GEOCHEMICAL CHARACTERIZATION AND GEOCHRONOLOGY OF THE PALEOZOIC MT. ATTREE VOLCANIC COMPLEX, TERRACE, BRITISH COLUMBIA, NTS 103I

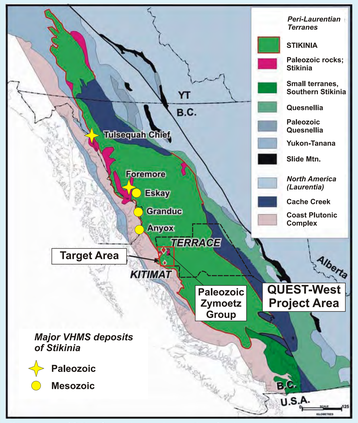
Pignotta, Geoffrey S., Meyers, Jessica L., Mahoney, J. Brian, Hardel, Bryan G.
Department of Geology, University of Wisconsin-Eau Claire

Geoscience BC

Abstract

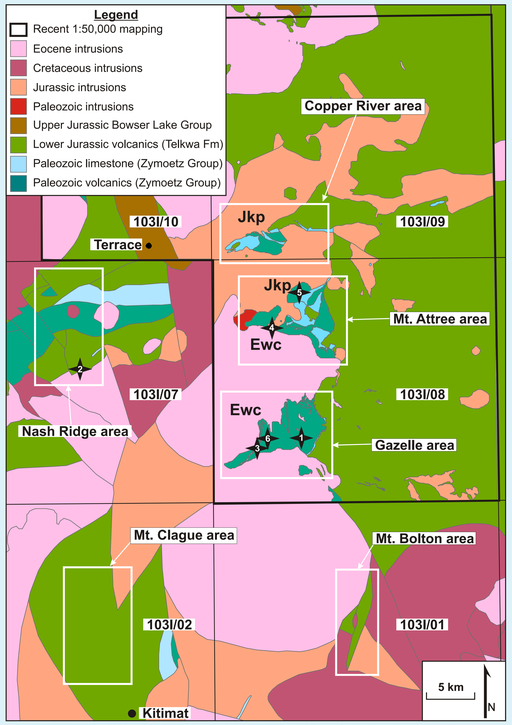
The Paleozoic Mt. Attree volcanic complex, exposed in the Terrace, British Colombia region, contains potentially economic volcanogenic hosted massive sulfide (VHMS) mineralization. The primary objective of this research is to establish a geochemical and geochronologic framework for the region and assess economic mineralization in the Mt. Attree volcanic complex. Geochemical and geochronologic samples were collected during the summer of 2009 from six target areas within the volcanic complex and from cross-cutting dikes interpreted to be potential feeders for the volcanics. Field observations and preliminary geochemical analysis shows that Mt. Attree volcanic complex compositions range from basaltic through rhyolitic, with andesitic compositions dominating. Initial interpretation of this geochemical pattern is that the volcanic complex was formed in continental margin or island arc setting. Further analysis of these samples will provide a better understanding of the tectonic setting during deposition/intrusion. Geochronology results from intrusive and volcanic units have shown that volcanics and associated intrusions within the targeted areas are Mississippian and Pennsylvanian in age with other dated intrusions revealing ages of deformation withing the Mt. Attree volcanic complex. This area is of potential economic interest due to its similarities to other Paleozoic VHMS deposits found in British Columbia.

Regional Overview



Terrane map of British Columbia, showing location of major volcanic-hosted massive sulphide (VHMS) deposits of Stikinia. Location of study area (Target Area outline) and overlap of project with QUEST-West project (area outlined in red). Economic mineralization in the Terrace-Kitimat area is concentrated along the intrusive boundary between the eastern margin of the Coast Plutonic Complex (CPC) and supracrustal rocks of Stikinia. Devonian to Permian arc volcanics and platform carbonates form the basement to Stikinia in the Terrace-Kitimat area and are overlain by Triassic and Lower Jurassic marine sedimentary and volcanic arc rocks. These supracrustal assemblages are intruded by Jurassic, Late Cretaceous and Eocene plutonic rocks of

Simplified Bedrock Geologic Map

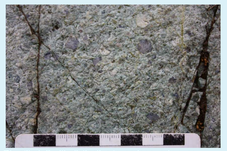


Modified from Nelson et al., 2008 and BC Digital Geology Map. Ewc=Eocene Williams Creek pluton; Jkp=Jurassic Kleanza pluton.

Field Photos

Welded dacitic to rhyolitic tuff with small quartz phenocrysts and flattened fiamme. From the north-eastern edge of Gazelle area exposures of Paleozoic volcanics.

Coarse-grained epiclastic volcanogenic rocks from the Copper River area, British Columbia. Clasts are predominantly porphyritic andesite and dacite.



