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

Levi Moxness
NDSU GEOL 422 Petrology
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Outline

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

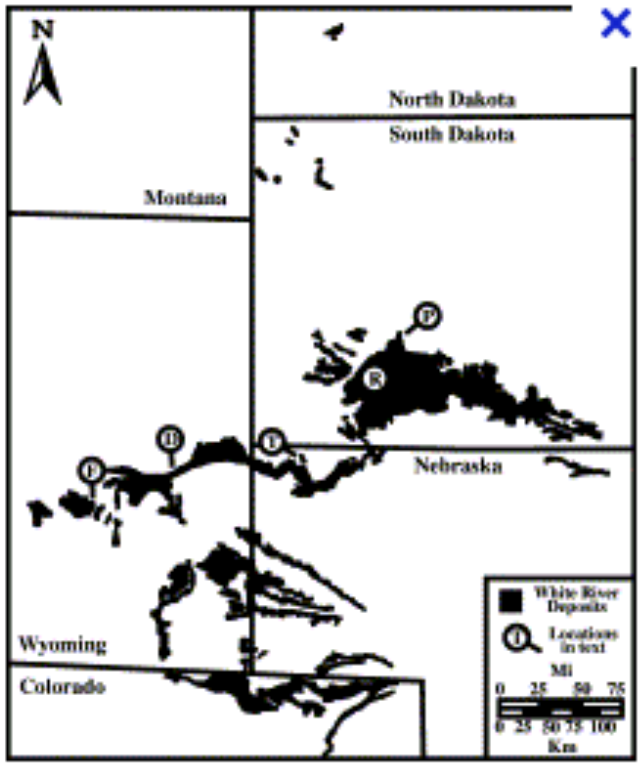
Introduction

- 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.



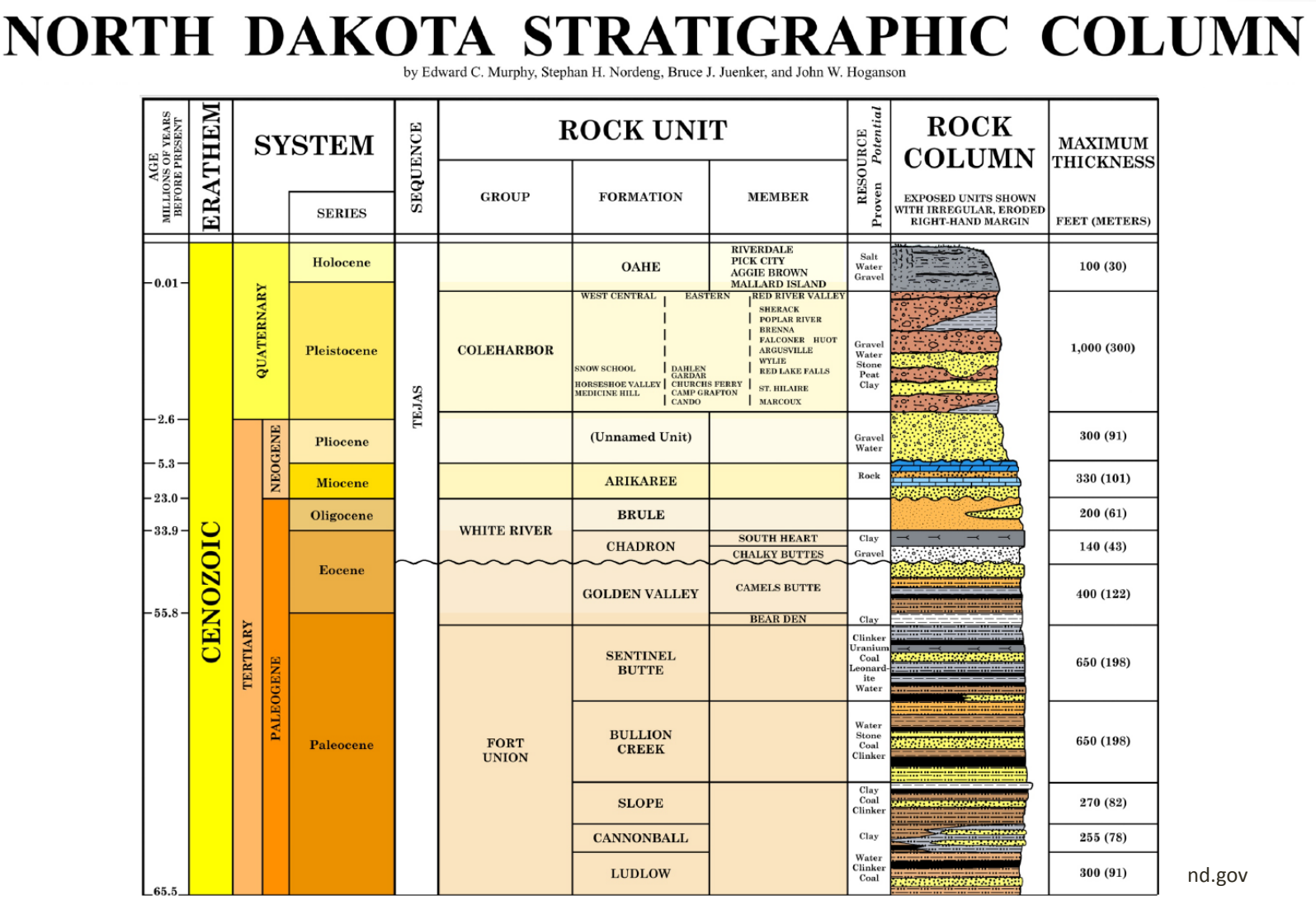
Map showing the extent of White River Group deposits (wikipedia.org)


Chalky Buttes Member
(light color)
NDSU Alum Stephen
Fried for scale (~2m)
Gravel/cobble lag
eroded out of butte

Stratigraphy

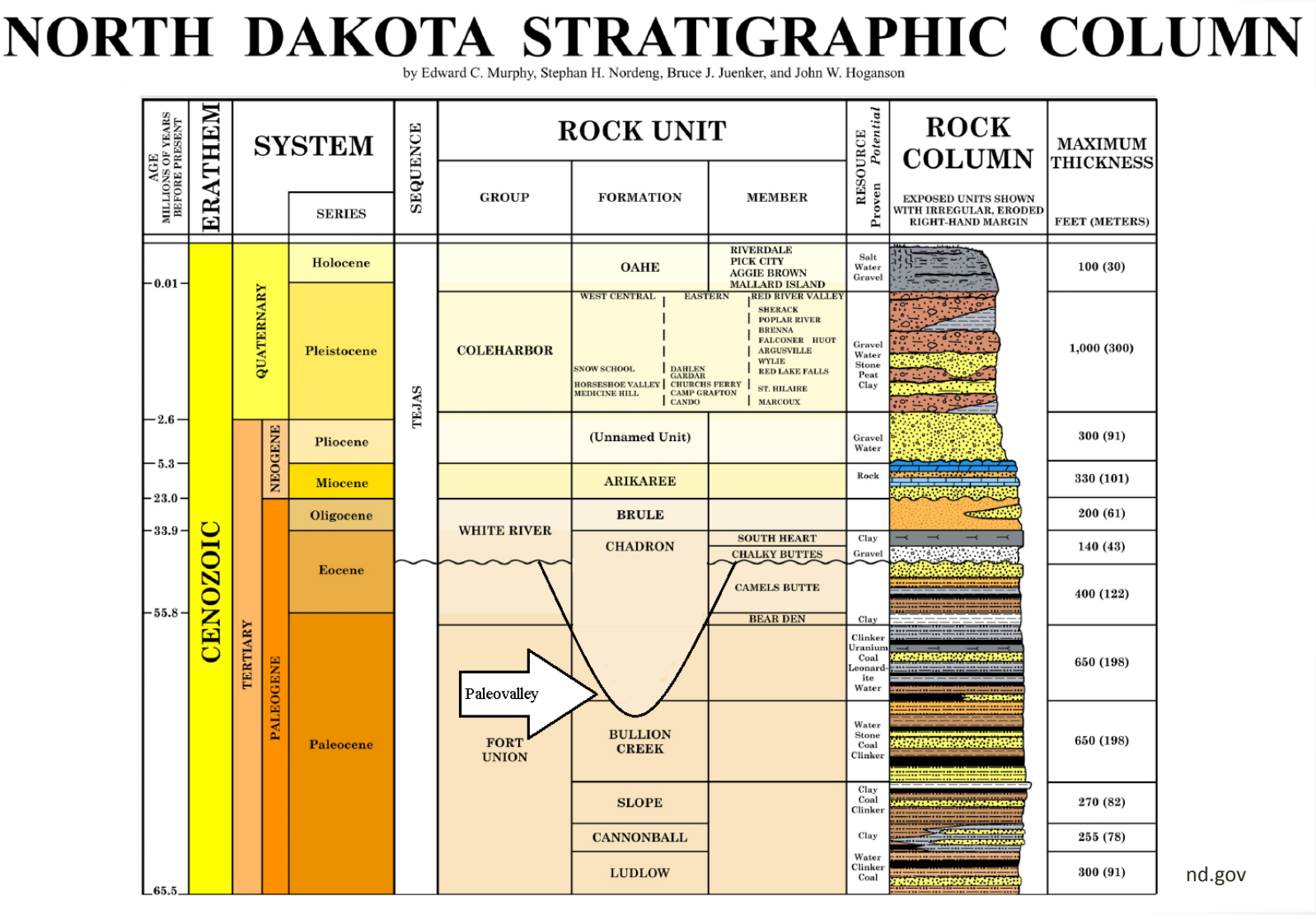
- Averages 6 meters thick in North Dakota
- Maximum thickness of 24 meters in the Chalky Buttes (Murphy et al., 1993)
- Eocene, not Early Oligocene
- Rests unconformably on Paleocene and Eocene rock units (Bullion Creek, Sentinel Butte, and Golden Valley Formations)

