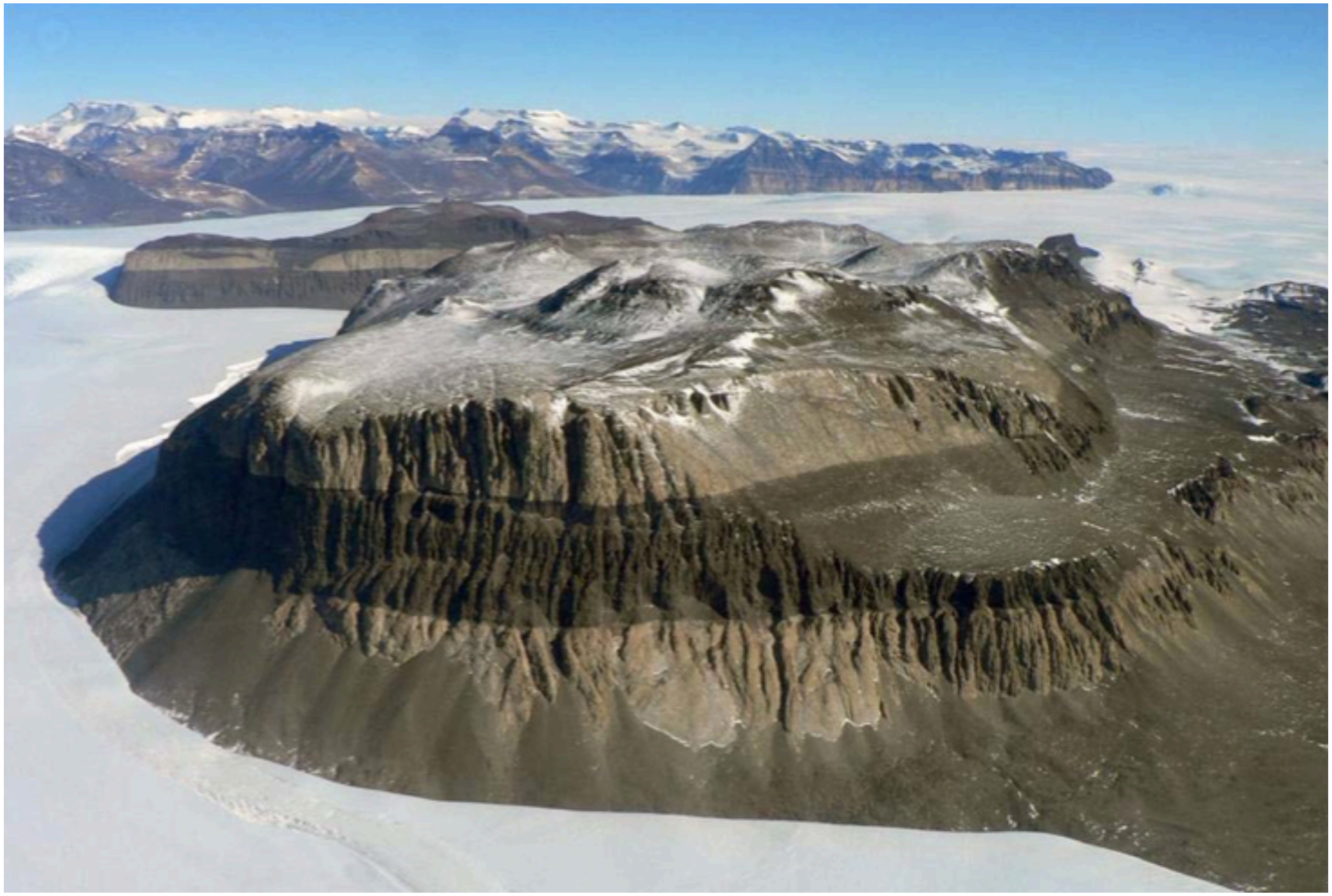
CLASSIFICATION OF ANTARCTIC TILL COBBLES THROUGH GEOCHEMICAL ANALYSIS & COMPARISON

Rachel Powers & Felix Zamora NDSU GEOL – 422
May, 2012

Study Area – Transantarctic Mountains

Study Area

Friis Hills, Southern Victoria Land



Courtesy of Adam Lewis 2008

Can provenance be determined from geochemical analysis?

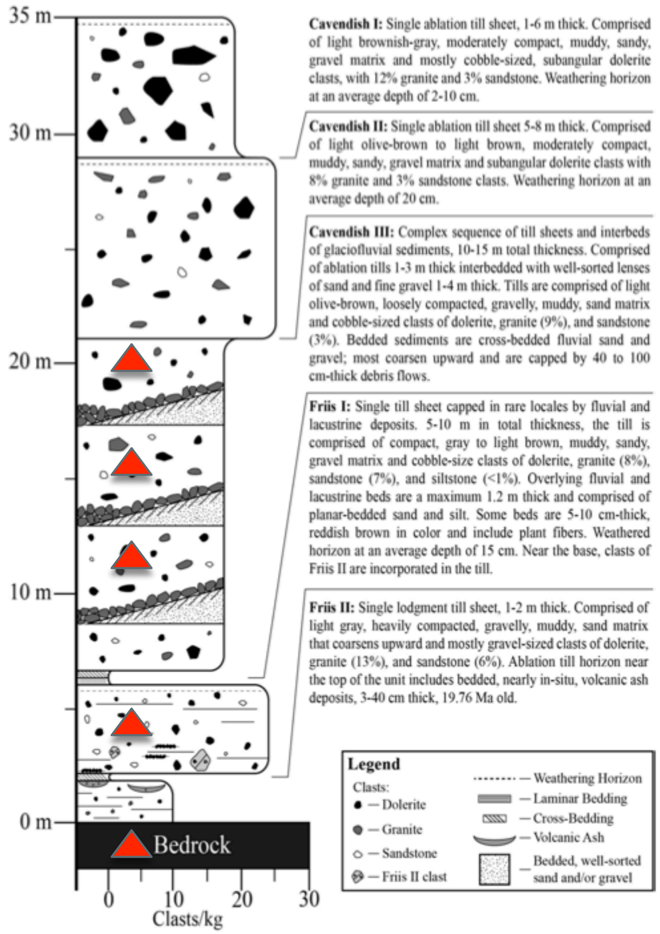
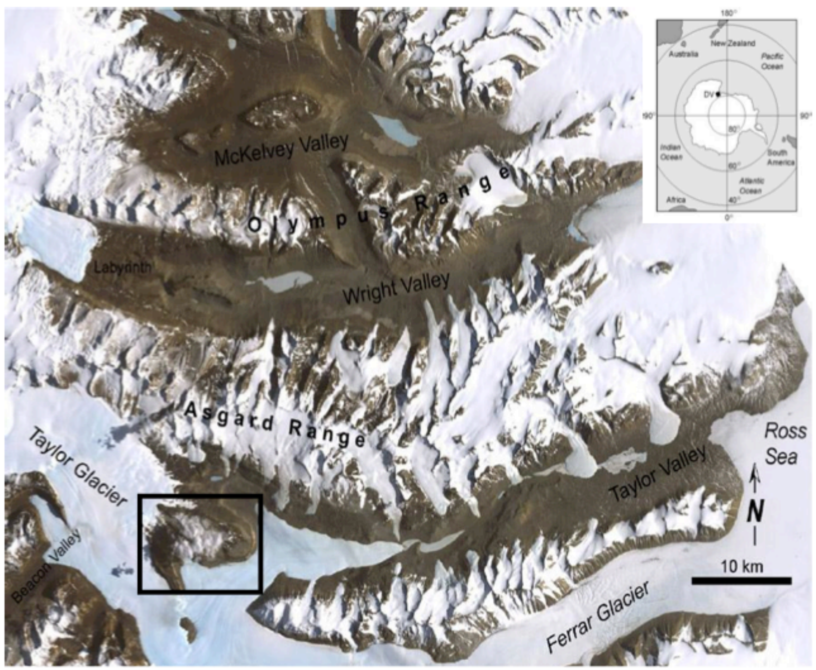


