QUANTIFYING MAGMATIC STRAIN IN PLUTONS USING ANISOTROPY OF MAGNETIC SUSCEPTIBILITY IN THE COAST PLUTONIC COMPLEX, BELLA COOLA, BRITISH COLUMBIA

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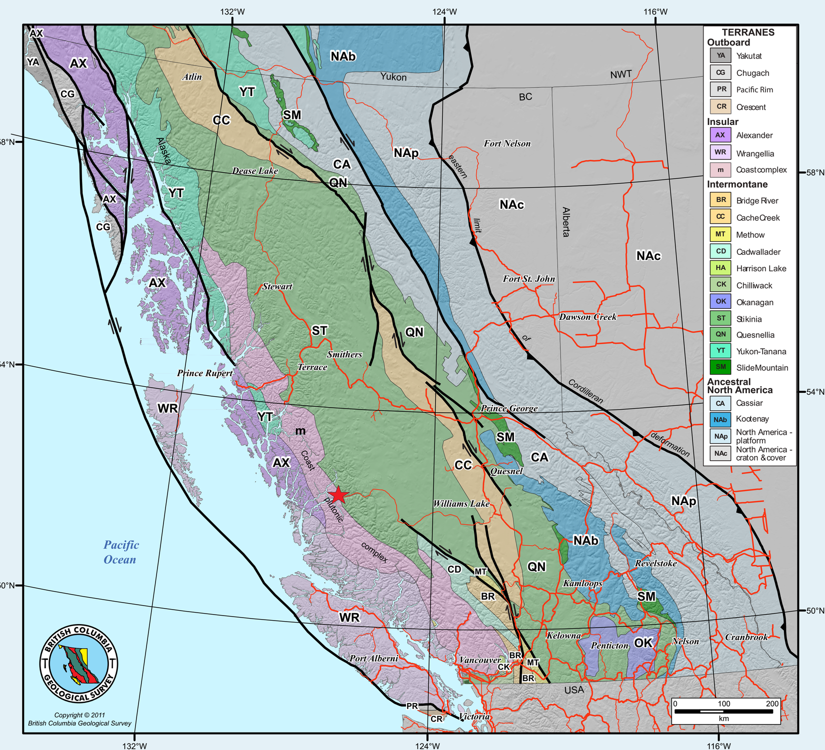
Abstract