Stratigraphy



nd.gov

Stratigraphy



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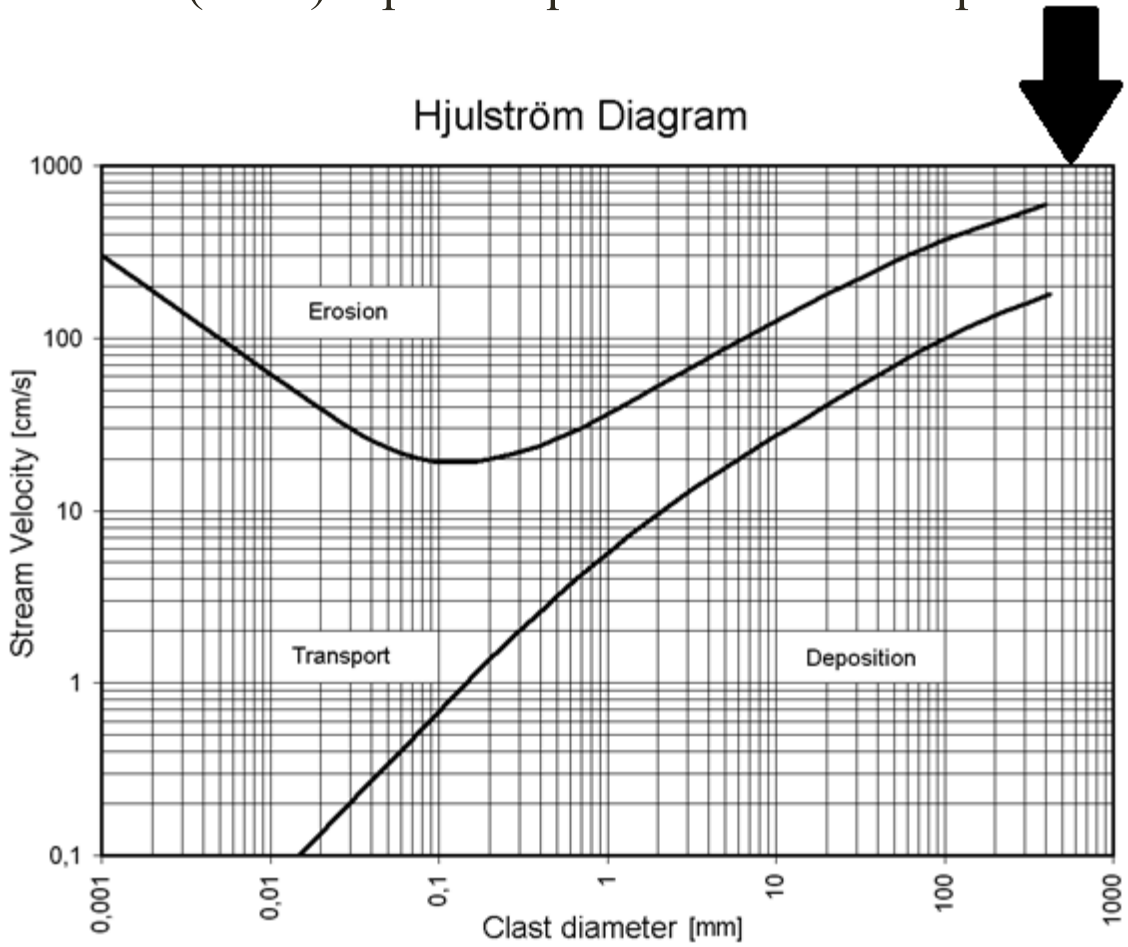
Depositional Environment

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



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

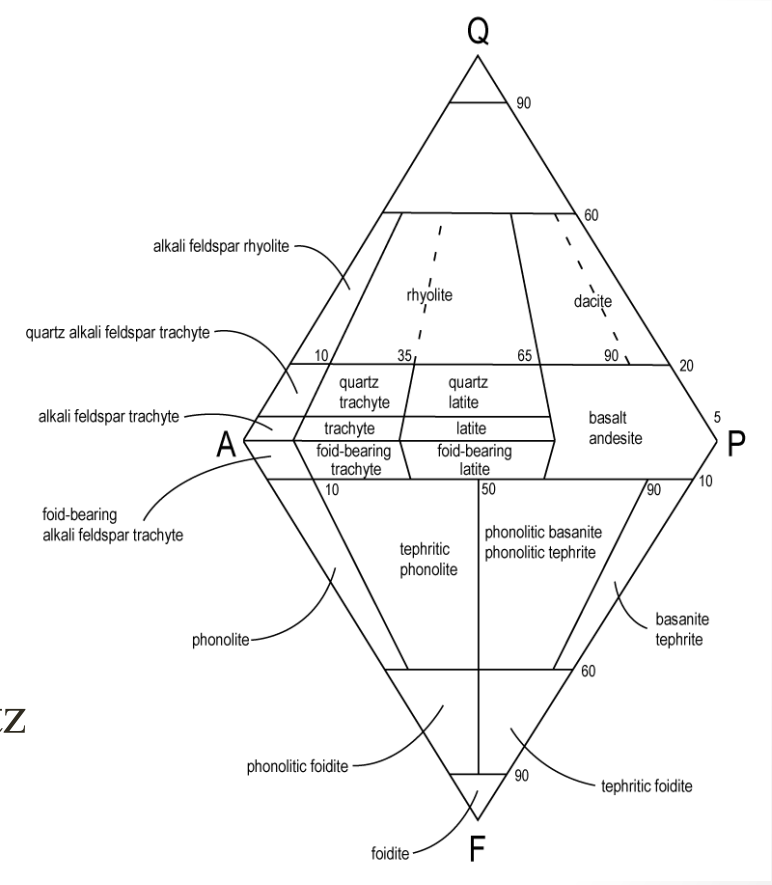
(Denson and Gil, 1965)

- 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

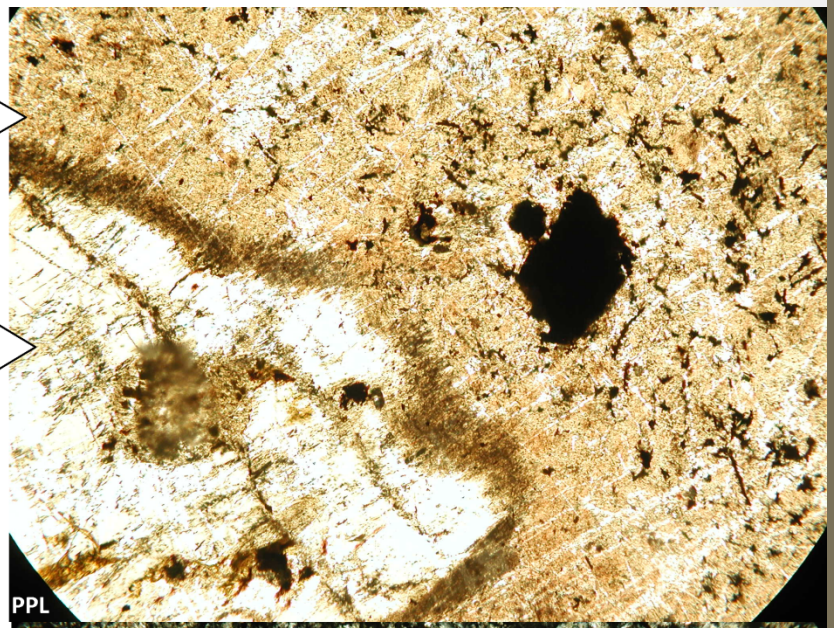
Porphyries

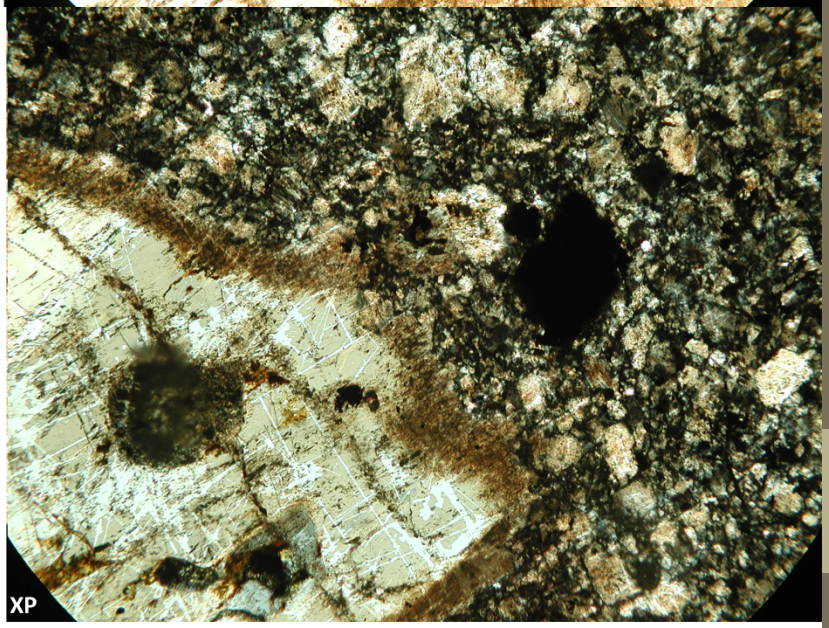
- Magma cools slowly

  Forms large crystals (phenocrysts)

- Finishes cooling quickly

  Remaining magma forms small crystals (groundmass)





X-ray Diffraction

Quartz latite porphyry?

