U3A

Microscopic identification of minerals 2

List of physical and optical properties commonly used in mineral identification

Physical	Optical
lustre	relief
hardness	colour
streak	pleochroism
cleavage	birefringence
colour	crystal system
specific gravity	uniaxial
habit	optic sign
	biaxial/axial angle
	cleavage
	extinction angle
	length fast/slow

Crystal systems

cubic	isotropic	
trigonal	uniaxial	anisotropic
tetragonal		
hexagonal		
orthorhombic	biaxial	
monoclinic		
triclinic		

Biaxial crystals

- Minerals that crystallise in the orthorhombic, monoclinic and triclinic crystal systems are biaxial i.e. they have two optic axes.

- all rays are essentially extraordinary rays.

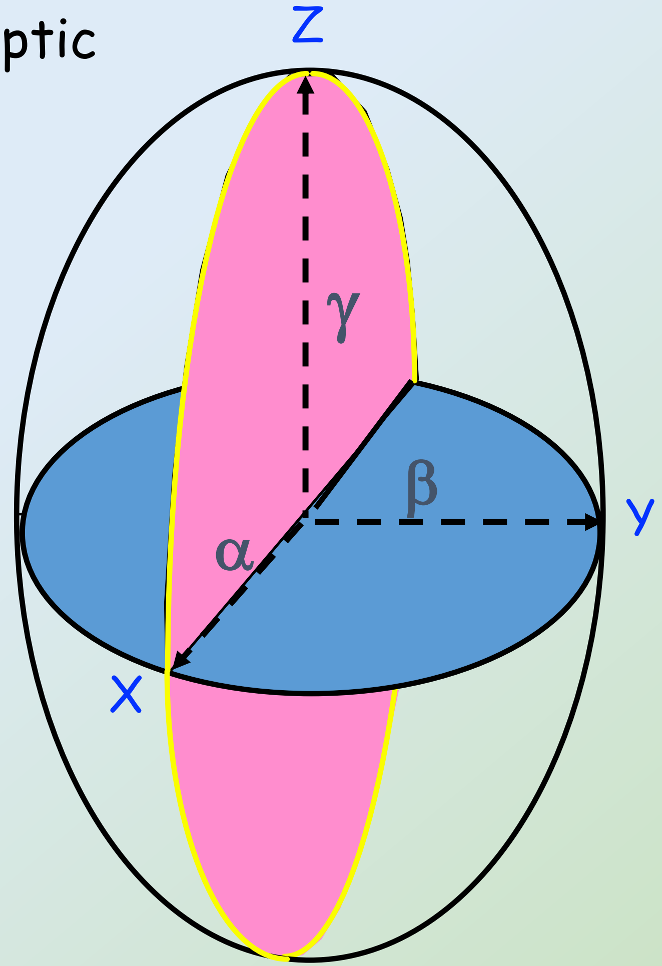
- biaxial minerals are characterised by three unique crystallographic axes X, Y and Z

- they have three distinct refractive indices γ, β and α defined such that:

$$\gamma > \beta > \alpha$$

Biaxial indicatrix

- A biaxial indicatrix is a triaxial ellipsoid with axes γ, β and α
- These 3 directions are called the principal vibration directions X, Y and Z corresponding to RIs of α, β and γ respectively
- plane containing γ and α → optic axial plane (OAP)



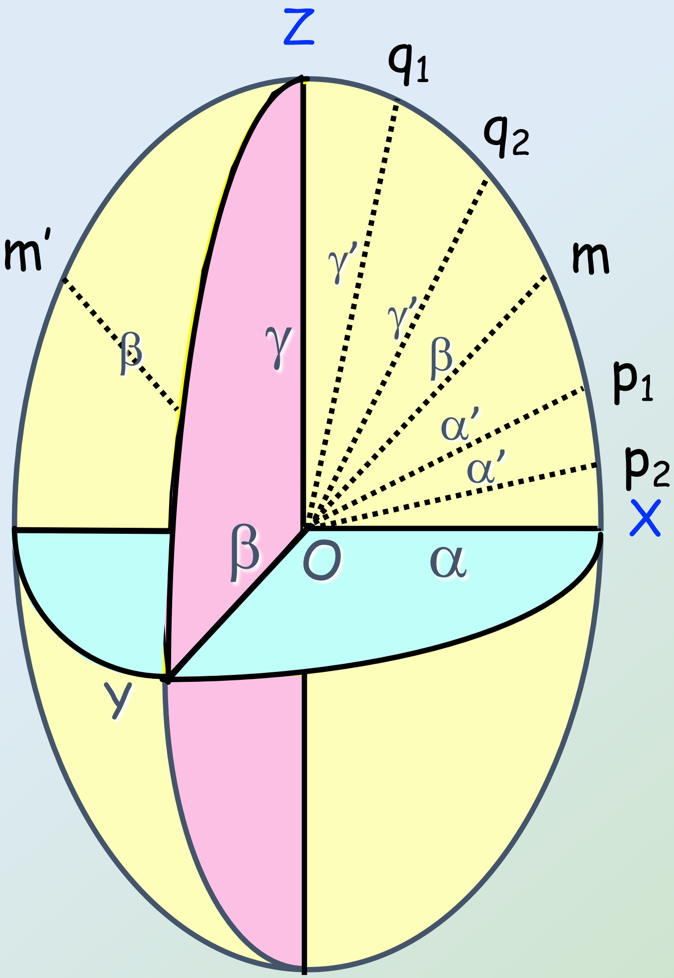
$$\gamma > \beta > \alpha$$

$$n_\gamma > n_\beta > n_\alpha$$

$$c_\gamma < c_\beta < c_\alpha$$

Vibration directions in the XZ plane

- XZ section = optic axial plane (OAP)
- β vibrates perpendicular to OAP



OZ = γ

Oq_1 = γ′

Oq_2 = γ′

Om = β

Op_1 = α′

Op_2 = α′

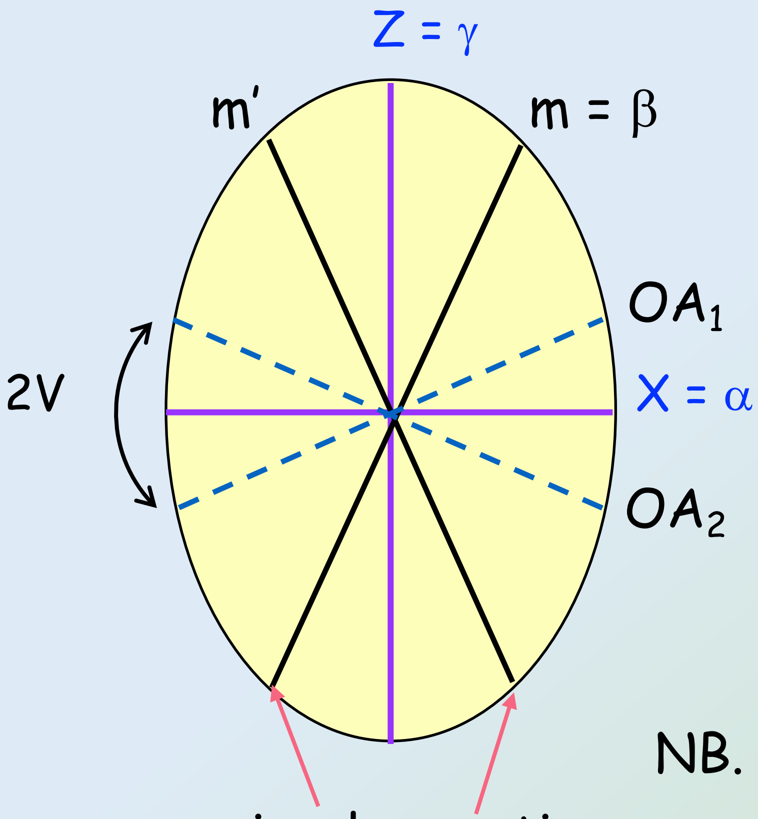
OX = α

γ′ is a RI between γ & β and α′ a RI between α & β

Sections through the biaxial indicatrix

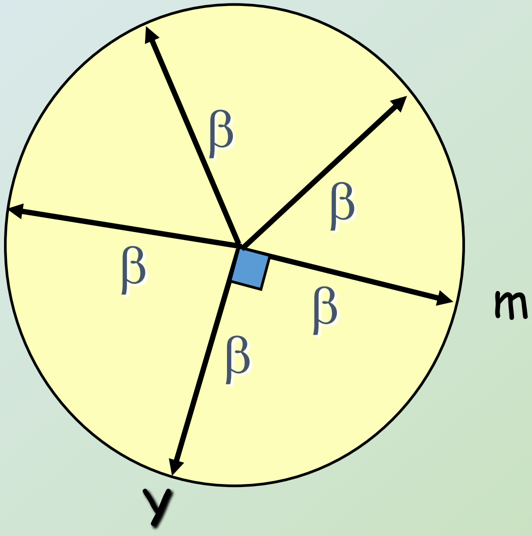
With two important exceptions, sections through the centre of the triaxial ellipsoid are ellipses

Optic axial (XZ) plane



circular sections

Circular section (perpendicular to optic axis)

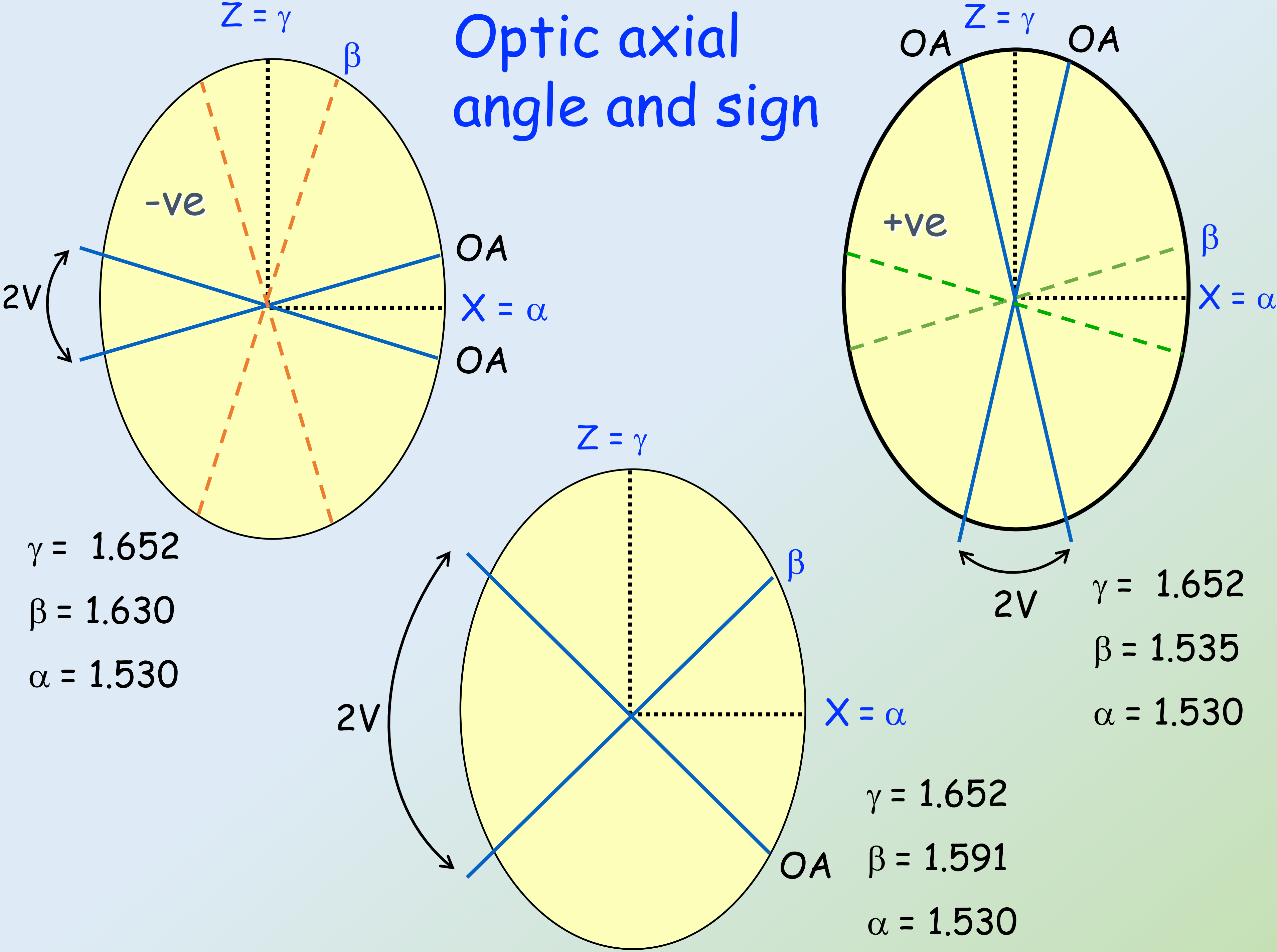


NB. (i) Optic axes lie in XZ plane
(ii) β vibrates perpendicular to the OAP

Optic axial angle

- The XZ plane containing the two optic axes is called the optic axial plane (OAP)
- the angle between the two optic axes varies depending on the relative values of β, α and γ
- the acute angle bisected by the optic axes is called the optic axial angle or 2V
- the principal vibration direction that bisects the acute optic axial angle is called the acute bisectrix or BXa
- the principal vibration direction that bisects the obtuse optic axial angle is called the obtuse bisectrix or BXo

