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Subject: EES – 346, Petrology Lab, Lab 3

Basic Definitions: -

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 α=β=γ=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.) Opaque Mineral: A mineral is opaque if it appears totally black and stays black regardless of the rotation of the stage under plane polarised light.

7.) Translucent Mineral: Light can pass through the mineral but is diffused so that images cannot be seen clearly.

8.) Transparent Mineral: If the mineral appears anything other than totally black (no matter what other colour is observed) it means that the light passes through the mineral, so the mineral is transparent.

9.) Crystal shape: Can be either euhedral, subhedral or anhedral (check lab 1 for more details).

10.) Crystal Habit: Following are the different crystal habits:

- Individual crystal analysis:
  - Cubic - cube shapes
  - Octahedral - shaped like octahedrons
  - Tabular or Platy - rectangular shapes
  - Equant - a term used to describe minerals that have all of their boundaries of approximately equal length
  - Acicular - long, slender crystals
  - Prismatic - abundance of prism faces
  - Bladed - like a wedge or knife blade
  - Capillary or Filliform - hairlike or threadlike
  - Foliated or Micaceous - easily split into sheets (muscovite, biotite)
  - Others - Stubby, Elongate, etc.

- Crystal aggregation analysis:
  - Arborescent or Dendritic - tree like growths
  - Reticulated - lattice like groups of slender crystals
  - Radiated or Divurgent - radiating groups of crystals
  - Fibrous - elongated clusters of fibers
  - Botryoidal - smooth bulbous or globular shapes
  - Globular or Colloform - radiating individual crystals that form spherical groups
  - Drusy - small crystals that cover a surface
  - Stellated - radiating individuals that form a star-like shape
  - Massive or Blocky - appearing as a solid mass with no distinguishing features
  - Granular - composed of many individual grains
  - Stalactitic - appearing stalactite shaped
  - Plumose - having feathery appearance
  - Reniform - having a kidney shaped appearance
  - Mammillary - having breast like shape
  - Elliptic or Pisolitic - composed of very small ellipsoidal structures
  - Others – Dipyramidal, Fine-grained, Asbestiform, etc.

11.) 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).

12.) Cleavage: Cleavages are planar surfaces of low cohesion produced by weaker atom bonds across them. Cleavages seen in thin sections are linear expressions of the intersection of particular planes of crystal faces with the cut surface of the thin section. Some minerals may have three “good” cleavages (e.g., calcite), some have a “perfect” cleavage (e.g., micas). Some may have no cleavages at all (e.g., olivine, which therefore has no “preferred” planes of splitting, and gets fractured, instead). The quality of cleavage is described as perfect, imperfect, good, distinct, indistinct, poor/weak, or absent. The quality decreases from perfect (dense, almost continuous and thin lines of cleavage) to weak cleavage (few, disperse segments of thicker lines) to absent (no cleavage, different curved and/or broken thick lines).

13.) Fracture: Fracture is the appearance of a surface broken in directions other than along cleavage planes. Fracture is the "chipping" of a mineral.

- Conchoidal - curved concavities resembling shells. e.g., flint, quartz, glass.
- Even - rough, approximately plane surfaces.
- Uneven - rough and completely irregular surfaces
- Hackly - sharp edges and jagged edges and depressions. e.g., most metals.
- Splintery or Fibrous - partially separated splinters or fibres. e.g., jadeite.
- Earthy or crumbly - this describes minerals that crumble when broken.

14.) 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.

15.) Inclusions and Alterations: Minerals can have inclusions, which can be solid (other finer-grained minerals) or fluid (liquid and/or gas) inclusions. Choose a higher magnification objective and describe the inclusions, if present (transparent or opaque, colorless or colored, relief, etc.). If altered, other minerals (alteration minerals) can appear at the margin of the analyzed mineral, or along its cleavages or cracks. Describe the alteration mineral separately using a higher magnification objective.

16.) 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.

