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Chapter 9
THE BUTTLE LAKE CAMP, CENTRAL VANCOUVER ISLAND, B.C.

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INTRODUCTION

The Buttle Lake Camp, a volcanogenic massive sulphide district with Paleozoic host rocks and ore, is 85 km southwest of Campbell River at the south end of Buttle Lake within Strathcona Provincial Park, central Vancouver Island, British Columbia (Fig. 1). The ore deposits are currently being mined by Westmin mines Ltd. through the operation of two underground mines, the H-W and Lynx. Proven and indicated ore reserves as of January 1, 1989 (Westmin Resources Ltd. Annual Report 1988) were 294,600 tonnes at 2.62 9 Au/t, 76.8 g Ag/t, 1.37% cu, 0.78% Pb, and 7.61% Zn for the Lynx Mine, and 11,597,600 tonnes at 2.30 g Au/t, 33.0 g Ag/t, 2.39% cu, 0.33% Pb, and 5.07% Zn for the H-W Mine. Production to the end of 1988 comprised 9,170,600 tonnes (approximately 65 percent of which was Lynx and Myra ore) at 2.16 gAu/t, 81.0 gAg/t 1.83% cu, 0.78% Pb, and 6.58% Zn.

The first claims in the Buttle Lake Camp region were staked in 1917 when Strathcona Park was opened for prospecting. Three showings were staked: the Lynx, Price and Paw (Myra) claims. Sporadic work continued on the ground until 1925. The property then remained dormant until 1946 when renewed interest brought about various examinations by individuals and companies. Western Mines acquired the claims in 1961 and concentrated their exploration in the Lynx claim group which had the best showings within the camp. By mid-1964, after potential ore zones consisting of 1.5 million tonnes were defined on five levels, a decision was made to begin production. Production, largely open pit, began in early 1967. From 1969 to the end of 1974 the Lynx open pit was gradually phased out in favour of underground ore development. The total tonnage produced from the Lynx open pit was 1.6 million tonnes. The Myra deposit (formerly the Paw group) was evaluated in 1970 and put into production as a separate mine by 1972. Mining at the Myra Mine terminated in late 1985 due to depletion of reserves. The Price showings received serious attention during the period from 1979 to 1981, which resulted in the discovery of the Upper Price zone. Reserves of 209,500 tonnes at 1.23 g Au/t, 53.1 g Ag/t, 1.10% cu, 1.07% Pb, and 8.31% Zn were blocked out but a production decision for this deposit has been put on hold indefinitely. The large H-W deposit was discovered in late 1979 and the decision to mine made shortly after in early 1980. The H-W mine officially come on stream in September of 1985. Also during this time period (in 1981), Western Mines changed their corporate name to westmin Resources Ltd. Divestiture of their oil and gas holdings in late 1989 resulted in a further name change to Westmin Mines Ltd.

GEOLOGICAL SETTING

Buttle Lake Camp ore deposits consist of many individual massive sulphide lenses grouped into several major zones within two main felsic volcanic stratigraphic intervals in the Paleozoic sicker Group within the Buttle Lake uplift (Fig. 2). The sicker Group is represented in the Buttle Lake Camp by four formations (Juras, 1987): the Late Devonian or older Price Formation, the sulphide deposit-bearing Late Devonian myra Formation, the Early Mississippian (?) Thelwood Formation, and the Mississippian(?) Flower Ridge Formation. The first three formations are also referred to as the Footwall H-W Andesite, the mine Sequence, and the Sharp Banded Tuff unit respectively. Four composite geologic cross sections form the basis of the lithologic and facies variation descriptions. The cross sections cover the length of the mine property at the following mine coordinates (mine north is 45° east of true north): 183+00 E (Fig. 3), 124+00 E (Fig. 4), 60+00 E (Fig. 5) and 5+00 E (Fig. 6). Descriptions below will be relative to true north.

Price Formation (Footwall H-W Andesite)

The lowermost unit exposed in the mine-area

(from) IAGOD, Field Trip #12
"Geol/Reg. Setting of Major Mineral Deposits in Southern B.C."

