EES - 311: MINERALOGY LAB REPORT 2

"All the work of the crystallographers serves only to demonstrate that there is variety everywhere where they suppose uniformity...that in nature there is nothing absolute, nothing perfectly regular"

- Georges-Louis Leclerc de Buffon

Om Vaknalli

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4th Year BS-MS EES Major

AIM

1. To identify and describe pleochroism of minerals.
2. To identify the order, degree and colour of birefringence of mineral(s) in cross polarized light.
3. To determine relief of the mineral (low, medium or high relief).
4. To describe the extinction and extinction angle of the mineral.
5. To identify the presence and type of twinning in the mineral.
6. To estimate the occurrence of zoning in the mineral.

THEORY

1. **Plane Polarised Light:** Plane polarized light (PPL) has one single plane of vibration, in which the direction of vibration is always perpendicular to the direction of propagation.

2. **Cross Polarised Light:** It is a light produced by a process wherein two polarisers with perpendicular orientation to one another are used on the incident and reflected lights. Under cross-polarised light, birefringent structures which are otherwise invisible become apparent.

3. **Isotropic Minerals:** It refers to the optical properties of the mineral, which are the same and independent of the orientation. Minerals that are isotropic are the minerals with cubic symmetry (the symmetry of minerals crystallized in the cubic system have $a=b=c$ and $\alpha=\beta=\gamma=90°$).

4. **Anisotropic Minerals:** It means that the properties of the material are not the same at all points or directions, but may vary continuously with changing direction (orientation) of observation. Examples of anisotropic behavior when changing orientation include different absorption of light, different refractive indexes, etc. All minerals, other than those belonging to the isometric system, are anisotropic.

5. **Ordinary and Extraordinary Rays:** One of the rays passing through an anisotropic crystal obeys the laws of normal refraction, and travels with the same velocity in every direction through the crystal. This light ray is termed the ordinary ray. The other ray travels with a velocity that is dependent upon the propagation direction within the crystal, and is termed the extraordinary ray. Therefore, each light ray entering the crystal is split into an ordinary and an extraordinary ray that emerge from the distant end of the crystal as linearly polarized rays having their electric field vectors vibrating in planes that are mutually perpendicular.

6. **Pleochroism:** A mineral shows pleochroism when the absorption colour changes when the stage is rotated under plane polarised light. It means that absorption of specific light wavelengths depends on the crystal orientation. This happens when the mineral is anisotropic. However, the intensity of pleochroism (the changing of colour) can be different (from strong to weak)**.**

7. **Relief:** It refers to the relative difference in refractive indices (RI) between neighboring crystals. Although relief is most useful as a comparative term (some minerals show higher relief than others), the relief can be positive or negative compared to a reference material of fixed and known RI. This reference standard is the resin, which has a known refractive index (n = 1.54 - 1.55). All minerals with relief higher than the resin have positive relief and all minerals with lower relief than the resin, have negative relief.

- *Positive Relief* - It refers to a mineral that stands out higher than the medium, and the mineral has a higher refractive index than its surroundings.
- *Negative Relief* - It refers to a mineral that appears to "sink in", and the mineral has a lower refractive index than its surroundings.
- *High Relief* - Minerals with high relief have sharp grain boundaries, and the difference in the two refractive indices is large.
- *Low Relief* - If the difference in the two refractive indices is small, it does not show up well in the enclosing material, and the mineral is said to have low relief.

8. **Extinction:** On rotation of the microscope stage, minerals that are anisotropic will become dark in one particular orientation under cross polarised light. Such minerals are said to be in extinction. Extinction angles can only be measured relative to planar crystal boundaries or cleavage planes. The extinction angle is the measure between the cleavage direction or habit of a mineral and the extinction. The extinction can be parallel, symmetric or oblique. Orthorhombic, tetragonal and hexagonal crystals = 0 extinction angle, i.e., they have straight extinction. Monoclinic and triclinic minerals have a finite extinction angle, i.e., they have inclined extinction.