Figure 3.1. Stratigraphic column for glacial deposits in the eastern Friis Hills paleovalley.

Smith (2011)

- Glacial erratics
- Indication of changes in flow patterns

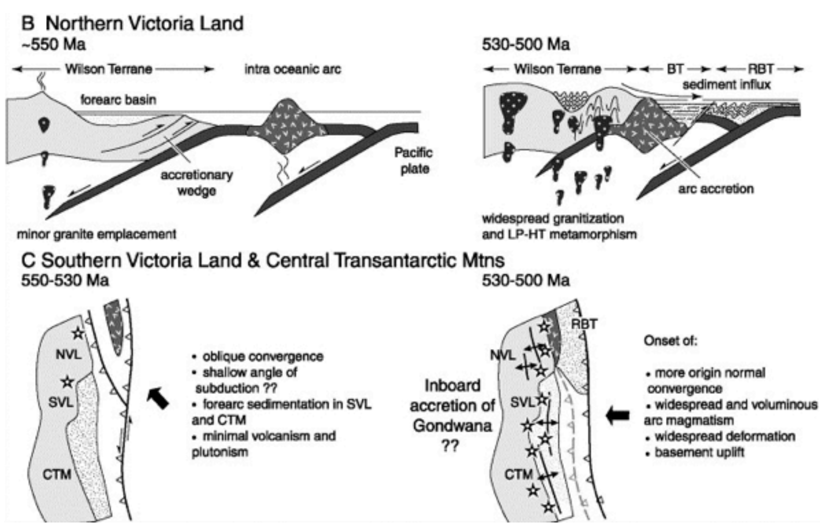
Petrologic and Tectonic Evolution of Ross Sea Region



Smith 2011

- 3 main emplacement phases of current bedrock exposures
- 3 granitoid suites
- Accretionary terranes
- Ages differentiated by Sr^{87}/Sr^{86} isotopic dating

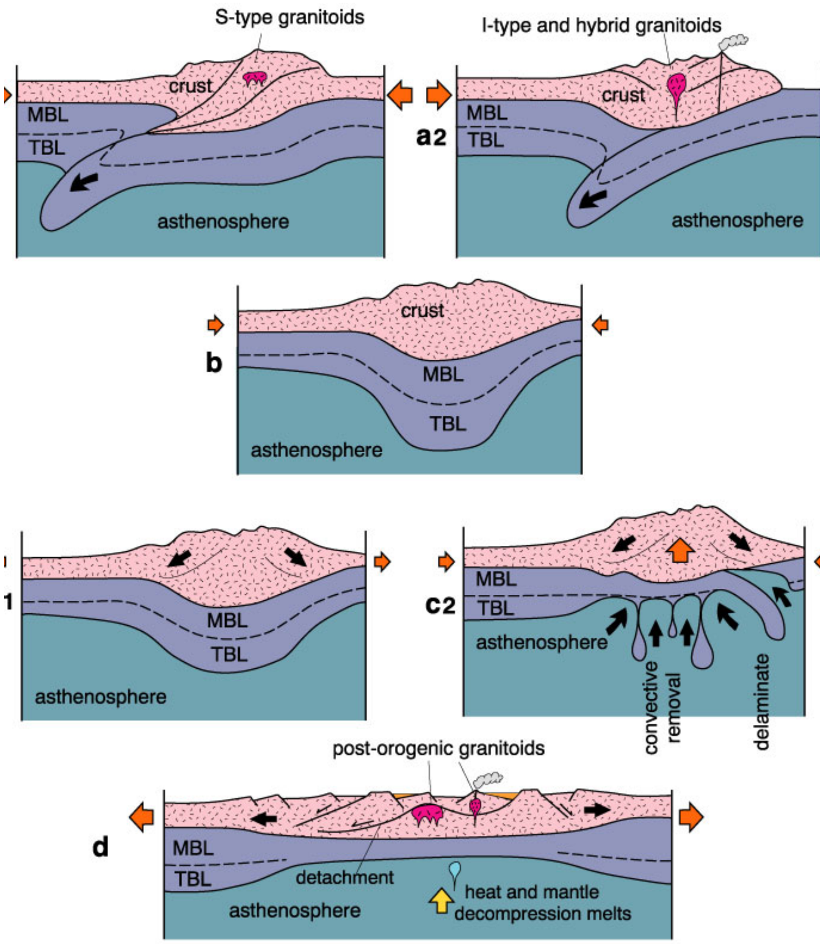
First phase of plutonism (DV1a)



Boger & Miller 2004

- Emplacement ceased c. 500 Ma
- Cordilleran I-type granitoid suite
- Hornblende-clinopyroxene assemblages
- Metaluminous, calcic and sodic compared to S-types
- Volcanic arc at continental margin

Second phase of plutonism (DV1b)



Winter 2010

- Emplaced concurrent with DV1a plutonism.
- Biotite granites
- Enriched in Al_2O_3, Na_2O, and Sr
- Homogenous felsic source
- Cessation of DV1b coincides with accretion of Bowers Terrane c. 490 Ma
- Change in subduction style?
- Increased sediment supply being subducted?
- Cessation of subduction altogether?

