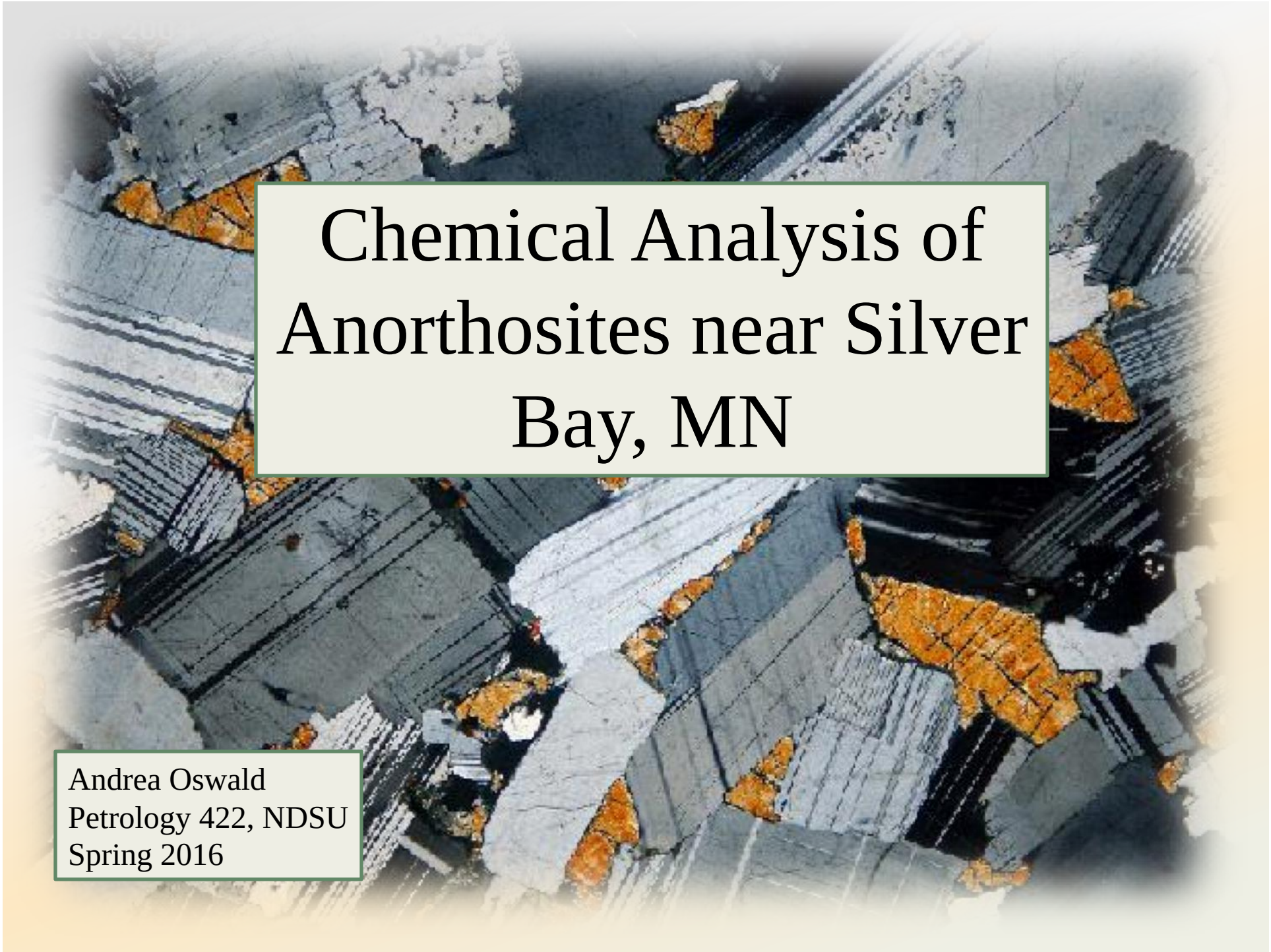

Chemical Analysis of Anorthosites near Silver Bay, MN

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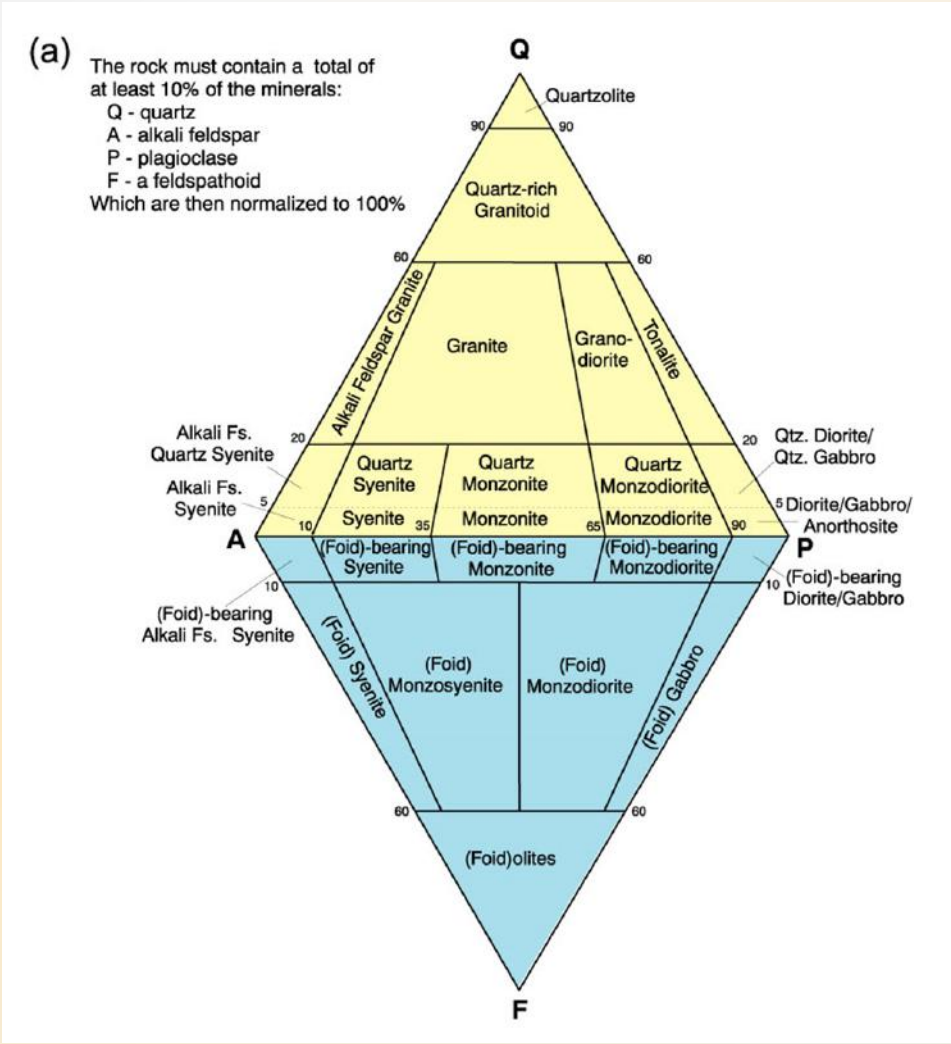
Petrology 422, NDSU
Spring 2016

Outline

- Background
- Location
- Previous work
- Hypothesis
- Methods
- Results
- Discussion
- Conclusion

