

Provenance of cobbles from the Chalky Buttes Member of the Chadron Formation, southwestern North Dakota

Levi Moxness
NDSU GEOL 422 Petrology
04/03/2012

Outline

- Introduction
- Background
 - Setting, Stratigraphy, Depositional environment
 - Cobble lithologies
- Methods
 - XRD, Whole rock geochemistry
- Results
 - TAS and Harker Diagrams
- Conclusions
 - Closing the book on the provenance debate.

Introduction

- Basal member of the White River Group in North Dakota
- Contains unique cobbles of volcanic porphyries
- Origins suggested from the Absaroka volcanic field in NW Wyoming, but little proof
- Can the cobbles' lithology be classified and compared to similar rocks from the Absoroka volcanic field?

Outcrop Extent

- Only remain as erosional remnants on isolated buttes in ND
- The Little Badlands are the most northeasterly occurrences of these strata in North America.



Map showing the extent of White River Group deposits (wikipedia.org)

Chalky Buttes Member
(light color)

NDSU Alum Stephen
Fried for scale (~2m)

Gravel/cobble lag
eroded out of butte



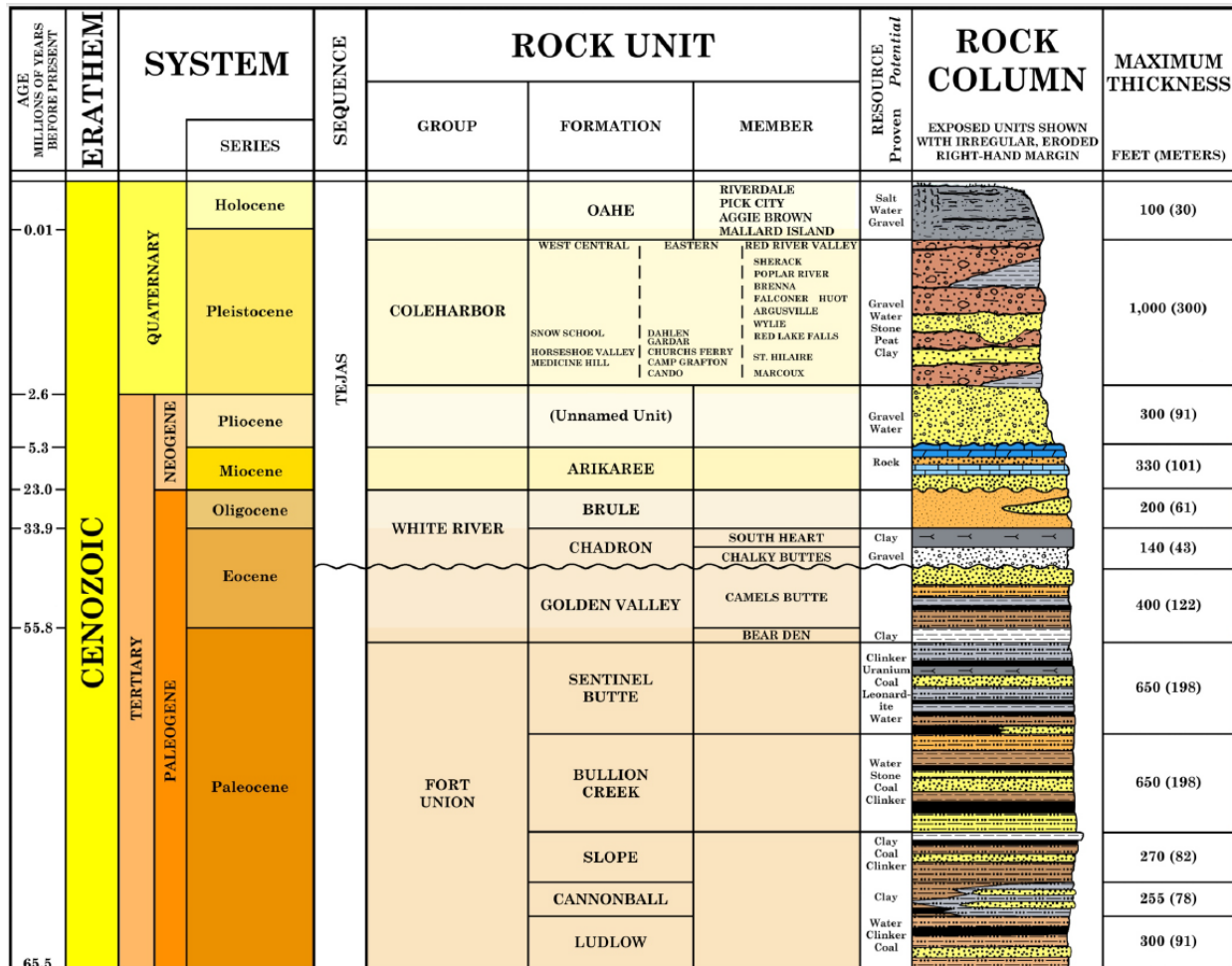
Stratigraphy

- Averages 6 meters thick in North Dakota
- Maximum thickness of 24 meters in the Chalky Buttes
(Murphy et al., 1993)
- Eocene, not Early Oligocene
- Rests unconformably on Paleocene and Eocene rock units
(Bullion Creek, Sentinel Butte, and Golden Valley Formations)