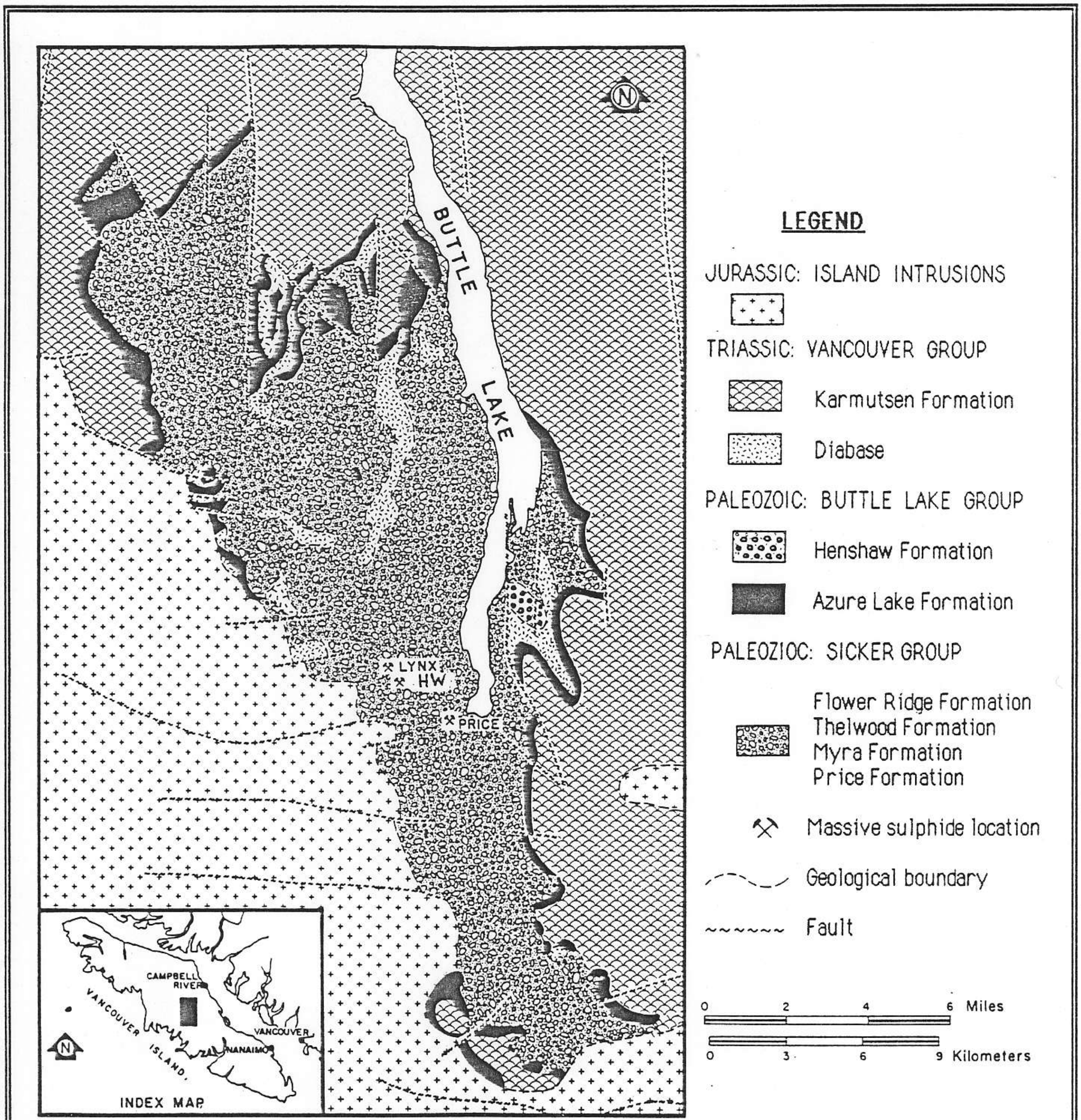

Figure 1. Geology of the Buttle Lake Uplift (modified after Muller, 1964).

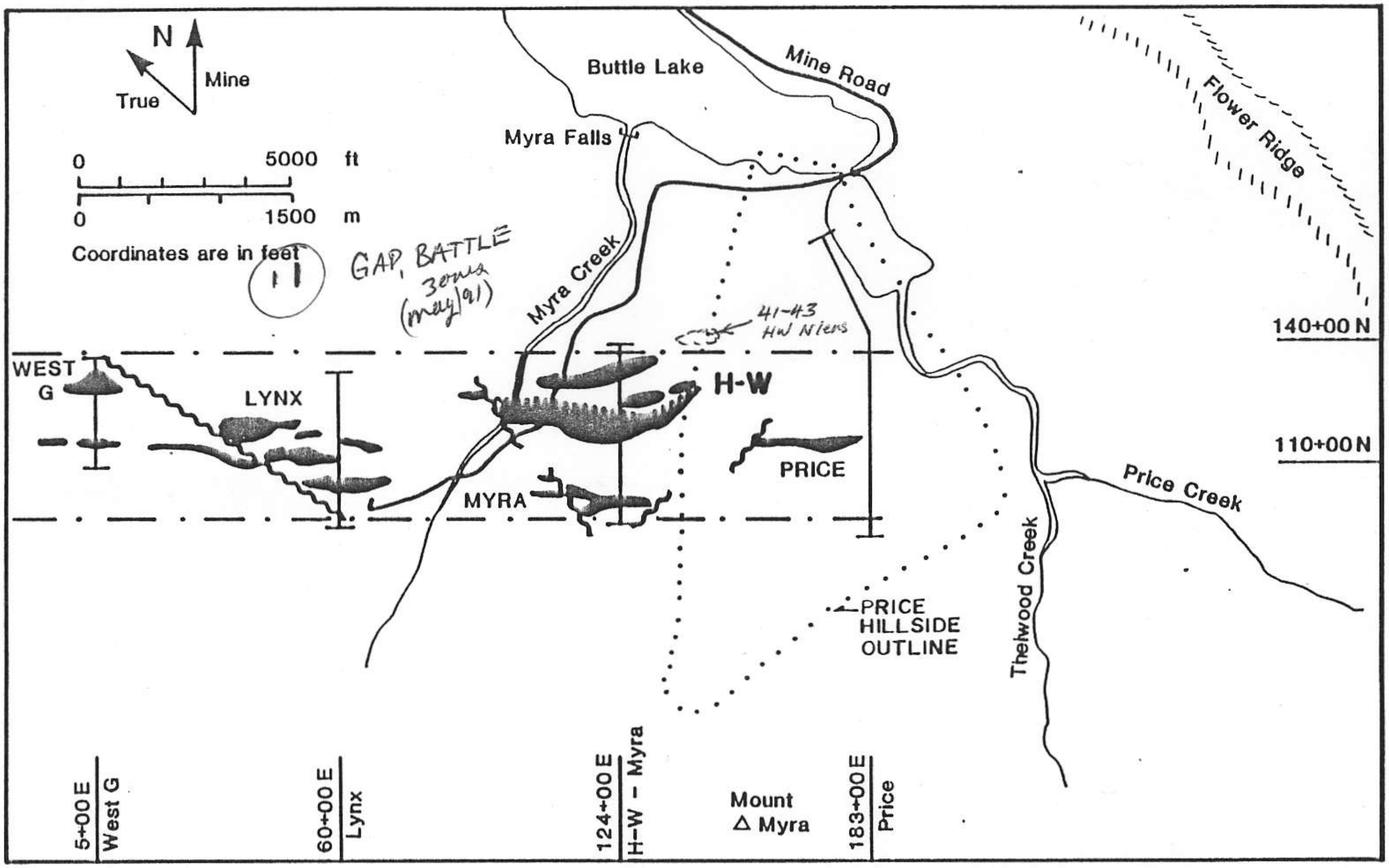

Figure 2: Orientation diagram for geological descriptions, Buttle Lake Camp, Vancouver Island, B.C. Descriptions in text are made relative to the northwestern trend of the massive sulphide ore zones (shown in plan projections as solid patterns: Walker, 1985). The area around the ore zones between the dashed-dot lines is defined as the central region. Lengths of section lines represent area covered in the respective cross sections: Price, H-W—Myra, Lynx, and West G.

