CLASSIFICATION OF ANTARCTIC TILL COBBLES THROUGH GEOCHEMICAL ANALYSIS & COMPARISON

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Study Area – Transantarctic Mountains
Study Area

Friis Hills, Southern Victoria Land

Courtesy of Adam Lewis 2008
Can provenance be determined from geochemical analysis?

- Glacial erratics
- Indication of changes in flow patterns

Figure 3.1. Stratigraphic column for glacial deposits in the eastern Fris Hills paleovalley. Smith (2011)
Petrologic and Tectonic Evolution of Ross Sea Region

- 3 main emplacement phases of current bedrock exposures
- 3 granitoid suites
- Accretionary terranes
- Ages differentiated by $\text{Sr}^{87}/\text{Sr}^{86}$ isotopic dating
First phase of plutonism (DV1a)

- 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

Boger & Miller 2004
Second phase of plutonism (DV1b)

- Emplaced concurrent with DV1a plutonism.
- Biotite granites
- Enriched in $\text{Al}_2\text{O}_3$, $\text{Na}_2\text{O}$, and $\text{Sr}$
- 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)

- Metaluminous, alkali-calcic, I-type
- Emplaced between 486 and 477 Ma.
- Higher K$_2$O, lower MgO & CaO
- Generally lower SiO$_2$
- Enriched in LREEs
- K-feldspar phenocrysts

Allibone et al. 1993
Petrography - Bedrock
Petrography - Erratics
Aluminum Saturation Index (ASI)

Since Al₂O₃ 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 accommodated by feldspar in a CIPW normative calculation (tool for assessing silica saturation or oversaturation). Excess Al is accommodated in micas (muscovite and Al-rich biotite).

Disadvantages
- Peraluminous granites are defined by their chemical nature, but their recognition is often based on petrography; this discrepancy may lead to inconsistency. (Zen, 1988)
- Another disadvantage to this system is that Na and K can be mobilized and transferred out of the magma by a separate fluid phase. (Best,
Alphabetical Classification-SIAMC

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

A: Island arc
B: Continental arc
C: Active continental margin
D: Passive continental margin
(Bhatia & Crook, 1986)
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

- High $K_2O$
- Low CaO & MgO
- Low Na$_2$O 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

- Smith, A.R. (2011). Sedimentology and Stratigraphy of Miocene-Age Glacial Deposits, Friis Hills, Antarctica (Master’s Thesis). North Dakota State University, Fargo, ND.