Laboratory 7:
Alkaline rocks

Learning Goals. After this Lab, you should be able:

- Identify the key rock-forming minerals in alkaline rocks
- Identify textures of alkaline rocks in thin sections
- Name alkaline rocks based on their textures and mineral modes using triangle diagrams

Material Needed: a) Microscope, b) Classification triangles and instructions on determination of plagioclase composition included with lab handout; d) a Manual on Optical Mineralogy (i.e. Minerals in Thin Section by Perkins and Henke)

Material Needed: a) Microscope, b) a Manual on Optical Mineralogy (i.e. Minerals in Thin Section by Perkins and Henke); c) classification triangles for volcanic and plutonic rocks

Lab Organization: You will start with a 30 min test on felsic-intermediate volcanic rocks. In the next two hours of the lab period you will examine reference thin sections of alkaline rocks with questions at 15 stations. Your knowledge will be tested in the next Lab, which starts with an independent assignment on a thin section of an unknown alkaline rock. As part of the thin section description on the test you will be asked to write a short explanation what petrographic observations made you think the rock has an alkaline affinity.

Introduction:

Alkaline rocks are generally considered to have more alkalis than can be accommodated by feldspars alone. The excess alkalis then appear in feldspathoids, sodic pyroxenes/amphiboles, or other alkali-rich phases. Alkaline rocks are deficient in SiO_2 with respect to NaO, K_2O, and CaO to the extent that they become critically undersaturated in SiO_2, and nepheline or acmite (Na clinopyroxene) appears in the norm. Alkaline rocks are extremely diverse; they constitute less than 1% of the total volume of igneous rocks, but account for 1/2 of all igneous rock names. For their classification you should use "Felsic Plutonic" and "Volcanic" triangles. Not included on these triangles are names for ultramafic and mafic alkaline plutonic rocks: urtite, ijolite and melteigite. Urtite is a plutonic Ne-Px rock with over 70% Ne and no Fsp. Ijolite is a plutonic Ne-Px rock with 30 to 70% Ne. Melteigite contains more than 70% mafic minerals and less than 30% nepheline. Alkaline rocks are more common in volcanic and hypabyssal facia, and less abundant as plutonic rocks. Their rock-forming minerals are nepheline, feldspar, clinopyroxene, amphibole, micas, olivine, leucite, melilite. Note that **neither quartz nor orthopyroxene can be found in alkaline rocks**. Common accessory minerals include zircon, sodalite, analcime, apatite, and magnetite.

Alkali clinopyroxenes are distinguished from other pyroxenes by their strong green and brown colour, stronger pleochroism and higher birefringence. However, the interference colour may be masked by the mineral colour. In thin sections we can identify 2 types of

alkali clinopyroxene: those pleochroic in brown or violet are Acmite or Ti- Augite, and those pleochroic in green are aegerines. Acmite is the Fe^{3+}-Na pyroxene ($NaFe^{3+}Si_2O_6$), and aegerine is a solid solution between augite (Al-rich Cpx) and acmite.

Amphiboles in alkaline rocks always contain Na and can be represented by sodic hornblende (strongly coloured in shades of green and brown) or by other sodic amphiboles (kaersutite, richterite, arfvedsonite, all of which exhibit blue pleochroism). The latter are rare and absent in the Reference Collection.

Leucite is found exclusively in K-rich mafic volcanics and associated hypabyssal intrusives. Leucite thus coexists with an anorthite-rich plagioclase, not with a sodic plagioclase. This assemblage makes tephrites rich in K and Ca. It is unusual as in most magmatic rocks enrichment in K is accompanied by enrichment in Na, i.e. the alkalies behave similarly. Leucite is readily weathered and therefore can be observed only in fresh magmatic rocks. With time it breaks down to a mixture of nepheline and K-feldspar. Fresh leucite is easily recognizable by very low birefringence, 8-sided polygonal shapes and twinning (T/s 1050)

Nepheline resembles the feldspars, but is uniaxial, lacks good cleavage and twinning, and has lower birefringence. Quartz lacks the clouding and secondary alteration common in nepheline. I often distinguish nepheline from feldpars because nepheline forms isometric grains, not elongate laths like feldspars. Nepheline easily breaks down and therefore the presence of secondary alteration is one of several distinguishing features. Common alteration product of nepheline is cancrinite, the easily recognizable "feathers" of yellow interference colours in nepheline rims. However, KFsp is often even more altered than nepheline, and is commonly covered by grey dust of clay mineral alteration.

