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ADVANCED ARGILLIC ALTERATION IN BONANZA VOLCANIC ROCKS, NORTHERN VANCOUVER ISLAND — TRANSITIONS BETWEEN PORPHYRY COPPER AND EPITHERMAL ENVIRONMENTS (92L/12)

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INTRODUCTION

Hydrothermally altered Bonanza volcanic rocks in the Quatsino map area (NTS 92L/12) were examined in order to describe the style of copper-gold mineralization in the extensive zones of argillic and advanced argillic alteration that occur in the area. This work is part of a province-wide study of intrusion-related advanced argillic, acid sulphate mineralization started in 1991 (Panteleyev, 1992). It is intended to investigate the potential for precious metal and copper-gold deposits in these settings and to develop genetic models.

Magmatic hydrothermal systems associated with subvolcanic porphyry intrusions can produce mineralization ranging from high-level porphyry copper to near-surface epithermal and hotspring types. Between the deep and shallow hydrothermal levels is a '*transitional*' environment in which strongly saline, relatively high temperature hydrothermal fluids of largely magmatic origin are active. These robust fluids are not representative, in a strict sense, of either porphyry copper or most epithermal systems. The associated mineral deposits and alteration are characterized and recognized by the presence of phyllic and/or (high-temperature) advanced argillic alteration and abundant sulphide minerals in a distinctive mineral suite. The copper and precious metal ores, in addition to abundant pyrite, may contain chalcocite, covellite, bornite and chalcopyrite as well as arsenic and antimony minerals, typically enargite/luzonite and tetrahedrite/tennantite and minor sphalerite, galena, arsenopyrite, gold and numerous other complex sulphosalt minerals. Characteristic gangue consists of abundant silica with kaolinite, dickite, sericite/illite, pyrophyllite, diaspore, alunite, barite and various other aluminous, sulphate and phosphate minerals including zunyite ($Al_{13}Si_5O_{20}(OH,F)_{18}Cl$). The mineralization has been variably referred to as *acid sulphate, high sulphidation, quartz-alunite, alunite-kaolinite (pyrophyllite), enargite-type, Nansatsu-type* and a number of other names. This type of mineralization can be considered to be a distinct deposit type or a subset of epithermal deposits (White, 1991).

The hydrothermally altered rocks typically contain quartz and vuggy to massive, residual 'slaggy' silica with kaolinite, dickite, alunite and, in some cases pyrophyllite, diaspore and zunyite. This alteration assemblage forms in zones of acid sulphate alteration, a product of sulphuric acid leaching. The sulphuric acid is formed in three ways, as summarized by Rye *et al.* (1992): as a product of magmatic vapour-derived SO_2 interaction with water – a potentially mineralizing magmatic-hydrothermal setting; a steam-heated system where H_2S is oxidized to sulphuric acid above the water table – usually an unmineralized zone, common in geothermal settings; and a supergene leaching environment. The alteration zones produced by these three processes can be large and visually striking. However discovery of ore is a difficult task unless the origin of the alteration and the depth-zoning relationships of the hydrothermal systems are understood.

Mineral deposit types found to date in advanced argillic Bonanza rocks in northern Vancouver Island include the Island Copper mine, Hushamu/Mount McIntosh (EXPO) and the Red Dog porphyry copper-gold-molybdenum deposits. In addition, a number of large siliceous zones with advanced argillic alteration have been explored in the Wanokana River - Pemberton Hills area and regions both to the east and west. These mineralized environments, among others in the province, are similar to a number of the high-level Andean (Sillitoe, 1991a) and southwest Pacific porphyry copper and related deposits with advanced argillic overprints (Sillitoe, 1989, 1991b). Potential for ore in this environment also occurs in deposits far removed from plutons, such as the structurally controlled high-grade veins at El Indio, Chile, the lithologically controlled replacement bodies at Lepanto, Philippines and the bulk mineable breccia zones at El Tambo, Chile. The extensive silica-clay replacement bodies at the tops of the high-level hydrothermal systems have been mined in Japan for ceramic materials. Some Japanese silica deposits such as in the Nansatsu district, are known to contain or be underlain at slight depth by both bulk-mineable and bonanza-type precious metal mineralization Izawa (1991).