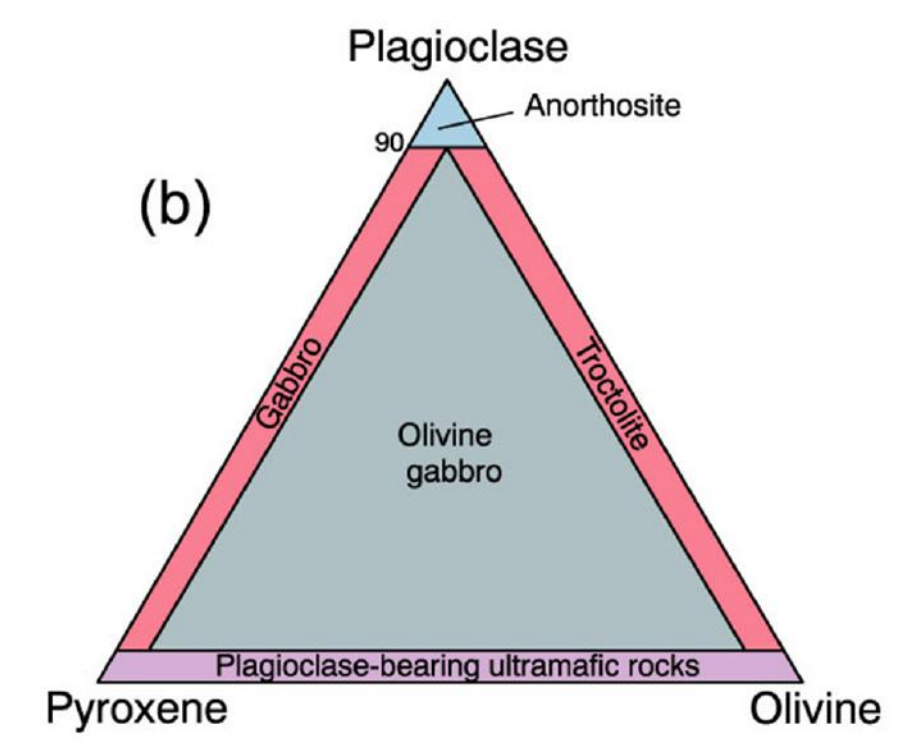
Anorthosite

- Phaneritic
- Intrusive igneous rock



Winter, 2013

Anorthosite

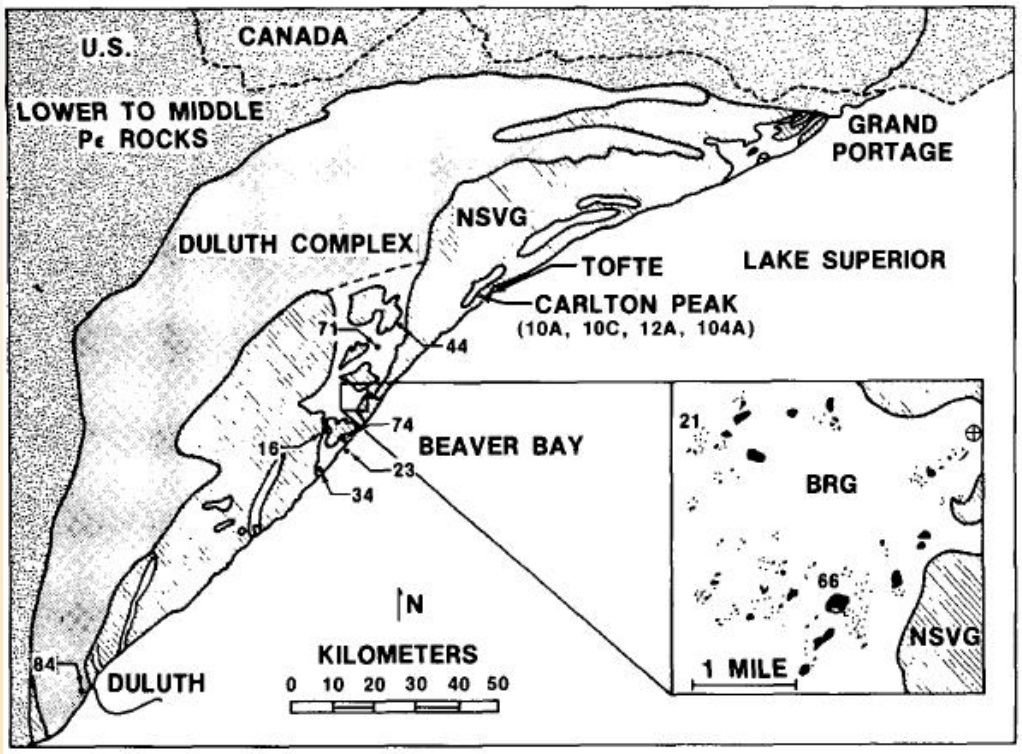


- 90-100% plagioclase
- 0-10% mafic minerals (pyroxene, ilmenite, magnetite, and olivine)

Winter, 2013

Regional Setting

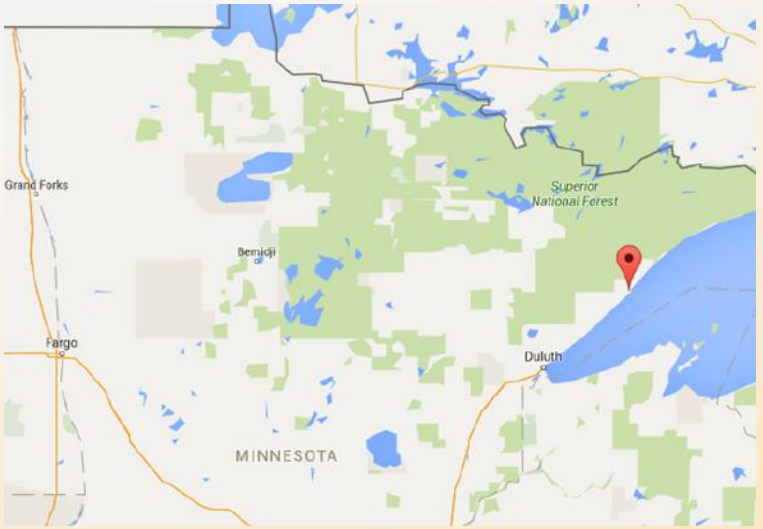
- Mid-continent rift system
- Keweenawan Supergroup
  - Intrusive & extrusive
  - ~1.1 Ga ago
