Fluid or Flop? Investigating the metasomatism at North Doherty pluton

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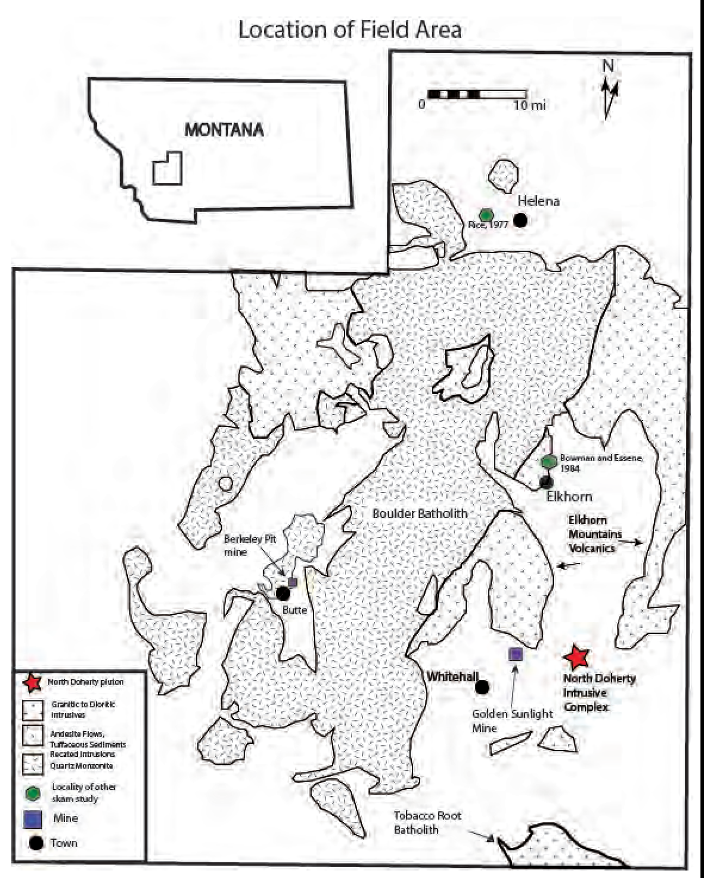
Overview

- Skarns are the world's largest source for tungsten and are common sources for Fe, Au, Cu, Zn, Mo, and Sn (Meinert, 1992).
- Geoscientists are currently modeling skarns to try and predict where a skarn deposit might be economically viable. To do this non-economically viable skarns have to be analyzed in addition to economically viable ones.
- Skarn samples collected next to the North Doherty pluton, SW Montana, are the focus of this study.
- Geochemistry of the granodiorite is not consistent with the being related to the Boulder or Tobacco Root batholiths: however, the field relationships are consistent with regional plutonism involved in the creation of both batholiths (Bean, 1981).
- The pluton's age is not known but is thought to be anywhere from 76 to 68 million years old, based on the ages of the nearby Tobacco Root and Boulder batholiths (Bean, 1981).



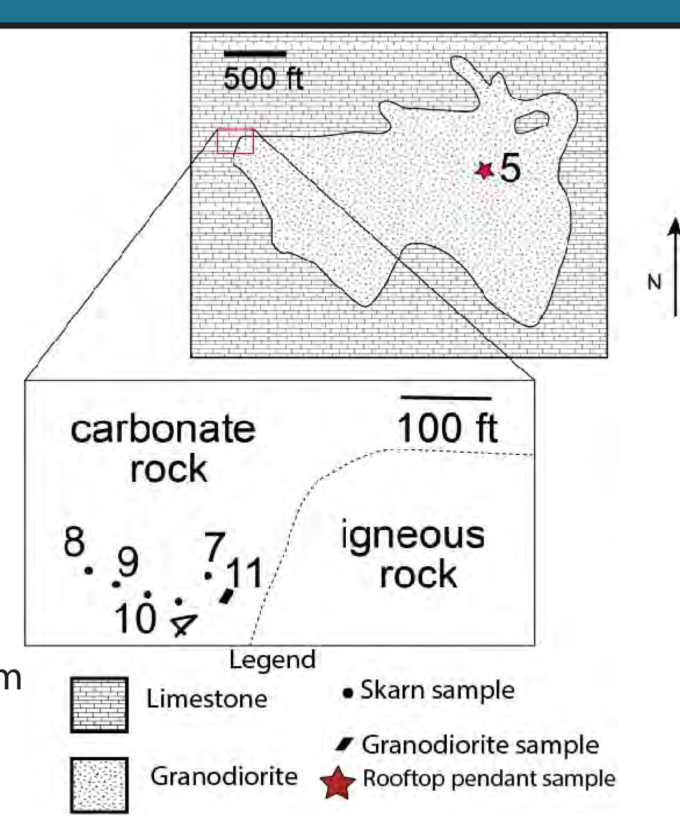
General geologic map of the area, (modified from Bean, 1981).

