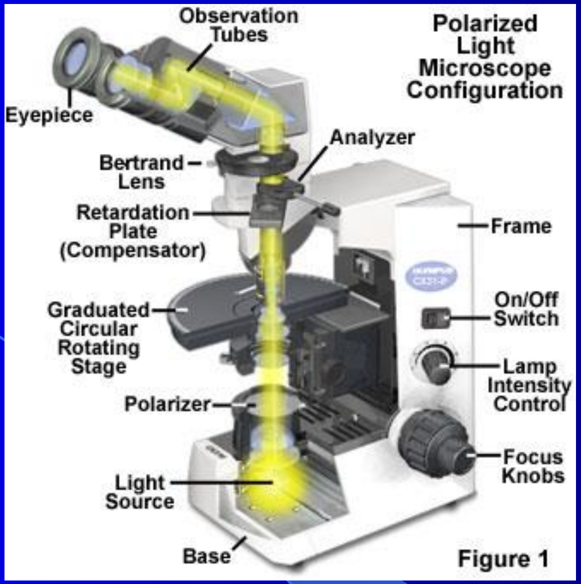
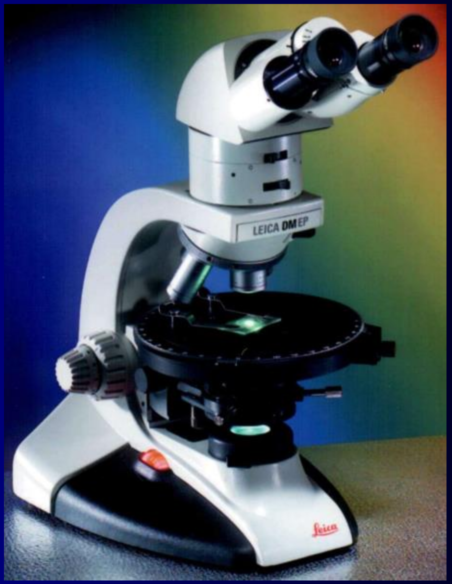
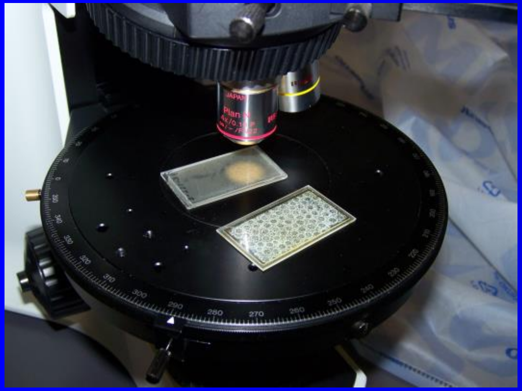
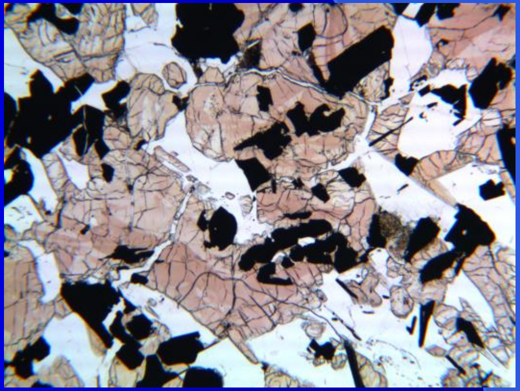
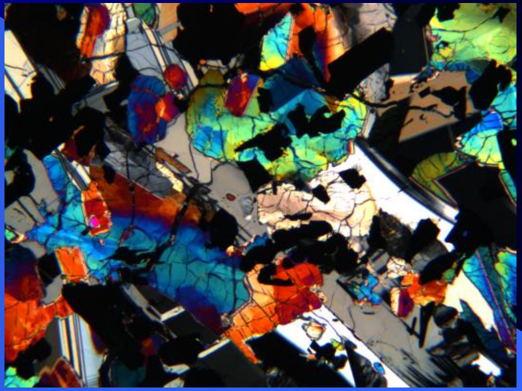
Polarizing Light Microscopy









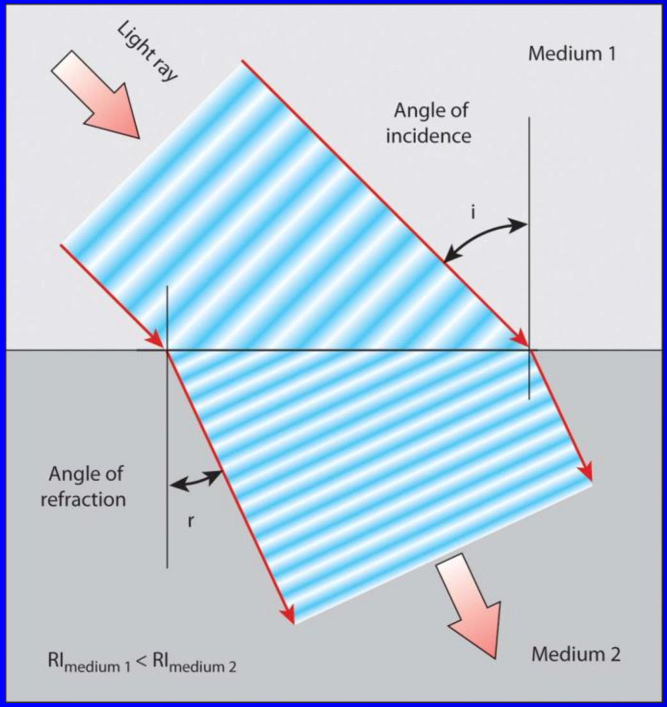


Refractive Index and Angle of Refraction

$$Refractive\ Index (R.I.) = \frac{velocity\ of\ light\ in\ a\ vacuum}{velocity\ of\ light\ in\ a\ medium}$$

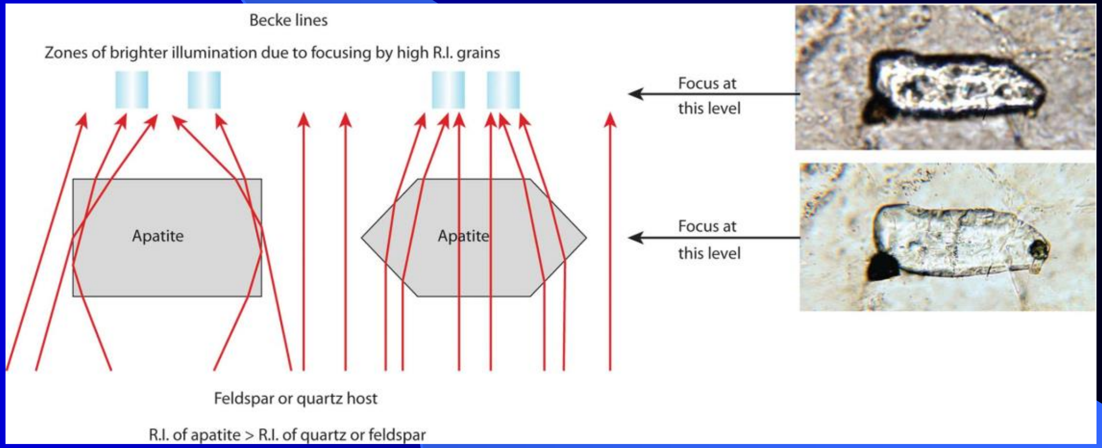
The refractive index varies with the wavelength of light.

Becke Lines – Super Important



Refraction – Snell's Law

$$\frac{\sin i}{\sin r} = \frac{R.I.2}{R.I.1}$$



Dispersion – index of refraction varies as a function of wavelength.