17.) 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

18.) 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° 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.

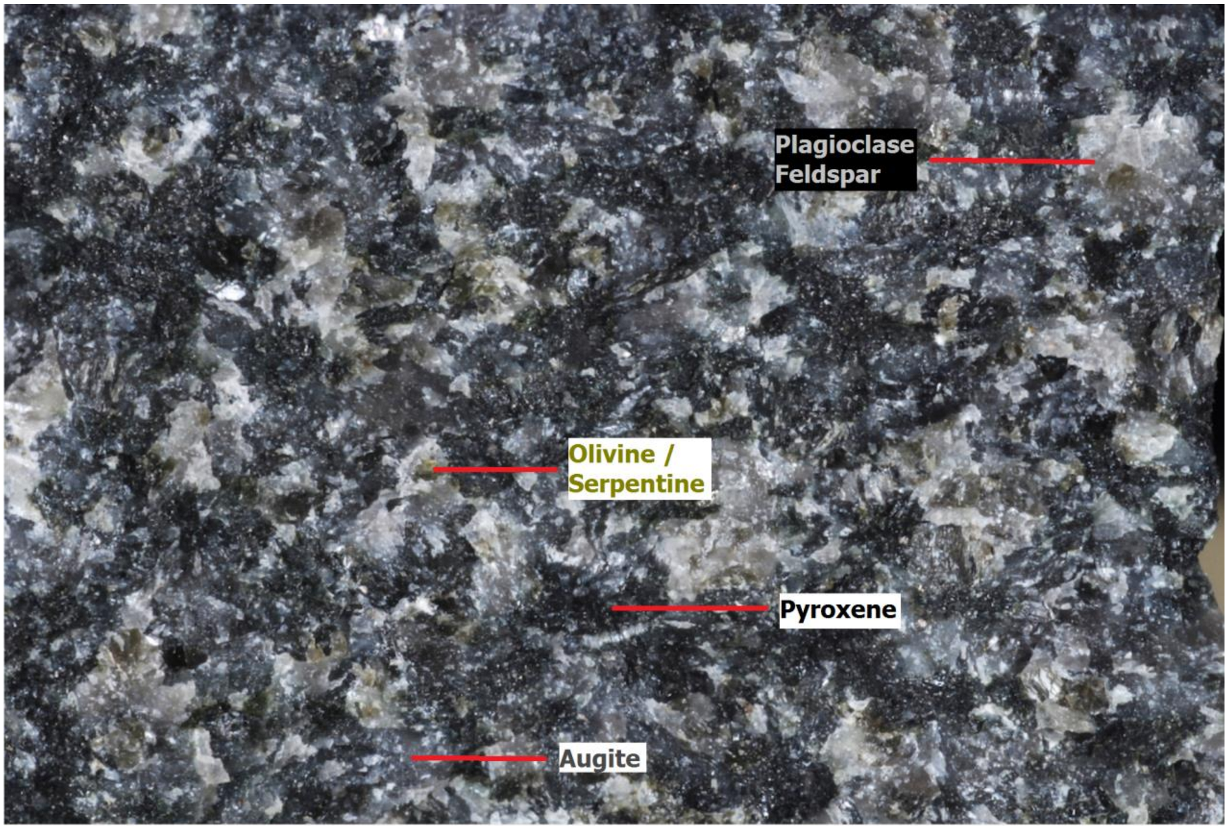
  - Swallow-tail Twinning: Form of penetration twinning in which two monoclinic crystals twin to form a v-shaped model. This form of twinning is most frequently observed in the mineral Gypsum. Twinning occurs on the {100} plane.
- Multiple or Repeated Twinning: If several twin crystal parts are aligned 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.