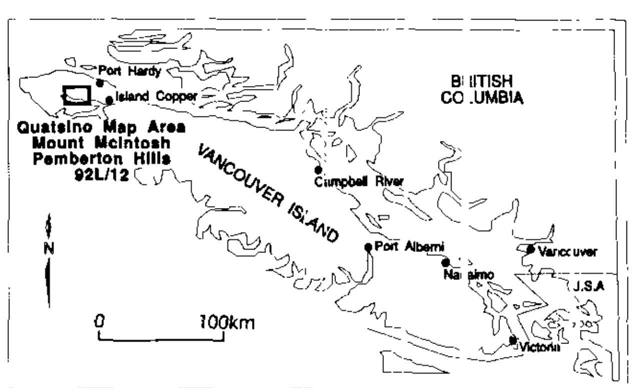

Figure 2-7-1. Location map.

THE BONANZA VOLCANIC BELT, QUATSINO MAP AREA

STRATIGRAPHY AND LITHOLOGIES

We mapped an area of about 125 square kilometres in the west-central part of Quatsino map area, between Nahwitti Lake on the north and Holberg Inlet on the south (Figure 2-7-1). Mapping was focused mainly in the northwest-trending belt of Lower Jurassic Bonanza Group volcanics and Jurassic Island Plutonic Suite. To the north, the Bonanza rocks are underlain by older rocks, part of the Upper Triassic Vancouver Group. This underlying unit comprises, in sequence, progressively older rocks of the Parson Bay, Quatsino and Karmutsen formations. In the south of the map area, along Holberg Inlet, are patches of sedimentary rocks of the Lower Cretaceous Longarm Formation, part of the Kyuqout Group. A simplified geological map of the area is shown on Figure 2-7-2.

Bonanza volcanics of northwestern Vancouver Island have been described in some detail by Muller *et al.* (1974) and Muller (1977). The rocks are generally considered to be andesitic to rhyodacite lava, tuff (and) breccia (Muller and Roddick, 1983). These volcanic units are exemplified by the apparently bimodal basalt-rhyolite assemblage near Quatsino Sound in the Mahatta Creek map area (NTS 92L/5), described by Nixon *et al.* (1993, this volume). In contrast, our mapping to the north, in the Quatsino map area, shows the volcanic assemblage to consist almost entirely of pyroxene-phyric basalt and pyroxene-plagioclase-phyric basaltic andesite flows, breccia and minor tuffaceous sediments. Only one small area with rhyodacite and rhyolite was noted in the succession; it is probably part of a local flow-dome complex. The mainly basaltic rocks in the volcanic belt north of Holberg Inlet are similar to the lithologies farther to the east in the Rupert Arm area near the Island Copper mine. The geology there is described by Northcote (1971), Northcote and Robinson (1973) and Cargill *et al.* (1976).

In our map area the Middle to Upper Triassic Karmutsen Formation consists of a succession of thick flows, dikes or sills and some pillow basalt, pillow breccia and tuff. Local intercalation of limestone towards the top of the unit is reported elsewhere (Muller *et al.*, 1974). The top of the unit