Optic axial angle and sign



γ = 1.652

β = 1.630

α = 1.530

γ = 1.652

β = 1.535

α = 1.530

γ = 1.652

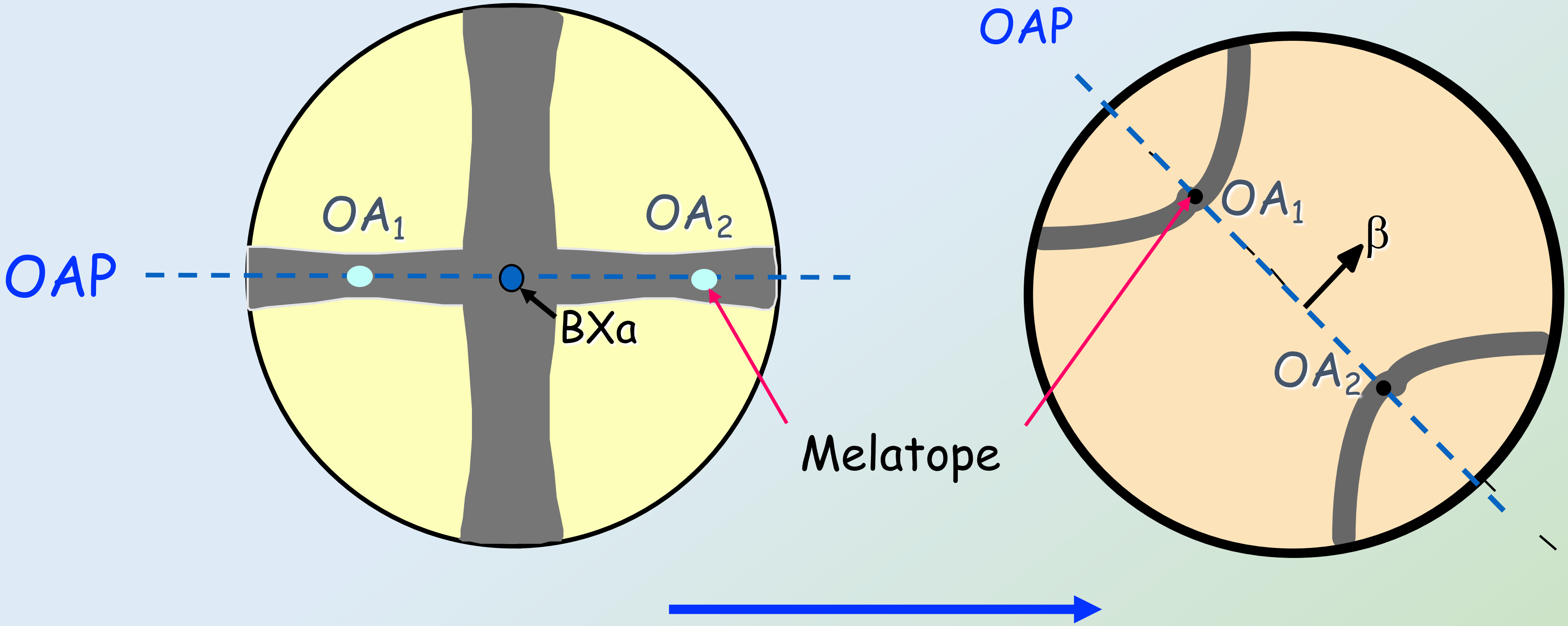
β = 1.591

α = 1.530

Summary of optic axial angles

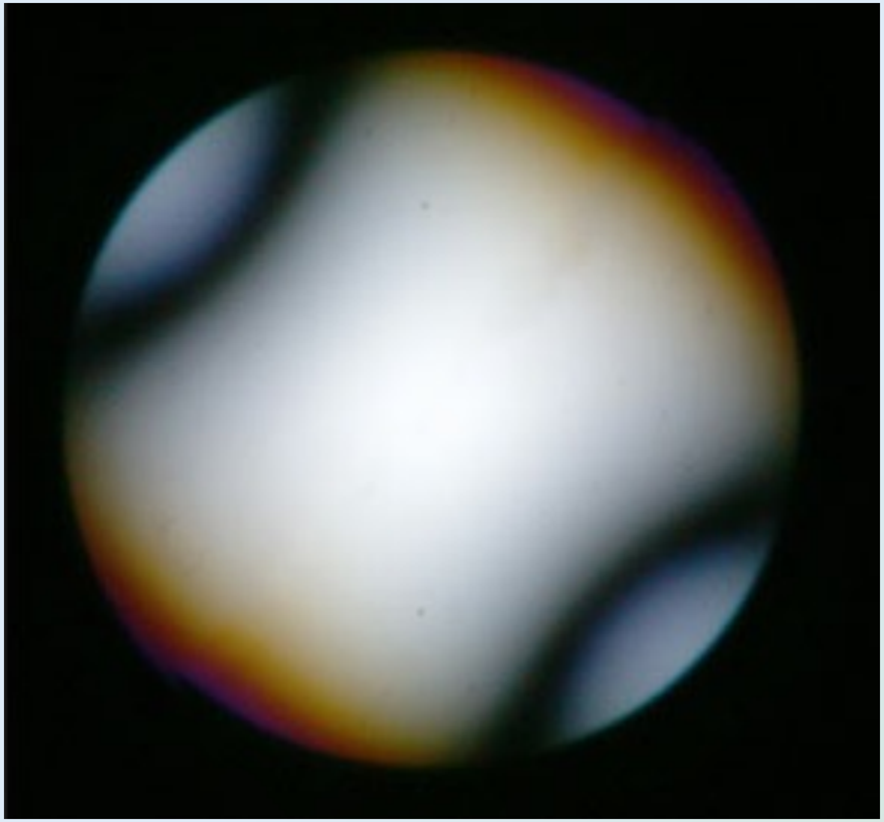
- A principal vibration direction that bisects an acute angle between optic axes is called the acute bisectrix or BXa
- a principal vibration direction that bisects an obtuse angle between optic axes is called the obtuse bisectrix or BXo
- when X (α) is the BXa the mineral is biaxial negative and Z (γ) is the BXo
- when Z (γ) is the BXa the mineral is biaxial positive and X (α) is the BXo
- when the 2V = 90° then the mineral is neither positive nor negative

BXa figures in conoscopic light

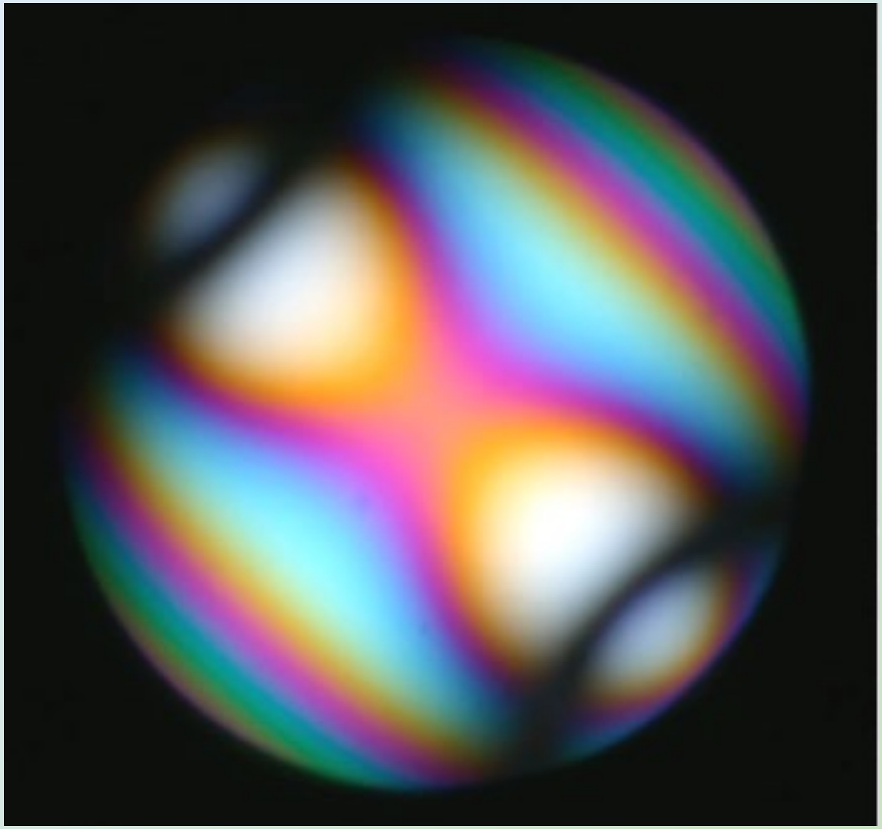


Rotate 45° clockwise

Bxa figure

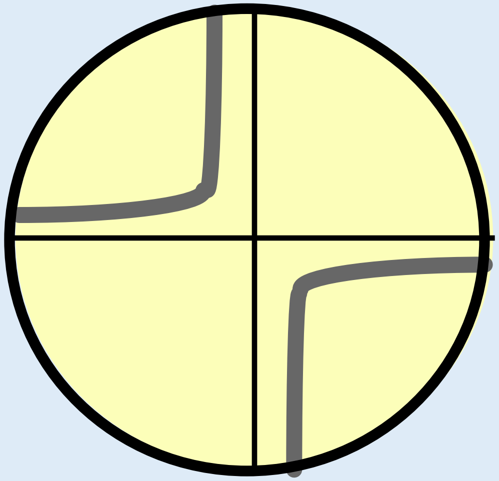


BXa figure in low birefringent biaxial mineral

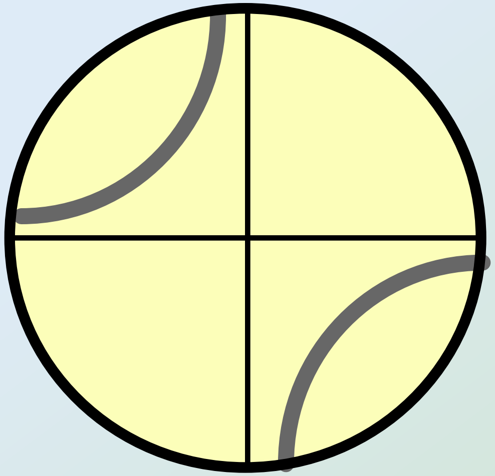


BXa figure in high birefringent biaxial mineral

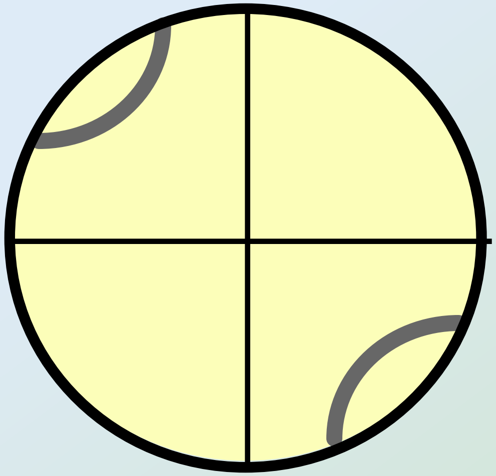
Estimation of 2V from BXa figures



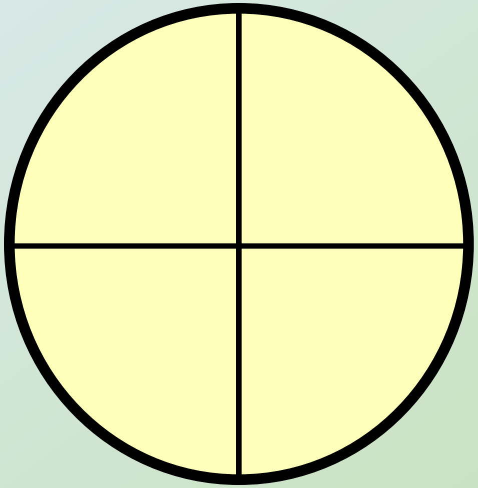
15°



30°



45°



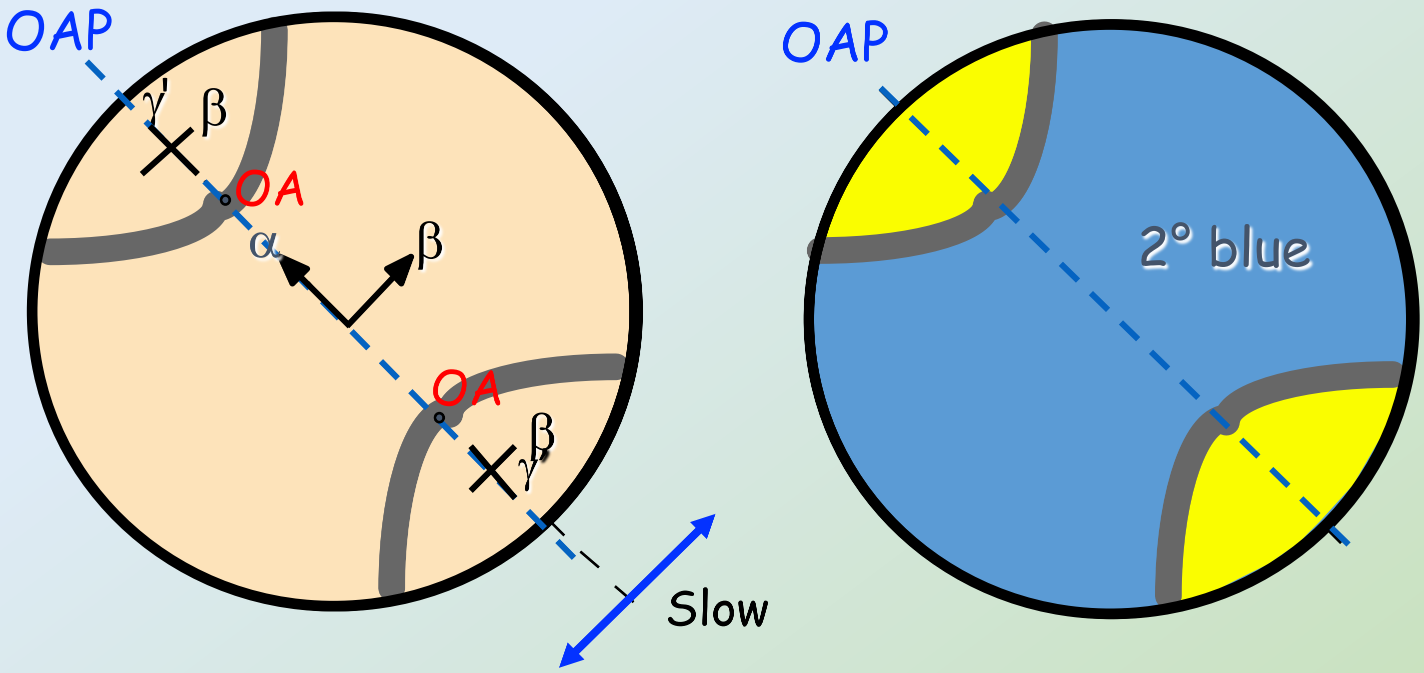
60°

Optic sign from BXa interference figures

Biaxial +ve

γ is the acute bisectrix

∴ β is the slow ray and addition occurs on convex side of the isogyres when the tint plate is inserted.

