Stratigraphy of the Middle Paleozoic Sicker Group and Contained Volcanogenic Massive Sulphide (VMS) Occurrences, Vancouver Island, British Columbia

Tyler Ruks[1], Jim Mortensen[1] and Fabrice Cordey[2]

[1]Mineral Deposit Research Unit, Department of Earth and Ocean Sciences, University of British Columbia, 6339 Stores Rd., Vancouver B.C., V6T 1Z4; Phone: 604.822.6136; Email: tyler_ruks@hotmail.com, jmortensen@eos.ubc.ca

[2]F. Cordey, CNRS UMR 5125, Université Claude Bernard Lyon 1, 69622, Villeurbanne Cedex, France; Email: cordey@univ-lyon1.fr

Abstract

Recent geological mapping in the Cowichan Lake uplift (this study) has been a continuation of our efforts to develop a stratigraphic framework for Sicker arc development and VMS mineralization in the Sicker Group. Work conducted on Cowichan Lake uplift mineral tenure owned by project sponsors Treasury Metals Inc. and Westridge Resources Inc. concentrated on resolving the geological setting and age of the Lara VMS deposit and other VMS occurrences in the area, as well as examining new bedrock exposure created by recent logging activity. Reconnaissance fieldwork on new bedrock exposure owned by Westridge Resources Inc. culminated in the discovery of a new, polymetallic VMS occurrence. Mapping in the Mount Brenton area by Treasury Metals Inc. has identified a prospective zone where intensely sericite-altered and pyrite-mineralized felsic ash tuff is overlain by silicified argillite and a chlorite-altered ash tuff of intermediate composition. A similar geological setting is associated with massive sulphide mineralization at the Lenora deposit (Ruks and Mortensen, 2006). Geological mapping and sampling were also focused in the vicinity of the Lady A iron formation (Treasury Metals Inc.; MINFILE 092B 033). The Lady A is similar to other iron formations occurring in rocks that are stratigraphically above VMS mineralization at the Lenora, Tyee and Richard III occurrences, and is believed to represent oxide-facies iron mineralization related to hydrothermal mineralizing systems similar to those that formed the underlying VMS deposits. Resolving the timing of iron formation mineralization in the Sicker Group is critical for establishing the duration of VMS-related hydrothermal activity.

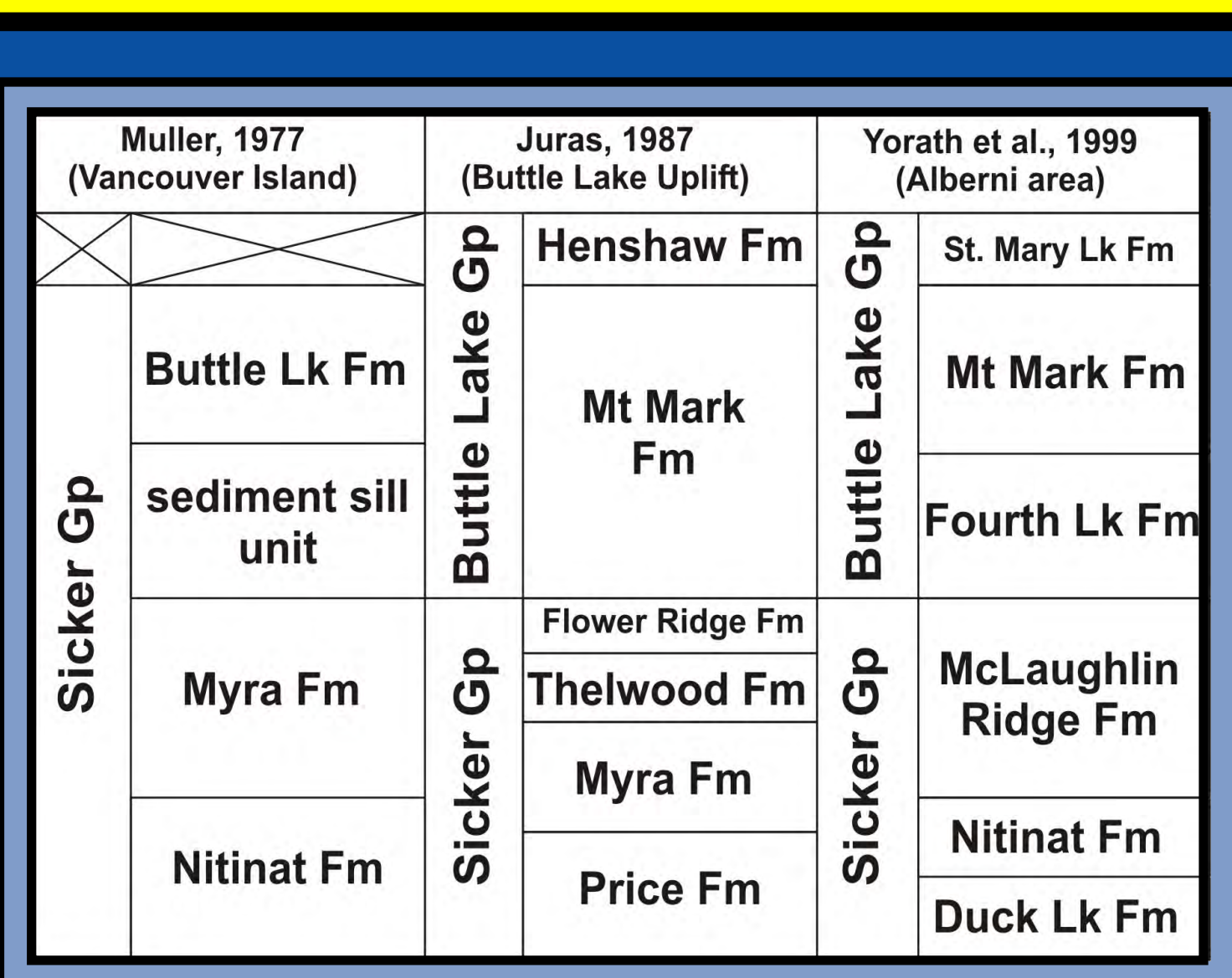
Geological mapping in the Cowichan Lake uplift of the Port Alberni area (Massey and Friday, 1989) indicates that this area is largely underlain by basalt to basaltic andesite volcanic rocks of the Duck Lake and Nitinat formations, respectively, in addition to felsic tuffaceous volcaniclastic rocks belonging to the McLaughlin Ridge Formation. McLaughlin Ridge Formation rocks in the Port Alberni area are interpreted to represent deposition distal from a volcanic centre, which is thought to be represented in the Saltspring Island-Cowichan Lake area by felsic intrusive rocks of the Saltspring intrusive suite (Massey and Friday, 1989). However, geological mapping of new exposures in the Port Alberni area (this study) indicates that felsic volcanic rocks of potential McLaughlin Ridge Formation age are present in significant quantities, necessitating a reinterpretation of the nature of the Sicker Group and its VMS potential in the Port Alberni area.

Mapping in the Hesquiat and Gold River areas, on the Dorado and Dragon properties (Paget Resources Corporation), has identified several new VMS occurrences hosted in potential Sicker Group rocks. Geological mapping and sampling on the Dragon property by previous workers indicates the presence of several polymetallic massive sulphide lenses with grades up to 7.33% Zn, 1.34% Pb, 173 ppm Cu, 680 ppb Au and 19.2 g/t Ag over a 2 m thickness (Jones, 1997). Geological mapping of the Dorado and Dragon properties indicates that mafic and felsic volcanic rocks and contained VMS mineralization are overlain by volcano-sedimentary and carbonate rocks, including calcareous tuffaceous sedimentary rocks and fossiliferous limestone, respectively. Nowhere else in the Sicker Group are carbonate rocks observed to directly, and apparently conformably, overlie felsic volcanic rocks and VMS mineralization. This relationship indicates that radical stratigraphic differences exist between rocks of the Dragon property and more well-studied exposures of the Sicker Group in the Cowichan Lake and Myra Falls areas. These stratigraphic differences may be explained by large changes in volcanic and sedimentological facies or the presence of a previously unrecognized cycle of arc magmatism and VMS mineralization on Vancouver Island.

Preliminary geochemical data for Sicker Group rocks of the Cowichan, Port Alberni and Hesquiat areas indicate that rocks of basalt through dacite-rhyolite composition are present in all areas, although felsic volcanic rocks are most abundant in the Cowichan area. Transitional to calc-calkaline affinities are most prevalent for volcanic rocks of the Cowichan area, whereas volcanic rocks of the Alberni and Hesquiat areas are characterized by tholeiitic to transitional affinities, indicating a possible transition from a volcanic arc to back-arc setting, respectively. Volcanic rocks of all areas exhibit light rare earth element enrichment and negative Nb-Ti anomalies, indicating generation in a subduction zone setting.

