An update on the mineral deposit potential of the Nootka Sound Region

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Geoscience BC

ABSTRACT

The Nootka Sound region is host to a few small ore deposits. These are skarns (Ford and Silverado) and in trusion-related Au mineralization, such as the Privateer in the Zeballos camp. The area was mapped in the 1980s by Muller et al. (1981), a large portion being categorized as a metamorphic complex representative of mid-crustal level rocks.

This over simplification and misidentification of metamorphic grade in the area, combined with difficult access, terrain, and proximity to parks have made exploration difficult. Preliminary work in the Nootka Sound region indicated that the rocks in the area were locally contact metamorphosed by the Jurassic Island and Tertiary Mount Washington intrusive suites, but had not been subjected to high-grade regional metamorphism and thus could be correlated with the rock units in the southern and eastern parts of Vancouver Island (cf. Massey, 1991; Massey, 1995; Yorath et al., 1999; DeBari et al., 1999;). Potential correlation of these rocks with the Sicker Group also makes these rocks prospective for volcanogenic massive sulphide (VMS) type mineralization, such as at Myra Falls (Barrett and Sherlock, 1996).

The primary goals of this study are to promote exploration in the area through improved geological mapping, lithogeochemistry, metallogeny and mineral-deposit studies. This paper summarizes this summer's mapping and some preliminary lithogeochemistry, which are part of a Geoscience BC project focused on improving the bed rock mapping in the Nootka Sound area. Basic prospecting and reconnaissance sampling were under taken during the mapping. Work continues on completion of a lithogeochemistry study of the various rock types and on a revised metallogenic interpretation of the area, based on new mapping, geochemistry and geochronology.

REGIONAL GEOLOGY

The study area is part of the Insular belt of the Canadian Cordillera (Jones et al., 1977; Wheeler et al., 1981) comprised of a number of accreted volcanic terranes. Thus the area consists mostly of meta-volcanic rocks and their plutonic counterparts. Regional deformation is not pronounced. However, some rocks locally display minor tectonic foliation. Regional metamorphic grade in the area ranges up to middle greenschist facies. Local contact-metamorphism around the intrusive rocks ranges from green-schist to migmatite, with many examples of partially melted inclusions of country rock. There are abundant brittle faults in the area ranging from local to grand scale. In most cases the volcanic rocks are greenschist equivalents of Sicker, Bonanza and Karmutsen. The volcanic rocks are in most cases impossible to distinguish in the field with it being virtually impossible to distinguish Sicker and Bonanza volcanics in the study region even by geochemistry. The intrusive rocks are typical of the Jurassic Island Intrusive and the Tertiary Mount Washington suites. Some of the more altered intrusive rocks may also be related to Sicker volcanism.

