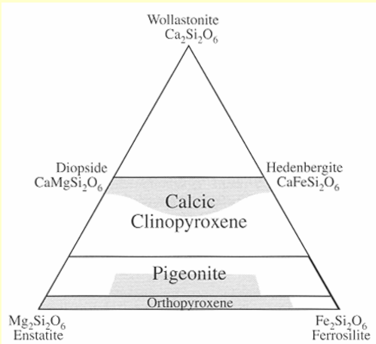
Clinopyroxene

- *Cpx - or Calcic Clinopyroxene*
- Monoclinic
- Composition based on 3 end member components
  - $CaSiO_3$ - wollastonite
  - $MgSiO_3$ - clinoenstatite
  - $FeSiO_3$ - clinoferrosilite
- Cpx general formula
  - Augite Ca,Mg,Fe,Al)$_2$(Si, Al)$_2$O$_6$
  - Common cpx
    - hedenbergite $CaFeSi_2O_6$
    - diopside $CaMgSi_2O_6$
- Variable composition = variable optical properties

Pyroxene

Compositional Groups



Clinopyroxene

Refractive Index

n_α = 1.664 - 1.745
n_β = 1.672 - 1.753
n_γ = 1.694 - 1.771

Generally the higher Fe content the higher the RI

- Will exhibit a moderate to high relief, with medium birefringence
- 2nd order blue to yellow interference colours
- biaxial +ve, with $2V_Z$ = 25 - 70°, increases with increasing Ca.

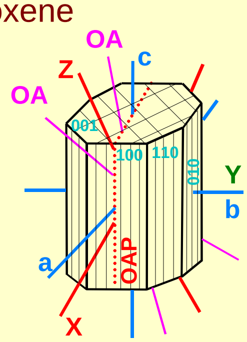
Clinopyroxene

- All clinopyroxenes crystallize with the same structure and there is complete solid solution among all species and they cannot be distinguished reliably based on their optical properties
- When identifying clinopyroxene it is best to call it a calcic clinopyroxene. To identify specific clinopyroxenes requires more advanced techniques

Clinopyroxene

Monoclinic

- 3 crystallographic axes, unequal length, not mutually perpendicular
- **a**^**c** = 105°
- The crystallographic and indicatrix axes do not coincide
- **X**^**a** = -20 to -33°
  (X lies in acute angle between a & c)
- **Y** = **b**
- **Z**^**c** = +35 to 48°
  (Z lies in obtuse angle between a & c)



Clinopyroxene

Colour and Pleochroism

- Cpx grains are usually colourless, but may be grey, pale green, brown or brownish-green. Darker pleochroic colours may reflect more iron rich compositions
  - X = pale green, bluish-green
  - Y = pale greenish-brown
  - Z = pale brownish-green, green, yellow-green
- Titanaugite (Ti-rich augite) displays a much more distinctive brown-violet pleochroism (resembles opx).

Clinopyroxene

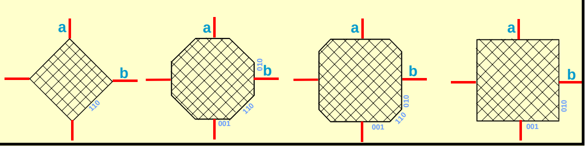
Cleavage, Fracture

- typical pyroxene cleavages parallel to {110}, which intersect at ~90°
- Basal sections showing two cleavages and exhibit symmetrical extinction.
- Longitudinal sections, cut parallel to (100), show parallel extinction and are length slow.
- Longitudinal sections, cut parallel to (010), show maximum birefringence, exhibit one cleavage and have inclined extinction with Z^c = +35 to 48°.

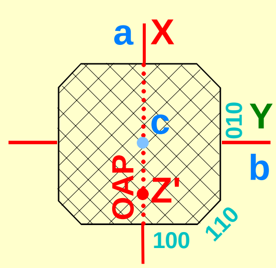
Clinopyroxene

Form

- euhedral crystals, stubby prisms, four or eight-sided (basal sections) with 2 cleavages
- longitudinal sections are rectangular and exhibit one cleavage; may form euhedral grains, irregular masses that enclose associated minerals



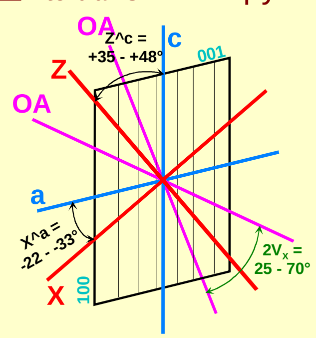
⊥ to c axis Clinopyroxene



Section of CPX

- Symmetrical Extinction
- Off Centred Optic Axis
- or Bxa Figure
- Optic Plane ll to 010