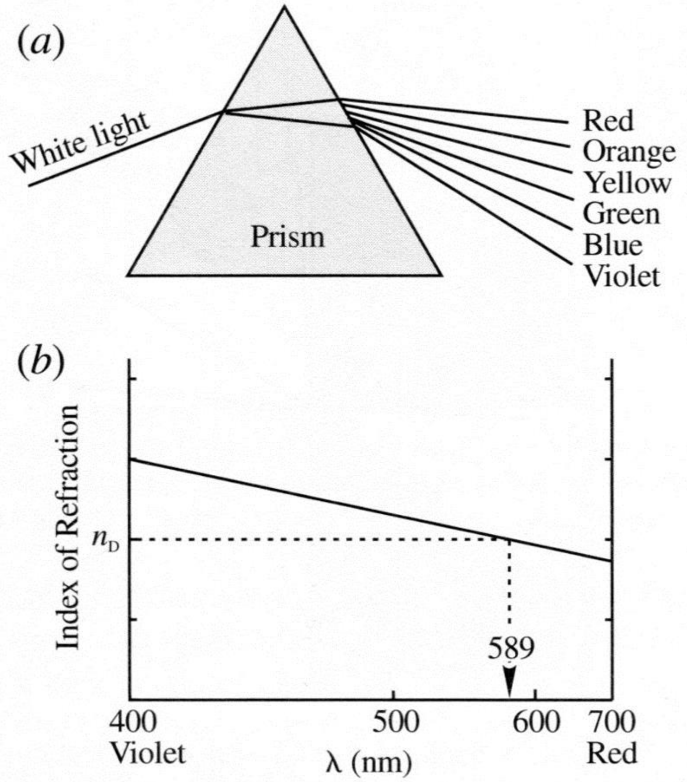
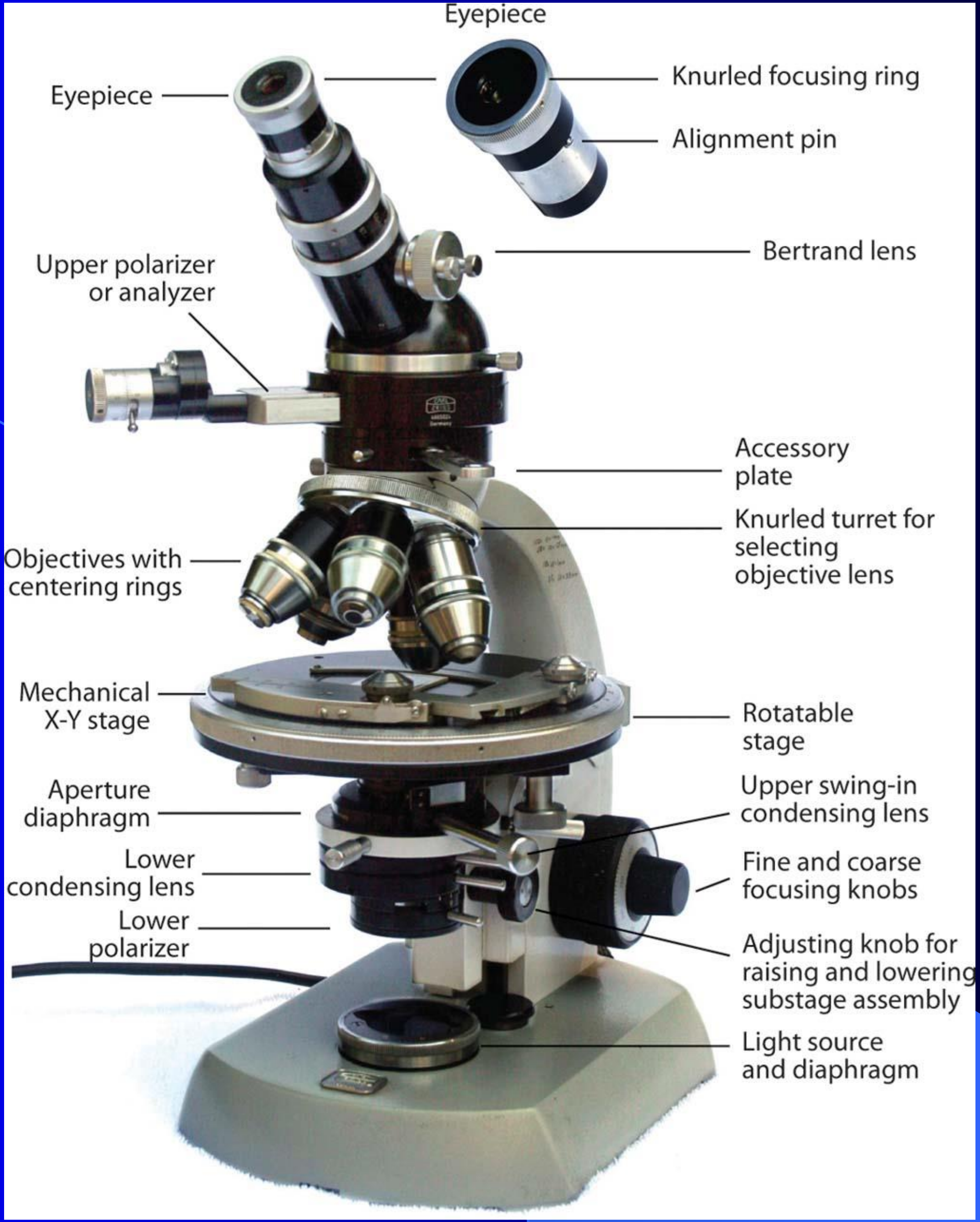
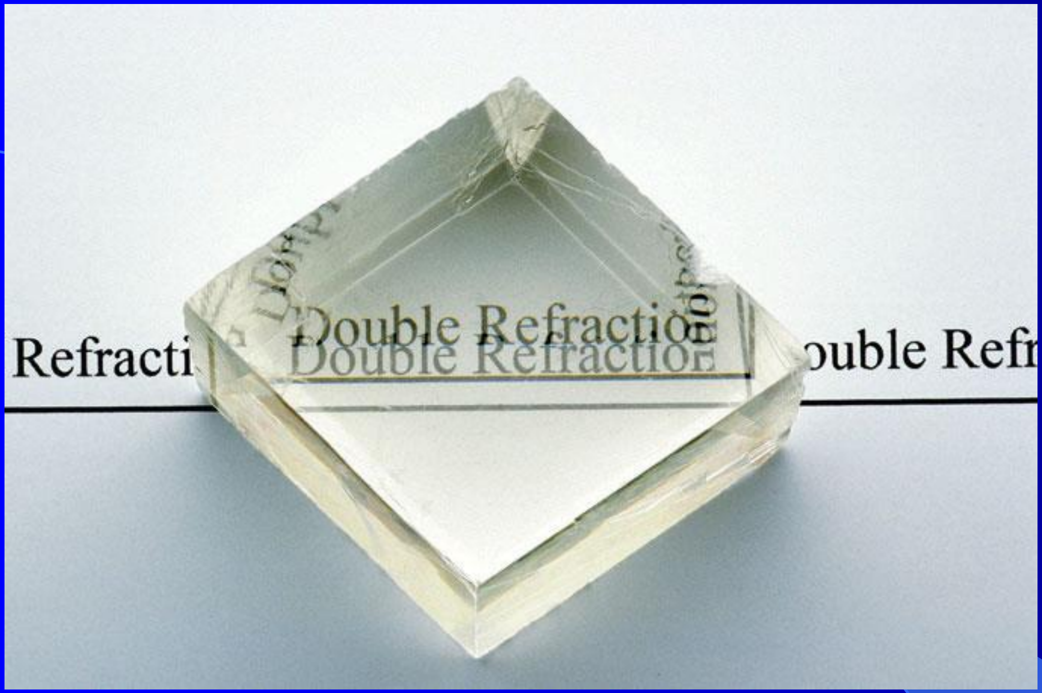


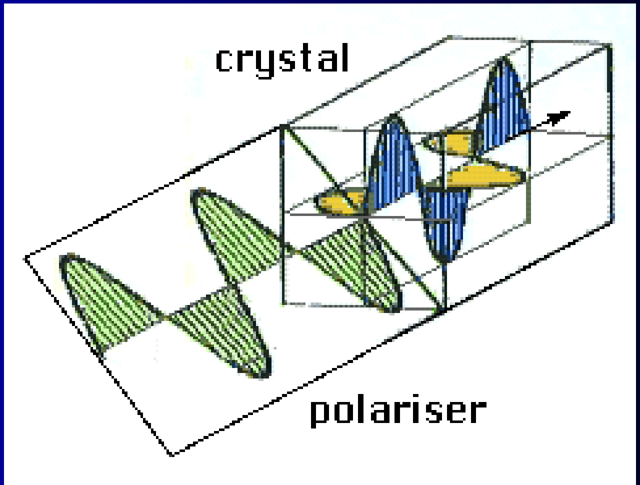
Figure 7.8 Dispersion of the refractive indices. (*a*) White light is spread into its spectral colors when passed through a prism because the index of refraction for violet light is larger than for red light. (*b*) Normal dispersion of the refractive indices. The index of refraction decreases with increasing wavelength. Strongly colored minerals may display abnormal dispersion of the refractive indices (index of refraction increases with increasing wavelength) for wavelengths that are strongly absorbed by the mineral.

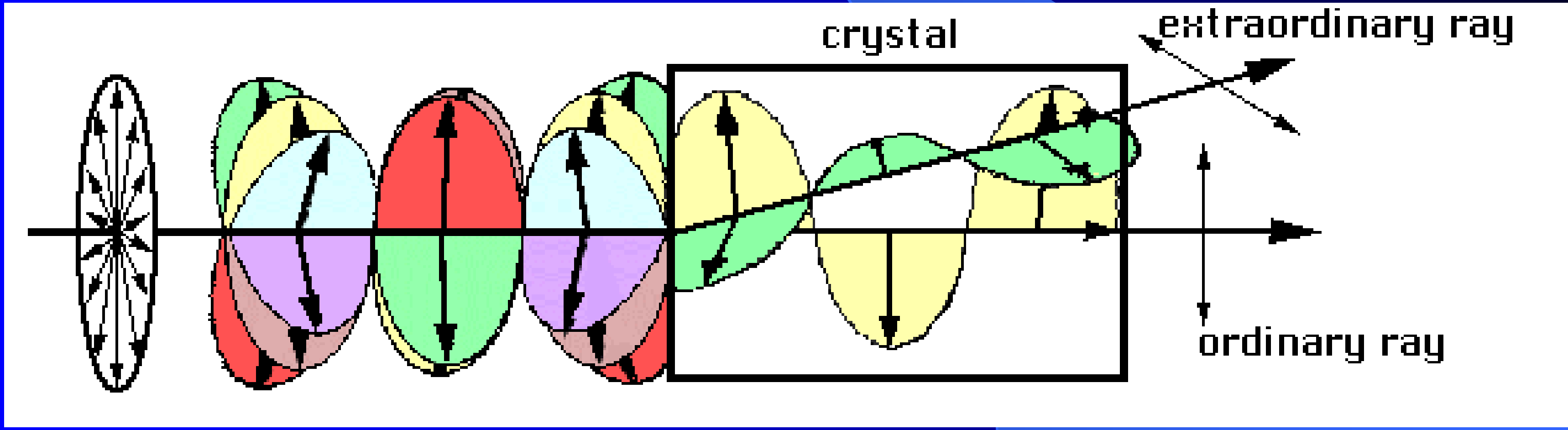
Polarizing Light Microscope (PLM)