Hypotheses

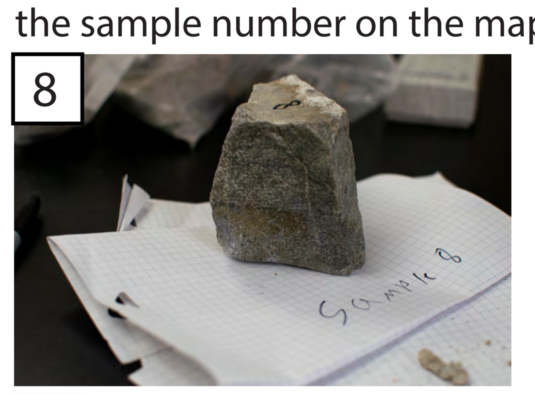
1. Skarn samples have been infiltrated by H_2O-rich fluids derived from the North Doherty pluton.
2. Skarn samples have experienced chemical changes due to fluid-rock interaction.

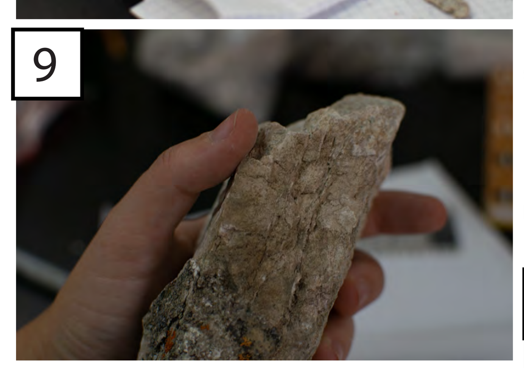
Samples

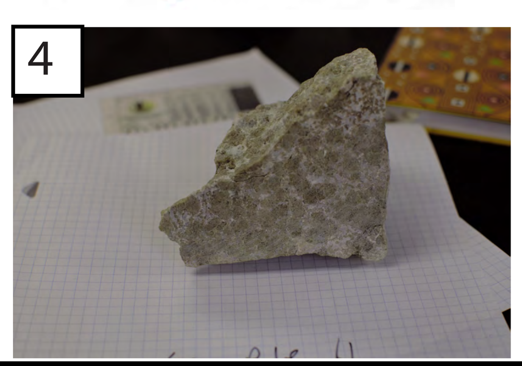
- Four samples were analyzed (hand samples, thin sections, and bulk-rock analyses.)
- The numbers on the top left corner correlate to the sample number on the map



Map of the North Doherty pluton (from Penniston-Dorland, unpublished).







Methods

Petrography

- Petrography was completed with a Nikon Eclipse LV100 Polarizing microscope with a QImaging Micropublisher 5.0-RTV camera in the Microscope Lab at the University of Maryland
- Identify minerals, and textures in thin section.
- Use graphs to make maps for the electron probe.

Electron Probe Microanalyzer

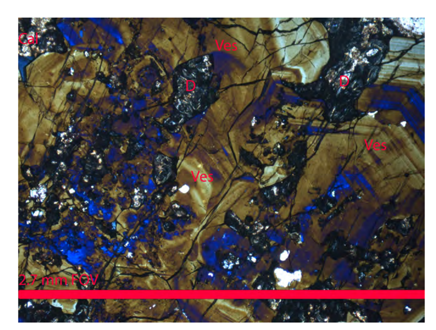
- A JEOL 8900R Electron Probe Microanalyzer was used to analyze the minerals.
- The EPMA is being used to confirm mineral identities. This is being done by performing Energy-Dispersive Spectroscopy (EDS), Wavelength-Dispersive Spectroscopy (WDS), and obtain backscatter electron images (BSE).
- Analyze vesuvianite grains with WDS to see chemical changes as distance increases from the pluton.