XRD results

(Folkers and Dolezal, 2010 unpublished work)

Groundmass

Orthoclase

Microcline

Phenocrysts

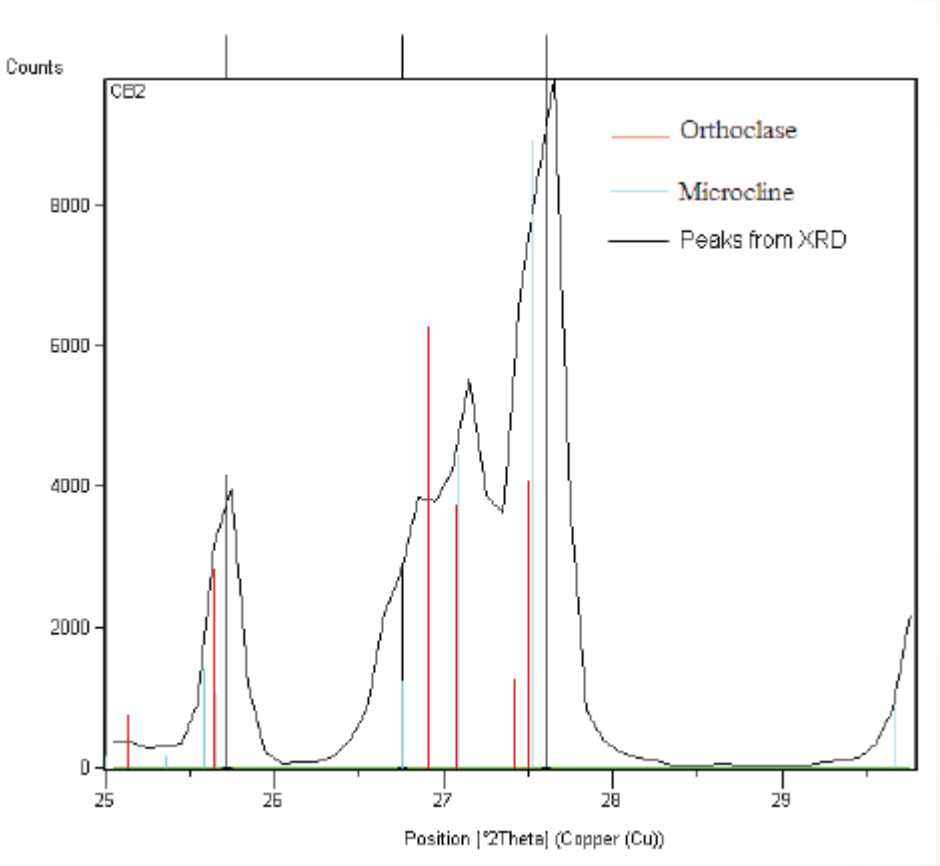
Sanidine

Anorthoclase

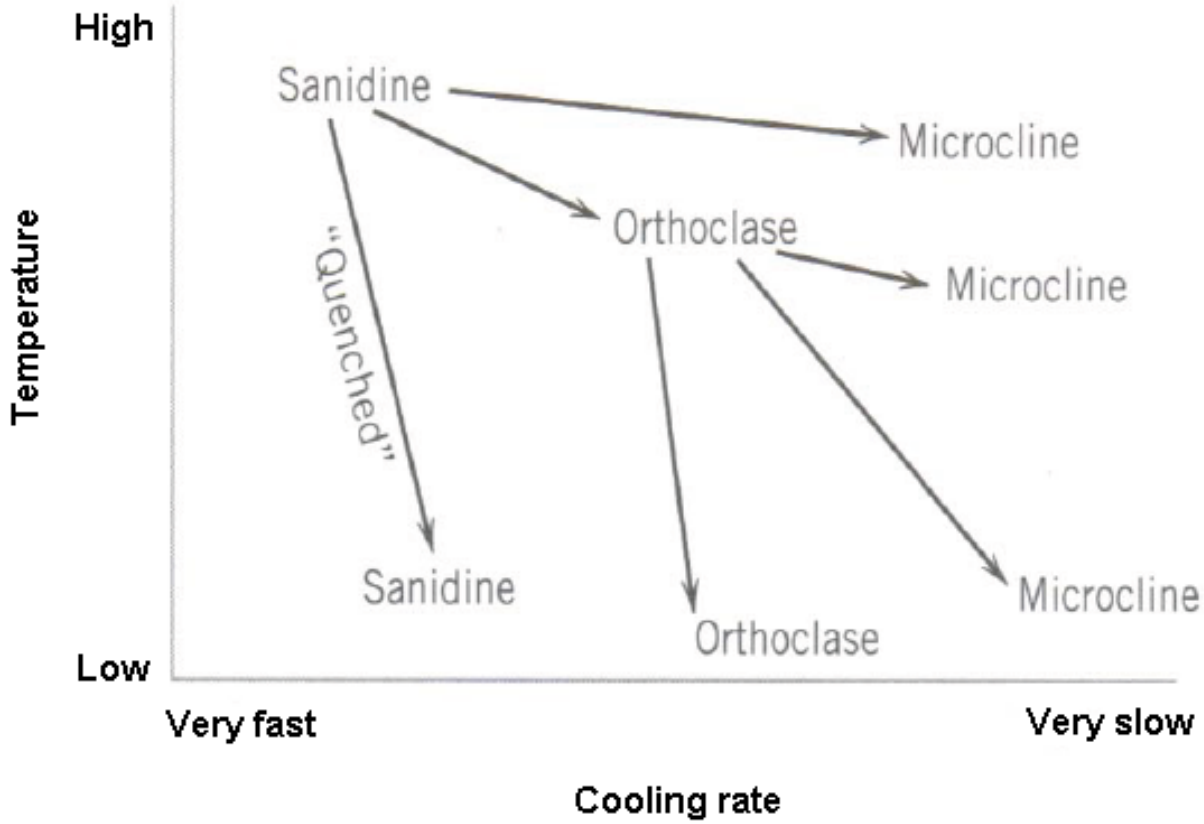
Orthoclase

Microcline

No Quartz?