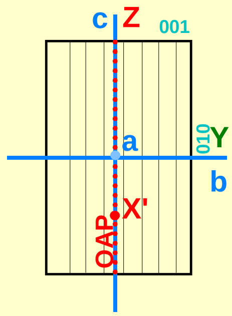
⊥ **to b axis** Clinopyroxene



Section of CPX

- ll to 010
- Inclined extinction
- Optic Normal Figure
- Maximum Interference Colour

⊥ **to a axis** Clinopyroxene



Section of CPX

- Parallel Extinction
- Off Centred Bxo

Clinopyroxene

Alteration

commonly alters to *uralite* (a fg, light coloured amphibole), or may alter to serpentine, chlorite, biotite, carbonates and /or other silicates

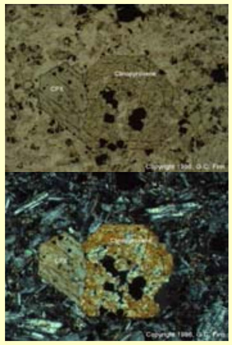
Occurrence

common in mafic igneous rocks, alkali-rich varieties may be found in more silicic rocks, often associated with olivine, orthopyroxene, and plagioclase

Clinopyroxene

Distinguished from opx by:

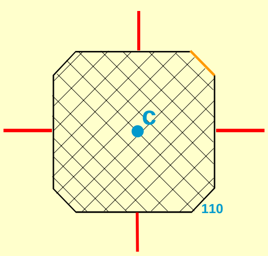
1. inclined extinction
2. higher birefringence, higher interference colour
3. lower 2V angle
4. optic sign (+ve)
5. Often opx and cpx are found together in the same rock, olivine may also be present



CPX page

CPX

By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°



Linking crystallographic and optic features in CPX

If the location of **Y** can be identified then :

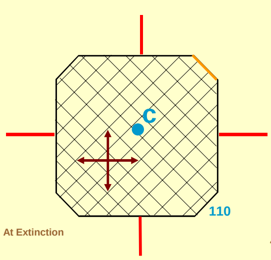
1) the position of the **OAP** (**XZ** plane) can be determined, and
2) The location of **b** can be determined

How to determine the position of the OAP

CPX

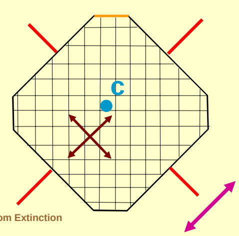
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°

Linking crystallographic and optic features in CPX



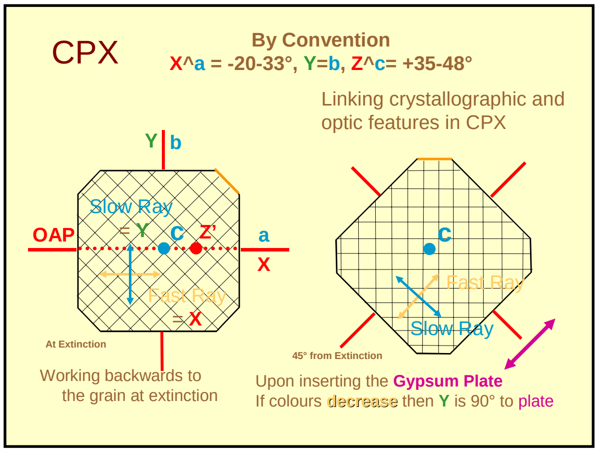
At Extinction

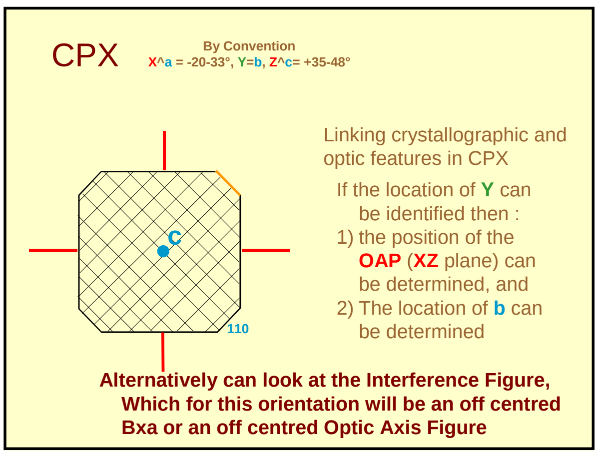
Vibration directions are parallel to crosshairs

