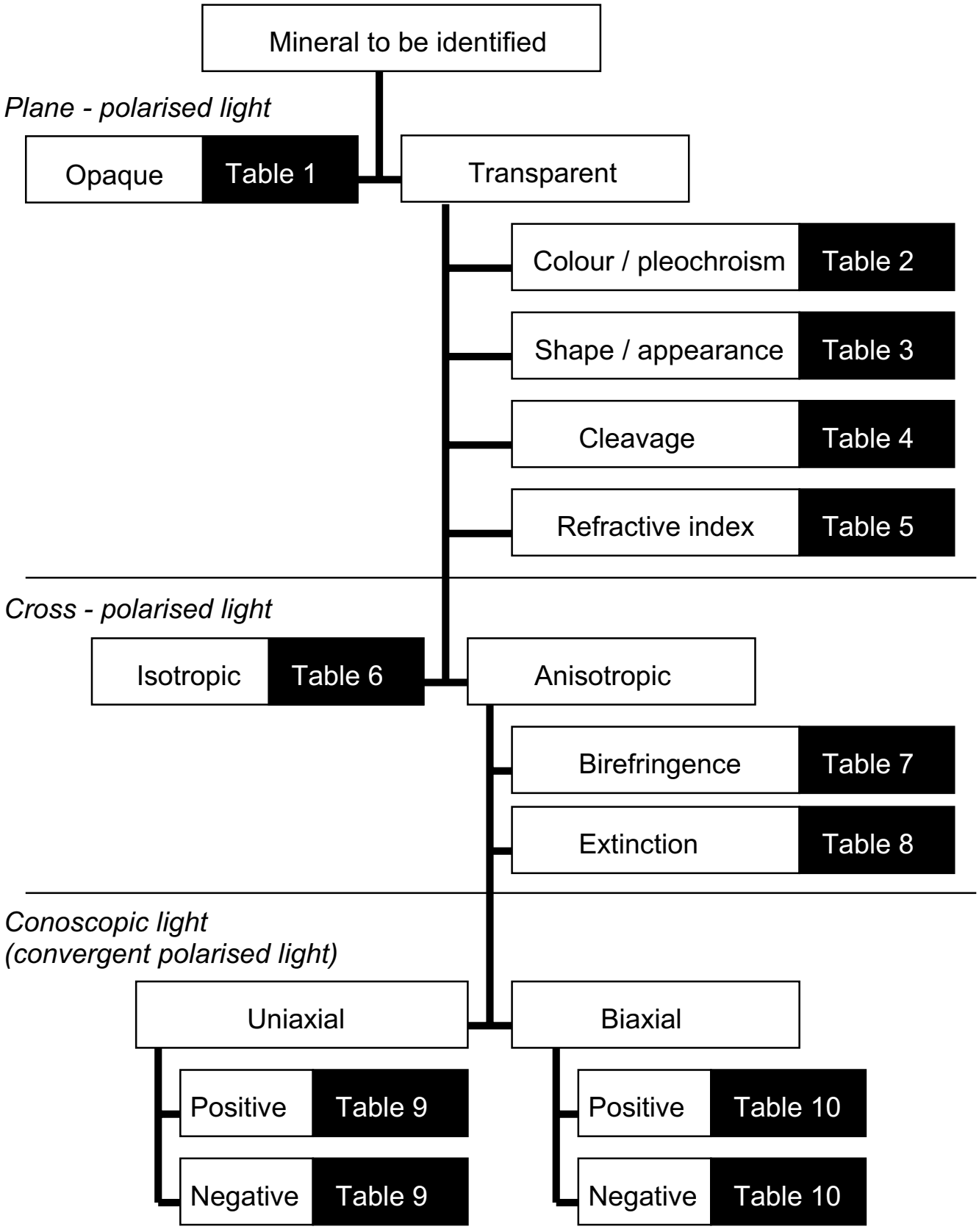
Flow chart for mineral identification in transmitted light microscopy



References

Note: You should always verify your identifications with a mineralogy textbook.

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Notations

Occurrence

m = metamorphic rocks
p = plutonic rocks
s = sedimentary rocks
v = volcanic rocks

Optical characteristics

2V = axial angle of biaxial minerals (in degrees)
n = refractive index (air, *n* = 1)
Δn = birefringence
var. = variable

On bar charts, solid bars indicate the common range of properties, hatched bars indicate the entire range of variation.