- *Parallel Extinction* - The mineral grain is extinct when the cleavage or length is aligned with one of the crosshairs. The extinction angle (EA) = 0°
- *Inclined Extinction* - The mineral is extinct when the cleavage is at an angle to the crosshairs. EA > 0°
- *Symmetrical Extinction* - The mineral grain displays two cleavages or two distinct crystal faces.
- *Undulatory Extinction* - This means that different parts of a crystal reach extinction at slightly different angles, giving the crystal an irregular, mottled look.

9. **Birefringence:** Birefringence is a value that can be used to determine interference colours of a mineral section in cross polarised light. Interference colour is the colour exhibited by a section of an anisotropic mineral under cross polarised light. The birefringence is the difference between the largest and smallest refractive index of a mineral section. The birefringence of isotropic minerals is zero in any direction.

- Common minerals with low order interference colours - Quartz, Plagioclase, K-Feldspar, Chlorite
- Common minerals with moderate order interference colours - Amphiboles, Pyroxenes
- Common minerals with moderate-high order interference colours - Muscovite, Biotite, Olivine
- Common minerals with very high order interference colours - Calcite

10. **Twinning:** Twinning is recognized by adjacent portions of a single crystal having different extinction positions. Twinning is most easily observed with crossed polars. A twin is a symmetrical growth of two or more crystals of the same mineral. The common plane of the twinned crystals (which is called the twinning plane) is a symmetry plane, seen in thin section as a straight line separating two identical crystals, which have a symmetrical optical orientation to the twinning plane.

- *Simple twinning* - Composed of only two parts.
- *Contact Twinning* - Contact twins share a single composition surface/twinning plane, often appearing as mirror images across the boundary. Plagioclase, quartz, gypsum, and spinel often exhibit contact twinning.
    - *Manebach Twinning* - A type of simple contact twinning seen in the orthoclase on the {001} plane. Diagnostic of orthoclase when it occurs.
    - *Baveno Twinning* - It is a type of simple contact twin on the {021} plane exhibited by orthoclase, microcline and other members of the feldspar group.
- *Merohedral Twinning* - It occurs when the lattices of the contact twins superimpose in three dimensions, such as by relative rotation of one twin from the other. An example is metazeunerite.
- *Penetration Twinning* - In this type of twinning, the individual crystals have the appearance of passing through each other in a symmetrical manner. Orthoclase, staurolite, pyrite, and fluorite often show penetration twinning.
    - *Carlsbad Twinning* - It forms a penetration twin in the mineral orthoclase. Crystals twinned under the Carlsbad Law show two intergrown crystals, one rotated 180^o from the other about the [001] axis. Carlsbad twinning is the most common type of twinning in orthoclase, and is thus very diagnostic of orthoclase when it occurs.
    - *Swallow-tail Twinning* - Form of penetration twinning in which two monoclinic crystals twin to form a v-shaped model. This form of twinning is most frequently observed in the mineral Gypsum. Twinning occurs on the {100} plane.
- *Multiple or Repeated Twinning* - If several twin crystal parts are aligned by the same twin law, they are referred to as multiple or repeated twins.
- *Polysynthetic Twinning* - If more than two crystals are multiple twins and have parallel twinning planes, the twinning is called polysynthetic twinning. Albite, calcite, and pyrite often show polysynthetic twinning.
    - *Albite Twinning* - The Albite twin law {010} indicates that the twins make a form, the faces are parallel to the mirror plane (010), i.e. perpendicular to the b-axis. Albite twinning is so common in plagioclase, that it's presence is a diagnostic property for identification of plagioclase when seen with crossed polarizers.
    - *Pericline Twinning* - It is a type of crystal twinning which show fine parallel twin laminae typically found in the alkali feldspars microcline. The Pericline law has faces in the zone [010], parallel to the b axis.
- *Cyclic Twinning* - When the multiple twins do not have parallel twinning planes, they are called cyclic twins. Rutile, aragonite, cerussite, and chrysoberyl often exhibit cyclic twinning, typically in a radiating pattern.
- *Lamellar Twinning* - If the individuals of polysynthetic twins are thin plates, the twinning is called lamellar e.g. plagioclase feldspars.
- *Tartan / Cross-Hatched Twinning* - It is a combination of albite and pericline twinning. It is the trademark twinning for identifying microcline.