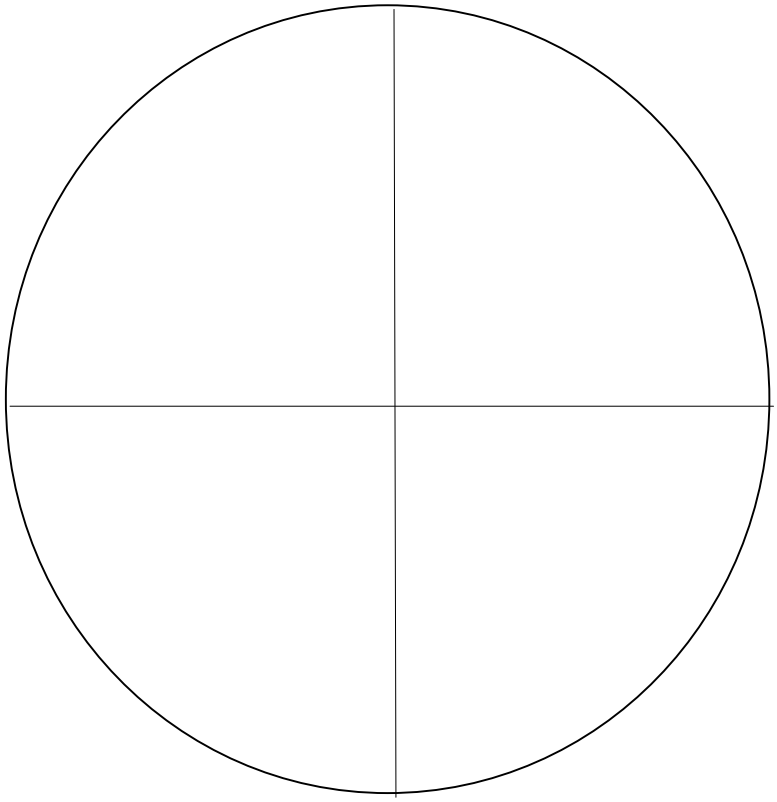
In Si-undersaturated rocks you can come across several isotropic minerals with negative relief. They also stand out because of their six-sided cross-sections - common appearance of dodecahedral crystals in thin sections. They are minerals of the sodalite group (sodalite, nosean and hauyne) and analcime, a zeolite. Minerals of the sodalite group are volatile-bearing framework silicates. You are very well familiar with a variety of hauyene, lazurite, an intensively blue gemstone found in contact metamorphosed carbonates. Nosean shows less intense blue colours in thin section (T/s 1050). Nosean can be found only in volcanic Si-undersaturated rocks, whereas plutonic rocks commonly contain sodalite, a colourless mineral of the sodalite group. However, sodalite in plutonic alkali rocks can be easily confused with analcime and in this Lab you are not required to distinguish between these.

Make sure that you see the following minerals in the Reference Collection:

- Uniaxial character of nepheline and its typical secondary product – cancrinite
- Primary cancrinite in T/s 53
- Aegirine
- Leucite, nosean and sodalite/analcime

TEST 1 Felsic-Intermediate Volcanics
30 minutes

Thin section _____
Your Name:_____
Magnification_____
Student ID:_____
Field of view width _____



Texture:

Description*:

Rock name:

* Should include determination of the plagioclase composition

Activity II

Now we will examine the alkaline rocks in hand specimens and under the microscope. Fifteen stations are prepared for you. Please move from one station to another, spending ~10 min on each short assignment and filling in the answers below. The TA will check the completion of all stations at the end of the Lab.

