Last Time

1. Properties of light
2. Minerals and light transmission
Light

• **Light** is a propagating wave front that moves fast.

• The velocity of light in a vacuum is one of the most important constants in science:

\[ V_c = 2.988 \times 10^8 \text{ m/s} \]

(this constant is usually designated \( C \))
• When light travels from one medium to another (vacuum to air, air to water), interesting refraction effects occur.

The **Index of Refraction** \((n)\) of a material is a ratio of \(C\) to the speed of light through a material \((V_x)\).

\[ n_x = \frac{C}{V_x} \]
In order to do petrography, you need to restrict the light that passes through your mineral specimens to waves that vibrate in a single direction. This is done with the help of a polarizing lens:

Source: Olympus Microscopes
There are 3 optical classes of minerals:
A) **Transparent** (minerals that transmit light and images)
B) **Translucent** (minerals that only transmit light)
C) **Opaque** (minerals that do not transmit light at all)

Optical microscopy/thin-section petrography studies transparent and translucent minerals. The vast majority of minerals fall within these classes. Even minerals that you might at first think are opaque (pyroxene, biotite) are translucent if they are sliced thinly enough.
Minerals and Light

• All isometric minerals are isotopic.
• All other minerals are termed anisotropic.
In order to better visualize how light travels through minerals, geologists came up with the concept of the indicatrix.

The indicatrix is an imaginary object that is defined by the indices of refraction. For isotropic minerals, it is spherical. For anisotropic minerals, it is an ellipsoid.
Identification of rocks and minerals in hand specimen is one of the important skills that all geology students need to learn. But even the best geologists are limited in the number of substances that they can ID.

Enter microscopy…

… many characteristics that are apparent in hand specimen can be more diagnostic at microscopic scales.
Today’s Agenda

1. Minerals properties under PPL (Plane polarized light)
2. Mineral properties under XN (crossed Nichols/polars)
The Petrographic Microscope

• Know your enemy!
Know your enemy!

The Petrographic Microscope
The Petrographic Microscope

• Know your enemy!
The Petrographic Microscope

• Know your thin-section!
Optical Properties

A: Plane-polarized Light (PPL)

1) **Colour:** Most minerals are colourless under PPL, but some minerals are intensely coloured. As a general rule, dark coloured minerals in hand specimen (e.g., pyroxene, amphibole, biotite etc.), are coloured in PPL. Light coloured minerals (quartz, fluorite, feldspars, muscovite etc.) are colourless.

http://www.union.edu/PUBLIC/GEODEPT/COURSES/petrology/ig_minerals.htm
Optical Properties

A: Plane-polarized Light (PPL)

2) **Pleochroism.** This is an interesting phenomenon where anisotropic minerals appear to change colour as they are rotated in PPL. It has to do with variable indices of refraction and is related to the crystal class of the minerals.

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Optical Properties

A: Plane-polarized Light (PPL)

2) Pleochroism.

Orientation is important!
Optical Properties

A: Plane-polarized Light (PPL)

3) **Cleavage**. Same property as seen in hand specimen, but you are now looking at 2 dimensional slices.
Optical Properties

A: Plane-polarized Light (PPL)

3) **Cleavage**. The only time that you will see more than one cleavage direction is when you are looking down the c axis of the crystal.

http://www.uwgb.edu/DutchS/PETROLGY/Tsecplp.htm
Optical Properties

A: Plane-polarized Light (PPL)

4) **Relief**: the ratio of the index of refraction of a mineral to the index of refraction of the material immediately adjacent to it (usually glass).

http://www.brocku.ca/earthsciences/people/gfinn/optical/relief1.jpg

http://www.uwgb.edu/DutchS/PETROLGY/Tsecplp.htm
Optical Properties

A: Plane-polarized Light (PPL)

The **Becke Line Test** tells you if the index of refraction of a mineral is higher or lower than the medium it is immersed in (usually oils). The Becke Line is a bright band of light that forms at the edge of crystals due to and edge effect.

"Becke Line in, crystal high. Becke Line out, crystal low".
5) **Crystallinity.** A crystal with sharp, geometric edges is said to be **euhedral.** One that has rounded edges (e.g., water abraded) is said to be **anhedral.**
Optical Properties

B: Crossed Nichols (XN)
Optical Properties

B: Crossed Nichols (XN)

6) **Extinction**: occurs when the indicatrix aligns up with the polars and the entire crystal goes black (extinct).
Optical Properties

B: Crossed Nichols (XN)

6) **Extinction**: For some minerals, extinction occurs in a sharp or sudden fashion (straight or unit extinction). In some minerals, it is more like a curtain effect where part of the crystal fades out while other parts do not (strained extinction). Many minerals go extinct when the cleavage directions are parallel to polars (parallel extinction). Others go extinct when the cleavage is inclined relative to polars (inclined extinction).
Optical Properties

B: Crossed Nichols (XN)

- **Polarizer directions**
- **Straight extinction** (goes extinct over a narrow angle of rotation)
- **Stained extinction** (like a curtain effect)
- **Parallel extinction** (extinction occurs when cleavage or crystal edges are parallel to polarizers)
- **Inclined extinction** (extinction occurs when cleavage or crystal edges are inclined to polarizers)
7) **Birefringence.** This is the most important property of minerals under crossed polars. It is defined as the difference between the index of refraction of the minimum and maximum refractive indices of a mineral.

For uniaxial minerals; \( n_o - n_e \) or \( n_e - n_o \).

For biaxial crystals; \( n_a - n_c \) or \( n_c - n_a \).

As far as you are concerned, you see pretty colours under XN.
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8) **Optical Twinning.** Same thing as physical twins whereby two or more crystals of a single mineral grow together in a mathematically predicable pattern (involves twin planes, twin axes etc).
Optical Properties

B: Crossed Nichols (XN)

Optical twins are slightly out of phase with one another. As you rotate the stage, one section goes extinct before the other does.
Optical Properties

B: Crossed Nichols (XN)

Plagioclase feldspar exhibits **polysynthetic twinning** (resembles prison stripes). Microcline feldspar exhibits **tartan twinning** (resembles the plaid of a Scottish kilt). Orthoclase displays **Carlsbad twinning** (not as prominent as the other feldspars).
Optical Properties

B: Crossed Nichols (XN)

9) **Zonation**. Some minerals change their composition as they grow, particularly those that form continuous series through solid solution during igneous processes (e.g., olivine, plagioclase). This can result in optical zonation.
Today’s Stuff To Do

1. Take home Lecture test 1  (due next Tuesday; 11:00 AM)
   NO ONLINE LECTURE THIS WEEK

Next Week

1. Thin Section microscopy in the Lab
2. Quiz 3 (last one; monoclinic and triclinic models)
3. Mineralogy lectures begin
GY 302: Crystallography and Mineralogy

Lecture 7b: Optical Mineralogy Part 2

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