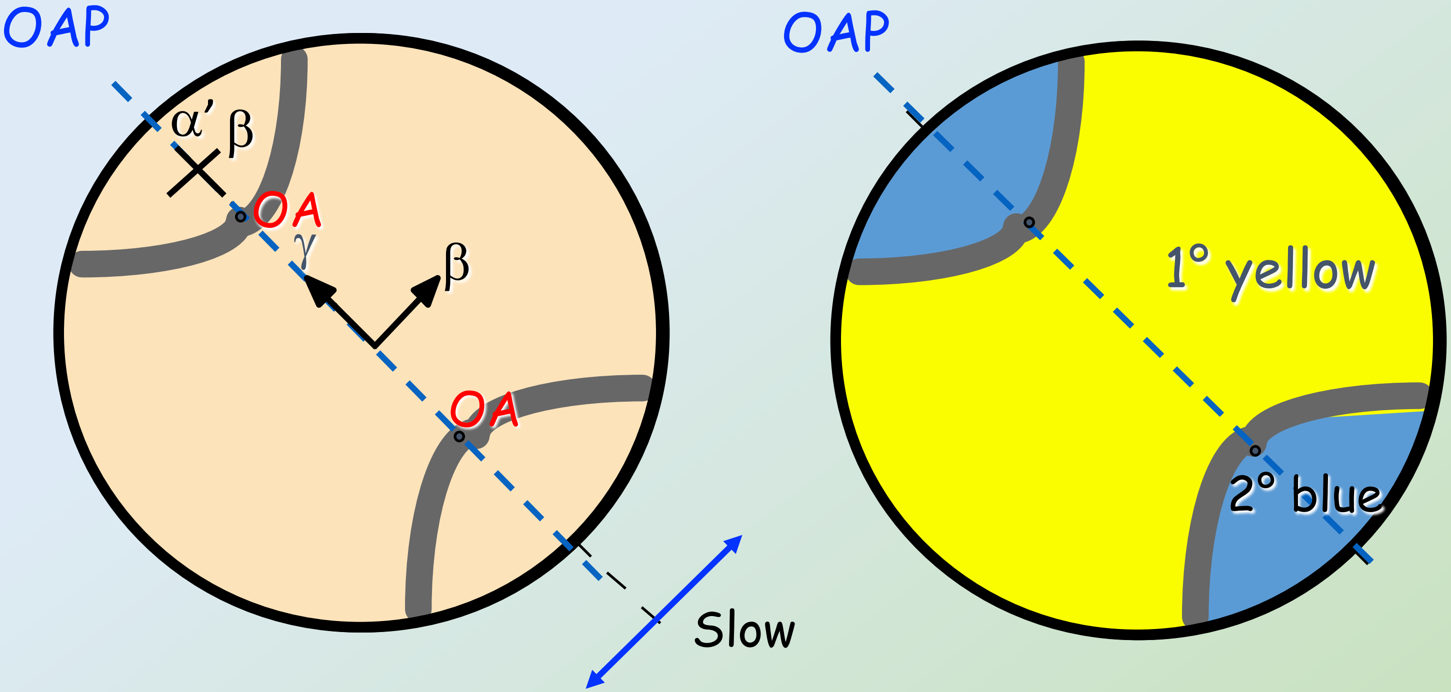


Optic sign from BXa interference figures

Biaxial -ve

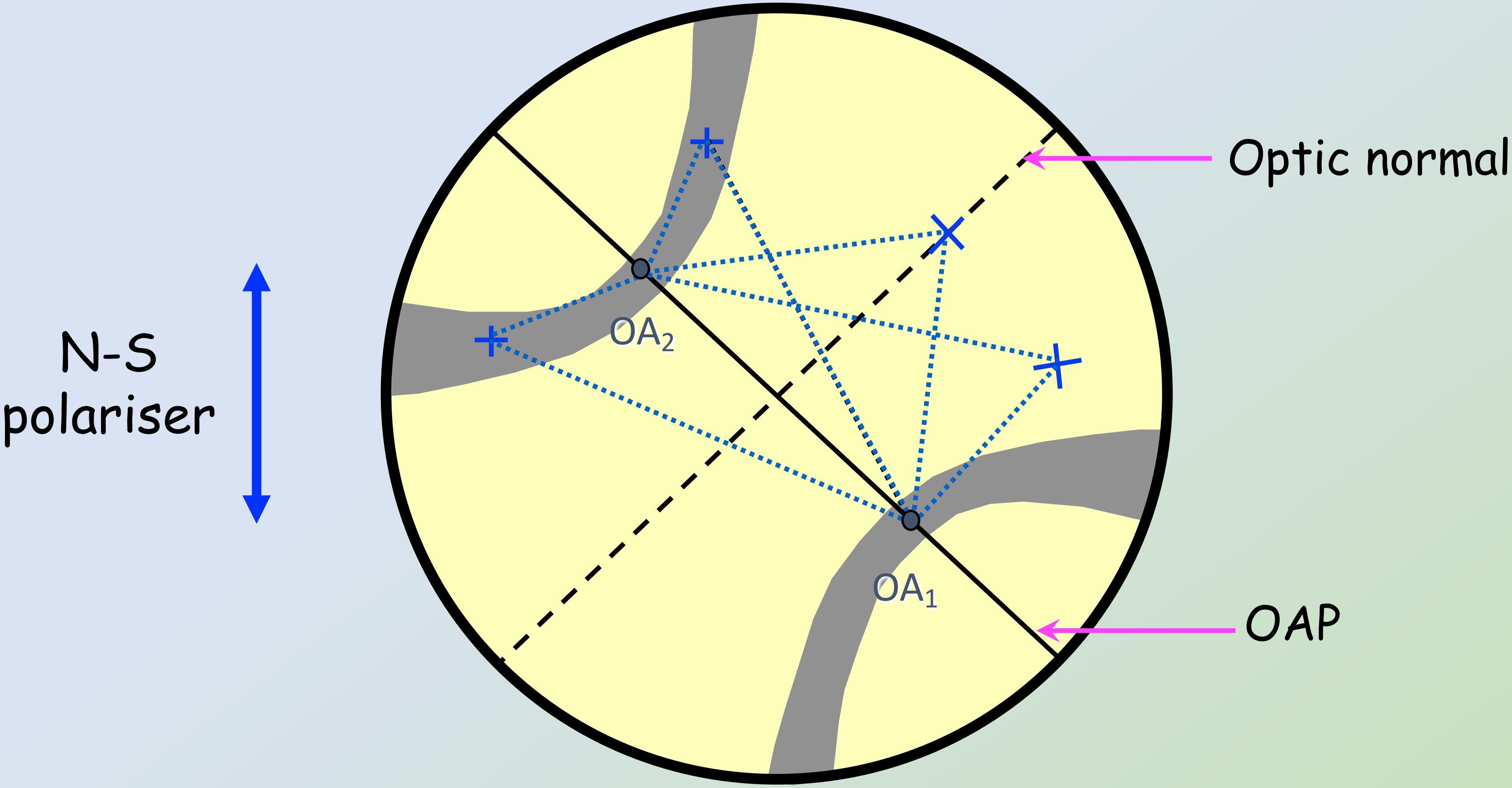
α is the acute bisectrix

∴ β is the fast ray and compensation occurs on convex side of the isogyres when the tint plate is inserted.



Biot-Fresnel Rule

The vibration directions (+) are the bisectrices of the lines joining the two optic axes and the ray. Vibration directions are N-S along isogyres



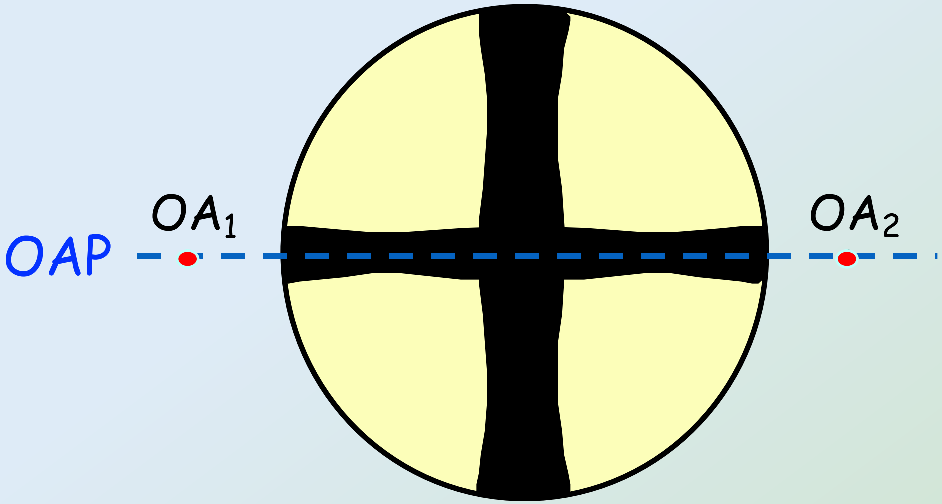
N-S polariser

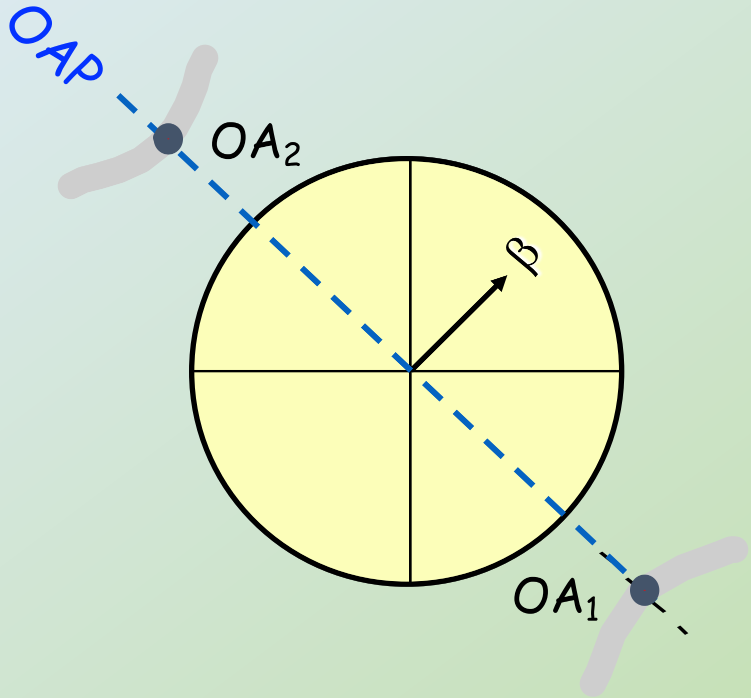
Optic normal

OAP

BXo figures

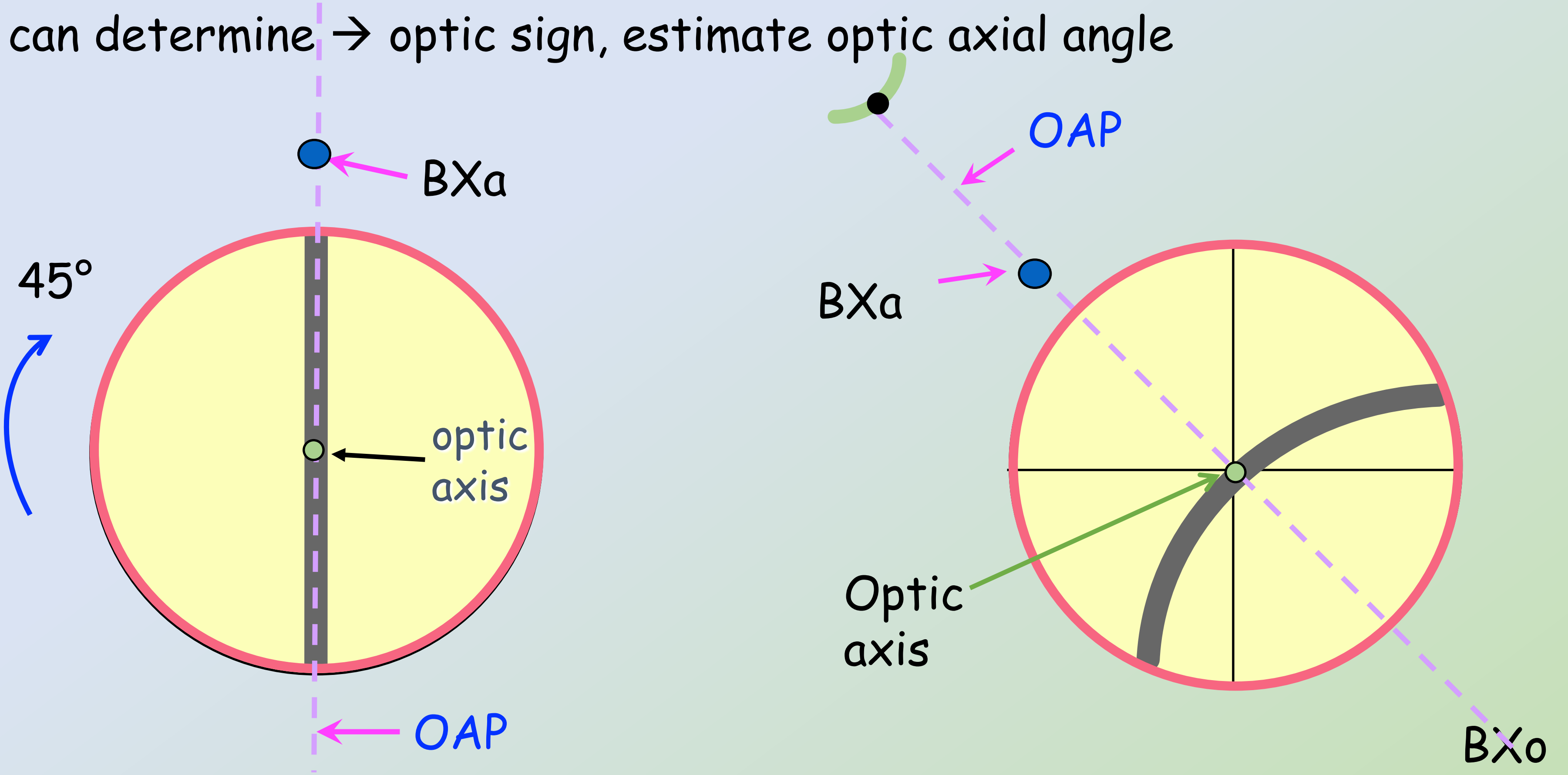
- As 2V increases in BXa figures from 0° to 60° the separation of isogyres increases
- for values above 60° → isogyres leave field of view
- for high 2V → isogyres leave field of view rapidly on rotation
- high 2V BXa figures very difficult to distinguish from BXo figure