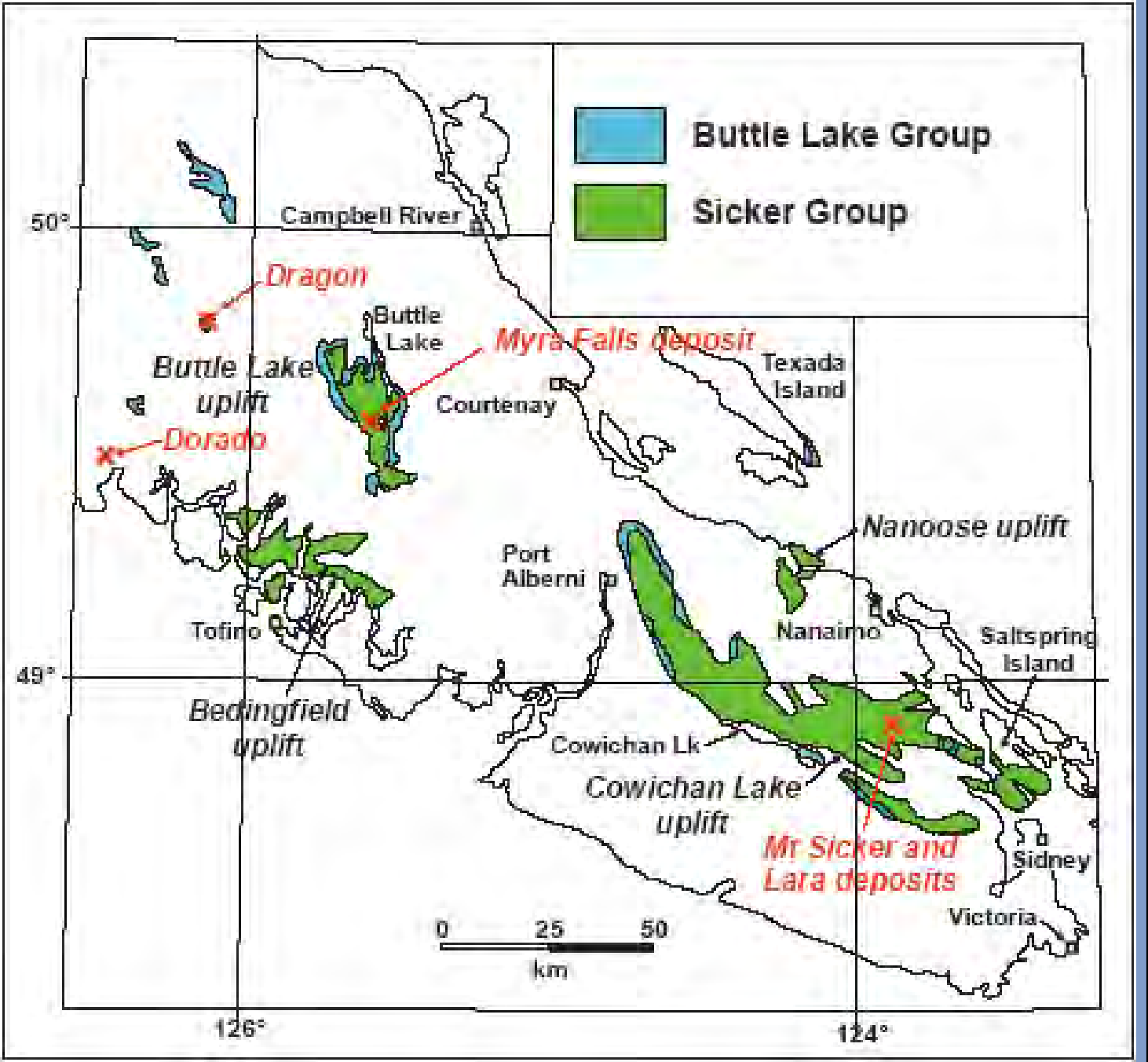
Introduction

The Middle Paleozoic Sicker Group (SG) on Vancouver Island is believed to record the evolution of an oceanic island arc that represents the basement of Wrangellia. The SG is exposed in several structural uplifts on Vancouver Island and the Canadian Gulf Islands, including the Buttle Lake, Bedingfield, Nanoose and Cowichan Lake uplifts and potentially portions of the Westcoast Crystalline Complex. SG strata in the Buttle Lake uplift host the producing Myra Falls volcanogenic massive sulphide (VMS) deposit, the largest producing VMS deposit in western Canada. Other VMS occur throughout the SG in the Cowichan Lake and Bedingfield uplifts, and in possibly correlative rocks of the Westcoast Crystalline Complex. A paucity of isotopic and fossil age control, and lack of a detailed understanding of the stratigraphy of the SG, has impeded the development of a robust model to explain the origins of Wrangellia and hampered exploration for stratigraphically controlled VMS mineralization. Our research combines geological mapping with geochronological, biostratigraphic, isotopic, and lithogeochemical studies to better understand the tectonic history and metallogeny of the SG. New geological mapping of key parts of the SG is aimed at better constraining stratigraphic relationships within the SG, and in particular the geological setting of VMS deposits. We are employing U-Pb and Ar-Ar dating of intrusive and extrusive rocks as well as microfossil (radiolarian and conodont) biostratigraphy of sedimentary units to develop a coherent chronostratigraphic framework for each of the SG uplifts. Whole rock lithogeochemistry together with Nd and Hf isotopic studies is being used to constrain the petrogenesis of SG magmatism and test for possible linkages to continental (possibly Laurentian) crust. Lead isotopic compositions of sulphide occurrences are being used to discriminate between syngenetic or epigenetic occurrences, in order to evaluate the potential for additional large VMS deposits in the SG. Results of the study will enhance our knowledge of Wrangellian tectonic evolution and metallogeny, and lead to a better understanding of a critical part of the history of crustal growth in the North American continent.



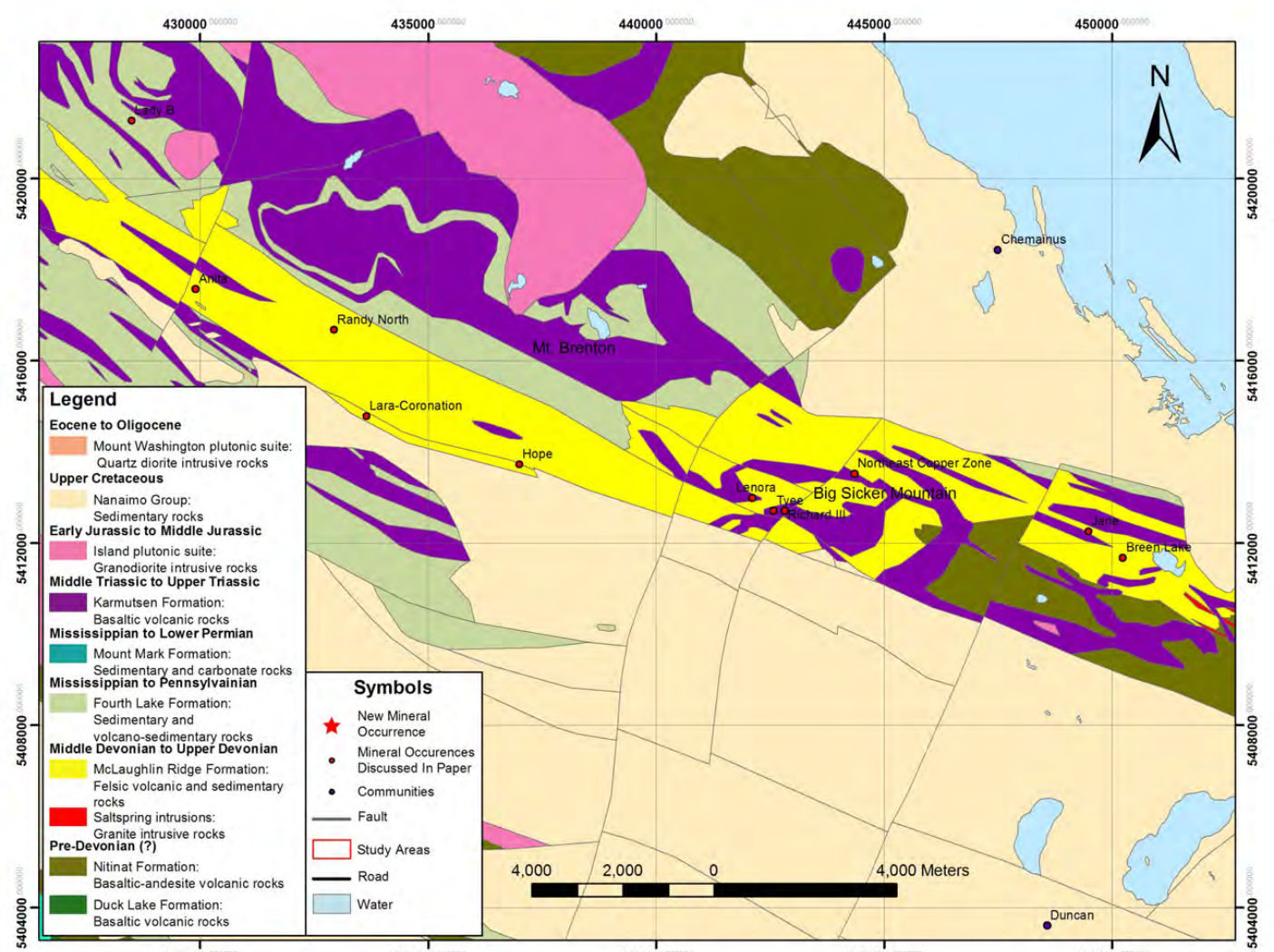
Muller, 1977 (Vancouver Island)		Juras, 1987 (Buttle Lake Uplift)		Yorath et al., 1999 (Alberni area)	
		Buttle Lake Gp	Henshaw Fm	Buttle Lake Gp	St. Mary Lk Fm
	Buttle Lk Fm		Mt Mark Fm		Mt Mark Fm
Sicker Gp	sediment sill unit				Fourth Lk Fm
			Flower Ridge Fm	Sicker Gp	McLaughlin Ridge Fm
	Myra Fm	Sicker Gp	Thelwood Fm		
			Myra Fm		Nitinat Fm
	Nitinat Fm		Price Fm		Duck Lk Fm

Stratigraphic nomenclature for the Sicker and Buttle Lake groups on Vancouver Island.

