GLY 4200C
LAB EXERCISE 10

INTRODUCTION TO THE PETROGRAPHIC MICROSCOPE AND RELIEF, BECKE LINE, AND OBLIQUE ILLUMINATION

Locate all of the following microscope parts. Refer to Figure1

1) Eyepiece (note the power)
2) Objectives (note the powers)
3) Coarse focusing control
4) Fine focusing control
5) Bertrand lens knob
6) Analyzer knob or slide
7) Compensator slot
8) Compensators
9) Illuminator
10) Condenser
11) Condenser focusing knob
12) Polarizer
13) Substage iris diaphragm
14) Illuminator iris diaphragm
15) Stage
16) Mechanical stage

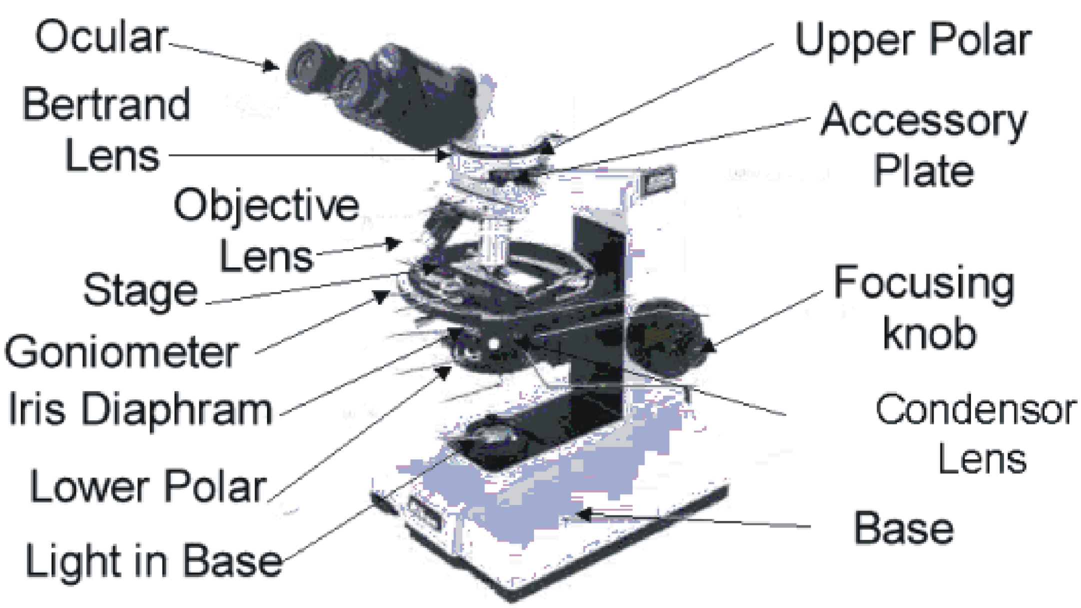

Figure 1

MICROSCOPE ADJUSTMENT:

1. Use a low power objective (3X or 4X).

2. Use a 10X eyepiece. Adjust the eyepiece so that the cross-hairs are visible.

3. Adjust the illumination so that it is even and covers the whole field of view.
4. Practice moving the microscope stage up and down. Move it until it is close to the objective. Observe the approach from the side, not looking through the eyepiece. Then focus by moving the stage downwards while looking through the eyepiece. Never focus while raising the stage. This procedure, if rigorously followed, makes it impossible to break a slide while focusing. Slides are EXPENSIVE ($20 up to more than $100 per slide).

5. Keeping the procedure in #4 in mind, place the slide you are given on the stage and get it in focus at low power.

6. Rotate the stage and observe any changes. The analyzer should be out. This is known as plane polarized light (pp).

7. Inset the analyzer. This is known as crossed-nicols (cn). Again, rotate the stage and observe what happens.

8. Change the objective to the next higher power. The stage should be lowered before the objective is moved, if necessary. Always grasp the objective at the turret, not at the end of the lens. Focus as in #4.

9. Observe the specimen under higher power, in pp and cn. The magnification of the microscope is given by the formula:

   Eyepiece Power x Objective Power = Magnification

   You should compute make a table listing the eyepiece power, objective powers, and all possible magnifications for your microscope.

10. Repeat steps 8 and 9 for the next higher power objective. **BE VERY CAREFUL WHEN USING HIGH POWER - MOST SLIDES ARE BROKEN UNDER HIGH POWER.**

11. Insert the Bertrand lens. If your microscope lacks a Bertrand lens, remove the eyepiece. This lens shows the image at the top of the objective lens and is used for generating interference figures. What do you see?

12. Practice inserting the compensators.

PLANE POLARIZED AND CROSSED NICOLS

There are two polarizing elements on petrographic microscopes. One is called the polarizer, the other is called the analyzer. The analyzer (and sometimes the polarizer) can be removed or inserted into the optical path.

