

GEOLOGY 17.01: Mineralogy

LAB 1: OPTICAL PROPERTIES AND THE PLM #1

Orthoscopic Light

Learning Objectives:

- Students will be able to describe optical properties of minerals in plane-polarized and cross-polarized light
- Students will be able to use the Nikon E200 POL microscope to determine optical properties of minerals in plane-polarized and cross-polarized light

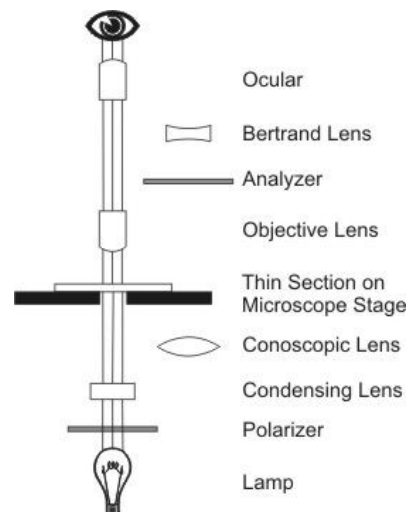
The polarized light microscope (PLM), or petrographic microscope, is a basic tool of the geologist. It exploits the fact that most minerals are translucent (i.e., if the mineral grain is thin enough then the light will pass through). When using a PLM, a petrographer examines light that has been altered by interactions with the internal structure of the mineral grains on its path through a sample. Each mineral is unique in its composition and/or structure, so each mineral has a unique affect on light when it passes through the mineral. Thus a geologist can identify minerals through their unique sets of optical characteristics. During laboratory sessions 2 and 3 you will investigate how a PLM works and how it can be used to characterize and identify minerals.

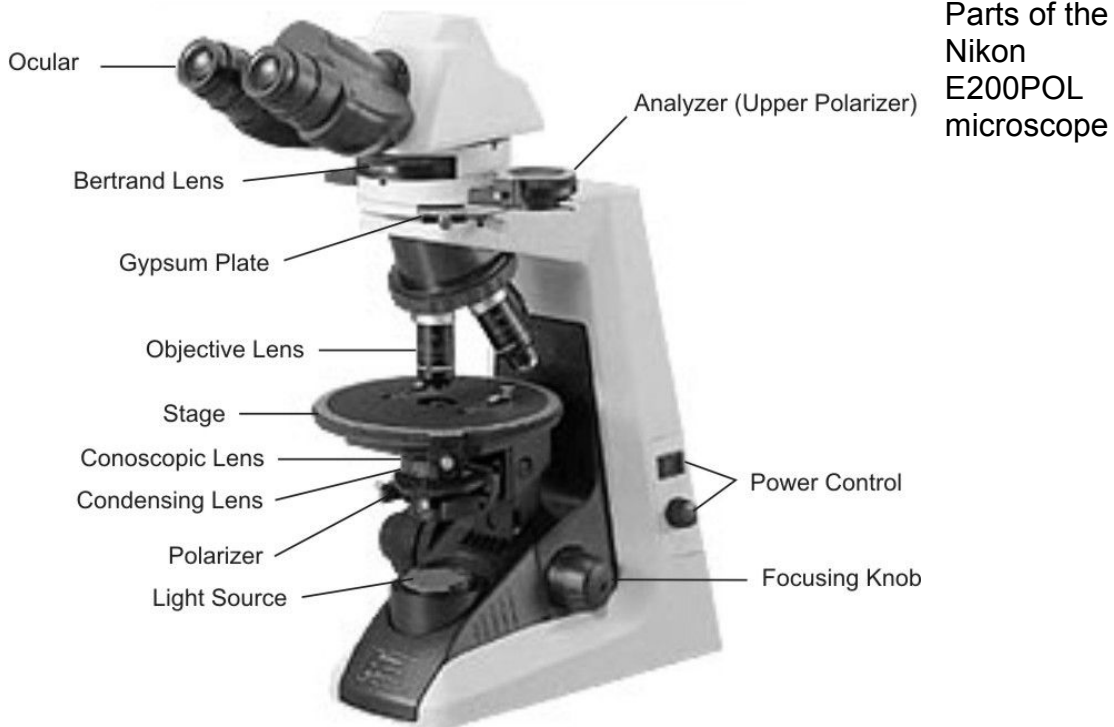
OPTICAL PROPERTIES IN PLANE-POLARIZED LIGHT

Light travels from the lamp at the base of the PLM, and through the polarizer before reaching the sample on the stage. The polarizer filters out all light waves except for those which vibrate in one specific plane. Thus we refer to the light that reaches the sample as plane-polarized. Two optical properties of minerals are documented in this simplest of PLM configurations: relief and color.