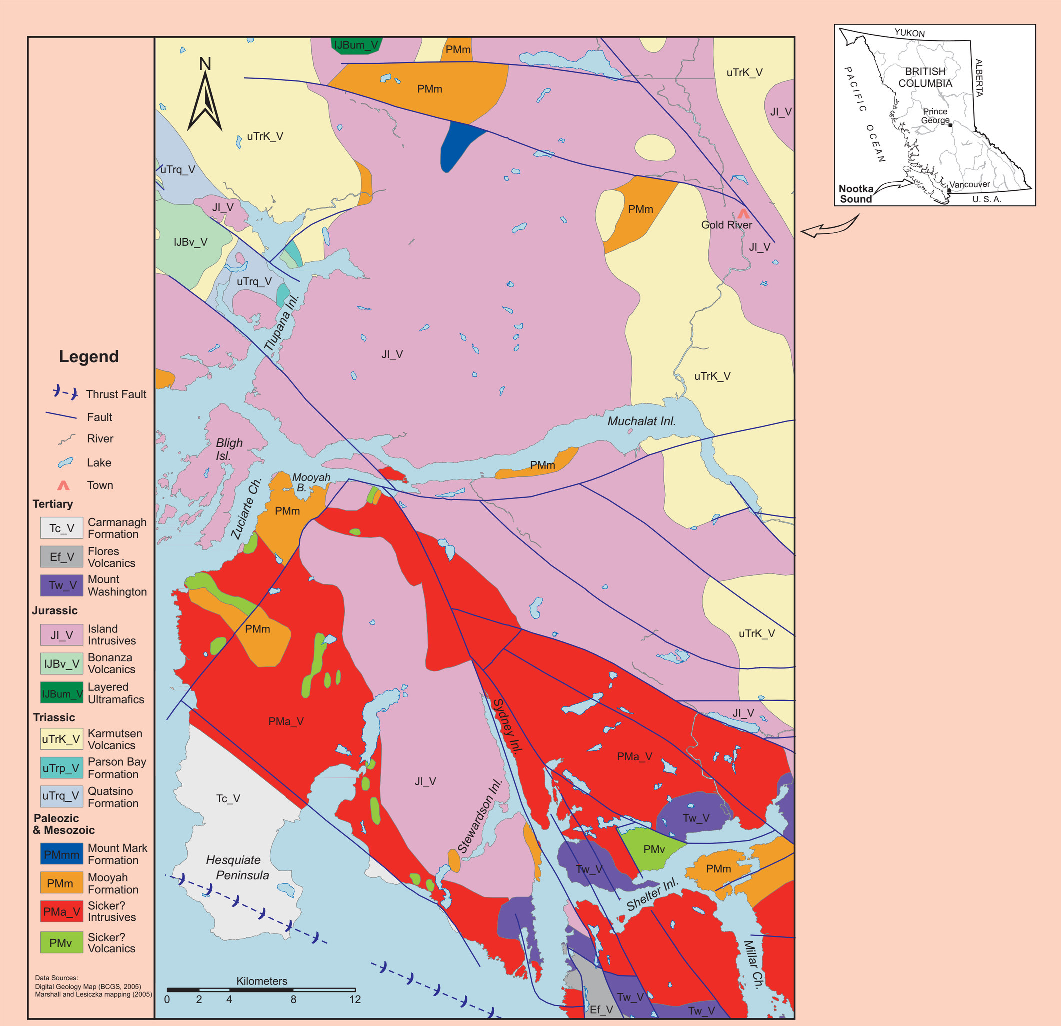

Fig. 1. Preliminary geologic map of the study area (after Muller et al., 1981 and Marshall et al., 2005)

LITHOLOGIES

A preliminary geology map (Fig. 1) and stratigraphic column (Fig. 2) for the rocks of the Muchalat Inlet area have been derived based on field observations, air photos, previously published reports and maps. Most of this year's mapping was concentrated on the areas surrounding and between Muchalat and Stewardson Inlets.

Older Basement Rocks

The older basement rocks are comprised of fine grained mafic rocks and more coarser grained intrusive rocks. The finer grained rocks appear to be mostly dykes or flows and exhibit no textures characteristic of extrusive volcanic rocks. Both the fine grained and coarser grained older basement rocks have been altered. Muller et al. (1981) mapped these rocks as Paleozoic and Mesozoic in age. Distinctive geochronologic relationships with most of the rocks in the area are absent, but the higher degree of alteration observed in these rocks was not seen in the Jurassic intrusive rocks nor the Triassic extrusive rocks. Thus we infer that these rocks are pre-Triassic. However the altered coarse grained rocks may be as young as early Jurassic and experienced a higher degree of alteration due to emplacement at depth. Geochronological work is underway to determine the exact age.

Fine grained volcanic and higher level intrusive fine grained rocks (Pmv)

These rocks are light to medium grey on the fresh surface and dark brown/maroon on the weathered surface. Grain size ranges fine grained (aphanitic to a few mm) basalt-dacite to a plagioclase phyric basalt-dacite and locally even a plagioclase hornblende phyric basalt-dacite. Plagioclase and hornblende phenocrysts are up to 2 mm. The contacts between the different types of volcanics are diffuse. There are varying amounts of alteration with chlorite, yellow-green epidote-quartz veinlets up to 2 cm wide, clasts up to 15 cm, and very small stringers (0.5 mm) of sulphides. The volcanics are intruded by dykes up to 3 meters and veinlets of hornblende diorite and biotite hornblende diorite as well as rhyolite dykes. Within the volcanics, there are dykes, patches and veinlets of equigranular coarser grained (2-3 mm) gabbro-like material due to partial remelting and recrystalization. The volcanics are highly fractured and deformed within brittle faults and shear zones.

Coarse grained intrusive rocks (PMa_V)

These rocks are dark grey to whitish when fresh and white to tan brown when weathered, ranging from diorite to hornblende diorite (with abundant mafics) to hornblende granodiorite. The intrusive rocks are equigranular, coarse grained with grain size varying from 1 to 5mm with generally finer grained mafic phases. There is epidote alteration and epidote quartz veining along fractures. Abundant fine grained, rounded to angular volcanic inclusions that generally range up to 30 cm with some up to 3 meters in length. There are abundant examples of local remelting and recrystalization of some of the volcanic clasts. Some basaltic inclusions have completely recrystalized to fine grained hornblende diorite. The intrusives are intruded by many basaltic dykes up to 1.5 m wide striking generally at 330 to 360° with steep dips.