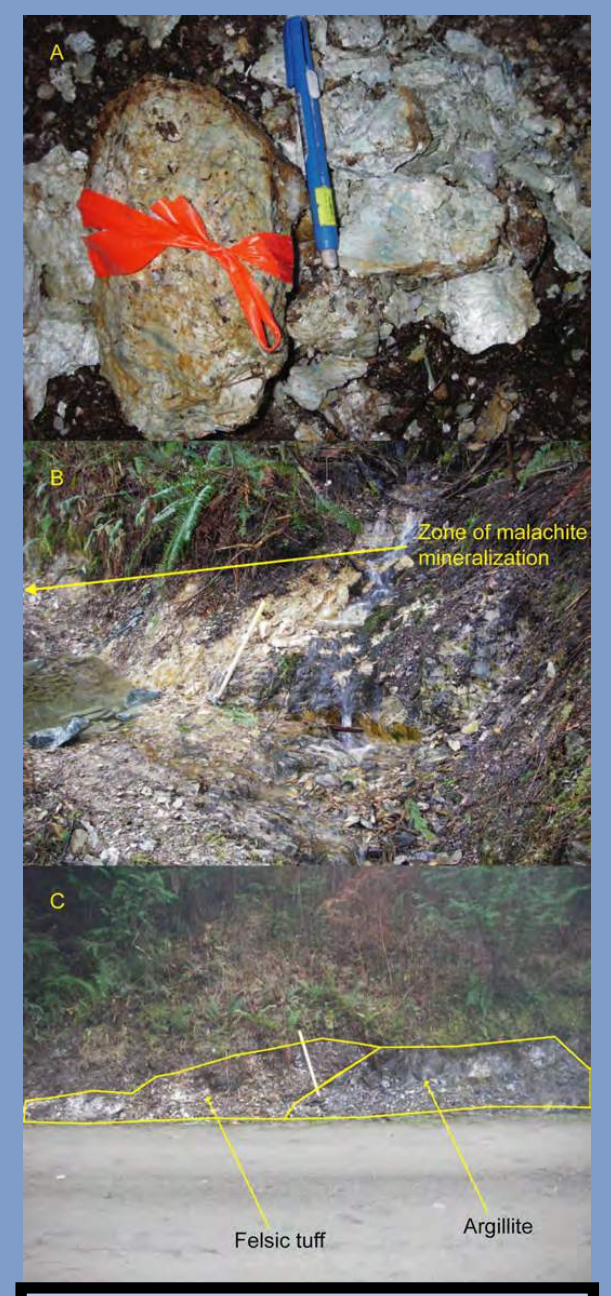


Distribution of Paleozoic strata and VMS occurrences of the Sicker and Buttle Lake groups on Vancouver Island and the Gulf Islands.

Cowichan Area: Treasury Metals Inc. and Westridge Resources Inc.



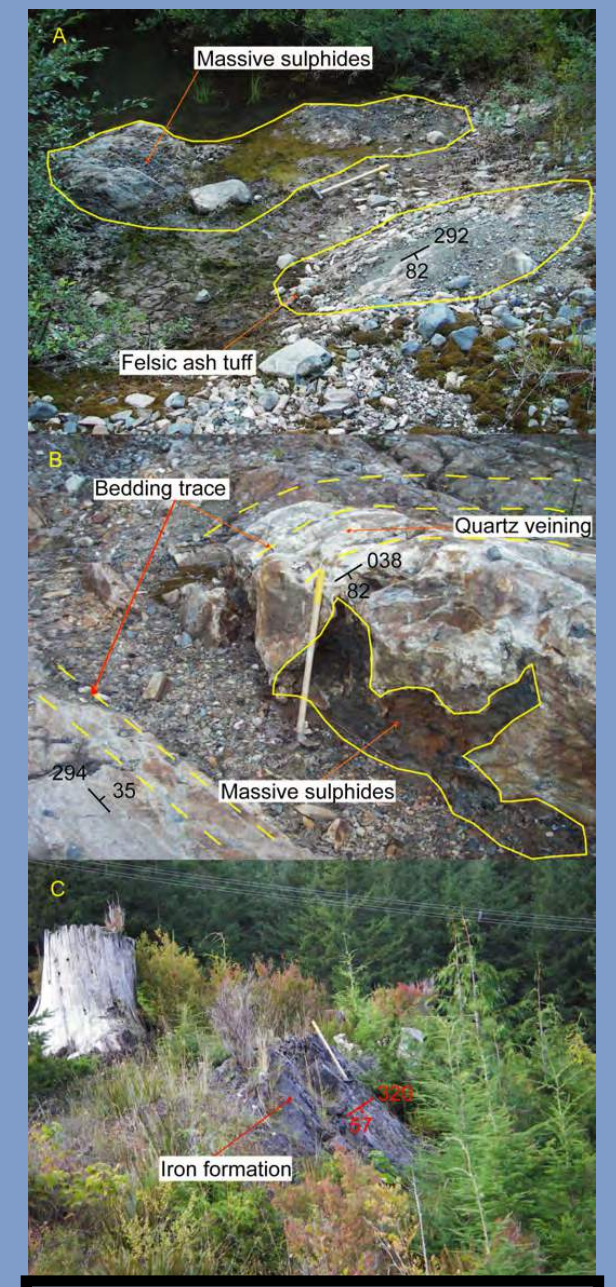
Regional geology, selected mineral occurrences and areas of study for 2008 fieldwork in the Cowichan Lake area (modified from Massey et al., 2005).



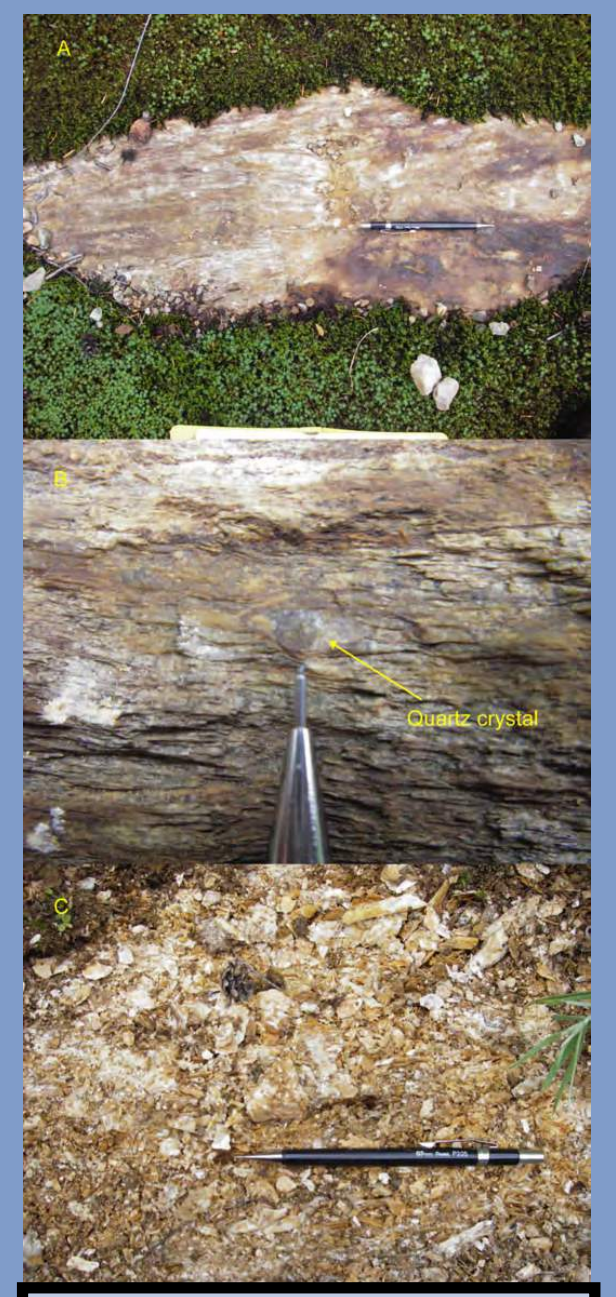
A) A new discovery of malachite mineralized, intensely silica-sericite altered felsic crystal tuff, approximately 700m northwest of the Northeast Copper Zone (MINFILE 092B 099), on Westridge Resources Inc. mineral tenure. B) Friable, altered felsic tuff associated with the mineralized zone. C) Altered felsic tuff hosting the malachite mineralization is interbedded with graphitic argillite and intermediate silty to sandy tuff.

A) A new discovery of massive magnetite mineralization within a variably silica-sericite-chlorite altered quartz-feldspar porphyry, approximately 1 km east of the Northeast Copper Zone on Westridge Resources Inc. mineral tenure. B) Close-up of replacement-style massive magnetite mineralization, cored by disseminated pyrite. C) Chalcopyrite stringer mineralization, hosted by the same lithology, flanks the area of massive magnetite mineralization. Chlorite alteration is strong along stringer margins.

A) A new discovery of massive pyrite plus chalcopyrite mineralization, hosted in a silica altered intermediate tuff and located approximately 1 km east of the Jane showing (MINFILE 092B 084) on Westridge Resources Inc. mineral tenure. B) Close-up of massive pyrite and chalcopyrite mineralization. C) Well bedded, silica altered felsic ash tuffs with abundant pyrite stringer mineralization, located approximately 1.2 km northwest of the Jane showing.