Both polarizing elements limit the vibration direction of light to a single plane. If the polarizer alone is inserted into the light path, the light entering the eyepiece is said to be plane polarized. If the polarizer and analyzer are both inserted, and if the planes of vibration are mutually perpendicular, then the condition is called crossed nicols. Polarizing elements were originally called nicols after William Nicol whose early work with calcite crystals elucidated some of the properties of polarized light. Light passing through crossed nicols will be completely absorbed, in theory. If the polarizers are not of good quality or any part in the light path is strained, some light will get through. If a lot of light is getting through the polarizer and analyzer directions are not perpendicular. It is good practice to check a microscope every time you use it, before doing any work, to be sure the polarizer and analyzer directions are crossed.

ISOTROPIC CRYSTALS

Certain substances are isotropic to visible light. Isotropic means that light is transmitted with equal velocity in all directions throughout the substance. All isometric system minerals, as well as all amorphous substances, behave in this manner. When examined under crossed nicols such substances remain black as the stage is rotated. This condition is known as "extinction". Certain minerals are black in plane polarized light. These minerals are opaque. It is obviously impossible to ascertain if an opaque mineral is in extinction or not.

ANISOTROPIC MATERIALS

Many crystalline materials, including all uniaxial (hexagonal and tetragonal crystal systems) and biaxial (orthorhombic, monoclinic, and triclinic crystal systems) minerals behave in an anisotropic manner with respect to visible light. Light may travel at different velocities in different directions within the crystal and may be absorbed preferentially at certain frequencies.

One property of such anisotropic substances is their ability to rotate the plane of polarization of light. When such a substance is placed between a polarizer and an analyzer it may rotate the plane of polarization of light coming from the polarizer, so that some of the light will pass through the analyzer. Such substances go into extinction every ninety degrees, when the minerals polarization plane lines up with either the polarizer or analyzer privileged direction.

There is one exception to this behavior of light in an anisotropic medium. Along an "optic axis" in an anisotropic substance light will behave isotropically and a grain will remain in extinction between crossed nicols.

RELIEF

Relief, in optical mineralogy, is the difference between the index of refraction (RI - general symbol n) of the mineral and the surrounding material, which may be the mounting medium or other mineral grains. The mounting medium for thin sections is usually Canada balsam (n = 1.54) or some type of epoxy (n usually = 1.54). Permanent grain mounts are prepared the same way. Temporary grain mounts are prepared using various oils with different known refractive indices. For this reason the index of the mounting medium, whatever it may be, is often denoted n_{oil}, or just n_o. The RI of the crystal is referred to as n_{grain}, or n_g.

Relief is recognized by the following characteristics.

High relief - Bold outline along the edge of the grain. The interior of the crystal is rough, with shadows.

Moderate relief - Moderate outline along crystal edge, and reduced shadows on the grain interior

Low relief - Outline faint to invisible, interior smooth (no shadows)

Relief should be determined relative to the mounting medium whenever possible. Relief is the difference in absolute value between the n_{oil} and n_{grain}. If n_{grain} = 1.60, the relief would be

$$| n_{grain} - n_{oil} | = | 1.60 - 1.54 | = 0.06$$

The following scale of relief may be used:

Relief (numeric value)	Relief (term)	Example Mineral
< 0.04	Low	Halite
0.04-0.14	Moderate	Actinolite
0.14-0.24	High	Epidote
0.24-0.36	Very high	Gahnite
> 0.36	Extremely high	Rutile

(NOTE: Different authors use slightly different ranges. The above represents an average.)

Relief in mineralogy also shares one property with topographical relief. When the edge of the grain is slanted, the grain will have a bold outline and will appear to have a much higher RI than it actually does. Therefore it is necessary to look at all edges and several different grains when determining relief.

To determine the relief examine the mineral under low power (initially) with the iris diaphragm wide open, and in plane polarized light. Observe if the minerals stand out or blend into the background. Gradually close the substage iris diaphragm. This will accentuate the relief. Under certain circumstances medium power may be advantageous (obviously if the crystals are very small).

EXERCISE 1:

1) Examine the Relief slide. There are six minerals arranged (more or less) in a circle. The minerals are apatite, beryl, fluorite, garnet, orthoclase, and quartz. Determine the apparent order of relief among those minerals. Note the order (from high to low) on your lab report. Try to estimate the relief using the terms high, moderate, or low.

2)Put the analyzer in so that you are examining the slide under crossed nicols. Which minerals are in extinction? (There should be two - garnet and fluorite. On one slide the quartz will also be in extinction.)

Use the above information, coupled with the mineral identification on the slide, to decide if your microscope inverts the image. (Two dimensional inversion is a simple interchange through the center, **x** to -**x**, **y** to -**y**.) Note the result on your lab report. Report your results on the top of the Laboratory 10 Report Form.