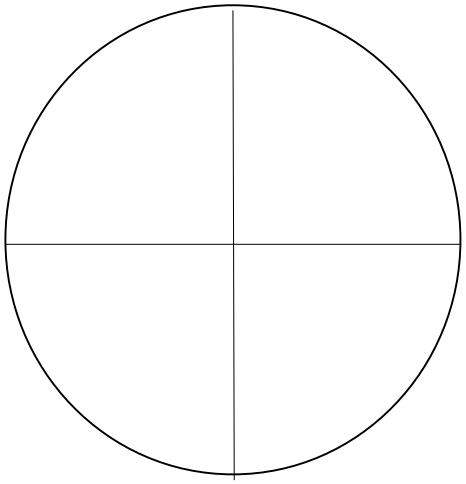
1. *Samples P2890, P126, P411, P140, P17, P702 are nepheline syenites and therefore containing feldspars and nepheline. Explain how you tell apart nepheline from feldspars using Lab specimens as examples.*

2. *Samples P13, P1432, P3358, P2892 have leucite phenocrysts. Describe what properties allows you to distinguish leucite from a) quartz; b) feldspars in hand specimens using Lab samples as examples.*

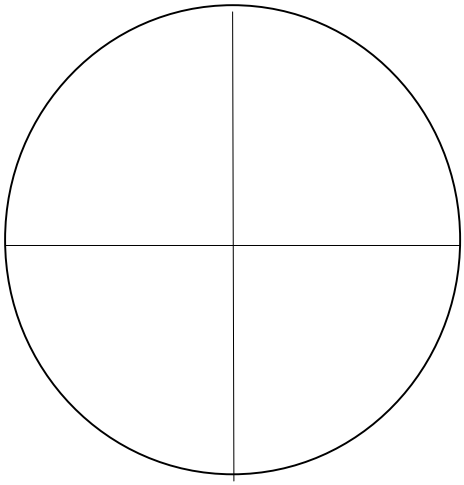
3. *Thin section 967. List all features observable in this thin section that indicate the alkaline nature of the rock.*

4. *Thin section 967. Estimate the proportion of albite/KFsp in perthites of the rock.*

5. *Thin section 1025. Draw how KFsp crystallized around sodalite.*



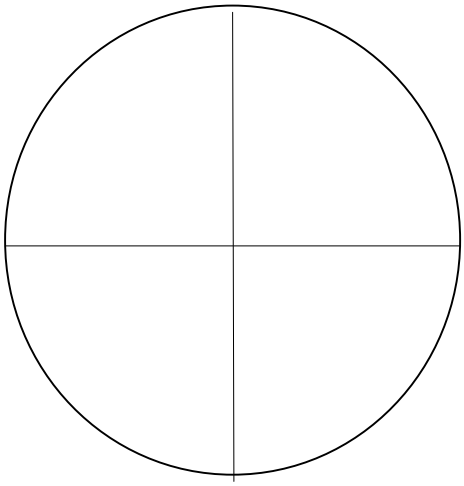
6. *Thin section 805. Draw replacement texture of primary augite by an aggregate of aegirine, amphibole, biotite and an opaque mineral.*



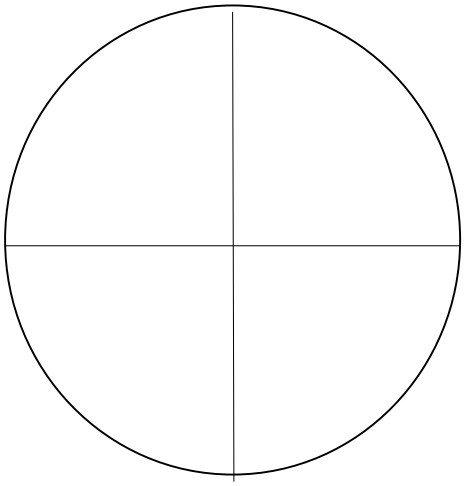
7. *Thin section 1154. Show you TA the difference between nepheline and Fsp under the microscope.*

8. *Thin section 1156. List all features observable in this thin section that indicate the alkaline nature of the rock.*

9. *Thin section 1156. Draw the texture of this rock with habits and textural positions of all minerals*

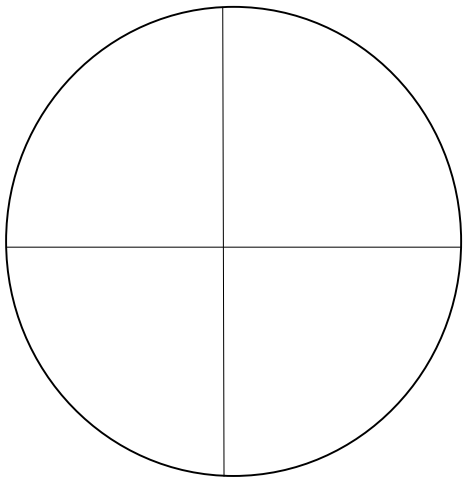


10. *Thin section 1050. Draw twinning in leucite how it is expressed in this rock*