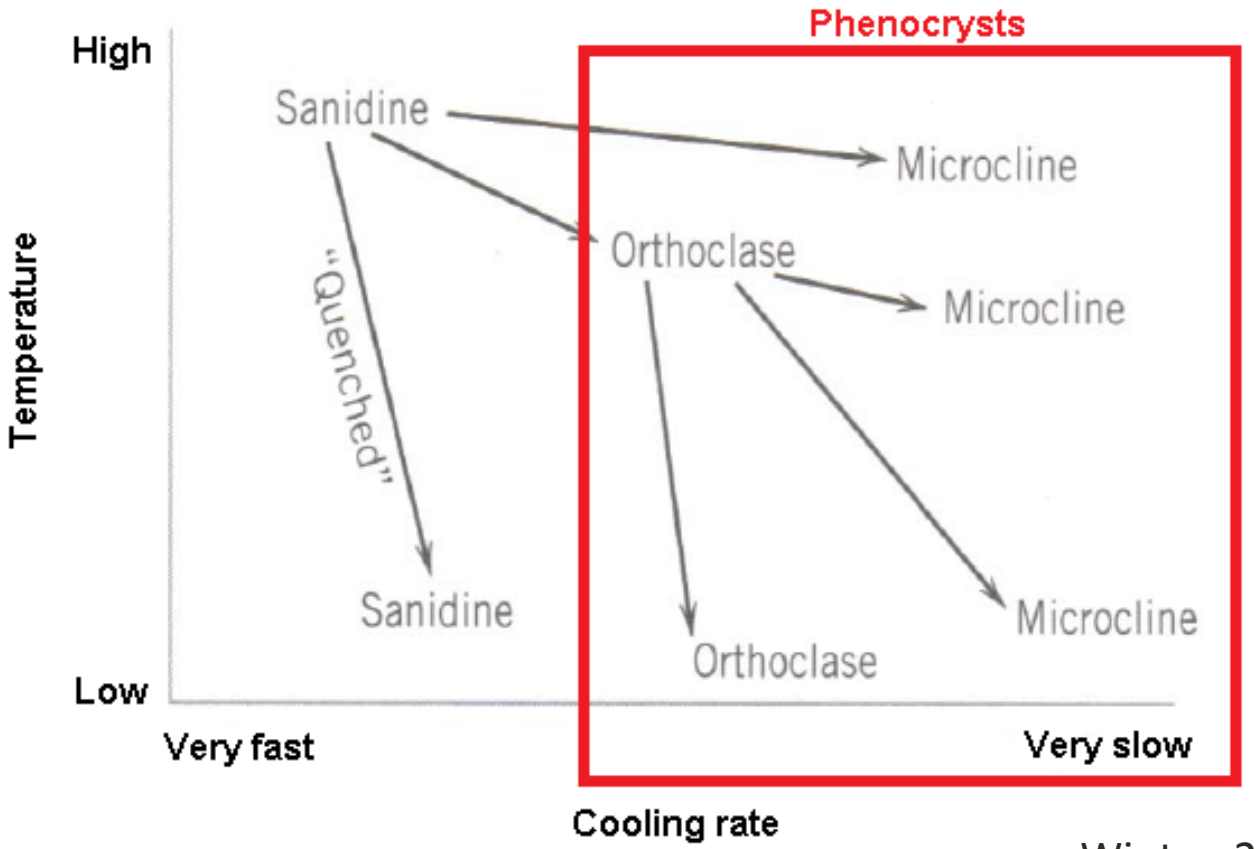
Cooling Rate



Winter, 2008

Cooling Rate

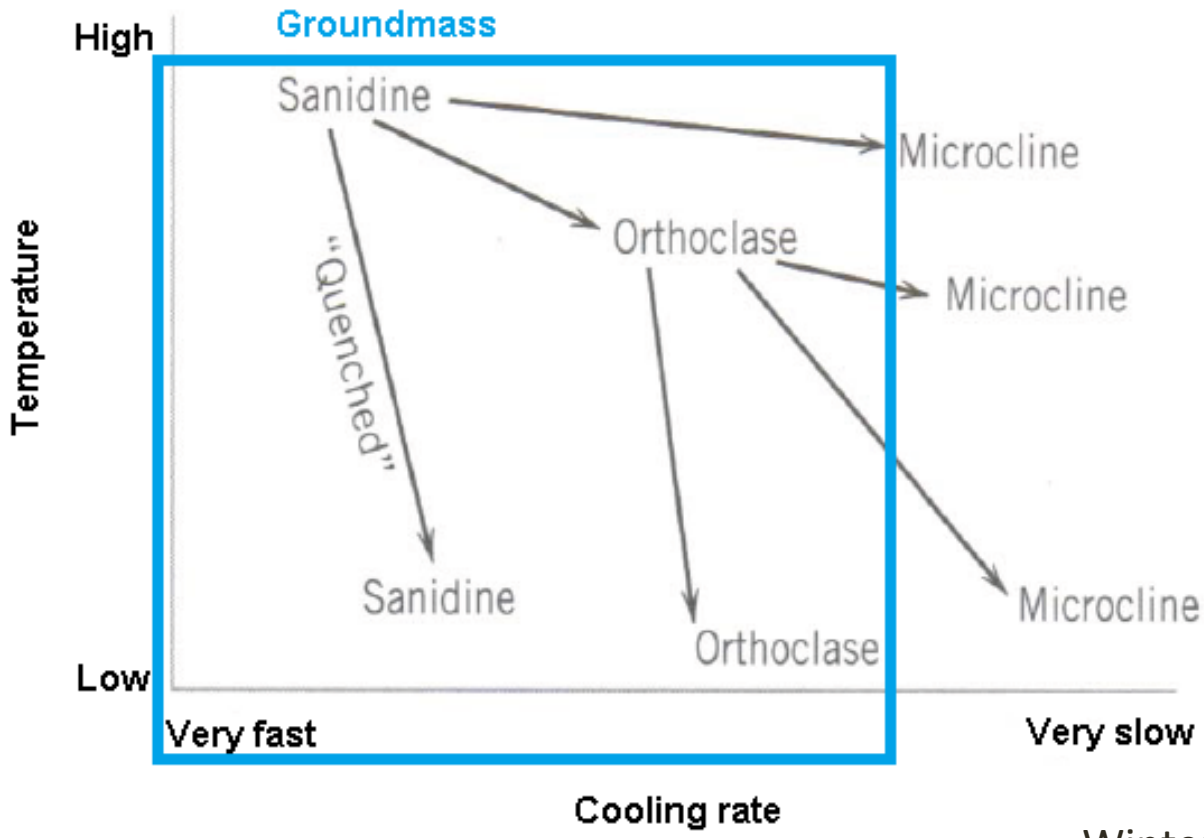
Phenocrysts predominantly orthoclase and microcline



Winter, 2008

Cooling Rate

Groundmass predominantly sanidine and orthoclase



Winter, 2008

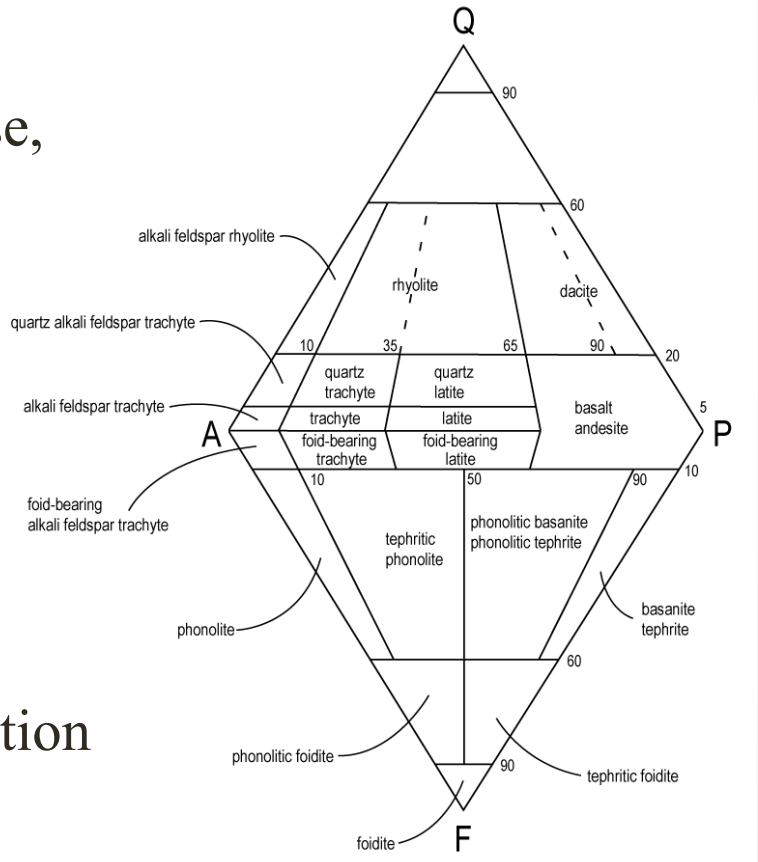
Folkers and Dolezal Results

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

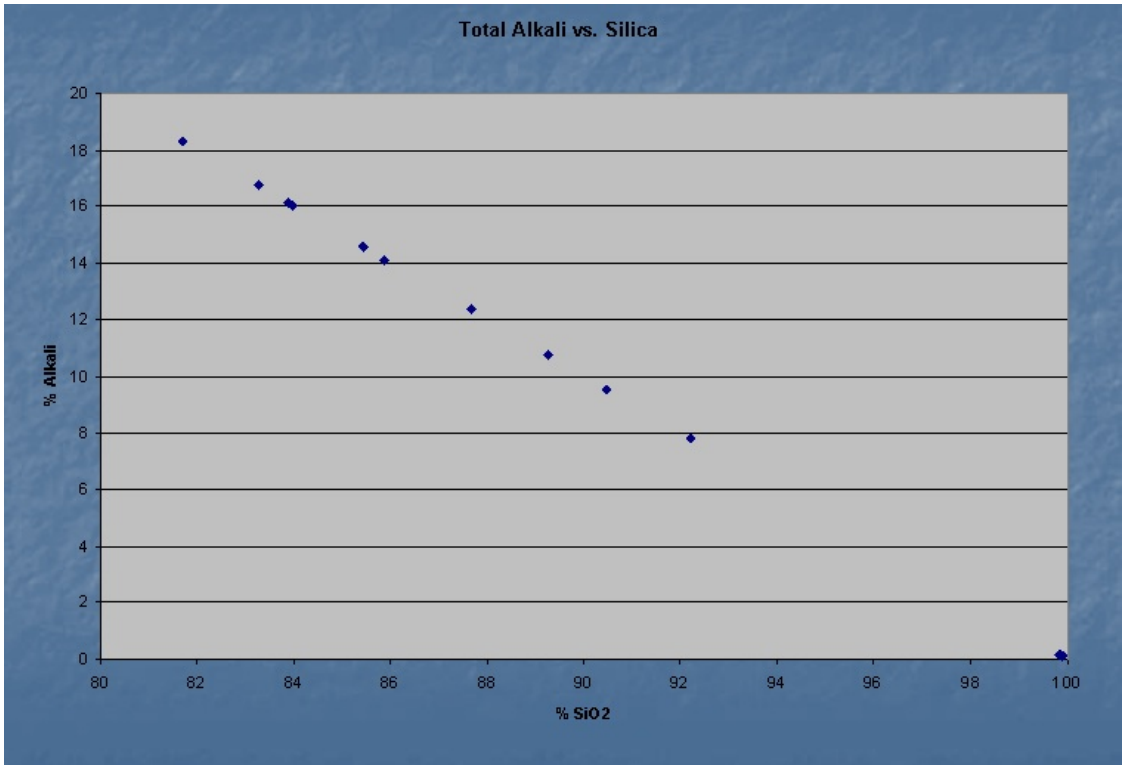


QAPF Diagram Wikipedia.org

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)