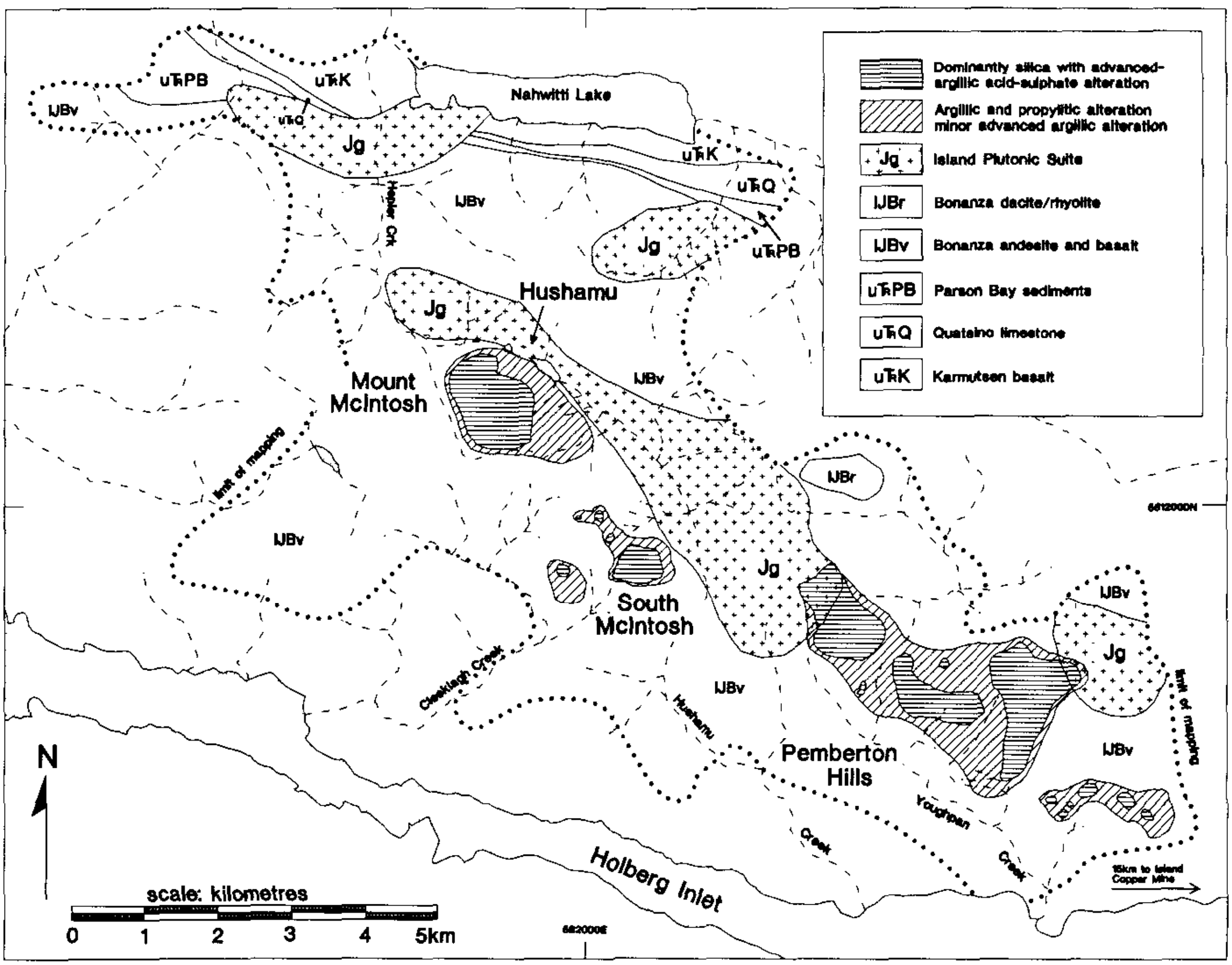

Figure 2-7-2. Generalized regional geology map with alteration patterns, part of NTS 92L/12.

is marked by a paraconformable contact with Quatsino limestone. The thick-bedded to massive, grey to black limestone grades upward into the Upper Triassic Parson Bay Formation that consists of thin-bedded to finely laminated dark grey argillite, shale and siltstone. These rocks are extensively intruded and altered to a calcsilicate assemblage throughout the Nahwitti Lake area. Muller *et al.* (1974) state that thicknesses of the Quatsino and Parson Bay units are up to 760 metres and 600 metres, respectively. In our map area both the units appear to be considerably thinner. The base of the overlying Lower Jurassic Bonanza Formation is difficult to establish precisely because the lower units of the Bonanza Formation consist of thin-bedded, tuffaceous sediments. These differ only slightly in appearance from the Parson Bay beds. The distinction between the units is, therefore, largely arbitrary when rock outcroppings are examined. The boundary between the two map units is further complicated by the presence of large intrusive bodies and the altered nature of the rocks, especially the calcsilicate members of the Parson Bay. We considered that the base of the Bonanza Formation is marked by the first presence of (chloritic) volcanic detritus; this seems to coincide with the presence of volcanic dust and ash-tuff beds and pyroxene basalt sills or flows in the Bonanza succession. The basal part of the Bonanza succession can be regarded as a transition from mixed sedimentary, volcaniclastic and tuffaceous deposition to dominantly volcanic conditions with pyroclastic, flow and lesser volcaniclastic accumulations. Fahey (1979) has estimated a thickness of about 1200 metres for the Bonanza volcanics near the Island Copper mine.

Rocks of the Island Plutonic Suite in the map area are medium-grained quartz diorite to porphyritic granodiorite stocks, with minor but economically important quartz feldspar porphyry dikes. A comagmatic relationship with the Bonanza volcanics is suggested by their compositions, contact relationships and range of Jurassic radiometric K-Ar dates (Muller *et al.*, 1974). Rubidium-strontium isochron ages of 174±10 Ma reported by Muller (1977) and 180 Ma obtained by R.L. Armstrong (J. Fleming, personal communication, 1992) provide the strongest support for an Early to Middle Jurassic age of magmatism.

CHEMICAL COMPOSITIONS

Descriptions by Muller *et al.* (1974) of 19 samples from the Cape Parkins section, Alert Bay – Cape Scott map area, on the map sheet to the south of our study area, suggest an overall andesitic composition for Bonanza volcanics with lesser dacite, rhyodacite and minor basalt. A calcalkaline petrogenetic character is interpreted, but some sodium enrichment due to albitization is recognized.