11. *Thin section 170. Observe the difference in colour between early clinopyroxene (phenocryst cores) and late clinopyroxene (phenocryst rims and groundmass grains. Write formulas of Ti-augite and aegirine.*

12. *Thin section P1503 240. The rock shows a classic, replacement of nepheline by cancrinite commonly used for nepheline identification. Draw the nepheline and the cancrinite how they occur in this rock*



13. *Thin section 52. This rock is unusually fresh for a nepheline-bearing alkaline rock, and this makes the identification of nepheline in the thin section diffecult. Find nepheline using conoscopy.*

14. *Thin section P218 318. Observe blue pleochroic alkaline amphibole reibeckite replacing aegirine in this rock. This rock is really unusual with respect to the assemblage of rock – forming minerals. The presence of what mineral (or minerals) makes the rock so unique?*

15. *Thin section 1485. Nepheline and alkali feldspar are present in this thin section. Describe how you tell apart these two minerals in this specific thin section without conoscopy.*

Alkaline Rocks
Reference Collection

Thin Section 967	4 thin sections
Sample Number	P43
Rock Name:	Alkali Fsp Syenite
Location: Salem Neck, Massachusetts	

Thin Section Description:
Texture: Hypidiomorphic, with subhedral K-Fsp and anhedral Amph and Cpx

88% K-Fsp in subhedral large crystals with simple Calsbad twins. All crystals are perthites, with 30-50% exsolution lamellae of albite. 3% of grains show microcline tartan twinning. Irregular rims of albite are common. Replaced by fine-grained grey powder of clay mineral (?).
5% Albite in subhedral crystals with K-Fsp lamellae, antiperthites. Clear grains of albite also commonly mantle perthitic K-Fsp.
5% Alkaline Clinopyroxene, anhedral to subhedral. Pleochroic from green to khaki green => aegirine. Always associated with amphibole. Some distinct cores of aegirine in amphibole.
5% Hornblende, anhedral to subhedral. Strongly pleochroic from brown to black. Always associated with Cpx and sometimes rims it.
2% Opaque minerals, subhedral
Traces Apatite

Secondary Minerals: Fine-grained grey clay mineral after K-Fsp. An excellent marker of K-Fsp under in PPL!

Thin Section 1025
Sample Number P327
Rock Name: Sodalite Alkali Fsp Syenite
Location: Laacher See, Germany

Thin Section Description:
Texture: Hypidiomorphic, coarse spherulitic texture.

78% K-Fsp (orthoclase and microcline) in euhedral elongate grains growing in radiate coarse spherulitic aggregate on crystals of isotropic mineral. N<N Balsam, rare grains are perthitic. Distinguished from albite by the lack of twinning and by tartan twinning present in few crystals.

15% Isotropic mineral with negative relief (Sodalite? Analcime?) in subhedral equi-dimensional crystals, some grains shows six-sided shape. Also present in anhedral interstitial crystals.

2% Alkali Clinopyroxene, in large strongly pleochroic anhedral crystals. Pleochroic from yellow-green to dark reddish-brown => Ti-Augute or Acmite. High interference colour of 3rd order. Distinguished from Amph by higher relief and lack of cleavage.

1% Clinopyroxene, weakly pleochroic in green, - Augite. Forms anhedral crystals with low birefringence.

2% Biotite, in large strongly pleochroic anhedral crystals. Pleochroic from yellow to dark brown-black. Distinguished from Cpx by lower relief

1% Opaque mineral

1% Sphene (?). A high relief, high birefringence mineral in euhedral rhombic and in anhedral grains, grey colour.

Comment: This rock is likely to be hypabyssal, formed at relatively shallow depths. Spherulitic aggregates are not found in abyssal plutonic rocks.

Thin Section 805
Sample Number P1716
Rock Name: Urtite
Location: Zimbabwe

Thin Section Description:
Texture: Hypidiomorphic

80% Nepheline, subhedral equidimentional crystals, often rectangular. N < or > N Balsam, with cleavage, uniaxial. Distinguished from quartz by the presence of cleavage and secondary alteration. Distinguished from Fsp by rectangular or hexagonal shapes, and by being uniaxial. Nepheline grains are replaced on rims by cancrinite.

