Chemical Analysis of Devils Tower

By: Ben Munson

NDSU Petrology Geol 422 May 6, 2014

Outline

- Basics of Devils Tower
- Hand Sample analysis
- XRF results
- SEM Results
- XRD Results
- Mineral Background

Devils Tower

http://www.a-roundtheworld.net/places/the-devils-tower/

Site Location

https://www.google.com/maps

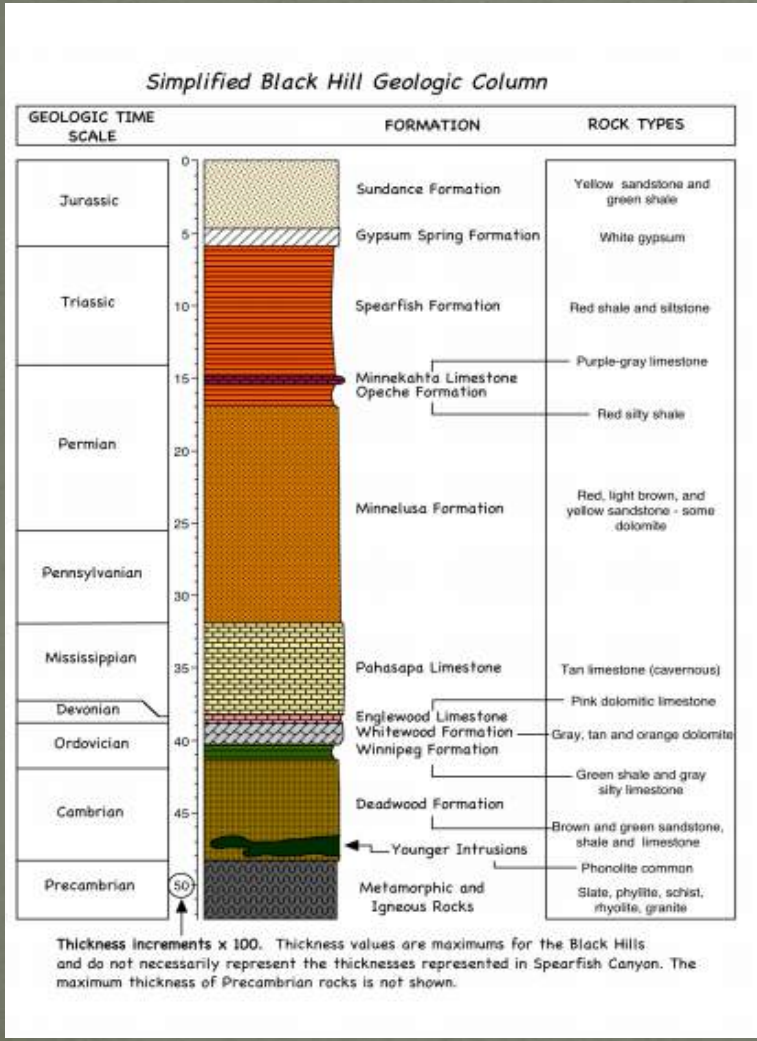
- Located in the northeastern corner of Wyoming
- Crook County, Wyoming
- Within the western stretch of the Black Hills
- Near the towns of Sundance and Hulett
- Coordinates
  - 44°35′ 26″ N 104°42′ 56″ W

Devils Tower Basics

- United States National Monument
  - Declared as 1st national monument in September 24, 1906
- Devils Tower rises 1,267 feet above the surrounding terrain
- The monument totals 1,347 acres
- Columnar joints measure between 2m and 3m in diameter at the bottom of the structure

http://www.answersingenesis.org/articles/wog/devils-tower

Devils Tower Geology

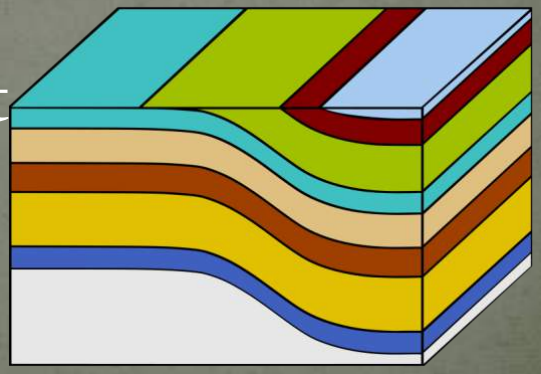


- Rises above the surrounding Sundance Formation (5 members)
  - Canyon Springs
  - Stockade Beaver
  - Hulett
  - Lak
  - Redwater
- Mostly sandstones and limestones
- The Sundance fm falls unconformably on the Gypsum spring formation
  - Deposited with the cretaceous interior seaway

(Fogerty, 2012)

Evolution of Intrusion

- Late cretaceous uplift event occurred in region
  - Possibly related to the Laramide Orogeny to the west
- Uplift particularly strong in the Northwest portion of the black hills
- Monocline forms 10km west of current Devils Tower location
- Uplift responsible for creating deep fractures and possibly melting of the mantle
- Followed by major depositional event



(Halverson, 1980)

Origin Hypotheses

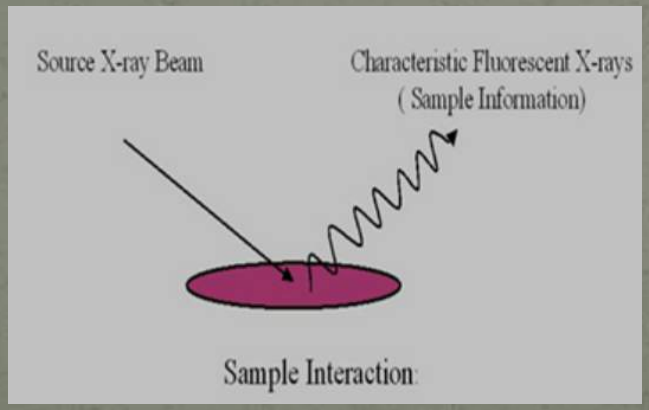
- Eroded Laccolith
  - Magma intruded up through underlying sedimentary rock beds but never reached the surface
  - Explains surrounding buttes as being different vents to a single large igneous body
- Volcanic neck
  - Remnants of an ancient “plugged” volcano with a large underground magma chamber.
  - Evidence of ash deposits and lava flows in the area is not present

(Halverson, 1980)

Hand Sample

- Coarse porphyritic sample with a gray to greenish gray matrix
- Holocrystalline texture
- Large white/creamy rectangular phenocrysts
- Sample collected with special permit