Minerals that rarely occur together

Quartz - nepheline
Quartz - leucite
Quartz - olivine

Orthopyroxene - nepheline
Orthopyroxene - leucite

Occurrence of common transparent mineral groups

Olivine *m,p,v,(s)*
- Forsterite
- Intermediate olivine
- Fayalite

Garnet *m,(p),s*
- Pyrope
- Almandine
- Spessartine
- Uvarovite
- Grossular
- Andradite

Aluminium silicates
- Kyanite *m*
- Andalusite *m,(p)*
- Sillimanite *m,(p)*

Pyroxenes *m,p,v,s*
- Clinopyroxene
  - Alkaline
    - Jadeite *m*
    - Aegirine-augite *p,v*
    - Aegirine *m,p,v*
    - Omphasite *m,p*
  - Subalkaline
    - Diopside *m,p*
    - Augite *m,p,v,(s)*
    - Ferroaugite *m,p,v,(s)*
- Pigeonite *v*
- Orthopyroxene
  - Enstatite *m,p,v,(s)*
  - Bronzite *m,p,v,(s)*
  - Hypersthene *m,p,v,(s)*

Amphiboles
- Clinoamphibole
  - Hornblende *m,p,v,(s)*
  - Tremolite - actinolite *m*
- Orthoamphibole *m*

Micas
- Biotite - phlogopite *m,p,v,s*
- Muscovite *m,p,v,s*
- Stilpnomelane *m*

Clay minerals
- Kaolinite *(m),(p),(v),s*
- Illite *(m),s*
- Montmorillonite (smectite) *(m),(v),s*

Feldspars
- Plagioclase *m,p,v,s*
  - Anorthite
  - Bytownite
  - Labradorite
  - Andesine
  - Oligoclase
  - Albite
- Alkali feldspar *m,p,v,s*
  - Orthoclase *m,p,v,s*
  - Microcline *m,p,v,s*
  - Sanidine *v*

Silica minerals
- Quartz *m,p,v,s*
- Tridymite *p,v*
- Cristobalite *p,v*

Feldspatoid minerals
- Leucite *v*
- Nepheline *(m),p,v*

Carbonates
- Calcite *m,p,v,s*
- Aragonite *s*
- Dolomite *m,s*
- Siderite *m*

Phosphates
- Apatite *m,p,s*
- Monazite *m,(p),s*

Sulphates
- Gypsum *m,s*
- Anhydrite *m,s*
- Baryte *m,(p),s*

Table 1 Opaque minerals

Note: Opaque minerals appear black in transmitted light. You cannot identify the optical properties of opaque minerals with the transmitted light microscope.

Common opaque minerals include:

Oxides
- Magnetite
- Ilmenite
- Hematite
- Chromite

Sulphides
- Pyrite
- Chalcopyrite
- Galena
- Pyrrhotite

Table 2 Colour / Pleochroism

Note: Colour is not always diagnostic. Many of the minerals listed here can also appear colourless.

	Isotropic	*Anisotropic*
Red	Sphalerite, garnet, spinel	Rutile, iddingsite, allanite
Pink / Violet	Sodalite, fluorite, garnet	Tourmaline, staurolite, glaucophane orthopyroxene, andalusite
Brown	Sphalerite, fluorite, garnet, spinel	Rutile, zircon, cassiterite, tourmaline ***(s)***, apatite, clinopyroxene, orthopyroxene, hornblende, biotite ***(s)***, allanite
Yellow	Sodalite, sphalerite, fluorite, spinel	Rutile, zircon, cassiterite, tourmaline, staurolite, chloritoid, clinopyroxene, orthopyroxene, hornblende, epidote, biotite, allanite
Green	Fluorite, garnet, spinel	Rutile, tourmaline, apatite, phlogopite, chlorite, clinopyroxene, orthopyroxene, alkaline clinopyroxene, jadeite, hornblende, epidote, glauconite
Blue	Sodalite, fluorite, spinel	Rutile, tourmaline, apatite, glaucophane, cordierite