Mooyah Formation (Pmm)

The Mooyah Formation is comprised of sedimentary and volcaniclastic rocks with variable lithologies. The rocks are best exposed in Mooyah Bay, Anderson Point and along the northeastern parts of Zuciarte Channel. The rocks are interbedded cherty shales, sandstones/greywackes and conglomerates of turbidite sequences with layers generally up to 20 cm thick with some more cohesive sandstone layers up to 1 meter thick and some pebble conglomerate layers up to 2 meters. Finely layered (1-2 cm) shaley beds are mostly found interbedded with coarser more massive layers of sandstone and/or siltstone/sandstone. The sandy layers are pebble rich with abundant (30%) white weathering feldspar-rich clasts in a sandy matrix. The silty/sandy rocks have interlayered light and dark gray laminations up to 1 m thick. Some layers contain feldspar crystals and small pebbles (4 mm) of chert, and can be gossanous locally. There are also alternating sandy and silty crystal tuffs with very subtle layering. The crystal tuffs have 3-4 mm feldspar and hornblende crystals and smaller shaley clasts. The conglomeratic rocks have well rounded fragments of volcanic rock up to 8 cm long, smaller fragments (2 cm) of a more felsic volcanic phase, quartz and feldspar fragments, and some hornblende crystals ranging up to 5mm in a very fine grained volcanic matrix with no visible bedding. There are also minor beds of limestone and fine grained diopside garnet skarn at a few locations. The finer grained sediments can be massive and have well developed bedding with NE strikes. They are light grey to black when fresh and a buff to rusty brown color on the weathered surface. Fining upwards sequences, ripple marks and rip up clasts in number of locations indicate tops up in all locations displaying geopetal indicators.

The Mooyah Formation is intruded by diorite, rhyolite and mafic dykes, and cut by quartz veins with minor epidote. There are some fine grained epidote clasts (5 cm) and epidotized patches. The rocks are slightly deformed by fracturing and shearing as well as by broad, low amplitude folds indicating antiformal closure to the north. The total thickness of the package is difficult to estimate due to possible apparent thickening due to folding and fault repitition. However we estimate the total package to be on the order of 1 km in thickness. Although the geochronology of the Mooyah formation is not yet established we have interpreted it as pre-Triassic. The volcaniclastic rocks of lower Mooyah Formation may be correlative with the McLaughlin Ridge Formation, while the upper Mooyah Formation is probably correlative with the Fourth Lake Formation (Yorath et al., 1999).

Karmutsen Formation (uTrK_V)

The Karmutsen rocks were not studied in detail. In general the Karmutsen volcanics (uTrK_V) are a relatively thick (~4km) Triassic succession of dominantly pillow and massive basalts with comagmatic dykes/sills, and minor sedimentary and volcaniclastic rocks (Yorath et al., 1999).