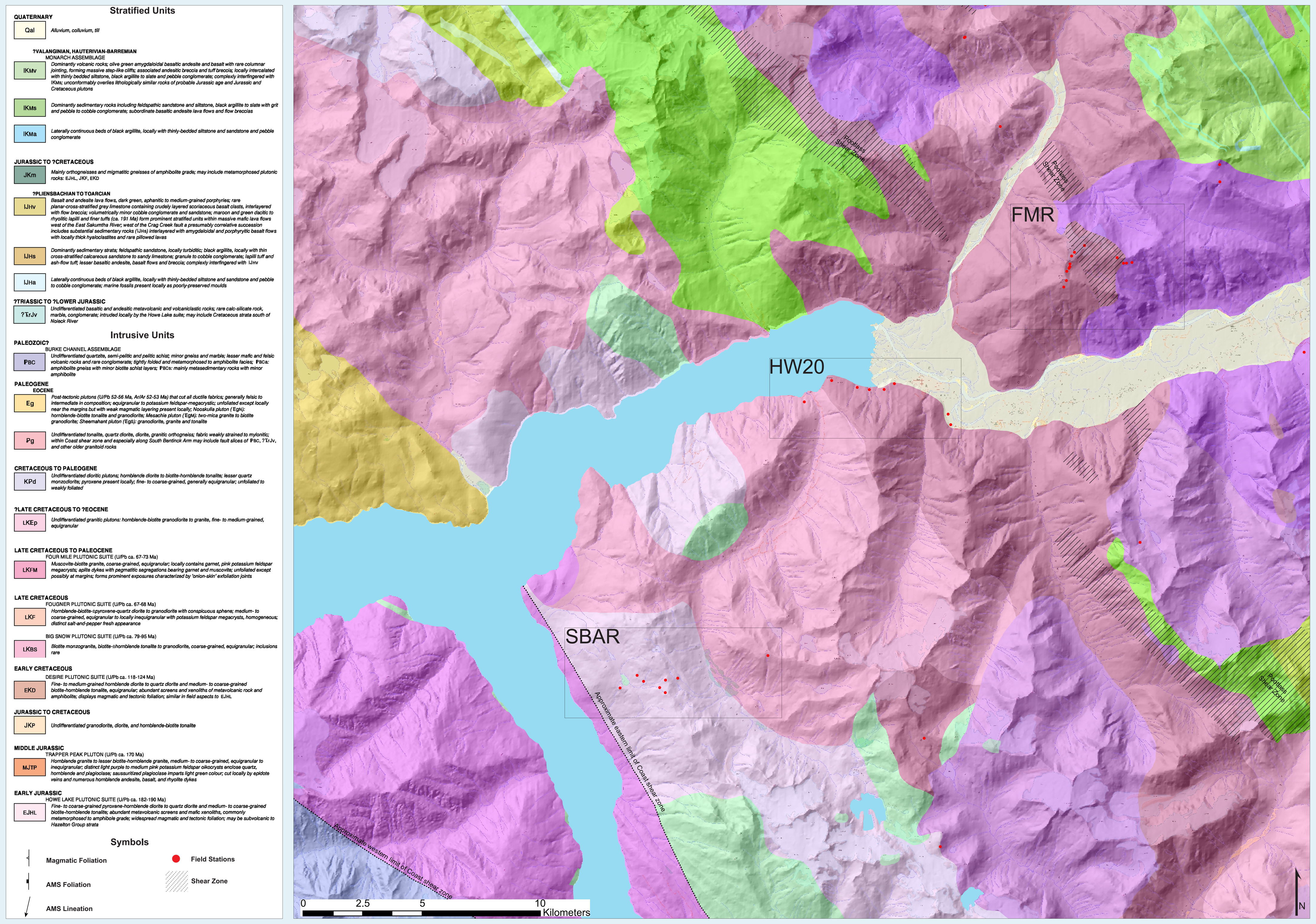
The Coast Plutonic Complex (CPC), British Columbia, Canada is a magmatic arc consisting of Jurassic through Eocene plutons. This study focuses on magmatic fabrics found in Mesozoic plutonic suites of the central CPC in the Bella Coola area, British Columbia. Magmatic fabrics (foliations and lineations) form during deformation of partially crystallizing magma and may record strain patterns that can be used to interpret the timing and nature of regional deformation during arc construction. Field mapping and anisotropy of magnetic susceptibility (AMS) are used to quantify the orientation, intensity and shape of the magmatic fabrics recorded in Jurassic through Cretaceous plutons. AMS is used to define magnetic fabrics within rocks. AMS data can be used to infer mineral fabrics even if fabrics are weak. AMS is a useful tool in the CPC because magmatic fabrics in plutons are often weak. Measured magnetic foliations correlate well with foliation measurements from the field and have a steep NW-SE orientation. Magnetic lineations, interpreted to reflect mineral lineations are shallow to moderately SE plunging. Shapes of fabric ellipsoids are generally oblate, indicating flattening strains in the arc, but some locally occurring prolate fabric ellipsoids suggest possible constriction associated with regional shear zones.