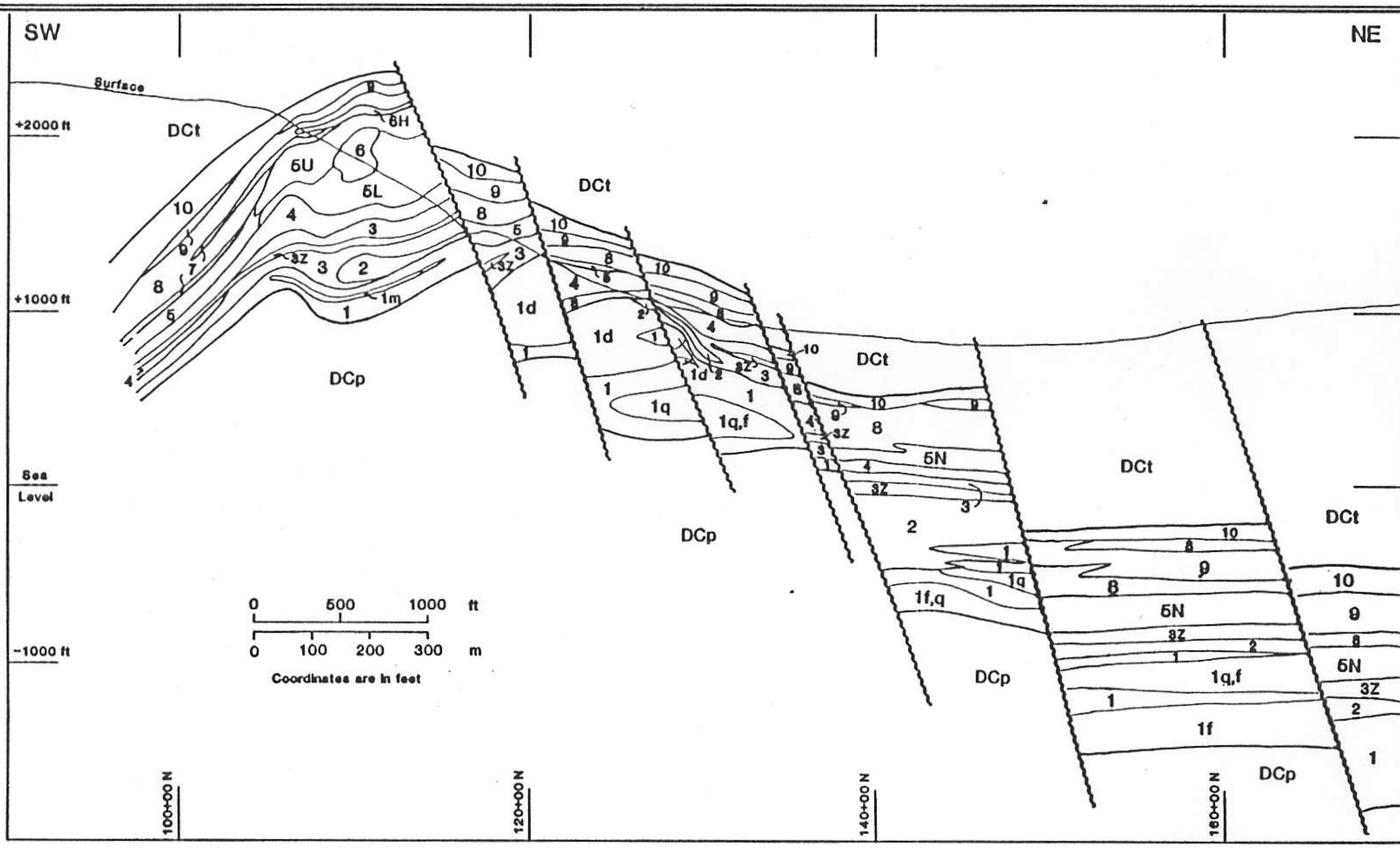

Figure 3: Generalized composite geology along Price section (183+00 E: after Juras, 1987), Buttle Lake Camp, Vancouver Island, B.C. Rock unit symbols are: DCp = Price Formation; 1 = H-W Horizon; 1d = H-W Horizon, dacite; 1f = H-W Horizon, feldspar porphyritic rhyolite; 1m = H-W Horizon, mafic flow member; 1q = H-W Horizon, quartz + feldspar porphyritic rhyolite; 2 = Hanging Wall H-W Andesite; 3 = Ore Clast Breccia unit; 3Z = Ore Clast Breccia unit, Interzone Rhyolite; 4 = Lower Mixed Volcaniclastics; 5L = Upper Dacite, lower member; 5U = Upper Dacite, upper member; 5N = North Dacite; 6 = Lynx-Myra-Price Horizon, G-Zone; 6H = Lynx-Myra-Price Horizon, G-Hanging Wall Zone; 7 = G-Flow unit; 8 = Upper Mixed Volcaniclastics; 9 = Upper Rhyolite unit; 10 = Upper Mafic unit; and DCt = Thelwood Formation.