  - North Shore Volcanic Group (extrusive), Duluth Complex (intrusive), Beaver Bay Complex (intrusive)



Morrison *et. al*, 1983

Silver Bay, MN

- Diabase/anorthosite outcrop
- Beaver Bay Complex



Courtesy of Google Maps, 2016

Beaver Bay Complex

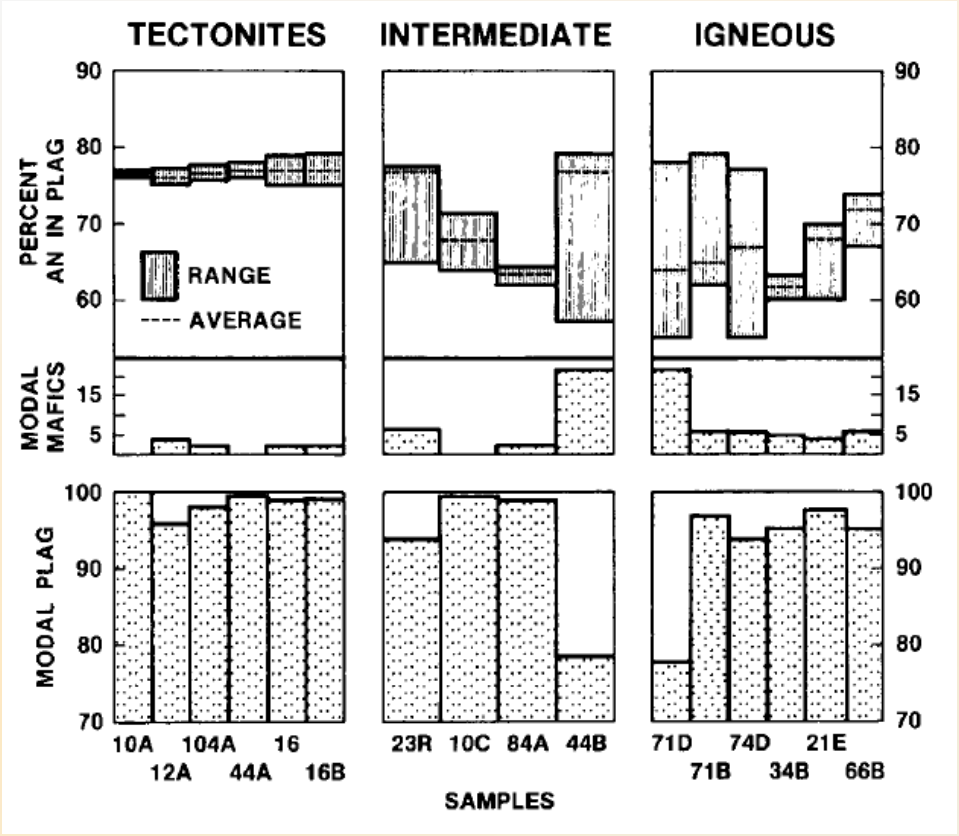
- Consists of three gabbroic plutons (oldest to youngest)
  - Beaver River gabbro
  - Beaver Bay ferrogabbro
  - Black Bay gabbro
- Beaver River gabbro is the largest and hosts all of the anorthosite inclusions