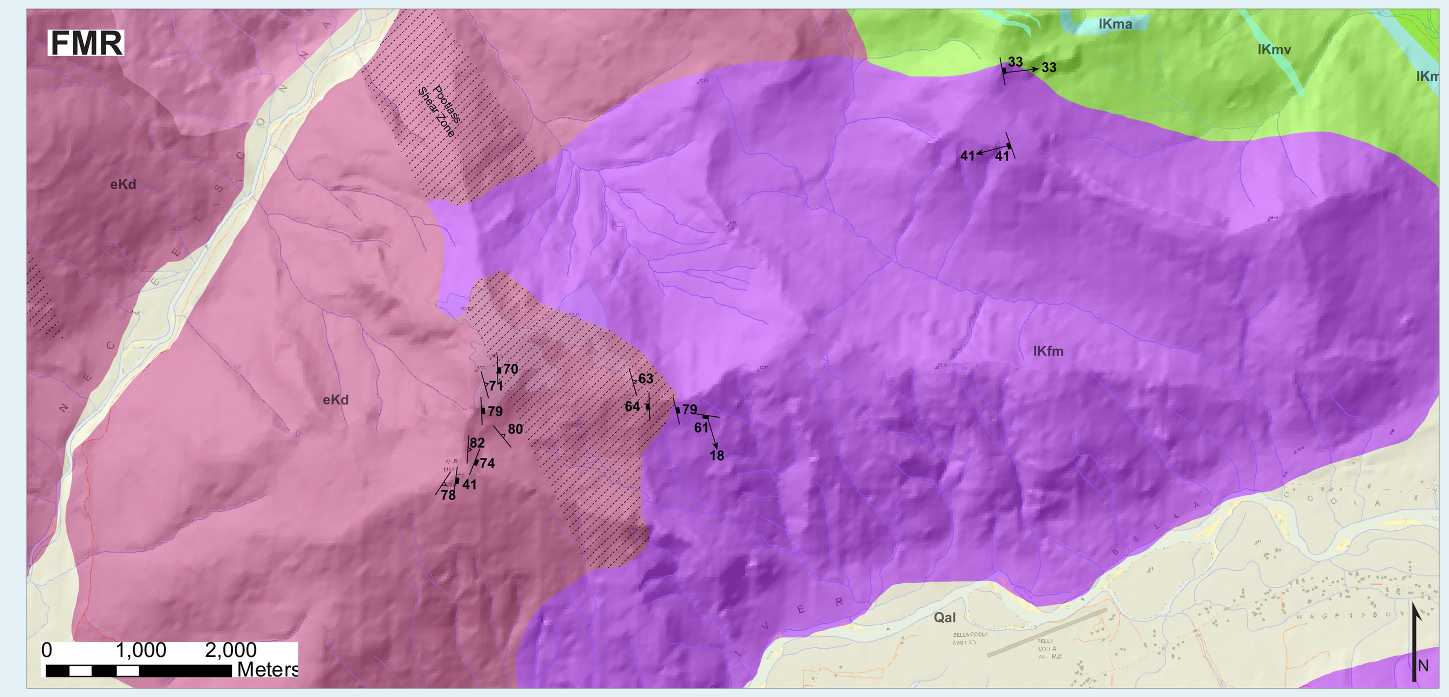
Regional Overview

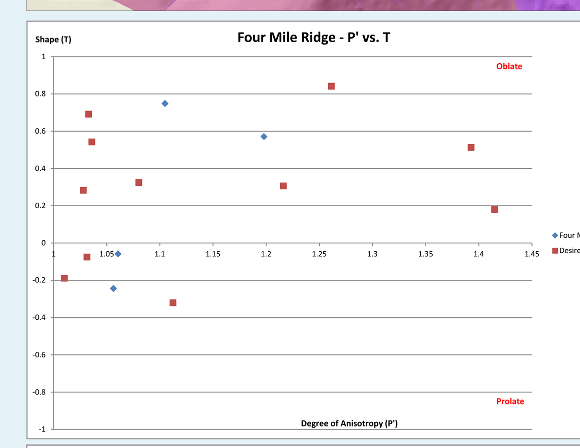


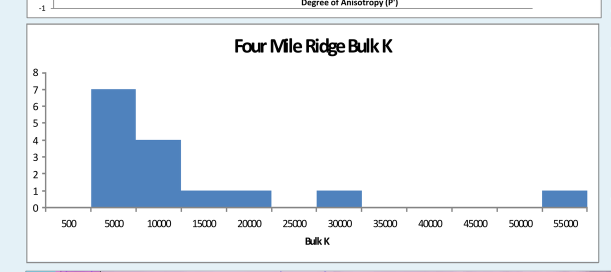
Terrane map showing the setting of the Canadian Cordillera in British Columbia, and the general setting of the CPC. The CPC is bounded to the east by volcanic and sedimentary rocks of the Mesozoic to Paleozoic Stikine terrane and in the west by the Coast shear zone and Alexander Terrane. Within the Bella Coola area regional shear