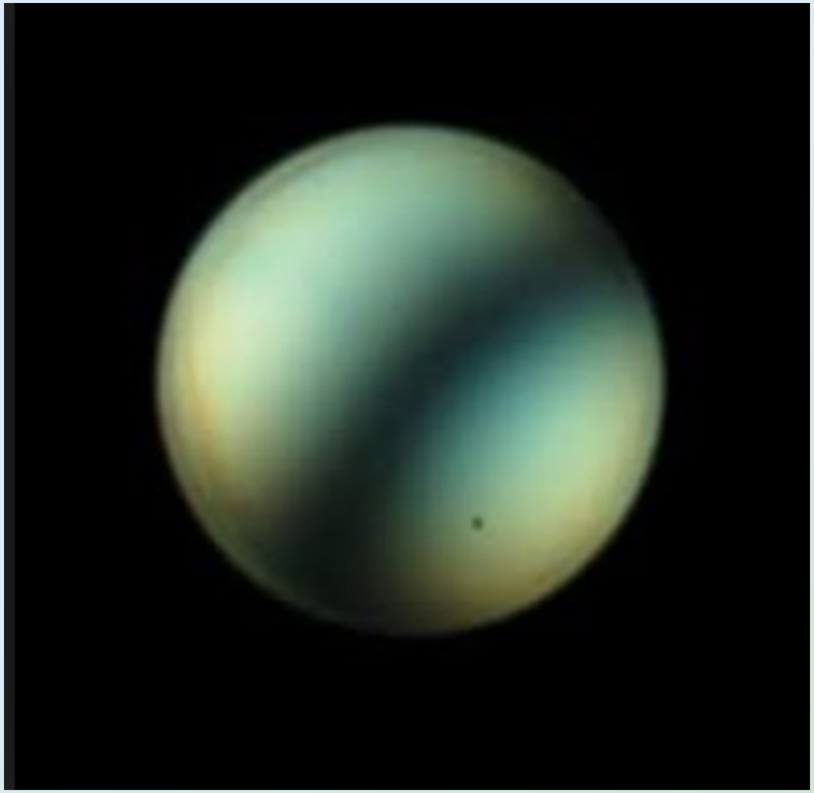


Optic axis figures

- Most useful biaxial interference figure for determining 2V and optic sign are grains that remain at extinction under crossed polars
- these figures are called optic axis figures
- N.B. acute bisectrix is on convex sides of isogyre
- can determine → optic sign, estimate optic axial angle



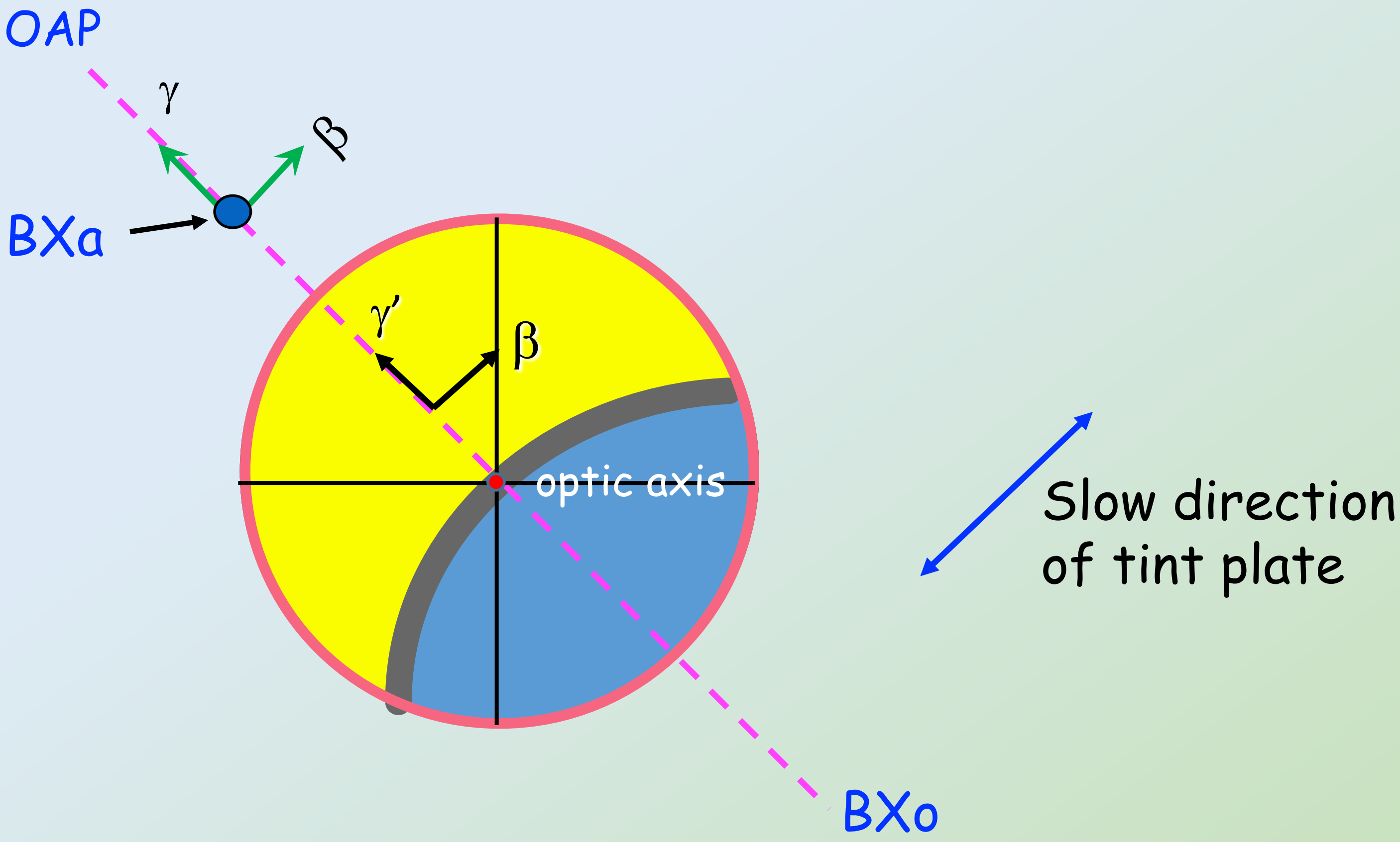
Biaxial optic axis figure



Determination of optic sign from optic axis figures

Case 1: When α is the BXa the mineral is biaxial -ve

∴ β is the fast ray. Compensation occurs on convex side of isogyre when β is parallel to slow direction in tint plate.



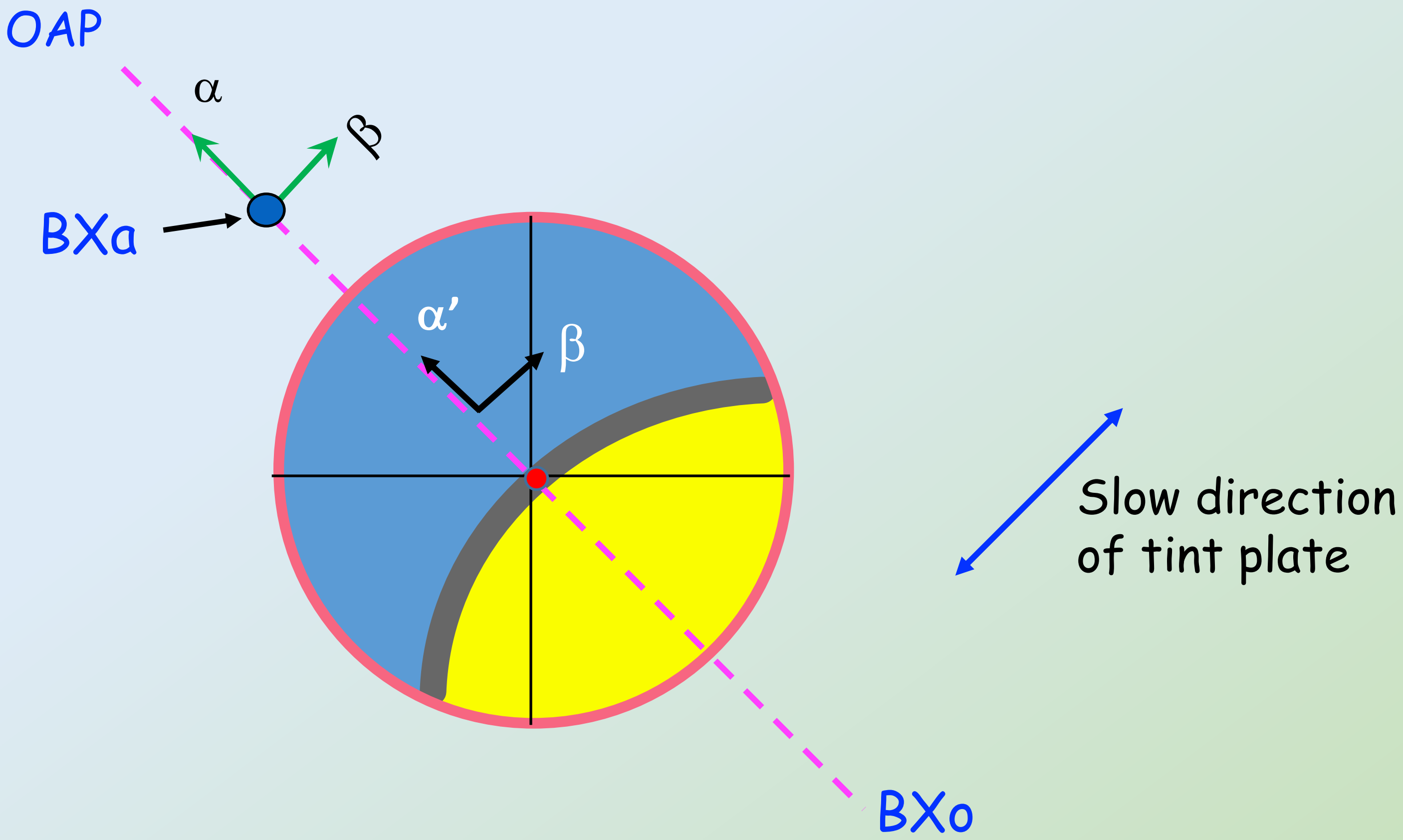
Slow direction of tint plate

Determination of optic sign from optic axis figures

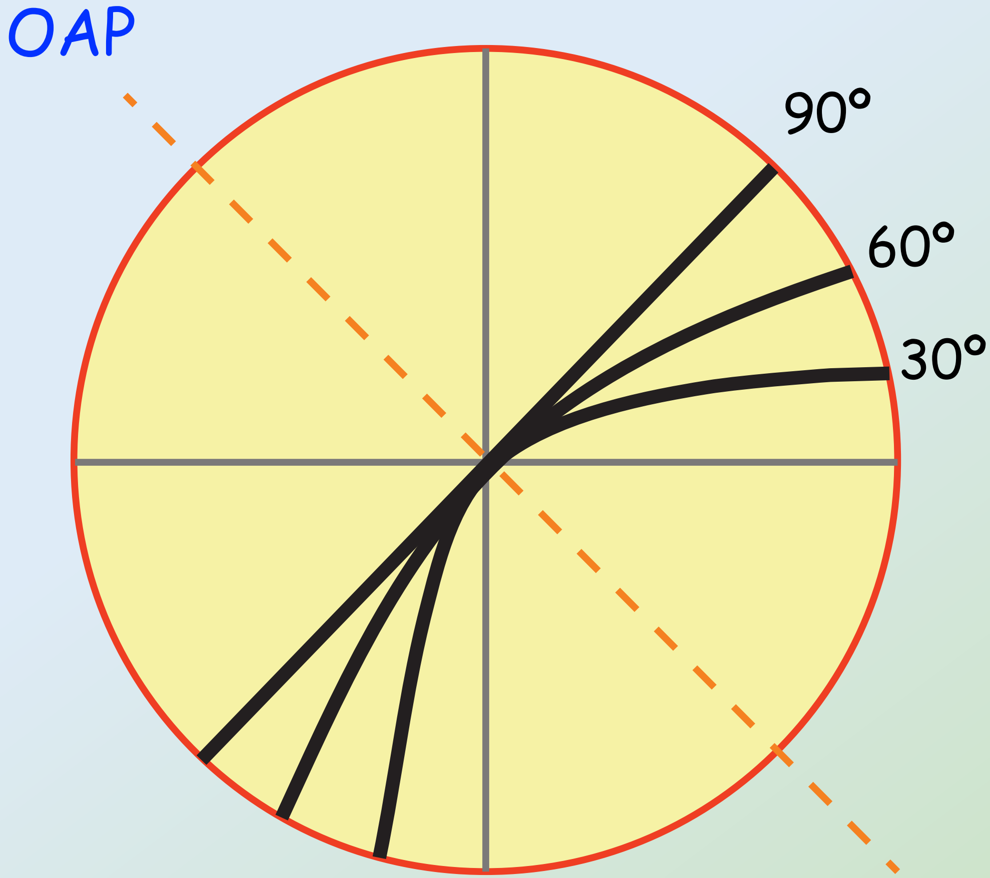
Case 2: When γ is the BXa the mineral is biaxial +ve

$\therefore$ β is the slow ray. Addition occurs on convex side of

isogyre when β is parallel to slow direction in tint plate



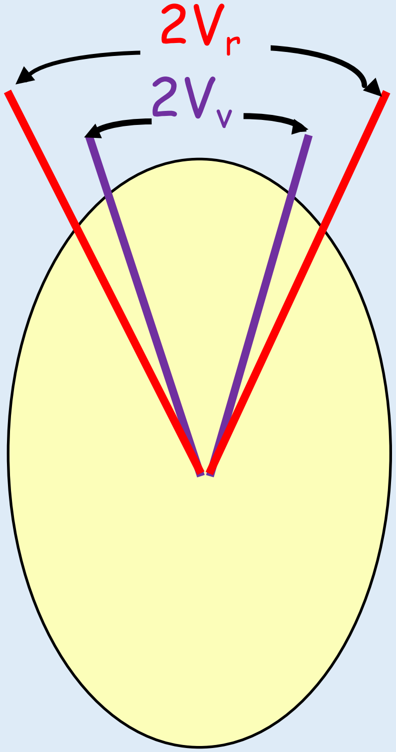
Estimation of 2V from optic axis figures



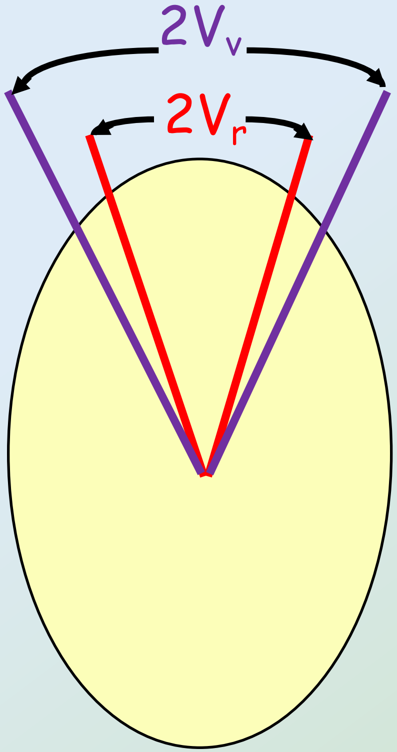
Optic axis dispersion

- In biaxial minerals, dispersion may cause the RI to change with wavelength
- this change may be greater for one principal vibration direction than for another
- angular separation of optic axes may vary continuously with wavelength
- dispersion causing 2V to vary with wavelength → optic axis dispersion
- on BXa and optic axis figures, isogyres have reddish-brown fringe on one side of the isogyre and violet fringe on the other