Table 3 Shape / appearance

Feature	*Type*	*Minerals*
Shape	Acicular (needle like) *(sometimes radial)*	Tourmaline, zeolite, serpentine, aragonite, rutile
	Foliated (flake like)	Biotite-phlogopite, muscovite, talc chloritoid, stilpnomelane
	Euhedral - plutonic rocks	Quartz, apatite, tourmaline
	Euhedral - volcanic rocks	Olivine, clinopyroxene, orthopyroxene hornblende, biotite, plagioclase feldspar, microcline, sanidine, quartz tourmaline, apatite
Twins *(most easily recognised in cross-polarised light)*	Simple	Plagioclase feldspar, orthoclase feldspar, clinopyroxene, cassiterite, staurolite, aragonite, fluorite, calcite, gypsum, spinel, sphene, chloritoid, hornblende, tremolite - actinolite
	Multiple	Plagioclase feldspar, leucite, microcline, cordierite, clinozoisite, calcite, aragonite, rutile, sphene, stilpnomelane
Intergrowths	Exsolution features	Clinopyroxene with orthopyroxene lamellae Orthopyroxene with clinopyroxene lamellae Hornblende with various amphibole lamellae "Perthite": Microcline with plagioclase (albite) lamellae
	Myrmekitic / graphic	Quartz / feldspar Nepheline / feldspar Feldspar / spinel *(reaction between feldspar and opaques)* Spinel / orthopyroxene *(reaction from olivine)*

Table 4 Cleavage

Δn	*Cleavage rare or absent*	*1 direction of cleavage*	*2 directions of cleavage*	*3 (or more) directions of cleavage*
Isotropic	Garnet			Halite Fluorite Sphalerite
< 0.01	Leucite Quartz Apatite	Gypsum Chlorite Topaz Zoisite Clinozoisite Staurolite Chloritoid	Orthoclase Sanidine Microcline Plagioclase feldspar	Nepheline Gypsum
0.01 - 0.03	Tourmaline	Cordierite Glauconite Sillimanite	Orthopyroxene Tremolite - Actinolite Glaucophane Wollastonite Hornblende Clinopyroxene Jadeite Alkaline clinopyroxene	Barite Kyanite
> 0.03	Olivine	Talc Muscovite Biotite - Phlogopite Stilpnomelane Epidote Monazite (poor)	Pigeonite Rutile Sphene (poor)	Calcite Dolomite Siderite