Previous Work

- Morrison *et al.*, 1983
  - Extensively sampled & analyzed anorthosites along North Shore
  - Grouped inclusions into four types based on texture & structure:
    - Tectonites, igneous, intermediate, & breccia w/ cataclastic textures
- Researchers studied the chemistry and isotopic data as to whether the xenoliths formed along with the diabase or at a much greater depth

Previous Work

- Morrison and others determined the anorthosites were based on variations in mode & plagioclase composition



Morrison, *et al*, 1983

Leading Question

- How do my chemical analyses of plagioclase crystals, in anorthosites, compare to the relevant scientific literature?

Methods

- Collection
  - March 18th, 2016
- Thin section
  - Michel-Levy method
- XRF
  - Chemical analysis

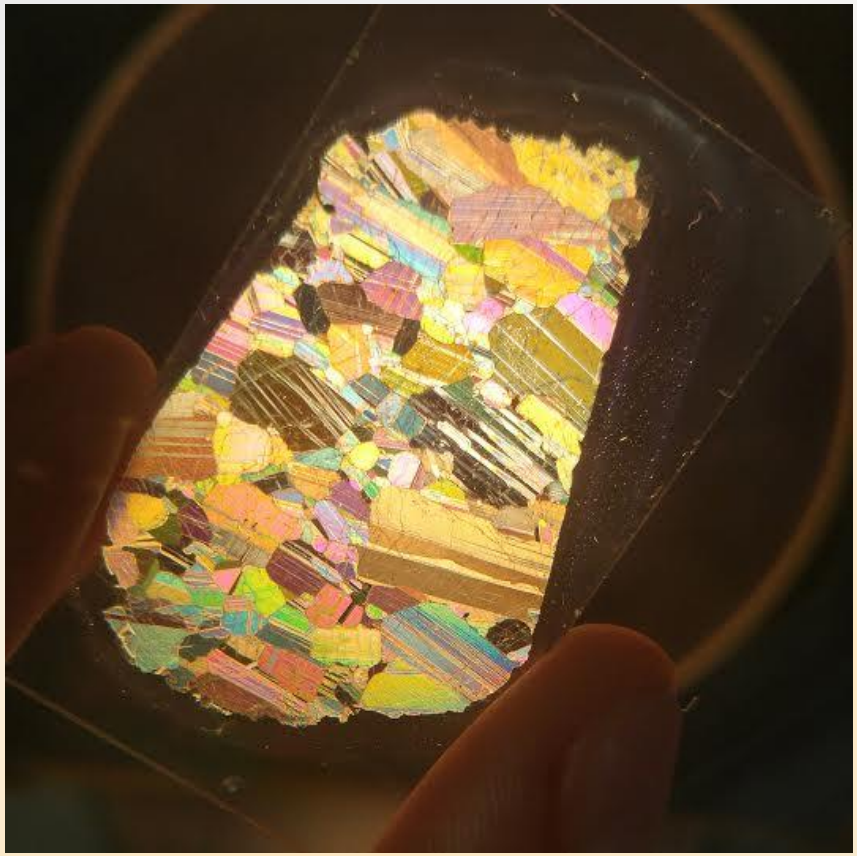
Collection in Silver Bay, MN

Sample-BRA

Thin Section-BRA

Courtesy of Kayleigh Alme

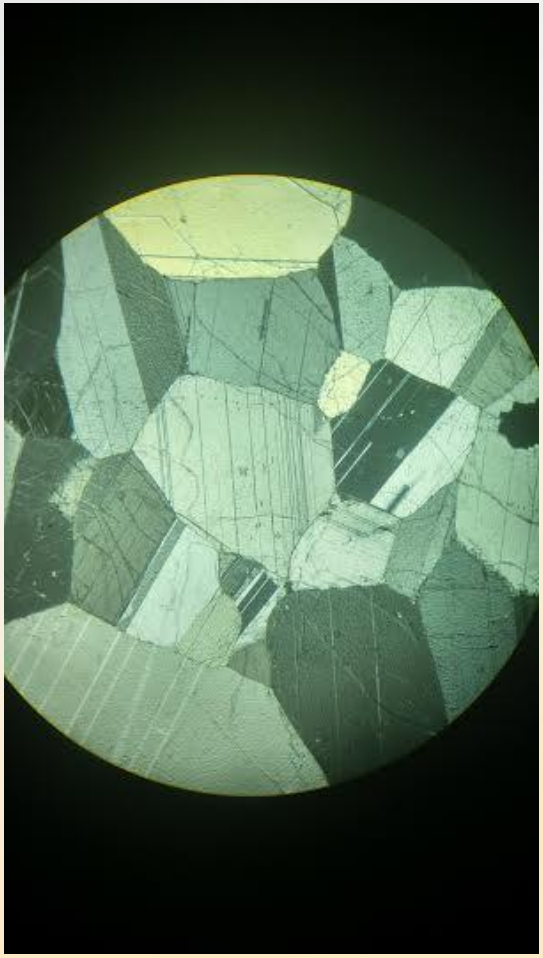
Thin Section-BRA

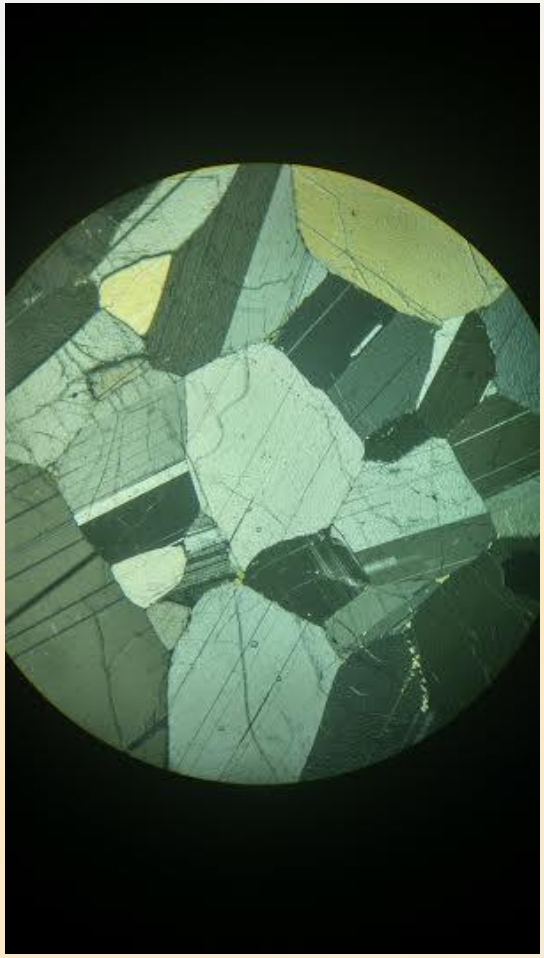


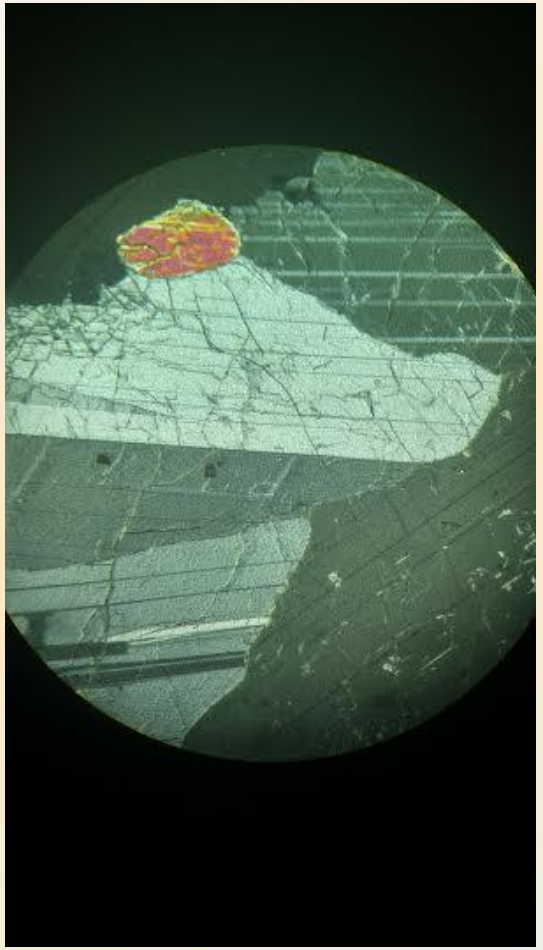