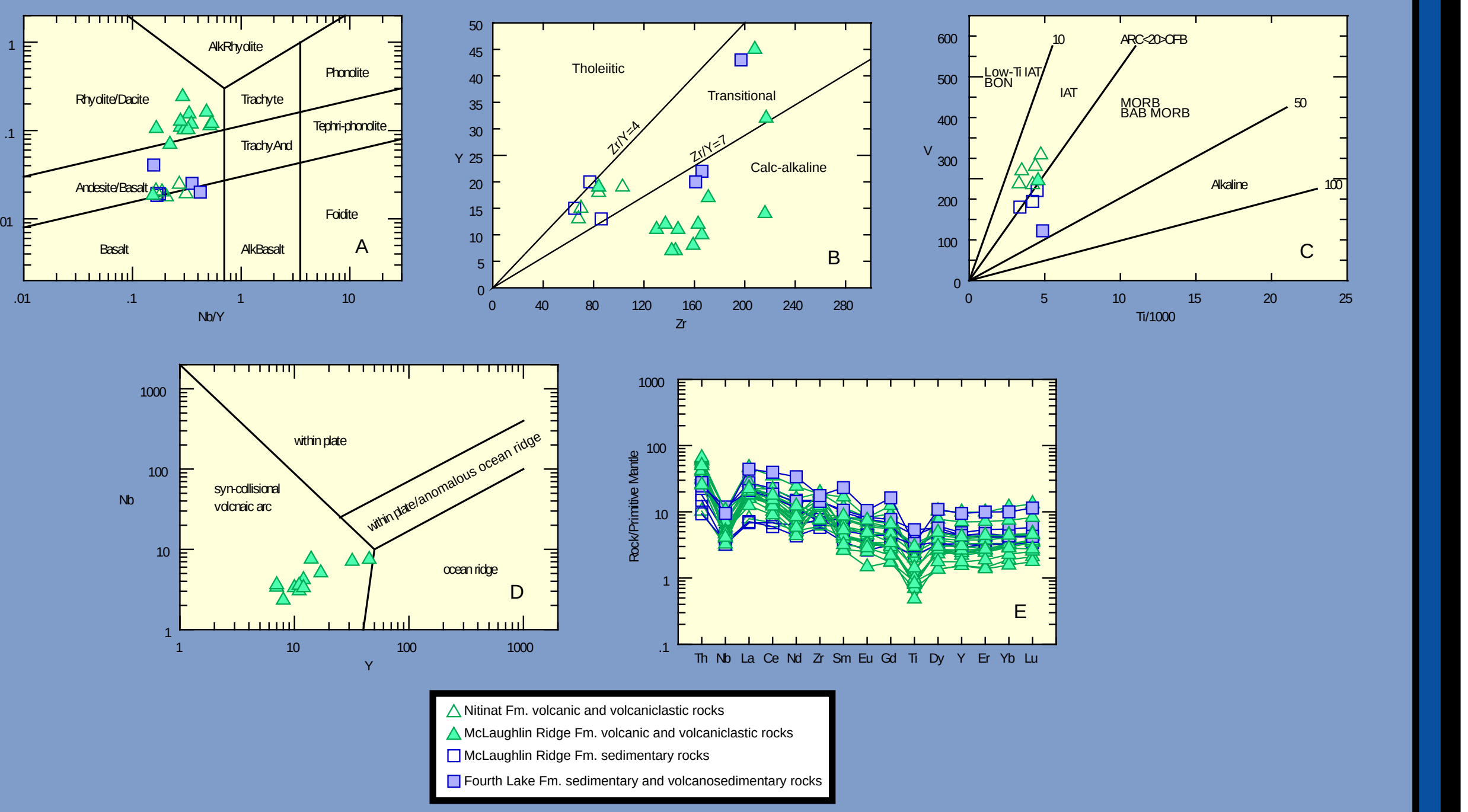


A) Massive sulphide mineralization in contact with silicified felsic ash tuff at the northwest pit, Coronation zone, Lara property of Treasury Metals Inc. B) Massive sulphide mineralization hosted by silica- and sericite-altered felsic ash and crystal tuff, northeast pit, Coronation zone; rocks on the east side of the massive sulphide mineralization are folded into the mineralization, suggesting the presence of drag folding. C) Fine- to medium-grained massive magnetite of the Lady B iron formation of Treasury Metals Inc. (MINFILE 092B 33).



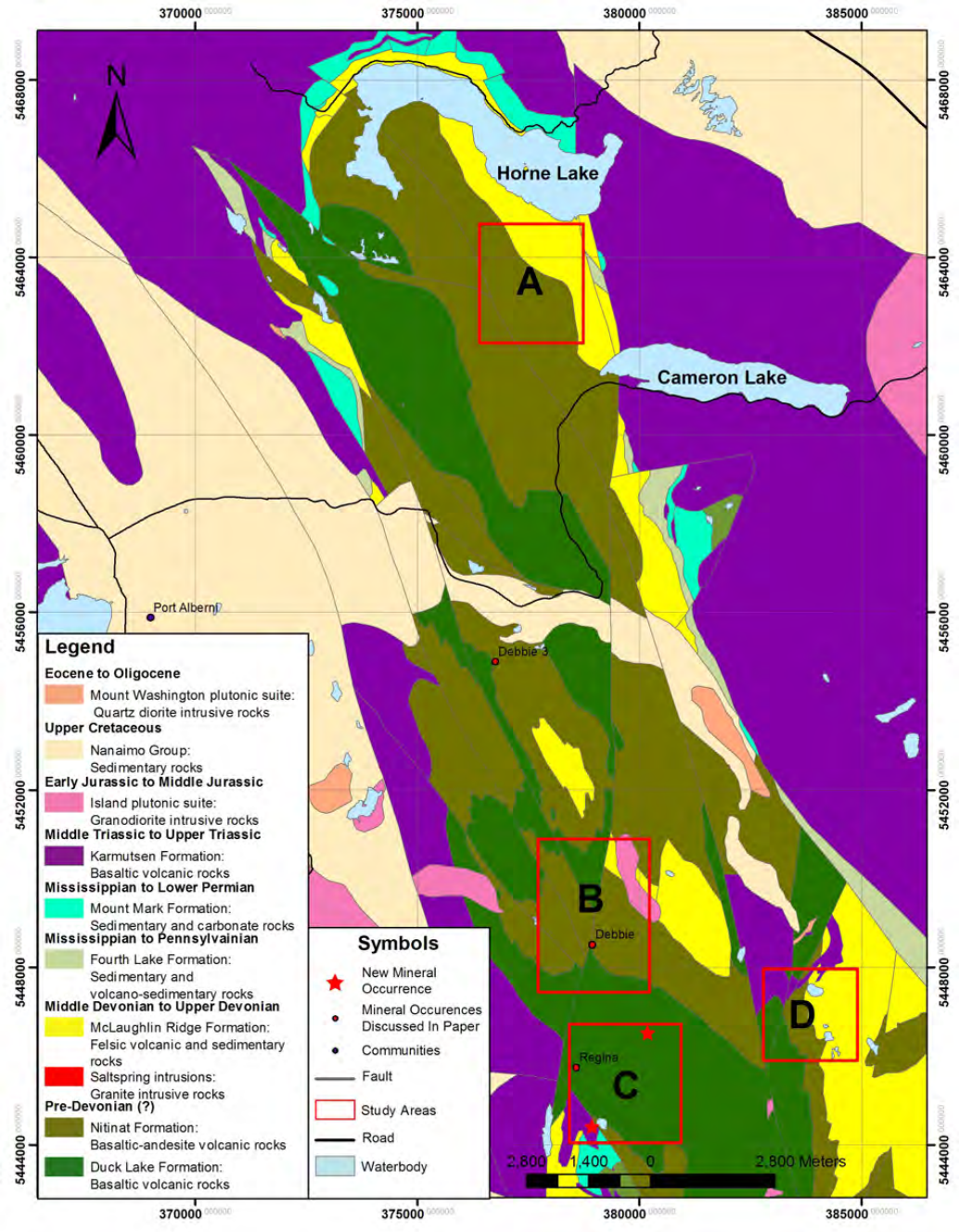
A) Sericite-silica altered, pyrite stringer mineralized felsic crystal tuff of the Randy Zone (MINFILE 092B 128), Lara property of Treasury Metals Inc. B) Quartz crystal forming an augen structure in foliated felsic tuff of the Randy North Zone. C) Strongly sericite altered felsic crystal tuff of the Randy North Zone.

A prospective zone for VMS mineralization, approximately 1.7 km north of the Hope showing (MINFILE 092B 110), Lara property of Treasury Metals. Here, an intensely silica-sericite altered felsic crystal tuff with disseminated pyrite mineralization (A) is overlain by silicified argillite (B). Silicified argillite is in turn overlain by intermediate silty to fine sandy tuff (C). This stratigraphic relationship is similar to that associated with the Randy North showing and the past-producing Lenora deposit (MINFILE 092B 001).