Phase three of plutonism (DV2)

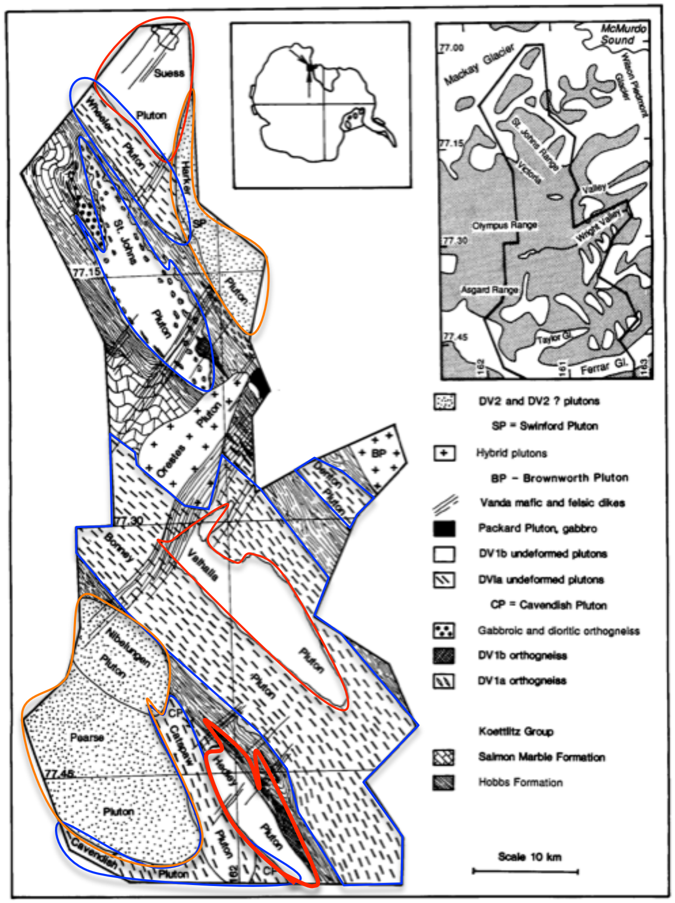
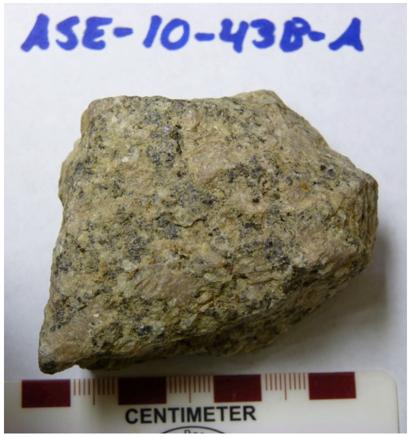


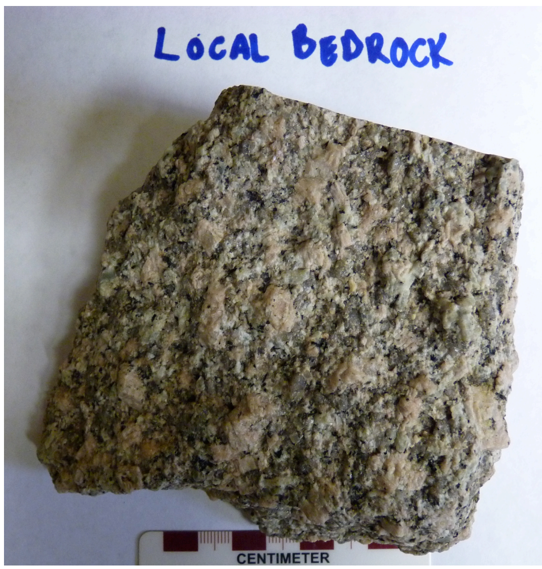
Fig. 1 Inferred basement geology if overlying ice, sediments, moraine, and Ferrar Dolerite were removed to expose the Kukri Erosion Surface. The DV1a and DV1b plutons (Bonney, Wheeler, Denton, St Johns, Valhalla, and Hedley Plutons) have a consistent northwest orientation and are cut by northeast-striking younger dikes and the ovoid Pearse, Nibelungen, Brownworth, Orestes, Swinford, and Harker Plutons.

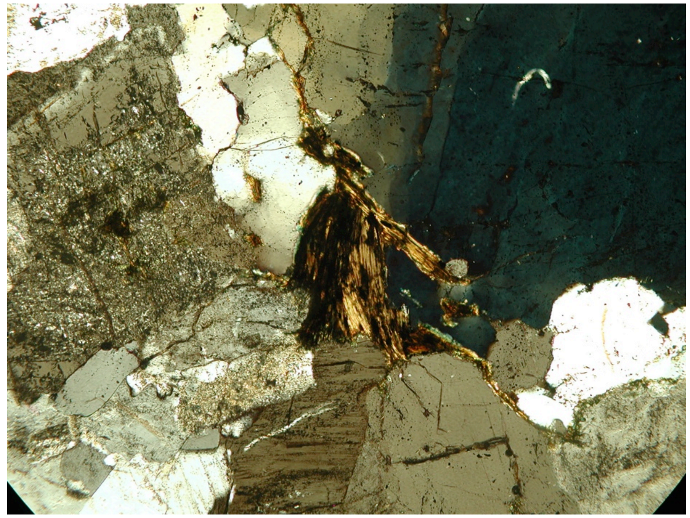
Allibone et al. 1993

- Metaluminous, alkali-calcic, I-type
- Emplaced between 486 and 477 Ma.
- Higher K_2O, lower MgO & CaO
- Generally lower SiO_2
- Enriched in LREEs
- K-feldspar phenocrysts