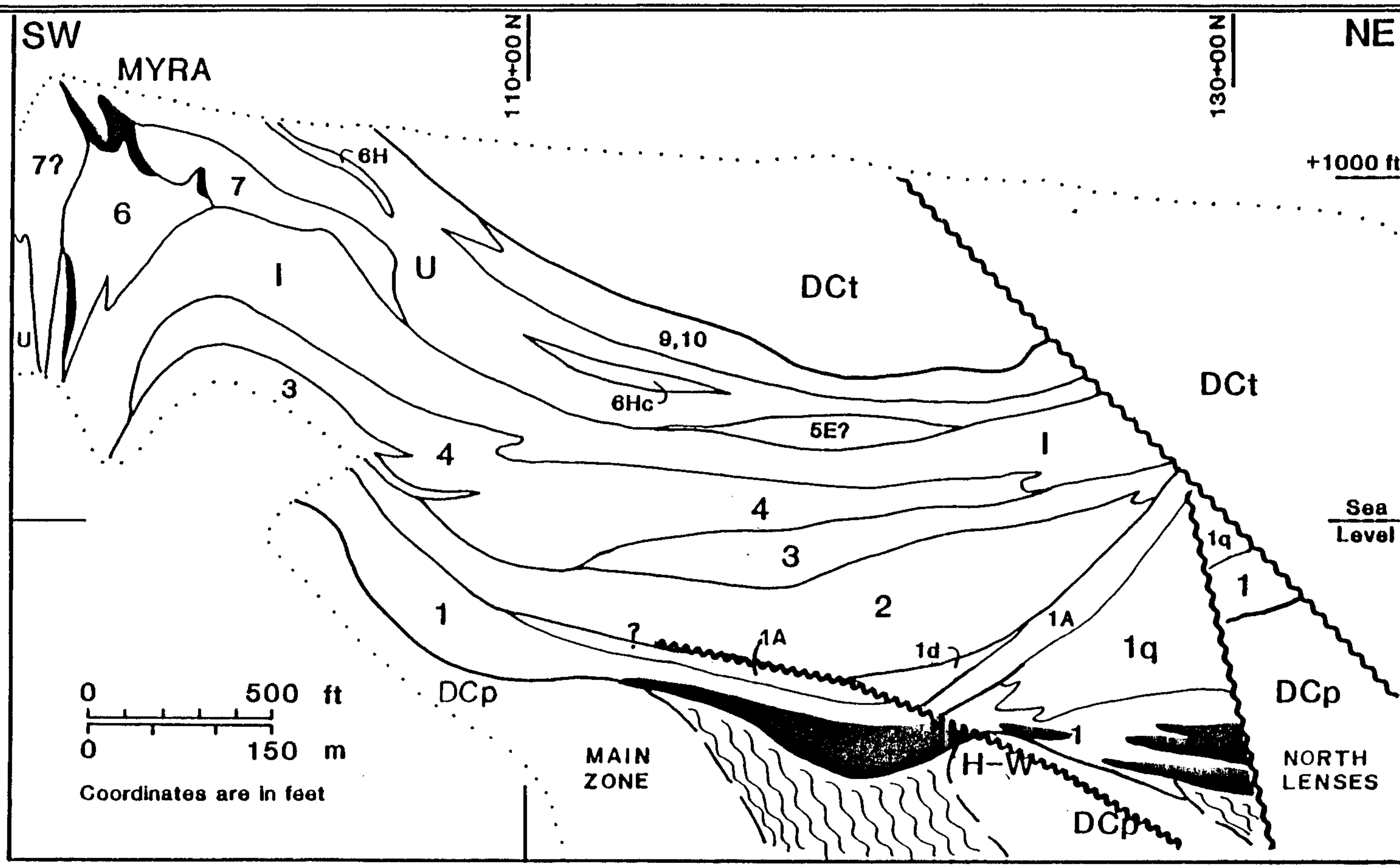

Figure 4: Composite geology along H-W—Myra section (124+00 E: after Walker, 1985). Rock unit symbols are the same as for Figure 3 except: 1A = H-W Horizon, argillite member; 5E = 5E Andesite; I = undifferentiated Myra Formation interzone units (Ore Clast Breccia unit, Lower Mixed Volcaniclastics, Upper Dacite); and U = undifferentiated Myra Formation upper units (Upper Mixed Volcaniclastics, Upper Rhyolite unit, Upper Mafic unit). Solid patterns represent massive sulphide bodies and wavy pattern represents hydrothermal alteration associated with sulphide mineralization. Letter "c" denotes chert. Fault separating the Main Zone and North Lenses is called the H-W Flat Fault.