The chemical compositions of 17 of the least-altered rocks in our map area are listed in Table 2-7-1 and illustrated on Figure 2-7-3; an additional 11 hydrothermally altered rocks are also shown to portray the effects of hydrothermal alteration. The analyses are representative of the abundance and distribution of compositional types in the map area. The rocks are mainly basalt and basaltic andesite. The less common samples of rhyolite and dacite were collected from one area, a ridge in the northern part of the map area that probably represents a flow-dome centre. Chemical compositions shown on the total alkali-silica (TAS) diagram indicate subalkalic, possibly thloeiitic rocks.

Both the Karmutsen and the basal part of the Bonanza Formation contain abundant pyroxene basalts of similar

TABLE 2-7-1
WHOLE-ROCK MAJOR OXIDE PETROCHEMICAL DATA

SAMPLE	Map Unit*	Rock Type**	Easting	Northing	SiO2	TiO2	Al2O3	Fe2O3***	MnO	MgO	CaO	Na2O	K2O	P2O5	LOI	Total	CO2	S	FeO
Unaltered																			
92AP01/1-1	1	1	578214	5612680	51.90	0.83	17.67	8.17	0.18	2.96	7.89	3.24	1.36	0.24	4.77	99.21	2.2[illegible]	0.004	5.38
92AP01/2-2	1	1	578159	5611115	50.79	1.01	17.09	9.54	0.19	2.91	9.47	2.75	0.22	0.20	5.25	99.42	2.1[illegible]	0.001	4.81
92AP11/5-53	1	1	578534	5612376	51.47	0.80	17.50	9.12	0.19	4.50	7.74	3.05	1.04	0.20	3.69	99.30	0.4[illegible]	0.004	5.15
92AP8/5-30	1	1	576128	5617652	46.37	0.81	15.34	10.13	0.17	10.09	10.94	1.52	0.85	0.12	2.93	99.27	0.2[illegible]	0.01	7.79
92AP5/8-18	1	1	581873	5616109	51.65	0.75	18.19	8.84	0.16	5.25	9.21	3.28	0.67	0.15	1.28	99.43	0.0[illegible]	0.10	6.42
92AP01/5-5	1	2	578644	5611570	54.14	0.86	16.60	8.13	0.16	2.60	5.01	3.42	1.25	0.17	7.16	99.50	0.2[illegible]	0.001	2.[illegible]6
92AP13/10-68	1	2	582167	5611310	55.28	0.86	18.74	6.80	0.27	2.44	7.52	3.15	1.13	0.19	3.07	99.45	1.0[illegible]	0.11	4.02
92AP20/8-128	1	2	586784	5609612	54.36	0.81	15.97	8.05	0.19	4.94	3.65	3.04	1.95	0.15	6.22	99.33	1.1[illegible]	0.04	3.98
92AP21/7-132	1	2	589941	5608133	53.48	0.78	15.95	8.36	0.25	5.88	6.63	2.66	1.80	0.15	3.55	99.49	0.7[illegible]	0.003	4.98
92AP16/1-77	1	2	586791	5610934	53.64	0.83	17.54	8.52	0.16	3.01	7.31	3.05	1.72	0.23	1.76	99.77	0.4[illegible]	0.014	3.88
92VKO8-1	1	2	585921	5611889	54.46	0.77	17.49	8.60	0.20	3.57	7.61	2.84	1.32	0.23	2.64	99.73	0.1[illegible]	0.10	4.88