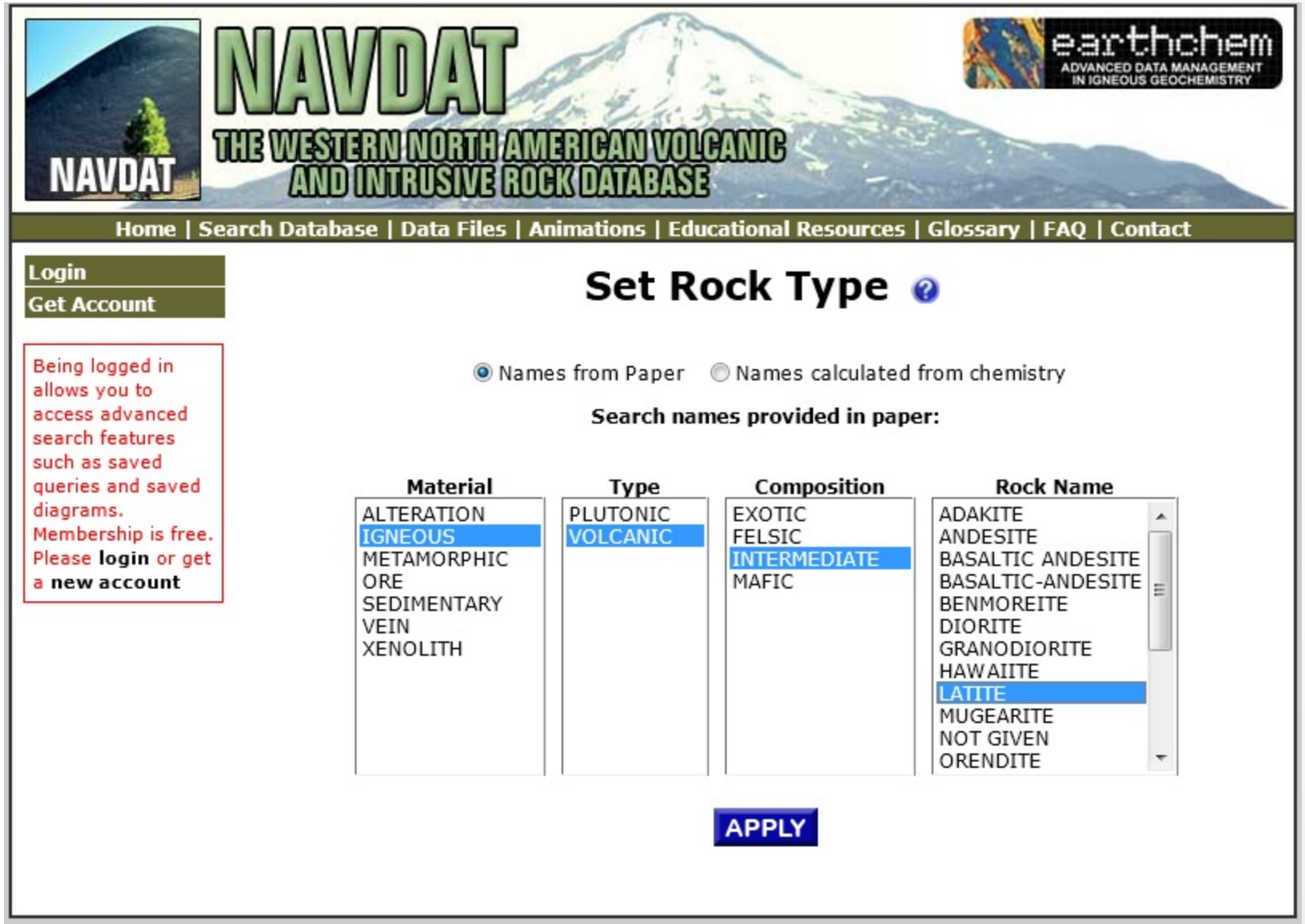
- However; paleoslope direction was more eastward than north
- Cobbles do not represent typical rock types

The **Absaroka volcanic field** / Beartooth Mountains (WY, MT)
(Denson and Gill, 1965)

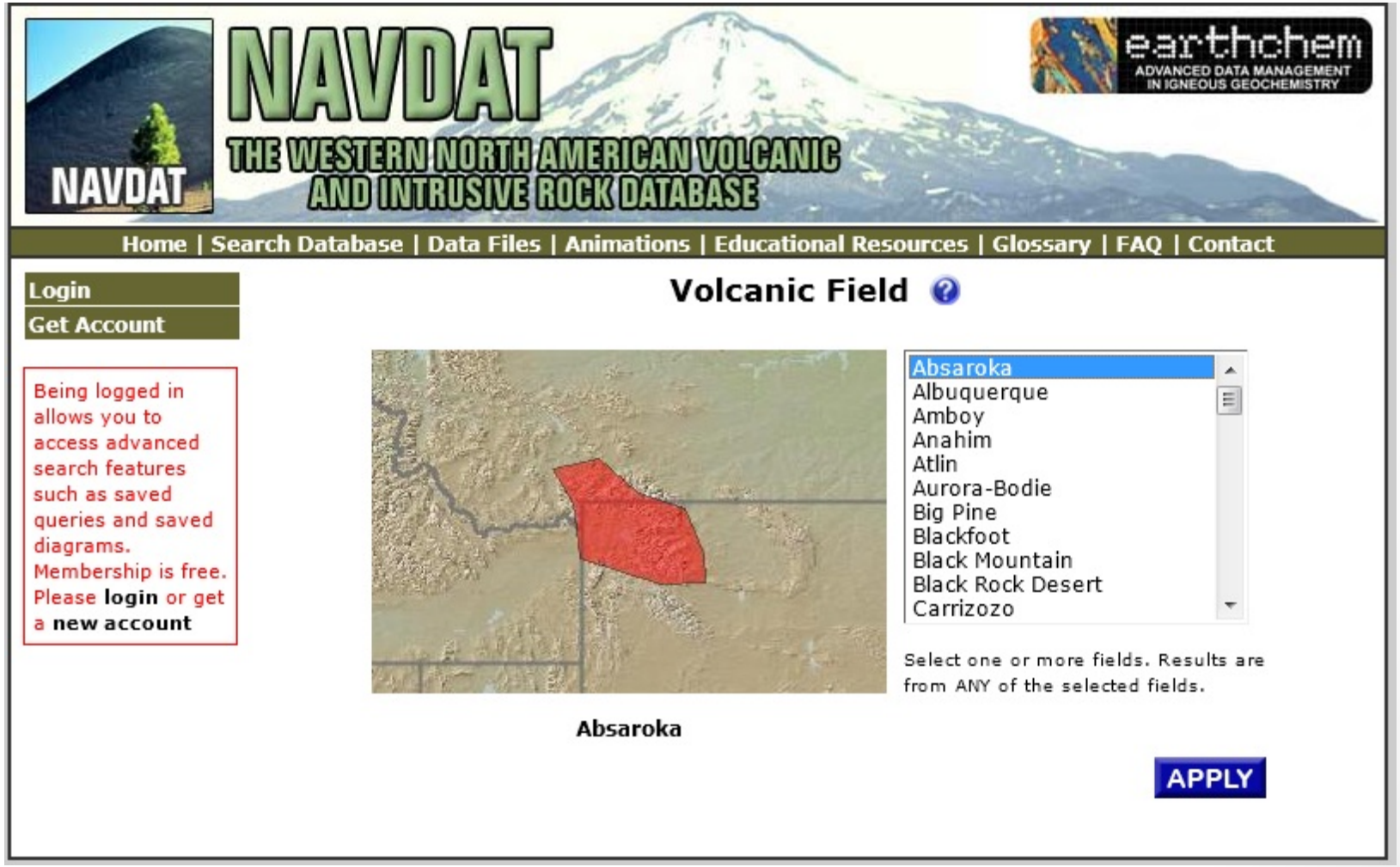
- Paleoslope favors this source (Seeland, 1985)
- Surficially looks like porphyries from dikes in the Beartooth Mtns