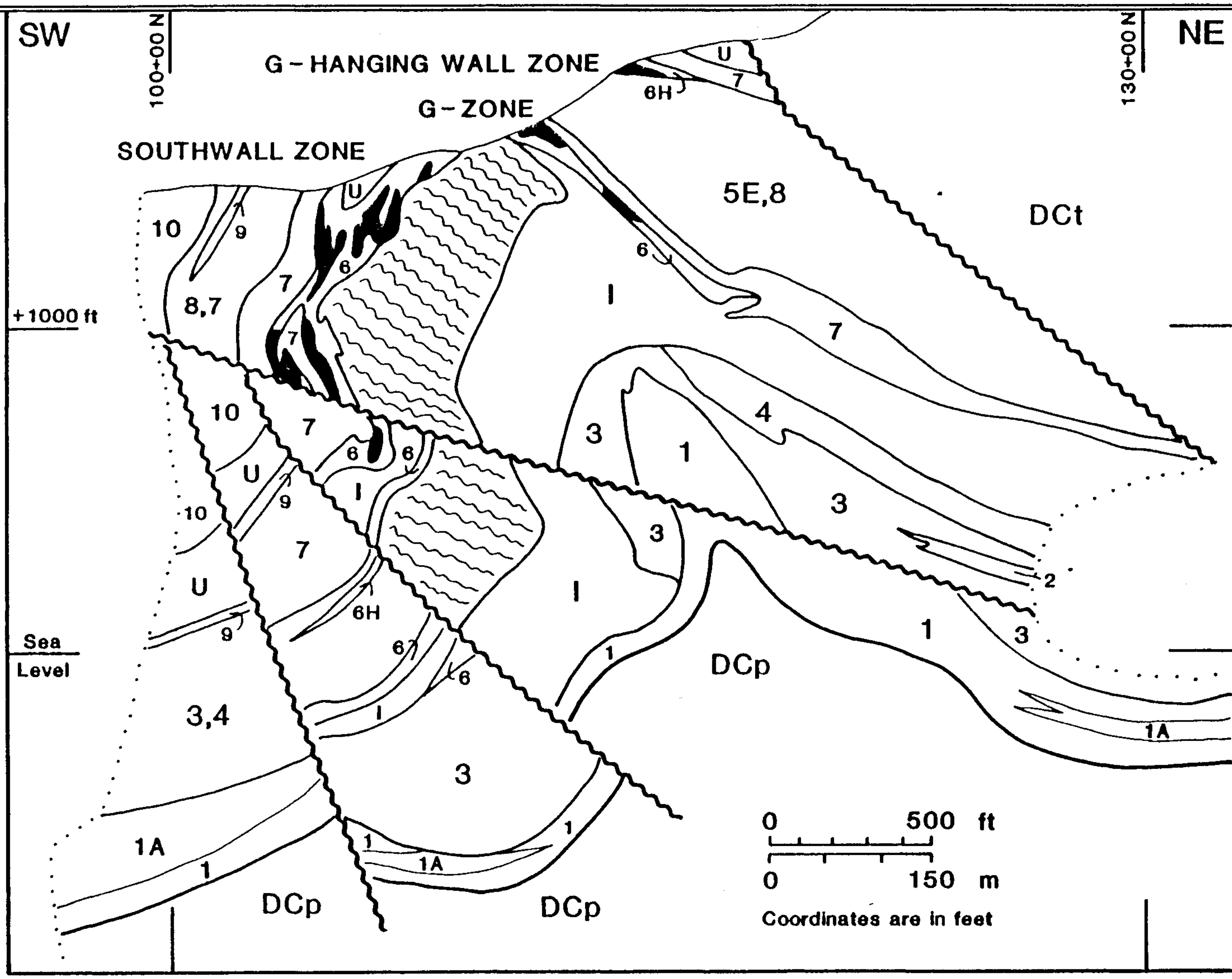

Figure 5: Composite geology along Lynx section (60+00 E: after Walker, 1985).
Rock unit symbols are the same as for Figures 3 and 4.

and in the Buttle Lake uplift is a thick sequence (> 300 m) of massive to pillowed basaltic andesite flows and flow breccias, and minor associated fine to coarse pyroclastic rocks. The Price Formation has been intersected in drillcore throughout the property but is exposed at surface only in a small region southwest of the mouth of Thelwood Creek. The base of this formation is not known. The formation is characterized by alternating, 30 to 150 m thick sequences of variably amygdaloidal,feldspar-phyric and pyroxene + feldspar porphyritic flow units.

Myra Formation (Mine Sequence)

The Myra Formation consists of a 310 to 440 m thick sequence of complex volcanic - dominant stratigraphy. Myra Formation lithologic units exhibit remarkable linear continuity (>7 km) along the northwestern trend of the ore zones, but abrupt lateral northeast to southwest facies changes. The Myra Formation is divided into ten general lithostratigraphic units (in decreasing relative age: Juras, 1987): H-W Horizon, Hanging Wall H-W Andesite, Ore Clast Breccia unit, Lower Mixed Volcaniclastics, Upper Dacite / 5E Andesite / North Dacite, Lynx-Myra-Price Horizon, G-Flow unit, Upper Mixed Volcaniclastics, Upper Rhyolite unit, and Upper Mafic unit.

H-W Horizon

The lowermost Myra Formation unit is the predominantly rhyolitic H-W Horizon. This horizon varies in thickness from approximately 15 m to 200 m and occurs throughout the mine-area. it consists of dacitic to rhyolitic flows, pyroclastic deposits, argillite, and sulphide mineralization. H-W Horizon units vary laterally from bedded argillite and felsic tuffs towards the southwest to complex felsic flow assemblages towards the northeast. It can be divided into five general parts: (1) an argillite member, (2) a felsic flow member, (3) a pyroclastic and volcaniclastic member, (4) a mafic flow member, and (5) a massive sulphide member. It is this unit that hosts the large H-W massive sulphide deposit.

The 1.5 to 45 m thick, argillite member is a more or less continuous unit. It consists of massive to thinly laminated beds of black siliceous argillite and normally graded, thinly bedded, fine to coarse rhyolite tuff and beds made up of varying mixtures of argillite and tuff (tuffaceous argillite to argillaceous tuffs) and minor chert. The argillites are composed of quartz, lesser feldspar, and variable but minor chlorite and carbonaceous matter. The tuff beds comprise quartz and feldspar crystals and a former vitric-rich host. Sedimentary structures observed include scour marks, load casts and rip-up clasts but no cross laminated structures were observed. The bedded sequences within this member reflect A-E and A-B-E turbidite deposits. Minor but ubiquitous sulphide mineralization consists of thin laminae or lenses of pyrite, or less commonly pyrrhotite, in the argillite beds, and pyrite or pyrrhotite disseminations and pebble-size clasts in some tuffaceous units.

The felsic flow member can be divided into three types: a quartz + feldspar porphyritic (QFP) rhyolite, an aphyric to feldspar porphyritic rhyolite, and a feldspar porphyritic (FP) dacite. Chemically, the first two are rhyolites whereas the dacite spans the dacite-rhyolite division. The FP and QFP rhyolite flow units occur throughout the H-W Horizon in the northeast region and parts of the central region (Figs. 3 and 4), but disappear towards the southwest. The feldspar porphyritic dacite flow units are present only in the central region and appear to have a different source area from the rhyolites. Unlike the distribution of the rhyolites, the dacite flows thicken southeastward towards the Price section (Fig. 3) and not towards the northeast area. The felsic flow units consist of autobrecciated to massive flows. Massive phases are predominant in the FP rhyolite and dacite flow types, and brecciated phases are more common in the QFP rhyolite flow types.