92VKO8-4	1	3	585900	5612159	74.22	0.27	13.05	2.09	0.11	0.86	1.72	3.27	1.87	0.08	1.84	99.38	0.0[illegible]	0.24	0.84
92AP16/7-83	1	3	585130	5612360	69.80	0.30	14.60	2.52	0.12	1.34	2.40	3.32	2.86	0.07	2.05	99.38	0.0[illegible]	1.09	1.00
92AP07/1-27	2	1	578376	5617526	48.68	2.33	13.19	14.34	0.29	6.21	10.63	2.63	0.27	0.19	0.65	99.41	0.0[illegible]	0.007	9.06
92AP22/1-140	2	1	579223	5618229	49.22	1.51	16.79	11.01	0.18	5.71	11.14	2.84	0.23	0.12	0.82	99.57	0.0[illegible]	0.013	7.97
Spilitized Matched Pair																			
92AP19/2-119	1	1	586779	5608443	49.23	0.90	19.21	9.01	0.19	3.05	10.03	2.63	0.44	0.20	4.45	99.34	1.7[illegible]	0.003	5.06
92AP19/2-120	1	4	586779	5608443	48.34	0.86	17.76	9.22	0.26	3.26	6.09	5.24	0.31	0.19	7.94	99.47	2.3	0.006	5.46
Hydrothermally Altered																			
91AP41a	1	4	580931	5613075	73.80	0.83	18.67	0.08	0.00	0.00	0.08	0.00	0.01	0.12	6.05	99.64	0.0[illegible]	0.05	0.00
91AP20/6-95	1	4	580931	5613075	96.34	1.67	0.95	0.17	0.00	0.00	0.01	0.00	0.00	0.01	0.59	99.74	0.0[illegible]	0.02	0.00
92AP19/1-109	1	4	587379	5609236	60.54	1.11	15.49	10.63	0.00	0.00	0.17	0.00	0.01	0.23	11.22	99.40	0.1[illegible]	8.16	[illegible]
92AP19/1-110	1	4	587379	5609236	70.16	1.45	18.65	1.34	0.00	0.02	0.16	0.00	0.01	0.20	7.42	99.41	0.2[illegible]	0.19	[illegible]
92AP19/1-111	1	4	587379	5609236	86.24	2.04	2.03	7.94	0.00	0.00	0.03	0.00	0.00	0.04	2.53	100.85	0.2[illegible]	0.10	0.22
92AP19/1-112	1	4	587379	5609236	93.90	2.81	2.13	0.74	0.00	0.00	0.03	0.00	0.00	0.03	1.12	100.76	0.0[illegible]	0.036	0.17
92AP19/1-113	1	4	587379	5609236	63.66	0.84	17.06	7.09	0.00	0.25	0.16	0.00	1.36	0.20	9.06	99.68	0.1[illegible]	5.78	0.07
92AP19/1-114	1	4	587379	5609236	66.68	0.67	12.92	8.55	0.00	0.21	0.14	0.00	1.51	0.21	8.38	99.27	0.0[illegible]	6.87	0.07
92AP19/1-115	1	4	587379	5609236	63.38	1.05	6.95	7.47	0.13	2.46	6.11	0.30	0.36	0.11	10.81	99.13	3.4	6.99	0.27
92AP19/1-116	1	4	587379	5609236	54.59	0.94	15.51	7.46	0.11	5.78	3.36	1.01	1.13	0.21	9.11	99.21	0.8	1.72	[illegible].23
92AP19/1-117	1	4	587379	5609236	56.74	0.83	16.02	8.44	0.17	4.48	3.56	2.62	2.60	0.17	3.60	99.23	0.2	0.57	[illegible].15
92AP19/1-118	1	4	587379	5609236	55.84	0.83	15.84	8.38	0.08	4.30	4.54	2.29	1.07	0.17	5.92	99.26	0.8	1.82	[illegible].00

