ANALYSIS OF MT. EREBUS VOLCANICS: A POSSIBLE ANORTHOCLASE PHONOLITE WITH MELT INCLUSIONS

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Context

- Discovered in 1841 by James Ross
- Mt. Erebus is the largest active volcano on Ross Island
- Resides over Terror Rift and Erebus hotspot
- Namesake of the Erebus Volcanic Province and member of McMurdo Volcanic Group

(Kyle, 1977) (Kyle et al., 1992) (Sims et al., 2013)

Mt. Ereubus, Ross Island. Photo Credit: USGS

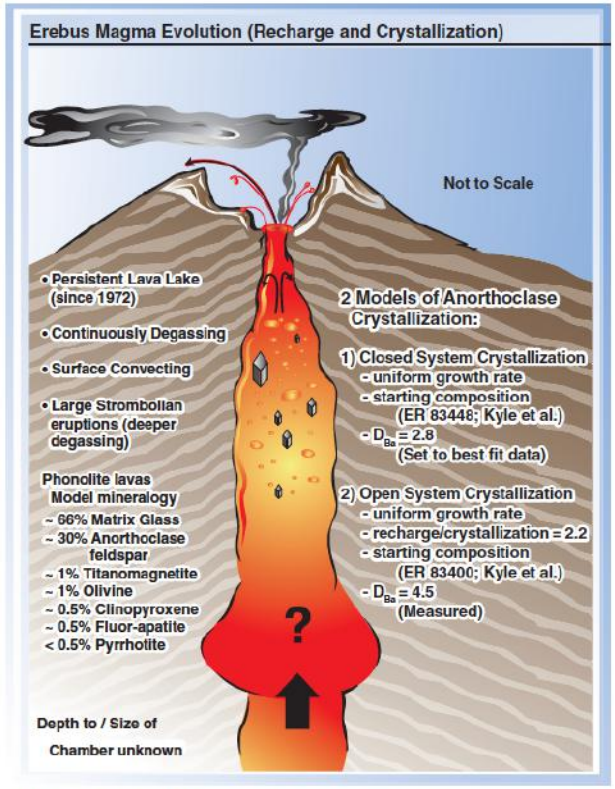


Fig. 1. Schematic illustration of the Erebus shallow magmatic system, detailing compositional constraints, model parameters and assumptions.

Mt. Erebus Overview. Photo Credit: Sims et al., 2013

Context

- Mt. Erebus is located on Ross Island near McMurdo Station
- Ross Island also boasts three other extinct volcanoes: Mt. Terror, Mt. Bird, and Mt. Terra Nova
- The island is composed largely of silica undersaturated phonolite porphyry and basanite

(Kyle, 1977) (Kyle et al., 1992) (Sims et al., 2013)

Photo Credit: British Antarctic Survey

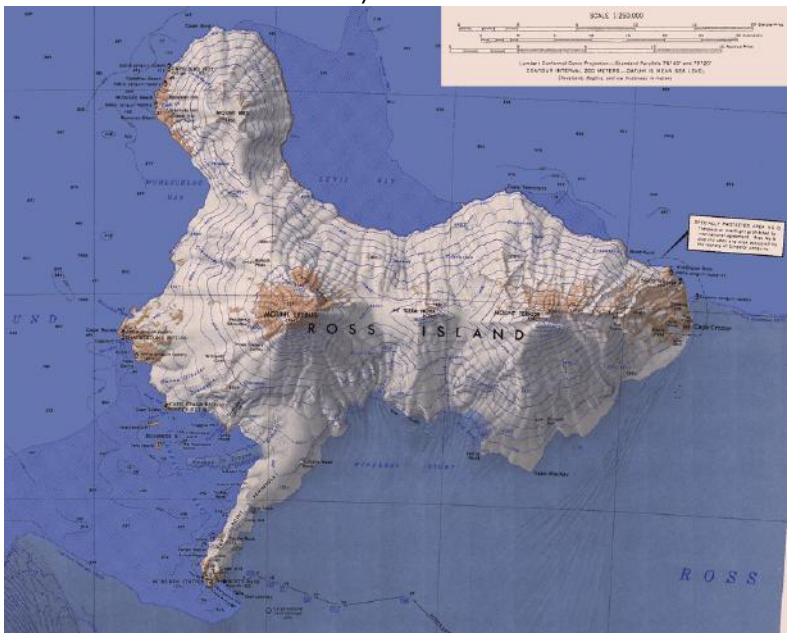


Photo Credit: USGS Photo Archive

Motivation

- This sample has yet to be analyzed
  - Beyond the allure of a brand new sample, there are also abundant and often euhedral crystal inclusions.
  - Within these crystals there are a large number of amorphous inclusions

- These elements make the sample noteworthy and open up questions

Guiding Questions

- Is this sample a cooled phonolite lava?
- Are the numerous inclusions in the otherwise perfect phenocrysts examples of preserved melt?
- Are the phenocrysts the so called anorthoclase "Erebus Crystals"

Volcanic Samples

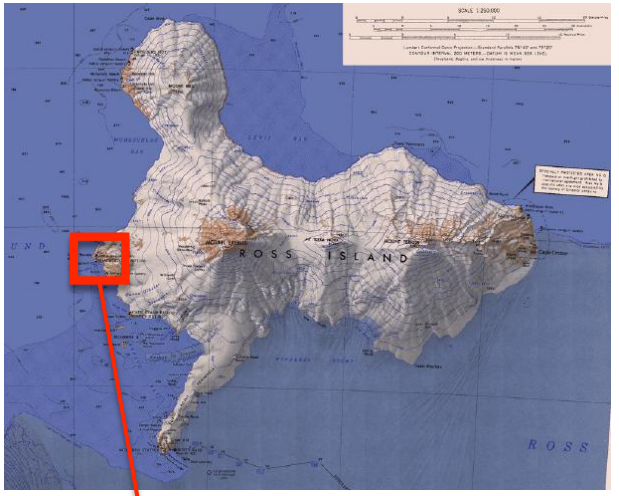
- Samples collected by Dr. Ashworth at Cape Royds, Ross Island.
- Porphyritic with phenocrysts, black and porous in hand sample
- Fine matrix, composition not discernable
- Weak structure, easily broken