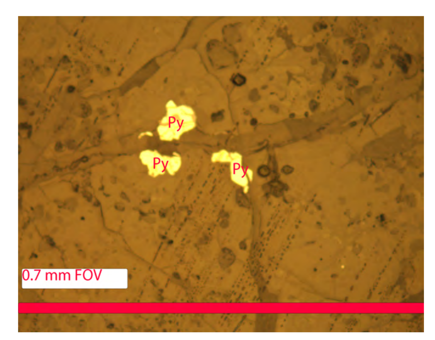
X-Ray Fluorescence

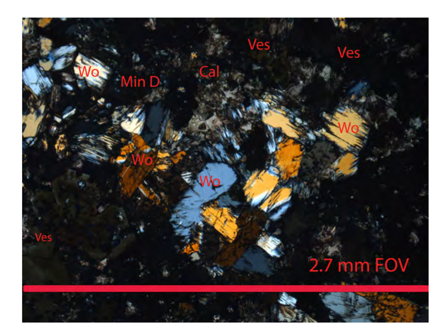
- The fine rock powders were sent out to Franklin and Marshall college to be analyzed by their PANalytical 2404 X-ray fluorescence vacuum spectrometer.
- The samples were analyzed for both major elements and trace-element composition.
- Identify mobile and immobile elements from trace element data.

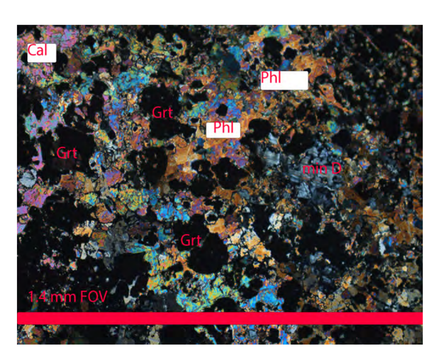
Results

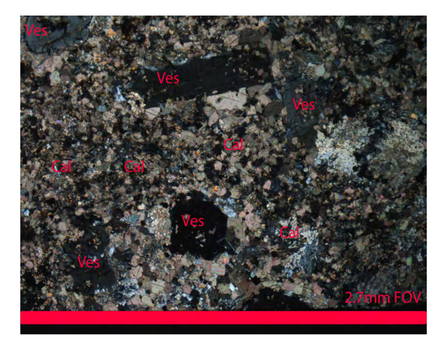
Petrography

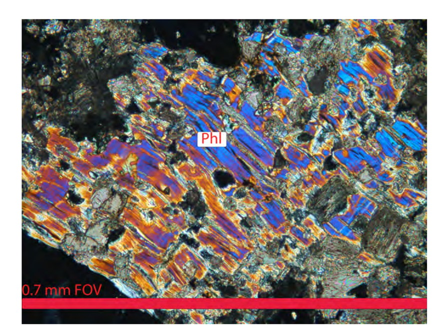

Vesuvianite from sample 4, XPL


Pyrite from sample 9, RFL

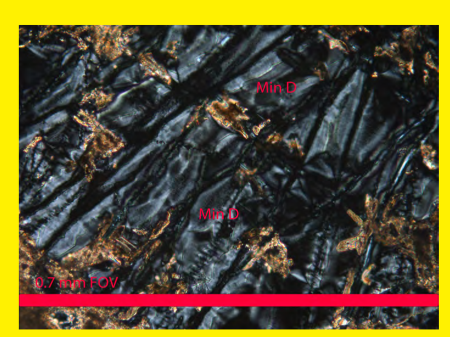

Wollastonite from sample 10, XPL

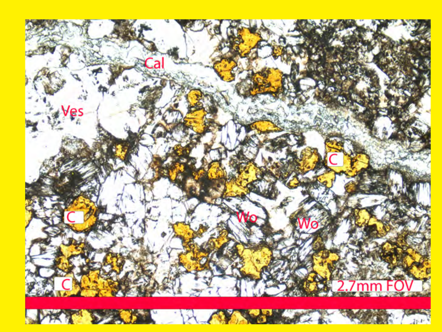

Garnet, Phlogopite, and Calcite from sample 9, XPL


Calcite and equant veusvianite from sample 8, XPL


Phlogopite from sample 4, XPL


Unknown minerals A, B, and D from sample 4 XPL


Unknown mineral D, from sample 4, XPL


Unknown mineral C from sample 10, PPL

Still unidentified!
Raman spectroscopy is planned!