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

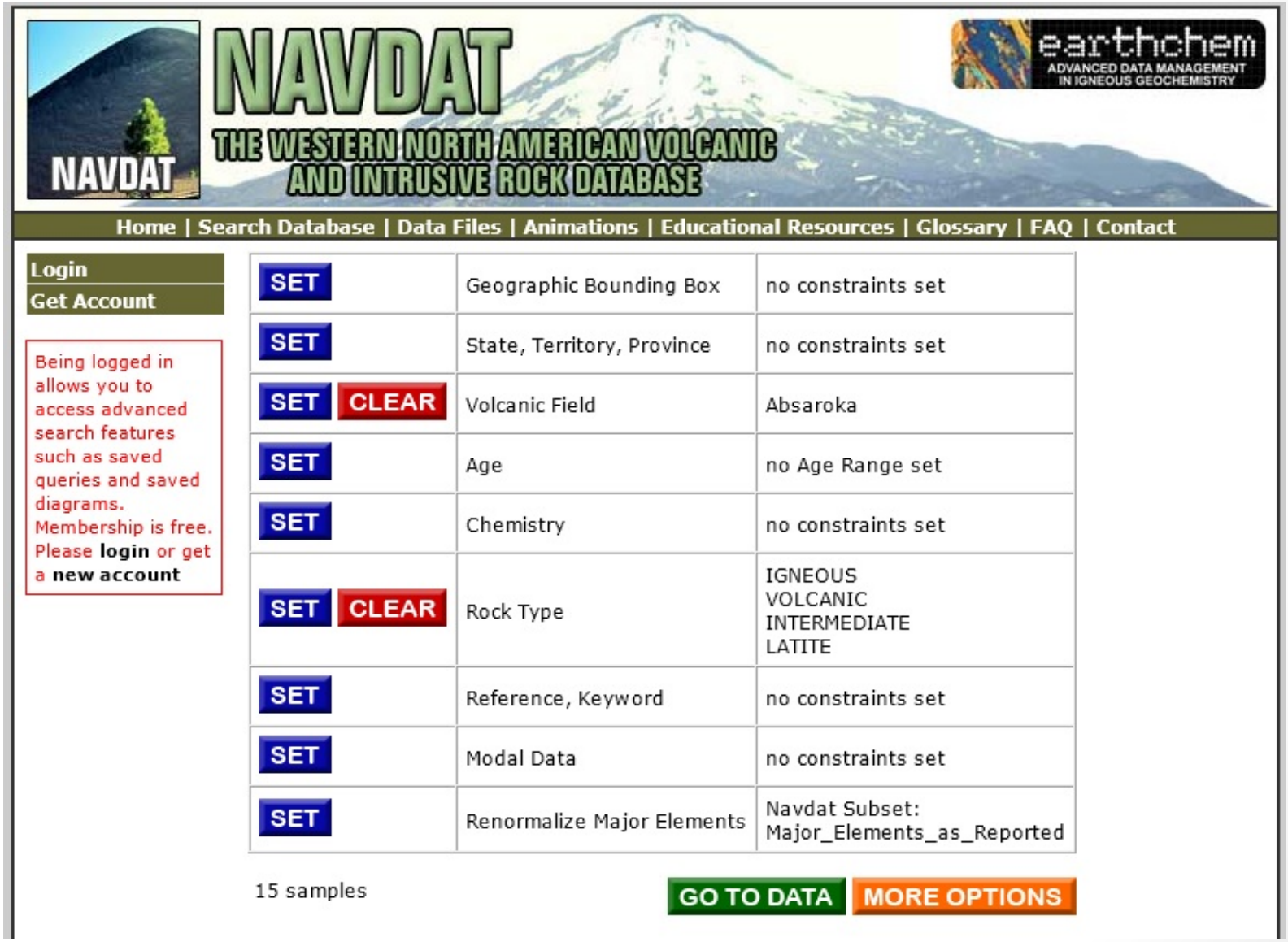
Source Area Geochemical Data



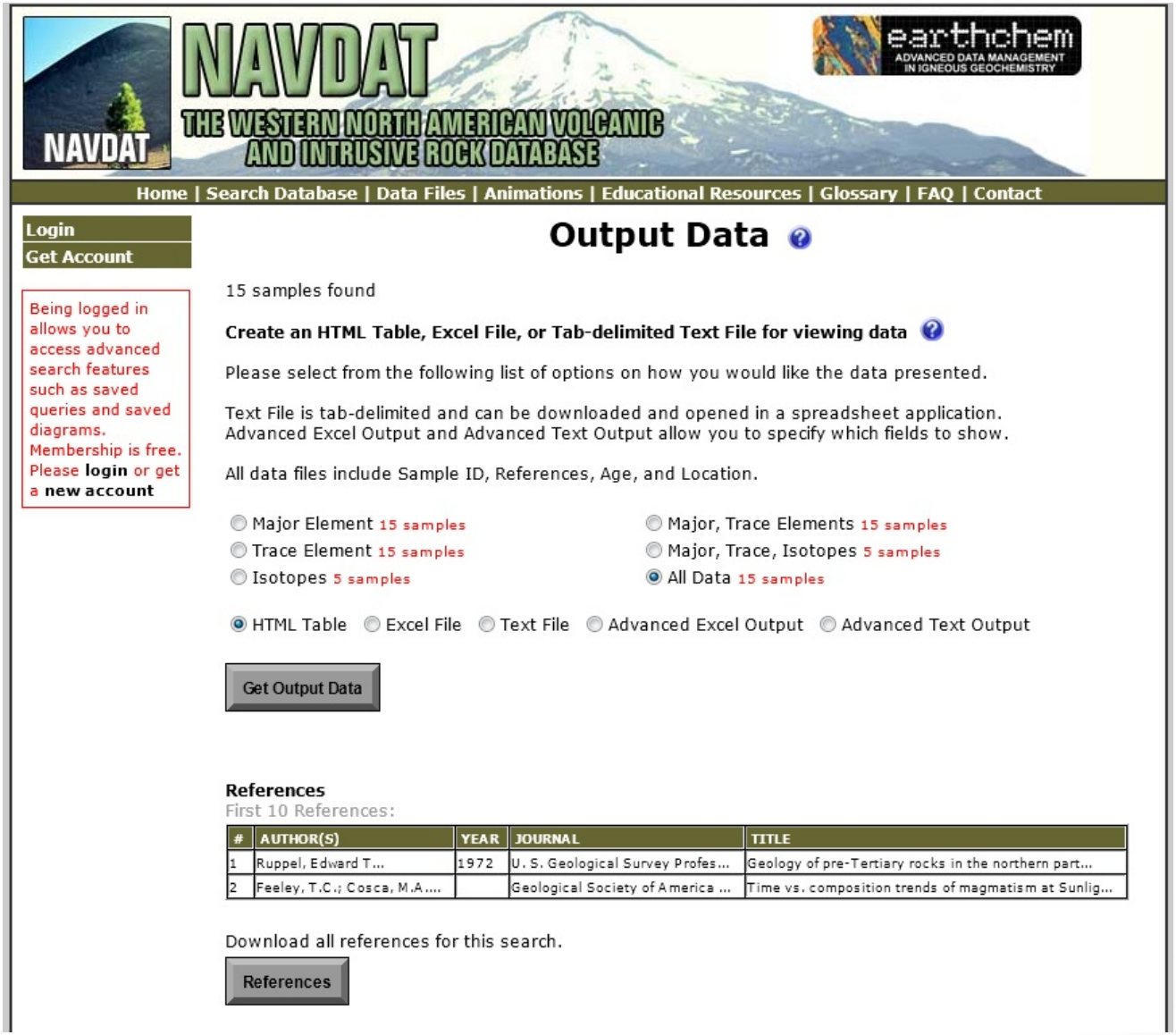
Source Area Geochemical Data



Source Area Geochemical Data



Source Area Geochemical Data



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

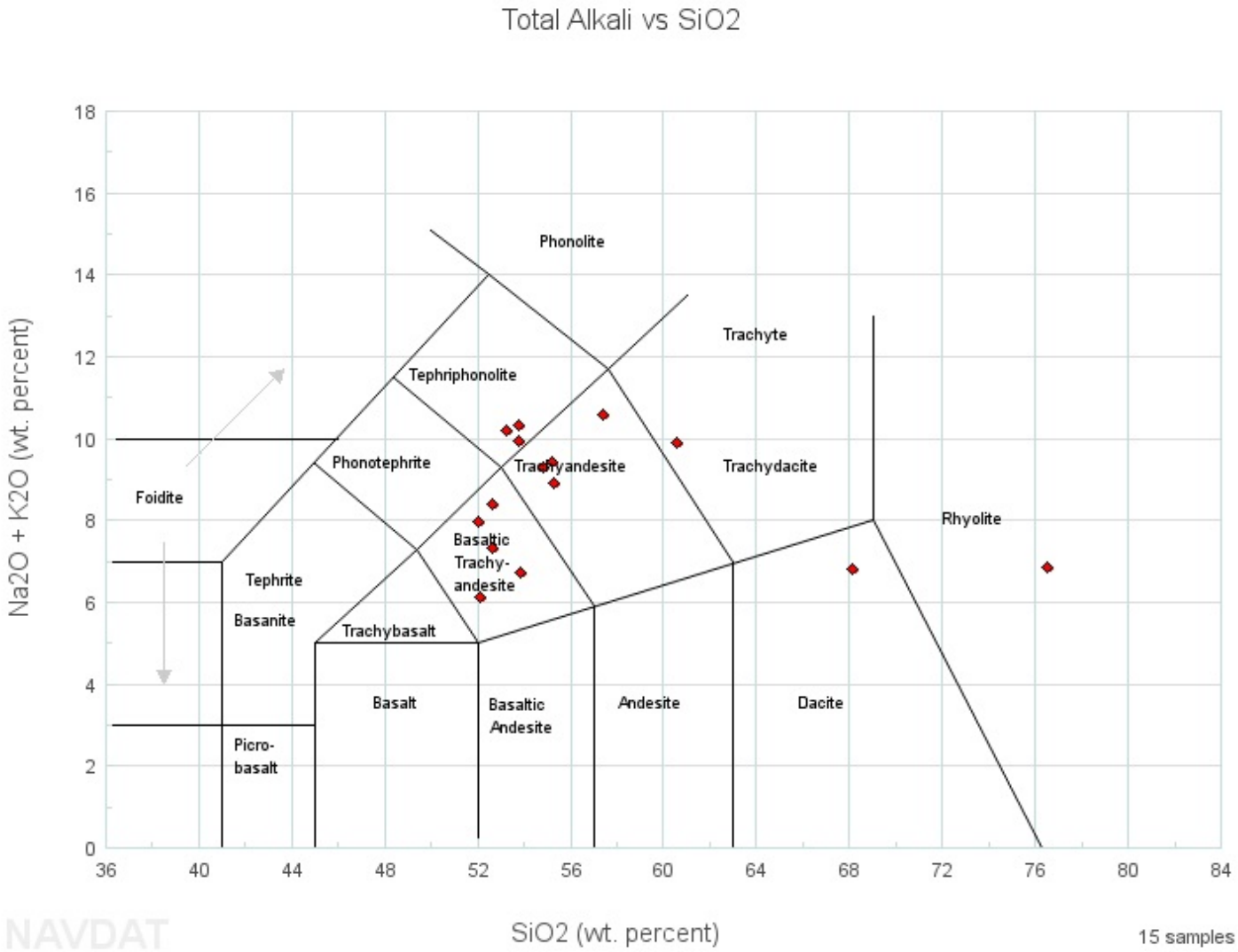
Harker Diagrams Animated by Age

TAS Diagram

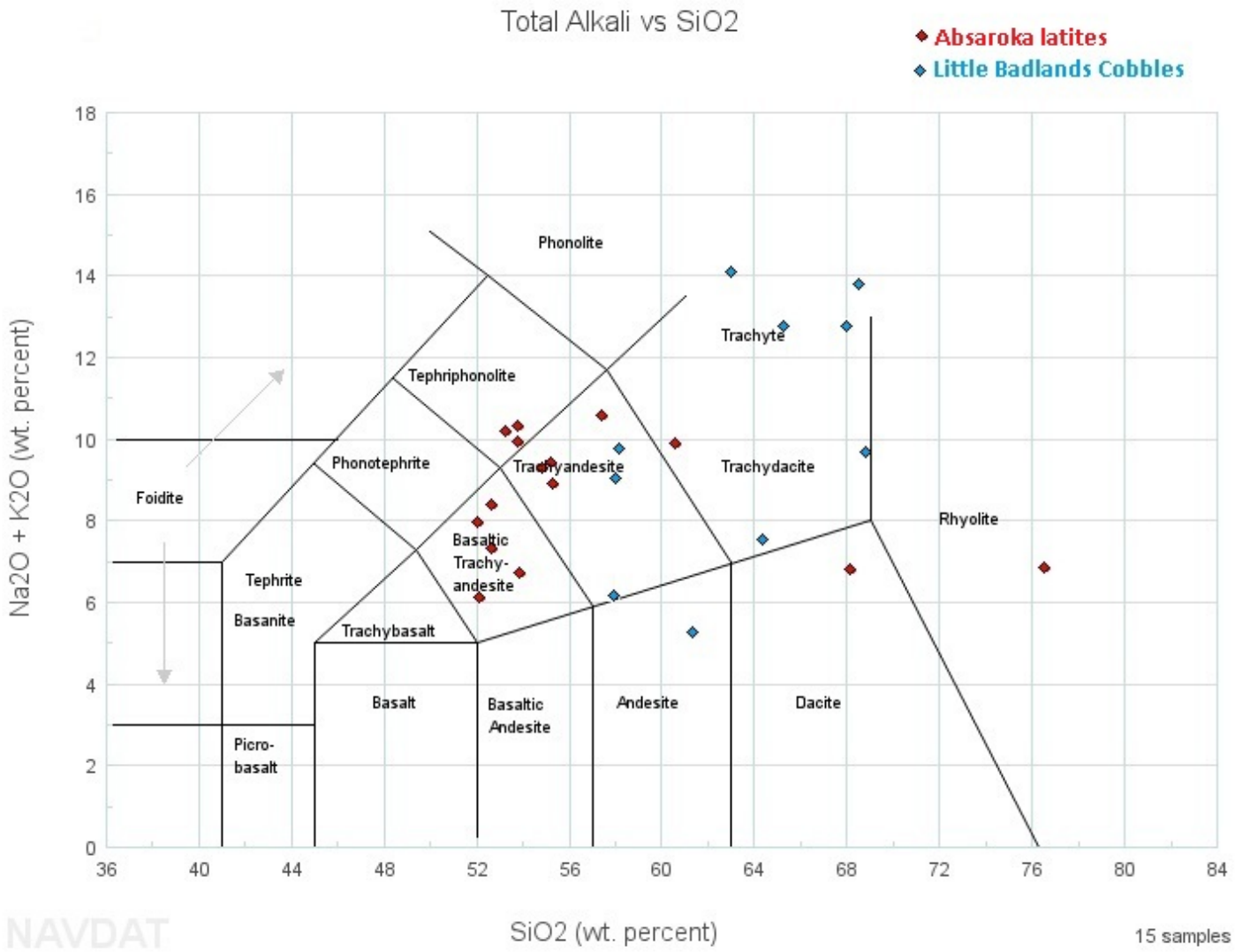
TAS Diagram Animated by Age

XYZ Plot

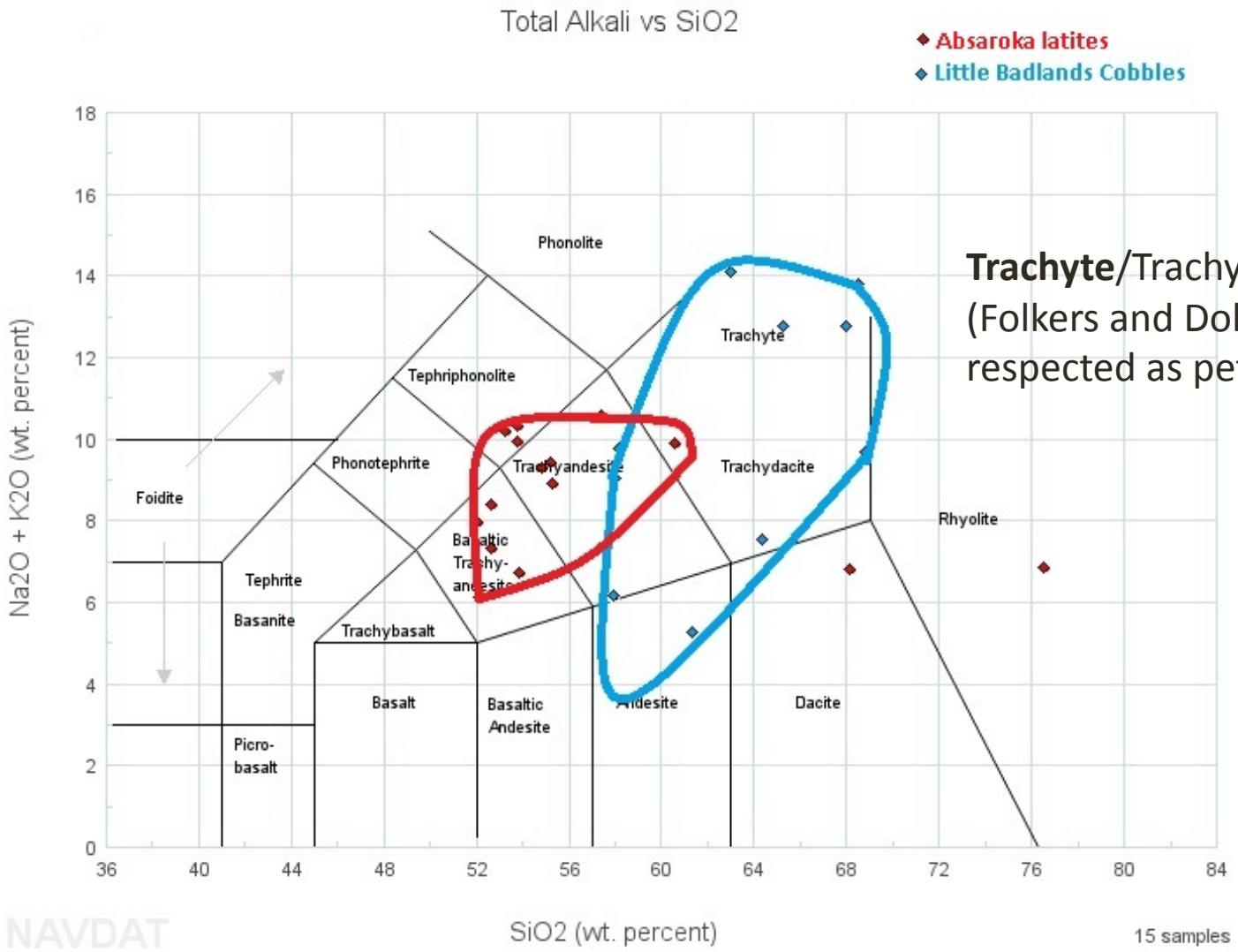