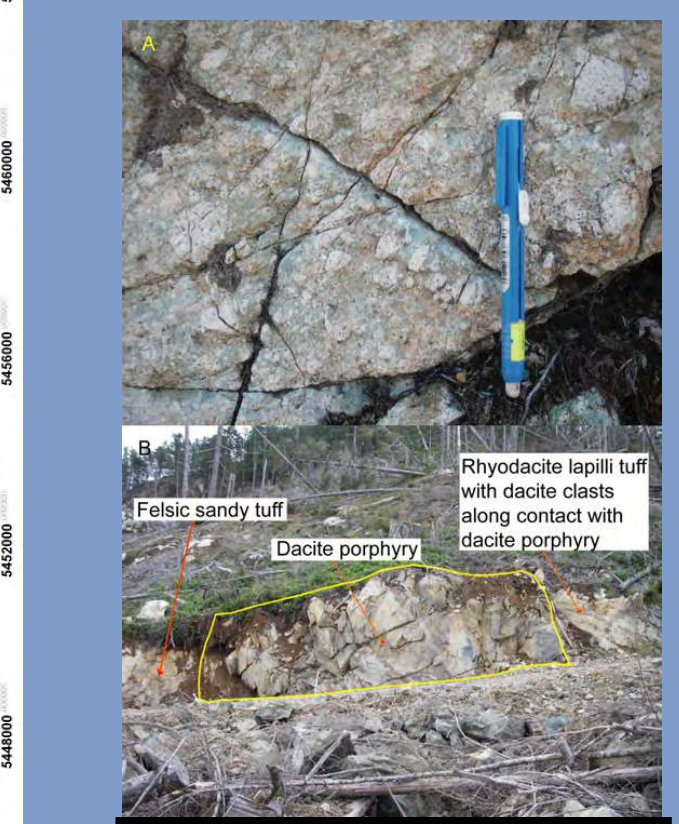


Lithogeochemical plots for Sicker Group rock units in the southeastern part of the Cowichan Lake uplift. Petrochemical fields defined from the following sources: Figure A: Zr/TiO2 vs Nb/Y plot (Winchester and Floyd, 1977); Figure B: Y vs. Zr diagram for discriminating tholeiitic versus calc-alkaline affinities (Lentz, 1998, 1999); Figure C: V vs. Ti (Shervais, 1982); Figure D: Nb vs. Y tectonic discrimination diagram (Pearce et al., 1984); Figure E: Multielement diagram normalized to primitive mantle (Sun and McDonough, 1989).

Port Alberni Area: Bitterroot Resources Ltd. and Mineral Creek Ventures Inc.

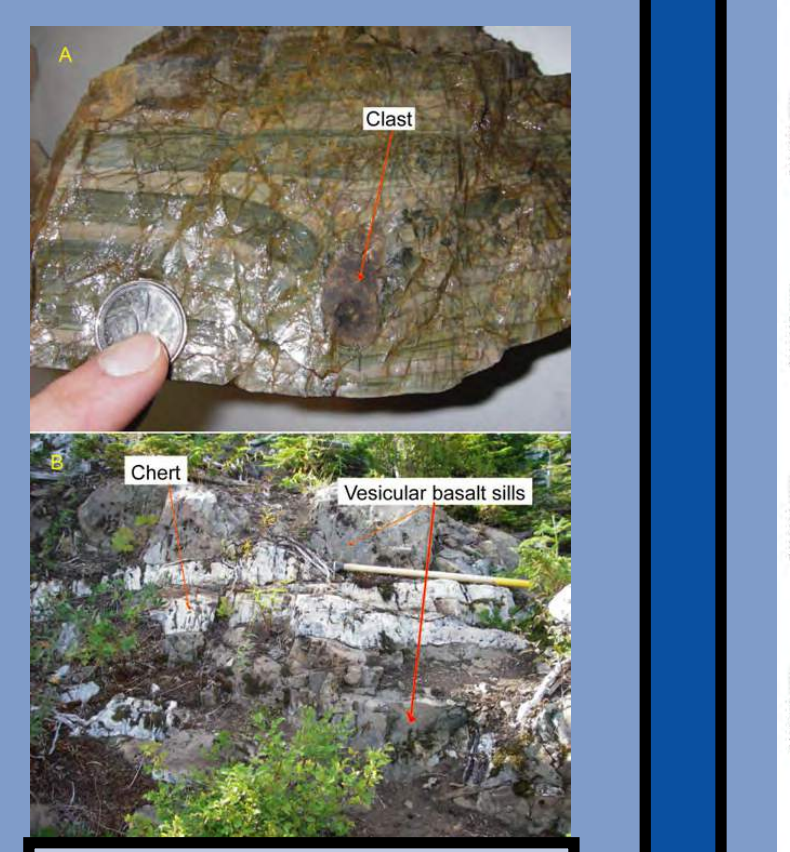


Regional geology (modified from Massey, 2005), selected mineral occurrences and areas of study for 2008 fieldwork in the Port Alberni area.

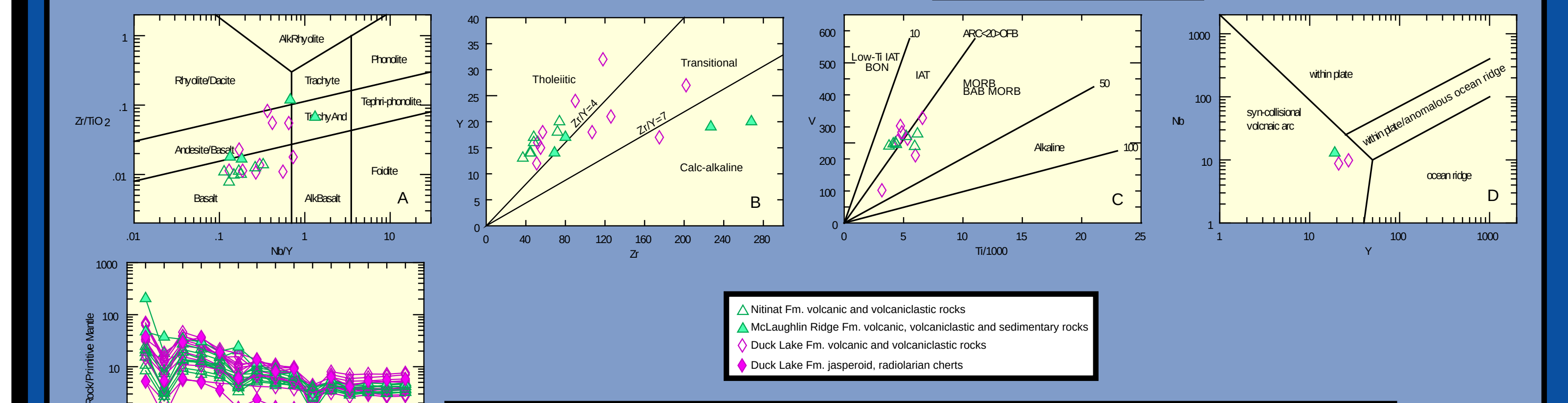


Newly discovered felsic volcanic rocks in the Horne Lake area (study area A on map): A) rhyodacite lapilli tuff; B) feldspar-quartz-phyric dacite porphyry intruding felsic lapilli and sandy tuff; clasts of dacite porphyry are found in the tuff near the contact zone with the intrusion, suggesting potential peperitic interaction.

Newly discovered mineralization in the Port Alberni area: A) stratiform massive pyrite in a new exposure along Duck Lake Main (study area C on map); the mineralization is interbedded with siliceous argillite, chert and mafic sandy to lapilli tuff; B) gossanous and silica-altered zones within a massive diabase are associated with quartz-vein-hosted pyrite and chalcopyrite mineralization; the dashed yellow line is the trace of the mineralized zone (Debbie property, Bitterroot Resources Ltd. and Mineral Creek Ventures Inc. mineral tenure).