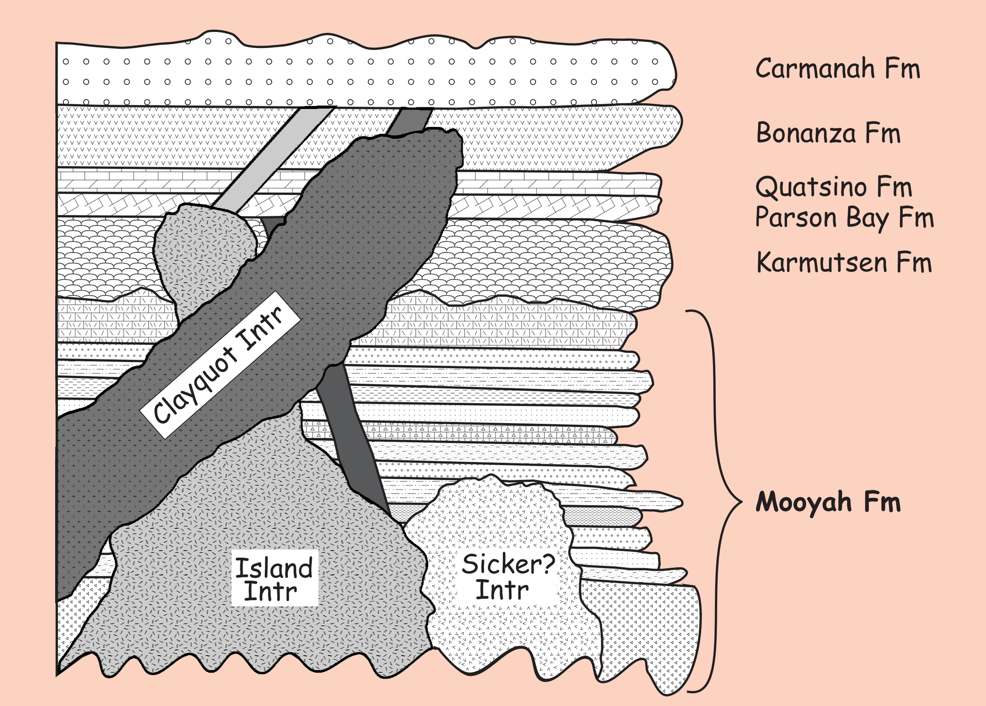

Figure 2. Idealized stratigraphic column. Unit thicknesses are not to scale. The base of the newly named Mooyah Formation is potentially equivalent to the McLaughlin Ridge Formation (Yorath et al., 1999) and the lower parts Mooyah Formation are possibly correlative with the Fourth Lake Formation (Yorath et al., 1999). The upper calcareous units of the Mooyah Formation may be possible correlatives with the Mount Mark Formation (Yorath et al., 1999). Note the intrusive rocks lableled as Sicker intrusives rocks are not dated and no contact relationships have been established in the field. Thus these rocks may possibly be an early generation of Jurassic Island Intrusive suite or may be as old as upper Paleozoic.

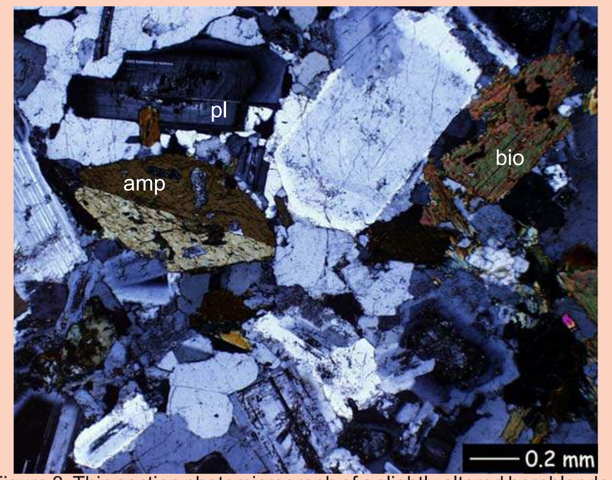

Figure 3. Thin section photomicrograph of a slightly altered hornblende-biotite diorite form the Island Intrusive Suite (Sample DM-05-182). Note the twinned poikiloblastic hornblende with typical amphibole (amp) cleavage intersection angles, zoned plagioclase (pl) and slightly altered biotite (bio). Photograph taken in plane polarized light.

Quatsino and Parson Bay Formations (UTrq_V and UTrp_V)

The Triassic Parson Bay Formation is not well represented in the study area. The few outcrops observed were shaley limestone and were consistent with other descriptions of this rock type (c.f. Yorath et al., 1999; Muller et al., 1974; 1981; Jeletzky, 1976). Likewise outcrops of the Triassic Quatsino Formation are not abundant and the reader is directed to other publications for more in depth discussions of these rocks (c.f. Yorath et al., 1999; Muller et al., 1974; 1981; Jeletzky, 1976)

Island Intrusive Suite (JI_V) and layered ultramafic (uTrKum_V)

Rocks from the Jurassic Island Intrusive suite vary from biotite-hornblende granodiorite to biotite-hornblende diorite (Fig. *3*). The rocks are black and white on fresh surfaces and white on the weathered surface. They are equigranular coarse grained with occasional (1 cm) quartz veins. The grain size ranges up to 8mm. There are numerous volcanic inclusions ranging from angular to rounded, generally up to 30 cm in length with few up to 1m in length. The clasts can be fine grained basalt to completely recrystalized finer grained mafic diorite. Clasts with partly recrystalized hornblende and plagioclase edges and remnant basalt cores are evidence of partial remelting and migmatization of the clasts. Within the diorite, there are also very large screens (10s of meters) of layered Mooyah sediments. The Island Intrusive rocks are intruded by number of different types of dykes ranging from fine grained granitic dykes (4 cm wide), mafic plagioclase phyric dykes, aphanitic rhyolite/dacite dykes (1m), diorite dykes (40cm wide) to mafic basalt-gabbro dykes up to 1.5 m in width. The rocks are locally fractured and sheared, but to a much lesser degree than the basement rocks. There is some vein type mineralization along faults and shears with minimal amounts of hydrothermal alteration comprsied of fine grained chlorite, epidote and quartz along fractures.