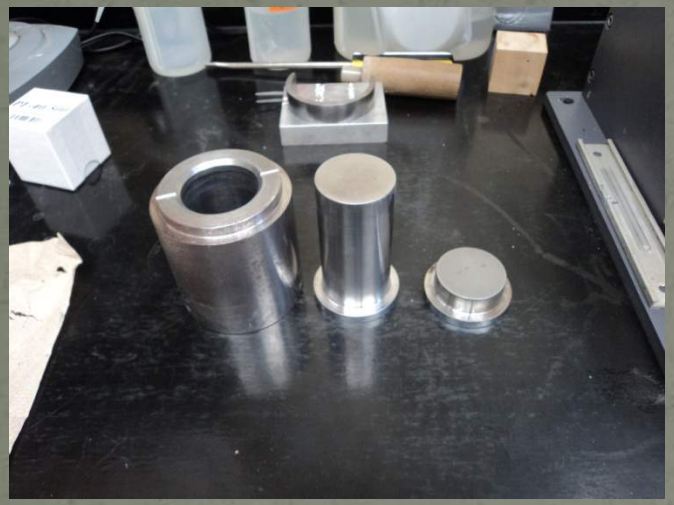
XRF: Methods

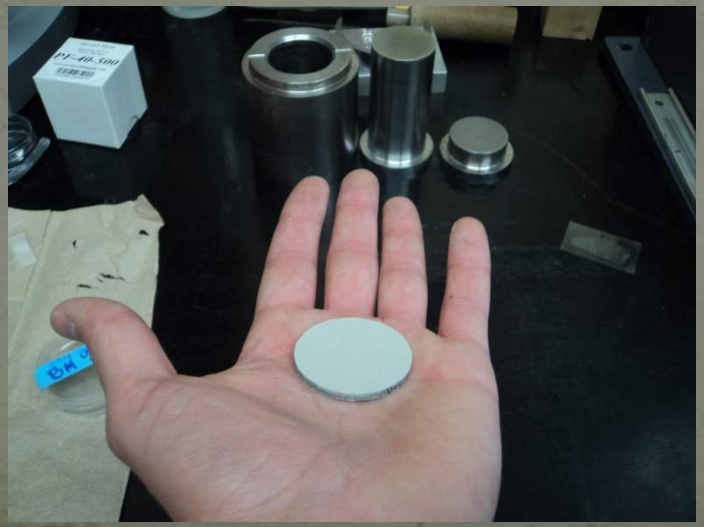


- X-Ray Fluorescence (XRF)
- Crushed sample into a fine powder
- Mixed powder with an adhesive
- Pressed pellet into a disc
- Analyzed powder in XRF machine for whole rock chemical analysis

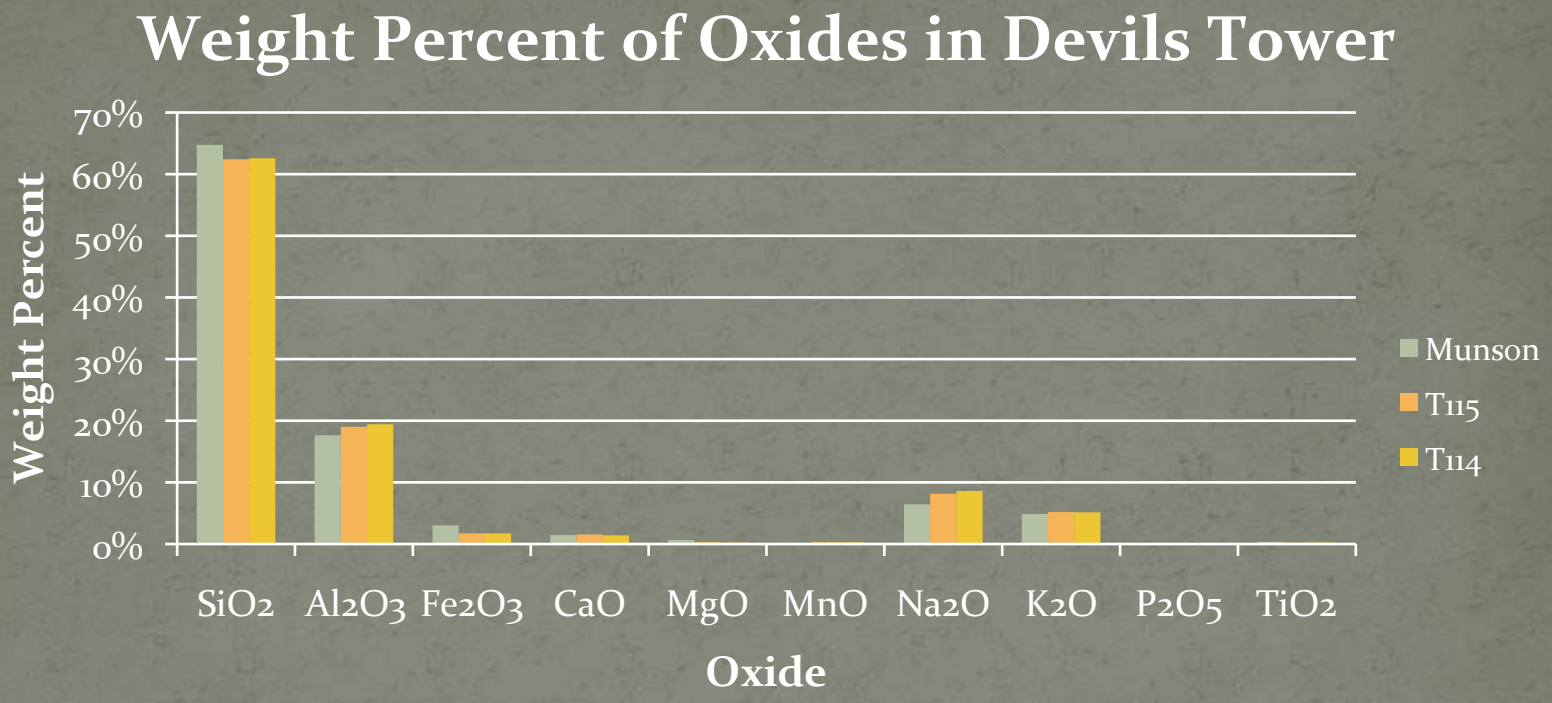
http://geology.uprm.edu/facilities/Class%20Forms/xrf.pdf

X-Ray Fluorescence: Methods





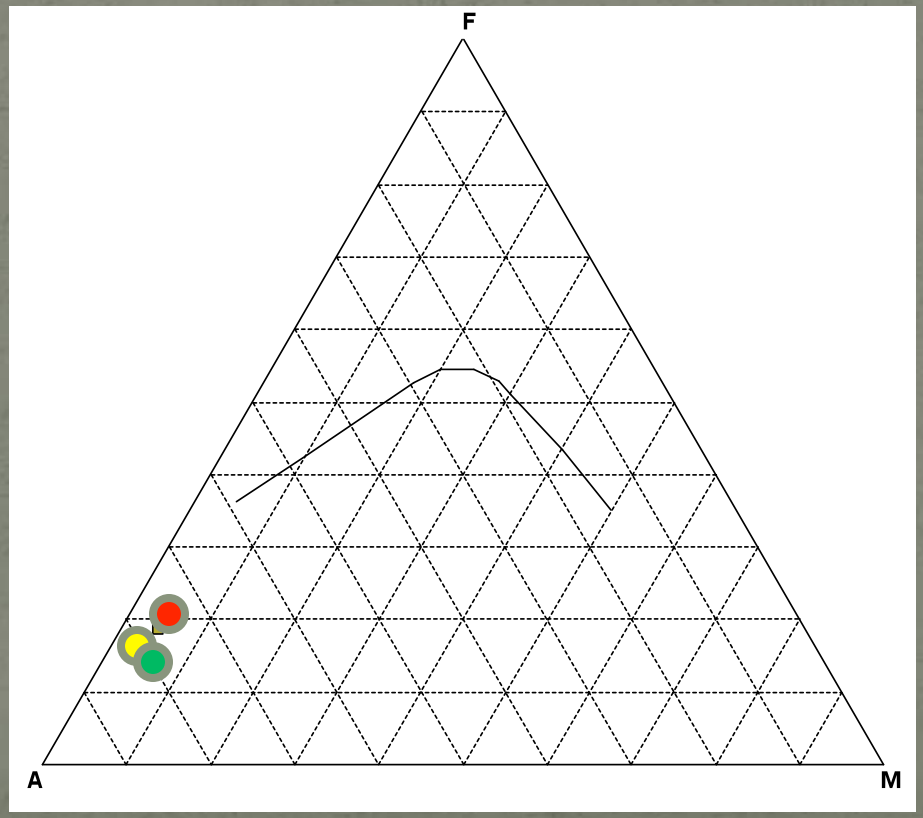
XRF: Results



Formula	SiO2	Al2O3	Fe2O3	CaO	MgO	MnO	Na2O	K2O	P2O5	TiO2
Munson	64.75%	17.64%	3.02%	1.46%	0.64%	0.14%	6.44%	4.87%	0.08%	0.35%
T114	62.58%	19.43%	1.73%	1.41%	0.22%	0.28%	8.61%	5.14%	0.10%	0.23%
T115	62.42%	19.02%	1.73%	1.54%	0.30%	0.30%	8.16%	5.18%	0.12%	0.23%