Stratigraphy

NORTH DAKOTA STRATIGRAPHIC COLUMN

by Edward C. Murphy, Stephan H. Nordeng, Bruce J. Juenker, and John W. Hoganson

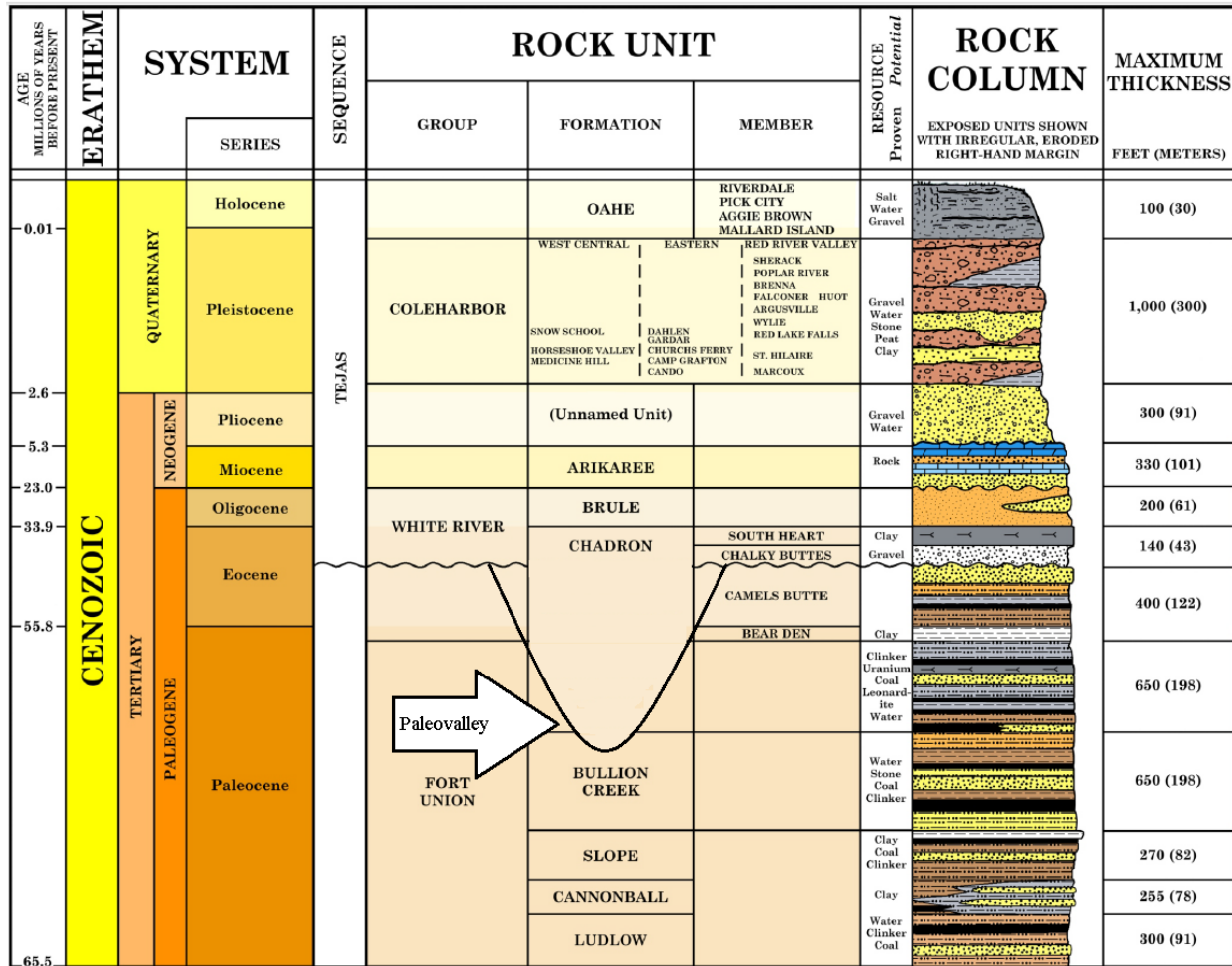


nd.gov

Stratigraphy

NORTH DAKOTA STRATIGRAPHIC COLUMN

by Edward C. Murphy, Stephan H. Nordeng, Bruce J. Juenker, and John W. Hoganson



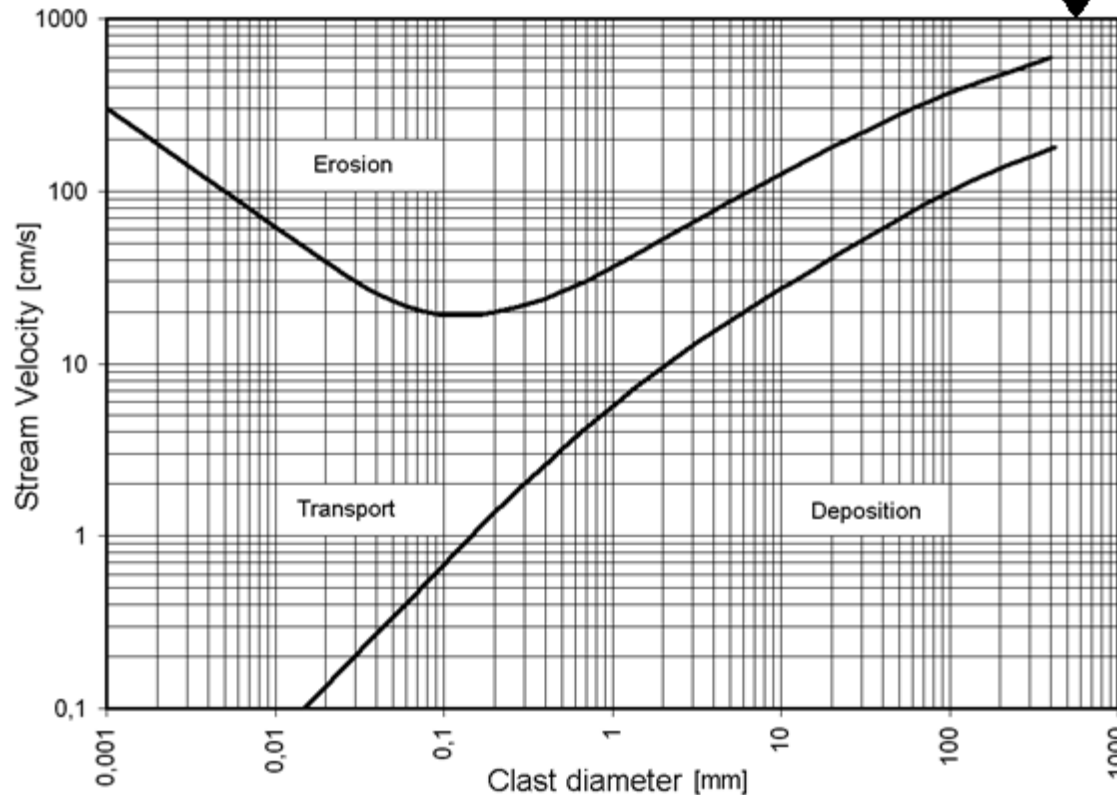
nd.gov

Depositional Environment

Clausen (1989) reported quartzite boulders up to 55 cm in diameter



Hjulström Diagram



Erosion: 600 cm/s
Deposition: 200 cm/s

- A powerful, erosive river
- Steep gradient
- Local Eocene Uplift?
- Black Hills and Rocky Mountain uplift from the late stages of the Laramide Orogeny

Depositional Environment

Clausen (1982) suggested a Pleistocene glaciofluvial origin for these cobbles

GLACIAL???

Abundant geological and paleontological evidence disputes a recent glacial origin for these sediments.

This Brontothere, a rhinoceros-like mammal, was abundant in the temperate climates of the Great Plains and went extinct during the late Eocene (30 million years before the Pleistocene).



Brontothere skull in the Chadron Formation, Badlands National Park

Cobble Lithology

Sedimentary Cobbles

- Mudstones
- Sandstones
- Sedimentary Quartzites
- Chert
- Agates
- Conglomerates
- Petrified wood
- Petrified coral

Unique
characteristics, but
they don't lead us
to an igneous
source



Cobble Lithology

Igneous Cobbles

Volcanic Porphyry
Ignimbrites
Granites
Lapilli Tuff?

Of these, the
porphyries are
especially distinct,
and have been
mentioned in
numerous studies
(Denson and Gill, 1965,
Clausen, 1989).



Porphyries

- Described as reddish-brown quartz latite porphyries

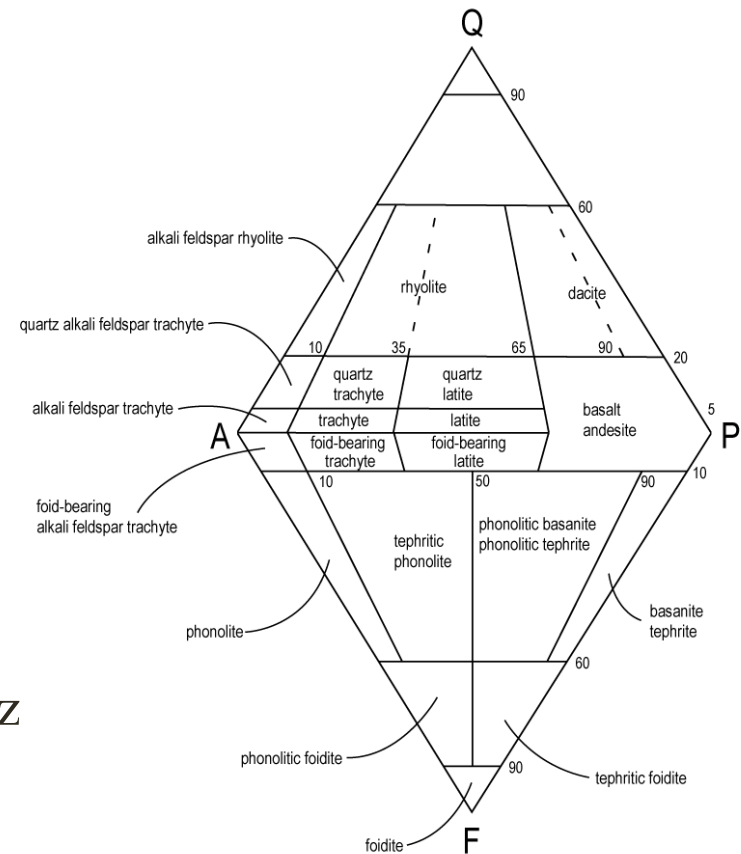
(Denson and Gil, 1965)