TECHNIQUES FOR ESTIMATING THE INDEX OF REFRACTION

Thus far we have estimated the relief in a very general way. It is far more useful to be able to actually estimate the refractive index. This will also allow us to be able to differentiate between minerals whose index is slightly above or below the mounting medium. Minerals with a high, very high, or extremely high relief always have a RI greater than the mounting medium. There are two techniques for determining the relationship between n_{grain} and n_{oil}. These are called the Becke line and the oblique illumination methods.

Becke line - A grain mount of the mineral is placed on the microscope stage. Use low power initially but shift to medium if it seems advantageous to do so. Focus on a grain. Lower the stage very slowly (this will defocus the grain). A thin white line will generally be seen to move into the grain (if $n_{grain} > n_{oil}$) or out of the grain into the mounting medium (if $n_{oil} > n_{grain}$). If $n_{oil} \approx n_{grain}$ then two colored Becke lines appear. See Figure 2 for further explanation.

* If the focal plane of the microscope is centered within the thin section (purple line) the grain boundary is in sharp focus (Figure 2, left).
* If the focal plane is too high, rays that would normally appear at the grain boundary now appear outside it and a bright border appears outside the grain (Figure 2, center).
* If the focal plane is too low, rays that would normally appear at the grain boundary now appear inside it and a bright border appears inside the grain (Figure 2, right).

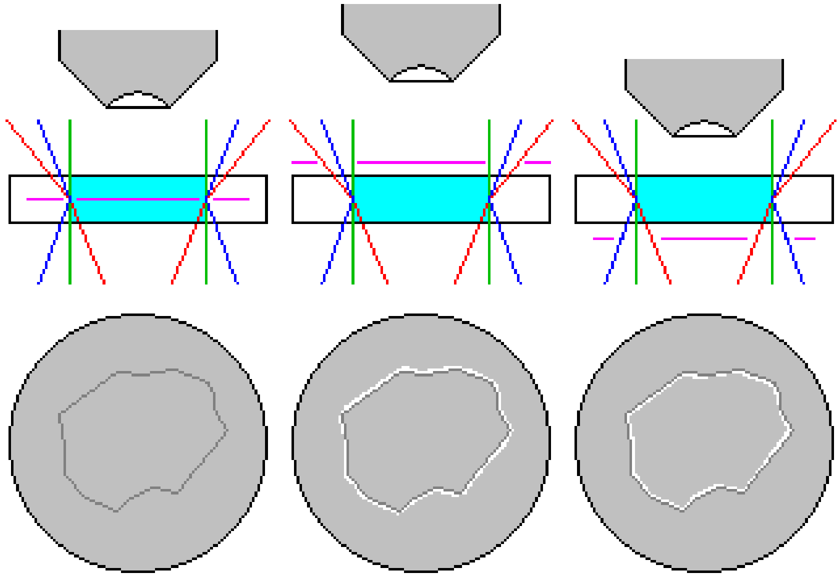

Figure 2

Figure 2: A grain that has lower refractive index than its surroundings will refract and relect light outward like a crude diverging lens.

Oblique illumination - Choose a grain for observation in PP light. The iris should be open at least part way (the edge of the grain must be visible). The edge of a compensator is inserted (any compensator will do) so that it casts a shadow on the grain. Observe which side the shadow appears on the grain relative to the direction from which the shadow enters the stage. Figure 3 summarizes the relations for most microscopes. **Note:** Some microscopes reverse the order shown. Be sure to examine a known mineral to ascertain how your microscope behaves, and note the result on your lab report).

For practice, determine the RI of fluorite and garnet from the relief slide. The correct values are $n_{fluorite} = 1.43$, and $n_{garnet} = 1.79$. To estimate the value of the refractive index:

1) Estimate whether the relief is low, moderate, high, very high, or extreme. If it is low or moderate, proceed to step 2. If it is high or above go directly to step 3.

2) Use the Becke line or oblique illumination methods to determine if the index is greater than or less than the mounting medium.

3) Using your estimate of relief and your knowledge of whether $n_{grain} > n_{oil}$ or $n_{oil} > n_{grain}$, estimate RI.