- *Calcite Twinning* - The two most common twin laws that are observed in calcite crystals are {0001} and the rhombohedron {011’2}. Both are contact twins, but the {011’2} twins can also occur as polysynthetic twins that result from deformation.

11. **Zoning:** Crystal zoning is a texture developed in solid-solution minerals and characterized optically by changes in the color or extinction angle of the mineral from the core to the rim. Zoning is a record of incomplete continuous reaction relations between a melt and the crystallizing solid solution as intensive parameters were changing in the magma system faster than kinetic rates could maintain equilibrium. Zoning can be of four types: Normal or continuous zoning; reverse zoning, oscillatory zoning and patchy zoning.

- *Normal or continuous zoning* - zoning in which the outer portions of the crystal have a lower-temperature composition than the core. Usually reflects progressive change of melt composition during growth of the crystal. Plagioclases are normally zoned from calcic cores to more sodic rims.
- *Reverse zoning* - zoning in which the outer portions of the crystal have a higher temperature composition than the core. Usually reflects mixing between host magma and more primitive magma during crystal growth.
- *Patchy zoning* - In many igneous rocks, the plagioclase shows patchy zoning, which consists of irregular corroded cores, the corroded portions having been filled and surrounded in crystallographic continuity by more sodic plagioclase. Several stages of patchy zoning may be present. This microstructure has been interpreted as being due to initial crystallization of relatively calcic plagioclase in a water-undersaturated magma at depth, followed by decrease in confining pressure, causing resorption, owing to the fact that the melting point decrease with falling pressure in most water-deficient system. The resorption appears to be followed by new crystallization of more sodic plagioclase that is stable under the lower-pressure condition, as rims on the cores and filling of cavities in the cores, forming pseudo-inclusions of sodic in more calcic plagioclase.
- *Oscillatory zoning* - zoning in which the composition varies cyclically from core to rim, producing concentric rings of lower and higher extinction angle and interference color.

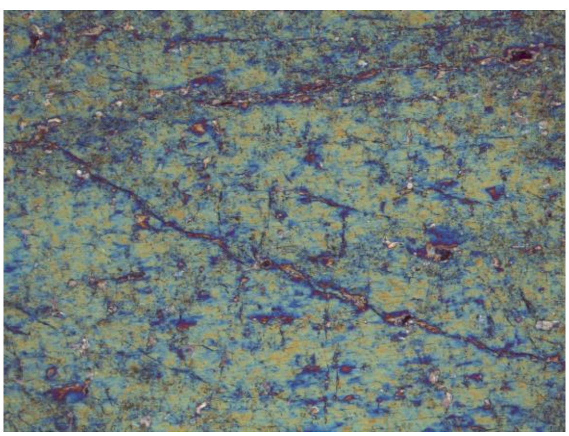
SILICATE MINERAL ANALYSIS

MINERAL NO.	1	2	3	4	5	6	7	8
Relief	Moderate to High	Positive High	Positive High	Positive Moderate	Positive High	Low	Moderate to high positive	Strong
Pleochroism	Weak	Strong	Weak	Weak	Weak	Absent	Moderate to strong	Strong Presence
Isotropism	Anisotropic	Anisotropic	Anisotropic	Anisotropic	Anisotropic	Anisotropic	Anisotropic	Isotropic
Extinction	Inclined	Near Parallel	Parallel	Inclined	Parallel	Inclined	Inclined	Near Parallel
Extinction Angle	38 - 45 degrees	Approx. 0 degrees	0 degrees	35 - 45 degrees	0 degrees	45 degrees	12 - 34 degrees	Approx. zero degrees
Order of Birefringence	High, 3rd	High, 2nd - 3rd	Low, 1st	High, 3rd	High, 3rd	Low, 1st	Moderate to Very High, 2nd - 4th	High,
Twinning	Polysynthetic	Simple, Lamellar	Simple, Lamellar	Simple, Polysynthetic	None	Polysynthetic, Albite	Contact	None
Mineral	**Diopside**	**Aegirine**	**Enstatite**	**Augite**	**Olivine**	**Anorthite**	**Hornblende**	**Biotite Mica**
Chemical Formula	CaMgSi2O6	NaFe(III)Si2O6	Mg2Si2O4	(Ca,Mg,Fe,Na)(Mg,Fe,Al)(Si,Al)2O6	(Mg,Fe,Mn)SiO4	CaAl2Si2O8	(K,Na)(Ca,Na)2(Mg,Fe,Al)5Si8O22(OH)2	K (Mg, Fe) 3(Al Si 3O 10) (F, OH) 2