Table 5 Refractive index

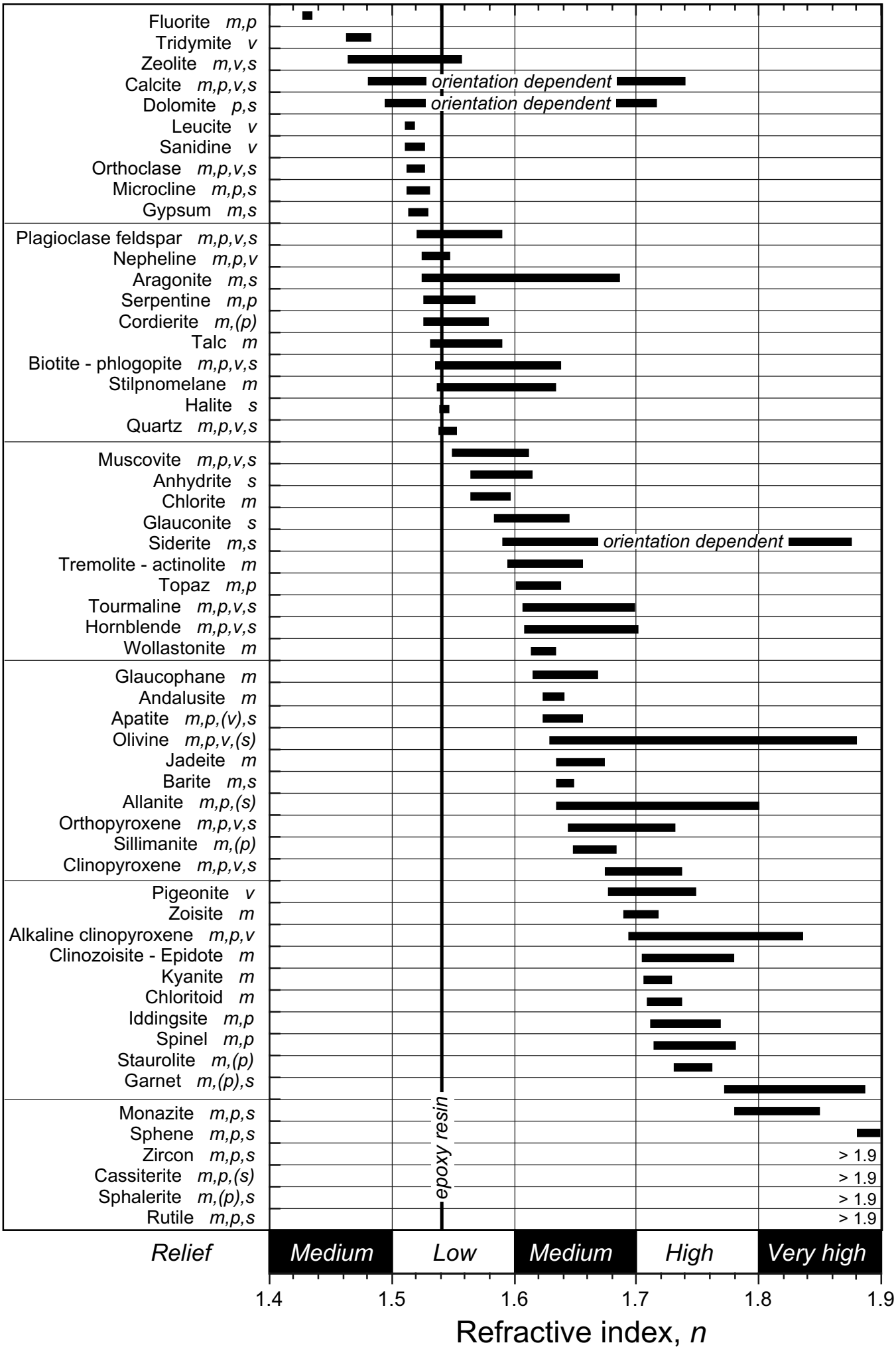


Table 6 Isotropic minerals

Mineral	*Refractive index*
Fluorite	1.40 - 1.46
Halite	1.54
Garnet	1.74 - 1.89
Spinel	1.72 - 1.78
Sphalerite	2.37 - 2.47
Volcanic glass	1.48 - 1.61

Table 7 Birefringence

Note: Birefringence varies with thickness and orientation of mineral grains. The maximum birefringence is characteristic for a mineral, and it is consequently critical to search for the grain that shows the highest interference colour.

Birefringence (Δn)	*Mineral*	*Birefringence (Δn)*	*Mineral*
0.001	Leucite	0.015 - 0.040	Tourmaline
0.003 - 0.004	Apatite	0.016	Kyanite
0.003 - 0.004	Nepheline	0.019 - 0.026	Hornblende
0.004	Tridymite	0.020 - 0.023	Sillimanite
0.004 - 0.011	Chlorite *	0.020 - 0.032	Glauconite
0.004 - 0.017	Serpentine	0.021 - 0.031	Clinopyroxene
0.005 - 0.011	Clinozoisite *	0.021 - 0.033	Pigeonite
0.006 - 0.018	Zoisite *	0.022 - 0.027	Tremolite - actinolite
0.007	Sanidine	0.029 - 0.037	Alkaline clinopyroxene**
0.007	Microcline	0.030 - 0.050	Talc
0.007 - 0.013	Plagioclase feldspar	0.030 - 0.110	Stilpnomelane
0.007 - 0.011	Andalusite	0.033 - 0.059	Biotite - phlogopite
0.007 - 0.011	Cordierite	0.035 - 0.041	Olivine
0.008	Orthoclase	0.037 - 0.041	Muscovite
0.009	Gypsum	0.038 - 0.044	Iddingsite
0.009	Quartz	0.044	Anhydrite
0.008 - 0.016	Orthopyroxene	0.049 - 0.051	Monazite
0.009 - 0.010	Topaz	0.060 - 0.062	Zircon
0.010 - 0.015	Staurolite	0.092 - 0.141	Sphene
0.010 - 0.030	Allanite	0.097	Cassiterite
0.012	Barite	0.156	Aragonite
0.012 - 0.013	Jadeite	0.172	Calcite
0.013 - 0.016	Chloritoid	0.180 - 0.190	Dolomite
0.013 - 0.018	Glaucophane	0.234 - 0.242	Siderite
0.014	Wollastonite	0.286 - 0.287	Rutile
0.014 - 0.045	Epidote		