Photo Credit: Gabriel Ferragut

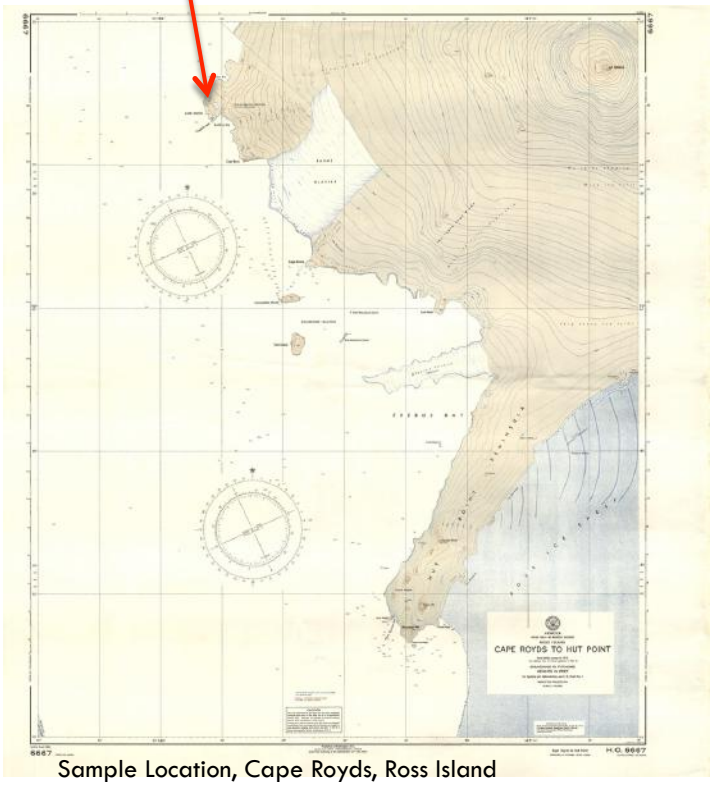
Photo Credit: Gabriel Ferragut

Volcanic Samples

- Samples collected by Dr. Ashworth at Cape Royds, Ross Island.
- Unknown age and origin
  - Derivative of lava flow or lava bomb?
  - 1 Ma or 20k Ma?
- GPS- 77° 33' S, 166° 10' E



Ross Island
Photo
Credit:
USGS
Photo
Archive



Sample Location, Cape Royds, Ross Island
Photo Credit: U of M Polar Geospatial Center

Methods-XRF

- Sample was inherently weak and porous
- Crushed to ~ 1cm scale using ceramic jaw crusher
- Sample was then ground to fine powder in puck mill
- Powder combined with volatile polyvinyl binder and compressed in cylinder at 15 kPa for 1.5 minutes and analyzed via x-rays

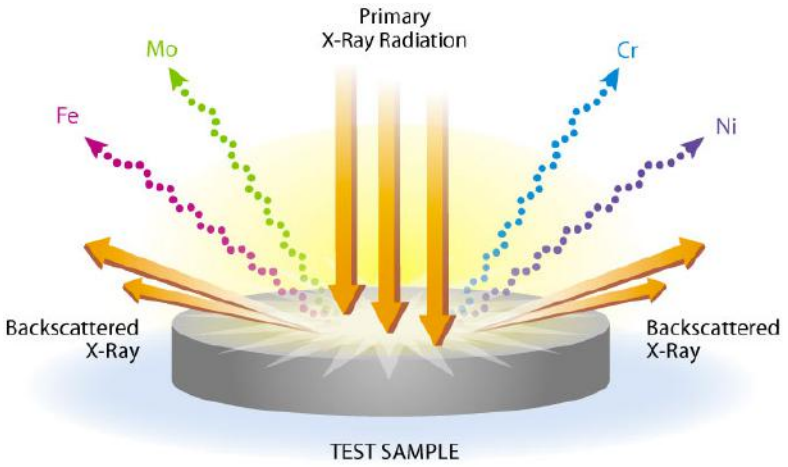


Photo Credit: 911Metallurgist

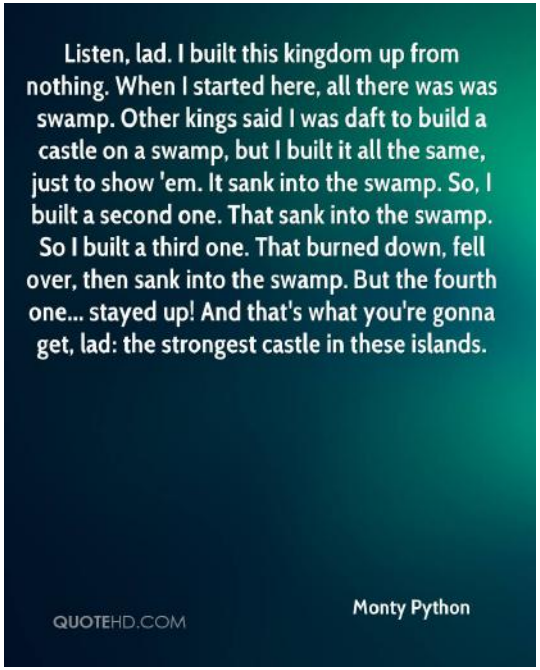
Methods-SEM

- A series of four thin sections were made
  - Thin Section #1:
    - Sample cut with rock saw (NDSU Geosciences) to appropriate size
    - Glued to slide with epoxy (10:3 ratio)
    - Further cut and ground to 0.25 mm with Buehler PetroThin saw (NDSU Soil Sciences)
    - Ground with #600 grit and then polished with #1000 grit
    - Inadvertently polished to oblivion