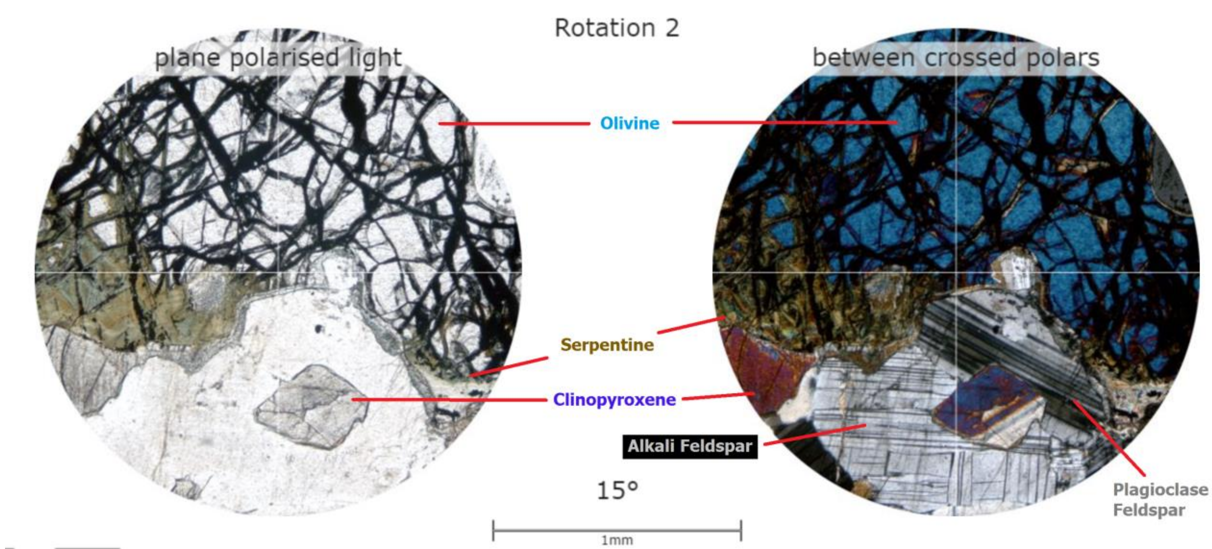
19.) Zoning: Crystal zoning is a texture developed in solid-solution minerals and characterized optically by changes in the color or extinction angle of the mineral from the core to the rim. Zoning is a record of incomplete continuous reaction relations between a melt and the crystallizing solid solution 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.

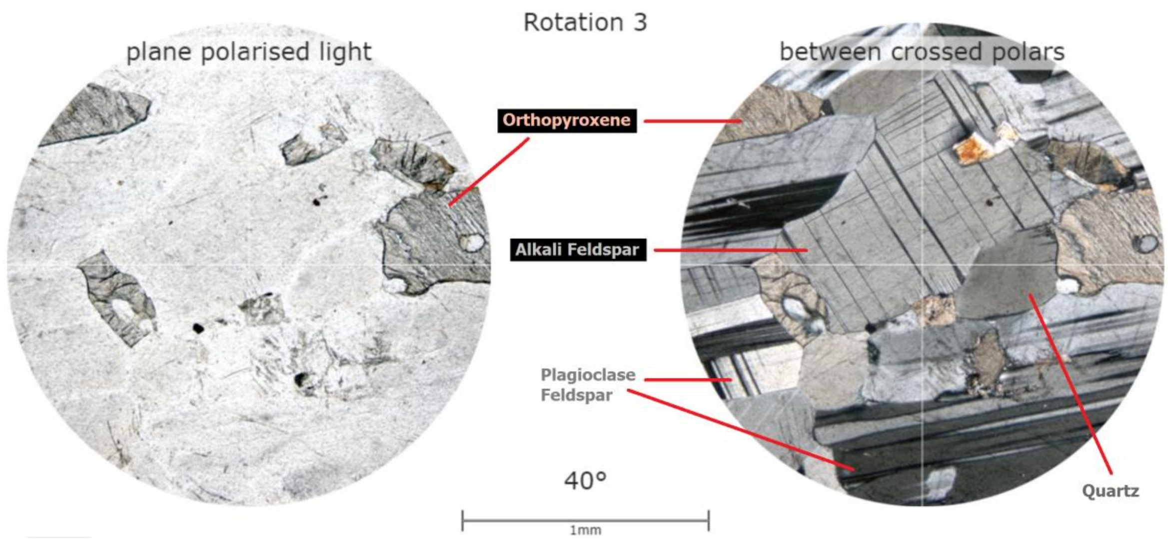
- Normal or continuous zoning: zoning in which the outer portions of the crystal have a lower-temperature composition than the core. Usually reflects progressive change of melt composition during growth of the crystal. Plagioclases are normally zoned from calcic cores to more sodic rims.
- Reverse zoning: 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-undersatured 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.