zones, including the Pootlass Shear Zone, cut the CPC. The CPC in the Bella Coola area (red star) is comprised of Jurassic through Eocene plutons that are the result of subduction along the western margin of North America. This study focuses primarily on Jurassic and Early Cretaceous plutons of the CPC which include the Four Mile, Big Snow, Fougner, Howe Lake, and Desire plutonic suites.

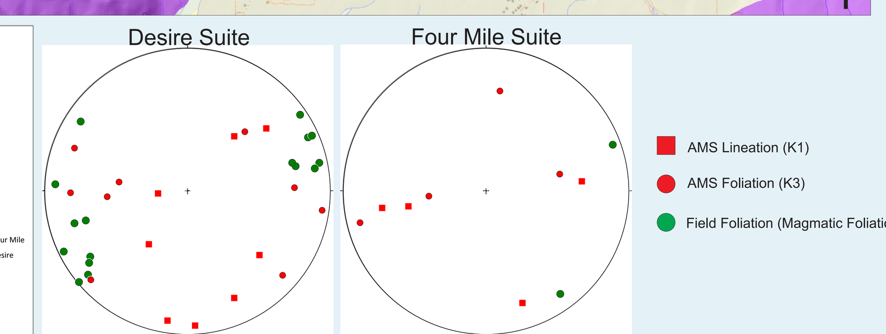
Magmatic and Magnetic Fabric Data and Results