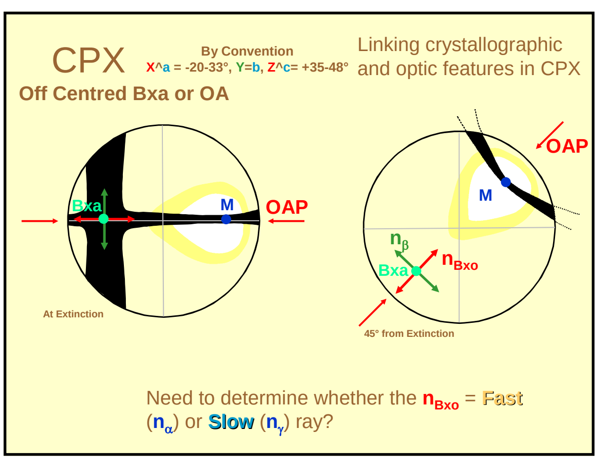


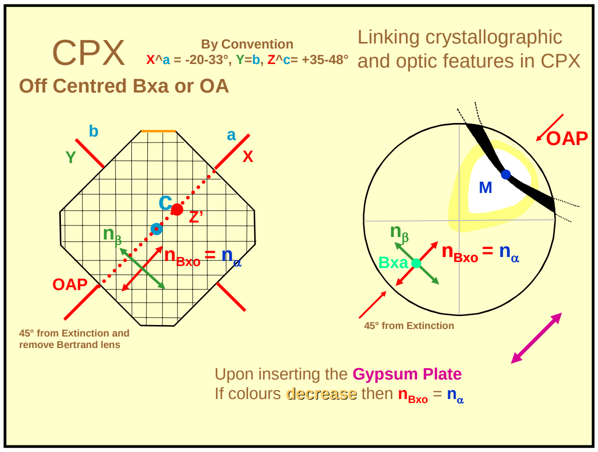
45° from Extinction

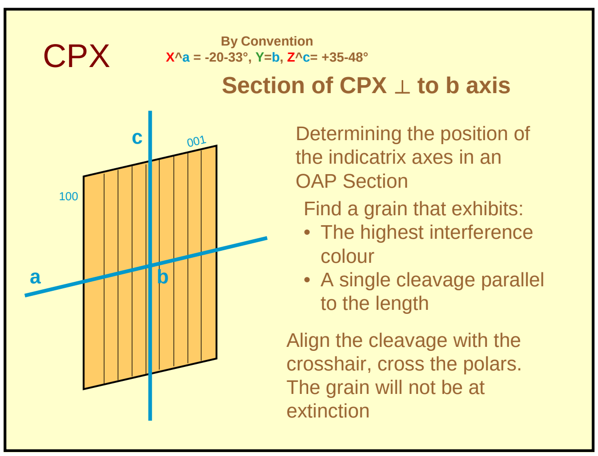
Upon inserting the **Gypsum Plate**
Colours can either **decrease** or
Colours can **increase**, parallel to plate

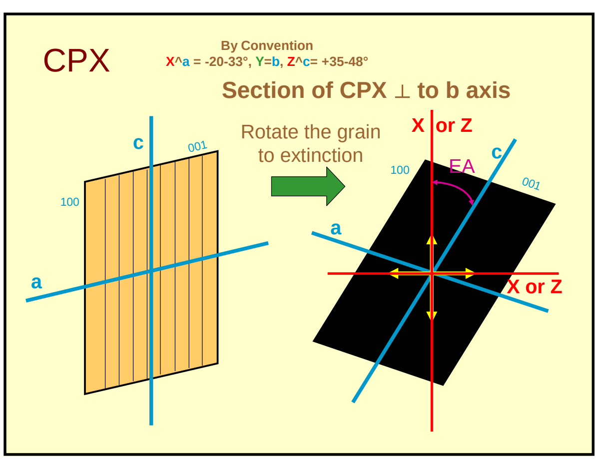

CPX
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°
Linking crystallographic and optic features in CPX
Y
b
OAP
Slow Ray
= Y
C
Z'
a
X
Fast Ray
= X
At Extinction
C
Fast Ray
Slow Ray
45° from Extinction
Working backwards to the grain at extinction
Upon inserting the Gypsum Plate
If colours decrease then Y is 90° to plate

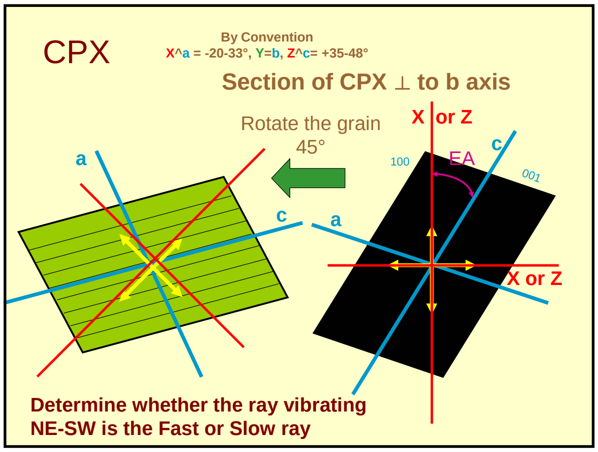

CPX
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°
C
110
Linking crystallographic and optic features in CPX
If the location of Y can be identified then :
1) the position of the OAP (XZ plane) can be determined, and
2) The location of b can be determined
Alternatively can look at the Interference Figure, Which for this orientation will be an off centred Bxa or an off centred Optic Axis Figure