MINERAL PICTURES

1. Diopside





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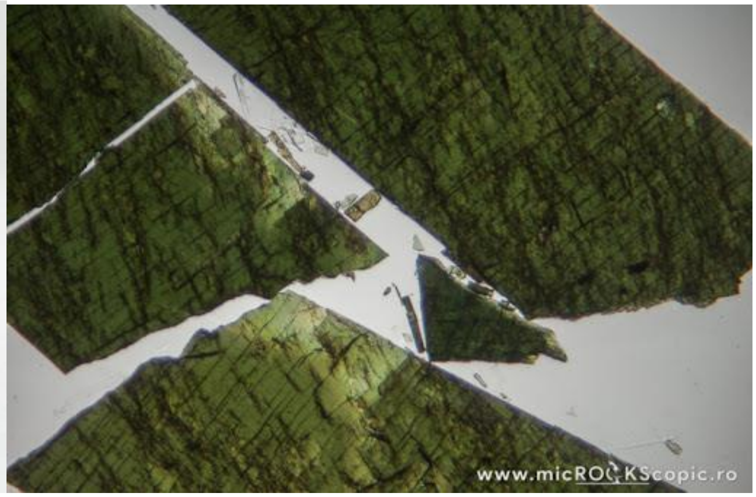

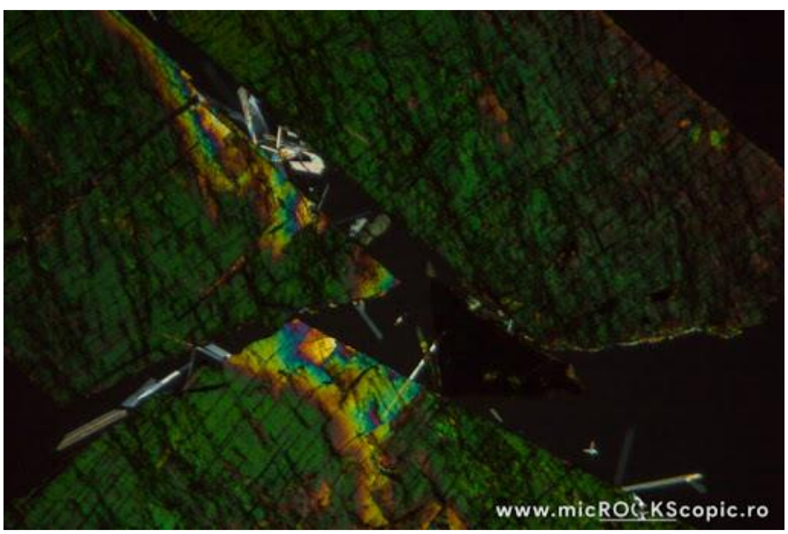

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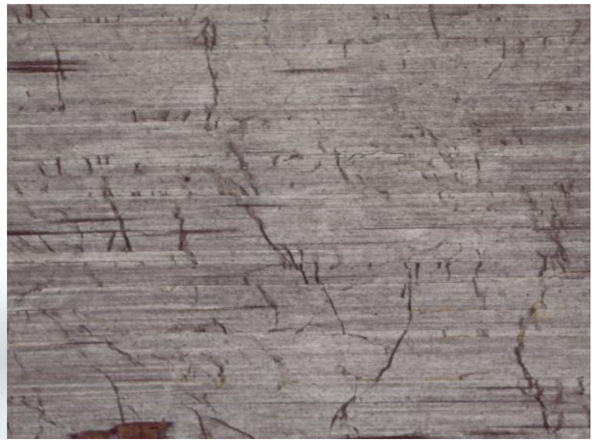