- Latite
Volcanic rock
Aphanitic to porphyritic texture

- Primary minerals
alkali feldspar
plagioclase

- Accessory minerals:
biotite
hornblende
pyroxene

Called a quartz latite when $>5\%$ quartz



QAPF Diagram

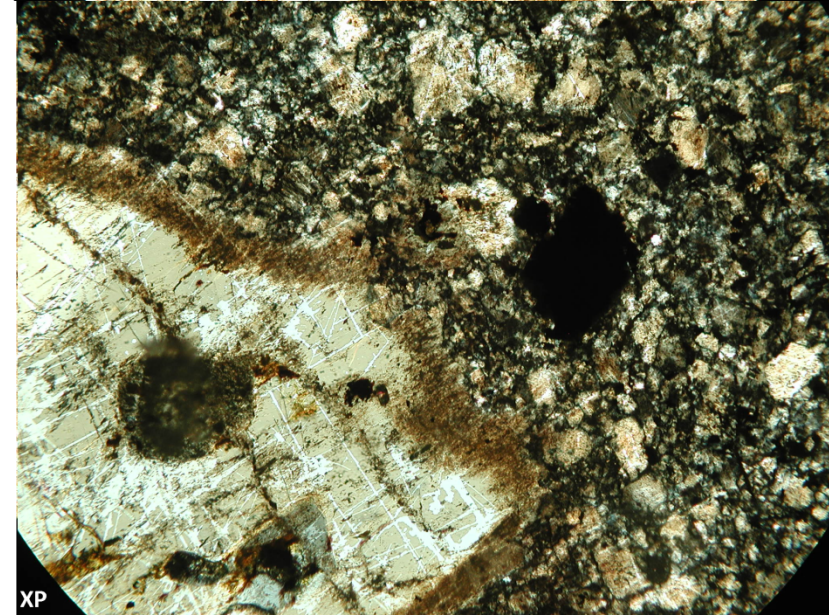
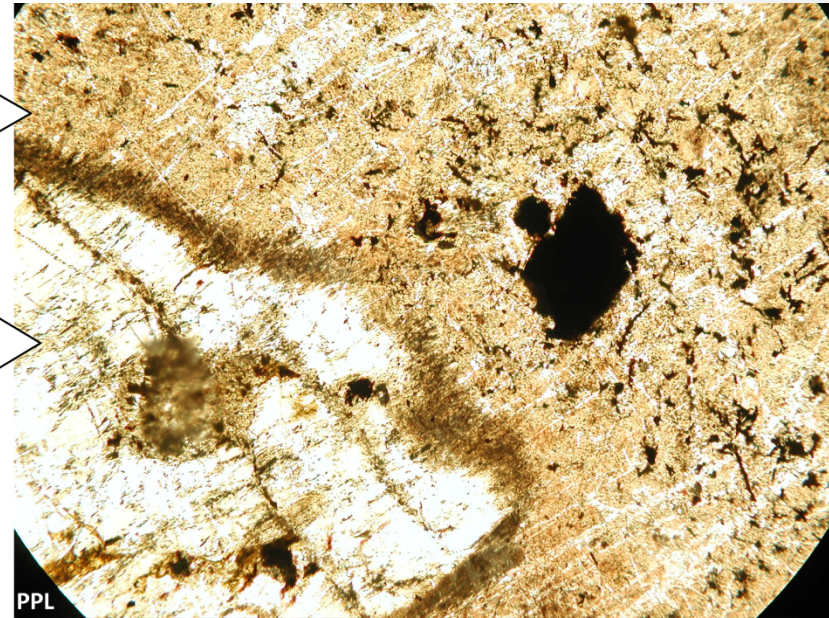
Wikipedia.org

Porphyries

- Magma cools slowly
Forms large crystals
(phenocrysts)
- Finishes cooling quickly
Remaining magma
forms small crystals
(groundmass)

groundmass

phenocryst



0 1
Scale (mm)

X-ray Diffraction

Quartz latite porphyry?

XRD results

(Folkers and Dolezal, 2010 unpublished work)

Groundmass

Orthoclase

Microcline

Phenocrysts

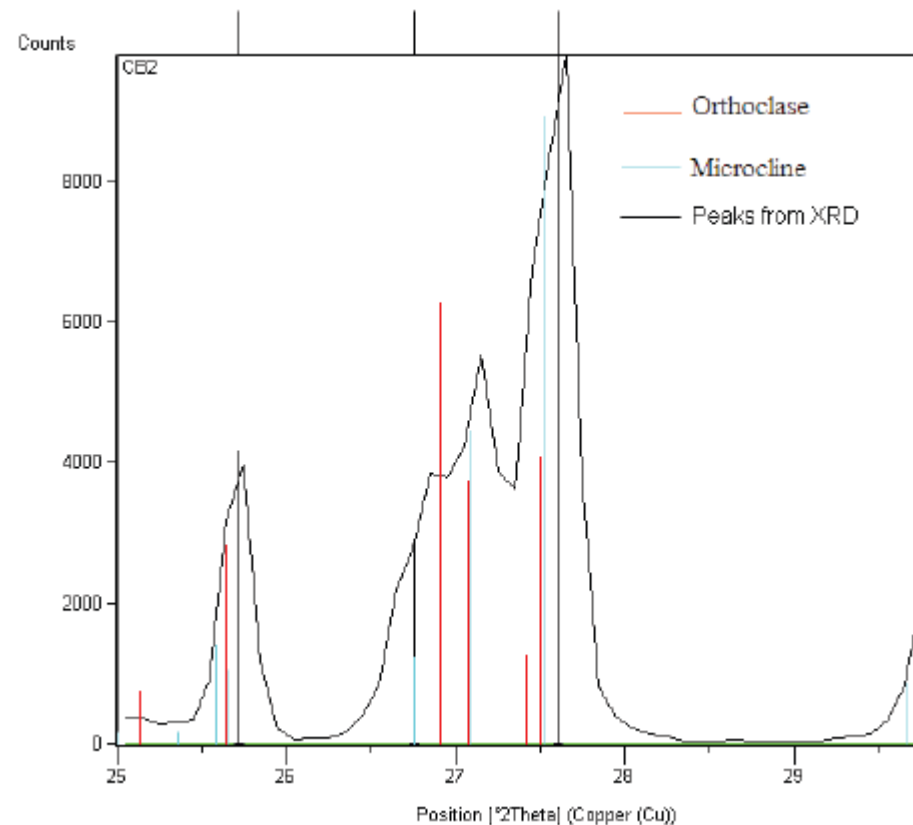
Sanidine

Anorthoclase

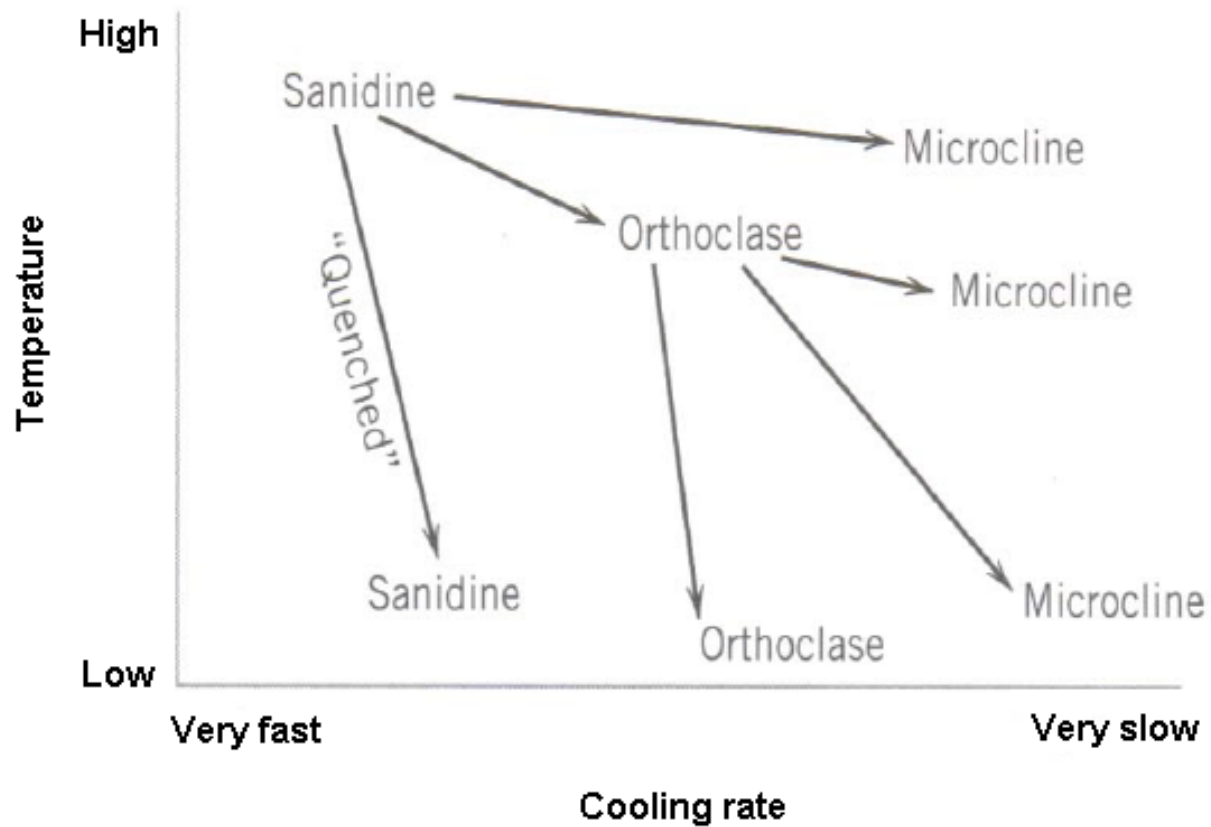
Orthoclase

Microcline

No Quartz?