To examine **relief** or **color** of a mineral be sure that the PLM is configured as follows (see figure of the E200POL to identify the parts):

- **Bertrand lens OUT** of the light path
- **Analyzer OUT** of the light path
- **Conoscopic lens OUT** of the light path

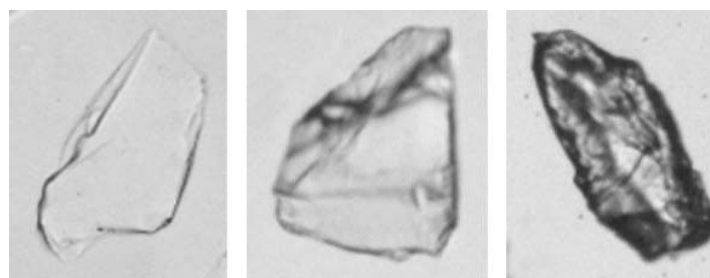




Relief and Relative Indices of Refraction (Becke Line)

Refractive Index (RI) is the ratio of the speed of light in a vacuum relative to the speed of light in another medium such as a mineral. The speed of light in any mineral will be slower than the speed of light in a vacuum and so RI values for minerals are always >1 ; the RI of translucent minerals range from 1.4 (opal) to 2.5 (diamond).

The greater the difference between RI of neighboring materials, the sharper and more strongly shadowed the boundaries between neighboring materials will appear. This relative contrast between a mineral and the material in which it is set within a thin-section (another mineral or epoxy) is called **relief**, and may be described as **low**, **medium** or **high**. Note that it is possible for the relief of a mineral to change as you rotate the stage. Such **variable relief** is commonly exhibited by calcite grains.