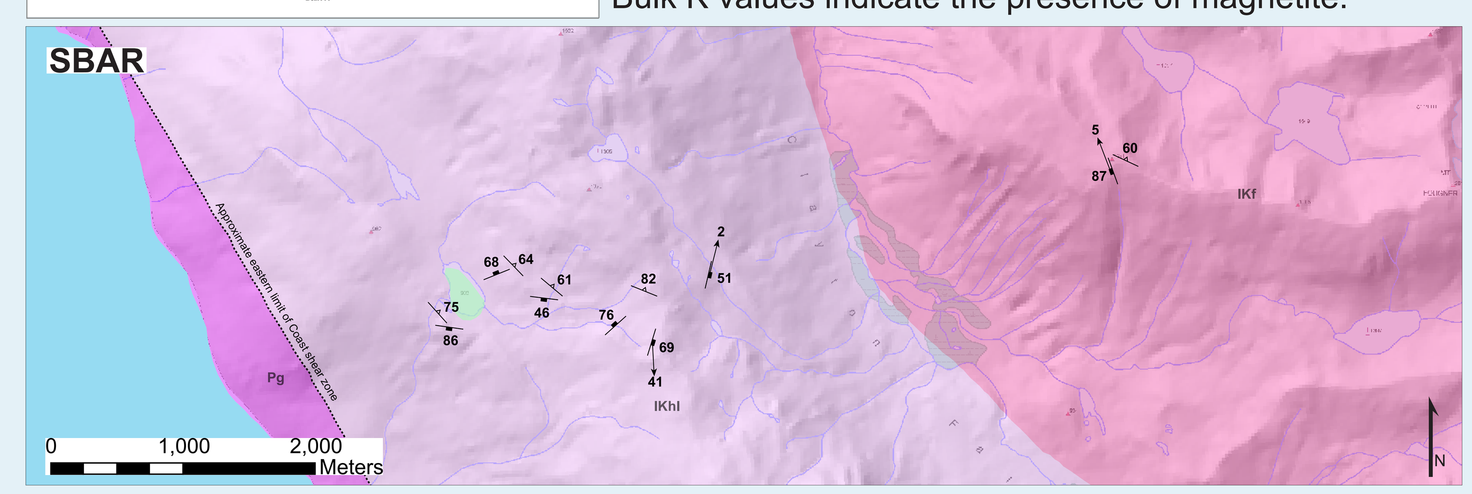




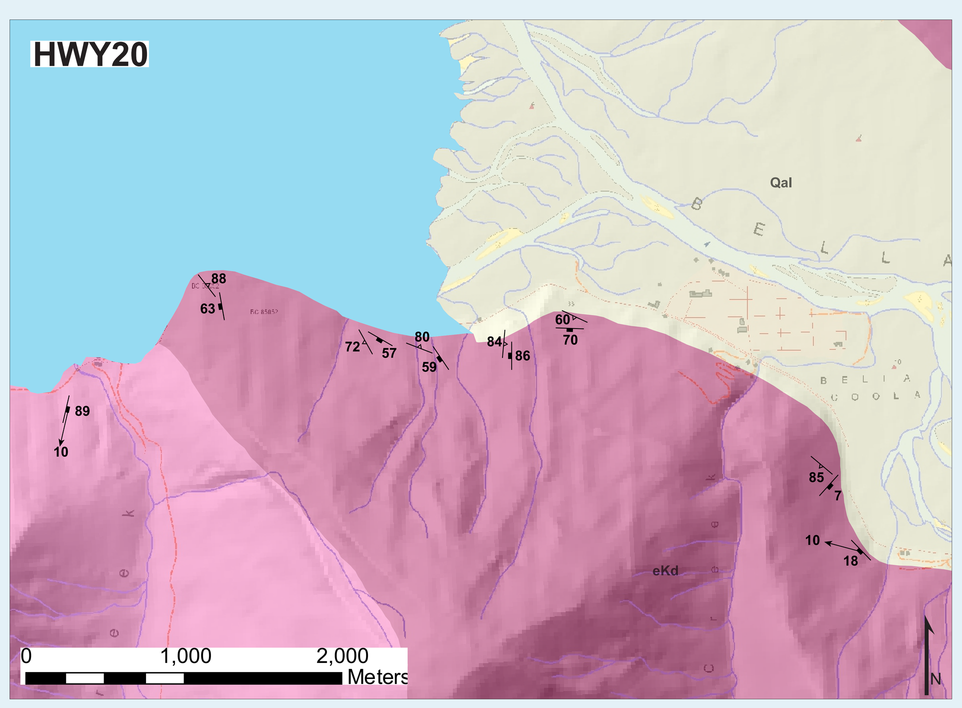


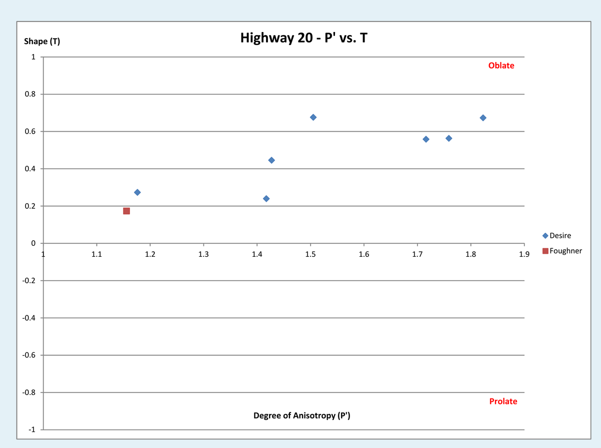


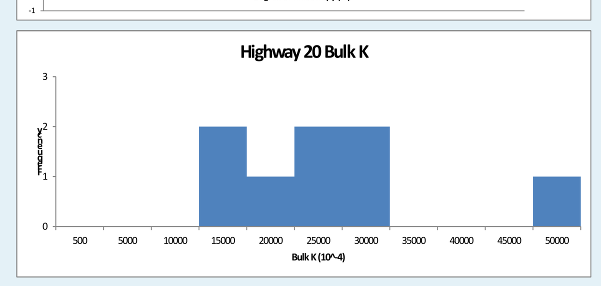
The two plutonic suites found in FMR are the Desire and Four Mile. Magnetic foliations measured in the field follow NW-SE trend correlate moderately well with AMS foliations. Some magnetic fabrics appear to be inverse (K1 = pole to foliation). This could be due to the presence of magnetite. Lineations are typically shallow. Fabric shapes near the Pootlass Shear Zone are oblate while fabrics shapes away from the shear zone are prolate. Bulk K values indicate the presence of magnetite.

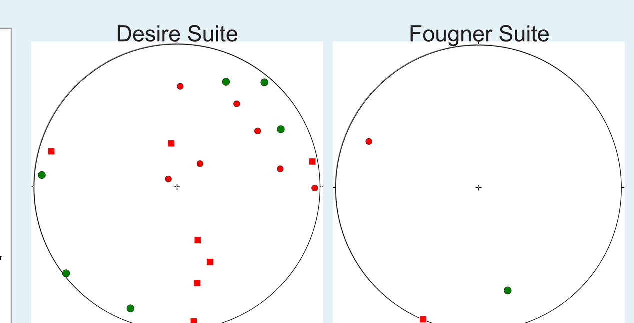


Here we focus on three areas within Bella Coola region: Four Mile Ridge (FMR), Highway 20 (HW20) and South Bentinck Arm Ridge (SBAR). The results of AMS analyses from each mapping area is presented below and to the right. Magmatic fabrics (i.e. field foliations) and magnetic fabric data obtained by AMS is plotted on stereonets for each of the areas. Bulk susceptibility (K) histograms represent the frequency of bulk susceptibilities measured in each sample and help characterize the magnetic minerals that contribute to the AMS. High bulk susceptibility indicates a contribution from ferromagnetic minerals like magnetite. P' vs. T plots compare the AMS fabric intensity (P') and shape (T).

