Thin-Section Petrography of Ceramics

Plane Polarized Light

- Use transmitted light (light comes from below through the specimen)
- Add a polarizer to filter out all light except that vibrating in ONE direction
MINERAL FEATURES IN PLANE POLARIZED LIGHT

- Transparency or Opacity
- Color
- Refractive Index
- Relief (how visible it is)
- Morphology (size and shape)
- Cleavage (breakage pattern)

TRANSPARENT
- Some light is transmitted through the grain
- The grain is either clear or colored in plane polarized light

OPAQUE
- Does not transmit any visible light
- Black in plane polarized light
- Need reflected light for further identification

COLOR
- May be a distinctive feature
- Minerals may be deeply colored OR have pale, subtle tints

Transparent Chlorite and Quartz with Opaque Magnetite

Glaucophane
Pleochroism in Biotite

REFRACTIVE INDEX (n)
- Measure of speed with which light passes through the crystal
- Usually simply measure relative to the mounting medium (1.54 for thin sections) or to quartz (also 1.54) using Becke line test

Garnet: $n = 1.72 - 1.89$
Quartz: $n = 1.54 - 1.55$
Epoxy: $n = 1.54$

RELIEF
- A measure of the relative difference in $n$ between a mineral grain and its surroundings
- Determined visually in ppl, used to estimate $n$

Quartz has low relief
Garnet has high relief

Grains with low relief

REFRACTIVE INDEX (n)
- Isotropic crystals have only 1 $n$
- Anisotropic minerals have 2 or 3 in different directions within the crystal (often almost exactly the same, occasionally very different as with calcite)
Calcite varies in relief depending on degree of microscope stage rotation.

**MORPHOLOGY**
- Grain Size
- Grain Shape

**6-sided grain of olivine**

Large Blobby Quartz and Small Radiating Fans of Chlorite

**Platy tablets and elongated grains of biotite mica**

**CLEAVAGE**
- Ability of a mineral to separate into smaller and smaller particles along a smooth plane surface
- Example: Micas have 1 good cleavage, peels off in perfect layers
- In thin section, mica cleavage planes appear as parallel lines if grain is oriented side up; if looking down onto the top surface of the grain it will just be very flat
Mica: side orientation showing single good cleavage

Mica from top, smooth surface

Cleavage Variables
- Presence/absence of cleavage
- Number of cleavage directions
- Angle between two cleavage directions
- Cleavage orientation relative to morphology (parallel to short or long direction)
- Cleavage quality (good or poor)

Two Cleavages at 90°, One Higher Quality

CROSSED POLARIZED LIGHT (cpl)
- Uses two polarizing plates with their allowed planes of vibration at right angles to each other
- Creates a different set of optical properties that can be observed in thin sections
ISOTROPIC

- Random or uniform arrangement of atoms in all directions
- Light moves with equal velocity in all directions, so there is only 1 refractive index (n)
- Dark in crossed polars

ANISOTROPIC

- Visible in crossed polarized light except at 4 positions of extinction as you rotate the stage
- Colors called interference colors or birefringence colors
- Color seen depends on retardation (slowness) (Δ) of 1 set of light waves compared to the other
- Also depends on crystal thickness (d)
  \[ \Delta = d (n_2 - n_1) \]

Michel-Levy Color Chart To Determine Birefringence (Δ, n1-n2)

Quartz in cpl, Low Interference Colors
Quartz in ppl is colorless

Olivine in cpl, Strong Interference Colors

Anhydrite, ppl

Calcite, ppl
Multiple (polysynthetic) twinning in plagioclase feldspar, cpl

Simple and multiple twinning in feldspars, cpl

Major Rock-Forming Minerals

- <40 of the more than 2,400 minerals known
- Most are silicates (contain SiO₂)
- Another 30 occur as accessory minerals

Calcite, cpl

Quartz, ppl

Quartz, cpl
PLAGIOCLASE FELDSPARS

Solid solution

Albite Na (AlSi3O8)                  Anorthite Ca (Al2Si2O8)

Plagioclase feldspar, ppl

Plagioclase feldspar, cpl

Simple + multiple twinning

Quartz

Plagioclase feldspar

Orthoclase feldspar, ppl
Orthoclase feldspar, cpl

Microcline feldspar

Muscovite Mica

Biotite mica, ppl

Biotite mica, cpl

Chlorite
Volcanic

Magma erupts onto surface of the earth, cools rapidly, forms fine-grained rocks (or even glass if cools too quickly to form mineral crystals)

Example: Basalt
IGNEOUS ROCKS

Plutonic

Formed deep within the earth from magma which has a chance to cool slowly and so more coarse-grained rocks are formed

Example: Granite

Detrital Sedimentary Rock Examples

- Shale
- Siltstone
- Sandstone
- Conglomerate and Breccia

Shale: Mainly clay-sized grains (<0.05 mm)

Shale (ppl)

Siltstone (0.005 – 0.0625 mm)

Siltstone  (ppl)
Sandstone (lithic grain), cpl

Sedimentary Carbonates:

Limestone with microfossils, ppl

Chert, cpl (microcrystalline quartz, 0.01 – 0.1 mm)

Chalcedony, cpl (cryptocrystalline quartz, < 0.01 mm)
METAMORPHIC ROCKS

Slate  Fine
Phyllite
Schist
Gneiss  Coarse

Metamorphic Rocks: Marble

Quartz-muscovite schist, cpl

Marble, ppl

Minerals and rock inclusions in ceramics