Igneous petrology EOSC 321

Laboratory 1:
Review of optical properties of minerals.
Ultramafic plutonic and volcanic rocks

Material Needed: a) Microscope, b) Glossary of rock names and textures (see Pages 24-25 and 43 of Winter); c) Lab1 Manual printed off the course website; d) tables to aid determination of mineral modes in thin sections; e) classification triangles; f) a Manual on Optical Mineralogy (i.e. Minerals in Thin Section by Perkins and Henke)

Microscopes: At the start of the lab period, you will be assigned a microscope and the combination to the microscope locker by your TA. You will have access to this microscope throughout the remainder of the course. The microscope will be shared with students from the other laboratories. Please keep the microscopes in working condition and, should a problem arise, let your TA know immediately so that repairs can be made.

Activity 1. It's been a long summer! Your TA will remind you how to use a petrographic microscope, how to rotate objectives without damaging their centering and how to focus without crushing thin sections.

You will start by reviewing optical properties of common rock-forming minerals. Sixteen microscope stations are prepared for you. Please move from one station to another, spending ~5 min on each short assignment and filling in the answers below.

1. *Thin section 37. In this peridotite (comprised of olivine, orthopyroxene and spinel) name one isotropic and one anisotropic mineral. How you see this expressed in their optical properties?*

   *isotropic mineral*_____

   *anisotropic mineral*_____

2. *Thin section 87. This thin section contains only one mineral, talc, a common secondary mineral in ultramafic rocks. What mineral does it resemble by optical properties?*

   _____

3. *Thin section 135. This thin section hosts one felsic and 3 mafic minerals. Compare optical properties of two mafic minerals by filling in the table below:*

	Cleavage (perfect, imperfect etc., at how many planes, at what angle)	*Pleochroism*	*Extinction (Parallel or inclined, at what angle if inclined)*
Hornblende			
Biotite			

4. *Thin section 56. One of minerals in this thin section has a very high relief. Describe this mineral by noting several of his characteristics*

	Mode, vol. %	*Colour*	*Grain Shape (Subhedral or anhedral, round or angular, isometric or elongate etc.)*
High-relief mineral			

5. *Thin section 208. Determine the birefringence of clinopyroxene in this rock by noting the maximal interference colour of the clinopyroxene and plotting it on the Michel-Levy Chart (page 32 of Perkins and Henke "Minerals in thin sections"). Remember that the standard thickness of a thin section is 300 microns.*

   $\delta = n_1 - n_2 =$ _____

6. *Thin section 150. What mineral in this thin section is the most euhedral, quartz, clinopyroxene, or an opaque?*

   _____

7. *Thin section 148. What is the most pleochroic mineral in this thin section?*

   _____

8. *Thin section 166. How many minerals are there in the rock?*

   _____

9. *Thin section P2713. Clinopyroxene and plagioclase contrast each other in relief and crystal shapes, i.e.*

	Relief (High, moderate, low)	*Crystal shape (Euhedral, subhedral, anhedral)*

Clinopyroxene		
Plagioclase		

10. <u>*Thin section 75.*</u> *Observe black and pleochroic haloes around small colourless and black inclusions in biotite. These are caused by alpha-irradiation from U-bearing mineral inclusions in the biotite, most likely zircon. The metamict zircon has become black and also caused a decay of the biotite crystal lattice around it.*

11. <u>*Thin section 45.*</u> *What colour is the volcanic glass in this thin section?*

_____

12. <u>*Thin section 79.*</u> *The rock contains quartz and feldspar. Which one of these minerals is replaced by a dark, higher relief aggregate of sericite? (Sericite is fine-grained muscovite)*

_____

13. <u>*Thin section 158.*</u> *Observe the tartan twinning of microcline*

14. <u>*Thin section 210.*</u> *Observe the bird's eye extinction of two types of micas in this rock, biotite and muscovite. What optical property is used to tell these micas apart?*

_____

15. <u>*Thin section 14.*</u> *Observe the change of relief of carbonate in this rock with the stage rotation caused by the extreme anisotropy of carbonate. Is the carbonate relief high or low?*

16. <u>*Thin section 1167.*</u> *The thin section showcases the typical appearance of serpentine, a common secondary phase in ultramafic and mafic rocks. Serpentine 1) has low relief, 2) commonly develops along fractures and cleavage planes of primary minerals, 3) can be either isotropic (if in fibrous aggregates) or anisotropic; and 4) is accompanied by formation of fine magnetite powder*

<u>Activity 2.</u> In the next two hours of the lab period you will examine reference thin sections of ultramafic rocks. Each thin section has a brief petrographic description to assist you in the identification of minerals, textures and rock classification. Please make sure you understand the reference petrographic descriptions and can find all of the minerals mentioned. You should also be able to understand why a rock is given a particular name. For these, you should recap how to assess mineral modes under a microscope, and how to plot these on rock classification triangles. Look through thin sections of different rock types so that by the end of the lab period you will have examined peridotite, pyroxenite, anorthosite and komatiite. You do not have to examine all ~20 reference thin sections, one thin section per each rock type (4) is enough for the review. Your knowledge will be tested in the next Lab, which starts with an independent assignment on a thin section of an unknown ultramafic rock.