* Map Unit: 1 = Bonanza volcanics; 2 = Karmutsen basalt;
** Rock Type Classification from TAS diagram: 1 = basalt; 2 = basalt/andesite; 3 = rhyolite/dacite; 4 = hydrothermally altered
*** Fe2O3 = total iron

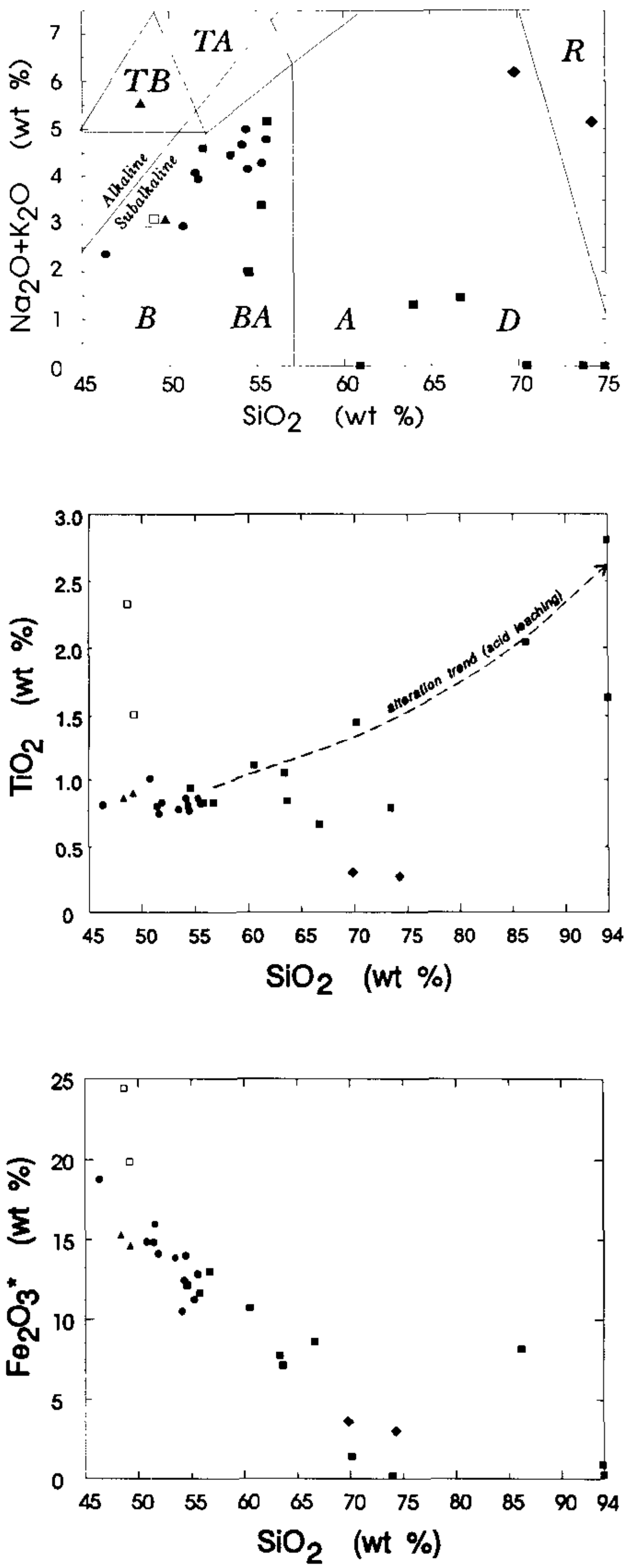

Figure 2-7-3. Whole-rock petrochemical plots. List of symbols: empty square = Karmutsen basalt; circle = Bonanza basalt/andesite; diamond = Bonanza rhyolite/dacite; triangle = spilitized Bonanza basalt; square = hydrothermally altered Bonanza volcanics.

appearance. The two units can be distinguished on the basis of TiO_2 content. It appears that Bonanza rocks contain less than 1 per cent TiO_2 and Karmutsen rocks have more than 1.5 per cent. The effects of large-scale spilitization are shown by a pair of samples (119 and 120, triangles on Figure 2-7-3). In the field, spilitized rocks that appear to predate the more intense argillic hydrothermal alteration can be recognized in the map area by their pronounced pervasive greenish cast and the abundance of chlorite and epidote. The effects of more intense hydrothermal alteration are profound base leaching with resulting silicification and (residual) alumina and titania increases. Chemical compositions of some hydrothermally altered rocks are shown as square symbols on Figure 2-7-3.

Structure

All the Bonanza rocks in the map area dip moderately to the south or southwest. The notable exception is in the Youghpan Creek area where an abundance of flat-lying sedimentary and tuffaceous beds is noted. These rocks possibly mark the site of a graben or caldera-like structure that disrupted the continuity of volcanic lava deposits along the trend to the volcanic arc. The bounding structures have