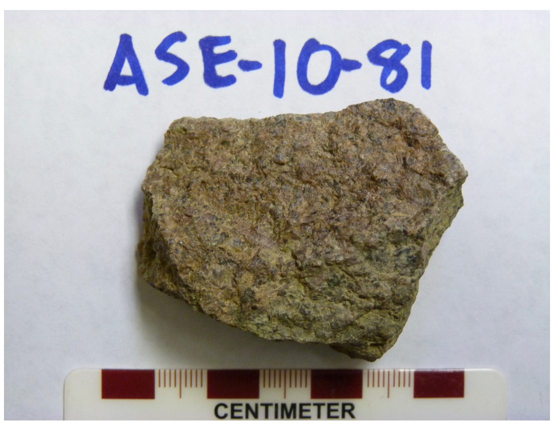
Petrography - Bedrock

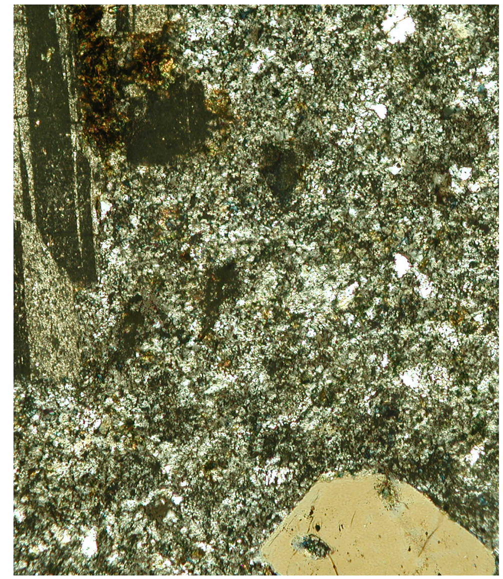


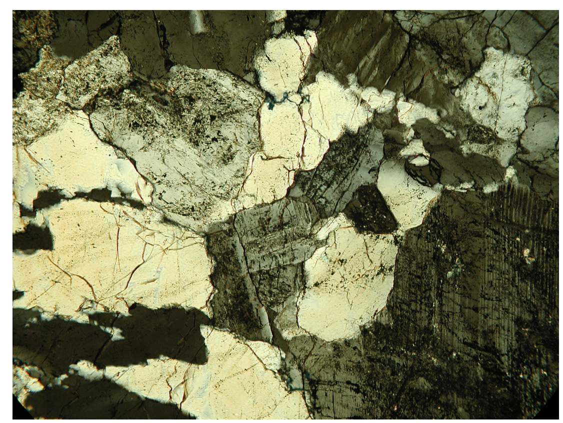




Petrography - Erratics

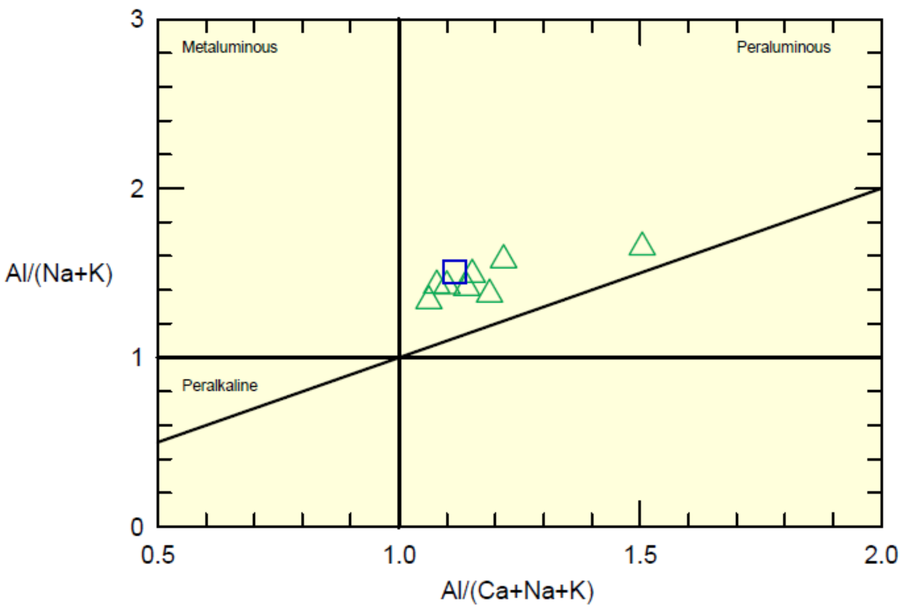






Aluminum Saturation Index (ASI)

Al/(Na+K) vs. Al/(Ca+Na+K)