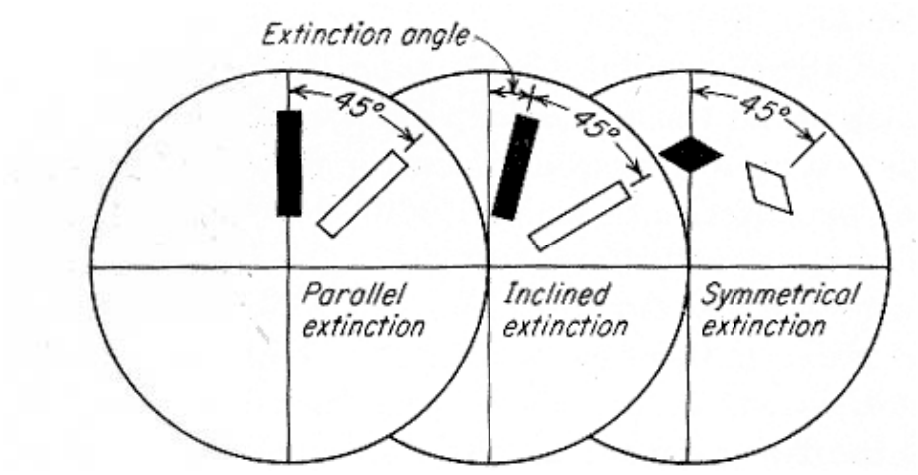
** minerals can show anomalous interference colours (blue, brown) due to a large dispersion of light of different colours*
*** includes aegirine, aegirine-augite and omphacite*

Table 8 Extinction

Note: Extinction is determined in relation to a reference direction within the mineral observed. This can be cleavage or crystal surfaces. Twin planes and lamellar exsolution phenomena are usually not suitable.

Δn	*Straight or symmetric (±5º)*	*Inclined (>5º)*
< 0.01	Nepheline, andalusite, cordierite	Plagioclase feldspar, orthoclase, sanidine, microcline
0.01 - 0.03	Orthopyroxene, zoisite, epidote, staurolite, sillimanite, tourmaline, serpentine	Hornblende, tremolite - actinolite, clinopyroxene, pigeonite, jadeite, clinozoisite, epidote, kyanite, chloritoid
> 0.03	Olivine, sphene, zircon, iddingsite, tourmaline, talc, muscovite, biotite - phlogopite anhydrite, cassiterite, aragonite, calcite, dolomite, siderite	Monazite, alkaline clinopyroxene

Extinction



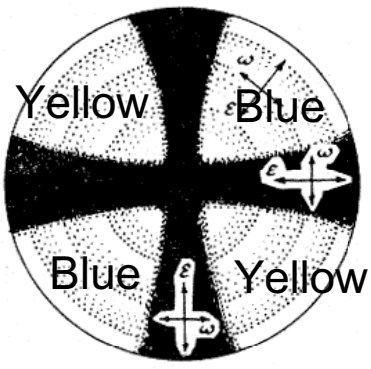
Kerr (1959). Optical Mineralogy, McGraw Hill

Table 9 Uniaxial minerals

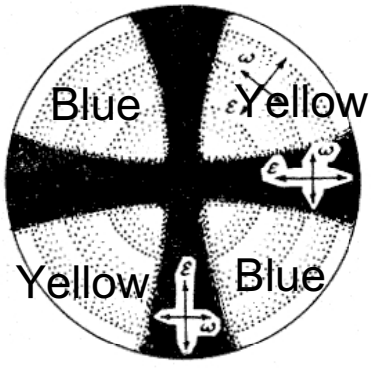
Minerals in brackets are biaxial with low 2V and can appear uniaxial

Uniaxial negative	*n*	Δ*n*
Nepheline	1.527 - 1.547	0.003 - 0.004
Apatite	1.630 - 1.655	0.003 - 0.004
(Sanidine)	1.517 - 1.526	0.007
Tourmaline	1.613 - 1.698	0.015 - 0.040
(Stilpnomelane)	1.612 - 1.745	0.030 - 0.119
(Biotite-phlogopite)	1.541 - 1.638	0.033 - 0.059
Calcite	1.486 - 1.658(*var.*)	0.172
Dolomite	1.500 - 1.716(*var.*)	0.180 - 0.190
Siderite	1.596 - 1.875(*var.*)	0.234 - 0.242
Uniaxial positive	*n*	Δ*n*
(Chlorite)	1.571 - 1.597	0.004 - 0.011
Quartz	1.544 - 1.553	0.009
(Pigeonite)	1.680 - 1.744	0.021 - 0.033
Zircon	1.925 - 1.993	0.060 - 0.062
Cassiterite	1.996 - 2.093	0.097
Rutile	2.603 - 2.903	0.286 - 0.287