Optic axis dispersion



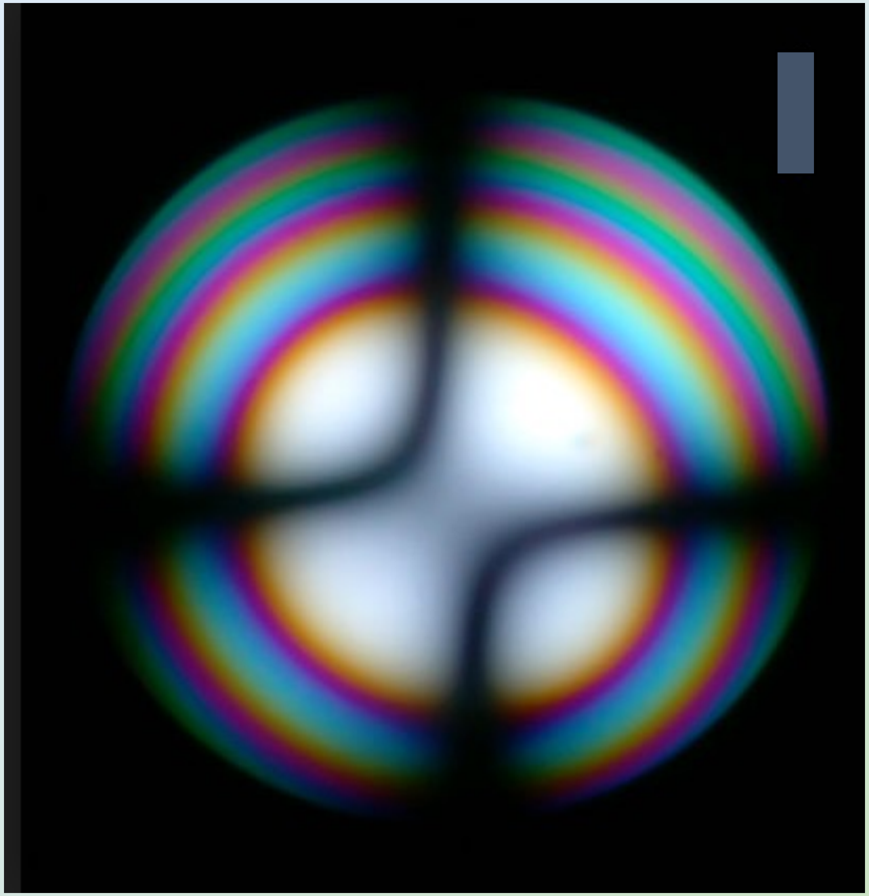
$r > v$



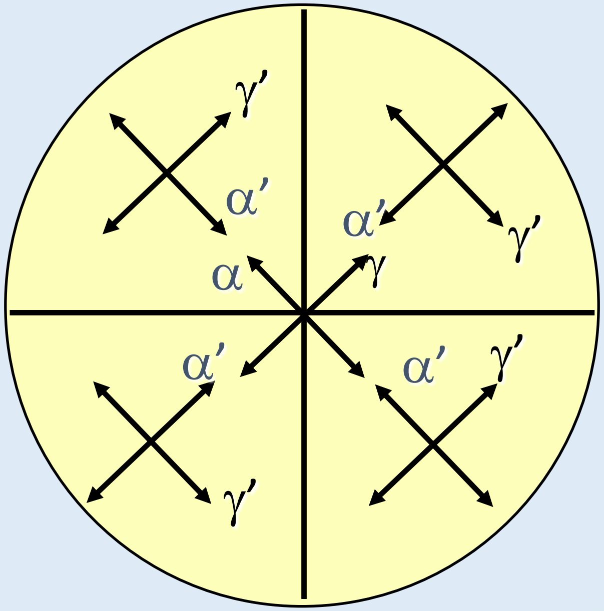
$r < v$

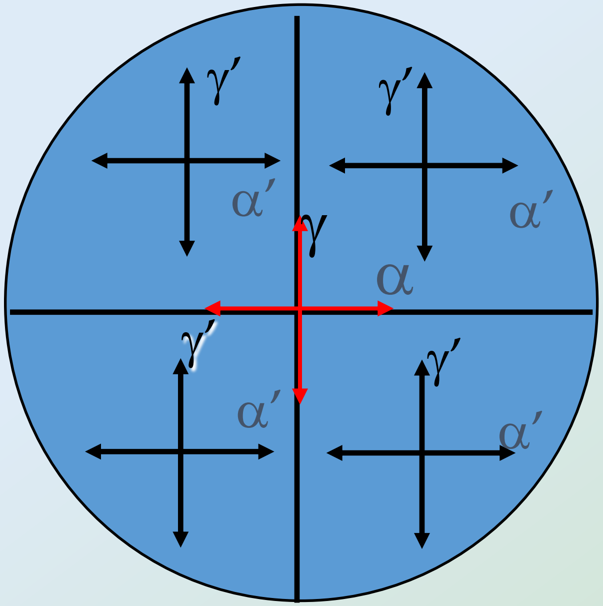
Optic axis dispersion in Bxa figure

In biaxial minerals, dispersion may cause 2V to vary continuously with wavelength. This phenomenon is called *optic axis dispersion.*



Flash figures



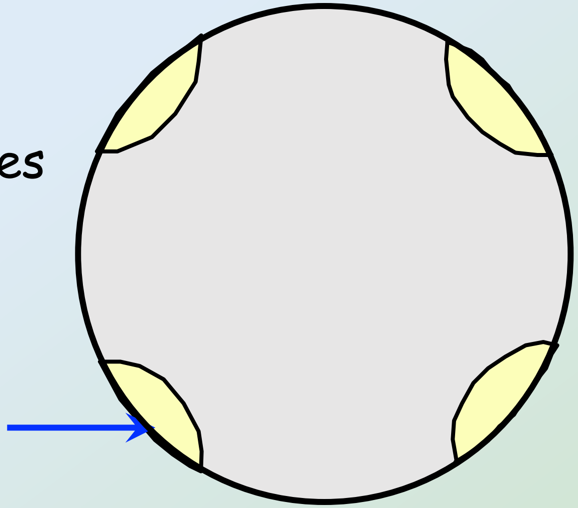


Some light passes

through and we

therefore see a

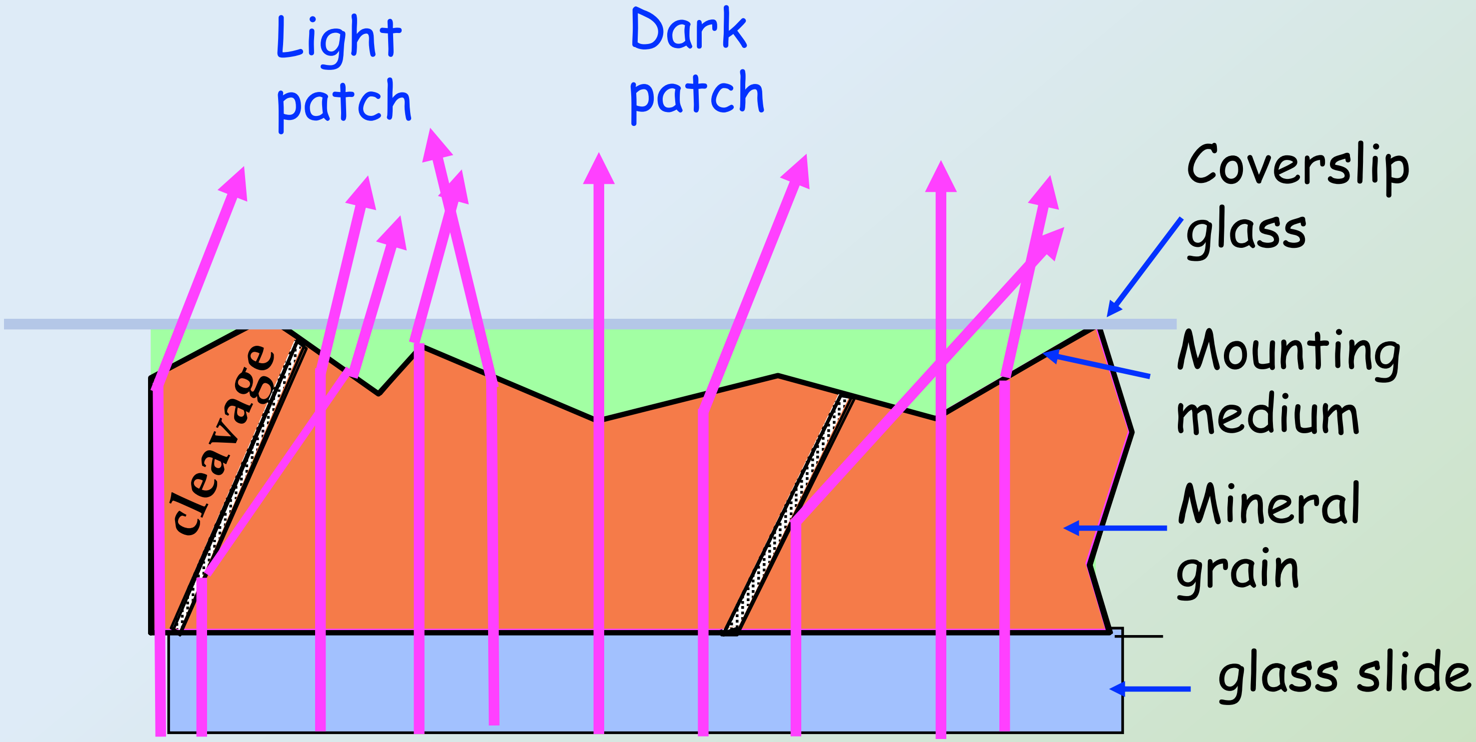
broad cross



Flash figure

Relief

- Surface definition in a grain is a consequence of difference in RIs of grain and the mounting medium
- irregular surface → refraction → uneven distribution of light → rough appearance called relief

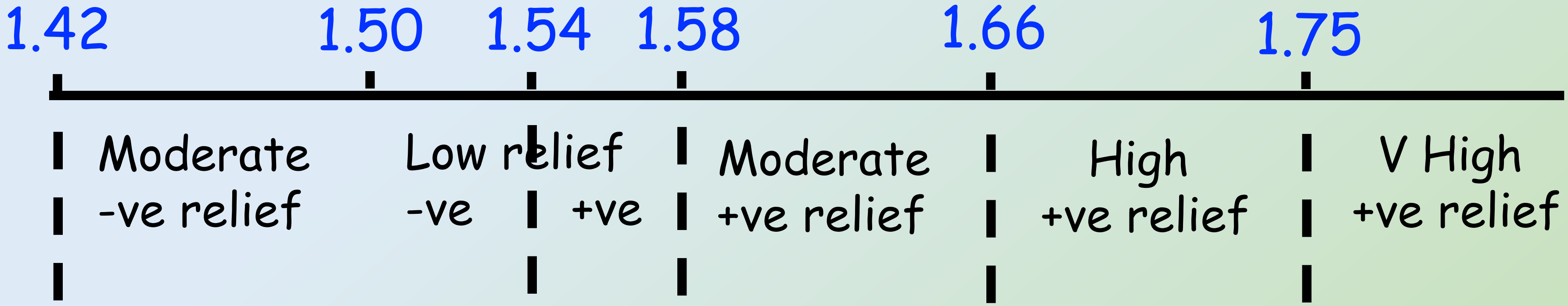


Light from sub-stage condenser of microscope

Relief

- In optical mineralogy we do not normally measure the refractive index of minerals for mineral identification but we can estimate them from their relief

- the description of relief below is related to a petropoxy mounting medium of RI = 1.54