Source Area Geochemical Data



TAS Diagram


Total Alkali vs SiO2
Absaroka latites
Little Badlands Cobbles
Na2O + K2O (wt. percent)
SiO2 (wt. percent)
Phonolite
Trachyte
Tephriphonolite
Phonotephrite
Trachyandesite
Trachydacite
Foidite
Rhyolite
Basaltic Trachy-andesite
Tephrite
Basanite
Trachybasalt
Basalt
Basaltic Andesite
Andesite
Dacite
Picro-basalt
NAVDAT
15 samples

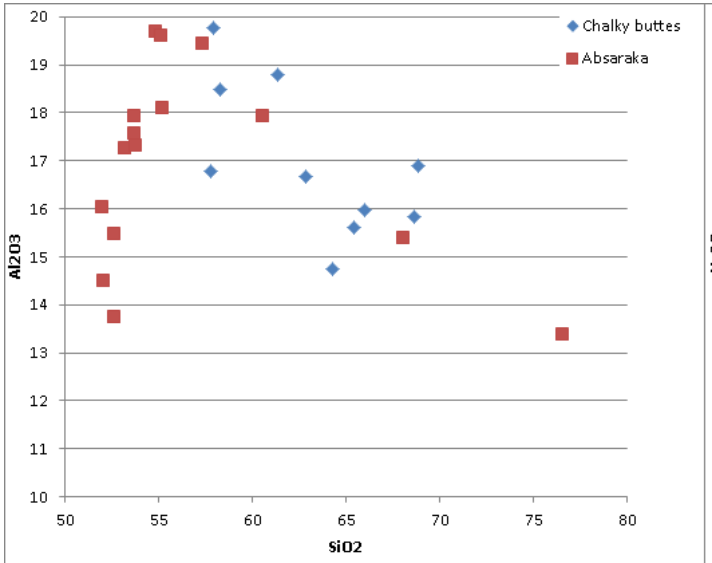
TAS Diagram

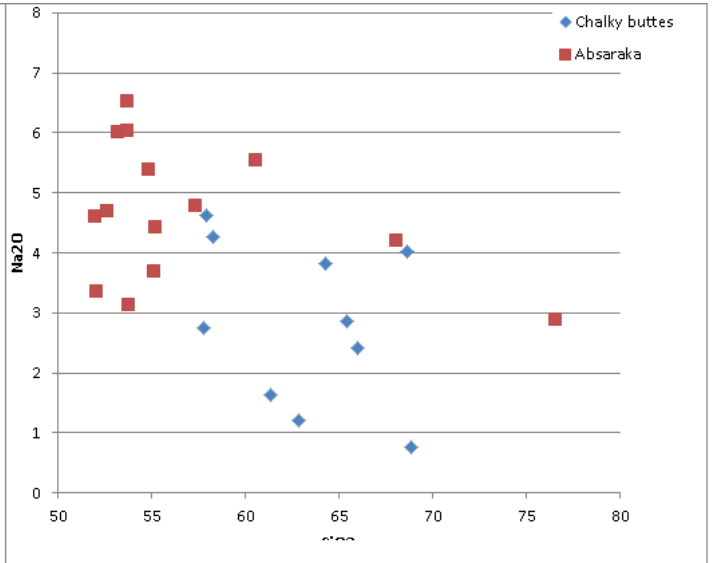


Trachyte/Trachydacite
(Folkers and Dolezal should be respected as petrologists)