Ultramafic rocks formed as intrusives or in volcanic bodies consist mainly of olivine, clinopyroxene and orthopyroxene with accessory spinelide (chromite or magnetite) and plagioclase. Typical alteration products of these primary phases are serpentine, chlorite, talc, amphibole and mica.

Reference collection: Ultramafic plutonic and volcanic rocks

Thin Section: 1615
Sample: P1607
Rock Type: Harzburgite
Location: Yalakom

Thin Section Description:

Texture: Hypidiomorphic granular, as grains of all minerals are subhedral

~90% Olivine- large grains, many of them are deformed and have undulose extinction. 50% is replaced by serpentine.

10% Orthopyroxene- usually shows lamellae (twins? Or Cpx exsolution?) . Less altered than Ol. Deformed as indicated by undulose extinction and bent lamellae.

1% Chromite. Interstitial, anhedral, dark brown, isotropic, often in intergrowths with Opx

Few grains of clinopyroxene, small, spatially associated with Opx

Secondary minerals:

Serpentine**,** colourless to yellow, with grey first order interference colour, fibrous under cross polars, replaces Ol and present in veins

Hematite - microcrystalline, occurs in serpentine, formed by oxidation of olivines

Note: minor degree of deformation

Thin Section: 1614
Sample: P1606
Rock Type: Harzburgite
Location: Yalakom

Thin Section Description:

Texture: Hypidiomorphic granular, as grains of all minerals are subhedral

~72% Olivine in grains cut by serpentine in fractures. Many grains are deformed and have undulose extinction.

20% Orthopyroxene forms larger grains than olivine, and shows cleavage. Opx is also less sserpentinized than Ol. Commonly shows deformation twinning. Deformed as indicated by undulose extinction and bent twin lamellae.

2% Chromite. Interstitial, anhedral, light brown, isotropic

1% Clinopyroxene- just 1 grain. Looks just like Opx, but has blue, 2nd order interference colour. The grain is with multiple parallel cleavage fractures bent due to deformation.

Secondary minerals:

5% serpentine. Yellow, isotropic, along Ol fractures, associated with fine balck powder of opaque mineral (most likely magnetite)

Thin Section: 920
Sample: P612
Rock Type: Harzburgite
Location:

Thin Section Description:

Texture: Hypidiomorphic granular, as grains of all minerals are subhedral

~90% Olivine replaced by serpentine (10-50 vol %) with opaque microcrystalline hematite.

5% Orthopyroxene. Distinguished by relief lower than that in Ol, cleavage, low birefringence, and presence of lamellae (twinning? Cpx exsolution?) . Colourless.

3% Chromite, opaque, in euhedral rhombic grains in interstities,

1% Clinopyroxene. Distinguished by relief lower than that in Ol, cleavage, and presence of lamellae (twinning? Opx exsolution?). Light green colour.

Secondary minerals:

Serpentine**,** colourless to yellow, with a grey, first order interference colour, fibrous under cross polars, replaces Ol and present in veins

Hematite - microcrystalline, occurs in serpentine

Comment: Note that hematite or magnetite (Mt) are common byproducts of olivine serpentinization. Serpentine takes less Fe than was originally present in olivine, and the excess of Fe deposits as oxides.

Thin Section: N35
Sample: ?
Rock Type: Altered chromite dunite
Location:

Thin Section Description:

Texture: Hypidiomorphic granular, as grains of all minerals are subhedral

~92% Subhedral olivine replaced in patches by two secondary minerals, serpentine and iddingsite

5% Black anhedral mineral assumed to be chromite as this mineral is the most common in peridotites

Secondary

3% Veins of fibrous serpentine and black fine-grained Mt (?) or other Fe oxide or hydroxide. Serpentine grows perpendicular to the vein and Mt occurs in between serpentine fibers.