Methods-SEM

- A series of four thin sections were made
  - Thin Section #2:
    - Same preparation as thin section #1
    - Ground with #600 grit and then ***GENTLY*** polished with #1000 grit
    - Inadvertently polished to oblivion

Monty Python and the Holy Grail
From fanpop.com



Methods-SEM

- A series of four thin sections were made
  - Thin Section #3 and 4:
    - Sample cut with rock saw (NDSU Geosciences) to appropriate size
    - Embedded in thermo-epoxy
      - Sample placed in 33mL uncured epoxy/hardener
      - Exposed to 105 °C for 5 min to reduce viscosity
      - Placed in vacuum with "Irrometer" gauge
        - 5 minutes at a reading of 16
        - 2.5 minutes at a reading of 25
        - 2.5 minutes at a reading of 30
      - Sample cured for 10 minutes at 140 °C to harden
    - Cut and glued to slide with epoxy (10:3 ratio)
    - Further cut and ground to 0.25 mm with Buehler PetroThin saw (NDSU Soil Sciences)
    - Ground with #600 grit and then polished with #1000
    - ***NOT*** polished to oblivion, both polished to 30 microns

Photo Credit: Gabriel Ferragut

Photo Credit: Gabriel Ferragut

Methods-SEM

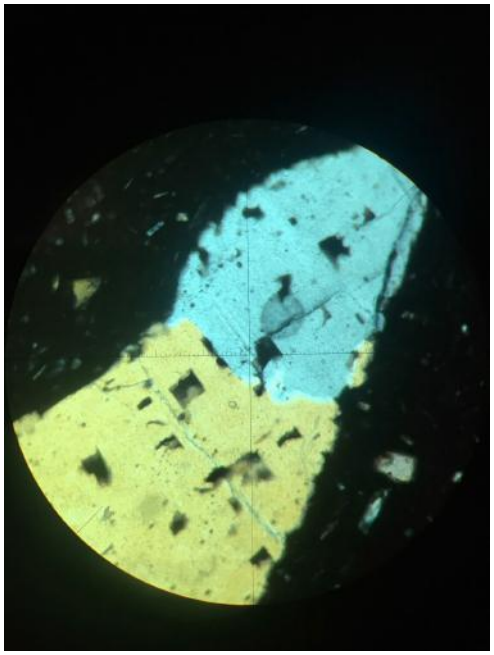
- Thin section #3 was further polished with 1micron grit for around 10 minutes before breaking in the mechanical polisher
- This polish was luckily sufficient to move on to SEM
- Coated with carbon with Cressington carbon coater