The new ultramafic unit found on the upper reaches of the Conuma Main is comprised of layered gabbros and pyroxenites (Fig. 10). The pyroxenite layers vary up to 60 cm in thickness and are comprised of relatively coarse grained (5mm) equigranular pyroxene, phlogopite and plagiclase. The pyroxene comprises 85% of the rock with 10% phlogite and 5 percent plagioclase. The gabrroic layers are generally thinner ranging up to 30 cm and are comprised of equal amounts of equigranular plagioclase and pyroxene with grain sizes ranging up to 7 mm. This unit is arbitrarily assigned to the Jurassic. No contact relationships were observed with the surrounding Jurassic Island Intrusive suite or the neighbouring Karmutsen rocks, thus the layered ultramafic rocks might be Triassic.

Bonanza Group Rocks (lJBv_V)

The Triassic Bonanza Group rocks are considered to be dominantly the extrusive equivalents and associated minor sediments of the Island Intrusive Suite. These rocks outcrop in the northern portions of the study area and also to the west on Nootka Island. The Bonanza rocks are calc-alkaline pyroclastic rocks and associated hypabyssal rocks (Yorath et al., 1999). The rocks tend to weather a slightly reddish colour and are generally dark grey on the fresh surface. The entire suite tends to be plagioclase phyric with the plagioclase phenocrysts ranging up to several mm in length. These rocks were not studied in detail duing this field season and no attempt has been made to subdivide the group into subunits as in Yorath et al. (1999), Muller et al. (1981) and Jeletzky (1954).

Mount Washington Intrusive Rocks (PEmw_V)

Tertiary intrusives are difficult to distinguish from the Jurassic Island Intrusive suite. In the field they have been distinguished by their large plagioclase phenocrysts in a finer grained matrix and fresher mafic minerals. The rocks range in composition from granodiorite to diorite with matrix grain size varying up to 4 mm and porphyritic plagioclase ranging up to 1 cm. The mafic contents vary up to 15% with amphibole generally the dominant mafic phase, but usually accompanied by biotite. The fresh surface is generally white with black mafic minerals and aphanitic basaslt to ghosted diorite clasts. Clasts are rare compared to the Island Intrusive suite, but they can range in size upto 30 cm and in some rare cases comprise up to 10% of the rock. The weathered surface is generally a light tan to white colour.

MINERALIZATION POTENTIAL

The study region is host to a number of different deposit types. The largest of these is the Silverado Mine and associated mineralization such as the Baltic and Danzig. These are recorded as Skarn and replacement type deposits in limestone and Island Intrusives (BCMinFile). The combined deposits produced 5,567 gms Au, 10,294 gms Ag and 87 kgs of Cu. Other interesting mineralization types hosted within similar rocks adjacent to the study area include the minor Au in pyrrhotite veins such as at Beano on the Little Zeballos River, VMS type mineralization within the Sicker Group at Myra Falls, Intrusion-related Au in the Zeballos camp, and Fe-skarn mineralization such as at the Ford Mine.

Sulphide Vein Type Mineralization

The sulphide vein type mineralization found on the H7000 spur north of Stewardson Main is similar to the mineralization at the Beano showing near the mouth of the Little Zeballos River. The mineralization at Beano consisted of three types (BCMinFile). These were quartz-calcite-pyrrhotite stringers, disseminated pyrrhotite and lenses of massive pyrrhotite. The H7000 mineralization resembles the lenses of massive pyrrhotite from Beano consisting of a vein of massive pyrrhotite with blebs and veinlets of chalcopyrite, and inclusions of altered host rock. The inclusions consist of chlorite and comprise approximately 10% of the vein material. The chalcopyrite veinlets appear to cut the massive pyrrhotite within the main vein and comprises as much as 2% of the rock. The vein strikes N-NE and dips 80° W. The vein is exposed at the edge of a small pond and dissapears beneath the pond. The total length of the vein in outcrop is approximately 1.5 metres. Preliminary geochemistry on a grab sample returns 0.5% Cu, elevated As and 0.005 ppm Au. The vein width varies from 10 to 30 cm in outcrop (Fig. 4). In polished thin section chalcopyrite veins (Fig. 5) and blebs are abundant and appear to postdate the pyrrhotite. There is arsenopyrite associated with the chalcopyrite in thin section. Lack of exposure makes the vein hard to follow. However, a gossanous region can be seen on the other side of the valley directly along strike from the vein.