>30 microns

=30 microns

Thin Section-BRA

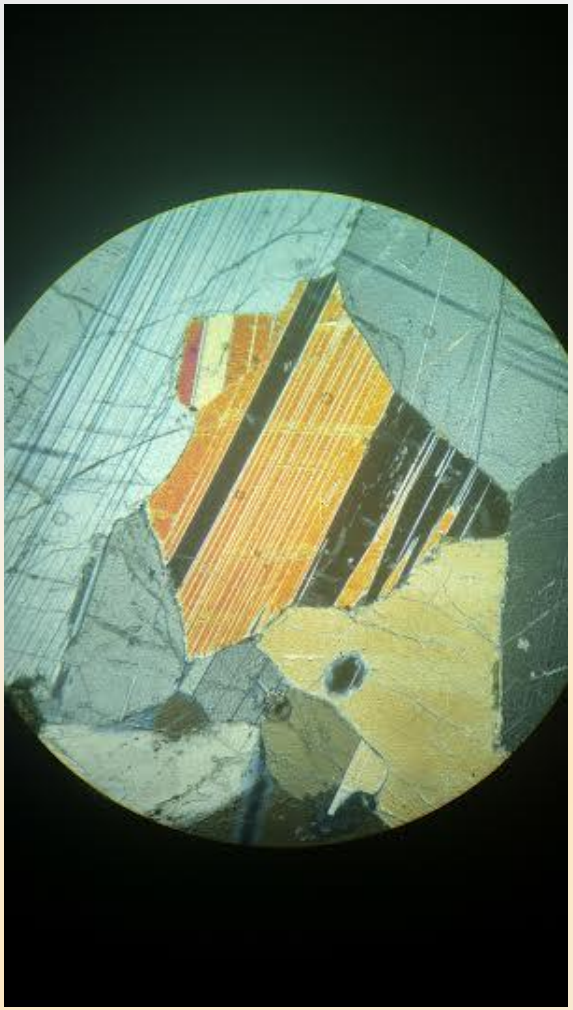


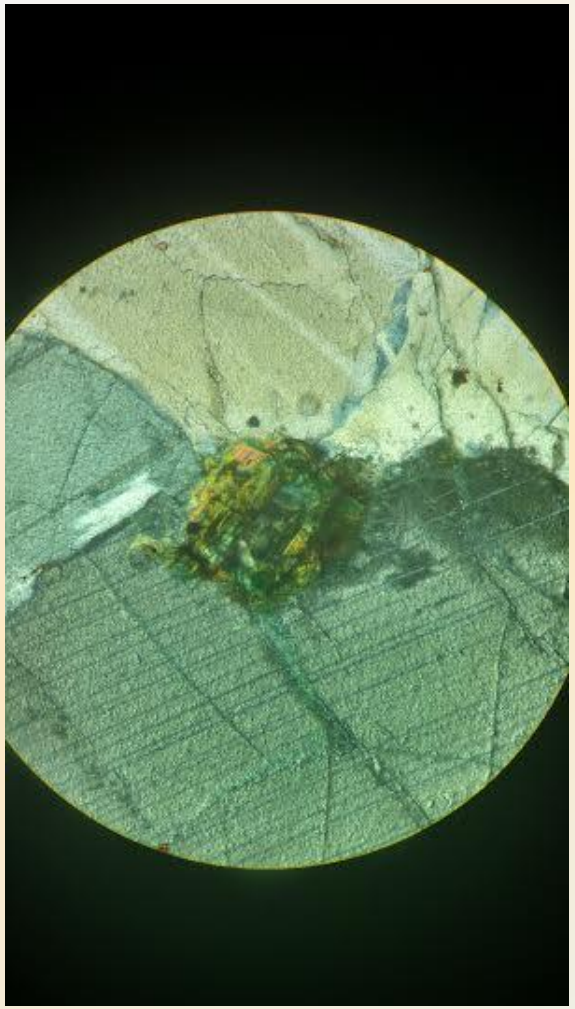




FOV 4.7mm, cross polarized

Thin Section-BRA

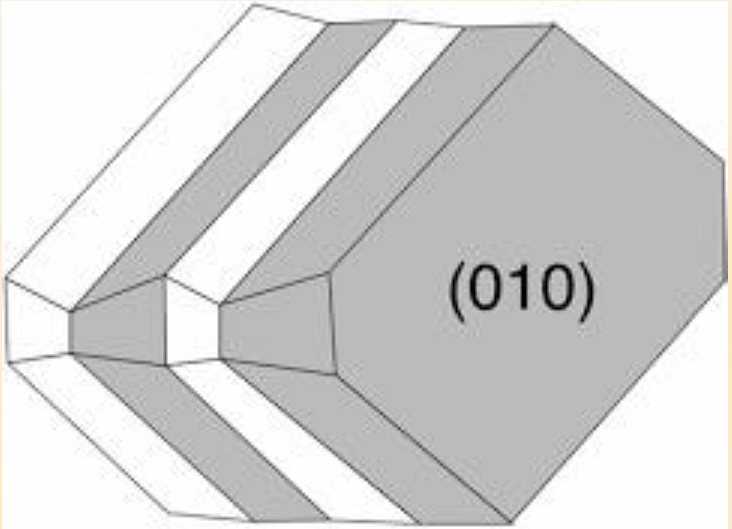




FOV 4.7mm, cross polarized

Michel-Levy Method

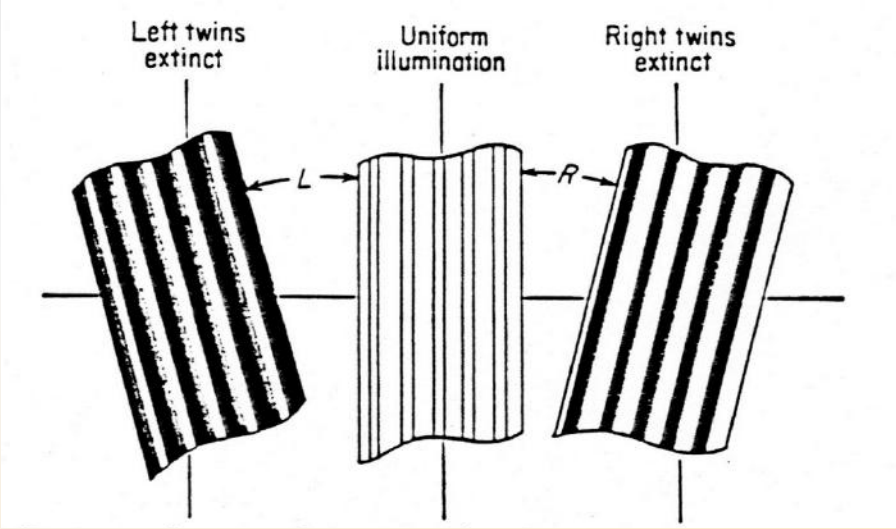
- Approximate plagioclase composition
- Measure extinction angles of albite twins in thin section
  - Cleavage parallel to (010)
  - Uniform illumination
  - Equality of angles from left and right



