Geologic Mapping of Lake Two, Pagami Creek Burn Area, BWCA, Minnesota

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Pagami Creek Fire

- Pagami Creek Fire occurred in late (2011)
- Prior to burn, only shoreline mapping by canoe (Miller, 1981)
- No detailed maps of interior
Objectives

• Build upon the work of Miller (1981)
• Construct the first detailed map of the inland portion of the Lake Two area.
• Understand the contact relationships and structures
Regional Geology

(Miller 2010)
Regional Geology

• Duluth Complex is continuous mass of felsic to mafic series of rocks in NE MN
  – Largest intrusion of MCR system
  – Consists several series of smaller intrusions
    • Felsic
    • Early Gabbroic
    • Anorthositic
    • Layered
• Active between 1110 and 1086 mya
  – Layered and anorthositic rocks between 1102-1094 mya (Costello 2010)
• Contact relationship between layered and anorthositic rocks suggests that the layered units intruded the anorthositic units even though they are similar in age
  – Sharp contacts
Regional Geology—Processes

- Mantle plume melt
- Crustal anatexis
- Felsic melt cap forms density barrier causing plagioclase crystal cumulates
- Density barrier is overcome, plagioclase cumulates intrude north shore volcanic group
- Olivine rich, cumulate depleted magma intrudes under anorthositic series forming main AGT
- Subsequent intrusions continue
• Costello 2010
• Costello 2010
• Costello 2010
Main Magmatic Stage (~1099 Ma)
Anorthositic Series

Plagioclase Crystal Mushes

• Costello 2010
Main Magmatic Stage (~1099 Ma)
Layered Series I

- Costello 2010
Previous Work

• MSGS 1875-1901

• Phinney 1960’s
  – Prior to the formation of the BWCA Phinney was able to access remote areas via float plane.

• Miller 1981 thesis
  – Restricted to canoe access and mostly shoreline mapping due to difficult terrain.
Area of Focus

- Jim’s Miller’s PHD
- Our study focuses on the burnt, newly exposed areas
Logistics

- Entered BWCA through Kawishwi Lodge
- Paddled to campsite near the Rock Island Lake Portage on Lake 2
- 6 people, 3 canoes, 1 dog, plus packs and food for 7 days
- Mapping groups (2 people) paddled out to their mapping areas each morning, returned in the evening (6PM)
- Fresh fish for dinner on the last night!
Logistics

Camp at sunset

Moose, Field Assistant
Logistics (continued)

• One group member had to leave camp on day 4, so for days 5-7 we mapped with one group of two, and one group of three.

• One canoe was left at the lodge.

• For the trip out both canoes were overloaded with people and gear.
The Burn

Ideal burn areas, easy walking (left) and plentiful, obvious outcrops (right)
The Reality of our Field Area
”The Burn”

Due to the incomplete burn, and some areas left untouched by the fire our mapping area was smaller than anticipated.
Our Map

- Anorthosite
- Poikilitic Anorthosite
- Mixed Zone
- Augite Troctolite
- Layered Troctolite
Anorthosite - An

- Anorthosite, Undifferentiated
  - Medium grained, white to light grey
  - Plagioclase +/- granular olivine, layered locally
  - Locally contains augite and oxides

Variable foliation within the troctolitic anorthosite. Pencils are aligned parallel to two opposing foliations

Troctolitic anorthosite (right) with poikolitic inclusion (left)
Poikilitic Anorthosite - poA

- Distinctive poikilitic texture
  - Brown olivine oikocrysts from 2 to >10 cm
  - Weather recessively
- Medium to coarse grained
- Weakly to moderately foliated
- Some rare local olivine layering
- Occasionally interlayered with An

Typical poikilitic texture

Very large olivine oikocryst
Layered Troctolite - ITr

- Distinctive modal layering of olivine rich (OP) and olivine poor (PO) layers
- Fine to medium grained
- Well foliated
- Very little to no augite/oxides (<<1%)
Augite Bearing Troctolite - aTr

- White, brown, and black, fine to very coarse grained
- Augite/oxide content is variable (<1% to > 5%)
  - Granular to ophitic
- Local plagioclase foliation
- Anorthosite inclusions
- Granular olivine
  - Rarely modally bedded

Typical augite bearing troctolite

Textural variation in the augite troctolite
Mixed Zone - Mx

- Mixed/Heterogeneous Series
  - Large area of highly heterogeneous rock types and textures
  - Sharp to gradational contacts
  - Contorted sub-vertical bedding defined by medium grained augite troctolite, augite bearing troctolite, troctolite, and coarse to very coarse augite troctolite beds
  - Anorthosite inclusions
    - Lensoidal to round
    - Centimeters to 10's of meters
  - Common pegmatitic olivine gabbro patches
  - Xenolith inclusions
    - Pegmatitic olivine gabbro (common)
    - Hornfels basalt (rare)
Mixed Zone Continued

Blocks and inclusions of anorthocite within troctolite

Bedded troctolite with large anorthocite inclusion and variable textures

Zone of pegmatitic olivine gabbro
Interpretation

• Modifications to the original map
  – Constraint of contacts and structures
  – Re-emergence of the Mixed Unit
  – Differentiation of the Anorthosite Undifferentiated and the Troctolitic Anorthosite
Interpretation

- **Structures**
  - Fault (normal/right-lateral oblique)
  - Large synform
  - lTr – poA contact and resultant structures
    - Synform / Antiform
    - Modal layering at contact
Cross-Section and Large Scale Interpretations
Structural Analysis

Great circles of all structural measurements (above). Blue is plagioclase foliation, green is modal layering, and red for dikes.

Poles to planes of plagioclase foliation (left) and modal layering (right).

Rose diagram of modal layering measurements (left). 18.5% were between 261 and 270 degrees, with a mean vector of 270.2 degrees, indicating the rock units were striking to the west and dipping to the north.

Conclusion: Analysis reveals that the modal layering of this area strikes to the west and dips to the south, which starkly contrasts the previously mapped area to the north, providing further evidence of a large scale synform
Problems and Future Research

- Lack of burn resulted in less coverage and less complete mapping than had originally been intended.
- Lack of outcrop/burn/time to properly constrain the fault and faulted contacts in the south.
- Western contacts appear to cut off abruptly, more exposure may have allowed for the inference of a second large fault, trending northwest.
- Incomplete coverage resulted in more speculation of the contacts than intended.
- Attempts to further trace out the large synform and fault may provide insight into the large scale processes of the Duluth Complex as a whole.
Conclusions

- Detailed mapping of Lake Two geology has revealed processes acting in a similar fashion to those previously described (Costello (2010), Miller (1981)).
- Mapping has shown that these intrusive crystalline systems are dynamic, highly variable, and likely controlled by several different factors.
The End—Thank you PRC-Jim, Dean, George, Mark S, Phil, Nigel, Marsha!!
References

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