Harker Diagrams

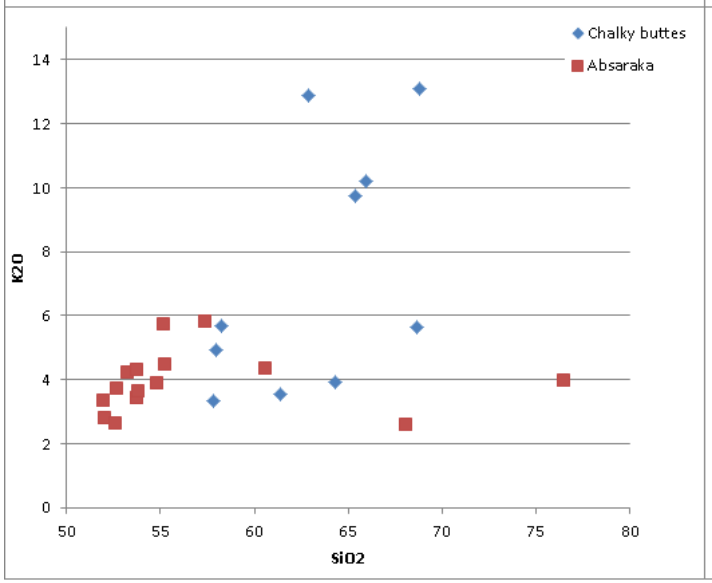
Al2O3 vs. SiO2

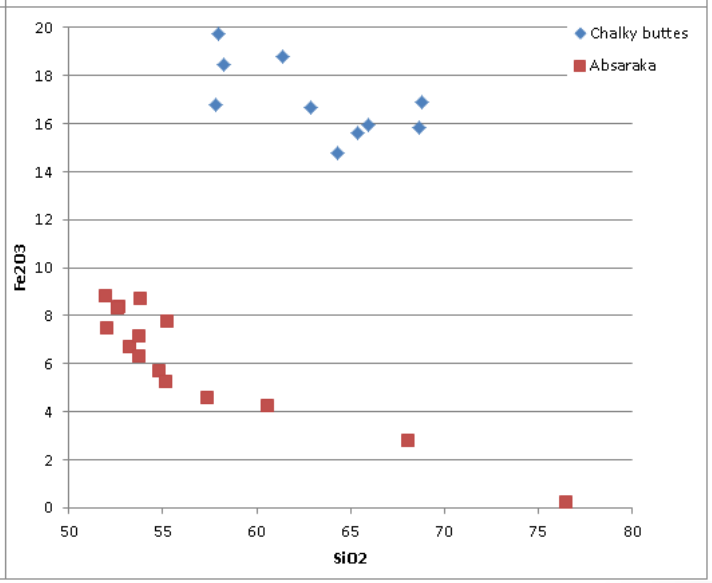




Na2O vs. SiO2

K2O vs. SiO2

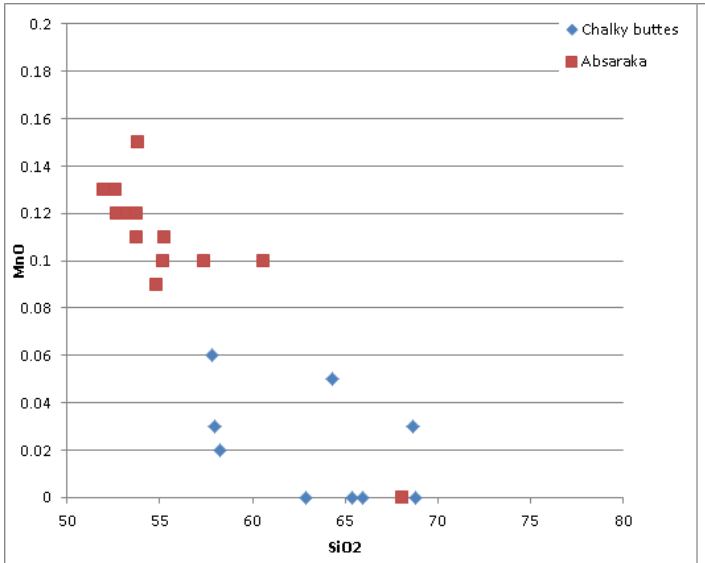


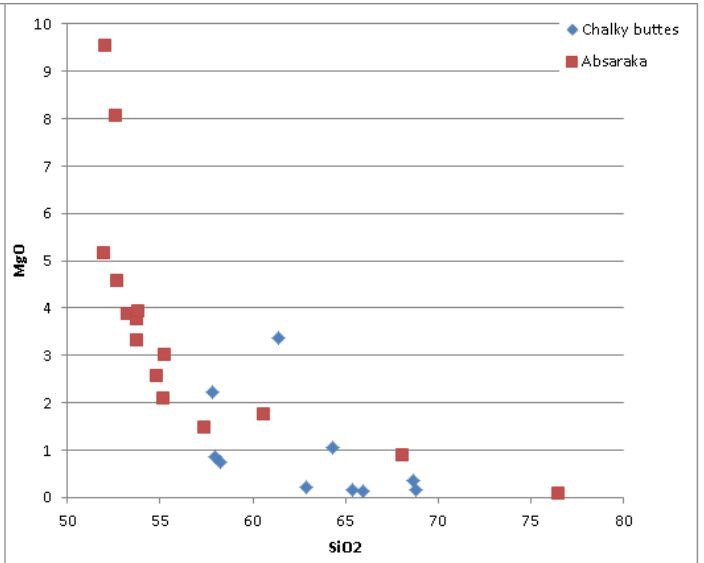


Fe2O3 vs. SiO2

Harker Diagrams

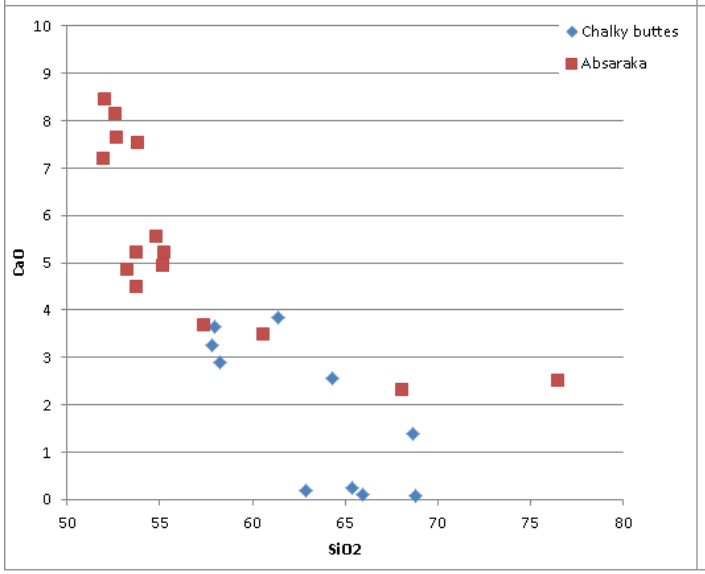
MnO vs. SiO2

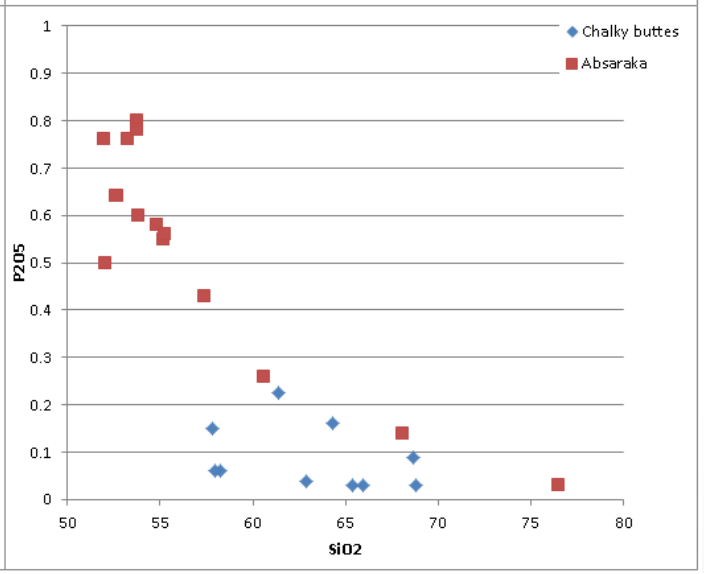




MgO vs. SiO2

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