10% Augite, large subhedral colourless crystals, often twinned. Strongly zoned, with green rims of Fe^{3+}- and Na- rich clinopyroxene. Extinct at 46º.

5% Aegirine, pleochroic from yellow green to blue-green. Forms rims on earlier augite and grows in radiate structures on augite and in interstities.

5% Biotite, in subhedral to euhedral grains, pleochroic from light yellow to green and brown. Zoned. Often forms intergrowths with an opaque mineral, aegirine, and sphene, that replace former euhedral augite (?) crystals.

1% Isotropic mineral with a negative relief (Sodalite? Analcime?), in anhedral interstitial crystals and in euhedral hexagonal grains.

1% Opaque mineral, euhedral

0.5% Apatite, euhedral in small or larger grains.

Few grains of sphene - high relief and bright high order interference colours

Secondary Minerals:

5% Cancrinite after Ne, replacing its rims. Interference colours are up to first order yellow, N << N Balsam. Typical alteration product of nepheline.

Comment: Chemical evolution of magma in this rock led to later replacement of primary augite by an aggregate of aegirine, hornblende, biotite, an opaque mineral and sphene. Former euhedral augite crystals are now recrystallized into finer-grained intergrowths of these minerals. Thus, we can suggest that magma evolved to become more Ti, Fe^{3+}, alkali, and water-rich.

Thin Section 1154
Sample Number P700
Rock Name: Nepheline-bearing alkali feldspar syenite
Location: Ice River Complex

Thin Section Description:
Texture: Hypidiomorphic

80% microcline K-Fsp. Occurs in euhedral large elongate crystals with accasional simple twinning. Twinning planes are parallel to the elongation. Can be distinguished by a typical microcline tartan appearance, uneven undulose extinction, the presence of perthites. Alteration covers some kFsp grains with brown "dusty" microscopic particles, but some other grains may be fresh.

7% Nepheline, subhedral equidimentional crystals, often round or rectangular. N < or > N Balsam, with poor cleavage, uniaxial. Distinguished from Fsp by round isometric shapes, uniaxial character, the absence of alteration, tartan twinning and perthites. Also, Ne grains often are altered into muscovite along margins.

6% Hornblende, euhedral rhombic crystals, pleochroic from light brown to dark brown, with 120^{o} cleavage. Zoned, with lighter brown rims.

5% Aegirine, subhedral, weakly pleochroic in green. Several grains show zoning and cores of colourless augite.

1% Sphene, in euhedral brown long rhombic crystals of extremely high relief

1% Isotropic mineral, N< N Balsam (Sodalite? Analcime?). Forms large anhedral crystals in interstities and poikilitically encloses nepheline

Few grains of Apatite, euhedral in small or larger grains.

Secondary Minerals:

Few grains of Muscovite (colourless mica) after nepheline.
Clay mineral after K Fsp

Comment: Kfsp in Thin Section 1156 is less perthitic and sometime shows microcline tartan twinning.

Thin Section	1156	2 thin sections
Sample Number		P702
Rock Name:		Nepheline-bearing alkali feldspar syenite
Location: Ice River Complex		

Thin Section Description:
Texture: Hypidiomorphic

80% microcline K-Fsp. Occurs in euhedral large elongate crystals with accasional simple twinning. Twinning planes are parallel to the elongation. Can be distinguished by a typical microcline tartan appearance, uneven undulose extinction, the presence of perthites. Alteration covers some kFsp grains with brown "dusty" microscopic particles, but some other grains may be fresh.

7% Nepheline, subhedral equidimentional crystals, often round or rectangular. N < or > N Balsam, with poor cleavage, uniaxial. Distinguished from Fsp by round isometric shapes, uniaxial character, the absence of alteration, tartan twinning and perthites. Also, Ne grains often are altered into muscovite along margins.

6% Hornblende, euhedral rhombic crystals, pleochroic from light brown to dark brown, with 120° cleavage. Zoned, with lighter brown rims.

5% Aegirine, subhedral, weakly pleochroic in green. Several grains show zoning and cores of colourless augite.