Determination of optical sign of uniaxial minerals by use of gypsum λ-plate



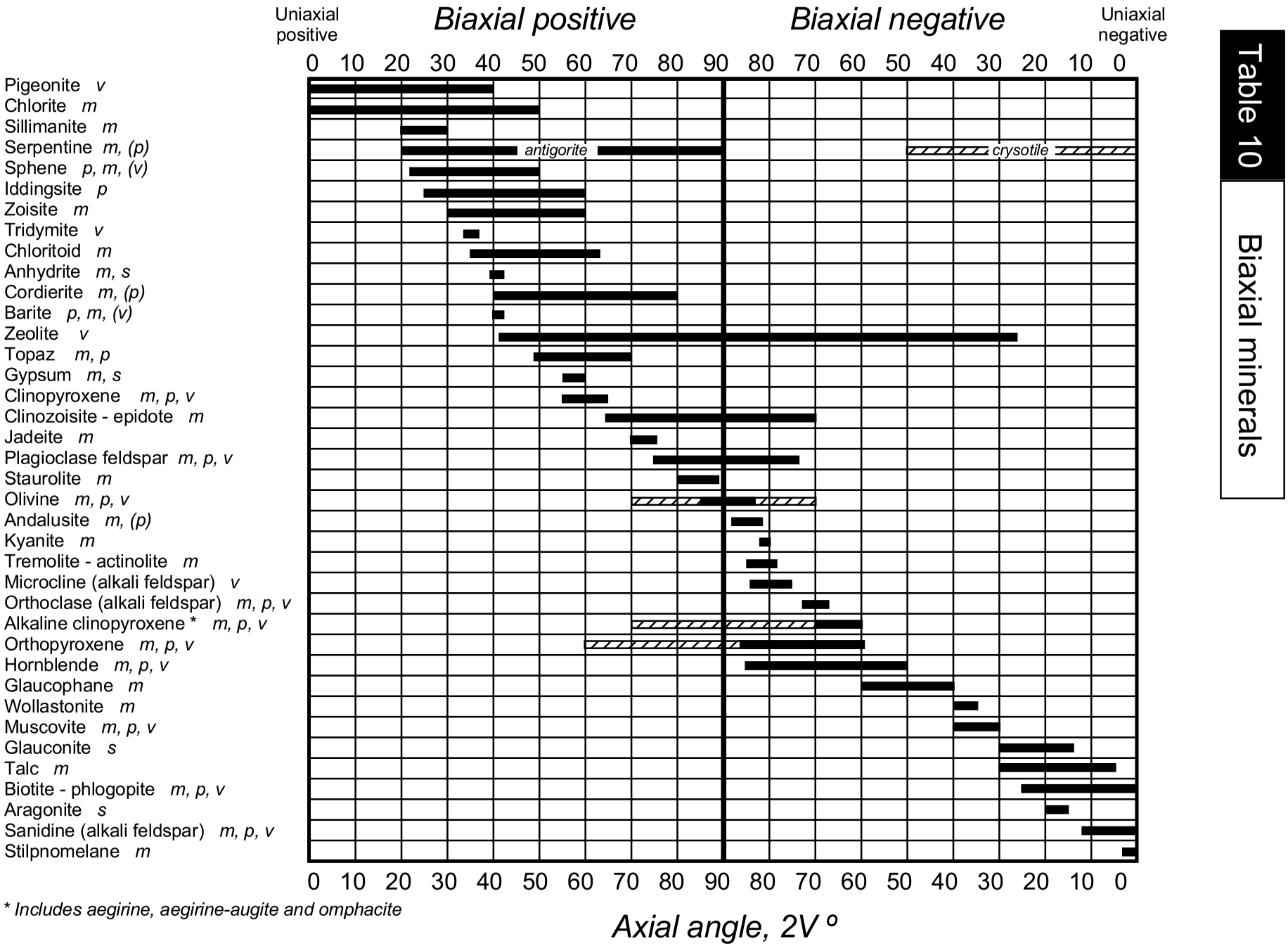
Uniaxial positive



Uniaxial negative

Table 10

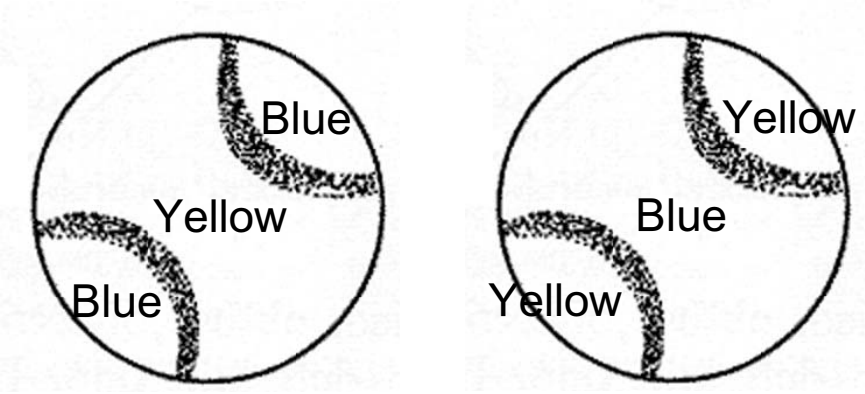
Biaxial minerals



* *Includes aegirine, aegirine-augite and omphacite*

Table 10	Biaxial minerals