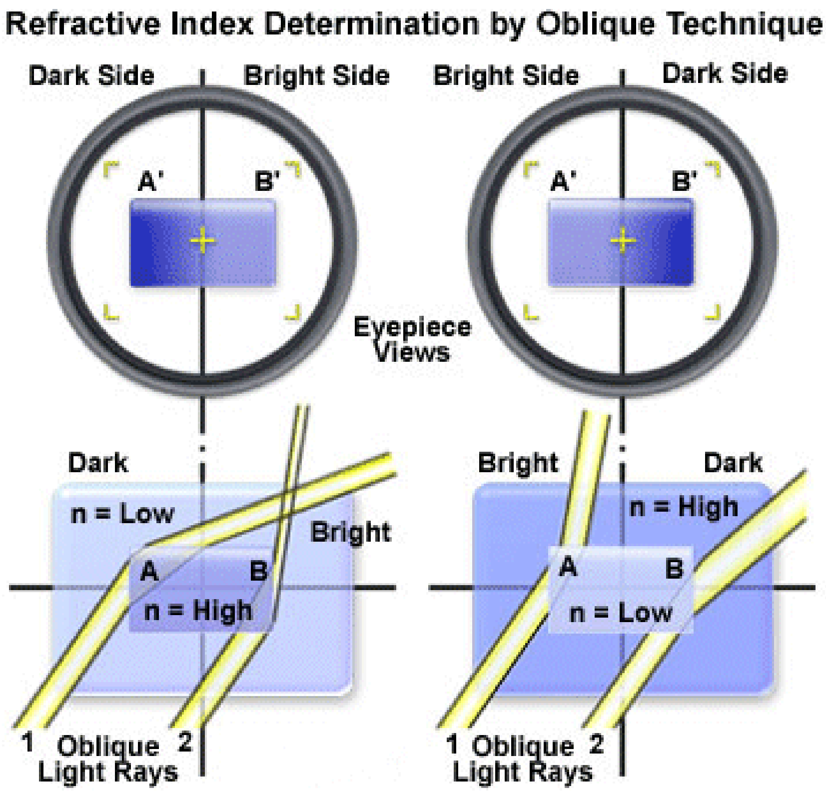

Figure 3

Figure 3:If the specimen is mounted in a medium of lower refractive index, shading that results from the oblique illumination will appear on the side opposite to that from which the light enters the specimen, and vice versa, as illustrated in Figure 3. For both diagrams presented in Figure 3, two equal sized oblique light rays are depicted entering the specimen through the surrounding medium at the same angle of incidence. At point A on the left-hand diagram, the light is spread over a larger area of the specimen than at point B, so that the area near point A on the specimen appears darker than the area near point B. Under these conditions, one side of the specimen will appear shaded or somewhat darker than the other side when viewed through the microscope eyepieces (A' and B' in the upper left portion of Figure 3). This is the case when the specimen refractive index is higher than that of the surrounding medium.

Examples:

1. Suppose you decide the relief is very high. An average value might be 0.30 greater than the mounting medium. Therefore 1.54 + 0.30 = 1.84. Keep in mind the actual value could range from 1.78 to 1.90 (if your estimate of relief is correct). As you get better at estimating relief you may decide the relief is on the high side of very high and use 0.33 as an estimate. This means your estimated RI is 1.87.

2. Suppose you estimate the relief is low. The Becke line test indicates that $n_{grain} < n_{oil}$. Low relief is about 0.02. Therefore 1.54 - 0.02 = 1.52. NOTE: With LOW relief both the Becke and Oblique Illumination methods give colored lines if the difference in RI's is less than about 0.02 to 0.03. If no colored lines are seen the refractive indices are certainly 0.02 or more different.

EXERCISE 2: Examine the grain mounts shown in Table 1 of the Lab 10 report form and determine:

1) The relief.

2) The relationship between n_{grain} and n_{oil}.

3) Your best estimate of the RI of the mineral.

Report your results as follows on the report form in Table 1. Your reports should include your name, date, microscope #, microscope brand and all information requested on the laboratory handout. Reports are due at the next meeting of your lab section.

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WRITE-UP FOR OPTICAL MINERALOGY LABS

Each successive optical mineralogy laboratory will introduce new features while examining a major group of rock forming minerals. You should examine all thin sections for all features introduced up to that point. Among the features you will be seeing are:

A. Relief
B. Estimation of the index of refraction
C. Isotropic versus Anisotropic behavior
D. Exsolution
E. Zoning
F. Twinning
G. Color in plane polarized light
H. Pleochroism
I. Interference color
J. Birefringence
K. Cleavage
L. Extinction Angle
M. Uniaxial Interference Figures
N. Biaxial Interference Figures

For each assignment you should examine each thin section. Spend a few minutes noting all the features you can see. Prepare a representative sketch of selected features, as directed in each lab assignment. Add a short written description. The written descriptions should elaborate on features shown in the sketch and describe all features seen that are not clearly shown in the sketch. Each sketch must be clearly labeled. The label must include the **mineral** (or, later, the **rock**) **name**, the **magnification** (eyepiece x objective) used, and whether the observations were done under plane-polarized (**pp**) or crossed-nicols (**cn**) conditions. You may split the sketch (half pp and half cn) is this is advantageous and each side is clearly labeled.