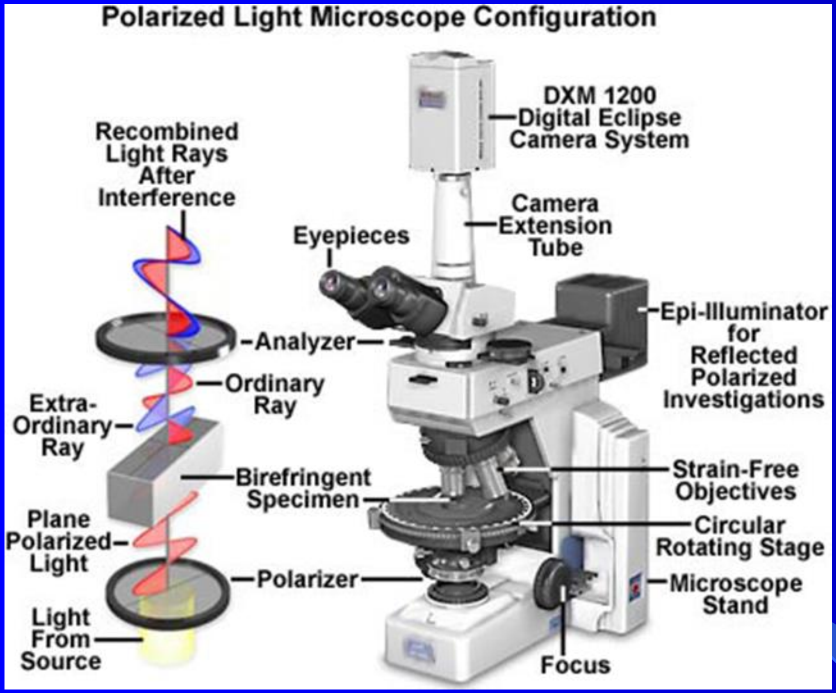


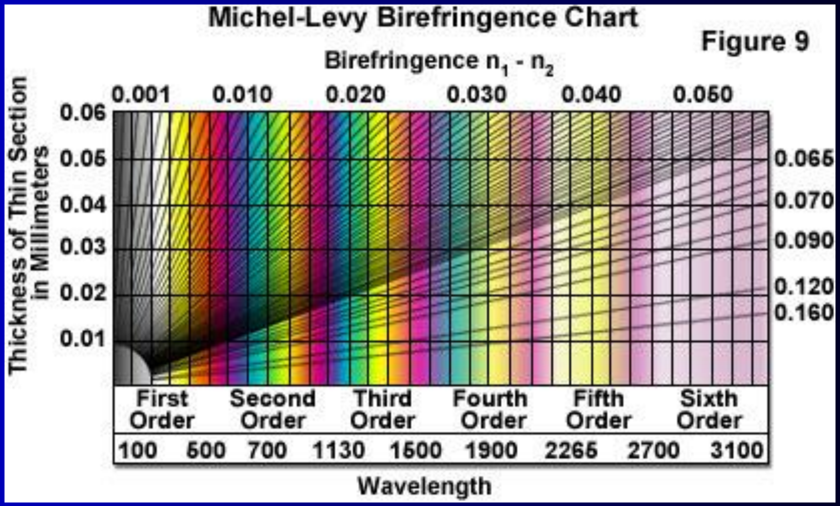
Double Refraction





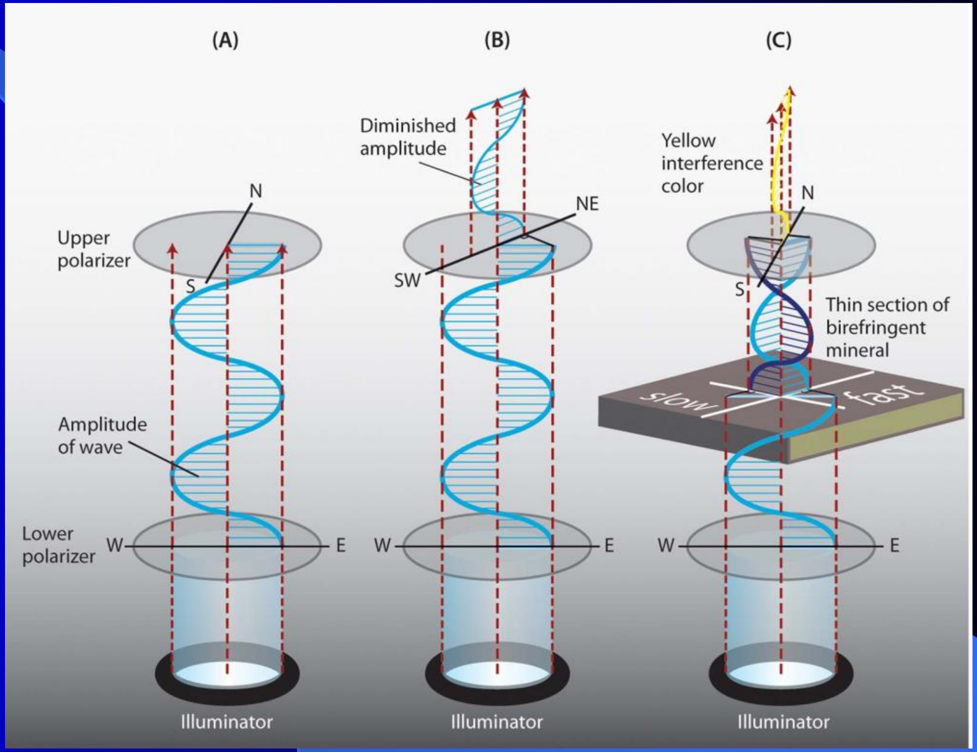






Birefringence – difference between maximum and minimum refractive indexes.

Retardation – amount by which the fast and slow light waves are out of phase. Function of birefringence and thickness of the mineral.



Retardation of Light

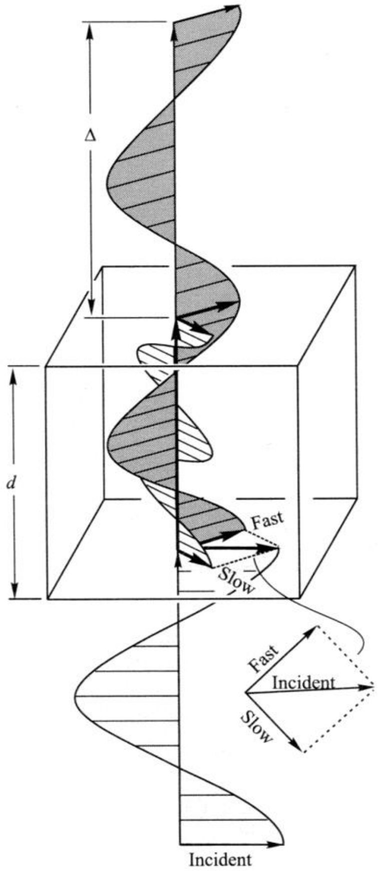


Figure 7.14 Development of retardation. Light entering the mineral with thickness *d* is split into slow and fast rays. In the time it takes the slow ray to pass through the mineral, the fast ray has passed through the mineral and traveled an additional distance Δ, which is the retardation.

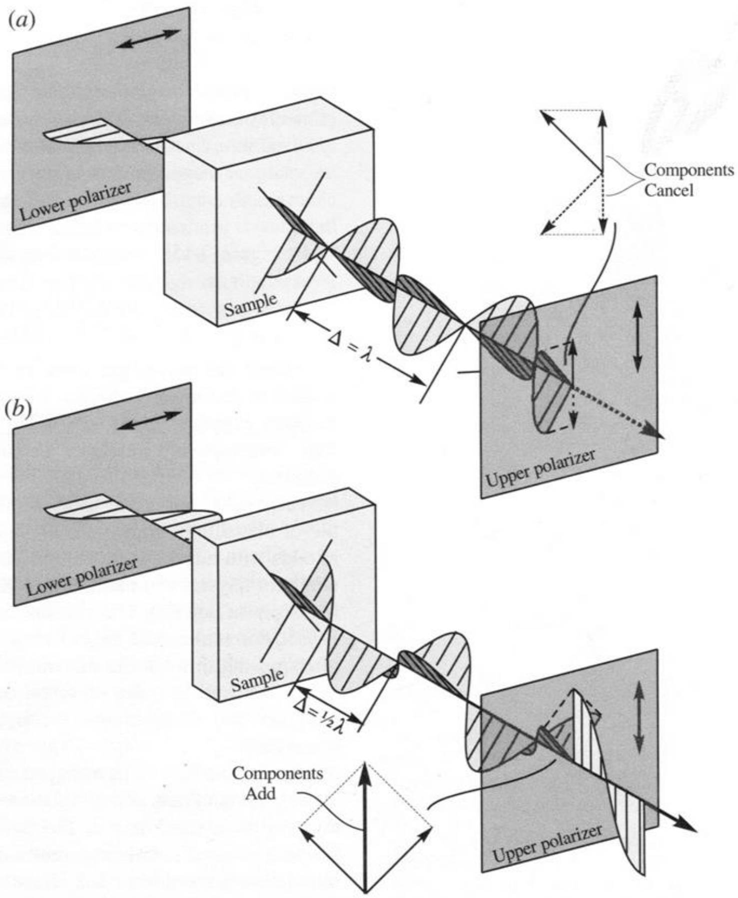
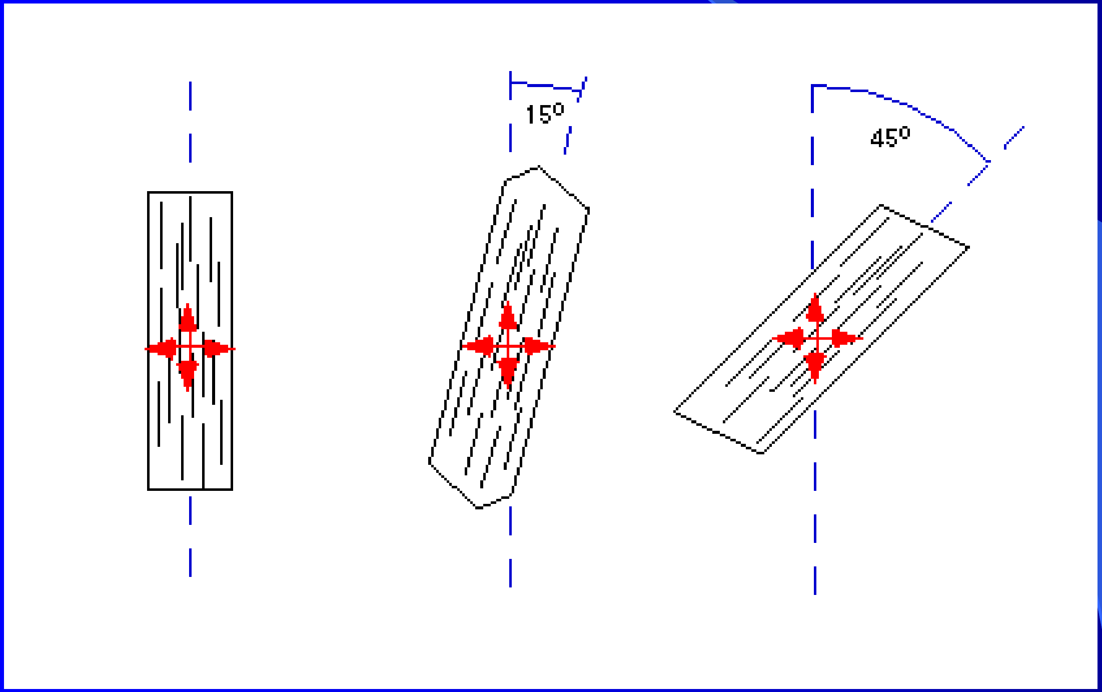