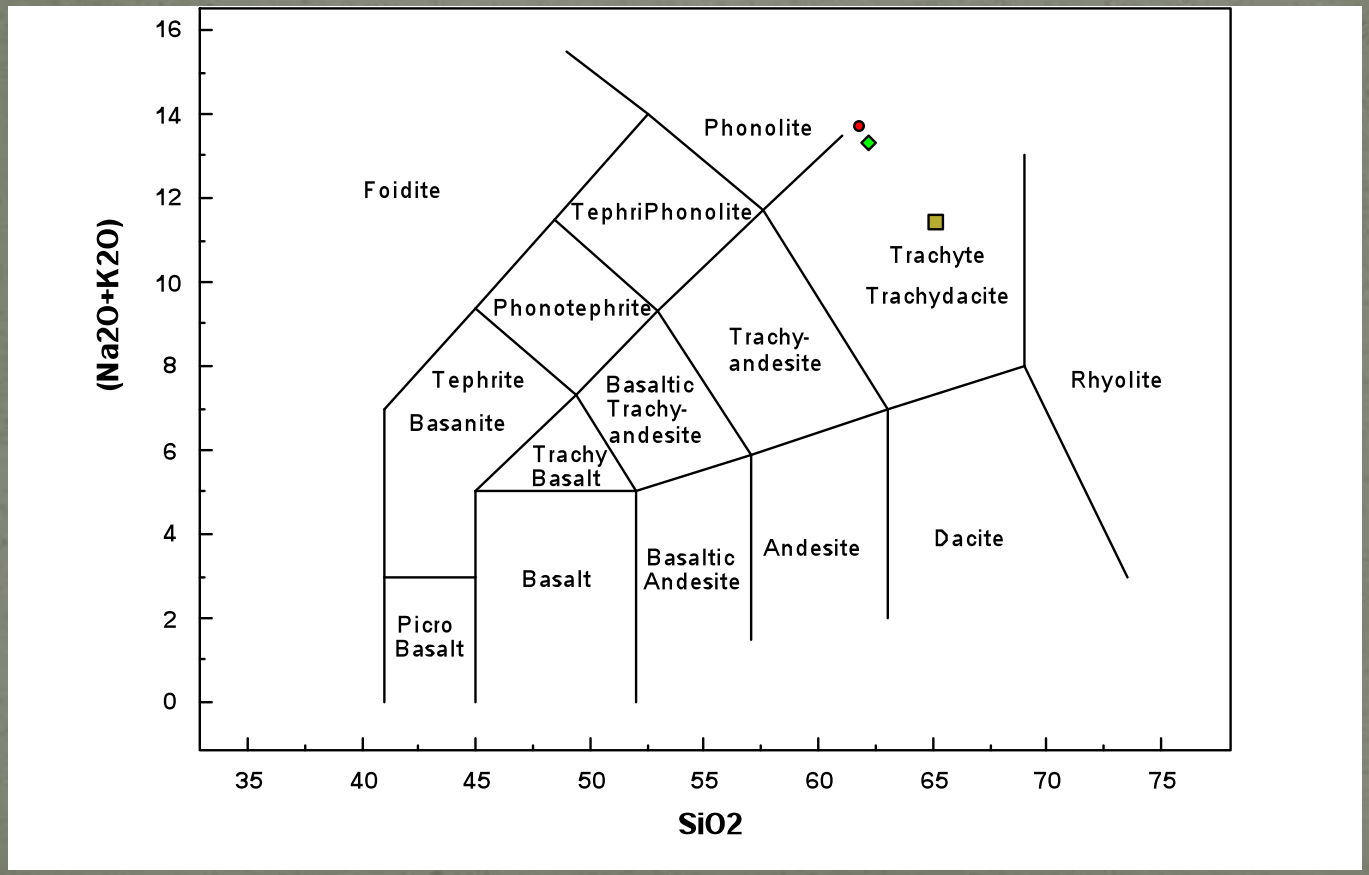
XRF: Results

- AFM graph plotted using PetroGraph
- Irvine and Baragar 1971 methods



XRF: Results

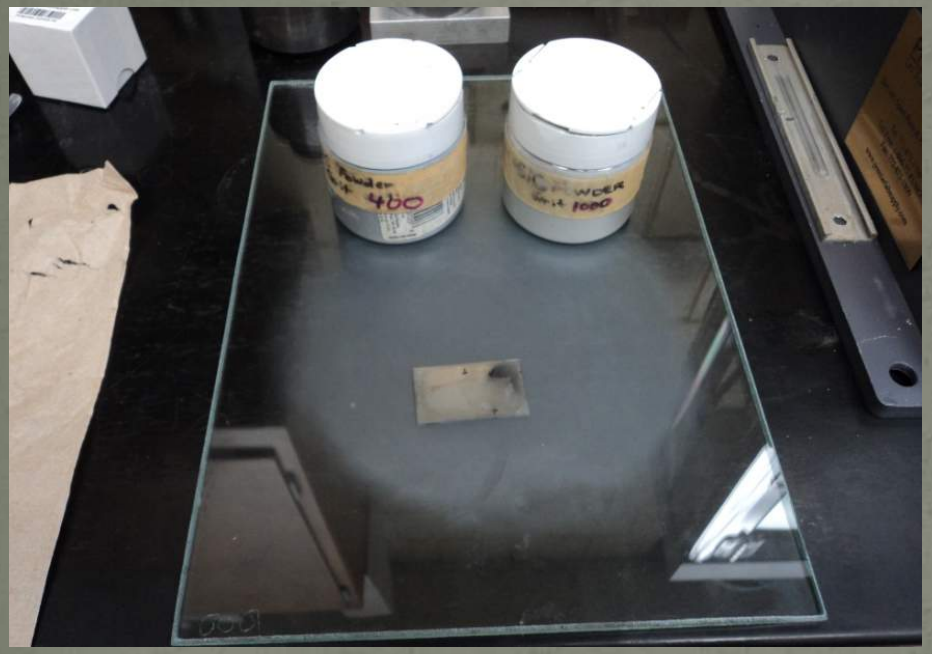
- AFM graph plotted using PetroGraph



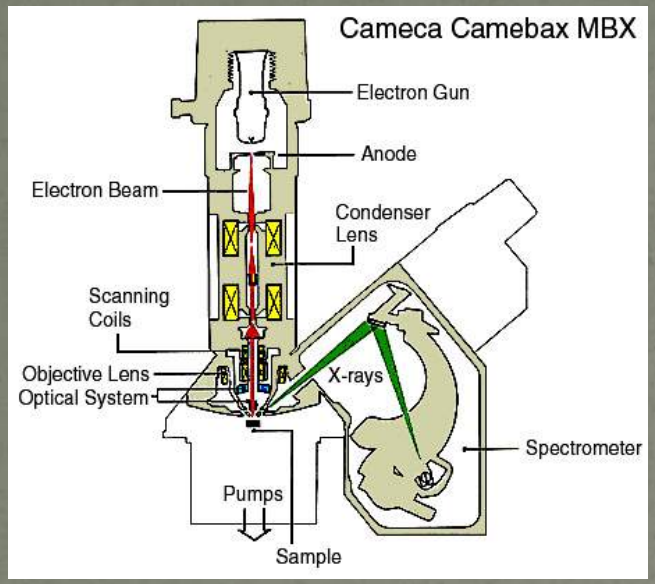
Thin Section

- Sample was already cut to size and in epoxy
- Glued sample to a new slide
- Cut sample with a diamond blade down to correct thickness
- Sanded thin section down to 30 microns using 400 and 1,000 grit