Photo Credit: Gabriel Ferragut

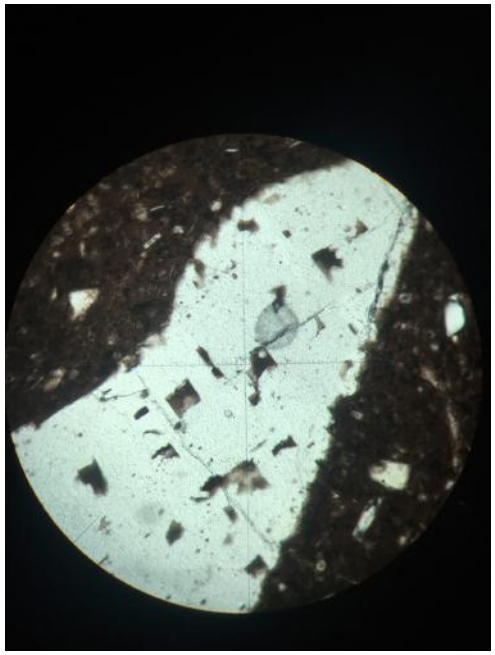
Photo Credit: Gabriel Ferragut

Methods-Microscopy

- Thin section #4 was used as a microscopy sample for context



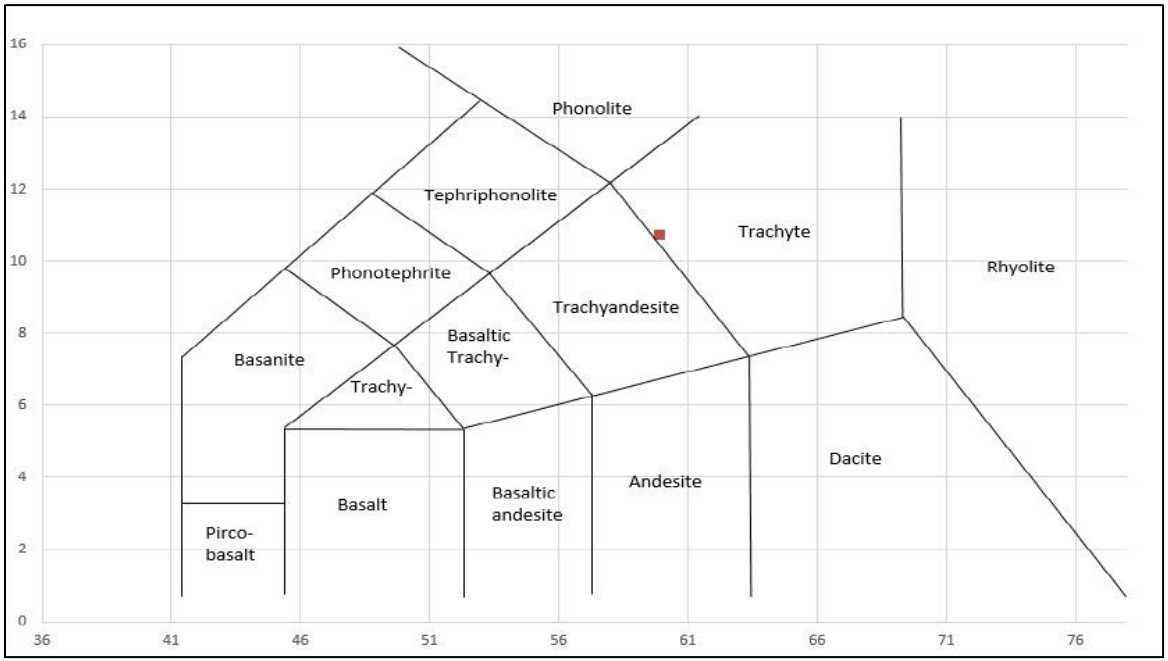
Phenocryst and inclusions, XP, FOV: 2mm
Photo Credit: Gabriel Ferragut



Phenocryst and inclusions, PPL, FOV: 2mm
Photo Credit: Gabriel Ferragut

Prepared thin section
Photo Credit: Gabriel Ferragut

Results-XRF



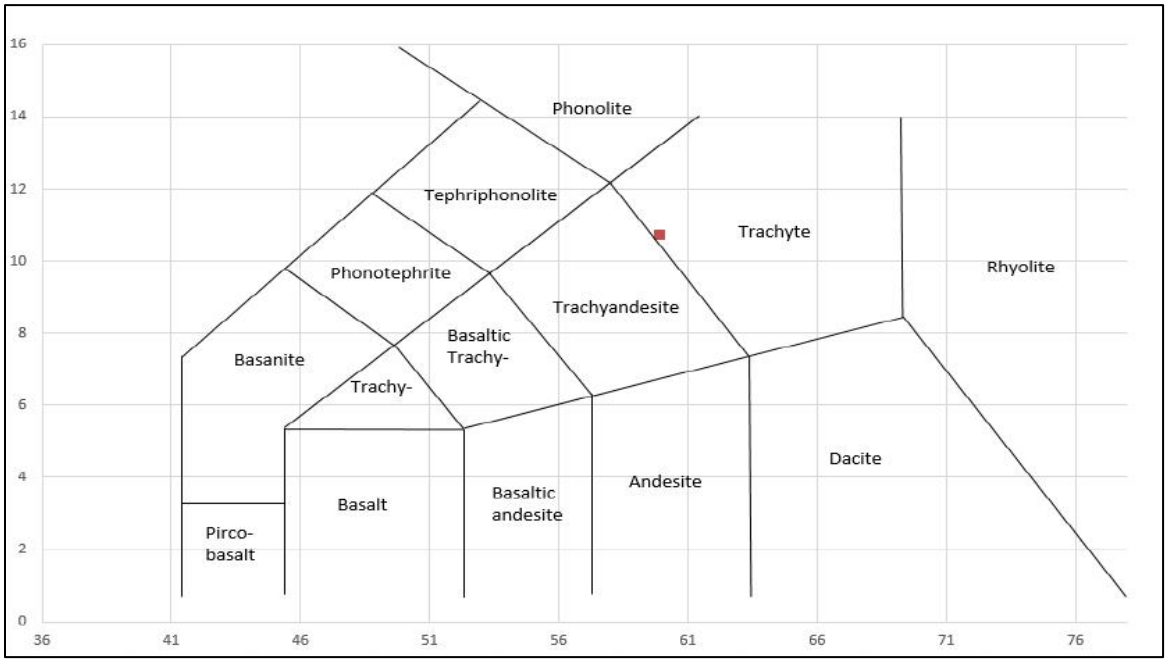
XRF Results, TAS Diagram (alkali composition on y-axis, silica composition on x-axis)

Sample	EL-1__18768
Date	4/15/2016
SiO2 (%)	59.9
Al2O3 (%)	18.1
Fe2O3 (%)	5.3
CaO (%)	3.3
MgO (%)	1.0
MnO (%)	0.2
Na2O (%)	6.3
K2O (%)	4.4
P2O5 (%)	0.4
TiO2 (%)	1.1

XRF Results, wt. % oxides

- Whole rock chemistry gave a composition of Trachyandesite-Trachyte.