Rock Analysis: -

1.)


Plagioclase
Feldspar
Olivine /
Serpentine
Pyroxene
Augite


Rotation 2
plane polarised light
between crossed polars
Olivine
Serpentine
Clinopyroxene
Alkali Feldspar
Plagioclase
Feldspar
15°
1mm



Observations: -

The rock is mainly melanocratic with some mesocratic elements in the interstitial spaces. This indicates the rock's majorly mafic composition. It has a coarse grained and phaneritic texture, resulting from an intrusive igneous setting of formation.

Mineralogy: -

Mineral No.		1	2	3	4	5	6	7
Plane Polarised Light	Colour	Whitish-Gray	Whitish-Gray	Whitish-Gray	Dark Gray	Gray	Whitish-Gray	Greenish-Ochre
	Crystal Shape	Subhedral	Subhedral	Subhedral	Anhedral	Subhedral	Anhedral	Anhedral
	Transparency	Transparent	Transparent	Transparent	Translucent	Translucent	Transparent	Translucent
	Habit	Massive, Prismatic	Prismatic, Stubby	Prismatic, Tabular	Massive, Fibrous, Prismatic, Acicular	Stubby, Prismatic	Granular	Fine-grained, Fibrous
	Lustre	Vitreous	Vitreous	Vitreous	Vitreous	Vitreous	Vitreous	Waxy
	Cleavage	Absent	2 (90°) Perfect	Poor	2 Perfect	2 Perfect	Poor	Poor
	Fracture	Conchoidal	Conchoidal	Uneven	Uneven	Uneven	Conchoidal	Uneven
	Relief	Positive Low	Negative Low	Positive Low	Positive High	Positive Moderate	Positive High	Negative High
	Pleochroism	Absent	Absent	Absent	Weak	Weak	Weak	Absent
Cross Polarised Light	Isotropism	Anisotropic	Anisotropic	Anisotropic	Anisotropic	Anisotropic	Anisotropic	Anisotropic
	Birefringence Colours	1st Order	1st Order	1st Order	1st Order	3rd Order	3rd Order	3rd Order
	Entinction	Undulatory	Inclined	Inclined	Parallel	Inclined, Complete	Inclined	Inclined
	Twinning	None	Cross-Hatched	Albite	None	Simple	None	None
	Zoning	None	None	None	None	None	None	None
Alterations and Inclusions		None	Mildly Pleochroic, Haloic Inclusions	Some Felsic and Mafic Inclusions	Some Felsic Inclusions	None	Haematite Alteration	Chlorite Alteration
Mineral		**Quartz**	**Alkali Feldspar (Microcline)**	**Plagioclase Feldspar (Albite)**	**Ortho-Pyroxene (Enstatite)**	**Clino-Pyroxene (Augite)**	**Olivine**	**Serpentine**
Chemical Formula		**SiO2**	**KAlSi3O8**	**NaAlSi3O8**	**Mg2Si2O4**	**(Ca,Mg,Fe,Na)(Mg,Fe,Al)(Si,Al)2O6**	**(Mg,Fe,Mn)SiO4**	**Mg6Si4O10(OH)8**

Name of the Rock: **Olivine Gabbro**