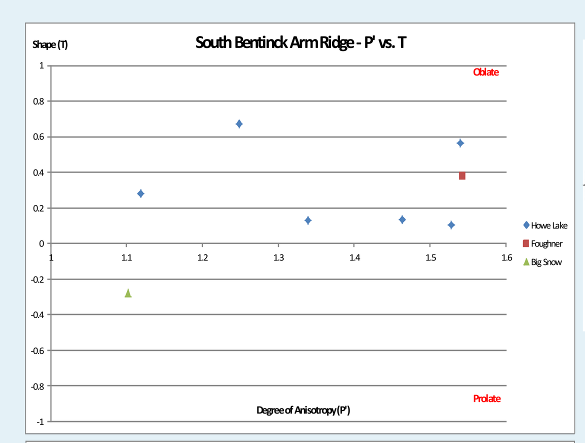


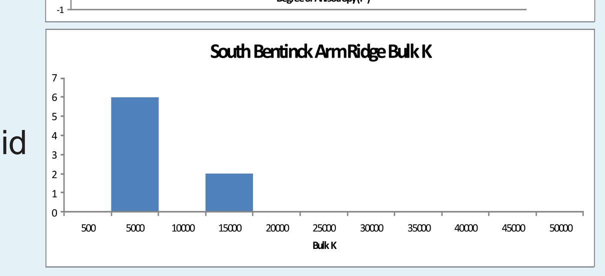


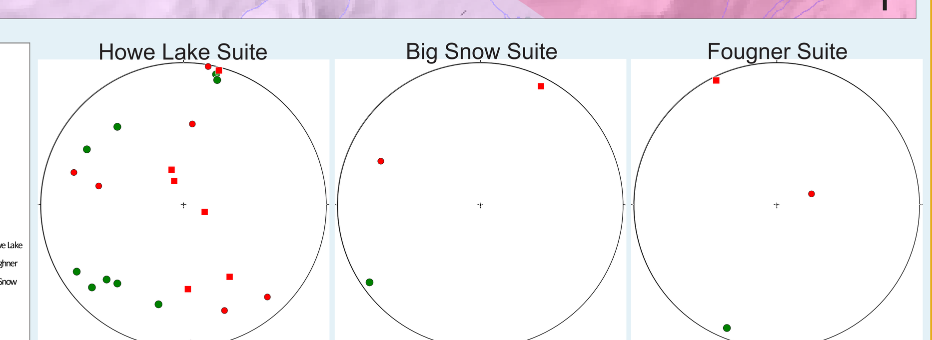




Units found in the HW20 area are the Desire and Fougner Suites. Magmatic foliations measured in the field follow a NW-SE trend and correlate moderately with AMS foliations. Lineations are shallow to steeply dipping. There is an overall oblate shape to the fabric ellipsoid which is supported by the variation in lineation plunge. Bulk K values indicate the presence of magnetite.

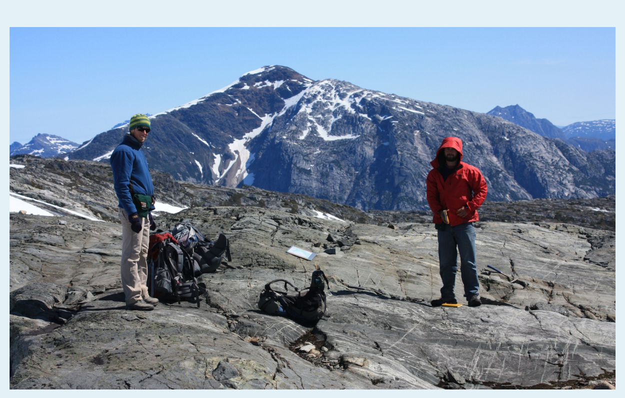






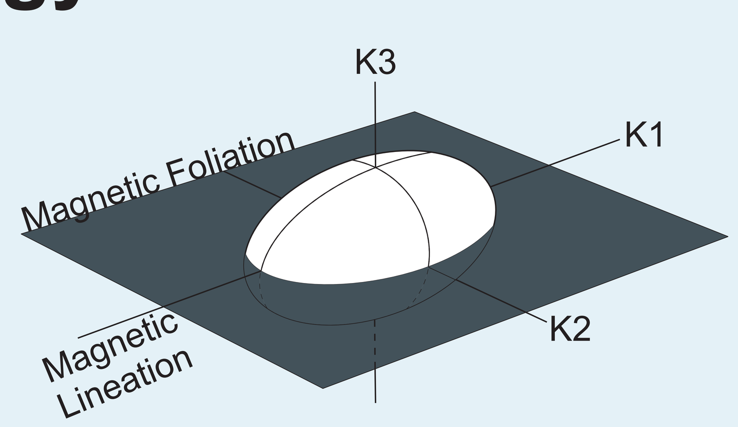
Three plutonic suites are found in SBAR: Big Snow, Fougner, and Howe Lake. Magmatic foliations measured in the field follow a regional NW-SE trend, but do not correlate well with AMS foliations. This is likely due to the presence of magnetite contributing to the AMS and overwhelming paramagnetic minerals (e.g., biotite). Overall, oblate fabrics are observed in this area. Bulk K values for all samples indicate the presence of magnetite.