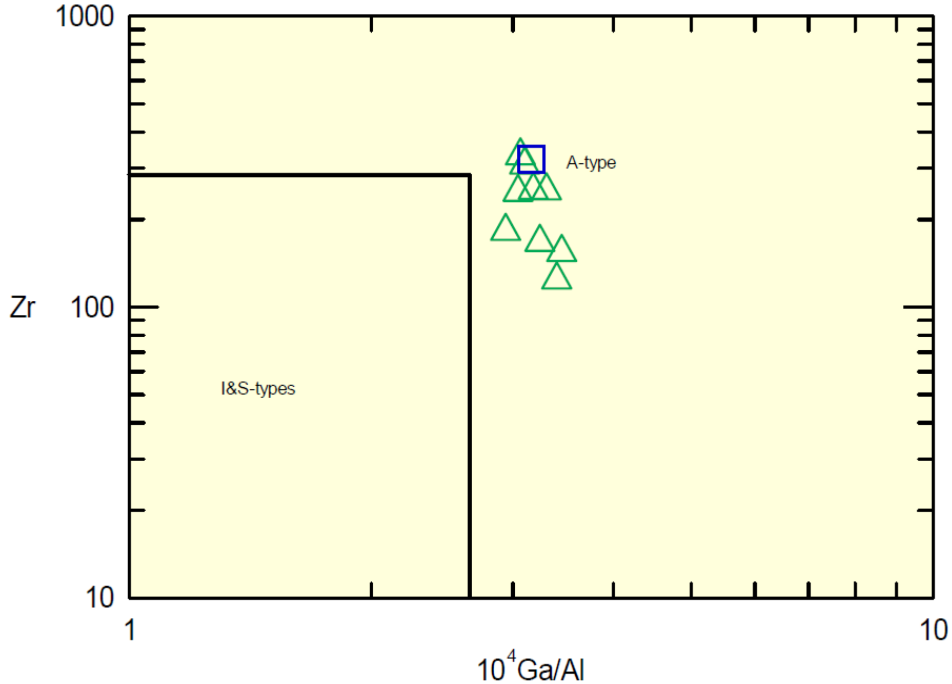


Background and Implications

- Since Al203 is the second most abundant component in most magmatic rocks, ASI is another method to classify granitic rocks.
- Peraluminous granitic rocks contain quartz, potassic feldspar and/or sodic plagioclase, and one or more aluminum-rich minerals. Peraluminous rocks contain more Al than could be accomodated by feldspar in a CIPW normative calculation (tool for assessing silica saturation or oversaturation). Excess Al is accomodated in micas (muscovite and Al-rich biotite).
- **Disadvantages**
- Peraluminous granites are defined by their chemical nature, but their recognition is often base on petrography; this discripancy may lead to inconsistency. (Zen, 1988)
- Another disadvantage to this system is that Na and K can be mobilized and transferred out of out of the magma by a separate fluid phase. (Best,

Alphabetical Classification-SIAMC

Zr vs. 10 Ga/Al



Background and Implications

- The first modern classification scheme of granitic rocks.
- It was developed in 1974 by Chappell & White. The inclusion of A-types, M-types, and C-types was later determined.
- I-type: metaluminous to weakly peraluminous, relatively sodic, and has a wide range of silica content (56-77 wt. %). These are associated with a mafic source.
- S-type: strongly peraluminous, relatively potassic and has a high silica composition (64-77 wt. %). These are associated with melting of metasedimentary rocks.
- M-type: originated from rising mantle, specifically in island arc setting.
- C-type: defined as charnockitic (term applied to any ortho-pyroxene bearing granite).
- A-type: determined by alkalinity, anhydrous characteristics, and presumed anorogenic tectonic setting. Associated with rift zones and within stable continental blocks. They range from peraluminous to peralkaline in composition.

Disadvantage

- -"A major problem with the alphabetical classification is that it carries the assumption that individual granitic rocks have a simple source, and that this source can be readily identified from the chemistry of the rocks. In actuality, granitoids rarely come from single sources, but instead are mixtures of mantle-derived mafic melts and melts of crustal rocks that may or may not contain metasedimentary components." (Frost et al, 2001)
- "A-type granitoids have proven to be the most controversial and least understood member of the alphabet classification system. There were a variety of granitoids that fell within the A-type classification and there were multiple petrogenetic pathways that could lead to rocks that met the largely chemical definition of A-type granitoids." (Eby,1990,1992)

Trace Element Discrimination Diagrams

Background

- Introduced by Pearce *et al*. in 1984
- "Discrimination boundaries, though drawn empirically, can be shown by geochemical modeling to have a theoretical basis in the different petrogenetic histories of the various granite groups." (Pearce *et al.*, pg. 956)
- Implemented trace elements include: Rb-Rubidium, Y-Yttrium, Nb-Noibium, Ta-Tantalum, Th-Thorium, Sc-Scandium, Zr-Zirconium and Ce-Cerium, among others.
- Classifications include ocean-ridge granites (ORG), volcanic-arc granites (VAG), within-plate granites (WPG), and collisional types (syn-COLG). These categories are subdivided further.

Disadvantages

- In the cases of VAG or syn-COLG, contamination is likely and can cause misclassification.

Intrusive Setting Discrimination Diagram

Volcanic Arc Granites:

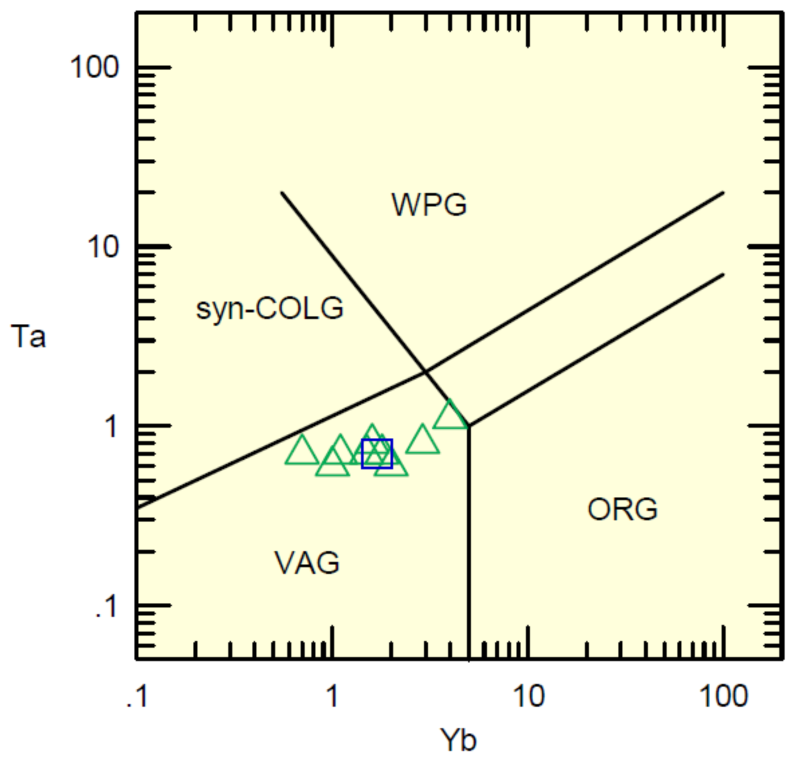
-Oceanic arcs dominated by thoeiitic OR calc-alkali basalt