Multiple albite twins

courses.washington.edu

Michel-Levy Method



- Take measurement of uniform angle
  - Rotate left until extinction - measure
  - Rotate right until extinction – measure
- Difference of measurements must not exceed 6˚
- Calculate average

http://faculty.uml.edu/nelson_eby/89.506/IMAGES/Michel-Levy%20plag%20comp.jpg

Michel-Levy Method

- Estimate composition by taking average of the three largest averages
- Plot onto graph

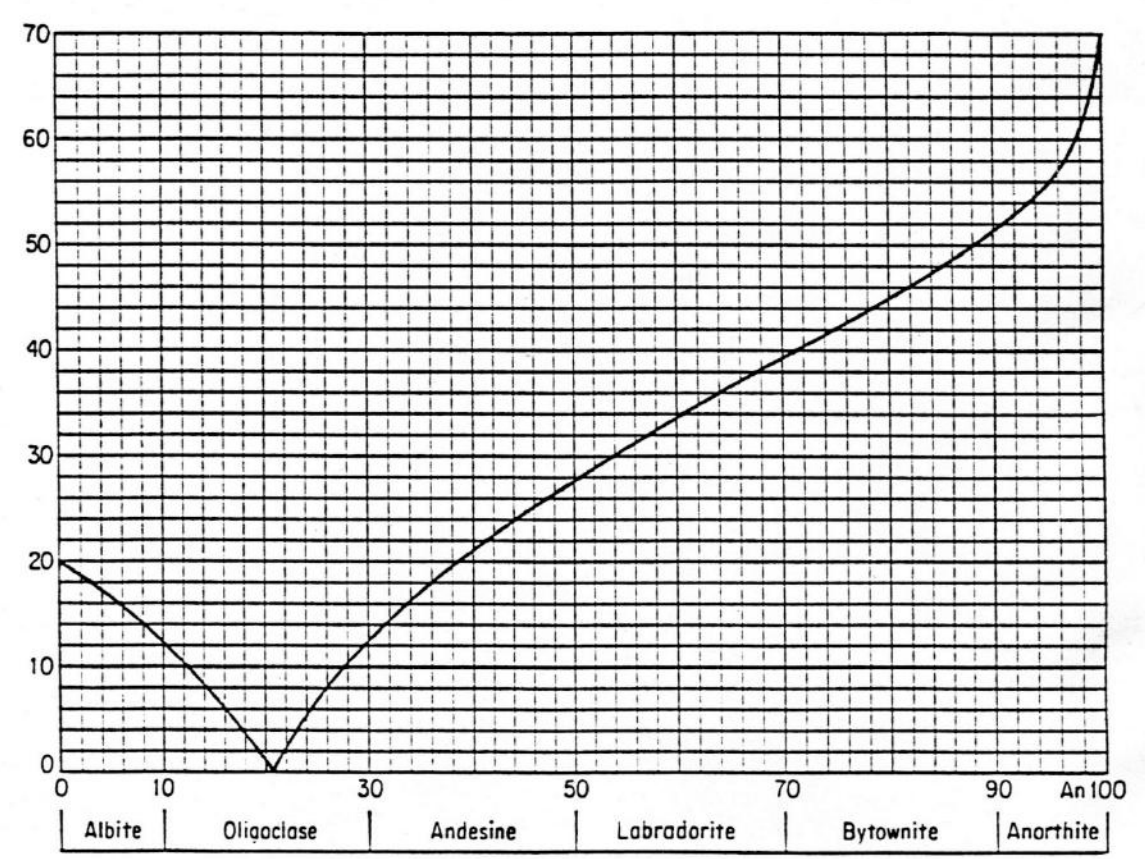


FIG. 13-26. Curve showing the maximum extinction angle of albite twins cut normal to (010) for the plagioclase feldspars (Michel-Lévy's method).

http://faculty.uml.edu/nelson_eby/89.506/IMAGES/Michel-Levy%20plag%20comp.jpg

X-Ray Fluorescence (XRF)

- A bombardment of high-energy X-rays onto a sample that results in secondary emissions from electrons transitioning an orbital shell
- Results in an elemental data