Secondary serpentine replaces up to 90% of olivine. Serpentine has low relief, grey interference colour and in some places of the thin section replaces olivine completely, while in others it accounts for only 10-20%. Olivine is also replaced by yellow product called “iddingsite”. It is a fine-grained mixture of Fe hydroxide minerals, clay, chlorite, talc and other minerals. Iddingsite in this thin section has higher relief than serpentine and occur in large “grains” with thinly-spaced “cleavage”.

Comment: Note that hematite or magnetite (Mt) are common byproducts of olivine serpentinization. Serpentine takes less Fe than was originally present in olivine, and the excess of Fe deposits as oxides.

Thin Section: 1298B
Sample:
Rock Type: Altered dunite
Location:

Thin Section Description:

Texture: Panidiomorphic. The texture is totally based on shapes of secondary minerals that constitute more than 50% of the rock.

~40% Olivine, present as "finger"-shaped remnants of larger grains interspersed with secondary serpentine. Identified by the high interference colour and extinction almost parallel to the elongation direction of the serpentine

1% Black opaque mineral, most likely chromite

Secondary minerals:

55% Serpentine, colourless, in long fibers. Has low, 1st order grey interference colour and intergrows with black fine powder of opaque minerals (most likely magnetite)

5% Talc, colourless, in euhedral isometric grains, with high 2nd order interference colours and typical bird's eye extinction pattern.

Note: Clinopyroxene grains would have an inclined extinction, unlike olivine. One vein of late serpentine-magnetite cuts through the t/s.

Thin Section: 1408
Sample: P984
Rock Type: Serpentenized wehrlite
Location:

Thin Section Description:

Texture: Hypidiomorphic

~89% Olivine, now totally replaced by yellow serpentine and opaque hematite

10% Clinopyroxene. Subhedral grains with twinning and exsolution lamellae of Opx

1% Orthopyroxene

Secondary minerals: Serpentine and hematite

Thin Section: 1655
Sample: P1657
Rock Type: Plagioclase Orthopyroxenite
Location:

Thin Section Description:

Texture: Medium-grained, hypidiomorphic, with euhedral Opx and anhedral Pl.

90% Orthopyroxene. Often with lamellae in middle part of the grain (twinning? Cpx exsolution ?)

8% Plagioclase. Distinguished by low birefringence, low relief and twinning; An66

1% Opaque mineral (Chromite? Magnetite?). Euhedral, interstitial

0.5% Clinopyroxene

0.5% Phlogopite, pleochroic from colourless to brown

Thin Section: 1864
Sample: P3384 Caution! The thin section is thinner on edge where minerals have untypically low interference colours!
Rock Type: Plagioclase Websterite
Location:

Thin Section Description:

Texture: Hypidiomorphic, all minerals are subhedral.

50% Clinopyroxene. Subhedral grains pleochroic from grey to light yellow. Often with lamellae and with twinning

47% Orthopyroxene. Subhedral grains pleochroic from grey to light yellow. Often with lamellae and with twinning

3% Plagioclase. Distinguished by low birefringence, low relief, twinning

Secondary minerals: Talc, in radiate intergrowths, with a typical high birefringence and a marked change of relief with rotation of the stage.

Thin Section: 1457
Sample: P1340
Rock Type: Clinopyroxenite
Location: 3 mi. N of Keremeos

Thin Section Description:

Texture: Hypidiomorphic, all minerals are subhedral

93% Clinopyroxene, pleochroic from light yellow to light green.

4% Black opaque mineral (magnetite?) with habits from euhedral to anhedral Interstitial.

2% Olivine

1% Biotite

Thin Section: 805
Sample: P1738 Rich in sulfide (pentlandite)
Rock Type: Clinopyroxenite
Location:

Thin Section Description:

Texture: Hypidiomorphic, all minerals are subhedral

80% Clinopyroxene, often twinned, altered in cleavage cracks into light brown amphibole

10% Pentlandite, anhedral, interstitial.

10% Olivine, distinguished from Px in plain polarized light by less alteration, clearer crystals and higher relief.

Secondary Alteration: Patches of serpentine

Thin Section: 804
Sample: P1738 Rich in sulfide (pentlandite)
Rock Type: Clinopyroxenite
Location:

Thin Section Description:

Texture: Hypidiomorphic, all minerals are subhedral

80% Clinopyroxene, often twinned, altered in cleavage cracks into light brown amphibole

10% Pentlandite, anhedral, interstitial.

10% Olivine, distinguished from Px in plain polarized light by less alteration, clearer crystals and higher relief.

Secondary Alteration: Patches of serpentine

Thin Section: 840
Sample:
Rock Type: Plagioclase Orthopyroxenite
Location:

Thin Section Description:

Texture: Hypidiomorphic, with subhedral Opx and anhedral Cpx and Plag.