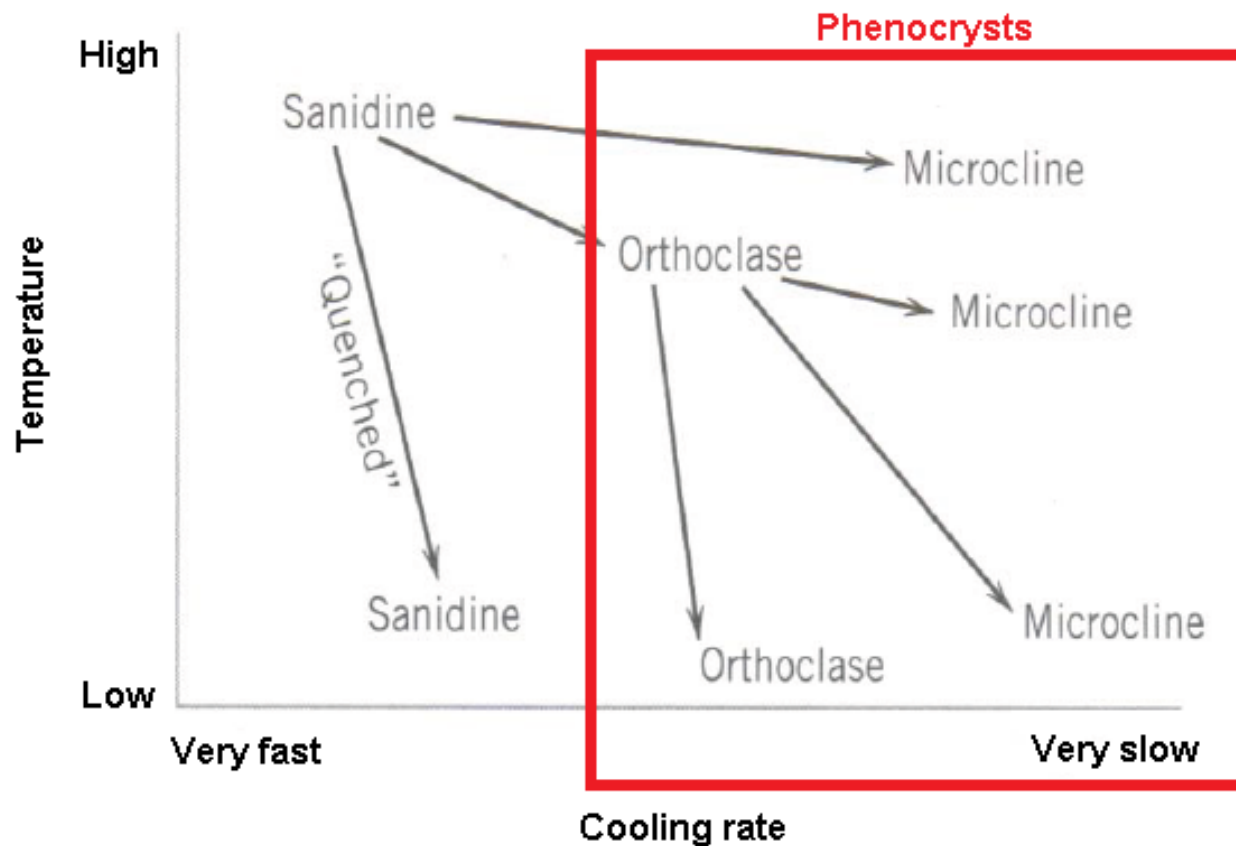
Cooling Rate



Winter, 2008

Cooling Rate

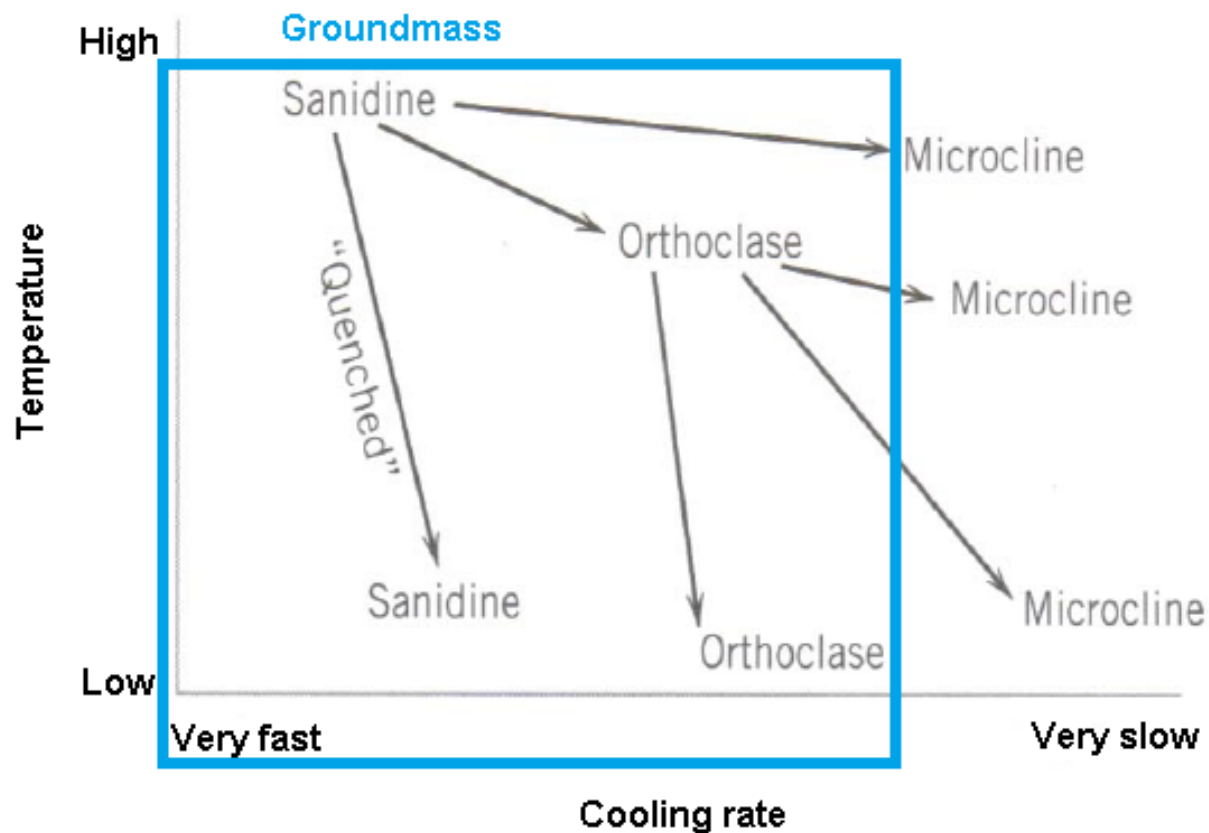
Phenocrysts predominantly orthoclase and microcline



Winter, 2008

Cooling Rate

Groundmass predominantly sanidine and orthoclase



Winter, 2008

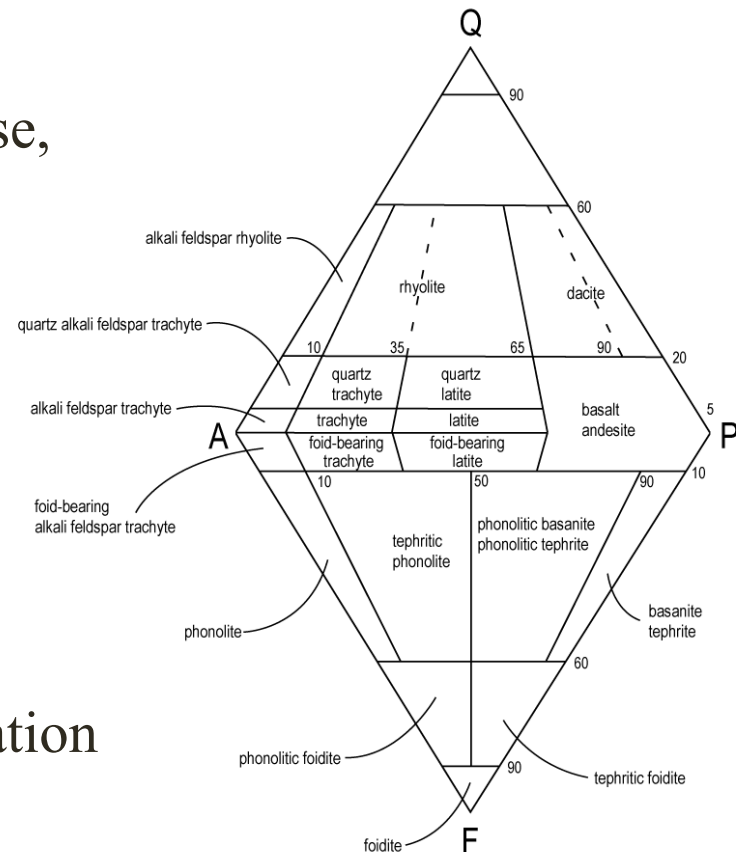
Folkers and Dolezal Results

Boldly disagreed with Denson and Gill (1965), Hoganson (1986), and Clausen (1989), who identified the specimens as quartz latite porphyries.