Figure 7.15 Interference at the upper polarizer. (*a*) The retardation (Δ) is one wavelength. Vector components of the two rays resolved into the vibration direction of the upper polarizer are in opposite directions so they cancel. No light passes and the mineral appears dark. (*b*) The retardation is one-half wavelength. Vector components of the two waves resolved into the vibration direction of the upper polarizer are in the same direction, so they constructively interfere. Light passes the upper polarizer and the mineral appears bright.

Extinction occurs when one of the vibration directions in the crystal parallels the E-W polarizer. In this case the polarized light is not split into two rays vibrating at right angles to each other. When the E-W vibrating ray encounter the upper polarizer which only permits rays vibrating in the N-S direction to pass, the crystal goes to extinction (becomes dark). The relationship between this angle and crystallographic directions can be an important piece of diagnostic information. Extinction can be parallel, inclined, or symmetrical.



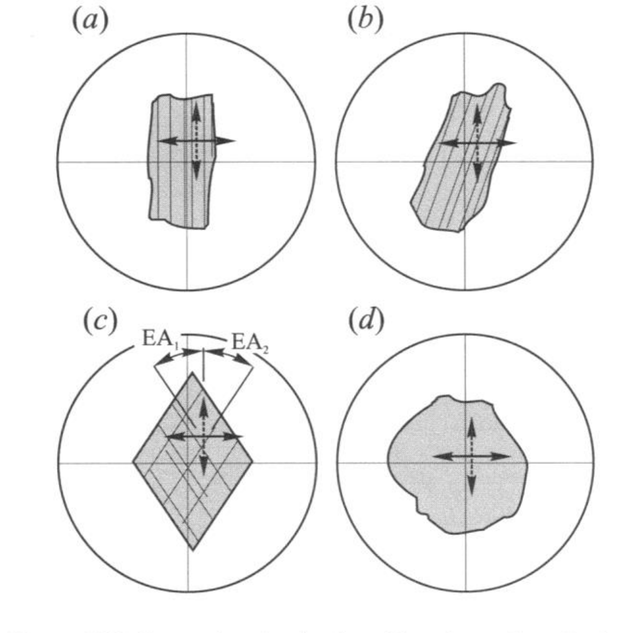
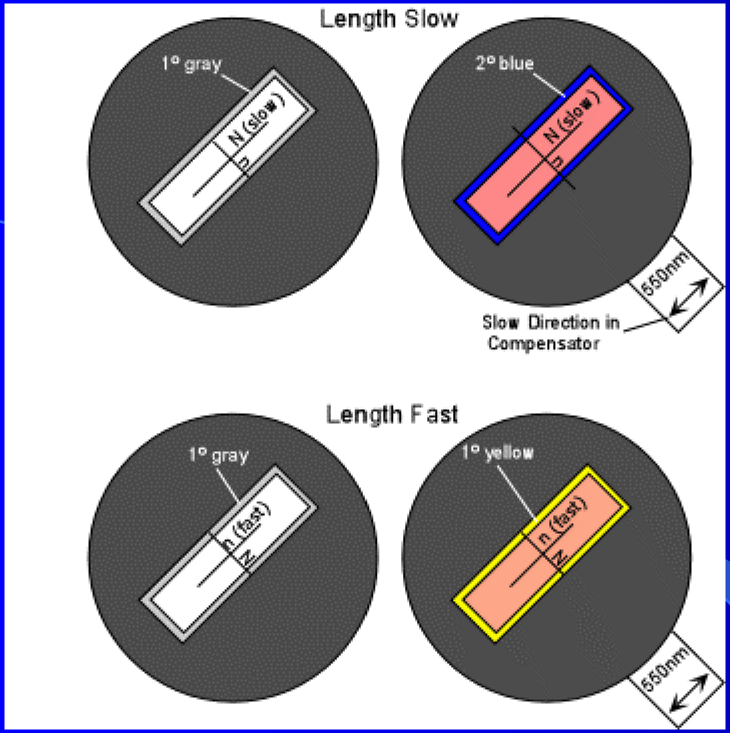
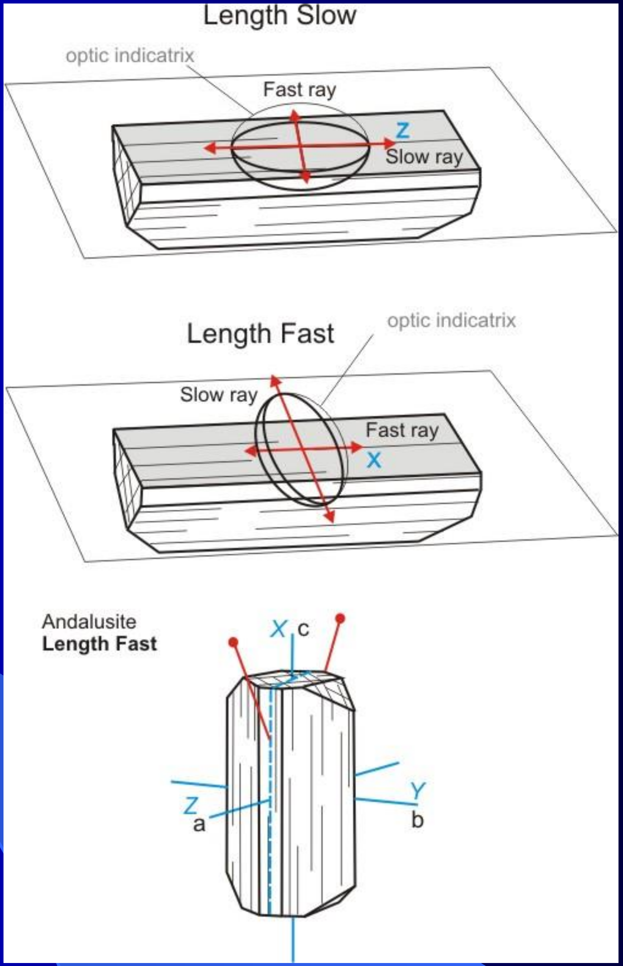
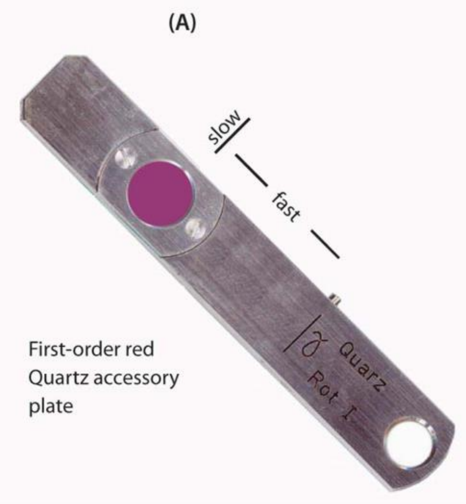


Figure 7.32 Categories of extinction. All grains are in extinction orientations. (*a*) Parallel extinction. The grain is extinct when the trace of cleavage or length is parallel to a cross hair. (*b*) Inclined extinction. The grain is extinct when the cleavage or length is at an angle to a cross hair. (*c*) Symmetrical extinction. Extinction angles EA_1 and EA_2 measured to the two cleavages are the same. (*d*) No extinction angle. The grain lacks cleavage or elongation from which to measure an extinction angle.