	sample 8	sample 9	sample 10	sample 4
Wollastonite (Wo)	■	■	■	■
Vesuvianite (Ves)	■	■	■	■
Calcite (Cal)	■	■	■	■
Grossular-Andradite (Grt)		■		
Pyrite (Py)	■	■	■	
Phlogopite (Phl)		■		
Unknown mineral A (A)				■
Unknown mineral B (B)			■	■
Unknown mineral C (C)			■	
Unknown Mineral D (D)		■	■	■

Mineralogy of samples

Fluid interperation

- The pressure is estimated to be 0.1 GPa which is based observations of the shallow emplacement of the pluton from (Fenn, 1968).

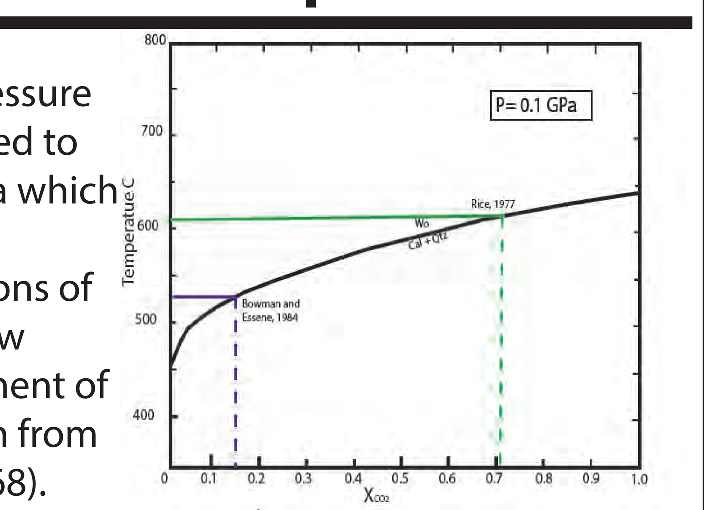
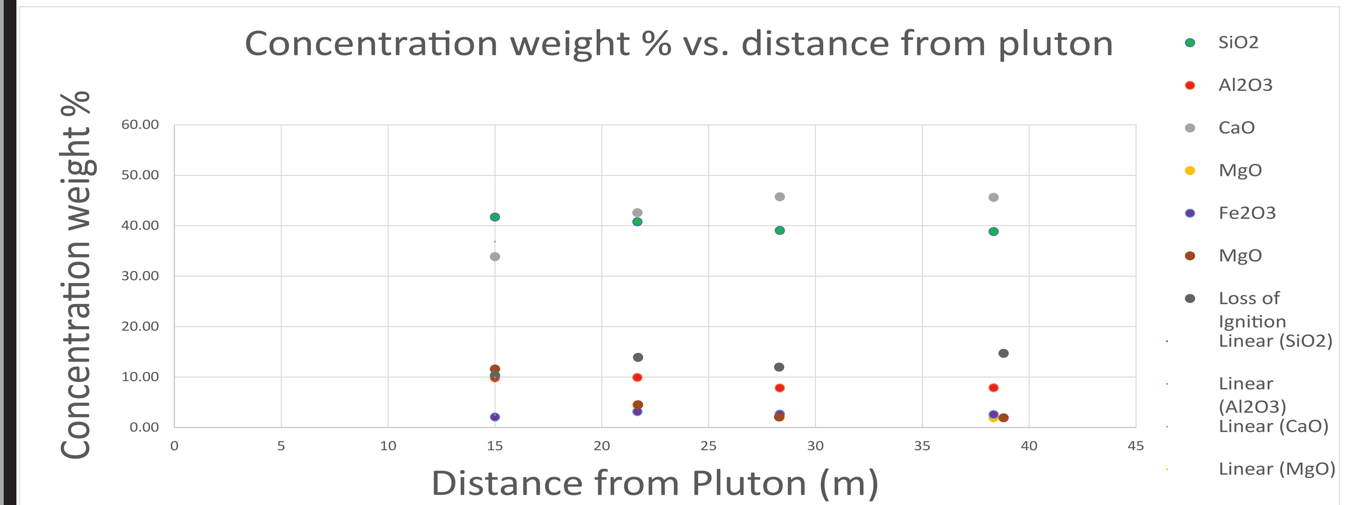


Figure adapted from adapted Winter (2015) using information Berman (1991).