Rhyolite tuff with distinctive lavender quartz eyes characteristic of most volcanic and some intrusive units found in the Nash Ridge area. Lavender quartz eyes also present in rocks found in the Mount Clague area.

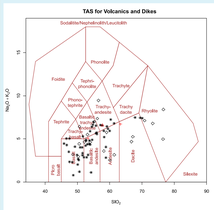
Dacitic intrusions from the Gazelle area. Foliation (note marker) is N-S and steeply dipping within the Gazelle area units.

Geochemistry

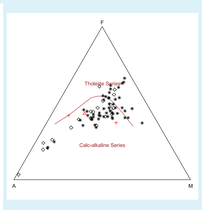
Example of cross-cutting andesite dikes sampled for geochemistry in the Mt. Attree Volcanic Complex

Legend

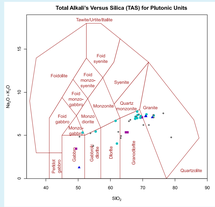
- Paleozoic (?) Intrusions
- Dikes cross-cutting Paleozoic volcanics
- Eocene Williams Creek Pluton
- Jurassic Dike
- Jurassic Hazelton Group Volcanics
- Jurassic Kleanza Creek Pluton
- Intrusions of Unknown Age
- Paleozoic Volcanics



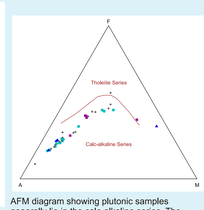
TAS classification diagram showing 1) sampled volcanics and dikes show a full spectrum of composition, 2) volcanics trend toward more felsic compositions and dikes toward more mafic compositions and 3) an overlap does exist between



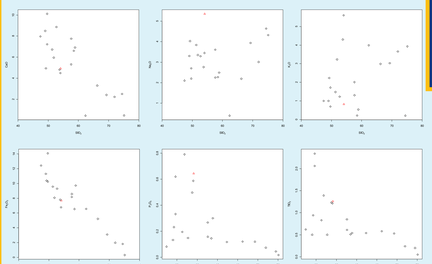
AFM diagram showing a range of calc-alkaline and tholeiitic signatures for both volcanics and dikes. Paleozoic volcanics seem to show a wide signature variation while dikes typically sit on the calc-alkaline and tholeiitic boundary.



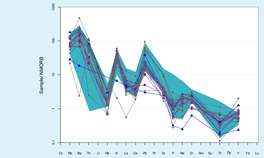
Total alkali versus silica (TAS) classification diagram showing plutonic samples from all target areas. Samples intrusive units show variable compositions from gabbro to granite.



AFM diagram showing plutonic samples generally lie in the calc-alkaline series. The three samples falling within the tholeiitic series consistently show anomalous geochemical signatures.



Harker variation diagrams for the suite of Paleozoic volcanic units in the Terrace area. Red triangle is a Jurassic Hazelton volcanic sample for comparison. Harker variation diagrams do not show consistent trends, however the scatter in the data, particularly at low SiO_2 values could indicate that for those compositions there is petrogenetic variability.



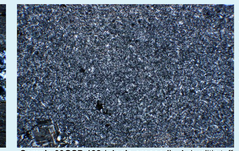
Trace element spider diagram of sampled plutonic units. Highlighted blue field represents Eocene Williams Creek pluton samples, showing large ion lithiphile elements (LILE) enrichment and Nb depletion. Most other plutonic samples show a similar trend, excluding various samples from un-dated intrusions and one Kleanza pluton sample.

Photomicrographs

Gazelle

Sample 09GSP-24c (nicols uncrossed): Dacitic to rhyolitic crystal vitric tuff with a tectonic foliation. Kinematic indicators, including sigma and delta plagioclase feldspar clasts indicate a top to the left sense of shear. Weak extensional crenulation cleavage observed is also compatible with a top to the left sense of shear.

Sample 09GSP-29 (nicols crossed): Boudinaged quartz vein in a quartz serecite schist, indicating extensional deformation. The quartz, plagioclase and hornblende matrix exhibits a visible fabric.

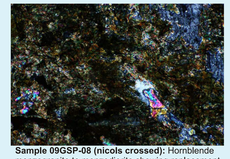


Sample 09GSP-132 (nicols crossed): A rhyolitic tuff with a fine quartz dominated matrix with a few medium-sized crystals, lacking any visible foliation or deformation.

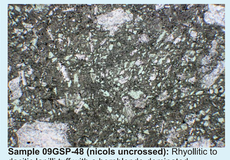
Gazelle Summary

All thin section samples taken from the Gazelle area are volcanic, and range from dacitic to rhyolitic in composition. Most of the rocks and thin sections show a tectonic foliation that is typically N-S and steeply dipping. A few of the sampled tuffs exhibit flow foliations with an overprinting tectonic deformation. There other samples that show no indication of deformation or flow foliation. The variability in the style and intensity of deformation suggest that there may have been multiple episodes of deformation and/or rheologic contrasts that partitioned strain in the Paleozoic volcanics.