The pyroclastic and volcaniclastic member makes up most of the H-W Horizon in the central region. The rock units consist of medium to thin bedded, fairly well sorted, normally graded sequences of quartz + feldspar crystal-lithic-vitric lapilli-tuff, and coarse to fine tuff. They occur throughout the H-W Horizon becoming generally finer grained towards the southwest. Other units in this member include unwelded to welded subaqueous pyroclastic flow deposits, heterolithic rhyolite-dominant debris flow deposits and unsorted and ungraded tuff-breccia deposits. The pyroclastic flow deposits extend to all regions. The debris flow deposits are constrained laterally, occurring only in the central region. The coarser felsic lapilli-tuff and tuff-breccia deposits predominate around and between the various felsic flow units in the northeast region. Massive sulphide clasts can be a common occurrence in all flow to breccia deposit types.

The mafic flow member in the H-W Horizon consists of aphyric to pyroxene-phyric komatiitic basalt flows and hyaloclastite. It is usually associated with the argillite member in the central region. Flows commonly overlie or are replaced by a hyaloclastite zone. It is characterized by feathery shard-like ultramafic clasts. They may be mixed with up to 40 percent fine to coarse felsic tuff, felsic tuff clasts, feldspar and quartz crystals, argillaceous material, and the occasional massive sulphide fragment. The matrix is fine-grained and has been silicified. This apparently chaotic deposit probably represents a peperite formed by the interaction of rapidly extruded, hot lava with the underlying, water-saturated and unlithified sediments (Juras, 1987).

Hanging Wall H-W Andesite

Hanging Wall H-W Andesite is an up to 100 m thick unit consisting mainly of basaltic andesite to andesite flows and related breccias. Less common pyroclastic deposits are made up of massive, lapilli-tuff, tuff-breccia, and bedded feldspar-crystal, fine to coarse tuff. The proportion of pyroclastic deposits relative to the flows and related breccias varies from 20:80 in the central region to approximately 60:40 in the northeast. In the H-W Myra and Price sections (Figs. 3 and 4), the H-W Horizon felsic flow member has influenced the distribution of Hanging Wall H-W Andesite rock units. The discontinuity of the Hanging Wall H-W Andesite in the Price section is caused by the formation of a paleo-barrier by the H-W Horizon dacite. However, in the H-W Myra section, the H-W Horizon dacite is quite thin and consequently has not affected the distribution of the overlying andesite flows. Instead, in that section the andesite flows encountered another paleo-barrier built by a series of H-W Horizon QFP rhyolite flows.

Ore-Clast Breccia Unit

The Ore Clast Breccia unit represents a series of volcaniclastic submarine debris flow deposits and lesser subaqueous pyroclastic deposits. The unique feature of this unit is the presence of massive sulphide clasts and lenses or 'rafts' (olistoliths) of pyrite-mineralized rhyolite coarse tuff to lapilli-tuff. The unit is up to 90 m thick and is found throughout the mine-area. Excellent exposures are present on the Price Hillside. The Ore Clast Breccia unit can be divided into three mappable members: (1) a rhyolite-rich volcaniclastic breccia having from 10 to 50 percent non-andesite or mafic volcanic constituents (average is 25 percent); (2) a rhyolite-poor volcaniclastic breccia with less than 10 percent non-andesite or mafic volcanic constituents; and (3) the Interzone Rhyolite, a rhyolite pyroclastic horizon. Generally, the rhyolite-rich member occurs in the lower to middle parts of the unit whereas the rhyolite-poor member is found in the middle to upper portions. The Interzone Rhyolite generally is found in the middle to upper portions of the Ore Clast Breccia unit.

Clast types present in the volcaniclastic breccia members can be highly variable. Generally, they comprise andesite, aphyric to weakly pyroxene-phyric mafic volcanics, dacite, QFP rhyolite, massive sulphide (pyrite >> sphalerite > chalcopyrite > galena), rhyolite fine tuff, chert and argillite. Clast sizes in the breccia members are also highly variable ranging from 1 cm to 1.5 m with rhyolite 'rafts' obtaining dimensions of up to 50 m long by 15 m wide.

Lower Mixed Volcaniclastics

The Lower mixed Volcaniclastics represent and e site dominant volcaniclastic deposits. The unit is up to 90 m thick and occurs throughout the property. It contains volcaniclastic breccias, tuff-breccia, bedded lapilli-tuff and coarse to fine tuff, and minor subaqueous pyroclastic flow deposits. Thin feldspar porphyritic andesite flows are present locally. The coarse clastic deposits occur mainly in the central region in the Price end and the West G end of the mine-area, whereas the Lynx and H-W Myra sections contain relatively greater sequences of finer grained, bedded deposits. The subaqueous pyroclastic flow deposits are most prevalent in the northeast region. Generally the Lower mixed Volcaniclastics thicken from the Price area to the H-W Myra section, before gradually thinning towards the Lynx and West G sections.

The bedded clastic sequences are largely made up of aphyric to plagioclase-phyric andesite cognate lithic fragments and plagioclase crystals. Towards the northeast region both clast and crystal components contain ubiquitous pyroxene grains. Coarse clastic deposits are made up of andesite and dacite with the andesite component by far the most common. It occurs as two types: variably feldspar-phyric cognate lithic clasts and strongly feldspar glomeroporphyritic flow clasts. The clast sizes (long axes) vary from 1 to 60 cm, averaging around 10 cm.

Upper Dacite / 5E Andesite / North Dacite

The Upper Dacite / 5E Andesite / North

Dacite units represent three approximately contemporaneous yet different eruptive events which occurred in non-overlapping relationships throughout the mine property. The upper Dacite unit, up to 60m thick, is best documented in the Price section (Fig. 3) and comprises two general parts: the Upper Dacite lower member and the Upper Dacite upper member. The lower member consists of resedimented deposits of dacite to rhyolite hyaloclastite and flow breccia, and subaqueous pyroclastic deposits. The upper member is made up of feldspar porphyritic intermediate flows containing variably rounded felsic blocks, and subaqueous pyroclastic deposits. The main difference between the two members is in the low amounts of hyaloclastite in the upper member. The 5E Andesite is best developed at the West G end (Fig. 6) and consists of up to a 250 m thick sequence of massive to pillowed, feldspar porphyritic basaltic andesite to andesitic flows and lesser flow breccia and lapilli-tuff deposits. Both the Upper Dacite and the 5E Andesite units are thickest in their respective central regions; they thin markedly towards the middle sections (Lynx and H-W - Myra) of the mine-area. Both units are absent in the northeast region. The North Dacite, a feldspar porphyritic felsic flow unit, is only present in the northeast area where it occupies the same general stratigraphic position as the other two lithostratigraphic units.

