Optical Mineralogy

A short review

Refractive index

- N ~ 1/(velocity of light)
- Snell's law

$$n = \sin i / \sin r$$

- Mineral relief
  - Negative, low, medium high compared with surroundings
- Becke fringe
  - Bright halo moved toward material of higher n when viewing distance is increased

Mineral Relief

- Negative relief
  - Alkali feldspars, feldspathoids
- Low relief
  - Quartz
- Moderate relief
  - Mafic minerals, apatite
- High relief
  - Zircon, calcite, garnet

Indicatrix

- The 3-D figure defined by the minerals refractive index
- Isotropic
  - The indicatrix is a sphere and there is only one index of refraction
- Anisotropic
  - The indicatrix is an ellipsoid and there are two or three mutually perpendicular indices

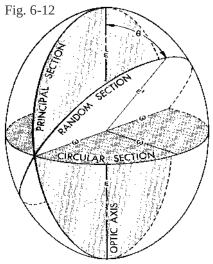
Double Refraction

- Anisotropic minerals exhibit double refraction for most grain orientations
- Double refraction causes interference coloration under polarized light
- The strength of double refraction is termed birefringence
- The maximum birefringence is a means to characterize minerals

Uniaxial Crystals

- Have two principal R.I. Termed ordinary (O) and extraordinary (E)
- Hexagonal and tetragonal minerals are uniaxial (i.e. quartz and apatite)
- Indicatrix is an ellipsoid of revolution
- O vibrates perpendicular to c axis
- E vibrates parallel to the c axis

Fig. 6-12



- Circular Section
  - (⊥ optic axis: all ω's)
- Principal Sections
  - (have ω and true ε: max & min n's)
- Random Sections (ε' and ω)
  - always have ω!!

Any cut through center of a uniaxial indicatrix will have ω as one *semiaxis*

Uniaxial Indicatrix

- Optically positive is prolate (elongate to c)
  - O fast
  - Quartz example
- Optically negative is oblate (flattened to c)
  - O slow
  - Apatite example

Biaxial Indicatrix

- Three mutually perpendicular principal indices, n_X, n_Y, and n_Z
- X is the fast vibration direction
  - lowest refractive index
- Y is the intermediate vibration direction
- Z is the slow vibration direction
  - Highest refractive index

Ordinary Light Observations

- Crystal form
- Cleavage
- Refraction relief
- Becke fringe
- Mineral color

Pleochroism

- The dependence of color on orientation in polarized light
- Some minerals have distinctive colors depending on their orientation when viewed in plane polarized light
  - Hornblende and Biotite have strong pleochrosim
  - Hypersthene has weak pleochroism

Crossed-Polar Observations

- Extinction angles
  - Relation of X, Y, and Z to crystallography
- Birefringence
  - Maximum difference ($n_Z - n_X$)

Extinction

- A mineral appears extinct (dark) if its vibration direction is parallel to the polarize under x-polarized light
- This is the case for:
  - Isotropic materials in any orientation
  - Uniaxial minerals perpendicular to c axis
  - Biaxial minerals perpendicular to optic axis
- Other orientations exhibit birefringence

Extinction Angle

- The angle measured between an extinction position and a prominent crystal direction
- For uniaxial minerals there is parallel extinction to the c axis
- For orthorhombic minerals there is parallel extinction to the three crystallographic axes
- Monoclinic and triclinic minerals have inclined extinction

Birefringence

- Other than isotropic materials and minerals oriented perpendicular to optic axis, the trace of two different indices lie in the plane of the thin section
- The difference ($n_Z - n_X$) is the birefringence
- The apparent birefringence ($n_Z' - n_X'$) is generally seen
- Only a few grains will show true ($n_Z - n_X$)

Measuring Birefringence

- Choose a grain with maximum interference colors
- Rotate 45° from extinction
- Match the mineral colors with a chart

Birefringence for I.D.

- Minerals may be classed as: low, moderate, high, and very high birefringence
- Low: 1st order – quartz, apatite
- Moderate: 2nd order – Augite
- High 3rd order – Biotite
- Very high – Carbonates, sphene