Michel-Levy Results

- Overall average 32.17˚
- An_{58} = Labradorite

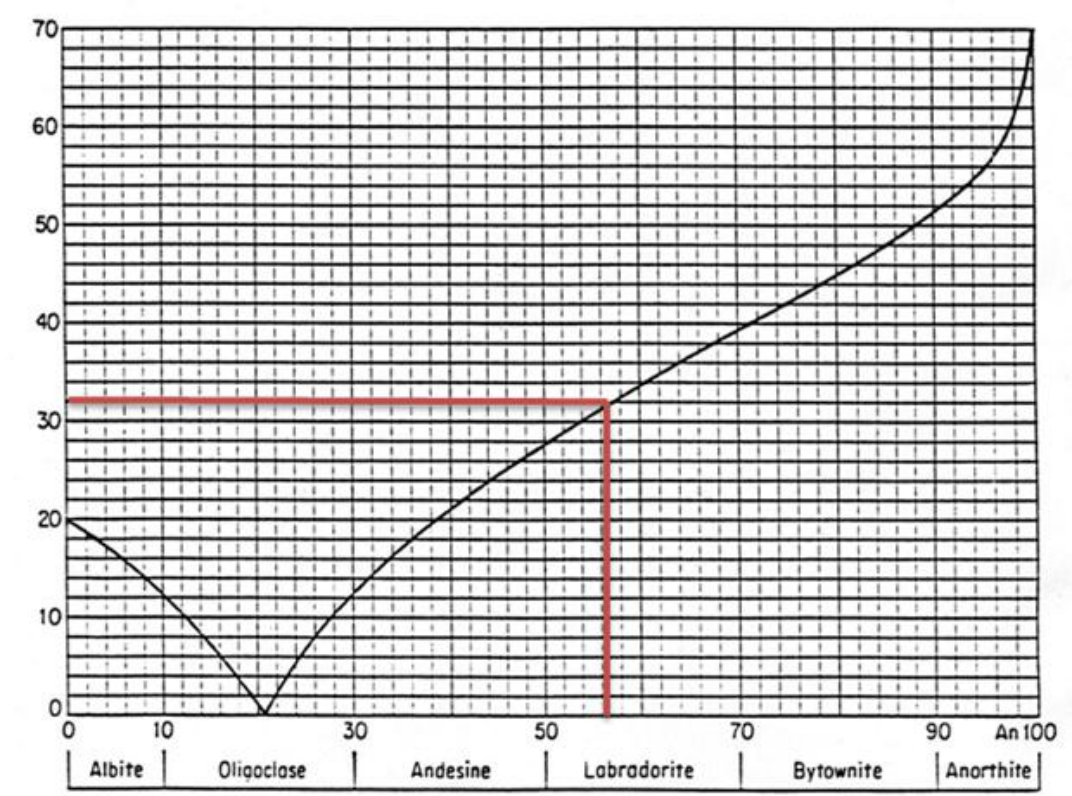


FIG. 13-26. Curve showing the maximum extinction angle of albite twins cut normal to (010) for the plagioclase feldspars (Michel-Lévy's method).

Left	Initial	Right	Avg.
71	39	1	35
43	21	353	25
64	32	0	32
50	22	351	29.5
43	24	2	20.5

XRF Analysis

Oxide	Wt. %	Mol. Prop	Cation Prop	# of O	Cations Basis of 8 O	End Member Recalc.	%
SiO_2	52.1	0.87	0.87	1.73	2.39		
TiO_2	0	0	0	0	0		
Al_2O_3	27	0.26	0.53	0.79	1.46		
Fe_2O_3	0.7	0.004	0.009	0.013	0.024		
MnO	0	0	0	0	0		
MgO	1.4	0.03	0.03	0.03	0.089		
CaO	15.7	0.28	0.28	0.28	0.77	0.77	75%
Na_2O	2.9	0.047	0.09	0.047	0.26	0.26	25%
K_2O	0.2	0.002	0.004	0.002	0.012		
P_2O_5	0.1	0.0003	0.0007	0.0018	0.0019		
Total	100.1	1.50	1.82	2.9		1.03	

Discussion

XRF Analysis

- An_{75} = Bytownite
  - More calcic

Michel-Levy Results

- An_{58} = Labradorite
  - About 50/50 Ca & Na

Mindat.org

Discussion

- Why don’t my two analyses (Michel-Levy & XRF) correlate?
  - Michel-Levy analysis from a small section of rock
  - XRF analysis from whole rock
    - Better average
- Ideally, researchers make multiple thin sections & analyses, like Morrison & others did
  - Ensure more accurate results
- Anorthosites in this region can have more than one texture & composition

Discussion

- Morrison and others concluded the plagioclase crystal compositions ranges from An_{55} – An_{79}
- My results were similar to Morrison and others findings although I strictly focused on one locality, Silver Bay, whereas they were all along the shore
- A scientific paper by Miller and Green, 2002 supported the evidence that the inclusions were a mixture of labradoric and bytownitic plagioclase

Further Discussion

- The anorthosites in this region are of particular interest due to their complexity of textures and formation
- Researchers hypothesize the anorthosites formed at a much greater depth than the diabase
- The internal structure of plagioclase suggests the anorthosites originated in a large crystal mush

Conclusion

- Anorthosites make up a large part of the Keweenawan region due to their intrusive nature
- There are four basic textural types of anorthosites
- My data, along with Morrison and others, and Miller & Green, concluded the plagioclase composition to vary from An_{55}-An_{79} (labradorite-bytownite)

Thank you

To Dr. Hopkins of the Soil Science department for use of his thin section equipment

&

Dr. Eidukat for his perpetual quest to teach students about minerals and rocks