They found no quartz, less plagioclase, and the presence of feldspathoid minerals (nepheline).

Tentatively suggested
“Foid-bearing **trachyte** porphyry”

This study agrees with the absence of quartz, but considers the identification of nepheline questionable

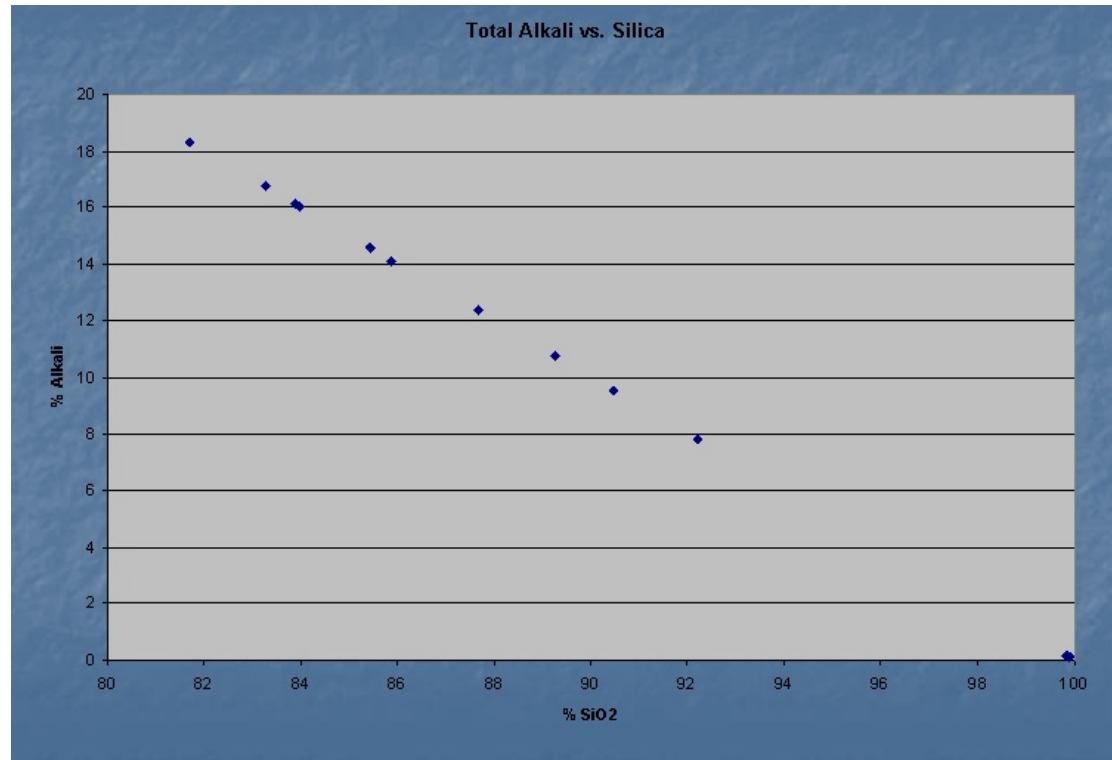


QAPF Diagram Wikipedia.org

Whole Rock Chemistry

Stephney and Wright conducted whole rock chemistry on 12 porphyries and ignimbrites in 2004

Were unable to make chemical comparisons to source areas



TAS diagram from Stephney and Wright, 2004

The Next Step

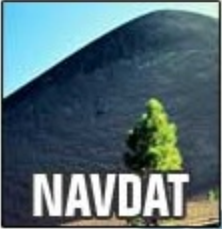
Two main source areas have been proposed
(other than Pleistocene glacial erratics from the Cordilleran Ice Sheet)
(Clausen, 1982)

The **Black Hills** (Stone, 1973)
However; paleoslope direction was more eastward than north
Cobbles do not represent typical rock types

The **Absaroka volcanic field** / Beartooth Mountains (WY, MT)
(Denson and Gill, 1965)
Paleoslope favors this source (Seeland, 1985)
Surficially looks like porphyries from dikes in the Beartooth Mtns


**Is it possible to actually compare geochemical data from the
Absaroka volcanic field to Chalky Buttes cobbles?**

Source Area Geochemical Data



NAVDAT

THE WESTERN NORTH AMERICAN VOLCANIC
AND INTRUSIVE ROCK DATABASE



earthchem
ADVANCED DATA MANAGEMENT
IN IGNEOUS GEOCHEMISTRY

Home | Search Database | Data Files | Animations | Educational Resources | Glossary | FAQ | Contact

Login
Get Account

Being logged in allows you to access advanced search features such as saved queries and saved diagrams. Membership is free. Please login or get a new account

Set Rock Type ?

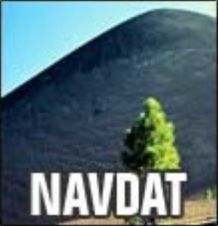
☒ Names from Paper ☐ Names calculated from chemistry

Search names provided in paper:

Material	Type	Composition	Rock Name
ALTERATION	PLUTONIC	EXOTIC	ADAKITE
IGNEOUS	VOLCANIC	FELSIC	ANDESITE
METAMORPHIC		INTERMEDIATE	BASALTIC ANDESITE
ORE		MAFIC	BASALTIC-ANDESITE
SEDIMENTARY			BENMOREITE
VEIN			DIORITE
XENOLITH			GRANODIORITE
			HAWAIIITE
			LATITE
			MUGEARITE
			NOT GIVEN
			ORENDITE


APPLY

Source Area Geochemical Data



NAVDAT

THE WESTERN NORTH AMERICAN VOLCANIC
AND INTRUSIVE ROCK DATABASE



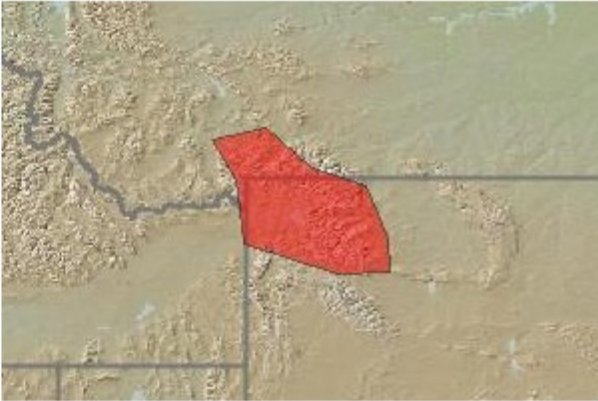
earthchem
ADVANCED DATA MANAGEMENT
IN IGNEOUS GEOCHEMISTRY

Home | Search Database | Data Files | Animations | Educational Resources | Glossary | FAQ | Contact

Login
Get Account

Being logged in allows you to access advanced search features such as saved queries and saved diagrams. Membership is free. Please **login** or get a **new account**

Volcanic Field ?



Absaroka

Absaroka

Albuquerque

Amboy

Anahim

Atlin

Aurora-Bodie

Big Pine

Blackfoot

Black Mountain

Black Rock Desert

Carrizozo

Select one or more fields. Results are from ANY of the selected fields.


APPLY

Source Area Geochemical Data



NAVDAT

THE WESTERN NORTH AMERICAN VOLCANIC
AND INTRUSIVE ROCK DATABASE



Home | Search Database | Data Files | Animations | Educational Resources | Glossary | FAQ | Contact

Login
Get Account



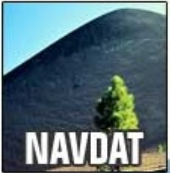
Being logged in allows you to access advanced search features such as saved queries and saved diagrams. Membership is free. Please **login** or get a **new account**

SET	Geographic Bounding Box	no constraints set
SET	State, Territory, Province	no constraints set
SET CLEAR	Volcanic Field	Absaroka
SET	Age	no Age Range set
SET	Chemistry	no constraints set
SET CLEAR	Rock Type	IGNEOUS VOLCANIC INTERMEDIATE LATITE
SET	Reference, Keyword	no constraints set
SET	Modal Data	no constraints set
SET	Renormalize Major Elements	Navdat Subset: Major_Elements_as_Reported

15 samples

GO TO DATA **MORE OPTIONS**

Source Area Geochemical Data



Home | Search Database | Data Files | Animations | Educational Resources | Glossary | FAQ | Contact

Login

Get Account

Being logged in allows you to access advanced search features such as saved queries and saved diagrams. Membership is free. Please **login** or get a **new account**

Output Data ?