1.42 1.50 1.54 1.58 1.66 1.75

Moderate
-ve relief

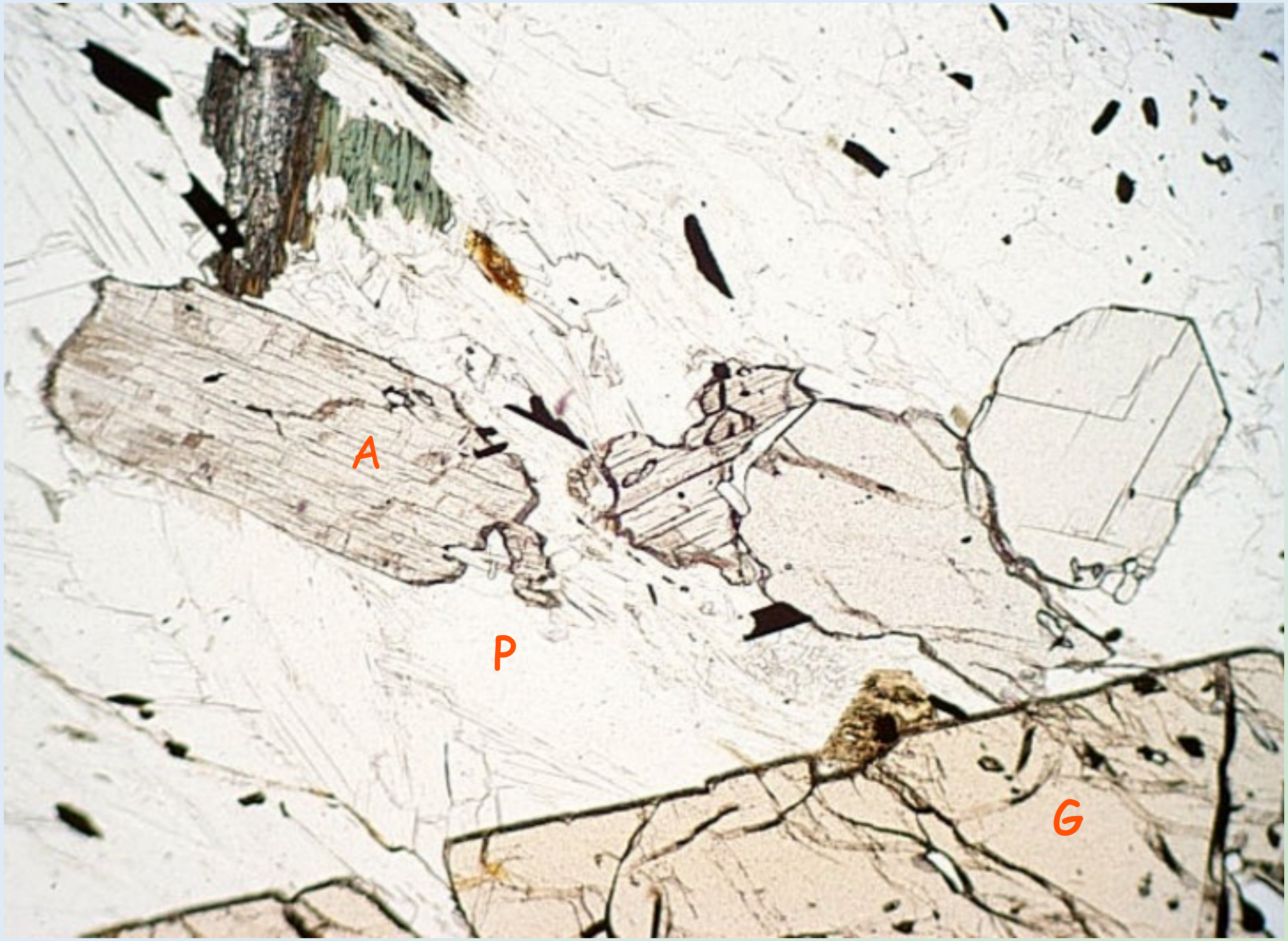
Low relief
-ve +ve

Moderate
+ve relief

High
+ve relief

V High
+ve relief

Relief



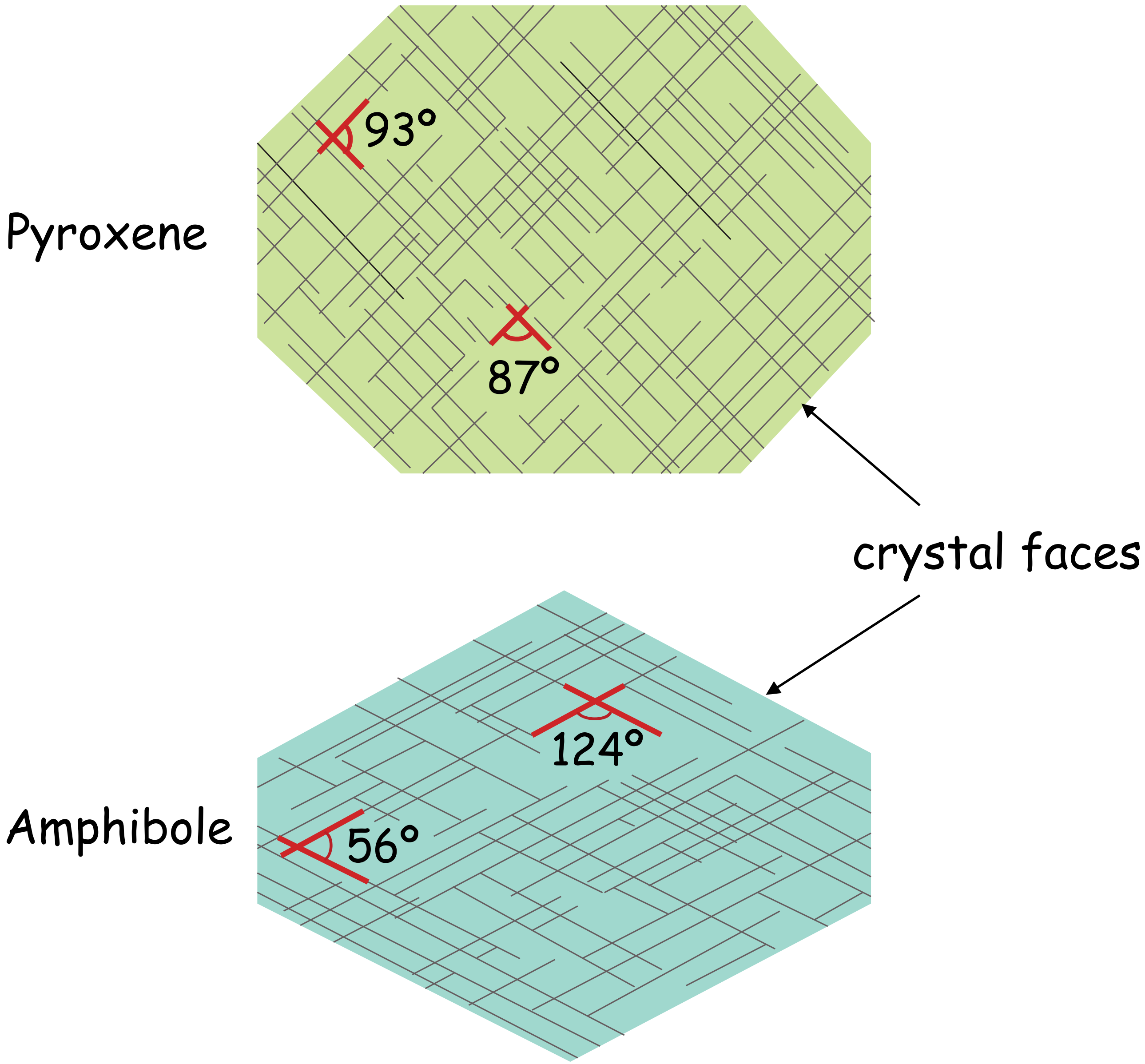
A = amphibole   G = garnet   P = plagioclase

RI of mounting medium is 1.54

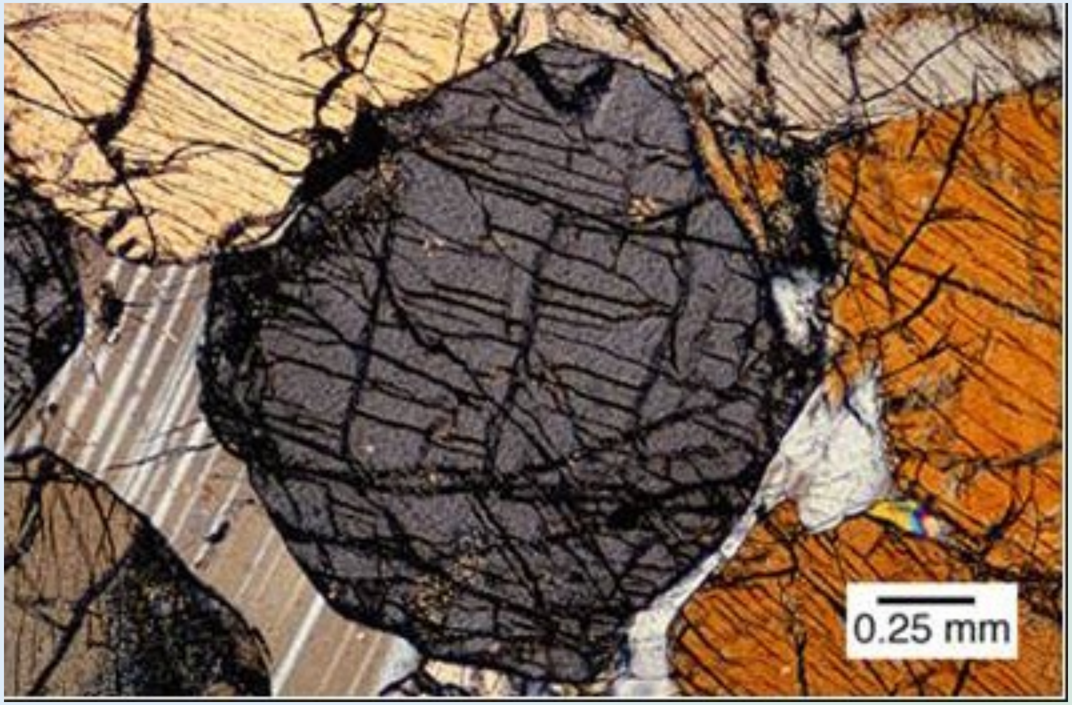
Becke line movement

- Mineral grains are generally thicker in middle → act as crude lenses
- a concentration of bright light (Becke line) forms parallel to grain boundary
- upon lowering the microscope stage, the bright Becke line moves into the medium with the higher refractive index (RI)

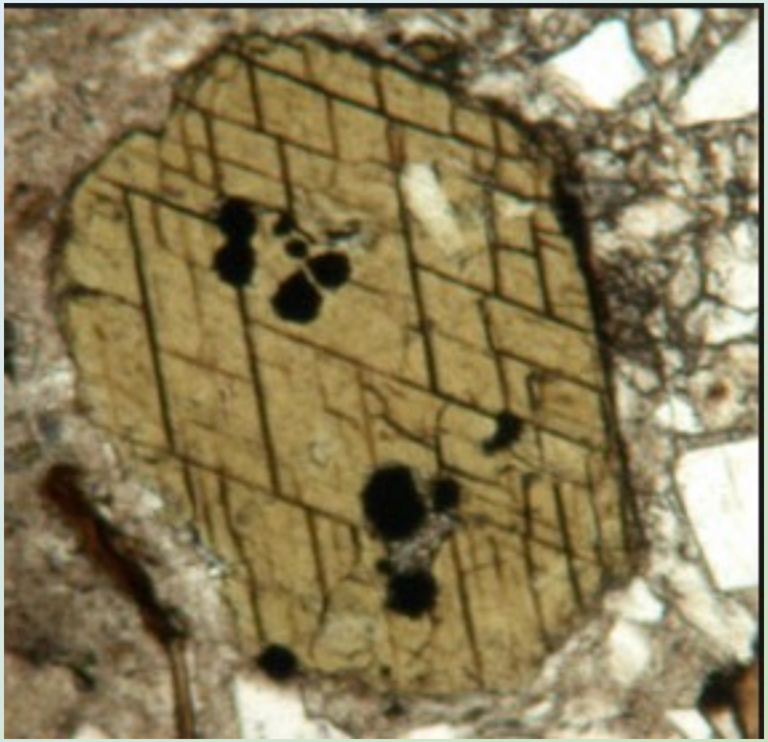
Mineral cleavage in thin section



Mineral cleavage in thin section



Photomicrograph of clinopyroxene
(crossed polars)



Photomicrograph of hornblende
(plane polarised light)

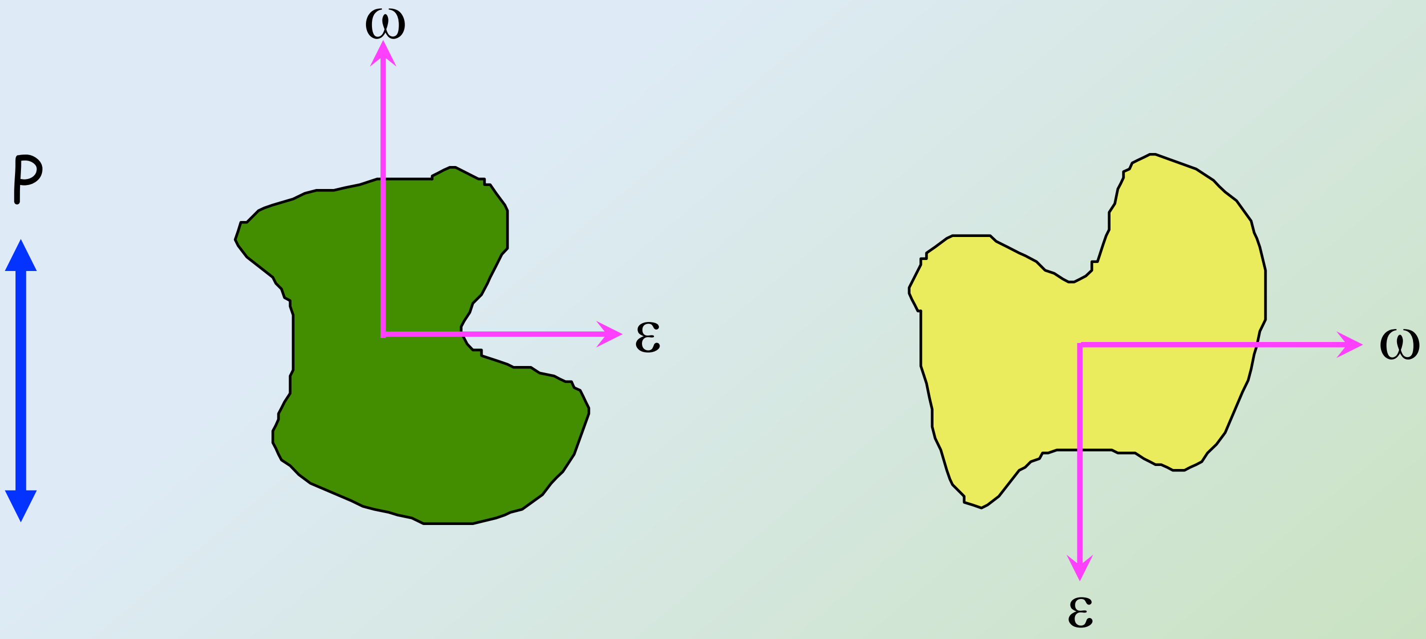
Colour and pleochroism

Colour

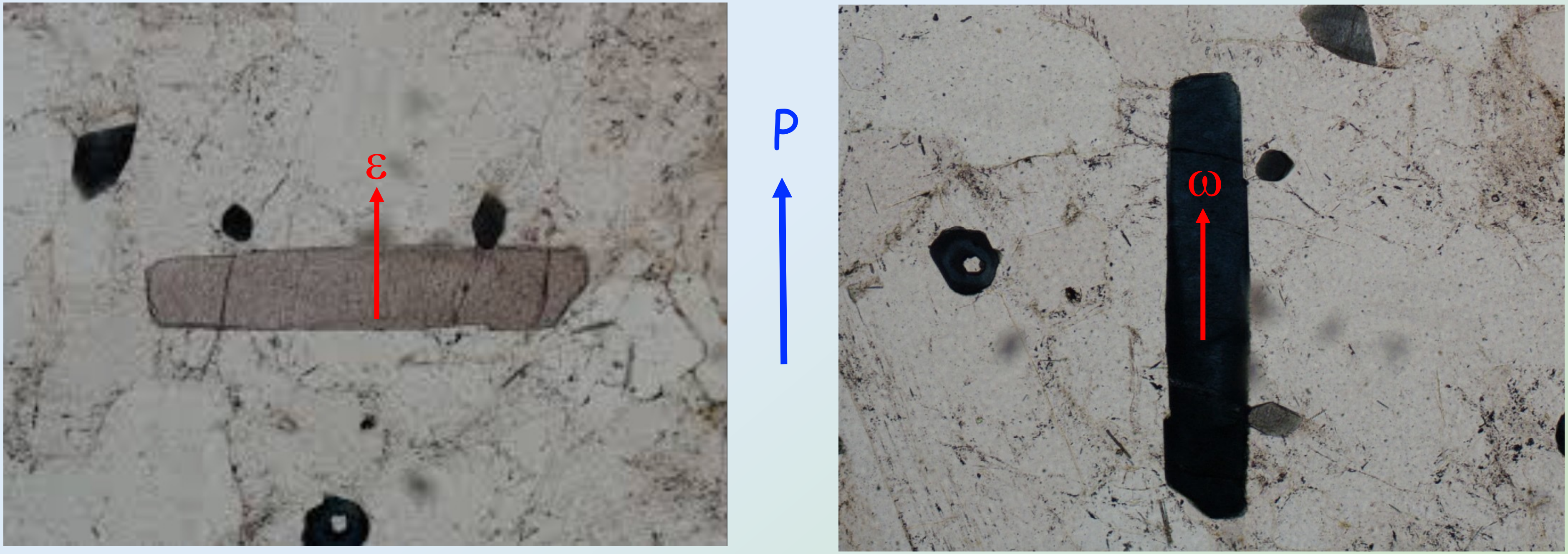
The effect of preferential absorption and transmission of certain wavelengths when viewed in plane polarised light