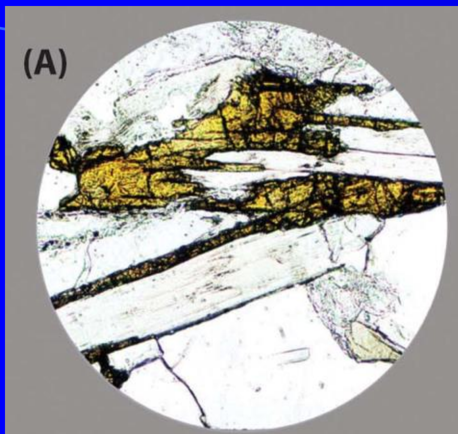
Sign of Elongation

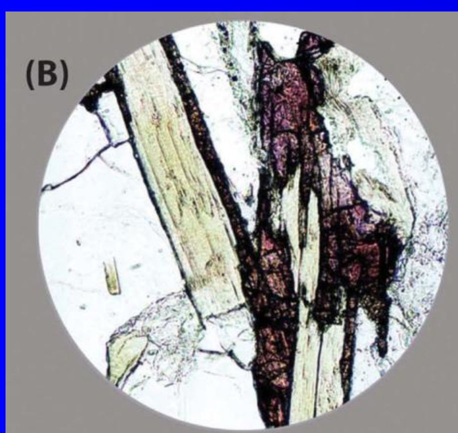




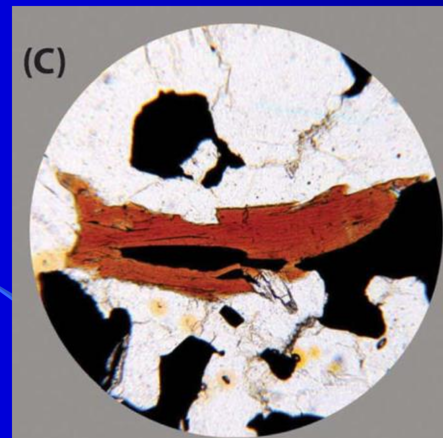


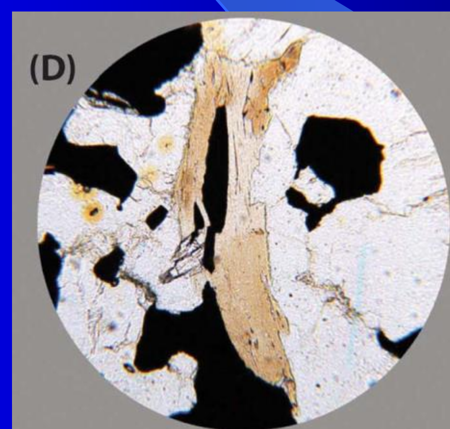
Pleochroism is the change in color that occurs when a mineral is rotated under plane-polarized light. This is due to the selective adsorption of certain wavelengths of light which causes the transmitted light to appear colored. The pleochroic colours are at their maximum when light is polarized parallel with a crystallographic axis. The axes are designated X, Y and Z. An absorption formula records the amount of absorption parallel to each axis in the form of X < Y < Z with the left most having the least absorption and the rightmost the most.



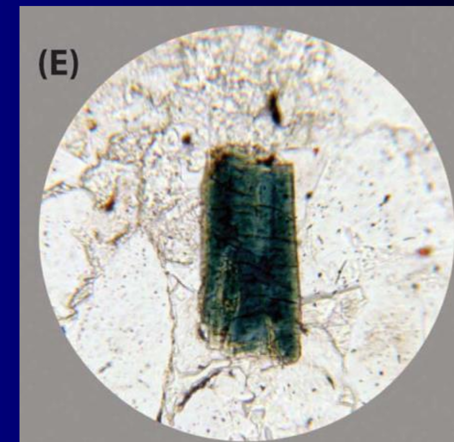


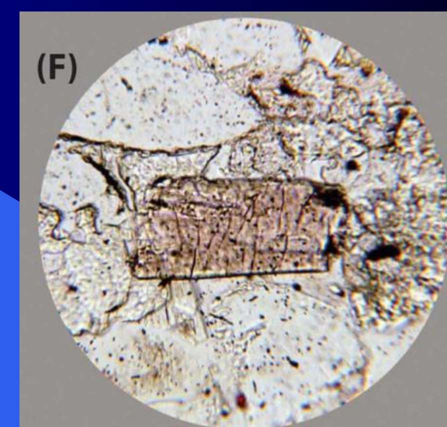
Manganese epidote piemontite





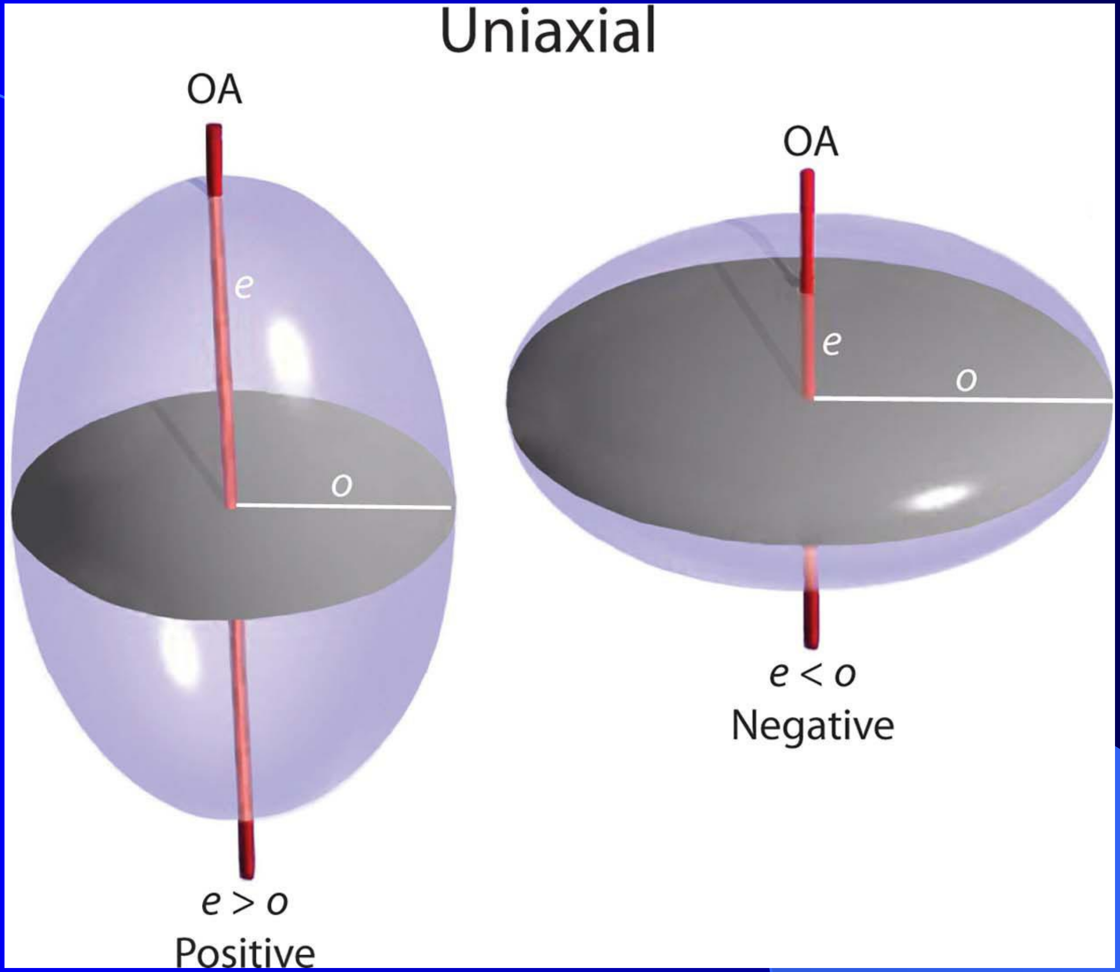
Biotite absorption is greater when cleavage parallels polarizer.





Tourmaline absorbs more light when the long axis of the crystal is perpendicular to the polarizer.

Uniaxial Indicatrix



Formation of isochromes and uniaxial optic axis inteference figure

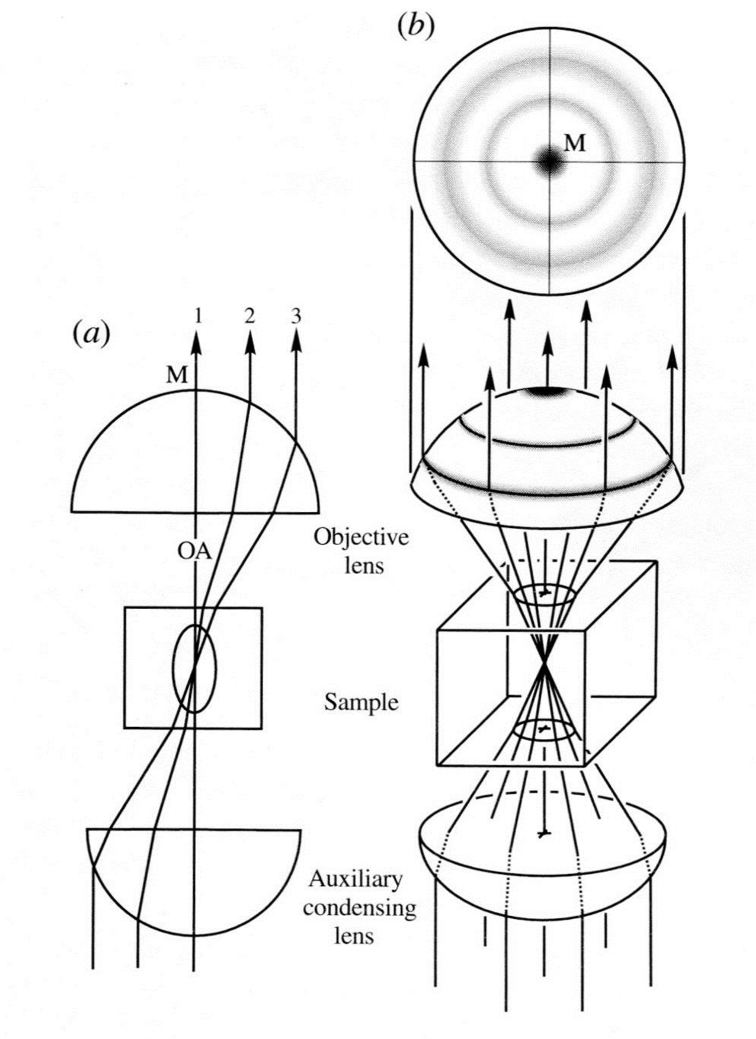


Figure 7.36 Formation of isochromes. (*a*) Light following path 1 that emerges at the melatope (M) experiences zero retardation because it follows the optic axis (OA). Paths 2 and 3 produce progressively higher retardation because both birefringence and pathlength through the sample increase as the inclination of the path to the optic axis increases. (*b*) Optical properties are symmetric about the optic axis, so rings of equal retardation are produced about the melatope.