15 samples found

Create an **HTML Table**, **Excel File**, or **Tab-delimited Text File** for viewing data ?

Please select from the following list of options on how you would like the data presented.

Text File is tab-delimited and can be downloaded and opened in a spreadsheet application. Advanced Excel Output and Advanced Text Output allow you to specify which fields to show.

All data files include Sample ID, References, Age, and Location.

☐ Major Element 15 samples

☐ Major, Trace Elements 15 samples

☐ Trace Element 15 samples

☐ Major, Trace, Isotopes 5 samples

☐ Isotopes 5 samples

☒ All Data 15 samples

☒ HTML Table

☐ Excel File

☐ Text File

☐ Advanced Excel Output

☐ Advanced Text Output

Get Output Data

References

First 10 References:

#	AUTHOR(S)	YEAR	JOURNAL	TITLE
1	Ruppel, Edward T...	1972	U. S. Geological Survey Profes...	Geology of pre-Tertiary rocks in the northern part...
2	Feeley, T.C.; Cosca, M.A....		Geological Society of America ...	Time vs. composition trends of magmatism at Sunlig...

Download all references for this search.

References

Source Area Geochemical Data

2 | Feeley, T.C.; Cosca, M.A. | Geological Society of America ... | Time vs. composition trends of magmatism at Sunlig...

Download all references for this search.

References

Maps

Display all results on a dynamic map.

Dynamic Map

Display results on a simple static map suitable for downloading.