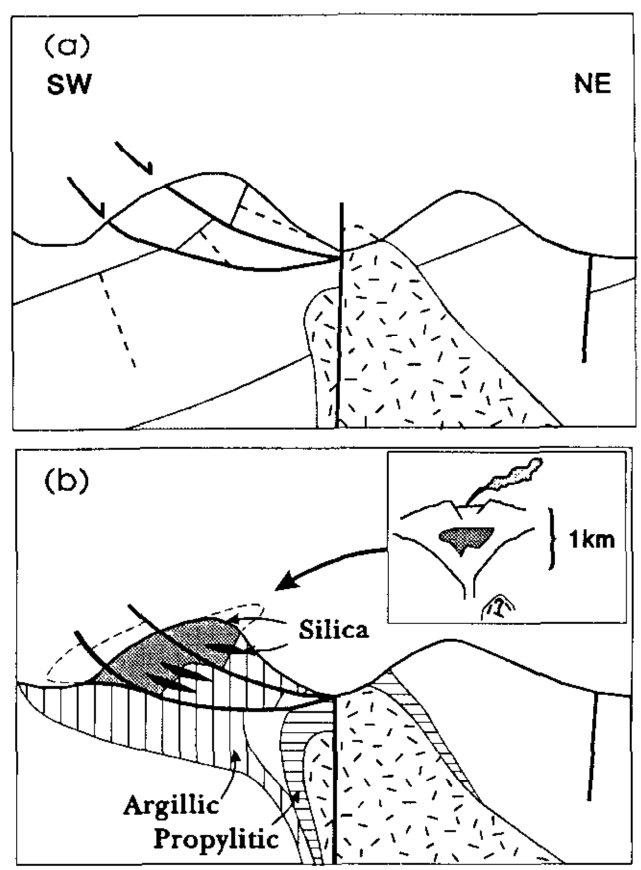

Figure 2-7-4. Structural style, diagrammatic cross-section; (a) large-scale fault block displacements of south and southwesterly dipping beds results in exposure of similar lithologies and stratigraphy in the map area; (b) tilting and low-angle normal faulting of hydrothermally altered rocks result in compression (telescoping) of alteration zones.

apparently acted as channelways for hydrothermal fluids as the bedded rocks are extensively and, in some cases, pervasively clay-altered.

The major regional structures are high-angle faults. The most prominent, and evidently the older, structural trends are west-northwest. The north to northeasterly trending structures are probably considerably younger. The northwesterly trending faults control the major valleys in the area and appear to bound fault blocks in which displacements are upward on the southwest side. Consequently everywhere in the map area it appears that the exposed rocks represent the basal, basaltic part of the Bonanza section. No other type of structural repetition of stratigraphic units is evident. A diagrammatic cross-section (Figure 2-7-4) illustrates the structural style and manner of juxtaposition of the structural and stratigraphic blocks in the map area. Some higher stratigraphic units are exposed on ridges in the southern part of the map area. There amphibole-bearing basaltic andesites occur in coarse breccia, lithic lapilli tuff and debris-flow slump-type deposits. The presence of carbonaceous wood fragments and the laharic appearance of some units suggests near-shore to subaerial depositional conditions.

HYDROTHERMAL ALTERATION

Porphyry copper-molybdenum-gold mineralization and hydrothermal alteration at Island Copper mine have been described by Cargill *et al.* (1976), Fleming (1983), Perello (1987) and Perello *et al.* (1989). Ore is associated with a high-level quartz feldspar porphyry dike, but is most extensively developed in the surrounding, brecciated Bonanza rocks. The mineralization and alteration took place during a series of hydrothermal events in which there was multiple overprinting of early-formed assemblages by later ones. The early alteration consists of stockworks carrying quartz, magnetite, amphibole and albite with later biotite, magnetite, chalcopyrite, pyrite, molybdenite and chlorite with peripheral epidote. An intermediate stage of structurally controlled quartz stockworks with sericite, chlorite, kaolinite and intermediate clay minerals is superimposed on the older alteration, together with some additional pyrite, chalcopyrite and molybdenite. A late-stage alteration is associated with emplacement of hydrothermal breccias containing an advanced argillic alteration assemblage with kaolinite, pyrophyllite, sericite and dumortierite. All these centrally located and relatively early alteration types are flanked by chlorite and epidote-bearing rocks and are overlapped by veinlets with carbonate minerals, zeolites and hydrocarbon compounds.

The alteration and style of mineralization at the Hushamu deposit is similar in many respects to the early magnetite-bearing alteration at the Island Copper mine but appears to be related to a large intrusive body of quartz diorite. Adjoining and to the south of the Hushamu deposit, hydrothermal alteration on Mount McIntosh consists of argillic and advanced argillic assemblages containing quartz stockworks with flanking propylitic Bonanza rocks around a core of pervasively silicified to vuggy siliceous rocks, 1 kilometre wide. The Mount McIntosh siliceous rocks contain kaolinite, zunyite, diaspore, pyrophyllite, alunite, abundant pyrite and locally enargite with traces of chalcopyrite, covellite, chalcocite and bornite (J. Perello and J. Fleming, personal communication, 1992). This alteration represents mineralization related to the Hushamu porphyry deposit but at a higher structural level. Mineralization appears to have taken place in a telescoped, that is, a compressed hydrothermal system. Late low-angle normal faults in the Hushamu area have tilted and further contracted the underlying porphyry body and the higher level alteration zones on the west, as illustrated diagrammatically on Figure 2-7-4.