Methodology

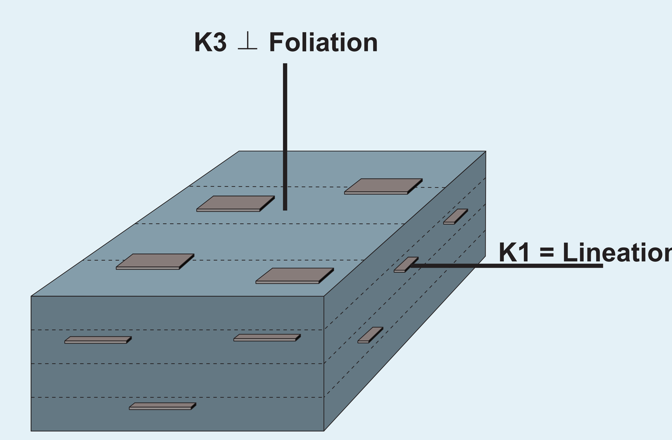


Targeted sample collection was conducted in Jurassic through Cretaceous plutons of during summer 2011 fieldwork. Samples were oriented in the field so that laboratory analyses could be placed back into geographic coordinates. After image analysis data were collected, samples were cut into two-centimeter cubes (above right) for Anisotropy of Magnetic Susceptibility (AMS) analyses. AMS was completed at the Institute for Rock Magnetism at the University of Minnesota using their Susceptibility Bridge.

AMS is based on the principle that all minerals have the capacity to become magnetized in the presence of an applied magnetic field. This property is called magnetic susceptibility (k). Rocks usually consist of many minerals and the susceptibility of each mineral contributes to the total susceptibility (bulk susceptibility) of a rock. Bulk susceptibility can be measured by placing a rock of known volume in a magnetic field of known strength. Rocks are magnetically isotropic when the strength of bulk susceptibility does not depend on the orientation of the rock within the applied field. However, most rocks are magnetically anisotropic, and the strength of bulk susceptibility does depend on the orientation of the rock (or minerals within the rock) in the applied field.



The anisotropy of susceptibility can be represented by a second order tensor: the susceptibility ellipsoid (above). The susceptibility ellipsoid is defined by three perpendicular, principle axes: K1 (maximum), K2 (intermediate) and K3 (minimum). The susceptibility ellipsoid represents the shape and intensity of magnetic fabrics (foliations and lineations). K3 is the pole to magnetic foliation and K1 is parallel to magnetic lineation. If K1=K2=K3 then the ellipsoid is a sphere, and the rock is magnetically isotropic. If K1=K2>K3 the ellipsoid is oblate (pancake-shaped) and if K1>K2=K3 then the ellipsoid is prolate (cigar-shaped).



Magnetic fabric ellipsoids can reflect the alignment of elongate or platy paramagnetic grains in the whole rock (above; e.g., hornblende). In plutonic rocks these magnetic fabrics are often interpreted to represent magmatic foliations and lineations. Magmatic foliations and lineations are often formed during the latest stages of crystallization of a magma and can record regional strain. A simplistic view is that elongate or platy grains are rotated passively during deformation of the crystallizing magma. Thus, AMS ellipsoids are used to infer fabric patterns in weakly deformed plutonic rocks.

Summary

- Magmatic foliations measured in the field show a regional NW-SE trend that does not consistently correlate with AMS fabrics.
- AMS results from the Howe Lake and Desire Suites could be interpreted as showing regional flattening recorded during the latest stages of pluton crystallization as there is not a strong lineation and these suites generally contain flattening fabrics based on P' vs. T plots.
- The smaller number of sample from other suites makes making regional interpretations difficult.
- The presence of magnetite and hornblende in the rock samples make interpretations of AMS tenuous. Magnetite has an extremely high K, and even small amounts will influence bulk K and fabric orientations. In plutonic rocks magnetite could be secondary, and therefore would not record magmatic strain. Additionally, hornblende and multi-domain magnetite create inverse magnetic fabrics that can further complicate AMS interpretations. These complications are being resolved using additional magnetic techniques.

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