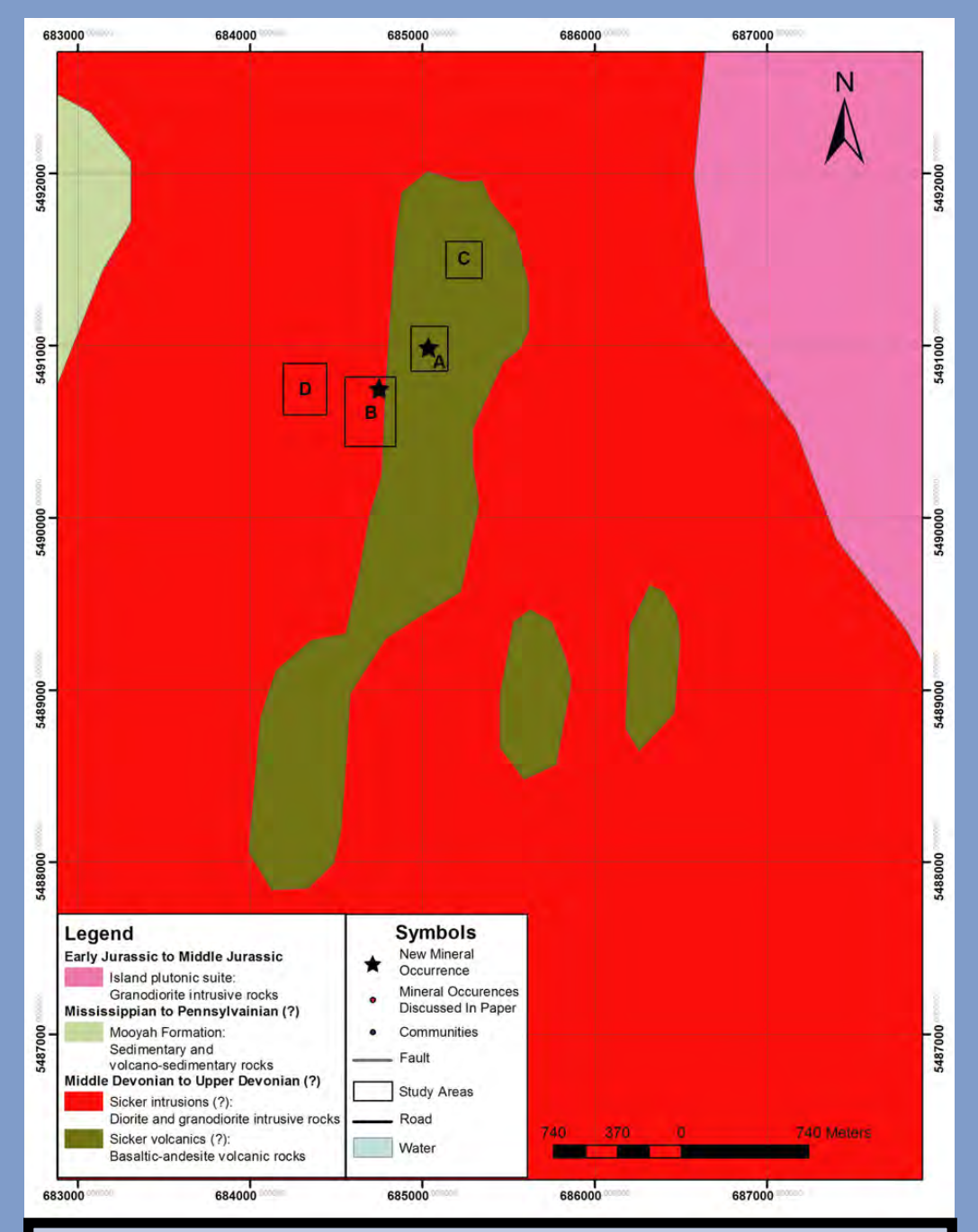


A) Bedding in radiolarian chert is deflected by a fine-grained, purple, rounded clast of unknown lithology (study area D). B) Highly quartz vesicular and often spherulitic basalt sills intrude radiolarian chert; recrystallization of radiolarian chert is often observed in areas where basalt sills are abundant.

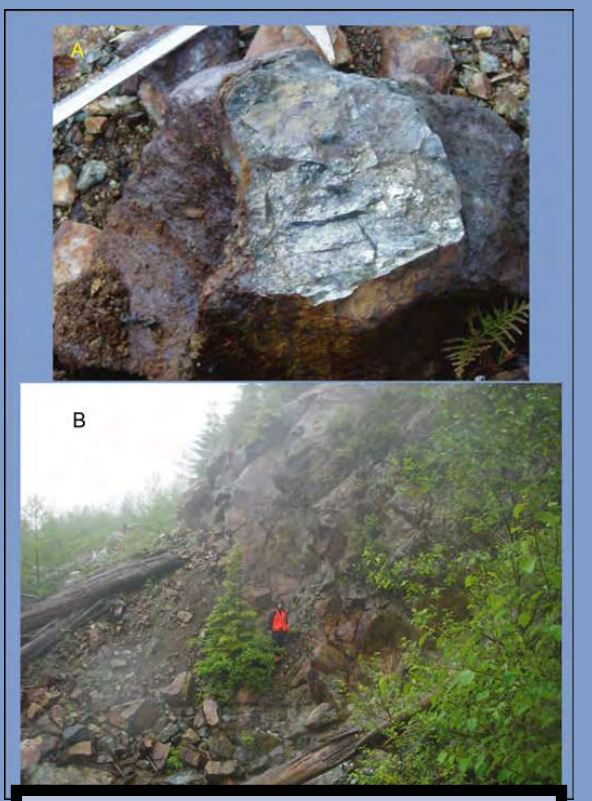


Lithogeochemical plots for Sicker Group rock units in the Alberni area, Cowichan uplift. Petrochemical fields defined from the following sources: Figure A: Zr/TiO2 vs Nb/Y plot (Winchester and Floyd, 1977); Figure B: Y vs. Zr diagram for discriminating tholeiitic versus calc-alkaline affinities (Lentz, 1998, 1999); Figure C: V vs. Ti (Shervais, 1982); Figure D: Nb vs. Y tectonic discrimination diagram (Pearce et al., 1984); Figure E: Multielement diagram normalized to primitive mantle (Sun and McDonough, 1989).

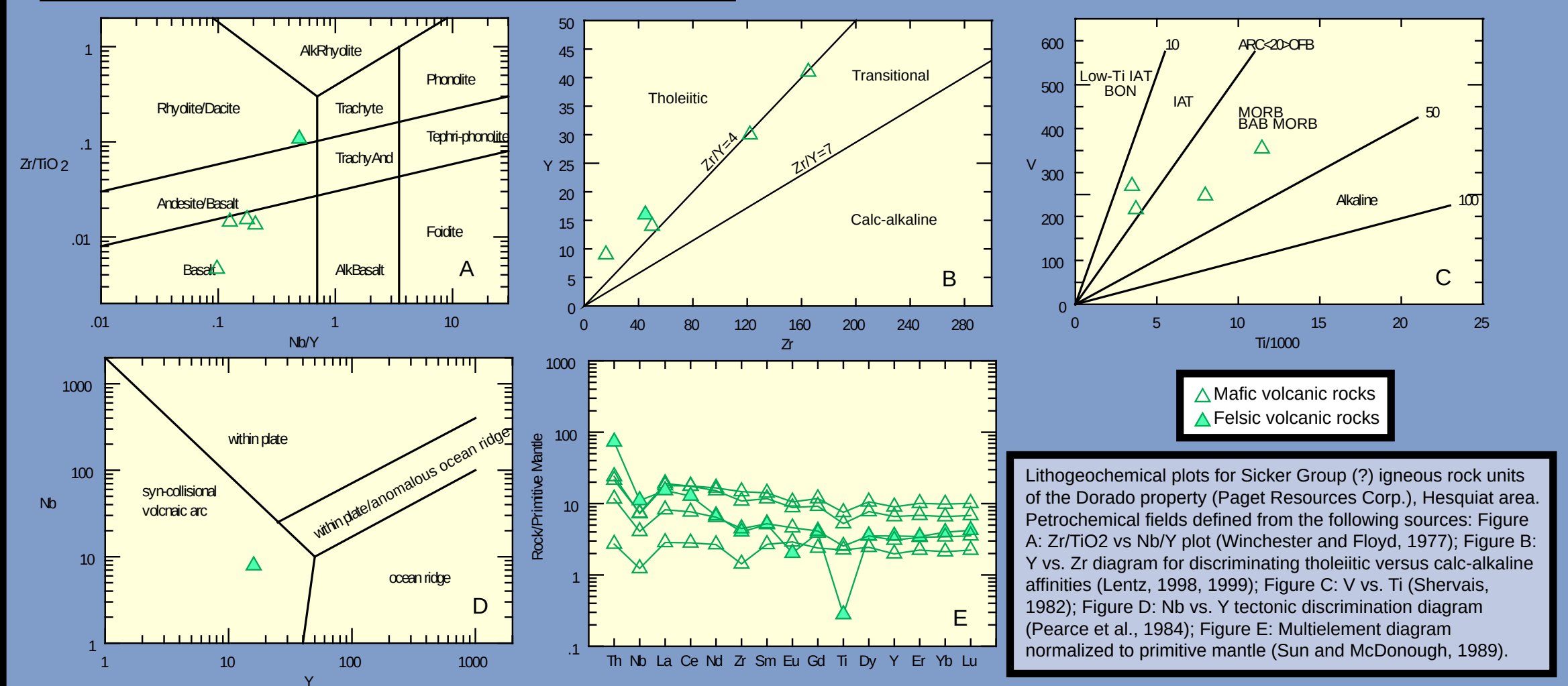
Hesquiat Area:
Dorado Property,
Paget Resources Corp.



Regional geology, selected mineral occurrences and areas of study for 2007 fieldwork on the Dorado property of Paget Resources Corporation (modified from Marshall et al., 2006).