Argillic and siliceous altered Bonanza rocks similar to those at Mount McIntosh also form large, resistant ridges or 'ledges' up to a kilometre long in the South McIntosh, Pemberton Hills and Wanokana River areas to the east-southeast of Hushamu and Mount McIntosh. The zones of siliceous clay alteration outline a belt of advanced argillic, argillic and flanking propylitic alteration at least 8 kilometres in length. The rocks are of exploration interest for their potential for epithermal gold-silver deposits and buried porphyry copper-gold mineralization. The silicified zones consist of both residual, acid leached, vuggy porous rocks as well as hydrothermally silicified rocks. In addition to abundant silica, the rocks contain kaolinite, dickite, pyrophyllite, white micaceous minerals including sericite, illite and paragonite, abundant alunite (mainly natroalunite), zunyite and locally native sulphur. In one quartz stockwork native gold was observed to occur together with alunite, possibly an arsenian variety, schlossmacherite. The amount of sulphide minerals in these altered rocks varies from trace amounts to patches and lenses of massive, fine-grained pyrite. Large areas of argillic, silicified rock containing between 5 and 10 per cent, and locally up to 30 per cent, fine-grained disseminated pyrite with lesser marcasite are common. Weathering and leaching of the pyritic rocks is actively taking place. Surface waters and streams in the vicinity of the hydrothermally altered rocks are markedly acidic. For a discussion of natural acidic waters in the area see the accompanying discussion by Koyanagi and Panteleyev (1993, this volume).

DISCUSSION

The presence of advanced argillic, acid sulphate hydrothermal alteration containing quartz-kaolinite-alunite-pyrophyllite with diaspore and zunyite mineral assemblages is confirmed in large areas of hydrothermally altered Bonanza rocks in the Quatsino map area north of Holberg Inlet. Mineralization of the acid sulphate or high sulphidation type is present containing enargite, some chalcopyrite and minor chalcocite, covellite, bornite with **an abundance of pyrite**. The deposits resemble relatively high temperature, acid fluid related 'Temora' type high sulphidation epithermal gold deposits as described by Thompson *et al.* (1986) and White (1991). The siliceous, argillic and advanced argillic zones are also similar to the high-level silica-clay caps found in the Nansatsu district of Japan (Izawa, 1991). The intrusive-related mineralization and some of the fracture-controlled sericite-rich quartz-pyrite alteration assemblages bear a closer affinity to intrusion-related porphyry copper-gold and porphyry gold mineralization. Similar deposits with phyllic alteration elsewhere are the Thorn property in northwestern British Columbia (NTS

104K) and the La Joya deposit (Inti Raymi mine), Bolivia (Long *et al.*, 1992).

The siliceous, hydrothermally altered rocks in the Quatsino map area can be referred to as siliceous caps but they are not siliceous sinters (subaerial deposits). White (1991) considers from genetic models based on the equivalent Nansatsu deposits that the tops of the siliceous bodies form at depths of 200 to 300 metres below the surface. The vertical extent of the siliceous bodies might be up to 1000 metres. Sillitoe (1993, in press) describes siliceous sinter as a product of subaerial geothermal systems. He contrasts this to the deeper origin of siliceous caps that form at or near the paleo-watertable. Sillitoe considers that the lensoid or planar siliceous caps can be up to 50 metres in thickness. Clearly the north Vancouver Island siliceous caps are larger than this, probably because they have a strong vertical to subvertical structural component related to hydrothermal channelways from porphyry intrusions at depth. As well there is additional potential for stratabound and bedding plane replacement deposits in these environments that remains to be tested.

The types of exploration targets in the large clay-silica altered zones are elusive. Certainly no ore is evident at surface in the well-exposed, resistant and topographically high-weathering siliceous zones. Erratic small silicified patches with high-grade gold can be expected to occur in narrow hydrothermal conduits that form breccias and vuggy quartz veins, for example, in outcroppings on the west bank of Youghpan Creek and the more widespread quartz stockworks on McIntosh Mountain. Most likely, the large clay-silica alteration zones might be leakage from deeper porphyry copper-gold deposits. Deeper mineralized zones contained within the silica caps, as in the Nansatsu district, Japan with aggregate resource of 1.5 million tonnes with 4.4 grams per tonne gold and 8.5 grams per tonne silver (Izawa, 1991) might be economically marginal in British Columbia, especially if the deposits are not oxidized and therefore refractory. However ore in structurally controlled high-grade veins that are hydrothermal feeder zones or fluid conduits, as at El Indio, Chile, are superb discoveries (Jannas *et al.*, 1990). Also stratigraphic (lithologic) permeability possibly combined with structurally controlled massive sulphide replacements such as the auriferous enargite deposits of Lepanto, Philippines and the nearby intrusion and breccia-related Far Southeast porphyry copper-gold deposit (Garcia, 1991) would be highly attractive exploration targets in this environment.

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