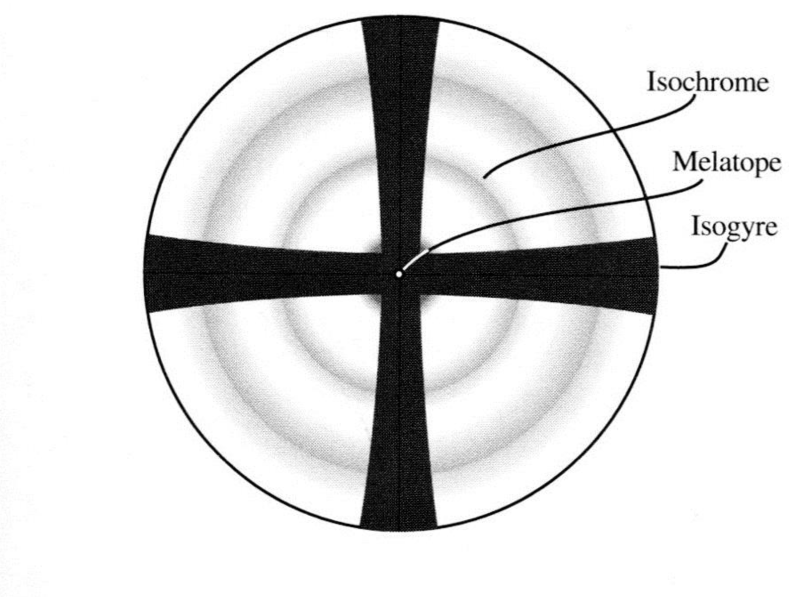
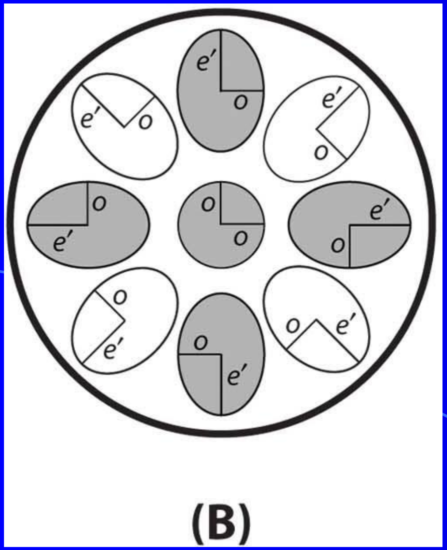
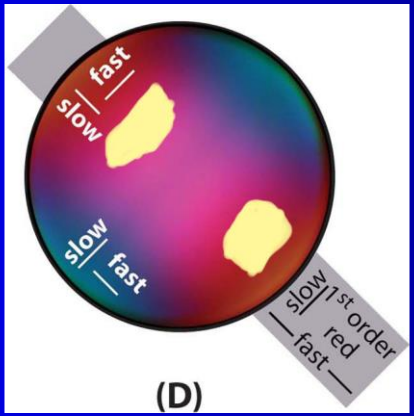
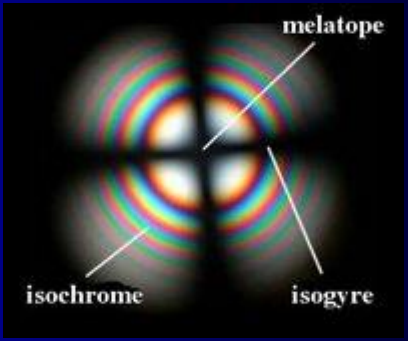


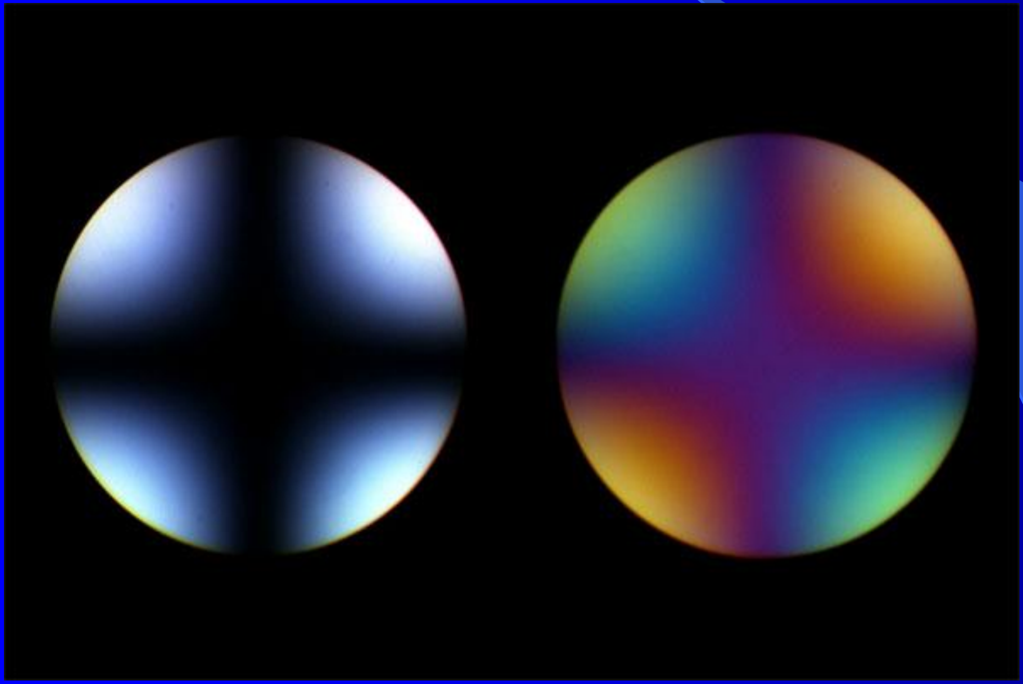
Figure 7.35 Uniaxial optic axis interference figure.