~90% Orthopyroxene, euhedral to subhedral. Slightly pleochroic, often with lamellar structures.

3% Clinopyroxene, smaller interstitial grains on edges of orthopyroxene. Only 1 big grains with lamellar structure is found.

5% Plagioclase, anhedral, interstitial, twinned

Few grains of Biotite and an opaque mineral

Thin Section: 927
Sample: P622
Rock Type: Chromite Olivine Orthopyroxenite
Location: Stillwater

Thin Section Description:

Texture: Not clear, as the thin section contains few mineral grains

~78% Orthopyroxene in very large (1 cm) crystals, euhedral to subhedral –

15% Olivine in smaller crystals, almost totally (90%) replaced by serpentine

5% Opaque euhedral mineral, most likely chromite

2% Plagioclase, anhedral, interstitial, twinned

Vein of talc

Thin Section: 1027
Sample: P332
Rock Type: Biotite Pyroxenite
Location: Grand Forks, B.C.

Thin Section Description:

Texture: Hypidiomorphic, all minerals are subhedral

43% Clinopyroxene. Based on the tan-olive colour and slight pleochroism, it is likely an augite (a variety of Al-rich clinopyroxene). Some grains have paler cores and there is a slight difference in extinction angle between core and rim. These are indicative of zoning. Replaced by biotite along cleavage cracks

43% Biotite, pleochroic from dark brown to yellow, in euhedral laths

3% Hornblende, brown-green

1% Magnetite, anhedral, often included as blebs in Cpx

1% Apatite, in euhedral small crystals with low birefringence and grey first order interference colours.

Comments The crystallization sequence from Augite to Biotite can be observed. Biotite crystallized last and replaced earlier Cpx.

Thin Section: 1652, 1653
Sample: P1663
Rock Type: Anorthosite
Location: Bushveld Complex

Thin Section Description:

Texture: Hypidiomorphic, with euhedral- subhedral Plag and anhedral Opx. Suggests that plagioclase may have started the crystallization.

91% Plagioclase

5% Orthopyroxene, Hypersthene. Has blebs (exsolution blebs?) of clinopyroxene

4% Clinopyroxene, in larger anhedral grains and in vermicular interstitial grains

Thin Section: 930
Sample: P624
Rock Type: Anorthosite
Location: Stillwater Complex

Thin Section Description:

Texture: Medium-coarse grained, grains 1-4mm. Hypidiomorphic, with euhedral-subhedral Plag and anhedral Opx, suggests that plagioclase may have started the crystallization.

85-95% Plagioclase. Carlsbad and Albite twins

5-10 % Orthopyroxene. Interstitial, anhedral, faint tan colour, with fine lamellar twinning

1-3 % Clinopyroxene. Interstitial, anhedral, faint tan colour, with fine lamellar twinning. Later alteration, shown by thin zones along cleavage cracks

Secondary minerals: zoisite after Px. High relief and birefringence.

Thin Section: 790
Sample:
Rock Type: Anorthosite
Location: Stillwater Complex

Thin Section Description:

Texture: Hypidiomorphic
~100% Plagioclase, habits from euhedral to anhedral
Secondary minerals: Chlorite and zoisite with typical anomalous blue interference colours

Thin Section: KM-8
Sample:
Rock Type: Komatiite
Location: Munroe Township, Ontario

Thin Section Description:

Texture: Hypohyaline, with 30% crystals and 70% glass.

Spinifex, characterized by parallel and radiate arrangements of elongate olivines and pyroxenes. Implies rapid crystallization from an ultramafic liquid.

70% Partly devitrified glass
30% Elongate skeletal crystals of mainly clinopyroxene and olivine (less). Branching Cpx crystals consists of groups of slightly diverging needles showing a sweeping style of extinction. Olivine grains can be distinguished by extinction parallel to the elongation of crystals
1% Fine-grained opaque mineral (Mt?)

Thin Section: KM-2
Sample:
Rock Type: Peridotitic Komatiite
Location: Munroe Township, Ontario

Thin Section Description:

Texture: Porphyritic, with large phenocrysts of Ol set in fine-grained groundmass of clinopyroxene. The groundmass has spinifex texture, characterized by radiate arrangements of elongate Cpx.

40% Olivine, in large euhedral phenocrysts, sometimes skeletal. Partly replaced by serpentine with fine-grained hematite.
70% Elongate skeletal crystals of clinopyroxene
Branching Cpx crystals consists of groups of slightly diverging needles showing a sweeping style of extinction.