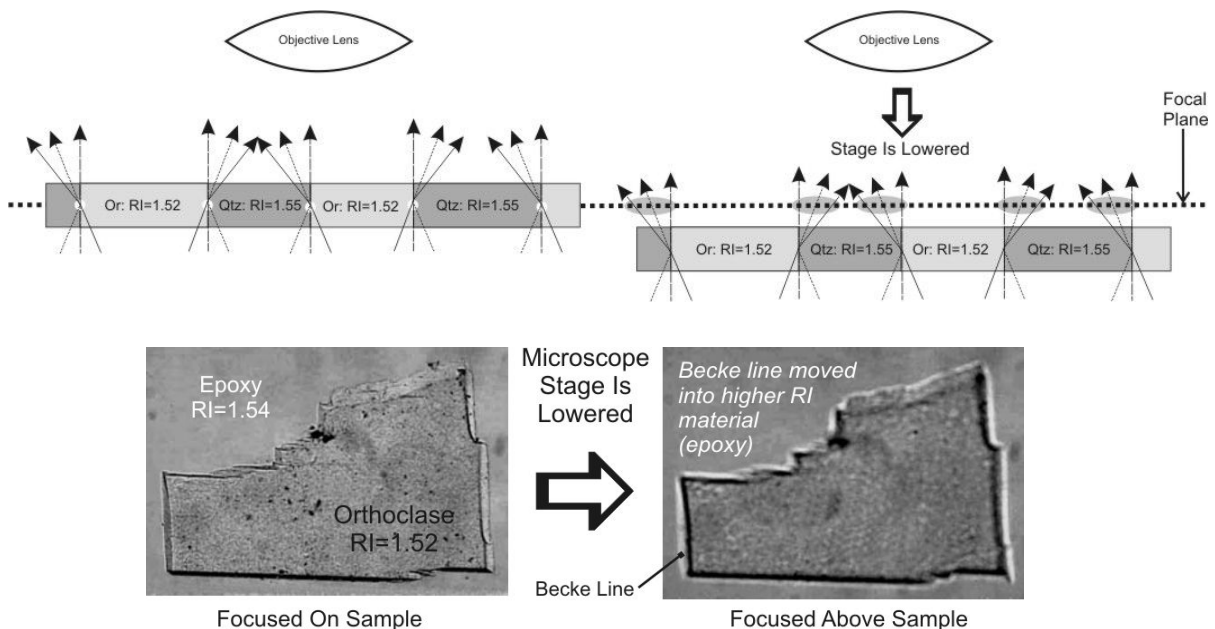


Low Relief
 $\Delta RI < 0.04$

Moderate Relief
 $0.04 < \Delta RI < 0.12$

High Relief
 $\Delta RI > 0.12$

It is possible to determine the relative values of indices of refraction for materials that are in contact by observing how light is reflected and refracted along grain boundaries. A band of light (**Becke line**) occurs along the boundary between two media with different refractive indices. At such contacts, oblique light rays will be refracted toward the material with a higher refractive index, and some rays will be internally reflected within the material with a higher refractive index. When a mineral grain is in focus, the Becke line will be narrow and occur along the grain contact. However, when the stage is lowered slightly and the microscope is focused on a plane slightly above the sample, the Becke line will broaden and shift into the material with the higher refractive index. (See figures below). The Becke line can be made more visible by reducing the intensity of light from the lamp, and by narrowing the diaphragm between the polarizer and the condensing lens.



The relief of a mineral in thin-section is commonly compared to that of the epoxy that affixes the sample to the slide which has a RI=1.54. Those minerals that have an RI less than that of epoxy are said to have **negative relief**, whereas those that have RI greater than that of epoxy are said to have **positive relief**. Most minerals have positive relief.

Examine the **Relief Scale Slide** and determine the relief characteristics for each of the six minerals.

	Degree of Relief (Low, Mod, High)	Sign of Relief (+ or -)
Apatite		
Beryl		
Fluorite		
Garnet		
Orthoclase		
Quartz		

Color and Pleochroism

Although color is notoriously unreliable as a diagnostic property for minerals in hand sample, in thin-section color is commonly diagnostic; like the powdered mineral material in a streak, the mineral sample in a thin-section is very thin (0.03 mm).

The light reaching a thin-section on a PLM is plane polarized. The wave vibrates in one plane and interacts with the ions along that plane. If the crystal lattice is such that the distribution of ions varies with the orientation of the crystal, then the light wave will interact with different set of ions as the sample is rotated. If the absorption of light varies as the sample is rotated, then the color will change as well. The change in a mineral's color, or intensity of color, when it is rotated is called **pleochroism**.

Full documentation of pleochroism includes the colors that the mineral exhibits, and the orientation of the mineral corresponding to each color. Most minerals exhibit their strongest colors when their length is oriented "east-west" on the stage. Tourmaline is one common mineral that exhibits an exception to this general pattern.

Examine the following thin-sections and determine the color/pleochroism:

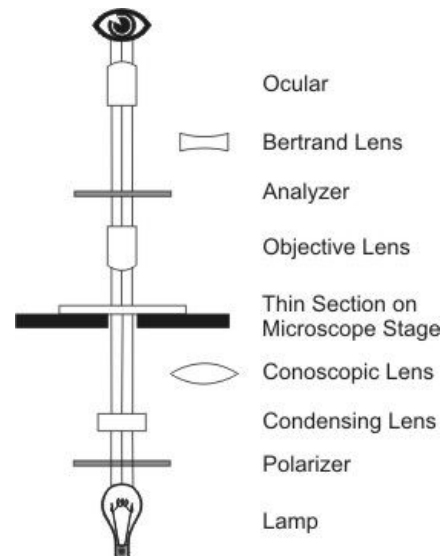
Piedmontite (Pink): _____
Augite _____
Hornblende _____

OPTICAL PROPERTIES IN CROSS-POLARIZED LIGHT

Light travels from the lamp at the base of the PLM, and through the polarizer before reaching the sample on the stage. The polarizer filters out all light waves except for those which vibrate in one specific plane. After the plane polarized light passes through the sample and the objective lens it reaches the analyzer, which is a second polarizing filter that blocks all light waves except for those vibrating perpendicular to those that the polarizer let pass. Thus we refer to the light that reaches the sample as cross-polarized. Three optical properties of minerals are documented in this simplest of PLM configurations: extinction angle, interference colors, and vibration direction.