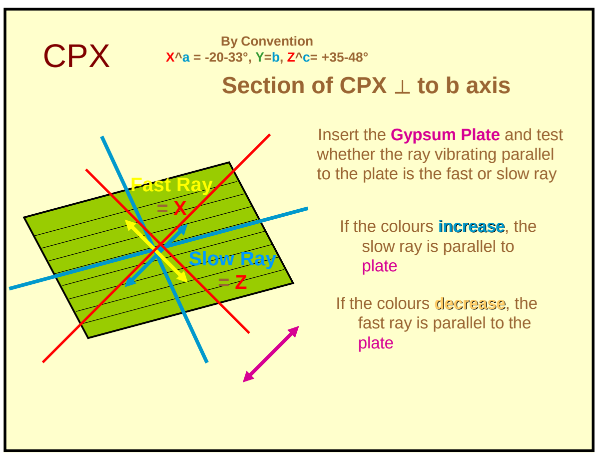

CPX
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°
Linking crystallographic and optic features in CPX
Off Centred Bxa or OA
Bxa
M
OAP
At Extinction
OAP
M
n_β
Bxa
n_{Bxo}
45° from Extinction
Need to determine whether the n_{Bxo} = Fast (n_α) or Slow (n_γ) ray?

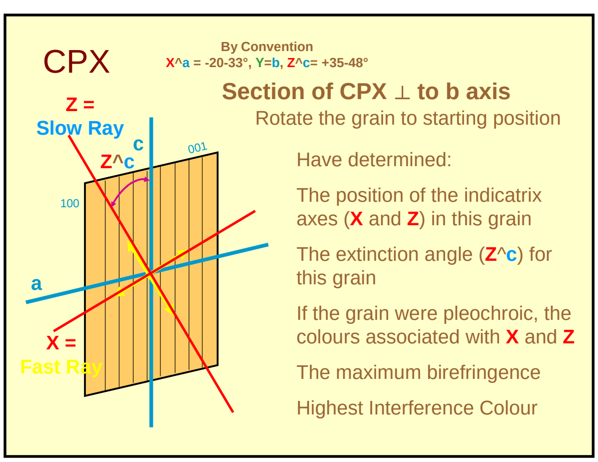

CPX
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°
Linking crystallographic and optic features in CPX
Off Centred Bxa or OA
b
a
Y
X
C
Z'
n_β
$n_{Bxo} = n_\alpha$
OAP
45° from Extinction and remove Bertrand lens
OAP
M
n_β
Bxa
$n_{Bxo} = n_\alpha$
45° from Extinction
Upon inserting the Gypsum Plate
If colours decrease then $n_{Bxo} = n_\alpha$


CPX
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°
Section of CPX ⊥ to b axis
c
001
100
a
b
Determining the position of the indicatrix axes in an OAP Section
Find a grain that exhibits:
• The highest interference colour
• A single cleavage parallel to the length
Align the cleavage with the crosshair, cross the polars. The grain will not be at extinction


CPX
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°
Section of CPX ⊥ to b axis
c
001
100
a
Rotate the grain to extinction
X or Z
EA
c
100
001
a
X or Z


CPX
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°
Section of CPX ⊥ to b axis
Rotate the grain
45°
X or Z
EA
100
001
a
c
a
c
X or Z
Determine whether the ray vibrating
NE-SW is the Fast or Slow ray


CPX
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°
Section of CPX ⊥ to b axis
Fast Ray
= X
Slow Ray
= Z
Insert the Gypsum Plate and test whether the ray vibrating parallel to the plate is the fast or slow ray
If the colours increase, the slow ray is parallel to plate
If the colours decrease, the fast ray is parallel to the plate


CPX
By Convention
X^a = -20-33°, Y=b, Z^c= +35-48°
Section of CPX ⊥ to b axis
Rotate the grain to starting position
Z =
Slow Ray
c
001
Z^c
100
a
X =
Fast Ray
Have determined:
The position of the indicatrix axes (X and Z) in this grain
The extinction angle (Z^c) for this grain
If the grain were pleochroic, the colours associated with X and Z
The maximum birefringence
Highest Interference Colour