Results-XRF



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TiO2 (%)	1.1

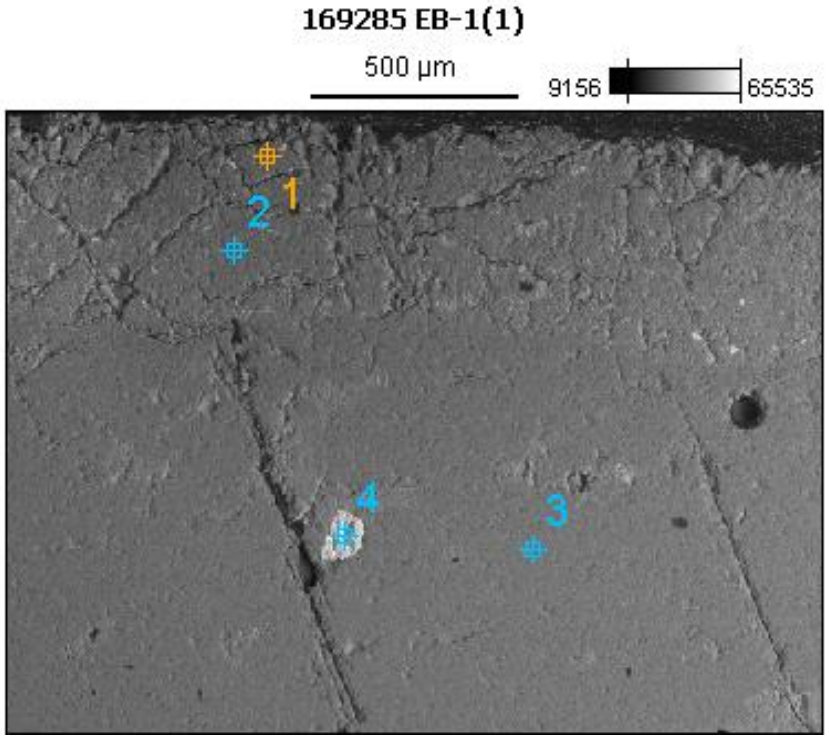
XRF Results, wt. % oxides

- Due to sample contamination? Likely not
- Nepheline Benmoreite, a variety of trachyandesite, is believed to be the parental source for the differentiation of anorthoclase phonolites at Mt. Erebus

(Kyle, 1977)

Results-SEM

- Initially difficult to identify location
- Matrix and crystals vary minimally in culture, mostly texture
- Pt.1/2 - glass matrix
- Pt.3 - phenocryst
- Pt.4 - inclusion within phenocryst

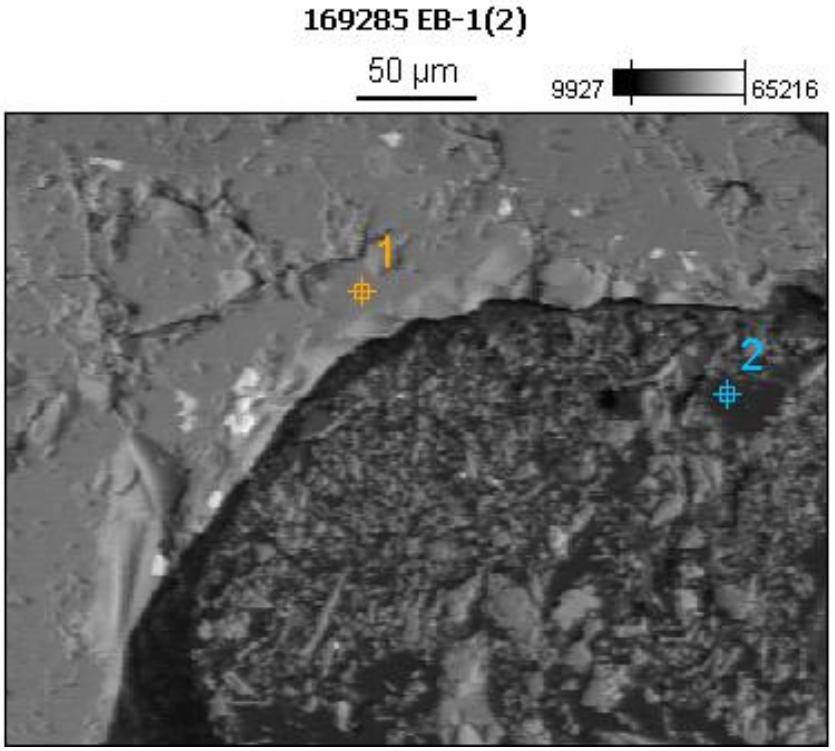


Compound %

		Na2O	MgO	Al2O3	SiO2	Cl	K2O	CaO	TiO2	MnO	Fe2O3
169285 EB-1(1)_pt1	0.00	10.78	0.38	18.92	55.92	0.28	5.73	1.62	1.09		5.26
169285 EB-1(1)_pt2	0.00	9.18	0.30	18.83	56.43	0.25	5.98	1.67	1.20		6.16
169285 EB-1(1)_pt3	0.00	8.24		22.51	61.95		2.50	4.79			
169285 EB-1(1)_pt4	0.00	1.16	3.54	2.14		0.22			26.53	1.72	64.69

Results-SEM

- Pt.1 Melt inclusion in (presumed) anorthoclase crystal
- Pt.2 Mixture of epoxy and silicon carbide grit