Thin Section

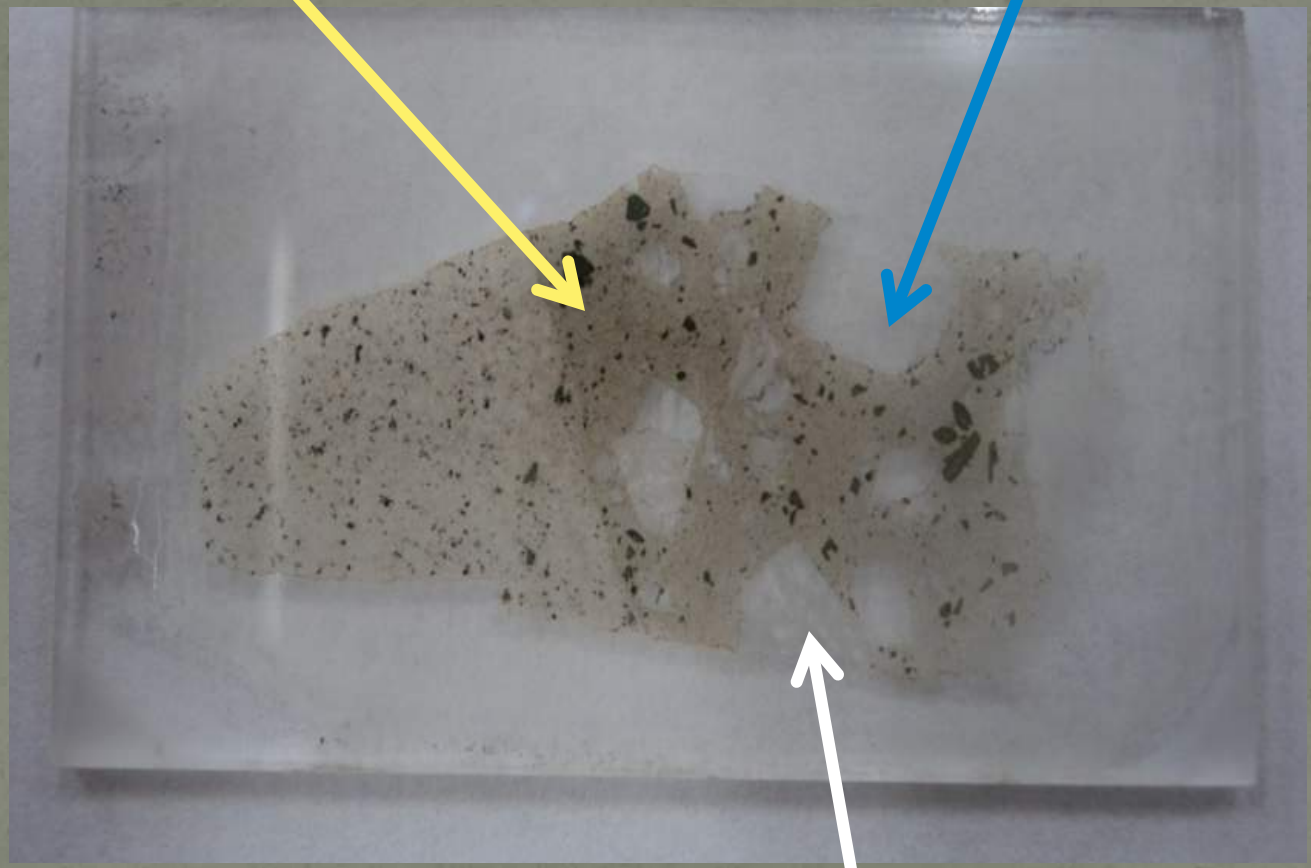


SEM: Methods

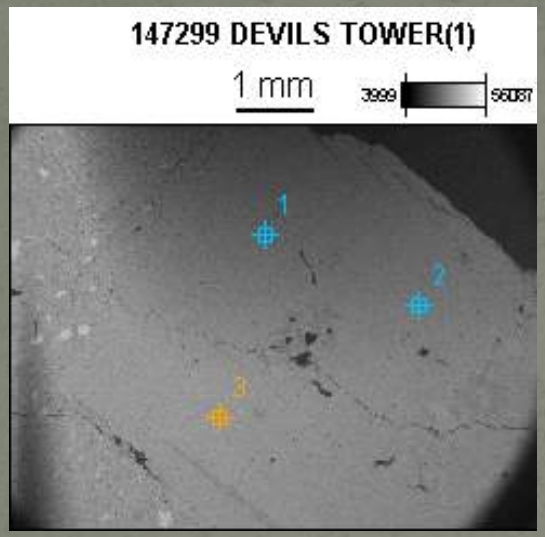


- Scanning Electron Microscope (SEM)
- Polished thin section using 1 micro grain grit
- Coated thin section with fine grained carbon
- Identified chemistry of Phenocrysts using the SEM

