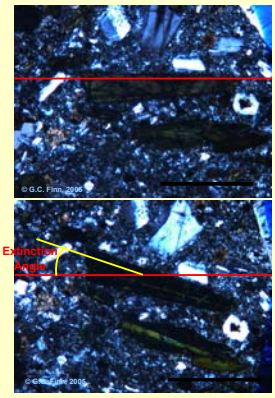
Optic Normal Section

- one cleavage
- Inclined Extinction
- Maximum interference colour
- Optic Normal Figure
- **Z^c** = +12-34°



Inclined Extinction

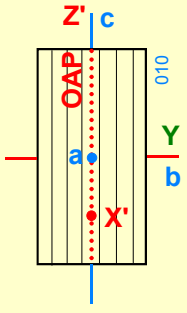
eg. Hornblende



Hornblende

Section ⊥ to a axis

- Parallel Extinction
- ~ Bxa Figure



Hornblende

Alteration

- may be altered to biotite, chlorite or other Fe-Mg silicates

Hornblende

Occurrence

- Hornblende is found in a variety of lithologies:
- Igneous (granites, through gabbros, syenites to ultramafics)
- metamorphic environments
- May be primary or secondary in origin

Hornblende

Distinguishing Features

- 2 cleavages
- grain shape
- inclined extinction
- pleochroism