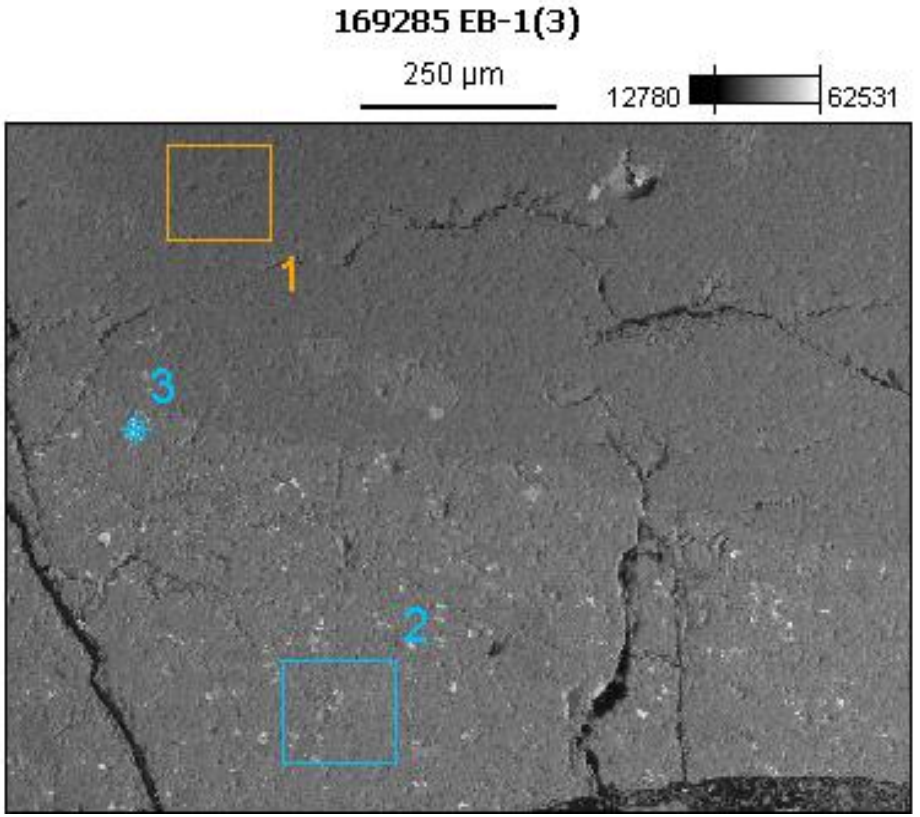


Compound %

		Na2O	MgO	Al2O3	SiO2	Cl	K2O	CaO	TiO2	Fe2O3
169285 EB-1(2)_pt1	0.00	9.62	0.37	19.28	57.11	0.24	6.04	1.68	1.17	4.50
169285 EB-1(2)_pt2	0.00					87.09				12.91

Results-SEM

- Pt.1 Boxed average of crystal composition
- Pt.2 Boxed average of matrix composition
- Pt.3 Likely unreliable



Compound %

		Na2O	MgO	Al2O3	SiO2	P2O5	Cl	K2O	CaO	TiO2	Fe2O3
169285 EB-1(3)_pt1	0.00	8.81		21.89	62.07			2.95	4.28		
169285 EB-1(3)_pt2	0.00	8.67	0.76	18.86	55.40	0.60	0.17	8.03	1.74	0.98	4.78
169285 EB-1(3)_pt3	0.00	10.47	0.42	18.40	55.57		0.38	6.33		1.83	6.60

Comparison

- The microprobe analysis of Kyle, 1992 show good agreement with the results of this project

Project Analyses (1st Set)

Compound %

		Na2O	MgO	Al2O3	SiO2	Cl	K2O	CaO	TiO2	MnO	Fe2O3
169285 EB-1(1)_pt1	0.00	10.78	0.38	18.92	55.92	0.28	5.73	1.62	1.09		5.26
169285 EB-1(1)_pt2	0.00	9.18	0.30	18.83	56.43	0.25	5.98	1.67	1.20		6.16
169285 EB-1(1)_pt3	0.00	8.24		22.51	61.95		2.50	4.79			
169285 EB-1(1)_pt4	0.00	1.16	3.54	2.14		0.22			26.53	1.72	64.69

Previous Work

TABLE 1—Precision of electron microprobe analyses based on repeated analyses of glass samples.

	wt. percent	1σ	Relative std.dev. %
SiO_2	55	0.30	0.55
Al_2O_3	19	0.12	0.63
TiO_2	1.0	0.02	2.0
FeO*	5.4	0.07	1.3
MnO	0.3	0.015	5.0
MgO	0.8	0.02	2.5
CaO	2.0	0.07	3.5
Na_2O	9.0	0.20	2.2
K_2O	5.4	0.04	0.75

The above image is this project's SEM data. Below this is the Average from Kyle, 1992.

Comparison

- The microprobe analysis of Kyle, 1992 show good agreement with the results of this project

Project Analyses (3nd Set)

Compound %

		Na2O	MgO	Al2O3	SiO2	P2O5	Cl	K2O	CaO	TiO2	Fe2O3
169285 EB-1(3)_pt1	0.00	8.81		21.89	62.07			2.95	4.28		
169285 EB-1(3)_pt2	0.00	8.67	0.76	18.86	55.40	0.60	0.17	8.03	1.74	0.98	4.78
169285 EB-1(3)_pt3	0.00	10.47	0.42	18.40	55.57		0.38	6.33		1.83	6.60