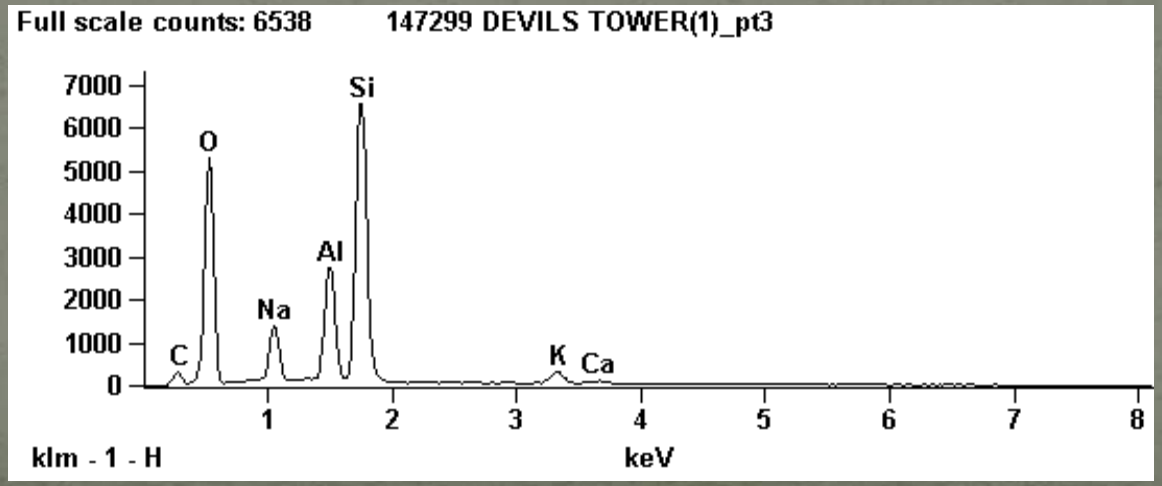
Layout



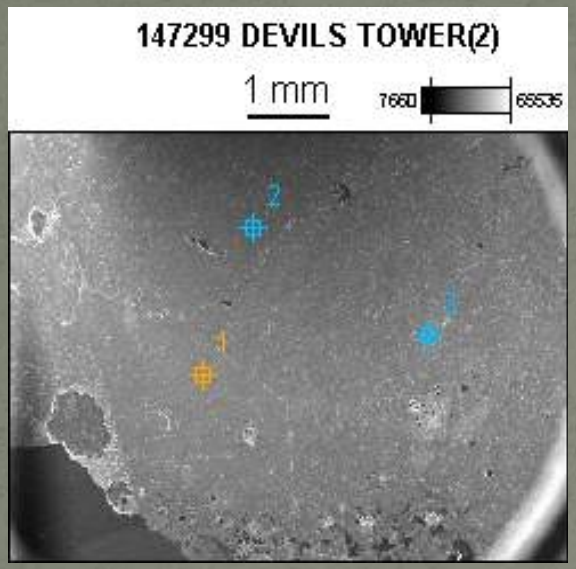
SEM Results

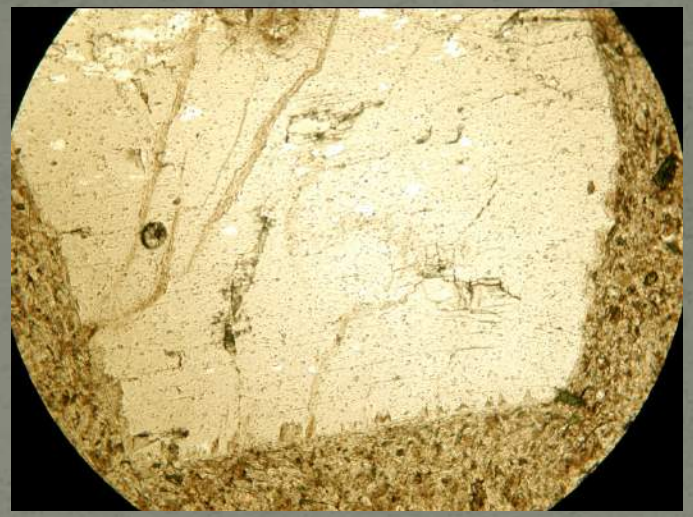


FOV: 8mm PPL

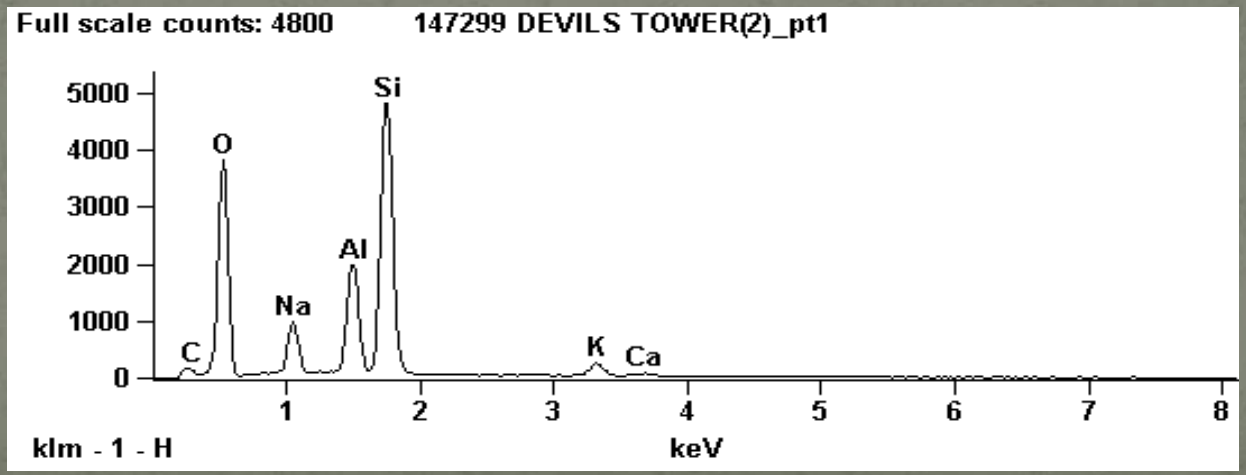


SEM Results

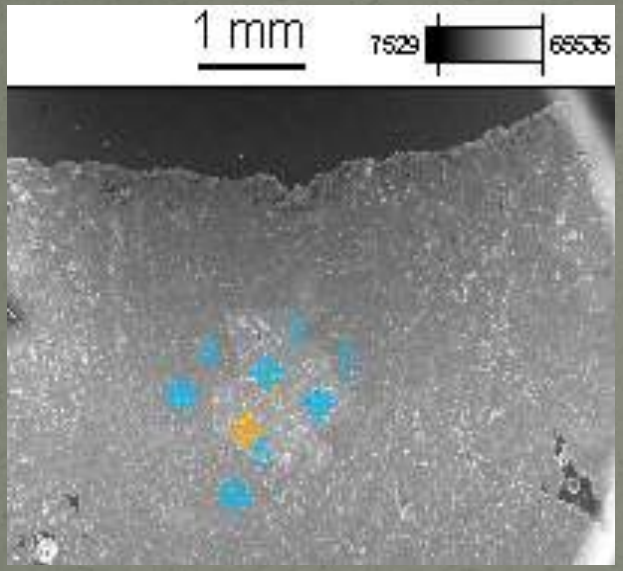


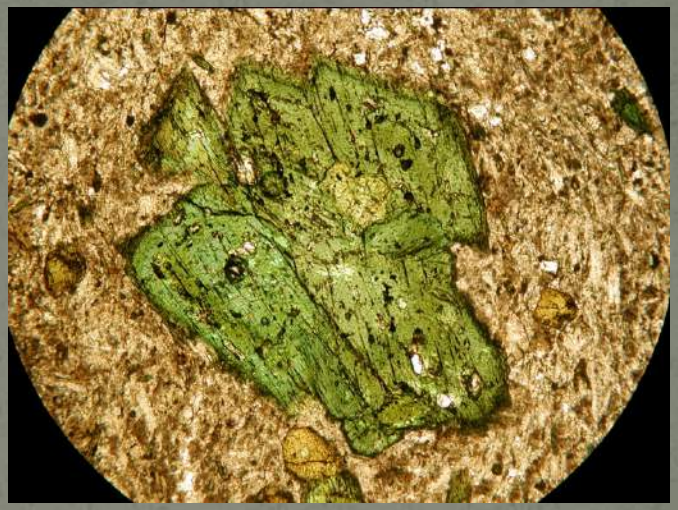


FOV: 2.5mm PPL

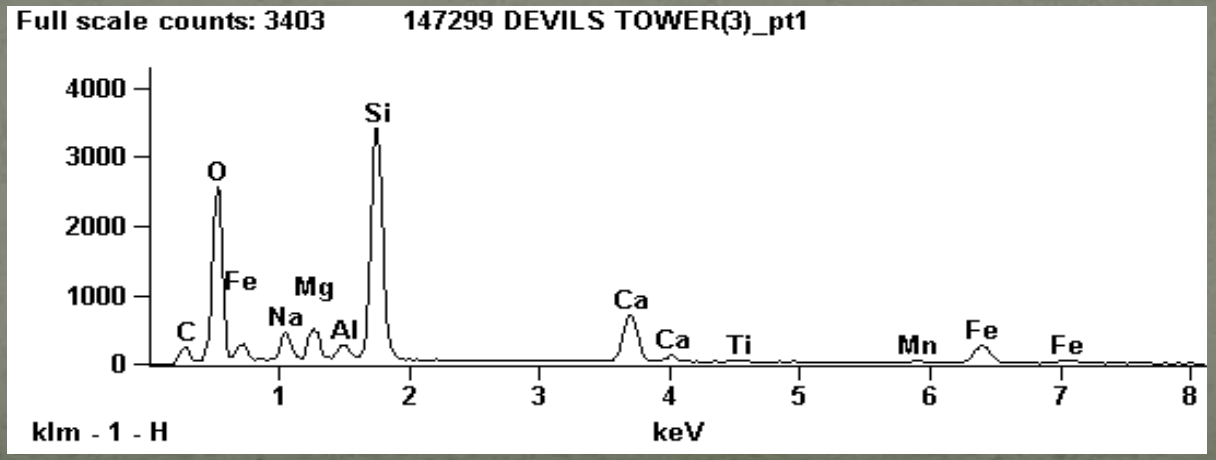


SEM Results





FOV: 2.5mm PPL



SEM Results

- Phenocryst DT1

		Na2O	Al2O3	SiO2	K2O	CaO
147299 DEVILS TOWER(1)_pt1	0.00	9.96	19.29	66.01	4.74	
147299 DEVILS TOWER(1)_pt2	0.00	10.64	19.97	65.46	2.97	0.96
147299 DEVILS TOWER(1)_pt3	0.00	10.68	19.95	65.15	3.52	0.70