Lynx Myra Price Horizon

The upper massive sulphide mineralized felsic volcanic units in the mine-area comprise the Lynx-Myra-Price Horizon. This horizon consists of two spatially distinct units: (1) the G-Zone member, and (2) the G-Hanging Wall Zone member. The two are separated by units from upper parts of the 5E Andesite in the West G and Lynx sections, and by the Upper Dacite upper member in the Price section and possibly the H-W-Myra section. In the West G and Lynx areas the separation is 30 to 150 m whereas in the Price end, it is 10 to 60 m. Both G-Zone and G-Hanging Wall Zone members can be traced throughout the mine property. The difference between the two lies in their lateral extent. The stratigraphically lower G-Zone member can be traced for at least 300 m in the West G section, over 825 m in the Lynx section, and only 300 m in the H-W-Myra and Price sections.

The overlying G-Hanging Wall Zone member is at least 1000 m wide in both West G and Price sections. No estimates can be made for the Lynx and H-W-Myra areas because of limited data. Extrapolation between the West G and Price sections suggests similar widths throughout the mine-area. Both zones vary in thickness from 1 to 45 m, but generally the G-Zone member is thicker than the G-Hanging Wall Zone member.

Both Lynx-Myra-Price Horizon members consist mainly of massive to bedded, fine to coarse quartz + feldspar crystal vitric rhyolite tuff and lapilli-tuff, and massive sulphide mineralization. The rhyolite tuffs commonly occur as normally graded, moderately to well sorted, thin to thick beds. They usually contain 5 percent disseminated pyrite and lesser sphalerite grains. Most samples also contain grey rhyolite accessory lithic clasts.

The G-Hanging Wall Zone member contains two additional lithologic units. They are a vitrophyric rhyolite coarse tuff to fine lapilli-tuff unit, and a chert unit. The tuffs locally are associated with bedded tuffaceous siltstone and mudstone deposits. Total thickness of tuff unit is usually less than 3 m. The chert unit occurs in the central regions in the Price and H-W-Myra sections. it is composed of thin to medium laminated beds of white to light green Chert, jasper, and, less commonly, black argillaceous chert. Thickness of this unit varies from 1 to 3 m.

G-Flow Unit

The G-Flow unit represants a number of thin (2 to 15 m thick) but widespread ultramafic (komatiitic basalts: cf. Juras, 1987) flows and flow breccia and hyaloclastite deposits overlying the two members of the Lynx-Myra-Price Horizon (Figs. 3, 4, 5 and 6). At the Price end, this unit consists of medium to dark green, pyroxene porphyritic, amygdaloidal, massive to pillowed flows, and lesser lapilli-tuff and coarse tuff deposits. In the H-W-Myra, Lynx and West G sections, the G-Flow unit is characterized by distinctly purple zones. These zones mainly consist of hyaloclastite and flow breccia and are moderately to intensely altered by carbonate and hematite. Associated massive to pillowed flows are less affected by this alteration and remain medium to dark green. The unit, thickest in the West G and Lynx areas, becomes steadily thinner towards the Price section. Laterally, it disappears towards the northeast region but thickens towards the southwest area.

Least altered flow units consist of 5 percent, augite glomerocrysts and trace chromite microphenocrysts. The flows are always amygdaloidal