Previous Work

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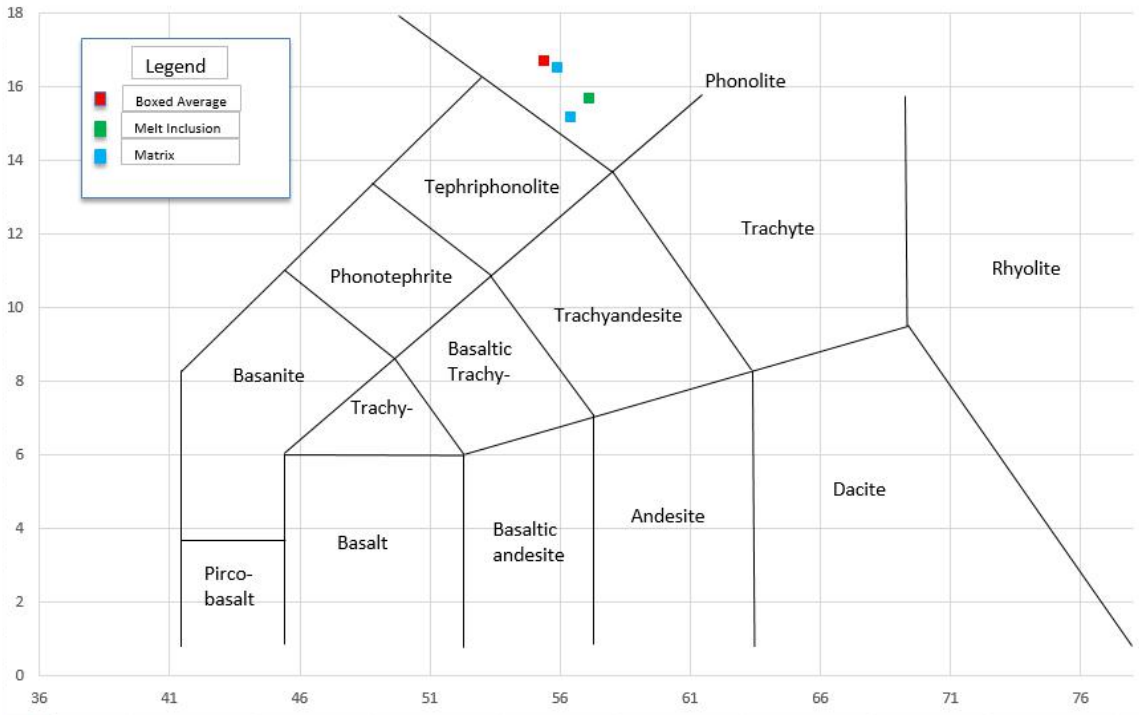
FeO*	5.4	0.07	1.3
MnO	0.3	0.015	5.0
MgO	0.8	0.02	2.5
CaO	2.0	0.07	3.5
Na_2O	9.0	0.20	2.2
K_2O	5.4	0.04	0.75

The above image is this project's SEM data. Below this is the Average from Kyle, 1992.

Comparison- Matrix vs. Melt Inclusion



- Both point source data and boxed averages for glass matrix are close to the inclusions
- Based on the closeness of these results I believe that the experimental data agrees with the widespread notion that melt is included within the crystals during formation

Comparison-Phenocryst composition

- Chemical Recalculation on 8 O basis
  - Anorthoclase: (Na,K) $AlSi_3O_8$
  - Na+K = 0.859 ~ 1
  - Al = 1.190 ~ 1
  - Si = 2.778 ~3

Analysis title		Phenocryst			Oxygens per formula =			
				Oxy =	8			
Oxide	**GFW**	**Wt.%**	**Mole Units**	**Oxygen Units**	**Normaliz. Ox Units**	**Atom Units**		
SiO2	60.084	61.95	**1.03106**	**2.06211**	**5.55576**	**2.778**	**Si**	Si ~3
TiO2	79.866	0.00	0.00000	0.00000	0.00000	**0.000**	**Ti**	Al+Na+K
Al2O3	101.961	22.51	0.22077	0.66231	1.78441	**1.190**	**Al**	2.049
Cr2O3	151.99	0.00	0.00000	0.00000	0.00000	**0.000**	**Cr**	
Fe2O3	159.688	0.00	0.00000	0.00000	0.00000	**0.000**	**Fe+3**	
FeO	71.844	0.00	0.00000	0.00000	0.00000	**0.000**	**Fe+2**	
MnO	70.937	0.00	0.00000	0.00000	0.00000	**0.000**	**Mn**	
MgO	40.304	0.00	**0.00000**	**0.00000**	**0.00000**	**0.000**	**Mg**	
CaO	56.077	4.79	**0.08542**	**0.08542**	**0.23013**	**0.230**	**Ca**	
Na2O	61.979	8.24	0.13295	0.13295	0.35819	**0.716**	**Na**	
K2O	94.196	2.50	0.02654	0.02654	0.07151	**0.143**	**K**	
H2O	18.015	0.00	0.00000	0.00000	0.00000	**0.000**	**H**	
Totals		**99.99**	**1.49673**	**2.96933**	**8.00000**	**5.057**		

Recalculation based on SEM (1st Set) Template Credit: John Brady, Smith College and Dexter Perkins, UND

Comparison-Phenocryst composition

- Chemical Recalculation on 8 O basis
  - Anorthoclase: (Na,K) $AlSi_3O_8$
  - Na+K = 0.937 ~ 1
  - Al = 1.161 ~ 1
  - Si = 2.792 ~3

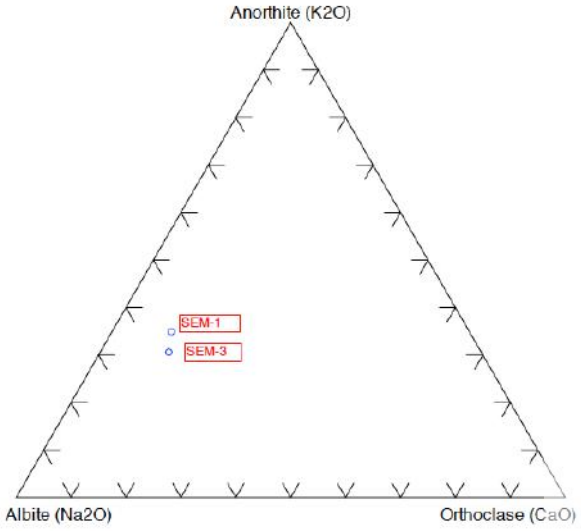
Analysis title		Phenocryst			Oxygens per formula =			
				Oxy =	8			
Oxide	**GFW**	**Wt.%**	**Mole Units**	**Oxygen Units**	**Normaliz. Ox Units**	**Atom Units**		
SiO2	60.084	62.07	**1.03305**	**2.06611**	**5.58414**	**2.792**	**Si**	Si ~3
TiO2	79.866	0.00	0.00000	0.00000	0.00000	**0.000**	**Ti**	Al+Na+K
Al2O3	101.961	21.89	0.21469	0.64407	1.74075	**1.161**	**Al**	2.098
Cr2O3	151.99	0.00	0.00000	0.00000	0.00000	**0.000**	**Cr**	
Fe2O3	159.688	0.00	0.00000	0.00000	0.00000	**0.000**	**Fe+3**	
FeO	71.844	0.00	0.00000	0.00000	0.00000	**0.000**	**Fe+2**	
MnO	70.937	0.00	0.00000	0.00000	0.00000	**0.000**	**Mn**	
MgO	40.304	0.00	**0.00000**	**0.00000**	**0.00000**	**0.000**	**Mg**	
CaO	56.077	4.28	**0.07632**	**0.07632**	**0.20628**	**0.206**	**Ca**	
Na2O	61.979	8.81	0.14214	0.14214	0.38418	**0.768**	**Na**	
K2O	94.196	2.95	0.03132	0.03132	0.08464	**0.169**	**K**	
H2O	18.015	0.00	0.00000	0.00000	0.00000	**0.000**	**H**	
Totals		**100.00**	**1.49753**	**2.95996**	**8.00000**	**5.097**		