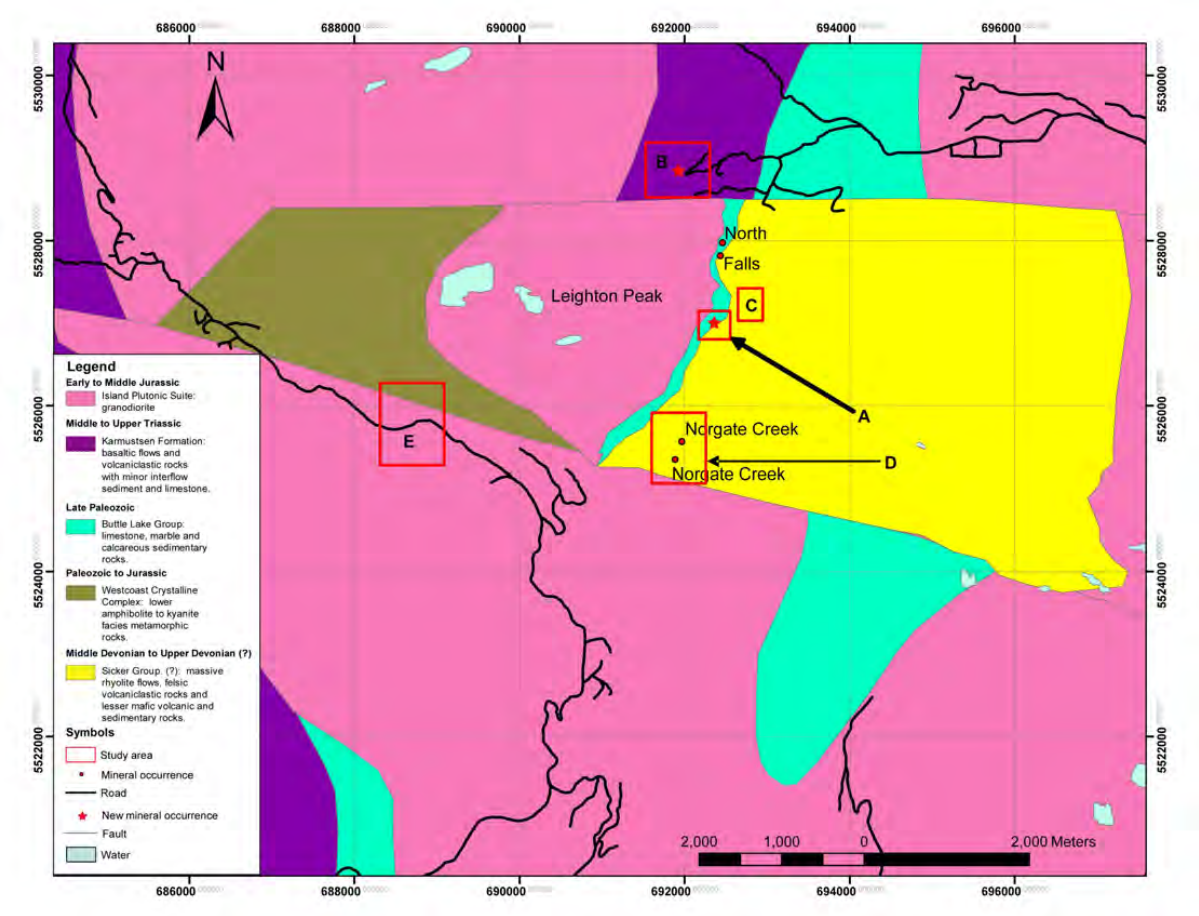


A) Massive pyrrhotite and chalcopyrite mineralization from region B (see map) of the Dorado property of Paget Resources Corporation; B) Strongly silica-altered and stockwork-sulphide-mineralized, clinopyroxene- and feldspar-phyric andesite porphyry from region B of the Dorado property.



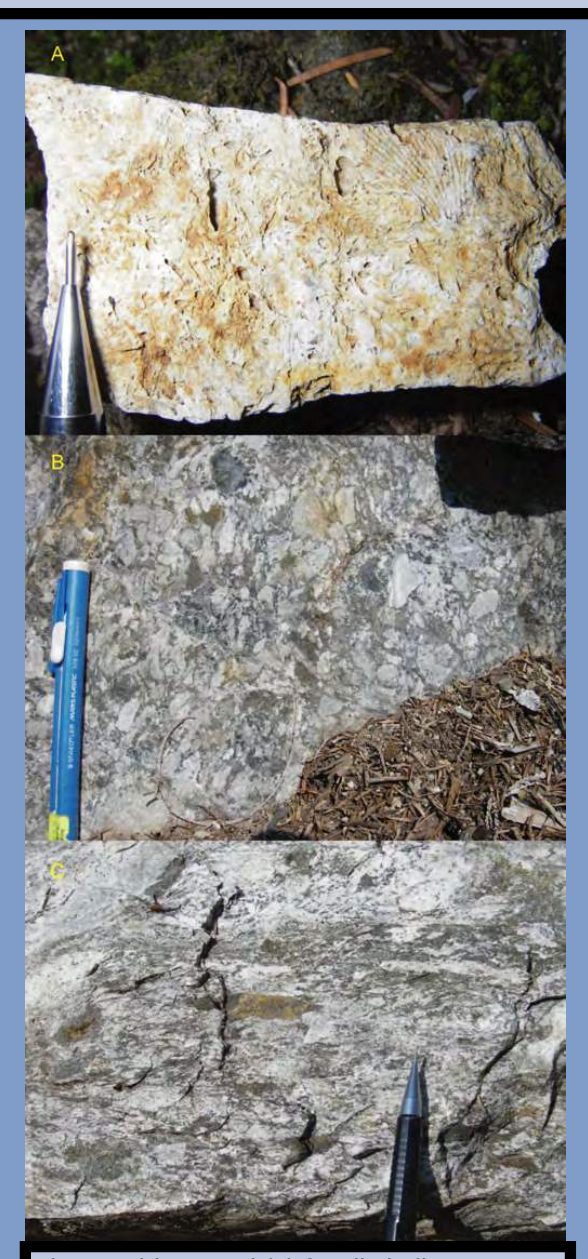
Lithogeochemical plots for Sicker Group (?) igneous rock units of the Dorado property (Paget Resources Corp.), Hesquiat area. Petrochemical fields defined from the following sources: Figure A: Zr/TiO2 vs Nb/Y plot (Winchester and Floyd, 1977); Figure B: Y vs. Zr diagram for discriminating tholeiitic versus calc-alkaline affinities (Lentz, 1998, 1999); Figure C: V vs. Ti (Shervais, 1982); Figure D: Nb vs. Y tectonic discrimination diagram (Pearce et al., 1984); Figure E: Multielement diagram normalized to primitive mantle (Sun and McDonough, 1989).

Gold River Area: Dragon Property, Paget Resources Corp.



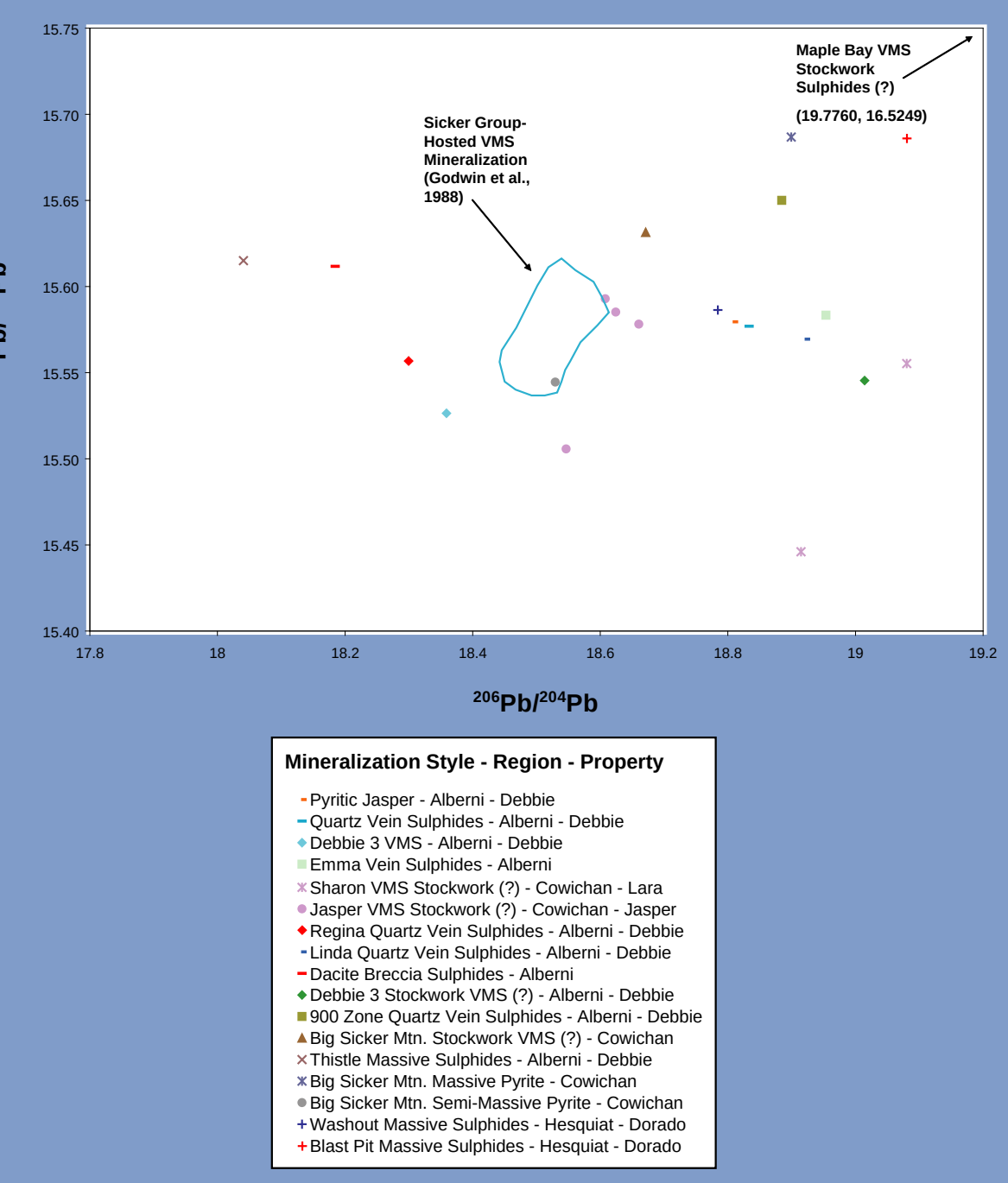
Regional geology (modified from Massey, 2005; Jones, 1997), selected mineral occurrences and areas of study for 2008 fieldwork on the Dragon property of Paget Resources Corporation.

A) New massive sulphide mineralization discovered this summer on the Dragon property of Paget Resources Corporation (study area A on map). B) Contact zone between massive, silica-altered and stockwork-sulphide-mineralized rhyolite, and overlying chert, felsic tuff and carbonate rock; this contact hosts all known massive sulphide occurrences on the Dragon property (study area B on map) . C) Folded, flow-banded rhyolite on the ridge to the east of Leighton Peak (study area C on map).



A) Branching coral (?) fossils in limestone conformably overlying felsic volcanic rocks and VMS mineralization on the Dragon property. B) Metamorphosed, heterolithic tuff breccia in the Norgate Creek area, Dragon property. C) Gneissosity in heterolithic tuff breccia, only meters away from figure B.