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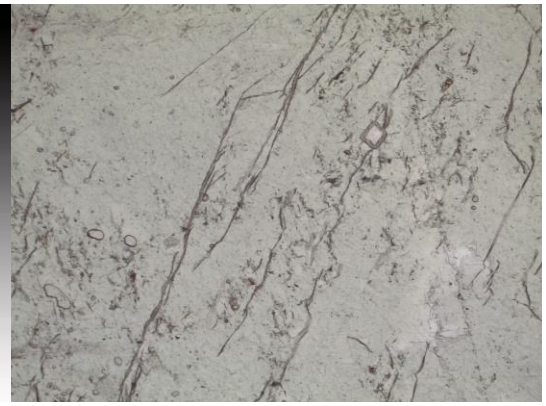
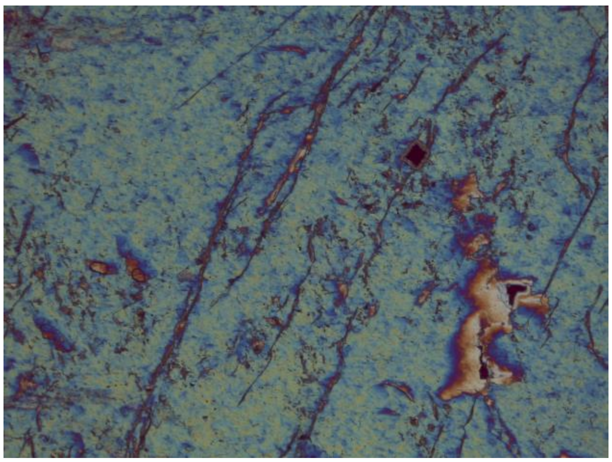
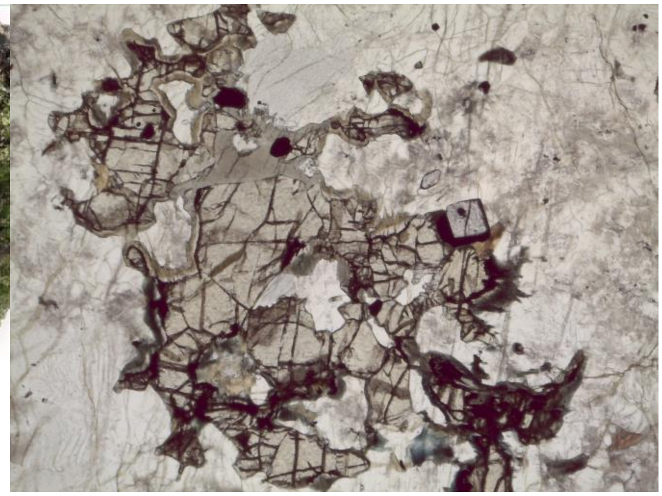
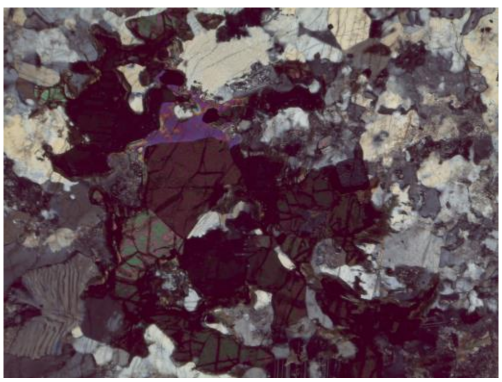
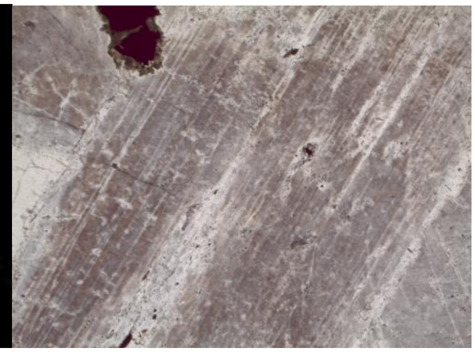
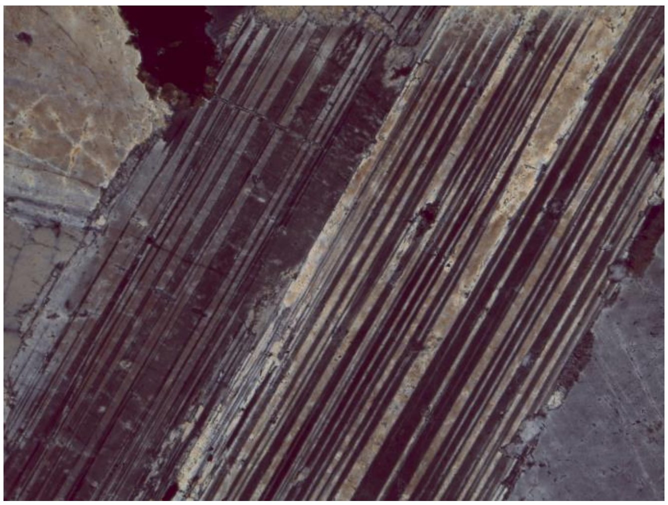