Pleochroism

- Differential absorption of ordinary and extra-ordinary rays
- only observed in plane polarised light



Pleochroism - tourmaline

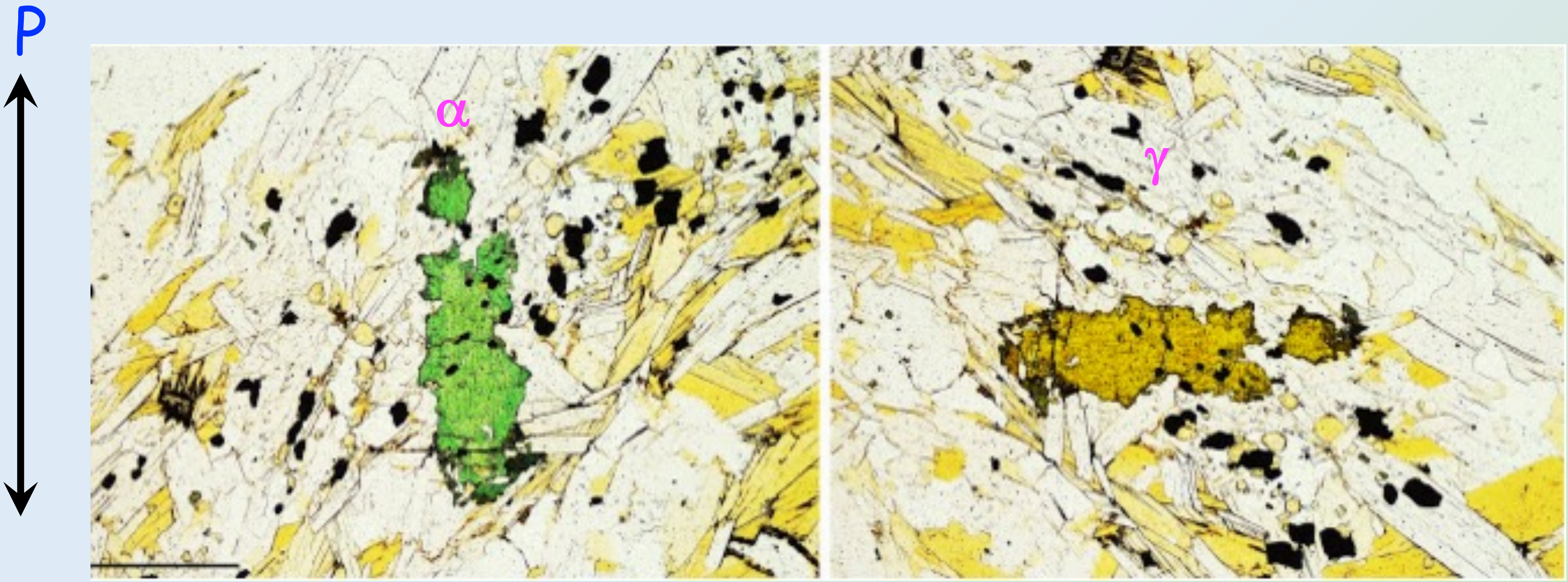


Pleochroic scheme ε = colourless ω = dark green

Pleochroism in tourmaline (plane polarised light)

Pleochroism - viridine

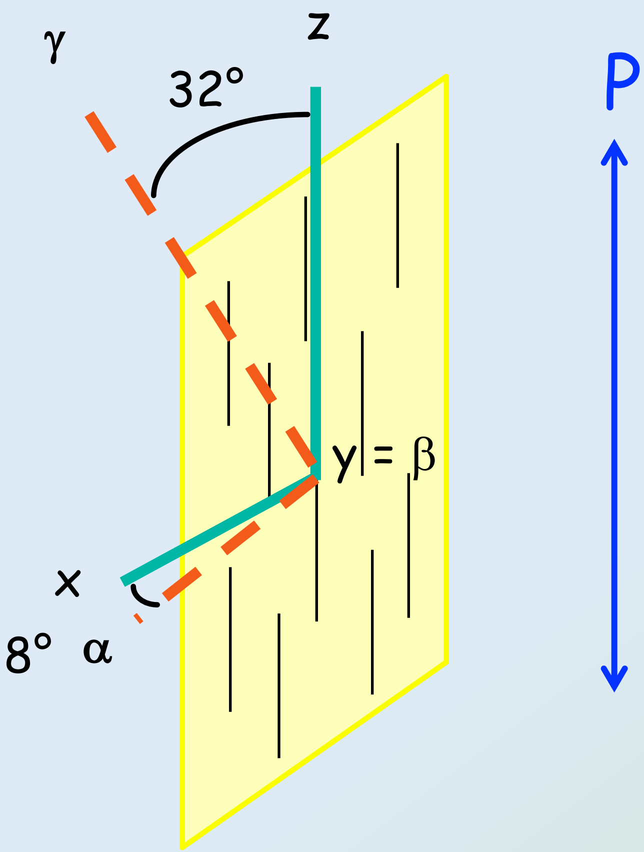
Viridine - green variety of andalusite where Mn^{2+} substitutes for Al

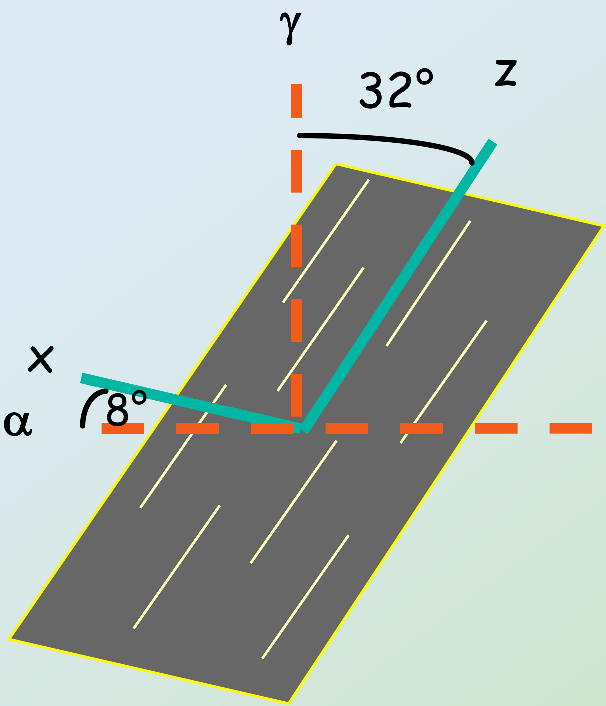


Pleochroic scheme α = emerald green β = yellowish-green γ = yellow

Pleochroism in viridine (plane polarised light)

Extinction angles in monoclinic crystals





When the cleavage is parallel to the polariser privileged vibration direction, the grain is not at extinction.

Rotation of the grain 32° clockwise causes the grain to go to extinction. the extinction angle is 32°

γ Λ z = 32° α Λ x = 8°

Optical properties for mineral identification

Plane polarised light		Crossed polars
colour	low birefring. grain	Isotropic or anisotropic
relief (est. RI)		uniaxial, biaxial
cleavage (angles)		optic sign
pleochroism		2V for biaxial minerals
crystal shape		dispersion
	high	birefringence
		extinction angles
		length fast or length slow

Strategy for mineral identification using optical methods

1. Examine grains of unknown mineral using colour, relief and grain shape to distinguish it. You need to insert and remove the analyser and rotate the stage as required

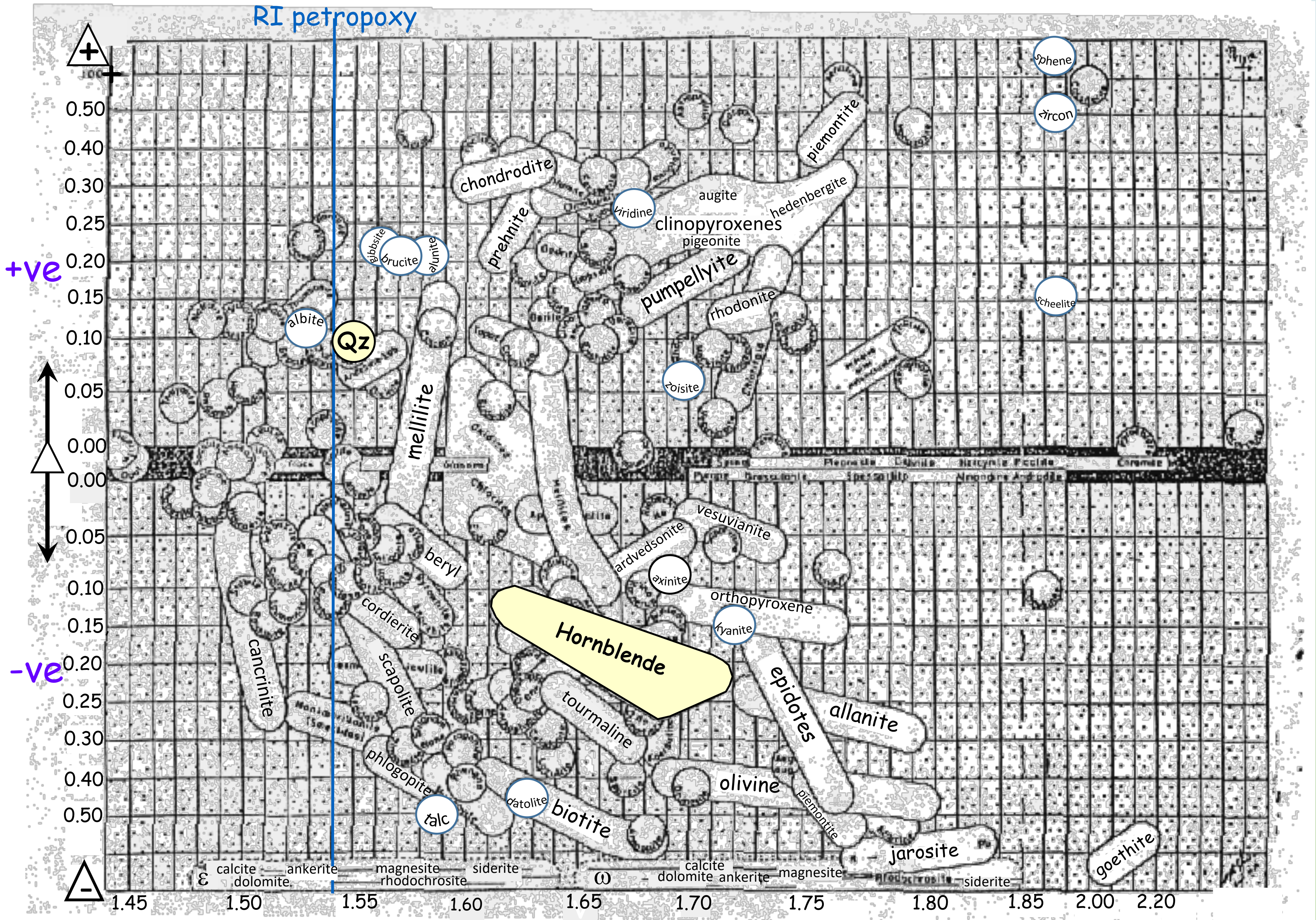
2. In plane polarised light, note relief, colour, pleochroism, crystal shape and cleavage (measure cleavage angle when 2 cleavages are present).

3. Under crossed polars, note whether mineral is isotropic or anisotropic.

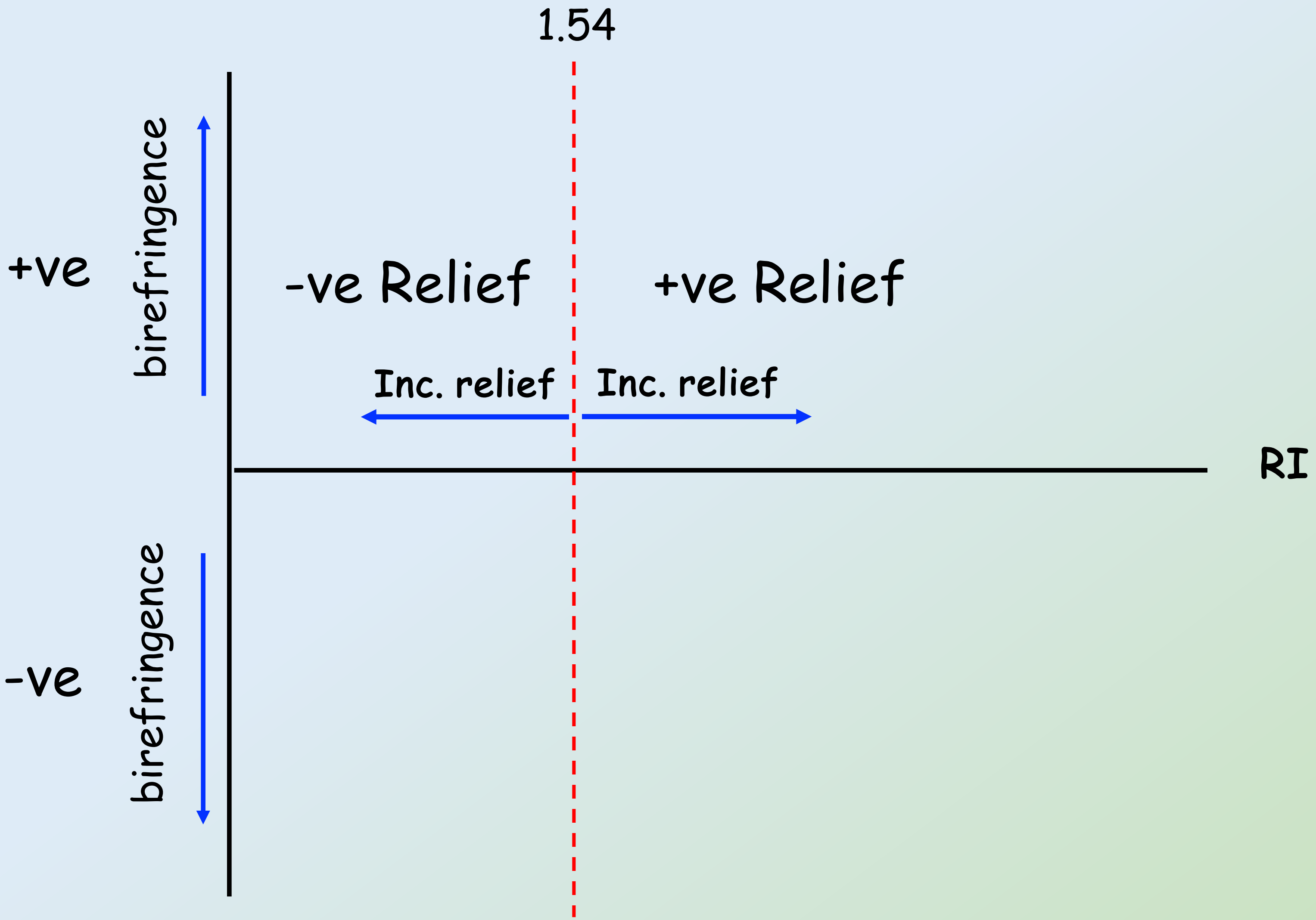
4. If anisotropic find grain with lowest interference colour (preferably extinct). View using conoscopic light and determine if uniaxial or biaxial, optic sign, 2V (if biaxial).