- Phenocryst DT2

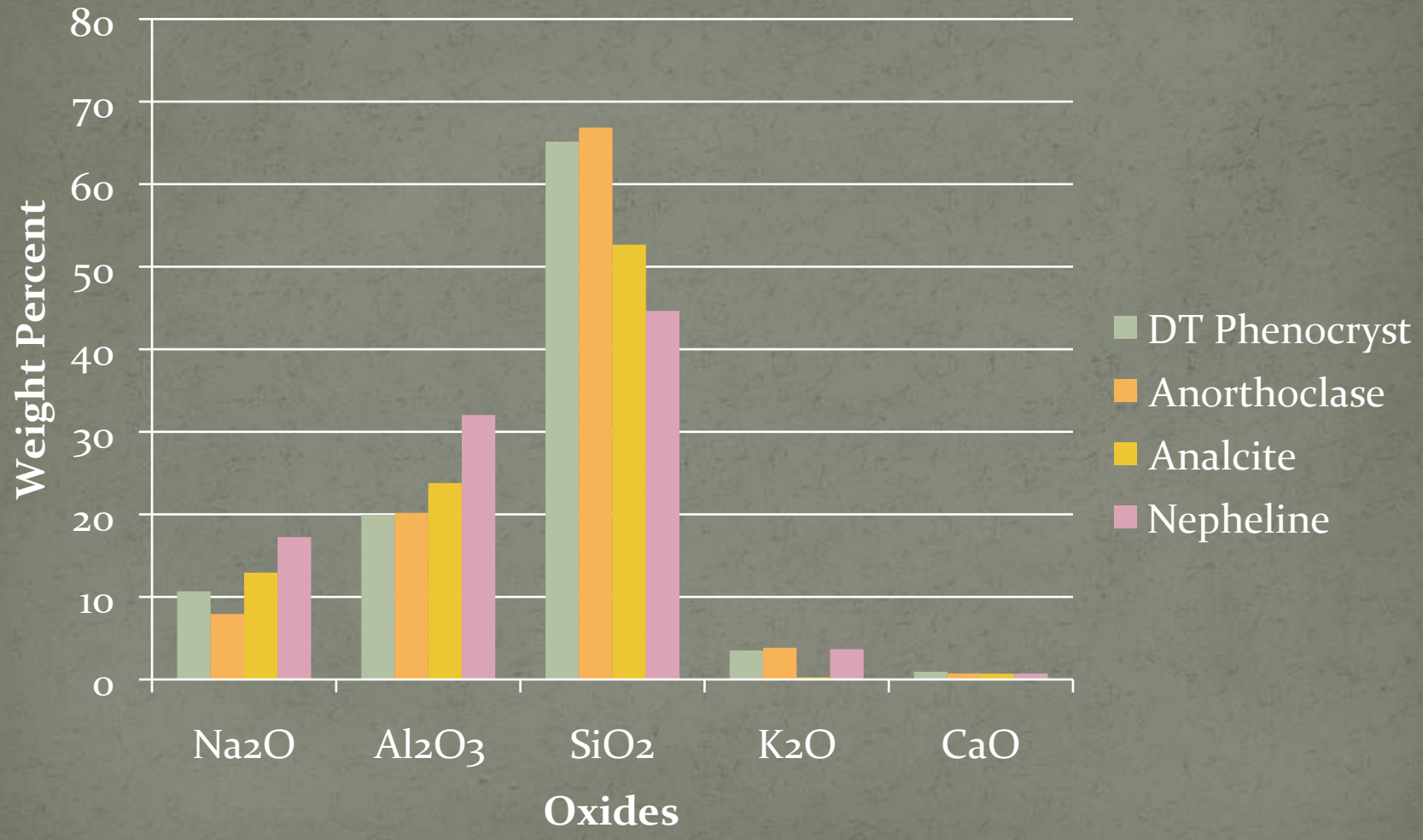
		Na2O	Al2O3	SiO2	K2O	CaO
147299 DEVILS TOWER(2)_pt1	0.00	10.31	19.81	65.11	3.86	0.91
147299 DEVILS TOWER(2)_pt2	0.00	10.64	19.43	65.48	4.45	
147299 DEVILS TOWER(2)_pt3	0.00	9.82	19.39	65.65	5.15	

- Potential Minerals

Oxides		Na2O	Al2O3	SiO2	K2O	CaO
Anorthoclase		7.93	20.18	66.85	3.84	0.73
Analcite		12.94	23.79	52.67	0.25	0.71
Nepheline		17.25	32.03	44.65	3.66	0.71

(Holverson, 1980)

Phenocryst Identification



SEM Results

- Phenocrsyt DT3

		Na2O	MgO	Al2O3	SiO2	CaO	TiO2	MnO	Fe2O3
147299 DEVILS TOWER(3)_pt1	0.00	5.76	4.93	2.25	49.19	16.05	0.47	1.24	20.10
147299 DEVILS TOWER(3)_pt2	0.00	4.68	6.49	2.78	49.44	18.19	0.49		17.94
147299 DEVILS TOWER(3)_pt3	0.00	6.45	4.43	2.87	50.66	14.93		1.39	19.27

- Pyroxene chemistry

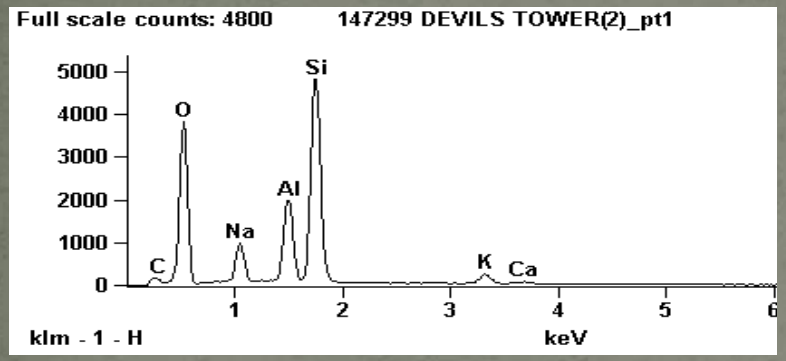
Oxides	Na2O	MgO	Al2O3	SiO2	K2O	CaO	TiO2	MnO	Fe2O3
Pyroxene	6.73	3.78	2.03	49.12	0.16	11.86	0.56	1.09	51.33

(Holverson, 1980)