1% Sphene, in euhedral brown long rhombic crystals of extremely high relief

1% Isotropic mineral, N< N Balsam (Sodalite? Analcime?). Forms large anhedral crystals in interstities and poikilitically encloses nepheline

Few grains of Apatite, euhedral in small or larger grains.

Secondary Minerals:

Few grains of Muscovite (colourless mica) after nepheline.
Clay mineral after K Fsp

Comment: Kfsp in Thin Section 1156 is less perthitic and sometime shows microcline tartan twinning.

Thin Section	1050	2 thin sections
Sample Number	P13	
Rock Name:	Nosean-bearing Tephrite	
Location:	?	

Thin Section Description:
Texture: Porphyritic

25% Phenocrysts:
25% Leucite, in euhedral equant trapezohedral crystals that show eight-sided cross sections. Very low birefringence makes leucite almost isotropic. Characteristic complex lamellar twins are usually arranged in a concentric manner, or intersect at angles of about 60°.
1% Garnet, in euhedral six-sided crystals, with extremely high relief, isotropic, yellow in colour.

75% Groundmass:
25% Leucite microphenocrysts, euhedral
27% Plagioclase, in euhedral laths with polysynthetic twins, N> N balsam, => calcic.
12% Cpx, green - Aegirine. Pleochroic from yellow-green to green. Present as microphenocryst in euhedral grains, zoned, with darker green rims. Also abundant in the groundmass as a microlite.
5% Vesicles, irregular shapes
5% Nosean microphenocrysts, in blue euhedral isotropic crystals. Sometimes altered into grey-brown mineral forming 2-dimentional grid
1% Garnet microphenocrsysts.

Thin Section 170
Sample Number P2902
Rock Name: Pheno-Tephrite
Location: ?

Thin Section Description:
Texture: Porphyritic

7% Phenocrysts:
4% Plagioclase, euhedral grains with polysynthetic and simple twinning, zoned, some are antiperthitic.
1% Nepheline, in euhedral equant rectangular or hexagonal grains, clouded with fine-grained brown secondary mineral. This alteration can be used as a "hallmark" of nepheline in this thin section.
1% Clinopyroxene, in subhedral-euhedral grains, strongly zoned. The zoning manifests itself by change of colour from purple in some cores to green to darker green in rims. Purple Cpx is likely to be Ti-augite, whereas green Cpx is probably aegirine. Green Cpx is pleochroic from yellow-green to dark green.

93% Groundmass:
50% Clinopyroxene, euhedral, in microphenocrysts and microlites. Some microphenocrysts show violet core, in contrast to microlites that are always green.
43% Aggregate of unidentifiable felsic minerals that include laths of feldspar and perhaps nepheline.

Comment: Because the groundmass in this rock is too fine-grained for petrographic observations, the rock is named after its phenocrystal assemblage "pheno-tephrite". Chemical evolution of the rock is unusual in starting from Ti-rich magmas crystallizing Ti-Augite, to more Fe^{3+} - and Na- rich magmas crystallizing aegirine.

Thin Section 240
Sample Number P1503
Rock Name: Nepheline Syenite
Location:

Thin Section Description:
Texture: Hypidiomorphic

70% Microcline Perthite
15% Nepheline replaced by cancrinite
10% Isotropic mineral with negative relief (Sodalite? Analcime?)
5% Aegirine-Augite, dark green, skeletal. replaced partly by biotite
traces of Sphene,

Secondary Minerals:
2% Cancrinite after Ne

Thin Section 52
Sample Number P2873
Rock Name: Nepheline Monzosyenite
Location: Blue Mountain, Ontario

Thin Section Description:
Texture: Allotriomorphic, all grains are anhedral
48% Microcline Fsp with tartan twinning.
15% Plagioclase with polysynthetic twinning
30% Ne – all low birefreingent crystals with no tartan or polysynthetic twinning
5% Cancrinite, in large anhedral grains. Interference colours up to second order blue, 1 set of cleavage is parallel to the elongation, uniaxial negative, n< n balsam, negative relief, parallel extinction, length fast
2% Hornblende, strongly pleochroic from black to green, with perfect cleavages at 120°
Traces Opaque mineral, most likely magnetite
1 grain of isotropic euhedral prismatic sodalite (?)