Intrusion-Related Au Mineralization

The study area has potential for Au mineralization similar to the Intrusion-related deposits in the Zeballos camp. The Zeballos mineralization (Figs. 6, 7, 8) is related to the emplacement of the Tertiary Mount Washington intrusive rocks. This study has tentatively identified another large intrusion of this type in Shelter Inlet. The occurrence of the Mount Washington in general proximity to volcanic rocks and Mooyah sediments is prospective. Another earmark of the Zeballos type mineralization is the presence of carbonate. No carbonate or mineralization was observed during this summer's field work. However there is much unexplored ground in the area. Additionally, a small stock of Mount Washington Intrusive as mapped by Muller et al., (1981) in Hisnit Inlet appears to be part of the Jurassic Island Intrusive suite. The intrusion was emplaced into Quatsino and Parson Bay carbonates and this makes it prospective for Silverado-type mineralization. A small marble quarry exists in the marbles near the intrusive contact amd indicates that metamorphic conditions are probably correct for skarn-type mineralization.

VMS Type Mineralization

The study area is host to some metavolcanic rocks. Preliminary geochemistry and the presence of the overlying Mooyah Formation indicate that some of the volcanic rocks are most likely Sicker Group volcanic rock equivalents and correlative to the rocks hosting the Myra Falls mine as described by Barrett and Sherlock (1996). The rocks at one locality (Fig. 9) are highly gossanous and contain abundant mineralized veins up to 15 cm wide comparable to typical VMS stockwork mineralization. The host rocks are massive flows and volcaniclastic rocks with abundant chlorite-epidote alteration. The gossanous zones extend up to 10 m in width and a grab sample from one of the highly weathered sulphide veins returned 2.5 % Cu.

Skarn Type Mineralization

Skarn mineralization has been reported at Silverado within the study area and nearby at a number of locations, most notably the Ford Fe-Skarn north of Zeballos. The Silverado is hosted within limestone of uncertain age near the flanks of a large Jurasic Island Intrusion. It is predominantly a Zn skarn with minor Ag, Au and Cu mineralization. The Ford skarn is hosted within Triassic carbonates. It is magnetite skarn and is associated with the emplacement of Jurassic Island Intrusions. There are two localities found this summer that have similar geological settings of calcareous rocks intruded by Jurassic Island intrusions. The exposed areas of carbonate were limited and although there was abundant evidence of calc-silicate skarn minerals, there was little observed sulphide mineralization. However, due to limited access and heavily vegetated terrane, there still remains abundant unprospected area.

Layered Ultramafic Rocks

Although not one of the targets of this project, layered ultramafic rocks (Fig. 10) were found on the Conuma Main in the north central portion of the study area (Fig. 2). As noted above these rocks have been arbitrarily assigned to the Jurassic but could also be Triassic in age. Ar-Ar dating is in progress. If these rocks are Triassic and thus related to massive outpouring of mafic lavas forming oceanic plateaus during relatively short time intervals then this rock type may be analogous with similar rocks hosting such deposits as Noril'sk-Talnakh, and the Thompson Ni belt. The presence of this rock type in the area certainly makes the region prospective for Ni- and PGE-rich magmatic sulphides (c.f. Green et al., 2004).

Figure 4. Gossanous zone containing a pyrrhotite vein cutting poorly bedded Mooyah Formation sediments from the H7000 spur of the Stewardson Main Line. The vein is comprised of predominantly massive pyrrhotite with minor veinlets and blebs of chalcopyrite visible in hand specimen. The vein host-rock contacts vary from sharp to diffuse. Hammer for scale.