Lead Isotopes



Lead isotope data for Sicker Group-hosted VMS mineralization of the Myra Falls and Cowichan areas plotted against other Sicker Group-hosted sulphide mineralization. This data indicates that a population of younger, epigenetic sulphide occurences is hosted in Sicker Group rocks. In addition, samples with lower isotopic ratios than the field for Sicker Group VMS may represent an older cycle of Sicker Group-hosted VMS mineralization. The Debbie property is owned by Bitterroot Resources Ltd. and Mineral Creek Ventures Inc., the Lara property is owned by Treasury Metals Inc., the Dorado property is owned by Paget Resources Corp. and the Jasper property is owned by Inspiration Mining Corp. Sulphides for "Quartz Vein Sulphides" and "Pyritic Jasper" are from gold-bearing quartz veins and pyritic jasperoid iron formations of the Debbie property, Alberni area, respectively. "Dacite Breccia Sulphides" are derived from a silica altered heterolithic breccia associated with the margins of a dacite flow, Alberni area. Sulphides from the Debbie 3 occurrence (MINFILE 092F 445) are from stratiform VMS mineralization of the Debbie property, Alberni area. Sulphides of "Debbie 3 Stockwork VMS (?)" are from pyritic veins spatially associated with the Debbie 3 VMS occurrence, Debbie property, Alberni area. Sulphides from the Emma vein are from an auriferous quartz-vein in the Cameron River area southeast of Port Alberni. Sulphides from the Sharon (MINFILE 092B 040) and Maple Bay occurences are from shear zone hosted and stockwork style vein sulphides in the Big Sicker Mountain area, respectively. Sulphides from "Jasper VMS Stockwork (?)" are from potential felsic volcanic associated stockwork style VMS mineralization of the Jasper MINFILE occurrence (092C 080), located approximately 59 km to the west of Big Sicker Mountain, Cowichan area. Regina, Linda and 900 Zone "Quartz Vein Sulphides" are associated with polymetallic, auriferous veins of the Debbie property, Alberni area. "Thistle Massive Sulphides" come from polymetallic massive sulphide mineralization of the past producing Thistle mine (MINFILE 092F 083), Alberni area. Big Sicker Mtn. Stockwork VMS, Massive and Semi-Massive Pyrite samples consist of pyrite dominant, polymetallic stockwork style VMS mineralization associated with felsic volcanic rocks on Big Sicker Mountain, Cowichan area. Washout and Blast Pit Massive Sulphide samples are from polymetallic massive sulphide mineralization associated with altered intermediate volcanic rocks of the Dorado property, Hesquiat area

Conclusions

Fieldwork in 2008 has continued with the focus of resolving the stratigraphy and tectonic history of the Sicker Group and its contained mineral occurrences via a combination of bedrock mapping and sampling for geochronology (U-Pb, Ar/Ar), biostratigraphy (macrofossils, radiolarians and conodonts), geochemistry (major and trace elements) and isotopic analyses (Nd and Pb; whole rock and sulphides, respectively).

Cowichan Area: In the Cowichan Lake uplift, the goal of the fieldwork has been to resolve the geological and stratigraphic setting of VMS mineralization, particularly for those VMS deposits and occurrences on mineral tenure owned by Treasury Metals Inc. and Westridge Resources Inc. During this summer, a new polymetallic massive sulphide showing was found on Westridge Resources ground, and a prospective zone for VMS mineralization was identified on Treasury Metals ground. Sampling for U-Pb (zircon) geochronology in the immediate vicinity of the Lady B iron formation (Treasury Metals Inc.) was conducted in order to constrain the longevity of the VMS mineralizing hydrothermal system in the Cowichan Lake area.

Alberni Area: Fieldwork in the Port Alberni area focused on examining new bedrock exposures southeast of Horne Lake, as well as continuing examinations of bedrock and mineralization hosted by rocks of the Nitinat and Duck Lake formations on ground owned by Bitterroot Resources Ltd. Examinations of new exposures in the Kammat and Peak lakes area were also conducted. Southeast of Horne Lake, recent logging activity has resulted in the discovery of a large area underlain by proximal felsic volcanic rocks. This finding is highly significant, as Sicker Group rocks of the Port Alberni area have previously been interpreted to represent a depositional area distal from felsic magmatic centres (Yorath et al., 1999). Not only does this new discovery indicate the presence of a new centre of felsic magmatism in the Sicker Group, but it has large positive implications for the VMS potential of Sicker Group rocks in the Port Alberni area.

Reconnaissance fieldwork in new exposures of Sicker Group rocks of the **Peak-Kammat lakes** area has shown that significant revisions are necessary to the existing geological map for the area. Sampling of abundant radiolarian chert in this area was conducted in order to determine an age for rocks of the McLaughlin Ridge Formation type section (Yorath et al., 1999). Abundant sampling for geochronology and radiolarian biostratigraphy was conducted on ground owned by Bitterroot Resources Ltd., in order to determine the age of mafic volcanic rocks of the Nitinat and Duck Lake formations. Resolving the ages of these units is critical for understanding the temporal evolution of the Sicker arc, and the earliest history of the Wrangellia Terrane. Two new mineral occurrences were discovered on the Bitterroot Resources mineral tenure, including stratiform massive sulphide mineralization interlayered with mafic volcanic rocks and silicified argillite, and pyrite-chalcopyrite mineralization associated with strongly silica-altered zones in massive diabase.

Nanoose Area: Reconnaissance fieldwork in the Nanoose area focused on resolving the age of sedimentary, carbonate and volcanic rocks that have previously been interpreted as potential correlatives to the Buttle Lake and Sicker groups. Abundant sampling for U-Pb (zircon) detrital geochronology and radiolarian biostratigraphy was conducted.

Gold River and Hesquiat Areas: In the Gold River and Hesquiat areas, geological fieldwork was carrried out on potential Sicker Group rocks underlying the Dragon and Dorado properties, respectively (Paget Resources Corp.), where new polymetallic massive sulphide occurrences were discovered. On the Dorado property, massive sulphide mineralization was discovered by Paget Resources Corporation geologists in several localities, both proximal to the contact zone between clinopyroxene-phyric, variably silica-altered and stockwork-sulphide-mineralized mafic volcanic rocks and overlying tuffaceous sedimentary rocks. A new polymetallic massive sulphide occurrence and a new highly prospective zone for VMS mineralization were discovered on the Dragon property. Massive sulphide mineralization on the Dragon property is located proximal to the contact between massive, variably silica-altered and stockwork-sulphide-mineralized felsic volcanic rocks (dominantly rhyolite flows) and overlying volcano-sedimentary rocks, chert and carbonate rocks. The juxtaposition of fossiliferous carbonate rocks and felsic tuff with underlying VMS mineralization and felsic volcanic rocks is observed nowhere else in the Sicker Group It raises the possibility that volcanic rocks and mineralization on the Dragon property may represent a cycle of arc magmatism and VMS mineralization not previously recognized on Vancouver Island.

Geochemistry: Preliminary major and trace element geochemistry for Sicker Group rocks of the Cowichan, Port Alberni and Hesquiat areas indicate that rocks of basalt through dacite-rhyolite composition are present in all areas, though felsic volcanic rocks are most abundant in the Cowichan area. Transitional to calc-calkaline affinities are most prevalent for volcanic rocks of the Cowichan area, whereas volcanic rocks of the Alberni and Hesquiat areas are characterized by tholeiitic to transitional affinities, indicating a possible transition from a volcanic arc to back-arc setting, respectively. Volcanic rocks of all areas exhibit light rare earth element enrichment and negative Nb-Ti anomalies, indicating generation in a subduction zone setting.

Lead Isotopes: Lead isotope data indicates that several cycles of VMS mineralization are present in Sicker Group rocks, including potential cycles both younger (Hesquiat area) and older (Debbie 3) than VMS mineralization associated with the past-producing Big Sicker Mountain and the producing Myra Falls deposits. Also, apparent stockwork/stringer-style VMS mineralization in the Sicker Group may actually be younger, epigenetic mineralization that is not prospective for VMS mineralization. This indicates that the lead isotope signatures of stringer-style sulphide mineralization should be evaluated by explorationists prior to drill testing as a cost saving measure.

Future Work

Fieldwork in 2009 will be pursued in the Cowichan Lake and Port Alberni areas, with additional work planned in potential outcrops of Sicker Group rocks in the Bedingfield Bay and Muchalat Inlet (Gold River-Hesquiat) areas. In the Cowichan Lake area, work will focus on understanding the stratigraphic and volcanological setting of VMS occurrences hosted by the Sicker Group, particularly those of the Lara/Coronation, Randy and Anita zones, north and west of Big Sicker Mountain (MINFILE occurrences 092B 129, 092B 128 and 092B 037, respectively). Particular emphasis will be placed on understanding the stratigraphic and volcanological setting of other potential VMS occurrences in the immediate vicinity of, and west of, Cowichan Lake. Additional regional work in the Alberni area will focus on identifying stratigraphic marker horizons within the Sicker Group that can be used to trace regional scale stratigraphy, particularly that belonging to the Duck Lake and Nitinat formations.

In the Bedingfield Bay and Muchalat Inlet areas, similar regional and focused outcrop-scale mapping and sampling will be conducted to better understand the stratigraphy and volcanological setting of potential Sicker Group rocks and VMS occurrences, most notably in the vicinity of the Rant Point occurrence (MINFILE occurrence 092F 494) and the Dorado and Dragon properties (Paget Resources Corporation). In parallel with the geological mapping and synthesis work, the authors will also carry out additional U-Pb dating, lithogeochemical, and Nd, Hf and Pb isotopic studies to constrain the age and magmatic evolution of Sicker Group volcanic rocks and to develop a framework through which VMS occurrences hosted by the Sicker Group can be distinguished from younger, epigenetic sulphide occurrences.

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