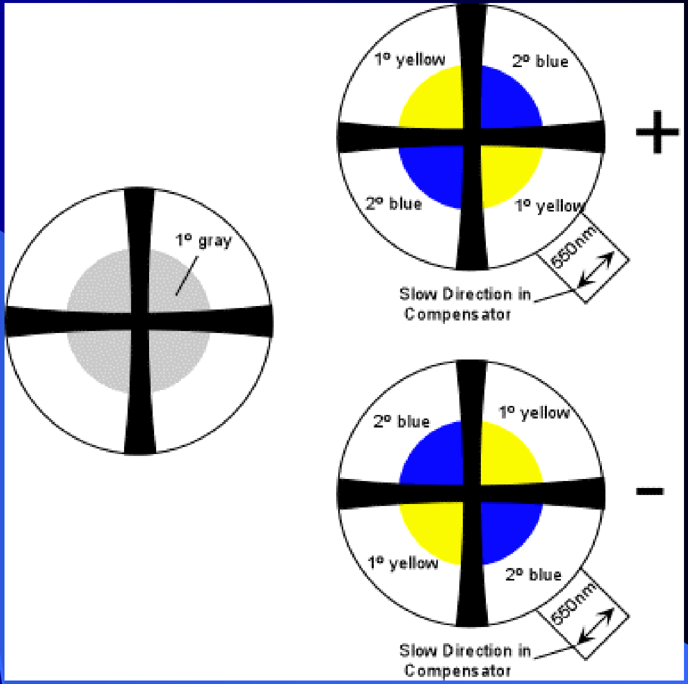
Uniaxial interference figures



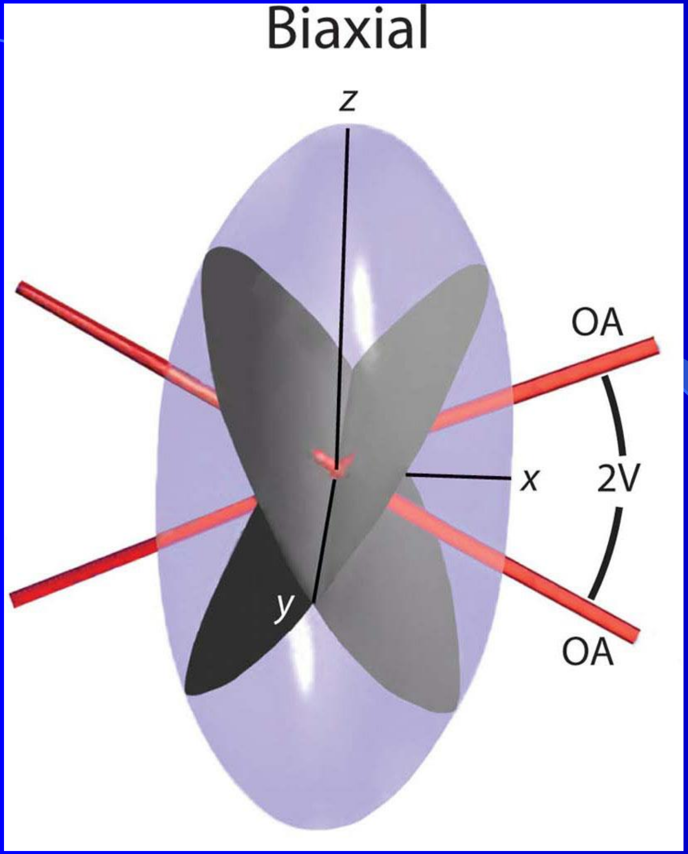


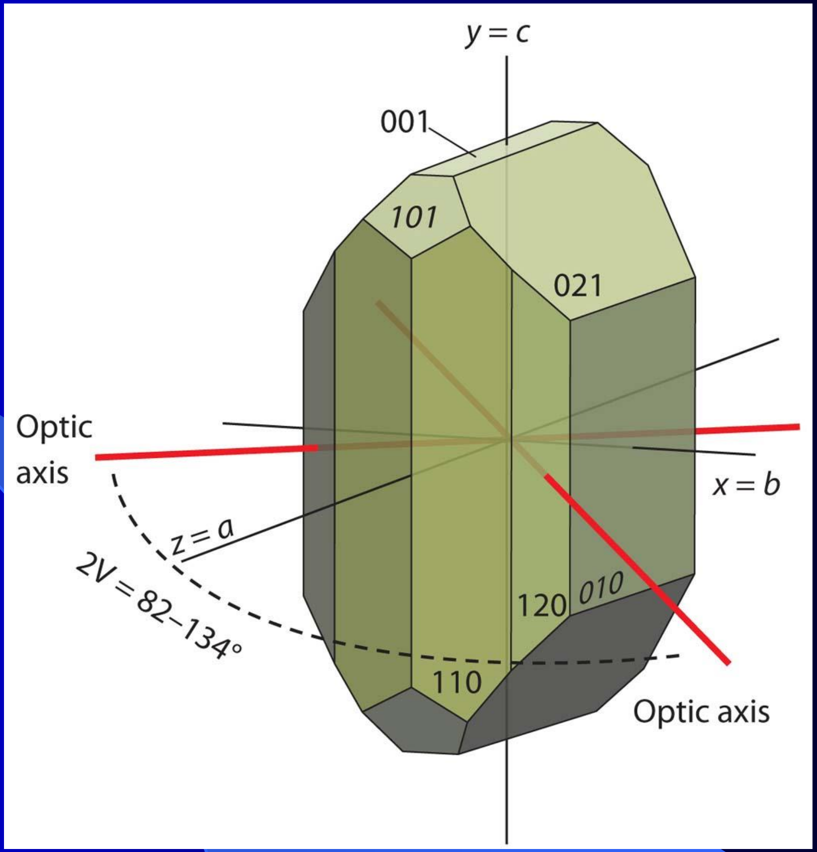




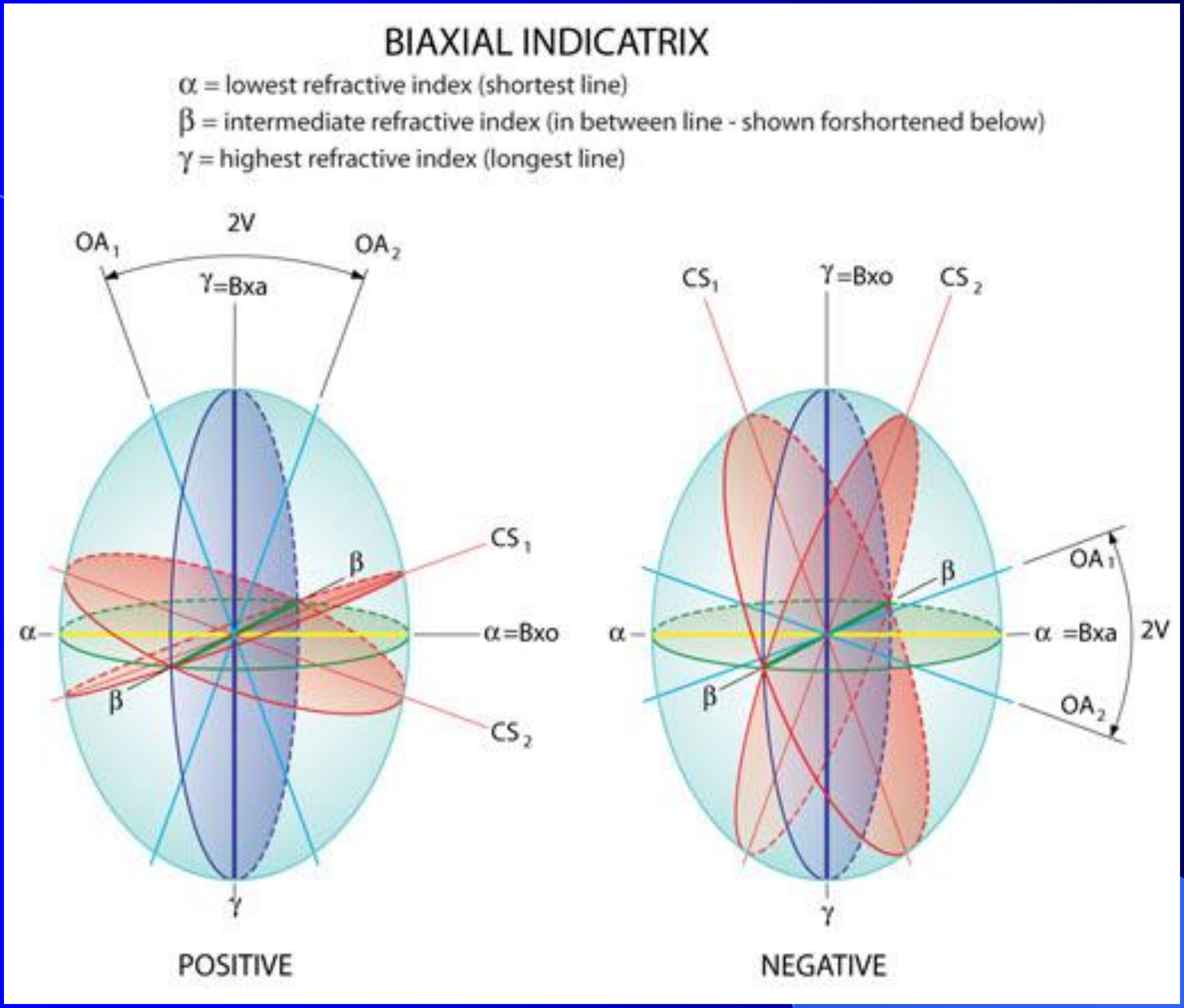


Biaxial Indicatrix and relationship to crystallography

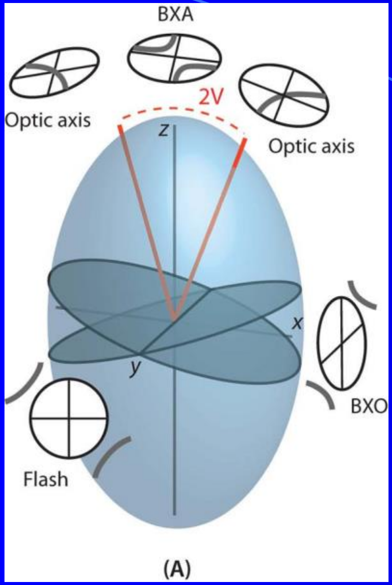


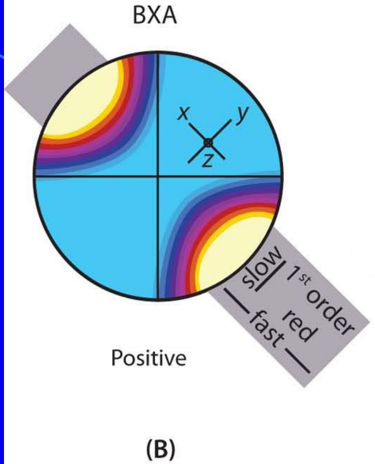


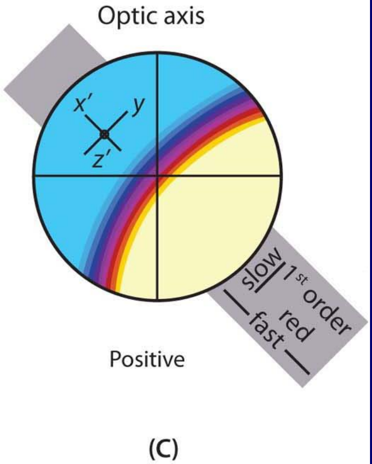
Biaxial indicatrix – positive vs negative