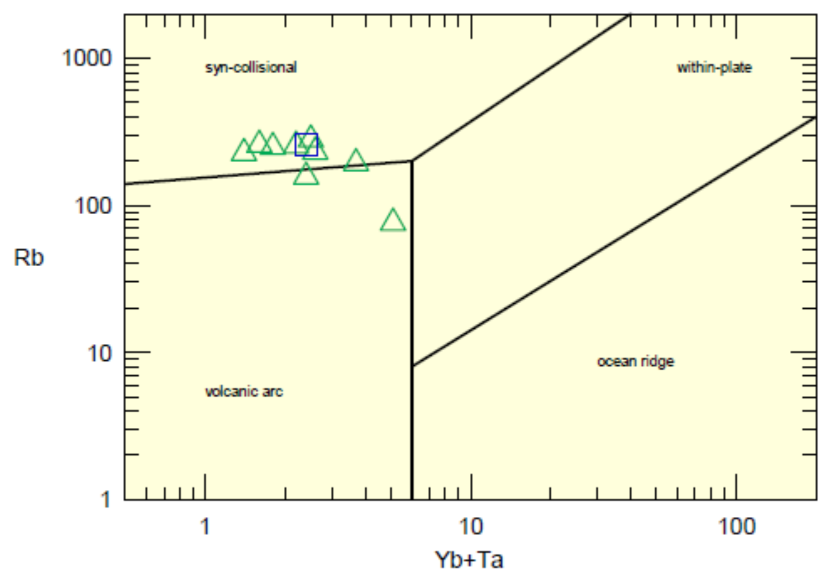
-Active continental margins

Syn-Collisional Granites:

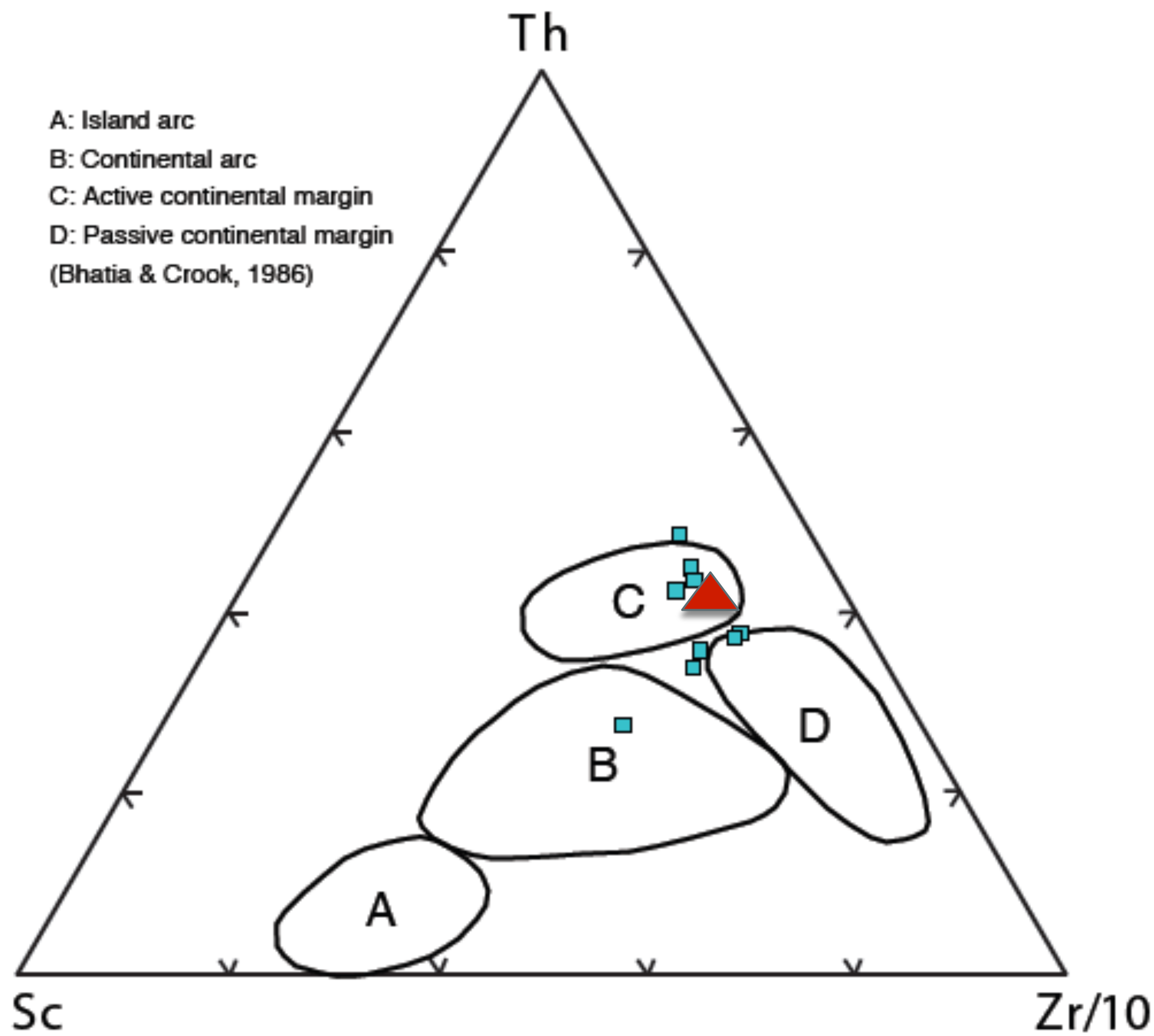
-Continent-continent collision

-Continent-arc collision

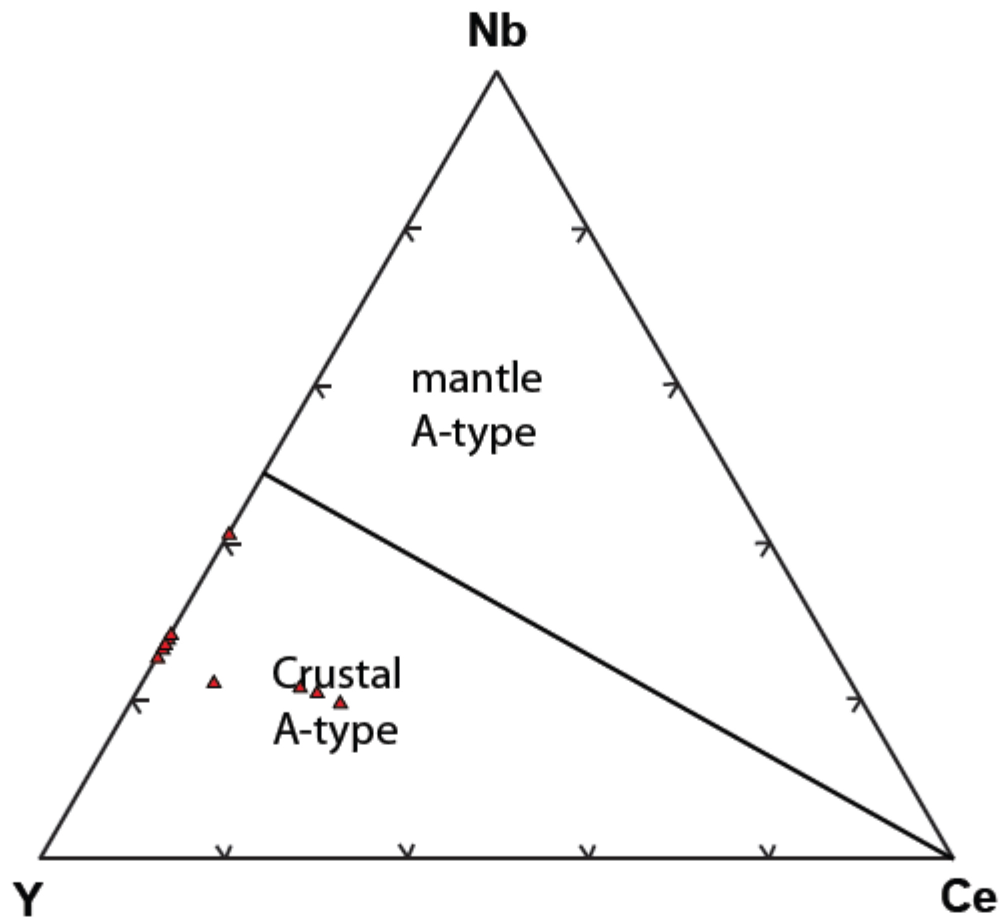




Th-Sc-Zr/10 Discrimination Diagram

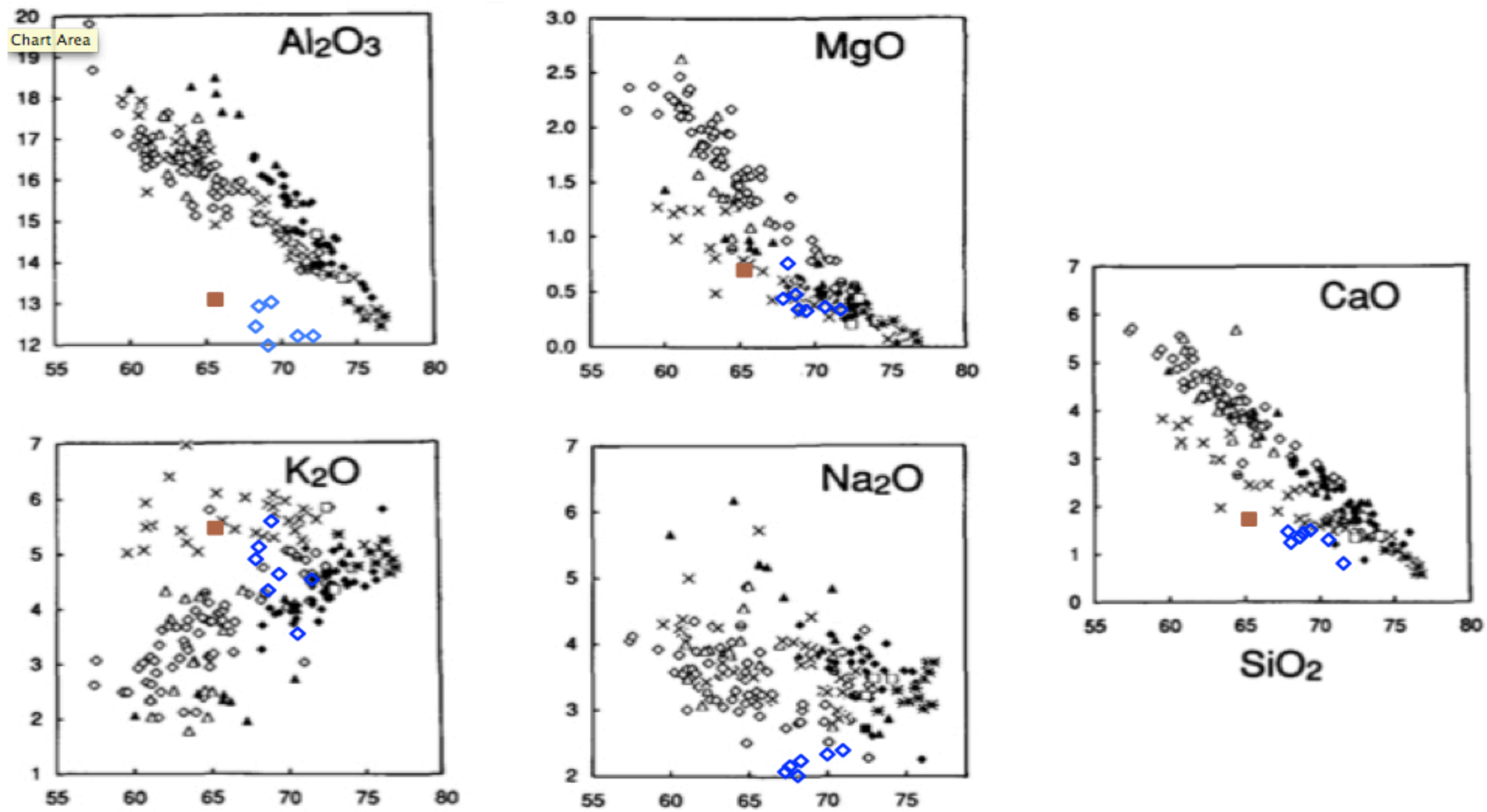


Nb-Y-Ce diagram to distinguish between mantle and crustal A-type granites



(Eby, 1992)