Recalculation based on SEM (3rd Set) Template Credit: John Brady, Smith College and Dexter Perkins, UND

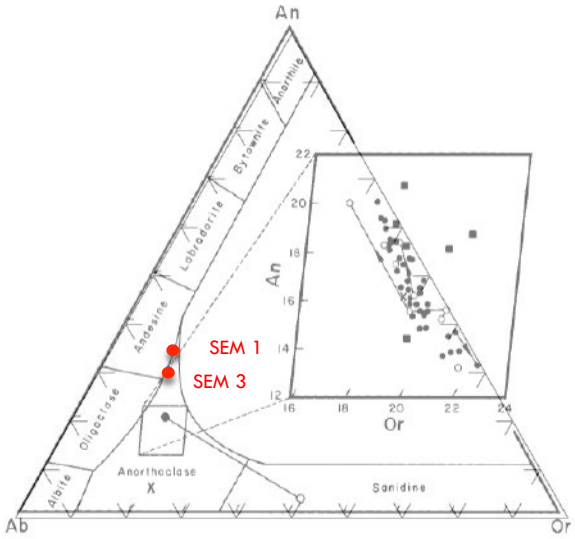
Comparison-End Member Calculation

- From 1st SEM Set (Mol. Prop.)
  - CaO: 0.08542 → 34.9% An
  - Na_2O: 0.13295 → 54.3% Ab
  - K_2O: 0.02654 → 10.8 % Or
  - Total: 0.24491
- From 3rd SEM Set (Mol. Prop.)
  - CaO: 0.07632 → 30.6% An
  - Na_2O: 0.14214 → 56.9% Ab
  - K_2O: 0.03132 → 12.5 % Or
  - Total: 0.24979

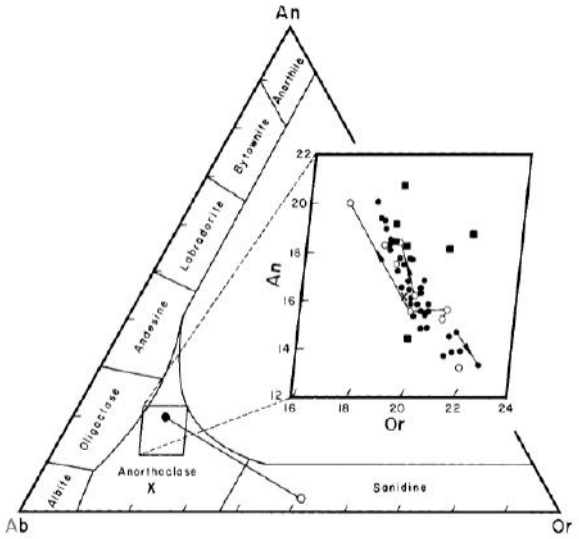
Comparison-End Member Calculation



Plot of SEM phenocryst data



Composite of SEM phenocryst data and data from Kyle, 1977



Anorthoclase analyses (Kyle, 1977)

- End member calculations in anorthite, albite, and anorthclase yield a phenocryst composition of anorthoclase that is borderline with andesine.
- Samples used in this project appear to have slightly higher calcium values

(Kyle, 1977) (Kyle et al., 1992)

Conclusion

- A first analysis of Mt. Erebus volcanics has been conducted
- Based on glass matrix and inclusion chemistry, this is a solidified porphyritic phonolite lava
- Comparisons of glass matrix and phenocryst inclusions indicate that they are phonolite melt inclusions
- Analyses of phenocrysts places them in an anorthoclase or anorthoclase-andesine feldspar composition

Acknowledgements

- Dr. Hopkins of NDSU Soil Sciences for allowing student use of Buehler PetroThin thin section saw.
- Dr. Saini-Eidukat of NDSU Geosciences for allowing use of lab equipment and mentorship on the project.
- Scott Payne and Jayma Moore of the Electron Microscopy Lab for their help in analyses
- Dr. Ashworth of NDSU Geosciences for collecting the samples used in the experiments
- Special thanks to Dr. Philip R. Kyle for his research on the Erebus Volcanic Province and supplying literature for this project

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Supplementary Resources

- Boudette, E.L., and Ford, A.B., 1966, Physical properties of anorthoclase from Antarctica: The American mineralogist, v. 51, p. 1374.
- Goldich, S.S., Treves, S.B., Suhr, N.H., and Stuckless, J.S., 1975, Geochemistry of the Cenozoic Volcanic Rocks of Ross Island and Vicinity, Antarctica: The Journal of geology, v. 83, p. 415–435.