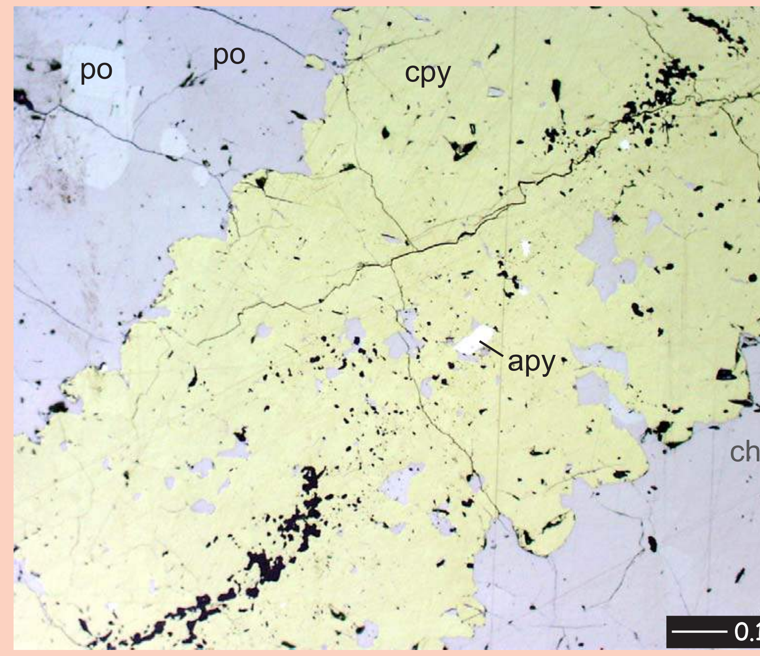

Figure 5. Polished thin section photomicrograph of the pyrrhotite vein shown in Figure 4. A veinlet of chalcopyrite (cpy) cuts the generally massive pyrrhotite (po). Arsenopyrite (apy) is present in lesser quantities in the chalcopyrite veinlets. Inclusions of chlorite (chl) are present in both the pyrrhotite and chalcopyrite. The chlorite in some instances appears to be pseudomorphs of amphibole and may represent metamorphosed inclusions of country rock. Photograph taken under partly crossed polars.

Sample number	Desc.	Au (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppm)	As (ppm)	S (wt.%)	Co (ppm)	Cr (ppm)
05-13	VMS	NA	**24700**	69	11	217	17.6	6	6.7	155	24
05-11	Po vein	0.005	4900	260	59	5	0.5	45	37.4	462	<1

Notes: NA: Not Analyzed, Po: pyrrhotite, VMS: Stockwork-like mineralization, wt.%: weight percent

Table 1. Selected geochemical results for the gossanous volcanic rock occurrence and the pyrrhotite vein (H7000 spur).

Also see: http://www.em.gov.bc.ca/DL/GSBPubs/GeoFldWk/2005/Paper27.pdf

Fig. 6. Slab of gold bearing quartz (qtz) vein from the Privateer Mine. Slab length is approximately 15 cm. Note the relationship between the galena (gn) which replaces arsenopyrite (apy) and gold (au) which cuts both the arsenopyrite and galena.

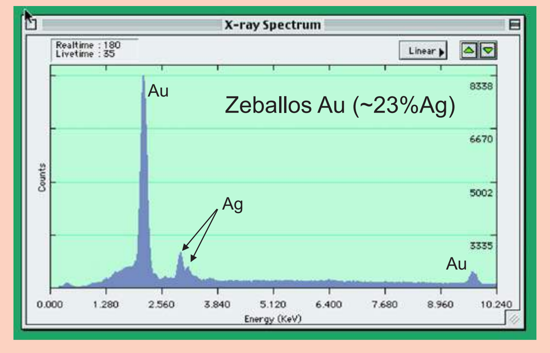

Fig. 7. Au-EDS spectrum for Privateer Mine sample. This is consistent with the gold containing 23 weight percent silver. This relatively high silver content is generally thought to represent gold precipitation in the epithermal environment. Thus the Privateer Mine may have a component of epithermal mineralization in its genesis.

Fig. 8. Photograph showing the back of 2-3A vein (Privateer Mine). Some deformation is accommodated in a brittle manner as evidenced by the splays coming off the main vein. While some structures within the vein show ductile deformation textures (see arrow). Hammer (with flagging tape) for scale.

Figure 9. Gossanous zone within altered mafic volcanic rocks, containing dispersed sulphide veins similar to a typcial VMS stockwork zone. The vein on the extreme left (arrow) contains 2.5 % Cu. The photograph is approximately 10 metres in width.