Simple Map



Plots

Harker Diagrams

Harker Diagrams Animated by Age

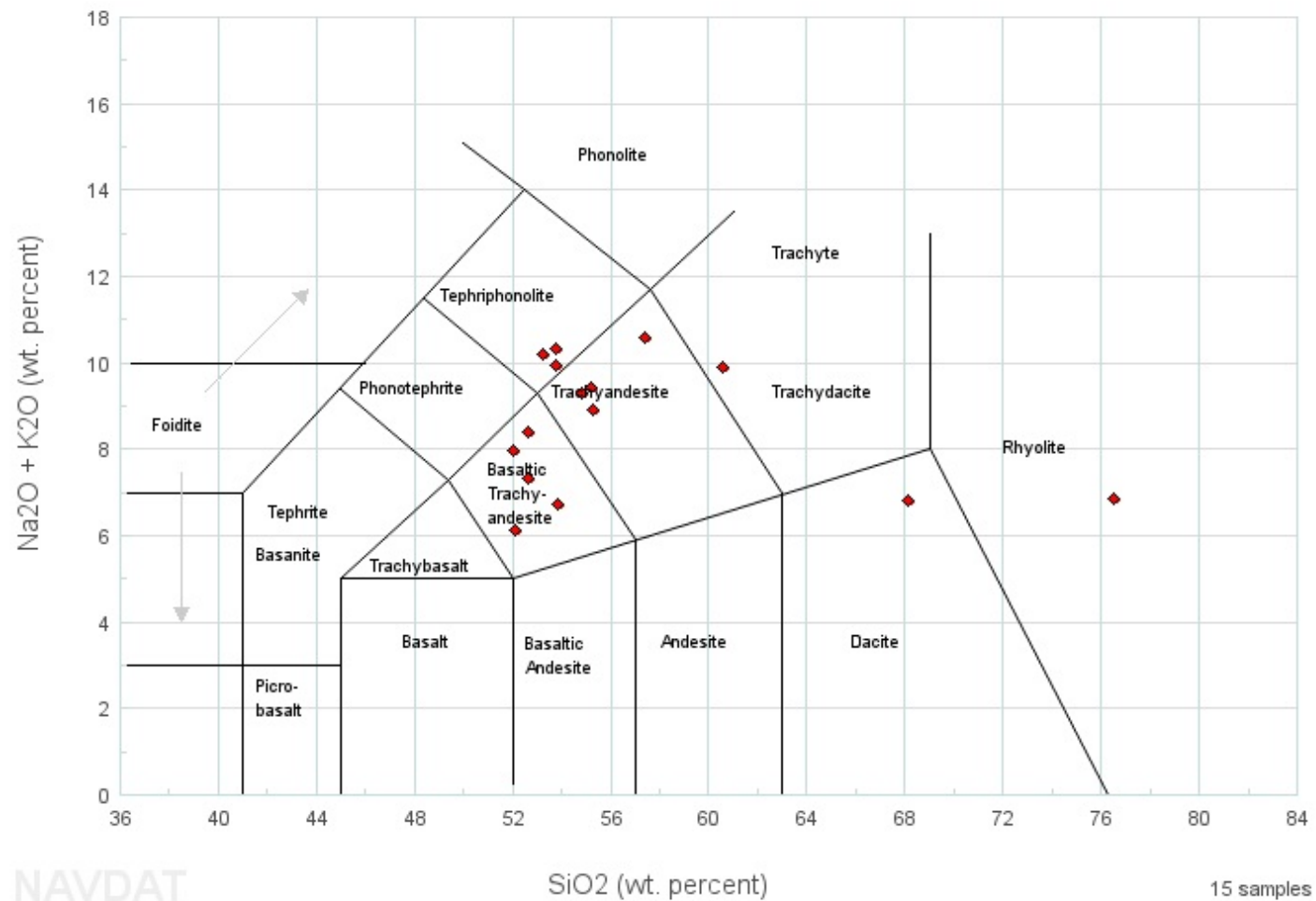
TAS Diagram

TAS Diagram Animated by Age

XYZ Plot

Source Area Geochemical Data

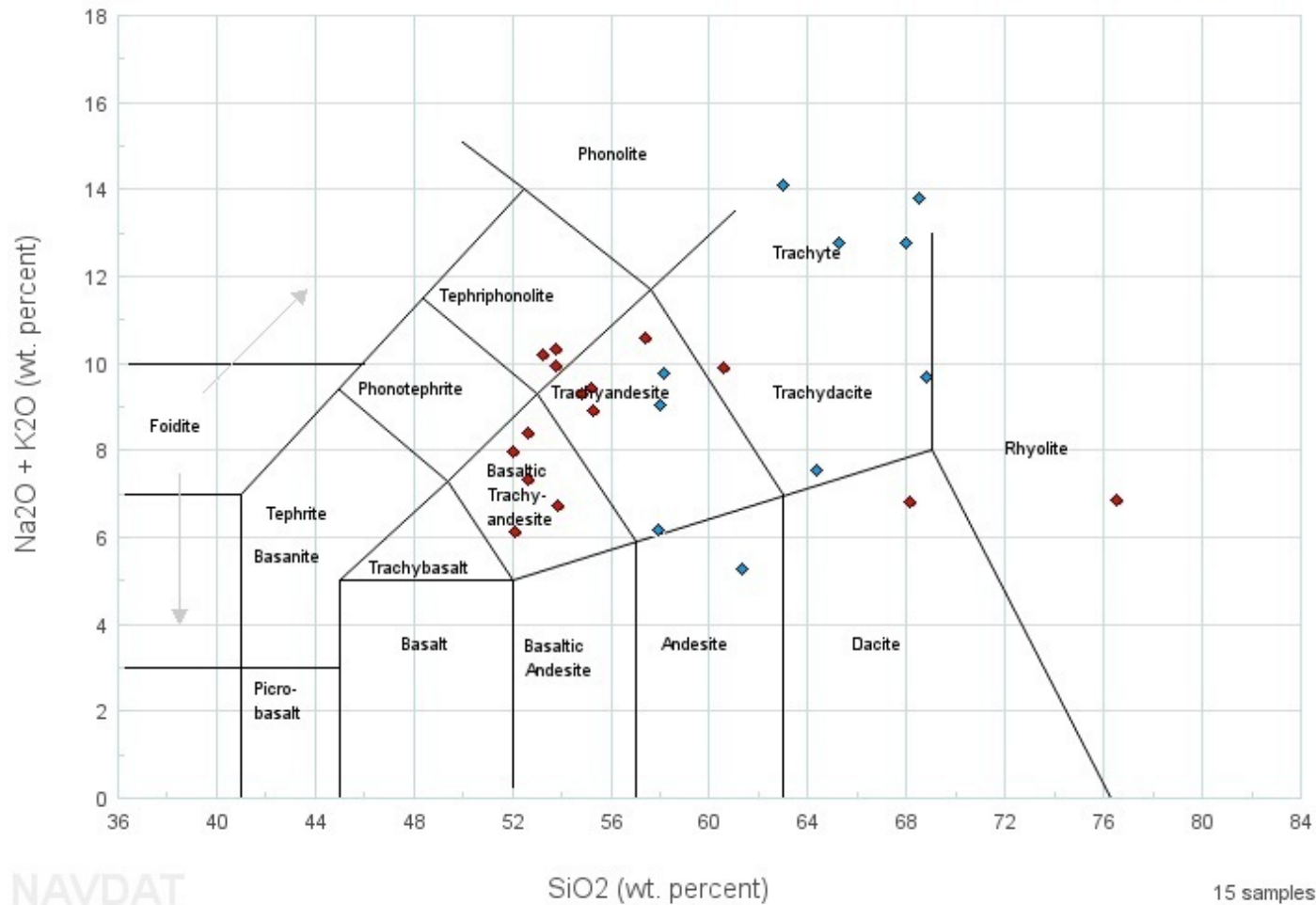
Total Alkali vs SiO₂



TAS Diagram

Total Alkali vs SiO₂

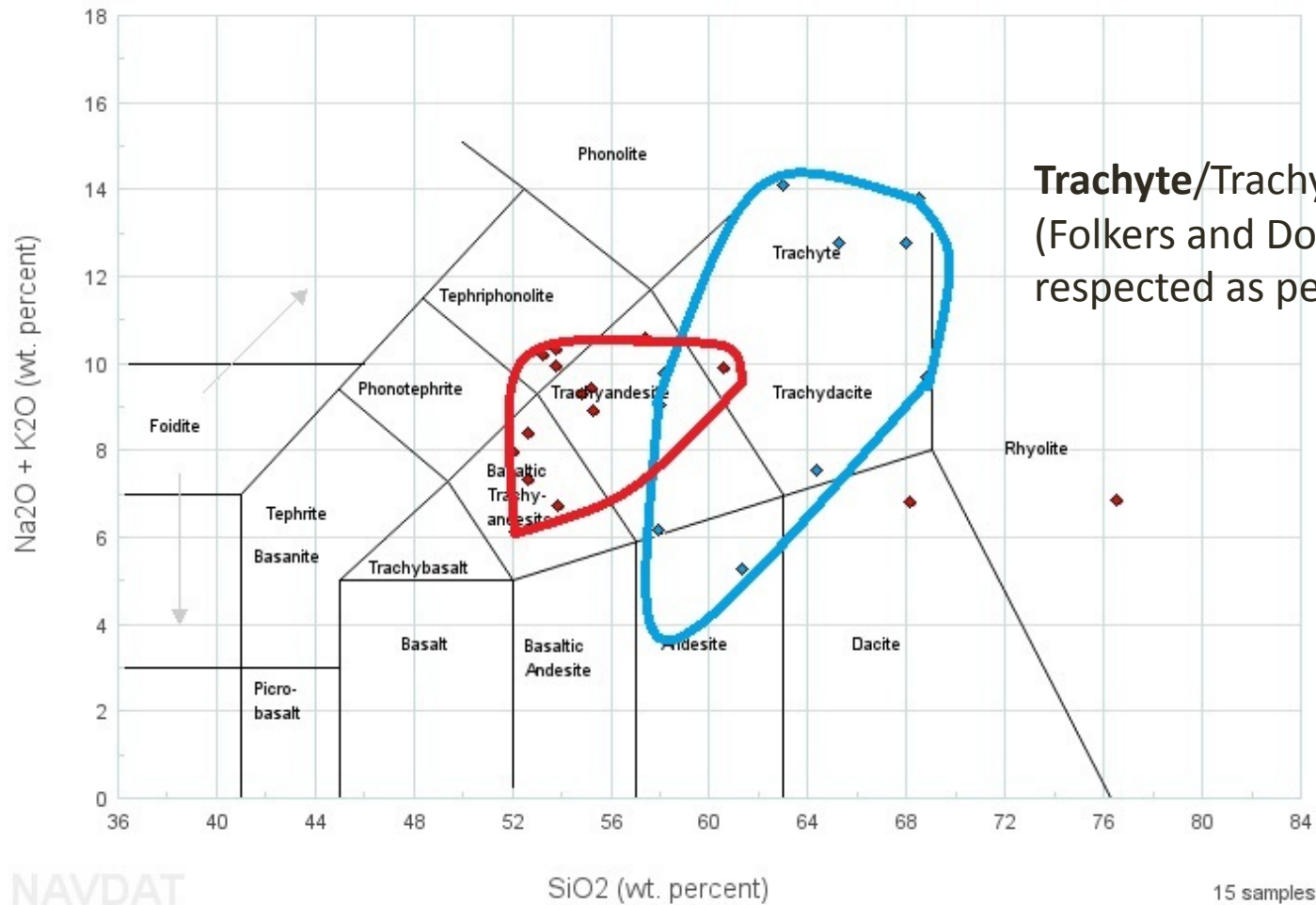
◆ Absaroka latites
◆ Little Badlands Cobbles