Comparing Major Element Geochemistry



Origins of Till Cobbles – DV2 Granites

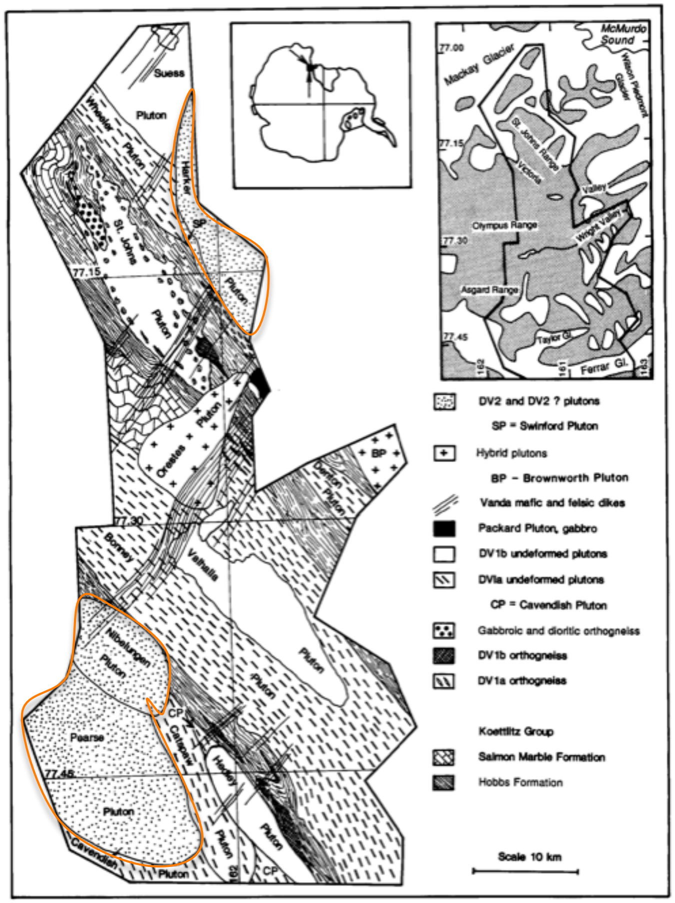


Fig. 1 Inferred basement geology if overlying ice, sediments, moraine, and Ferrar Dolerite were removed to expose the Kukri Erosion Surface. The DV1a and DV1b plutons (Bonney, Wheeler, Denton, St Johns, Valhalla, and Hedley Plutons) have a consistent northwest orientation and are cut by northeast-striking younger dikes and the ovoid Pearse, Nibelungen, Brownworth, Orestes, Swinford, and Harker Plutons.

- High K_2O
- Low CaO & MgO
- Low Na_2O consistent with I-type suite
- Peraluminous
- Large orthoclase grains
- Trace elements agree with continental collision
- Volcanic Arc Granites

Conclusions

- No single classification scheme accurately reflects the full complexity of a given rock
- Multiple classification schemes are needed to differentiate between rocks of different origins and identify the processes responsible for their petrology
- Cobbles in Friis Hills tills can be correlated to the youngest granites suite of Southern Victoria Land
- A more nuanced approach comparing specific plutons is required to enhance the spatial resolution of potential erratic sources

References

- Allibone, A.H., Cox, S.C., & Smillie R.W. (1993). Granitoids of the Dry Valleys area, southern Victoria Land: geochemistry and evolution along the early Paleozoic Antarctic Craton margin. *New Zealand Journal of Geology and Geophysics* **36**, 299-316.
- Allibone, A.H., Cox, S.C., Graham, I.J., Smellie, R.W., Johnstone R.D., Ellery, S.G, & Palmer, K. (1993). Granitoid of the Dry Valleys area, southern Victoria Land, Antarctica: plutons, field relationships, and isotopic dating. *New Zealand Journal of Geology and Geophysics* **36**, 281-297.
- Best, M.J, 2009, Igneous and Metamorphic Petrology: John Wiley & Sons, pp. 34-35.
- Boger S.C. & Miller J.M. (2004). Terminal suturing of Gondwana and the onset of the Ross-Delamerian Orogeny: the cause and effect of an Early Cambrian reconfiguration of plate motions. *Earth and Planetary Science Letters*. **219**, 35-48.
- Eby, G.N., 1992, Chemical subdivision of the A-type granitoids: petrogenetic and tectonic implications: Geology, v. 20, p. 641-644.
- Eby, G.N., 1990, The A-type granitoids: a review of their occurrence and chemical characteristics and speculations on their petrogenesis: Lithos, v. 26, p. 115-134.
- Faure, G. & Mensing, T.M. (2010). The Transantarctic Mountains: Rocks, Ice, Meteorites and Water. Springer: New York.
- Frost, R.B., Barnes, C.G., Collins, W.J., Arculus, R.J., Ellis, D.J. and Frost, C.D., 2001, A geochemical classification for granitic rocks: Journal of Petrology, v. 42, Number11, p. 2033-2048.
- Korhonen, F.J., Saito, S., Brown, S., Siddoway, C.S., Day, J.M.D. (2010). Multiple Generations of Granite in the Fosdick Mountains, Marie Byrd Land, West Antarctica: Implications for Polyphase Intracrustal Differentiation in a Continental Margin Setting, **51**. 627-670.
- Pearce, J.A., Harris, N.B., and Tindle, A.G., 1984, Trace element discrimination diagrams for the tectonic interpretation of granitic rocks: Journal of Petrology, v. 25, Part 4, pp. 956-983.
- Smith, A.R. (2011). *Sedimentology and Stratigraphy of Miocene-Age Glacial Deposits, Friis Hills, Antarctica* (Master's Thesis). North Dakota State University, Fargo, ND.
- Winter, J.D., 2010, Principles of Igneous and Metamorphic Petrology, 2nd ed: Upper Saddle River, NJ, Prentice Hall, pp…….
- Zen, E., 1988, Phase relations of peraluminous granitic rocks and their petrogenic implications: Ann. Rev. Earth Planet. Sci., v. 16, pp. 21-51.