Figure 10. Gently eastward-dipping layered ultramafic rocks on the Conuma Main Forestry Road. The layers are comprised of alternating bands of coarse grained gabbro (gbo) and relatively finer grained peridotite (pdt). Hammer for scale.

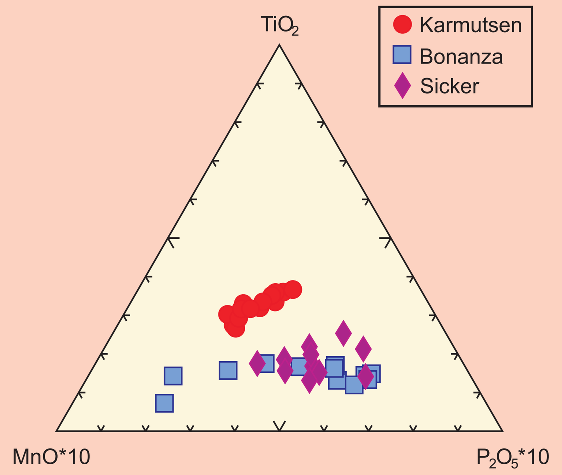

Fig. 11. Ternary (Mullen, 1983) diagram showing the data for all volcanic rocks from Yorath et al. (1999) and Barker et al (1989). This diagram can be used to distinguish Karmutsen volcanic rocks from the other two volcanic units on Vancouver Island.

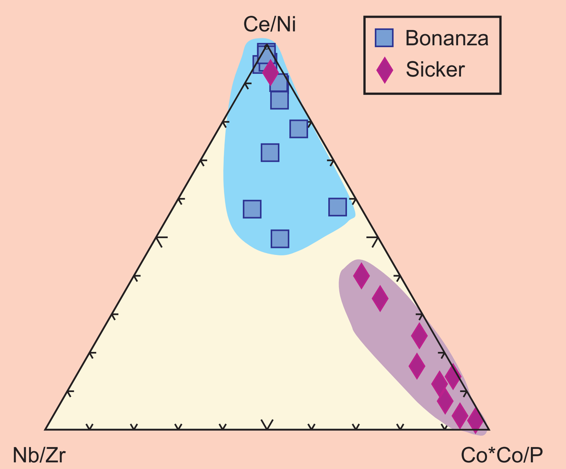

Fig. 12. Ternary diagram showing the data for all volcanic rocks from Yorath et al. (1999) and Barker et al (1989). This diagram performs **reasonably** well at distinguishing between Bonanza (blue squares) and Sicker (purple diamonds) volcanic rocks

GEOCHMEMICAL DISTINCTION BETWEEN THE VOLCANIC UNITS

One of the major problems with mapping in the Nootka Sound region is the distinction of the volcanic rocks in the area. In other parts of Vancouver Island Volcanic textures and stratigraphic relationships can be used to distinguish between the various volcanic rocks. In general the volcanic rocks in the Nootka Sound region tend to be massive. Discriminationg between the Karmutsen and the other two volcanic rocks can be done on a Mullen-type diagram (Fig. 11). An additional diagram (Fig. 12) can be used to discriminate between the Bonanza and Sicker volcanic rocks. This diagram has been used to determine some of the volcanic rocks mapped in the Muchalat Inlet area (Fig. 1).

CONCLUSIONS

Field work is consistent with the rocks of the West Coast Crystalline complex experiencing a much lower grade of metamorphism than suggested by Muller et al. (1981). These preliminary results (Fig. 2) indicate that the rocks contained within the complex are probably correlative with other stratigraphic units on Vancouver Island, especially the sediments within the Mooyah Formation. The base and upper portions of the Mooyah Formation are probably correlative with the McLaughlin Ridge and Fourth Lake Formations respectively. Additionally this summers field work has identified some exploration targets:

1) **At least one new occurrence of the Mount Washing Intrusive Suite which is associated with Au-mineralization in the neighbouring Zeballos Gold Camp.**
2) **A previously undocumented occurrence of layered mafic rocks near the contact between Jurassic and Triassic rocks has potential for Ni- and PGE-rich magmatic sulphide mineralization.**
3) **Encouraging Cu numbers (2.5% Cu) from complex vein networks and possible stockwork mineralization from the altered volcanics near Stewardson Inlet.**
4) **Potential for skarn mineralization in the area similar to the neighbouring Silverado and Ford Skarns.**
5) **Massive pyrrhotite veins with minor chalcopyrite mineralization are similar to the veins described from the nearby Beano Au deposit on the Little Zeballos River.**

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