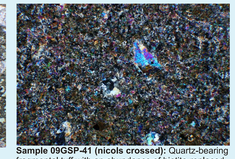
Mt. Attree



Sample 09GSP-08 (nicols crossed): Hornblende monzogranite to monzodiorite showing replacement of biotite by hornblende, as well as alteration of plagioclase feldspar crystals.



Sample 09GSP-48 (nicols uncrossed): Rhyolitic to dacitic lapilli tuff with a hornblende-dominated tuffaceous matrix supporting quartz and plagioclase feldspar lapilli. No visible deformation or foliation.

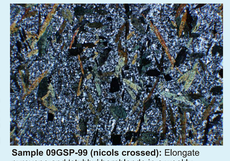


Sample 09GSP-41 (nicols crossed): Quartz-bearing fragmental tuff with an abundance of biotite-replaced hornblende. No visible deformation or foliation.

Mt. Attree Summary

Rock types sampled in the Mt. Attree area include a monzogranite to monzodiorite, fragmental tuffs, lapilli tuffs and calc-silicates. The majority, if not all, samples have undergone greenschist to amphibolite grade metamorphism along with chlorite/epidote alteration. Often primary textures have been eliminated. The majority of samples contain abundant hornblende, as well as the replacement of biotite by hornblende. This replacement indicates a period of high-temperature metamorphism.

Other Areas



Sample 09GSP-99 (nicols crossed): Elongate pyroxene and 'stubby' hornblende in a weakly deformed tuff. Pyroxene and hornblende crystals show a weak preferred orientation. From Nash Ridge Area.

Sample 09GSP-144 (nicols crossed): Recrystallized rhyolitic tuff (?). Quartz dominated matrix supporting medium to large quartz, pyroxene, biotite and hornblende crystals. No visible foliation or deformation. From Mt. Clague area.

Sample 09GSP-17 (nicols uncrossed): Foliated quartz sericite schist. Some post-deformation replacement of hornblende, shown by lack of deformation in biotite. From East of Gazelle.

Summary

Rock types sampled outside of the Gazelle and Mt. Attree areas include rhyolitic to dacitic tuffs and tonalites. Regions of deformation with post-deformational mineral growth exist, but no preferential growth orientation is evident. The majority of samples have quartz-dominated matrices supporting medium to large intact crystals. Paleozoic volcanics and plutonics east of the Gazelle and Mt. Attree also consistently contain lavender quartz eyes (phenocrysts).

Economic Mineralization

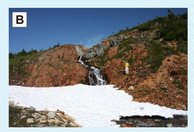
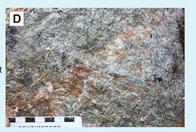
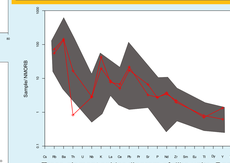
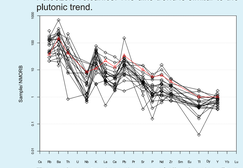


Photo A, taken in the Gazelle area, shows a gossan in a quartz sericite schist in contact with an unfoliated fragmental volcanic. Assay results from this area yielded no enrichment in base metal content. In other Gazelle area locations, gossan and economic mineralization was observed (e.g., photo B). Economic minerals commonly exhibit cross-cutting relationships with respect to the tectonic foliation and metamorphism. This is shown in photo C (a close-up of the gossan in photo B) and photo D, where chalcocite stringers cut across the fabric. This cross-cutting relationship indicates that some of the mineralization is post-depositional and post-deformational.

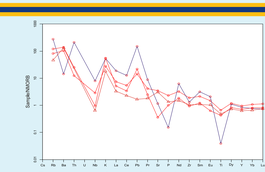




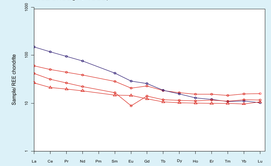
Trace element spider diagram of dike units. Red lines/data points are known Jurassic Hazelton dikes. Shaded field represent various dike samples collected throughout the target areas that cut Paleozoic volcanics. The dike trend is similar to the plutonic trend.



Trace element spider diagram of all volcanics. Red lines/data points are Jurassic Hazleton volcanics. Black lines/data points represent Paleozoic(?) aged volcanics.