5. Find grain with maximum interference colour determine birefringence. If mineral is elongate or has a single cleavage and inclined extinction, measure extinction angles and determine sign of elongation.

6. Consult identification chart and textbook

RI petropoxy
+
+ve
-ve
0.50
0.40
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.40
0.50
sphene
zircon
piemontite
chondrodite
augite
hedenbergite
viridine
clinopyroxenes
pigeonite
prehnite
gibbsite
brucite
alunite
pumpellyite
rhodonite
scheelite
albite
Qz
zoisite
mellilite
vesuvianite
ardvedsonite
axinite
beryl
orthopyroxene
kyanite
cordierite
Hornblende
cancrinite
scapolite
epidotes
allanite
tourmaline
olivine
piemontite
phlogopite
talc
datolite
biotite
jarosite
goethite
ε
calcite
dolomite
ankerite
magnesite
rhodochrosite
siderite
ω
calcite
dolomite
ankerite
magnesite
siderite
1.45
1.50
1.55
1.60
1.65
1.70
1.75
1.80
1.85
2.00
2.20

Birefringence/optic sign vs RI (relief)



1.54

+ve

birefringence

-ve Relief

+ve Relief

Inc. relief

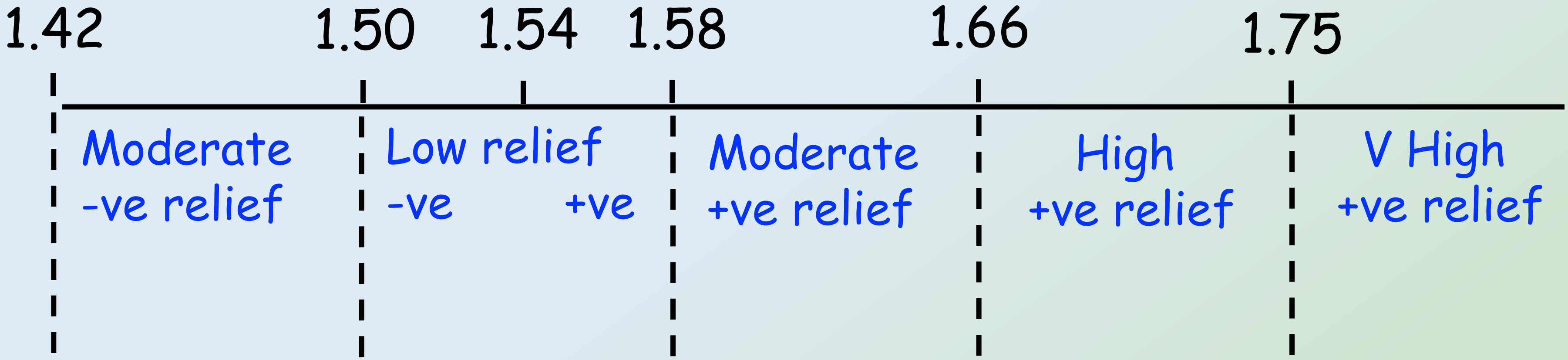
Inc. relief

RI

-ve

birefringence

Relief



1.42 1.50 1.54 1.58 1.66 1.75

Moderate
-ve relief

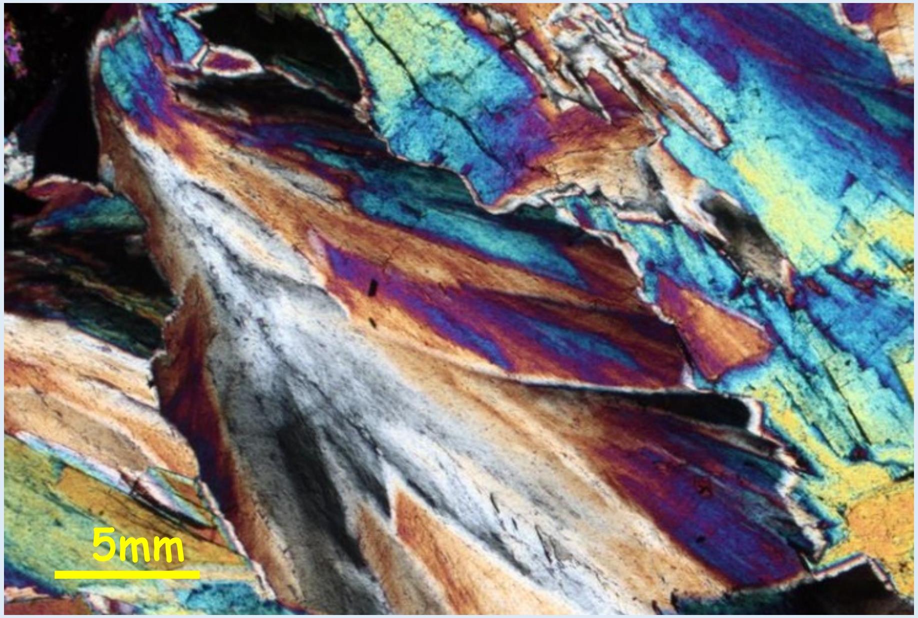
Low relief
-ve +ve

Moderate
+ve relief

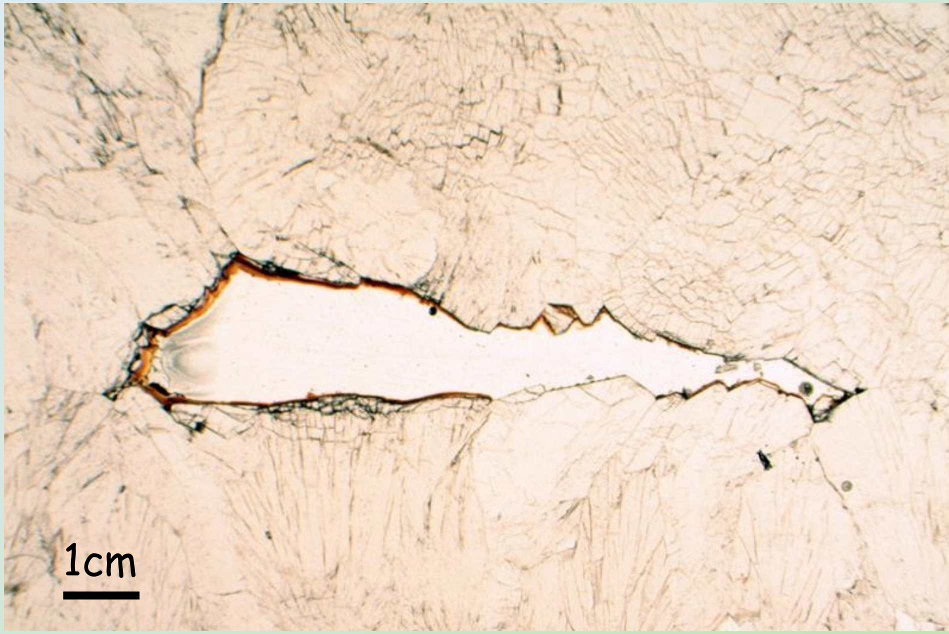
High
+ve relief

V High
+ve relief

Unknown mineral



Unknown mineral, crossed polars

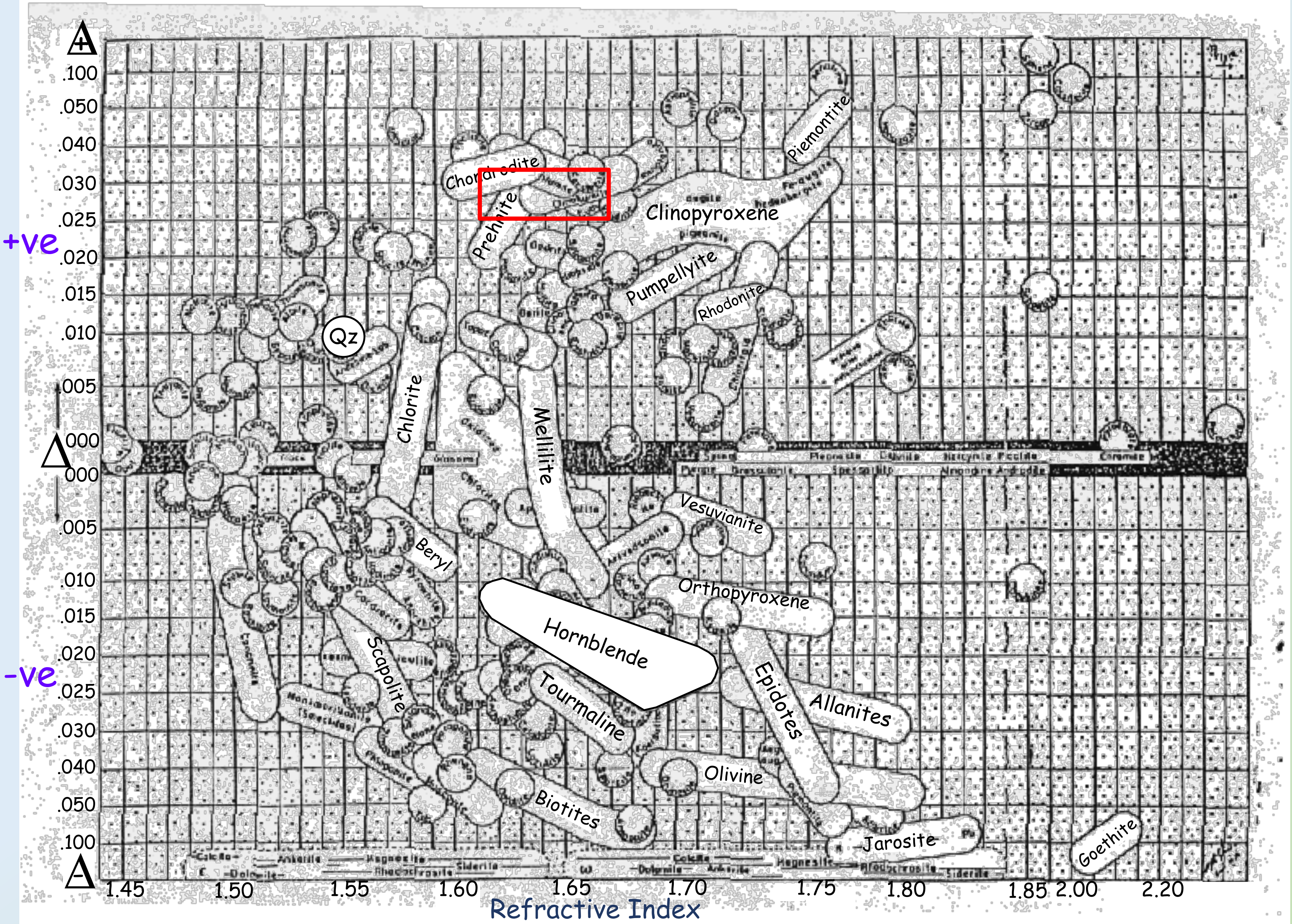


Unknown mineral, PPL

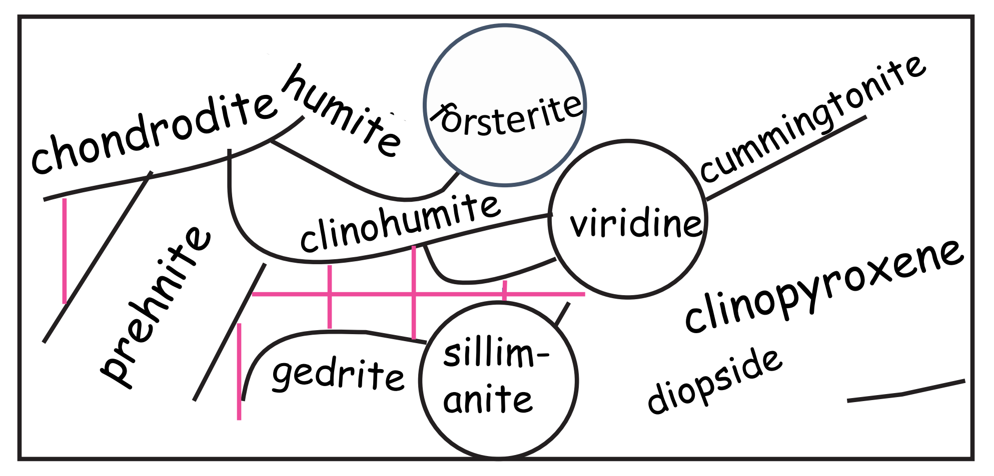
Optical properties of unknown mineral

relief ->	moderate
colour:	colourless
Optics:	biaxial
$\gamma - \alpha$	0.028
cleavage:	1 good
optic sign	+ve
2V:	~65°
straight extinction	
habit	radiating crystals

Optical mineral identification chart



Mineral identification



Possibilities from chart

chondrodite X	inclined extinction, rounded shaped grains
prehnite	colourless, straight extinction, 1 good cleavage
clinohumite X	inclined extinction, poor cleavage
humite	yellow-brown, poor cleavage
sillimanite X	low 2V, 20° - 30°, acicular aggregates or blocky
cummingtonite X	inclined extinction (monoclinic), ~60° cleavage
diopside X	2 good cleavages at 90°, pleochroic green, inclined extinction
forsterite X	equant crystals, cleavage not evident, v. high 2V
gedrite X	brown colour, V,high 2V
viridine X	strongly pleochroic green to yellow