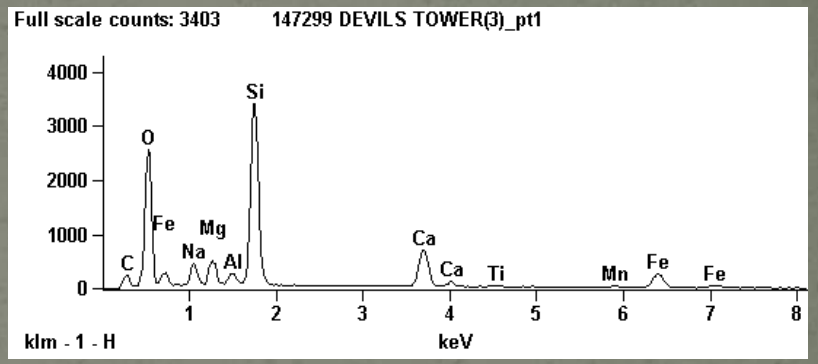
Phenocrsyt Identification

SEM Phenocryst Results

- Anorthoclase
- DT1 and DT2:
- $(Na,K)AlSi_3O_8$

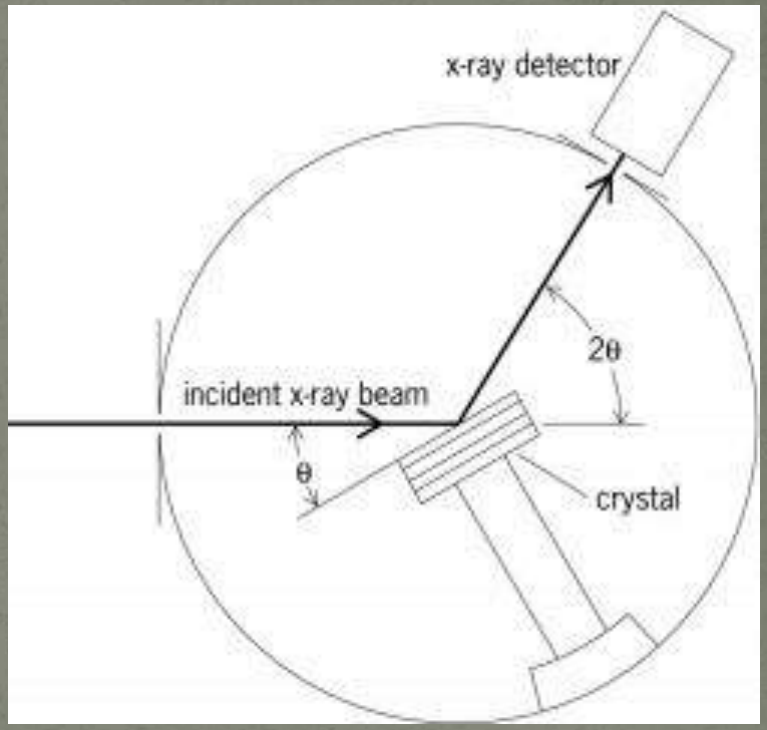


- Aegirine-augite
- DT3:
- $(Ca,Na)(Mg,Fe^{+2}, Fe^{+3})Si_2O_6$



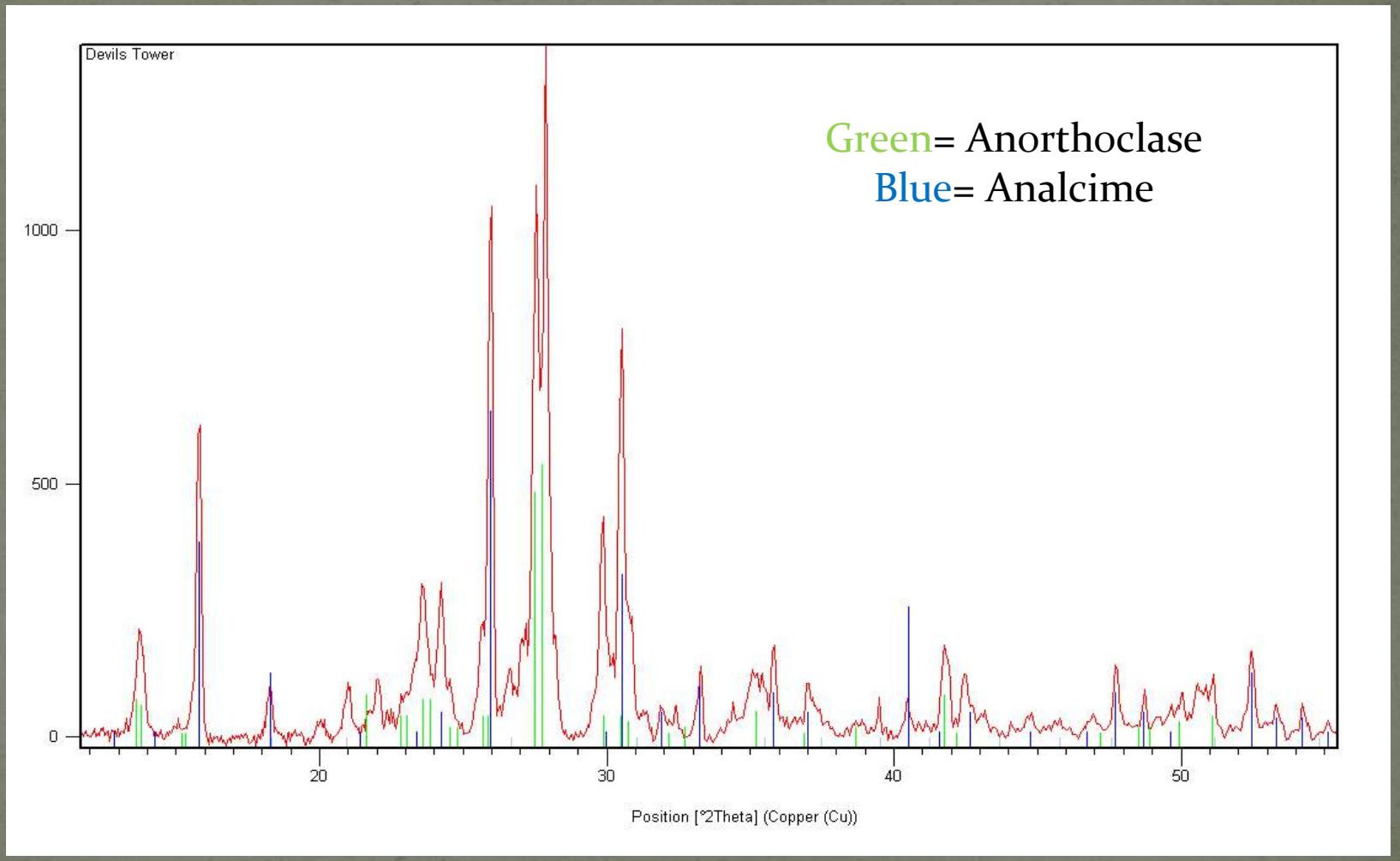
XRD Methods

- X-Ray Diffraction (XRD)
- Data is from 2012 petrology project
- Used X'PERT Software for data analysis
- XRD data examines whole rock chemistry
  - Particularly interested in the matrix material



http://encyclopedia2.thefreedictionary.com/x-ray+diffraction

XRD Results

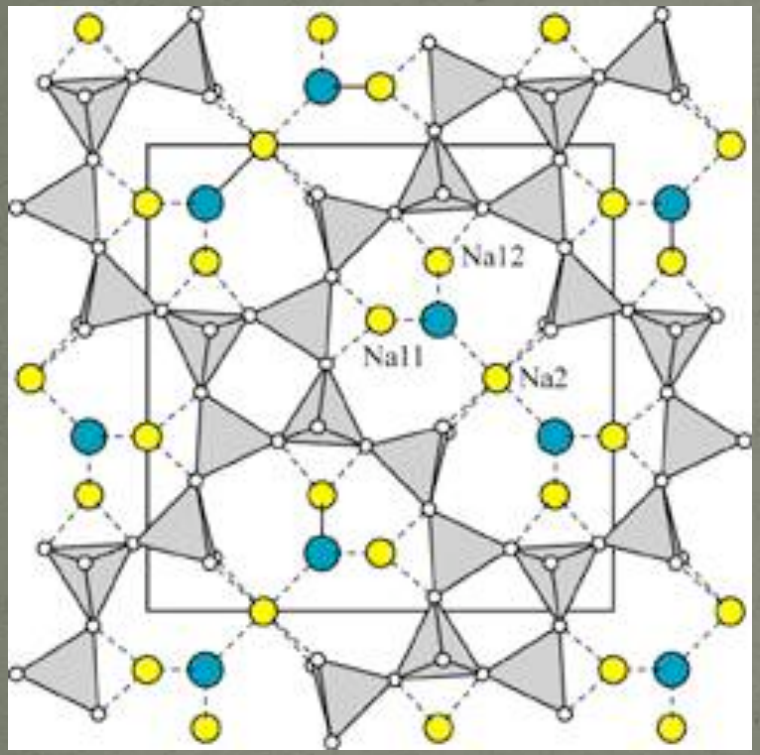

Devils Tower
Green= Anorthoclase
Blue= Analcime
1000
500
0
20
30
40
50
Position [°2Theta] (Copper (Cu))