To examine **extinction angle**, **interference colors** or **vibration direction** of a mineral be sure that the PLM is configured as follows (see figure of the E200POL to identify the parts):

- **Bertrand lens OUT** of the light path
- **Analyzer IN** the light path
- **Conoscopic lens OUT** of the light path

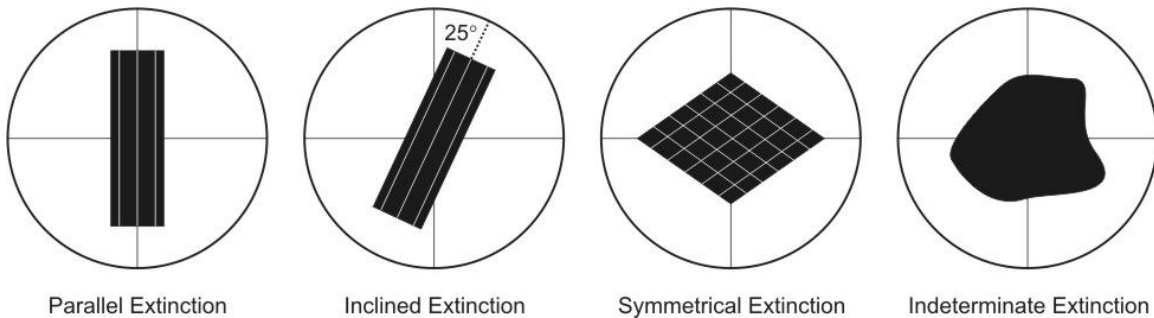


Extinction Angle

As you rotate an anisotropic mineral on the stage of a PLM with crossed polars the colors will brighten and darken every 90°. Note that the color (wavelength) does not change, just the brightness of the light (amplitude). When the mineral grain is darkest, it is said to be extinct. Extinction occurs when one vibration direction of a mineral is parallel with that of the polarizer so that all of the plane-polarized light is blocked by the analyzer.

If a mineral exhibits a distinct long direction or cleavage(s), then the angular relationship between these features and the four positions of extinction can be documented. Extinction angle cannot be measured for minerals that lack either a long axis or cleavage (e.g., quartz or olivine)

- **Parallel Extinction:** The mineral grain goes extinct when the long axis, or the cleavage is parallel to the crosshairs (e.g., orthopyroxene, biotite)
- **Inclined Extinction:** The mineral grain goes extinct when the long axis, or the cleavage is at an angle to the crosshairs. In this case, the angle between the mineral and the closest crosshair can be documented. (e.g. clinopyroxene, hornblende)
- **Symmetrical Extinction:** The mineral grain goes extinct when the crosshairs bisect the angle made by two distinct cleavages. (e.g, calcite, hornblende)



Examine the following thin-sections and determine the character of extinction (circle the correct answer; determine the angle if extinction is inclined):

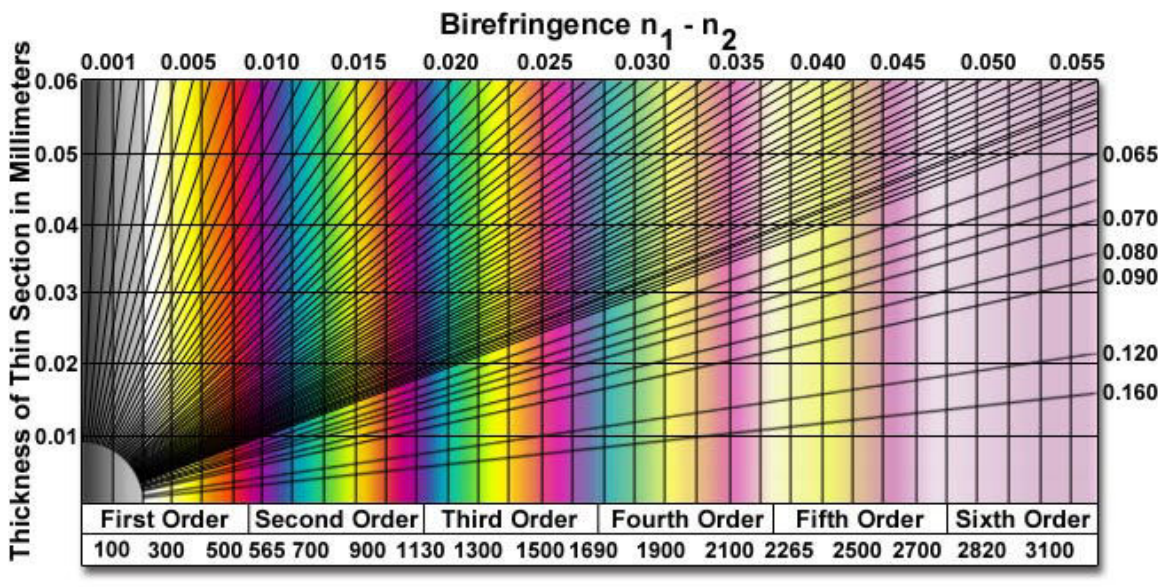
Calcite :	Parallel	Inclined (°)	Symmetrical	Indeterminate
Diopside:	Parallel	Inclined (°)	Symmetrical	Indeterminate
Enstatite:	Parallel	Inclined (°)	Symmetrical	Indeterminate
Tremolite:	Parallel	Inclined (°)	Symmetrical	Indeterminate