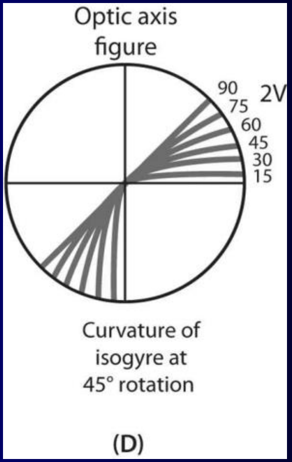


Determining optic sign and 2V

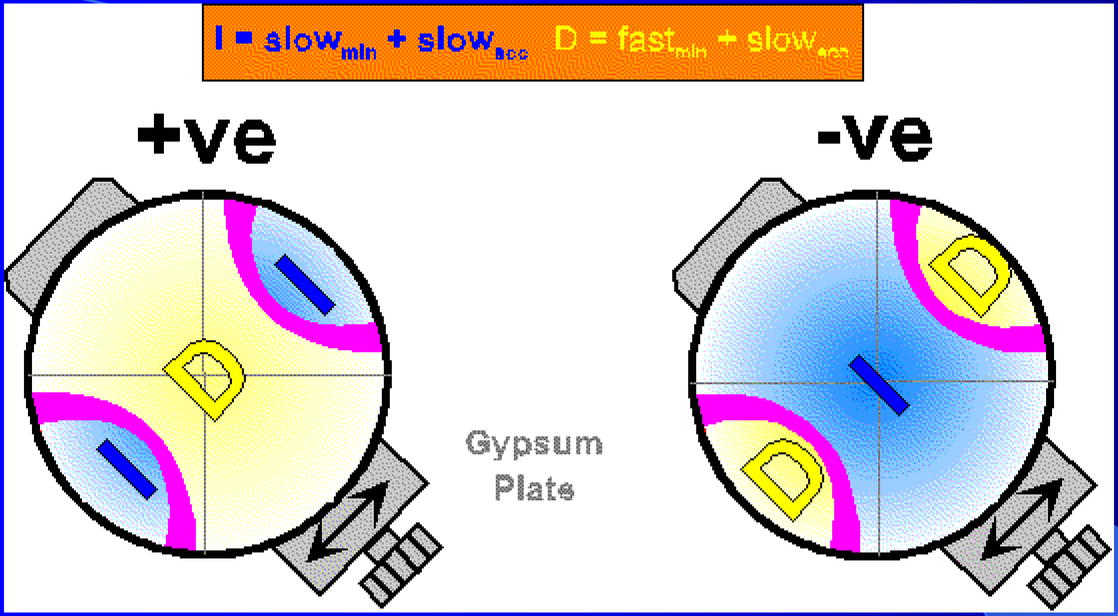


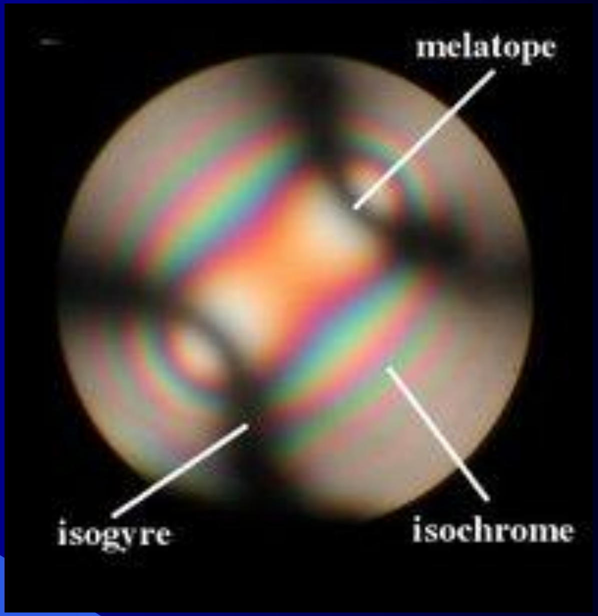


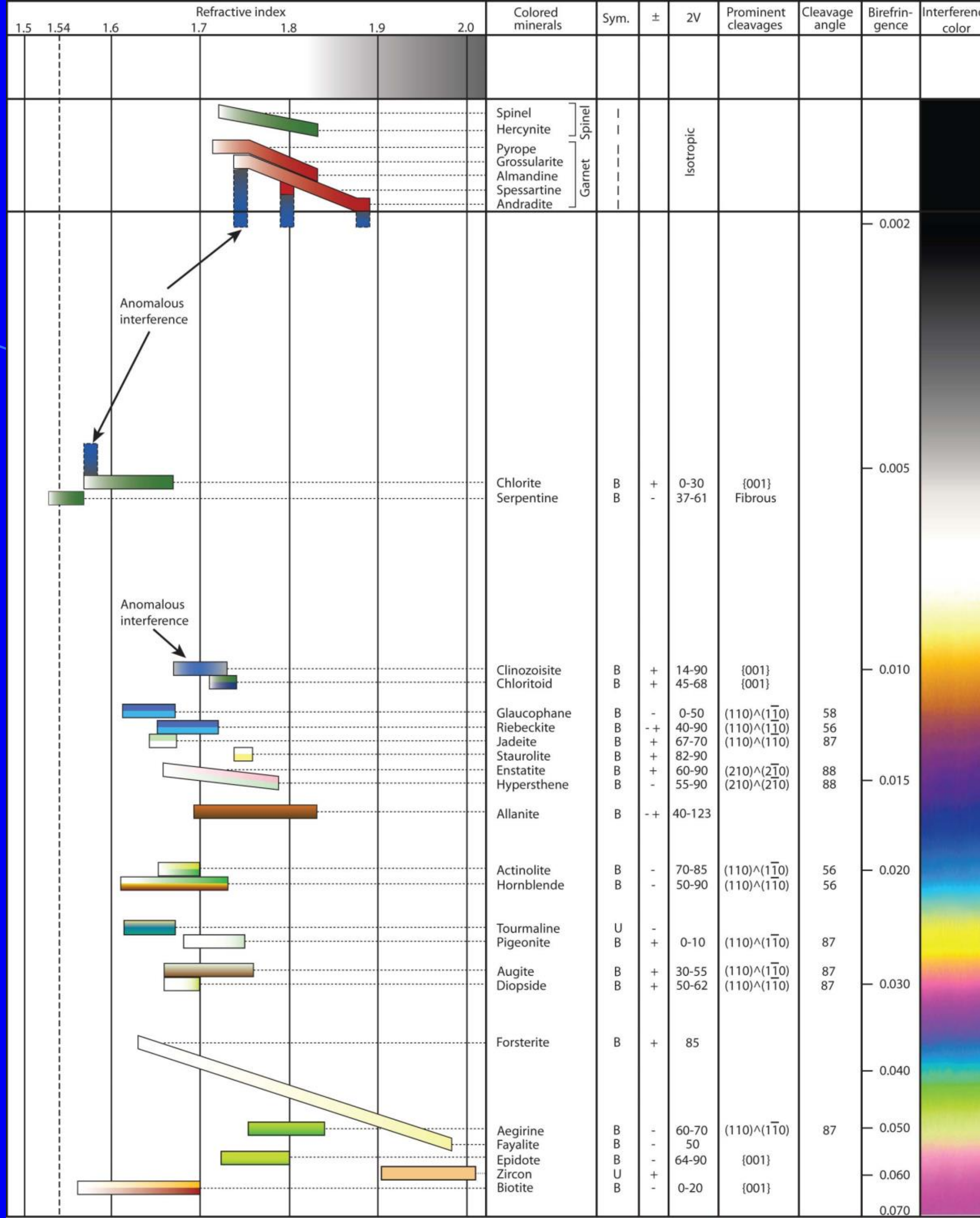




Determining optic sign







Refractive index
1.5
1.54
1.6
1.7
1.8
1.9
2.0
Colored minerals
Sym.
±
2V
Prominent cleavages
Cleavage angle
Birefringence
Interference color
Spinel
Hercynite
Spinel
Pyrope
Grossularite
Almandine
Spessartine
Andradite
Garnet
I
I
I
I
I
I
I
Isotropic
Anomalous interference
0.002
0.005
Chlorite B + 0-30 {001}
Serpentine B - 37-61 Fibrous
Anomalous interference
0.010
Clinozoisite B + 14-90 {001}
Chloritoid B + 45-68 {001}
Glaucophane B - 0-50 (110)^(1$\bar{1}$0) 58
Riebeckite B - + 40-90 (110)^(1$\bar{1}$0) 56
Jadeite B + 67-70 (110)^(1$\bar{1}$0) 87
Staurolite B + 82-90
Enstatite B + 60-90 (210)^(2$\bar{1}$0) 88
Hypersthene B - 55-90 (210)^(2$\bar{1}$0) 88
0.015
Allanite B - + 40-123
Actinolite B - 70-85 (110)^(1$\bar{1}$0) 56
Hornblende B - 50-90 (110)^(1$\bar{1}$0) 56
0.020
Tourmaline U -
Pigeonite B + 0-10 (110)^(1$\bar{1}$0) 87
Augite B + 30-55 (110)^(1$\bar{1}$0) 87
Diopside B + 50-62 (110)^(1$\bar{1}$0) 87
0.030
Forsterite B + 85
0.040
Aegirine B - 60-70 (110)^(1$\bar{1}$0) 87
0.050
Fayalite B - 50
Epidote B - 64-90 {001}
Zircon U +
0.060
Biotite B - 0-20 {001}
0.070

in 30 µm-thick section

Birefringence	Colorless minerals	Sym.	±	2V	Prominent cleavages	Cleavage angle
	Fluorite	I		Isotropic	{111}	
	Analcite	I		Isotropic		
	Sodalite	I		Isotropic		
	Leucite	I & U		Isotropic		
	Halite	I		Isotropic	{100}	
0.002	Melilite	U	+ -		{001}	
	Vesuvianite	U	-			
	Cristobalite	U	-			
	Tridymite	B	+	40-90		
	Apatite	U	-			
	Nepheline	U	-			
0.005	Kalsilite	U	-			
	Sanidine	B	-	18-54	(001)^(010)	90
	Orthoclase	B	-	33-103	(001)^(010)	90
	Microcline	B	-	66-103	(001)^(010)	89
	Albite	B	+	77	(001)^(010)	86
	Zeolite	B & U	+ -	15-90		
	Quartz	U	+			
	Cordierite	B	- +	65-104	{010}	
0.010	Clinozoisite	B	+	14-90	{001}	
	Andalusite	B	-	73-86	{110}	
	Gypsum	B	+	58	{010}	
	Corundum	U	-			
	Barite	B	+	37	{ (001)^(010) (210)^(21̄0)	90 78 }
	Anorthite	B	-	78	(001)^(010)	86
	Wollastonite	B	-	38-60	(100)^(001)	84
0.015						
	Kyanite	B	-	83	(100)^(010)	90
	Anthophyllite	B	- +	70-90	(210)^(21̄0)	55
0.020	Sillimanite	B	+	21-30	{010}	
	Lawsonite	B	+	76-87	(100)^(010)	90
	Tremolite	B	-	65-86	(110)^(11̄0)	56
	Pigeonite	B	+	0-10	(110)^(11̄0)	87
0.030	Cummingtonite	B	+	75-90	(110)^(11̄0)	55
	Anhydrite	B	+	43	(010)^(100)	90
	Scapolite	U	-		(100)^(110)	90
	Paragonite	B	-	0-40	{001}	
0.040	Muscovite	B	-	30-47	{001}	
	Grunerite	B	-	85-90	(110)^(11̄0)	55
	Phlogopite	B	-	0-15	{001}	
	Olivine	B	-	80-90		
0.050						
	Talc	B	-	0-30	{001}	
0.060						
0.070