Extended trace element plot for volcanic samples from the Gazelle and Mt. Attree localities. After Sun and McDonough, 1989)



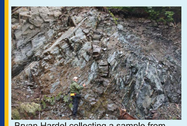
Rare earth element (REE) plot for volcanic samples from the Gazelle and Mt. Attree localities. Note symbols do not match legend above; circles from Gazelle area and triangle from Mt. Attree area. Note that one sample (blue) from the Gazelle area shows different REE pattern. After Sun and McDonough, 1989)

Summary

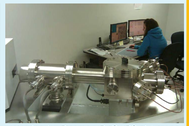
- Geochemical data from Paleozoic volcanics, potential feeder dikes and Paleozoic and undated intrusions all suggest that the Mt. Attree volcanic complex represents a collisional arc setting, likely an island arc.
- Comparison of volcanic, dike and intrusion compositions show little distinction and generally overlap, suggesting a similar origin.
- Preliminary REE analyses on selected Paleozoic volcanic samples also show similar trends for both Gazelle and Mt. Attree areas. However there is one sample, possibly a younger rhyolitic dike that intrudes the Paleozoic package in the Gazelle area, that suggest a different magma lineage than the other volcanic samples.
- No previous volcanic ages existed prior to this study. Here we confirm that volcanics and intrusives have Mississippian to Pennsylvanian ages.
- Other dated intrusions, all of which were at least weakly deformed and have fabrics sympathetic to fabrics in the Paleozoic volcanic package, were acquired to help to bracket ages of deformation. Deformed plutonic samples that cut the Paleozoic package range in age from Mississippian to Eocene.
- The Mt. Attree volcanics contain extensive areas of gossan. Preliminary assay results are low. Field observations of economic minerals that cut foliation suggest that in part mineralization is not primary.

Methods

- Geochemical and geochronologic samples collected from targeted areas throughout the Terrace region, British Columbia. Targeted areas including Gazelle, Mt. Boulton, Mt. Clauge, Copper River, Mt. Attree and Nash Ridge. See map right.
- Geochemical samples analyzed for major, trace and rare earth elements using Siemens XRF (x-ray flourescence) spectrometer and Thermo-Finnigan Element 2 Inductively-Coupled Plasma Mass Spectrometer (HR-ICPMS) at UWEC.
- Geochronologic samples analyzed using Nu Plasma HR MC-ICPMS (high resolution multi-collector inductively coupled plasma mass spectrometer) at Arizona LaserChron Center. Additional samples analyzed using TIMS (thermal ionization mass spectrometry) in Pacific Center for Isotopic and Geochemical Research at the University of British Columbia.



Bryan Hardel collecting a sample from deformed dike in the Mt. Attree volcanic complex near Terrace British Columbia. Mt. Attree volcanics here are strongly foliated and altered.



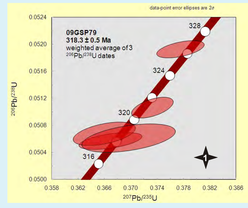
Using the Nu Plasma HR-ICMPS at Arizona LaserChron Center. Zircon mounts are loaded into the instrument and observed on a computer monitor at high magnification. Individual zircons are chosen for analysis.

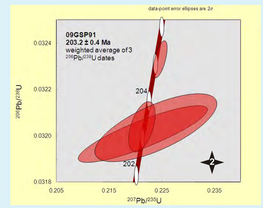
Jessica Meyers measuring bedding

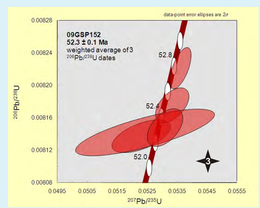
Jessica Meyers and Liz Balgord on traverse.

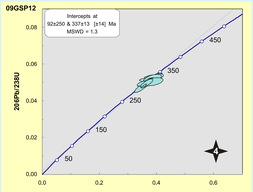
Geochronology

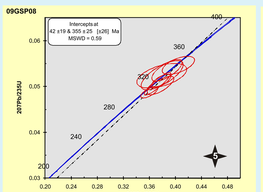
Below are concordia diagrams and a probability plot from samples collected from six localities within the targeted areas for geochronology. Ages 1-3 come from weakly to strongly deformed intrusions that cut Mt. Attree volcanics in several localities. Intrusions were dated to help bracket age of volcanism/deposition and deformation. Ages were acquired using the TIMS method by Rich Friedman of the BC PCGIR. Ages 4-6 are intrusive, volcanic and detrital ages respectively. The intrusive and volcanic samples are both Mississippian in age with the detrital probability plot giving a maximum depositional age from volcanogenic sands that are likely Pennsylvanian in age. Ages from the Arizona Laserchron Center using Laser Ablation HR MC-ICPMS.

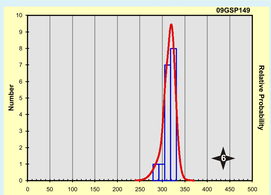












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