Determination of optical sign of biaxial minerals by use of gypsum λ-plate



Biaxial positive Biaxial negative

Optical axial angle

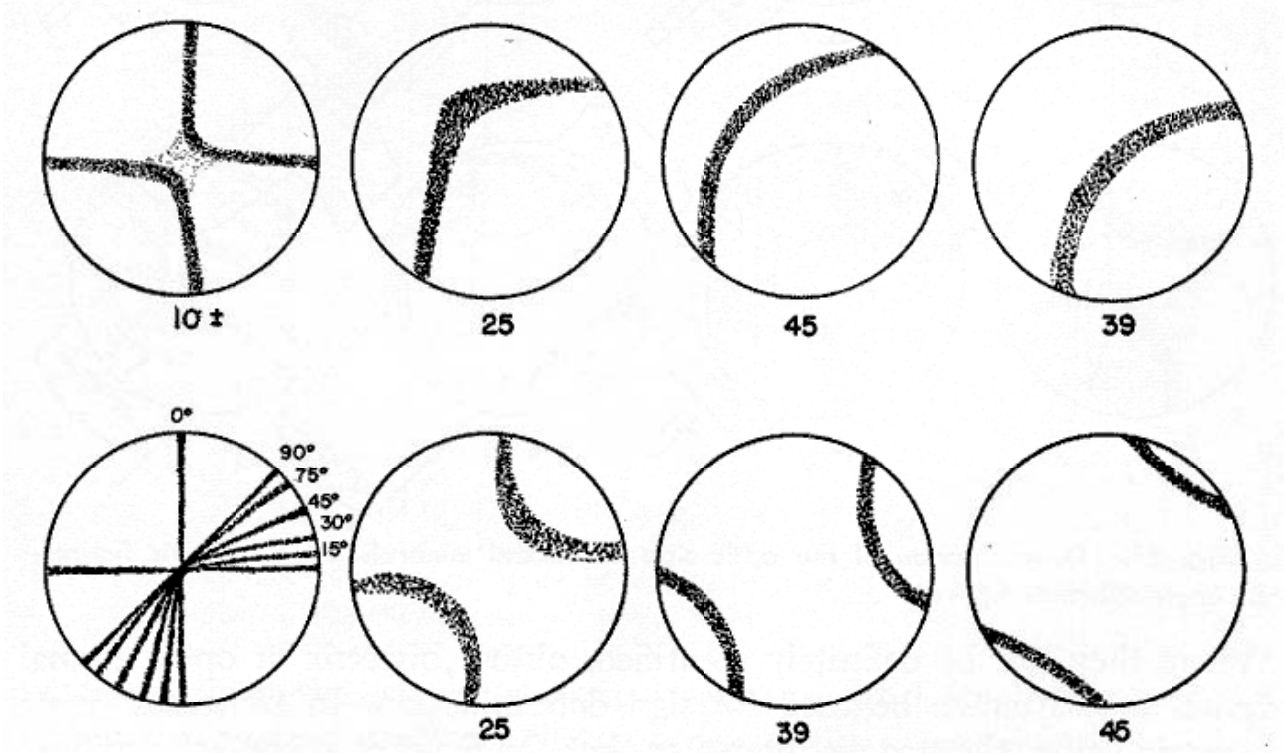


Fig. 28. Estimation of optic angle from acute bisectrix and optic axis figures.

After Moorhouse (1959). The study of rocks in thin section. Harper & Bros. New York