Interference Colors and Birefringence

When white light passes through an anisotropic mineral it splits into to waves that travel through the mineral at different speeds. How far behind the slow ray lags

depends on the thickness of the slide and the birefringence of the mineral ($RI_{Fast} - RI_{Slow}$). Because the wavelength of each color is different, the number of wavelengths that each color in the slow ray lags behind is different. When the rays recombine into a single ray when it emerges from the mineral, some colors will increase in intensity, whereas the intensity of others will decrease. Some colors will be cancelled out completely. The result will be a unique interference color that is controlled by the mineral's characteristic birefringence, and the thickness of the slide. All of the possible colors that could be produced by the interference of light that passes through a thin-section have been computed and are represented graphically as a spectrum in the figure below.

The thickness of a thin section is standardized to 0.03 mm so if the sample was prepared correctly then you can determine the birefringence of a mineral from the interference color chart based on the maximum interference colors exhibited by a mineral: follow the sloping line from where the matching interference color meets the horizontal 0.03mm line up to the corresponding birefringence value. An interference color is described in terms of its color, and its order (e.g., 1st order red, 2nd order blue, 2nd order red).



Examine the following thin-sections and determine the maximum interference colors and birefringence (δ):

- Calcite :** Color _____ Order _____ δ _____
- Enstatite:** Color _____ Order _____ δ _____
- Natrolite:** Color _____ Order _____ δ _____
- Tremolite:** Color _____ Order _____ δ _____

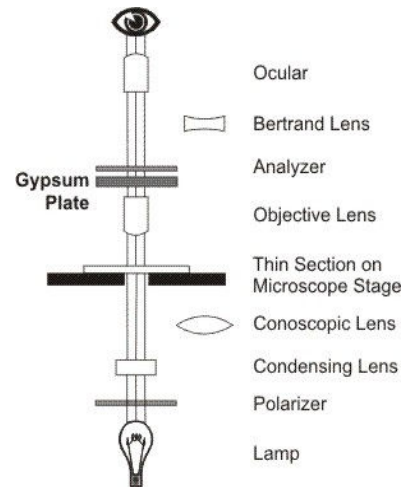
Sign of Elongation

If mineral crystals tend to grow in an elongate form, then the length of the mineral will be either parallel to the slow vibration direction or parallel to the fast vibration direction.

- **Length Slow (Positive Elongation):** Crystals are elongated parallel to the slow direction (the same elongation direction as gypsum).
- **Length Fast (Negative Elongation):** Crystals are elongated parallel to the fast direction (the opposite elongation direction as gypsum).

To determine the sign of elongation, do the following:

- Rotate the crystal into a northeast-southwest orientation (long direction of the crystal parallel to the slow direction in gypsum plate).
- Observe the interference color of the mineral grain.
- Insert the gypsum plate
- Observe the new interference color of the mineral grain.
- If the color **increases by a full order** (550nm) (e.g., 1st order grey to 2nd order blue; 2nd order blue to 3rd order blue-green) then the mineral is **length slow** or **positive elongation** (interference added)
- If the color **decreases by a full order** (550nm) (e.g., 1st order grey to 1st order yellow; 2nd order blue to 1st order grey) then the mineral is **length fast** or **negative elongation** (interference subtracted)



Examine the following thin-sections and determine the sign of elongation (circle the correct orientation).

Natrolite:	Length Fast/Positive	Length Slow/Negative
Enstatite	Length Fast/Positive	Length Slow/Negative
Tremolite:	Length Fast/Positive	Length Slow/Negative