TAS Diagram

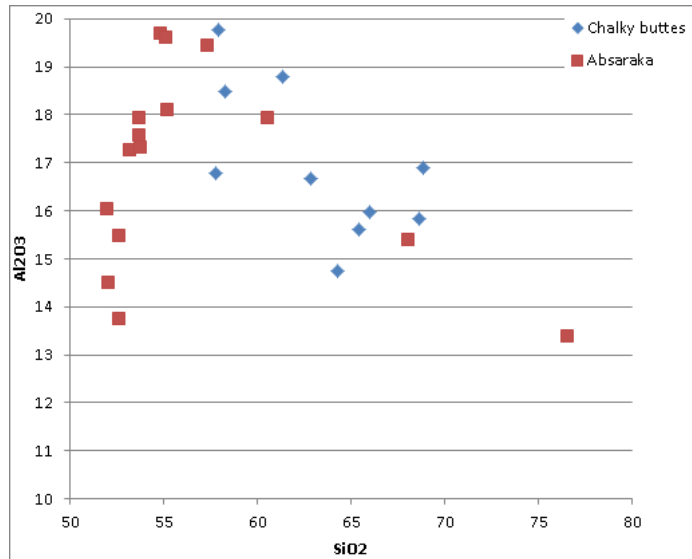
Total Alkali vs SiO₂

◆ Absaroka latites
◆ Little Badlands Cobbles

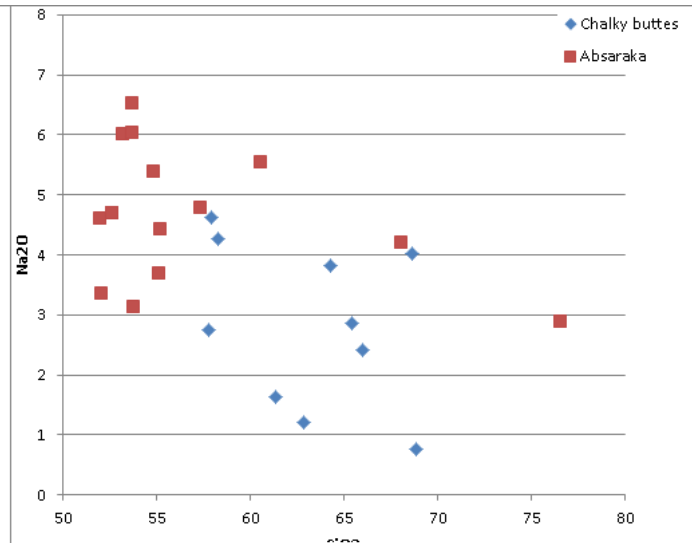


Harker Diagrams

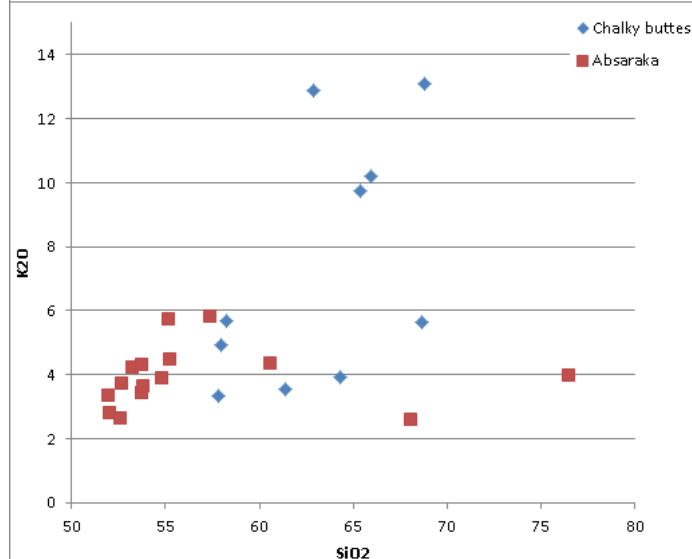
Al₂O₃
vs.
SiO₂



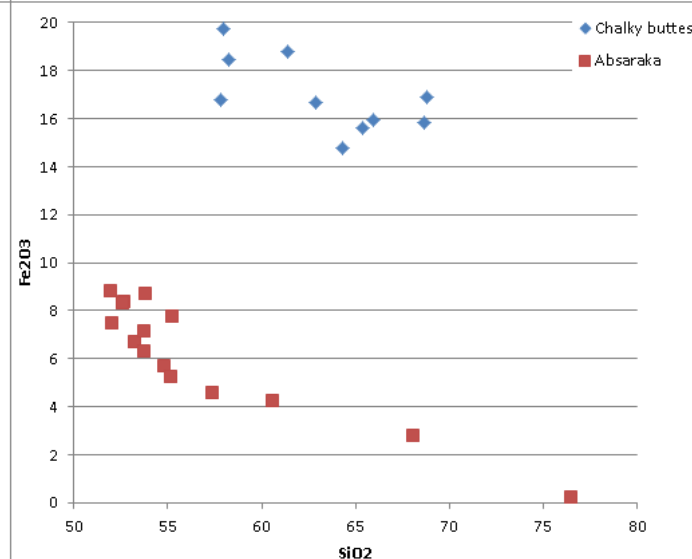
Na₂O
vs.
SiO₂



K₂O
vs.
SiO₂

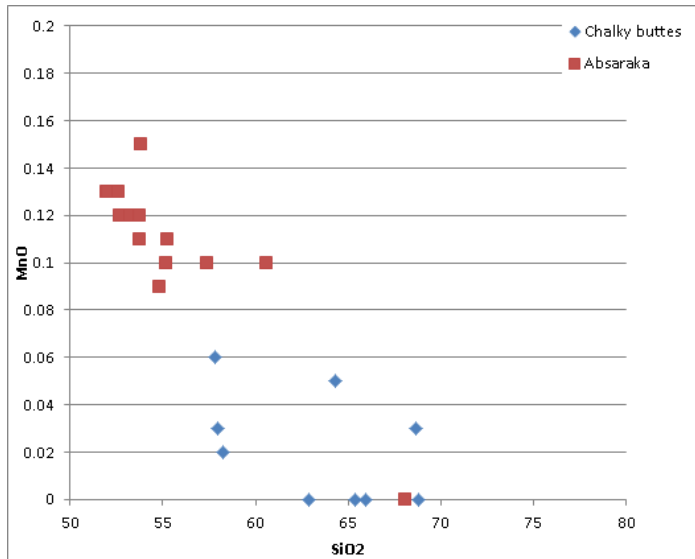


Fe₂O₃
vs.
SiO₂

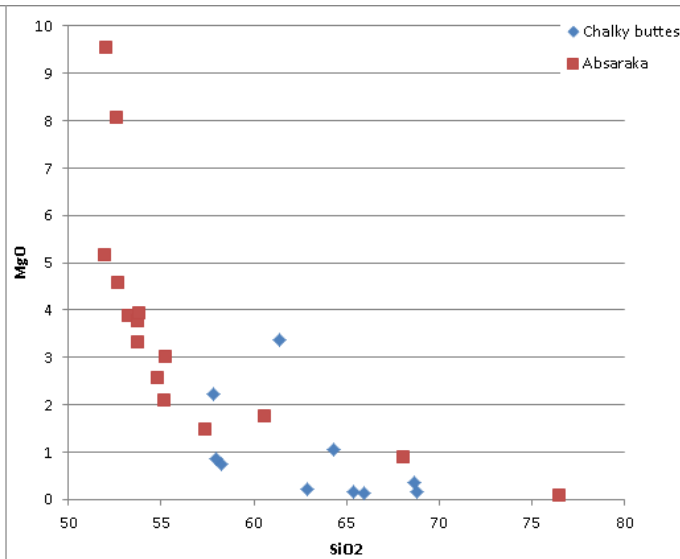


Harker Diagrams

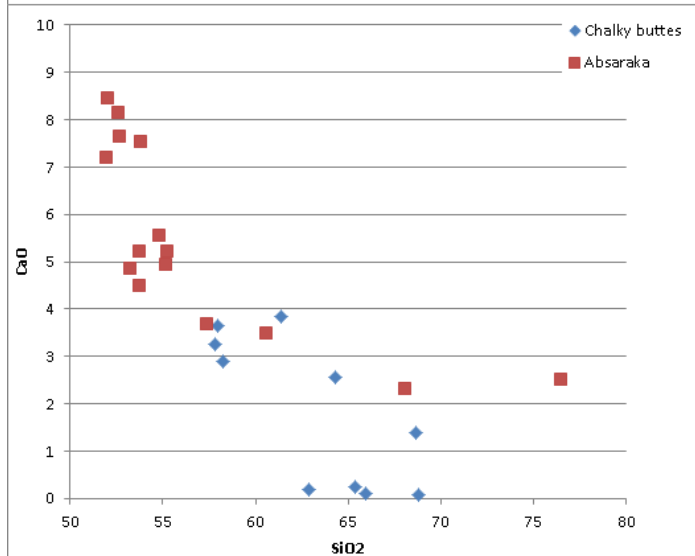
MnO
vs.
SiO₂



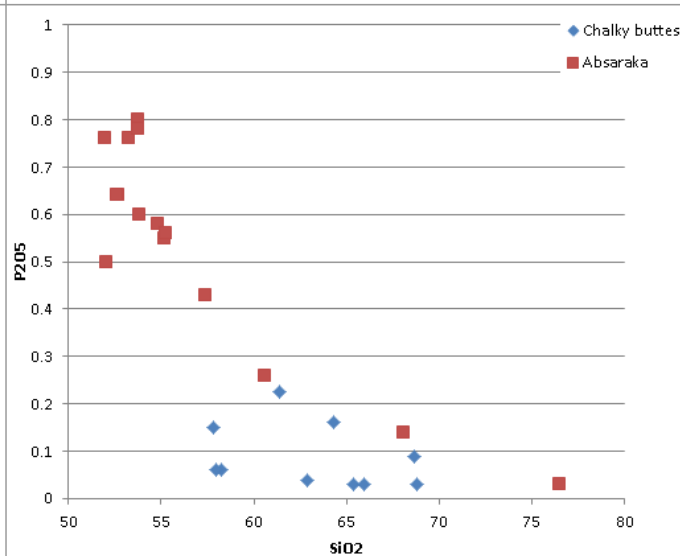
MgO
vs.
SiO₂



CaO
vs.
SiO₂



P₂O₅
vs.
SiO₂



Conclusions

- Do whole rock chemistry analyses of the two samples match up perfectly? No.
- Would one expect them to? No.
- Even a rock as specific as a quartz latite porphyry will vary in composition.
Processed by different people, at different times, with different equipment
- Are the two samples similar or dissimilar enough to finally close the door on the provenance debate?

This latite sample isn't similar enough to be a smoking gun
If it is too dissimilar, it may just be the "wrong" latite

References

- Clausen, E. N., 1986, Origin of Quartz Latite Porphyry Cobbles found at base of White River Group Sediments in Southwest North Dakota, North Dakota Geological Society Volume , Pages 41 - 45 (1986)
- Denson, N. M. and Gill, J. R. 1965. Uranium-bearing lignite and carbonaceous shale in the southwestern part of the Williston Basin - a regional study. Geological Survey Professional Paper 463, 75 p. with maps, US Government printing Office, Washington, D. C.
- Murphy, E. C., Hoganson, J. W., and Forsman, N. F., 1993, The Chadron, Brule, and Arikaree Formations in North Dakota: North Dakota Geological Survey Report of Investigation 96, 144 p.
- Seeland, D. 1985. Oligocene paleogeography of the northern Great Plains and adjacent mountains, In (Flores, R.M. and Kaplan, S.S., eds.) Cenozoic Paleogeography of west central United States. pp. 187- 205. SEPM, Rocky Mountain section
- Stone, W. J., 1973, Stratigraphy and sedimentary history of middle Cenozoic (Oligocene and Miocene) deposits in North Dakota [Ph.D. dissertation]: Grand Forks, University of North Dakota, 217 p.
- Winter, J. D. 2010. Principles of Igneous and Metamorphic Petrology. Pearson Education, Inc.
- Whole rock chemistry data from www.navdat.org
- Stratigraphic column of ND from nd.gov (https://www.dmr.nd.gov/ndgs/Publication_List/pdf/MISC%20SERIES/MS-66.PDF)
- QAPF diagram from wikipedia.org (http://en.wikipedia.org/wiki/QAPF_diagram)
- Analytical results from Folkers and Dolezal, 2010 and Stephney and Wright , 2004