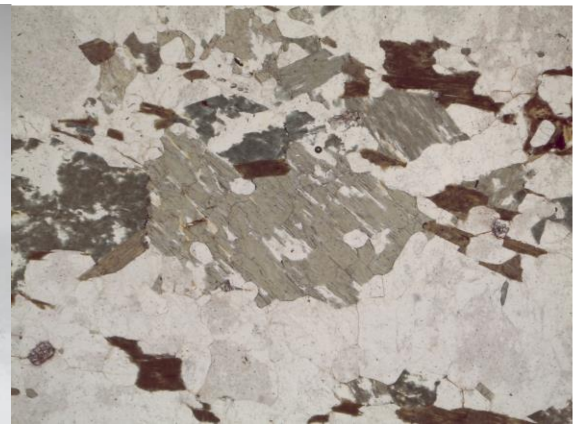
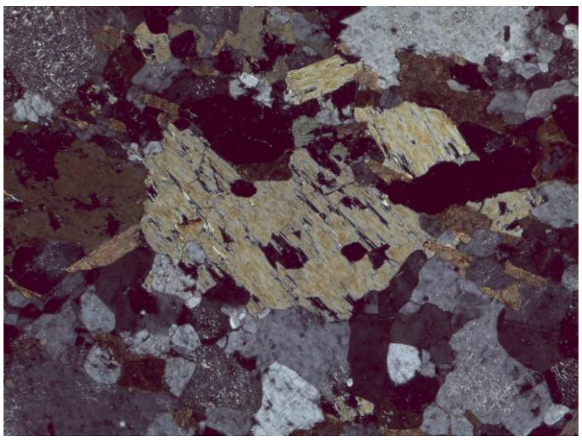
5. Olivine

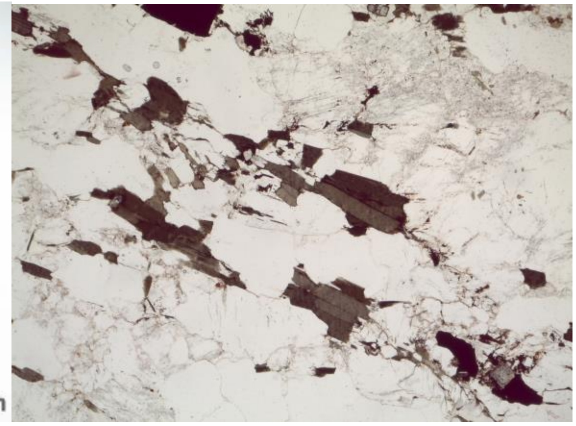
6. Anorthite

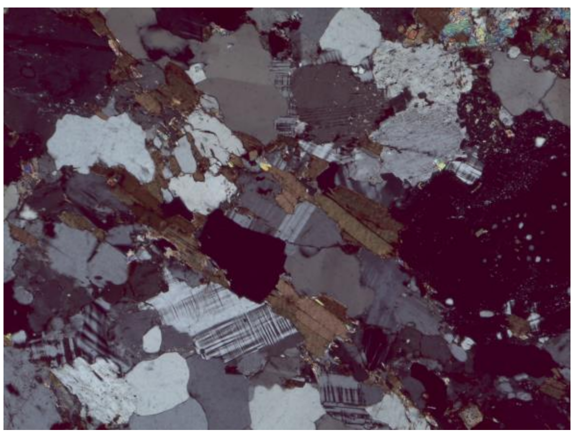




7. Hornblende

8. Biotite Mica





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