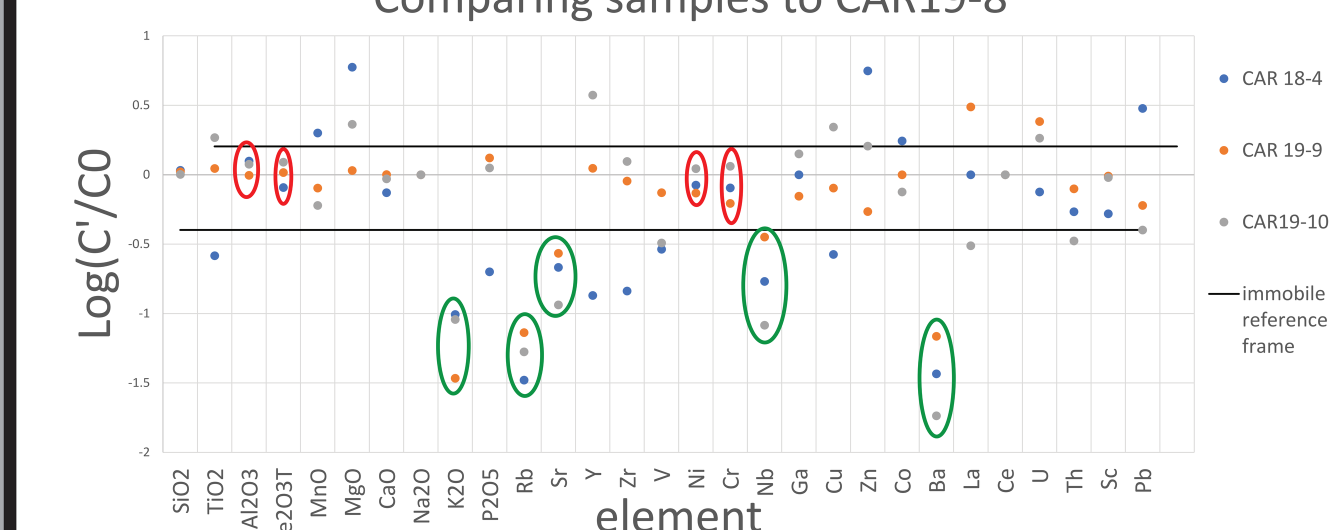
- The temperature has assumed to be about anywhere 493 C° to 607 C°. The temperature range are estimates during contact metamorphism from nearby plutons (Bowman and Essene, 1984; Rice 1977). These studies are associated with the Boulder Batholith.
- All the samples contain wollastonite and calcite, but no quartz which indicates the fluid is above the curve and that this fluid's composition is <0.72 XCO_2 and at least 28% water content.

Geochemistry



- The accuracy for the bulk-rock XRF analysis is <±0.4% for the major elements.
- The most abundant chemical components of the skarns are CaO, SiO_2, Al_2O_3, Fe_2O_3, and MgO. These element concentrations change as the distance from the pluton increases.

Comparing samples to CAR19-8



- The immobile elements circled in red were chosen and were analyzed further and determined to be immobile within 2 standard deviations and no major volume change has occurred.
- The elements circled in green, are mobile elements and were lost during the metamorphism is >60% loss, which is indicative of fluid movement.
- The immobile reference frame used was determined by (Penniston-Dorland and Ferry, 2008) to account for the heterogeneity of the rocks.

Conclusions

- All samples contain wollastonite which provides information about the H_2O-content of the fluid. For likely temperatures and pressures of skarn formation, the fluid composition is XCO_2<0.72.
- The elements consistently lost during metamorphism include K, Rb, Sr, Nb and Ba. Calculations show that >60% of these elements were lost during fluid-rock interaction.

Future work

- Collect 3 limestones, 1 marble, and 1 granodiorite at the field site this summer and make field observations.
- Complete WDS for the vesuvianite porphyroblasts in each thin section.
- For all additional 5 samples and make thin sections for the limestone, marble, and granodiorite, complete and add the new XRF data to the current dataset.
- Complete mass spectrometry for oxygen isotope composition of samples for as many samples as possible (if equipment is functioning) to determine whether fluid has oxygen isotopic composition of pluton.
- Perform Raman spectroscopy for current unknown minerals.

References

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