Analcime

- Chemical Formula: $Na(AlSi_2O_6)$-H_2O
- Cubic
- Color: White, Pink, grey, Colorless in thin section
- Framework: Aluminosilicate framework with $(SiAl)O_4$ Tetrahedral linked together forming several different rings
- Continuous rings form channels which are filled with water molecules
- Physical properties
  - Hardness= 5-5.5
  - Cleavage: (100) poor
- Incompatible with free Quartz

(Klein, 2002) and (Deer et al, 1997)

Analcime

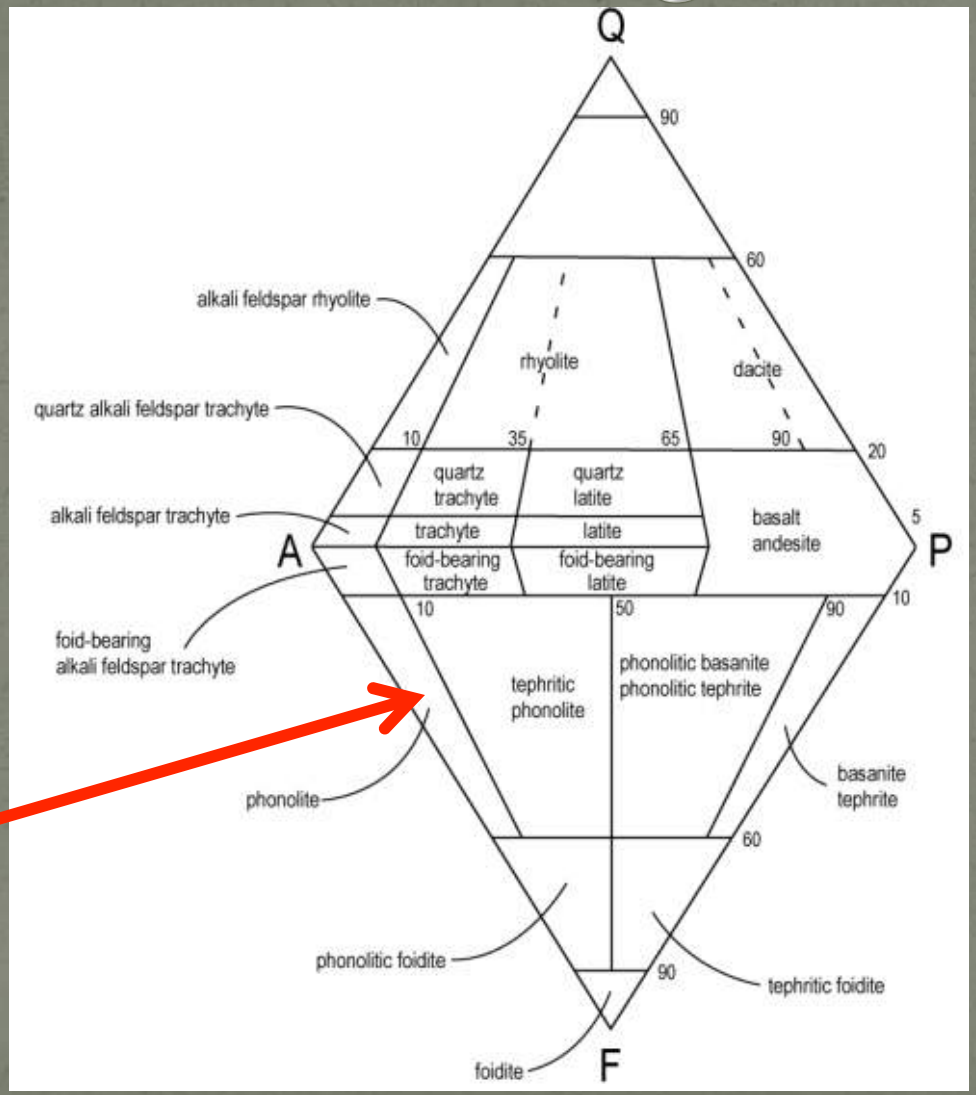


http://www.iza-online.org/natural/Datasheets/Analcime/analcime.htm

- Classified as a zeolite
  - Hydrous silicates
  - Framework Aluminosilicates
  - Water molecules fill voids within structure
- Analcime structure, chemistry, and occurrence are very similar to the Feldspathoid group

  (Klein, 2002)

QAPF Diagram



DEVILS TOWER

(Winter, 2010)

Analcime in Devils Tower

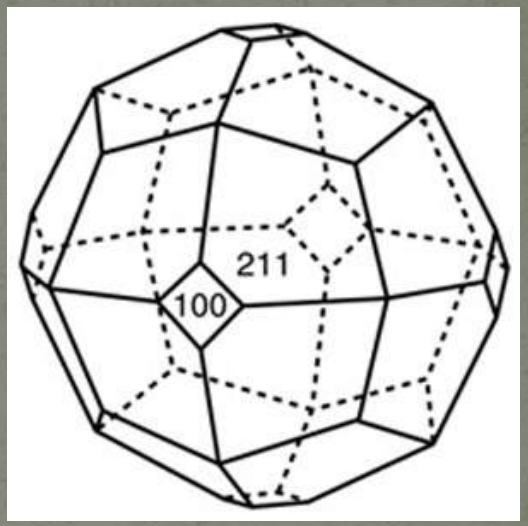
- There are several theories as to why Analcime is in Devils Tower
  - Analcime crystalized from a liquid (primary)
    - Indicated by euhedral analcime grains being observed in thin section
    - Magmatically derived hydrous fluids
  - Alteration of Leuctie
    - Leucite $KAlSi_2O_6$ Analcime $Na(AlSi_2O_6)$-H_2O
    - Late stage replacement
  - Hydrothermal origin
    - Crystallizes after emplacement in sediments with Na-rich fluid source (data doesn't support the pressure needed)

(Halverson, 1980)

Analcime in Devils Tower

- Pressure needed
  - 8 Kb
- Temperature needed
  - 600 degrees Celsius
- Halverson estimated that this indicates the maximum depth of formation at 43 km
- Also generated from a sodic trachytic magma

(Halverson, 1980)



http://www.tobias-weisenberger.de/5

http://www.mindat.org/photo-168183.html

Recap

- Used XRF to analyze whole rock chemistry
  - Identified sample as a Trachyte
- Created a thin section
- Used SEM to identify phenocryst
  - Anorthosite, Agerine-Augite
- Used XRD to identify minerals
  - Analcime

References

- Deer, W.A., Howie, R.A., Zussman, H.J., 1997, Rock-Forming minerals 2nd ed.
- Fogerty, S., 2012 Bridal Veil Falls: hjp://sites.google.com/site/geologyofspearfishcanyon/bridal-veil-falls (accessed May 2014).
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- Klien, C., 2002, The 22nd edition of the manul of mineral science: Hoboken New Jersey, John Wiley & Sons, Inc., 559
- Winter, J.D., 2010, Principles of Igneous and Moetamofphic Petrology, 2nd ed: Upper Saddle River, NJ, Prentice hall.

Questions?