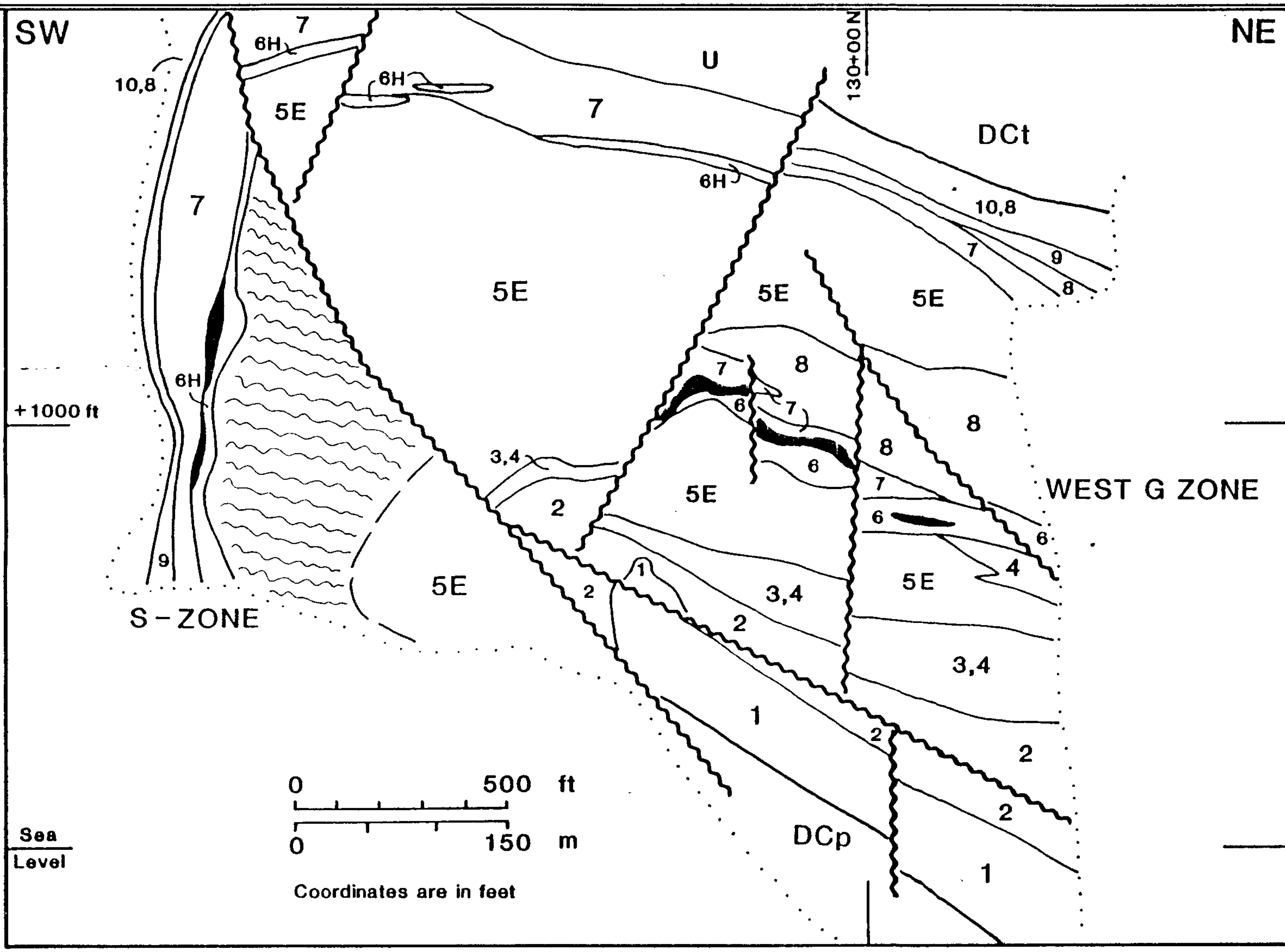

Figure 6: Composite geology along West G section (5+00 E: after Walker, 1985).
Rock unit symbols are the same as for Figures 3 and 4.

with generally 3 percent (up to 15 percent) chlorite, epidote and calcite amygdules. Flow units in the Lynx and West G sections have distinctly more calcite and less chlorite amygdules. Pillowed flows contain magnetite-rich (price area) or hematite-rich (West G section), fine-grained relict selvages, and jasper in pillow interstices.

Upper Mixed Volcaniclastics

The Upper Mixed Volcaniclastics represents a mafic to intermediate volcanic dominant volcaniclastic unit consisting of bedded fine to coarse tuff and lapilli-tuff sequences, and massive coarse lapilli-tuff to tuff-breccia deposits. The unit is up to 50 m thick and occurs throughout the mine property, being best developed in the central regions of all four sections. Bedded tuff sequences are thinly to medium bedded, moderately well scrted and normalty graded, and consist largely of feldspar crystal intermediate to mafic tuffs. In places, maroon fine tuff beds mark the tops of the graded deposits. Tuffs in these sequences are composed of broken plagioclase crystals and aphyric to occasionally plagioclase porphyritic mafic volcanic vitric clasts. Massive lapilli-tuff and tuff-breccia deposits contain plagioclase crystals and a wide variety of vitric and flow clasts. Main clast types (in decreasing order of relative abundance) comprise weakly plagioclase porphyritic mafic to intermediate volcanic cognate lithic clasts, aphyric to plagioclase-phyric, felsic cognate lithic clasts, plagioclase + pyroxene porphyritic basaltic cognate to accessory lithic clasts, and strongly epidotized andesite accidental clasts. A lateral compositional variation of the clast types is recognized. Intermediate and felsic volcanic constituents are uncommon towards the southwest region but become increasingly more abundant towards the northeast area. The mafic volcanic clast distribution generally follows the reverse of the above pattern.

Upper Rhyolite Unit

The Upper Rhyolite unit is the stratigraphically highest rhyolite horizon in the Mine Sequence. Distribution of rock types in the Upper Rhyolite unit consists of two general parts: (1) a pyroclastic deposit-rich member; and (2) a siliceous argillite - chert dominant member. In most areas the siliceous argillite - chert member underlies the pyroclastic member.

The pyroclastic deposit member is up to 50 m thick and made up of thin to medium bedded, normally graded, crystal-lithic-vitric coarse tuff to lapilli-tuff, and lesser fine tuff and tuff-breccia deposits. This member displays a distinct lateral facies variation from the northeast region to the southwest area. It is thickest towards the northeast region, being approximately 50 m in thickness, where it consists mainly of lapilli-tuff deposits with subordinate coarse tuff and tuff-breccia beds. The sequence is generally coarsening-upward. The member in the central region (in all sections) is composed of moderately well sorted, fine to coarse tuff and fine lapilli-tuff, and a heterolithic tuffaceous breccia deposit which can form up to 25 percent of the sequence. The pyroclastic member in the southwest region is finer grained and markedly thinner (approximately 10 m) where it eventually disappears. Generally the deposits are crystal-rich comprising plagioclase, lesser quartz and trace amphibole. main lithic components are: QFP rhyolite accessory clasts, mica-poor weakly phyric to sericite-rich QFP felsic cognate lithic clasts, and mafic volcanic accidental clasts.

The siliceous argillite - chert member consists of thin to medium laminated beds of grey to black siliceous argillite, white to pale green chert, green to gray rhyolite fine tuff, and minor jasper. This member ranges from 1 to 15 m in thickness and is largely confined to the central regions of all sections. siliceous argillite is the most common rock type in this member.

Upper Mafic Unit

The Upper Mafic unit is the uppermost lithostratigraphic unit in the Myra Formation. it is present throughout the property being thickest (> 200 m) in the southwest region and thinning to approximately 5 to 20 m towards the northeast area. The main rock types present are basaltic in composition and occur mainly as hydroclastic and pyroclastic deposits. Flow and flow breccia, and mixed sedimentary and pyroclastic units are less common.

Hydroclastic and pyroclastic deposits are poorly to moderately sorted and form generally coarsening-upward sequences. Lower parts consist of normally graded coarse tuff to lapilli-tuff deposits. Up section the main deposits become composed of lapilli-tuff and tuff-breccia units. Clast sizes vary from 1 mm to 50 cm but more commonly range from 2 to 15 cm. The main clast type is a strongly pyroxene + feldspar porphyritic basalt. Non-volcanic clasts include jasper ± magnetite, chert, mafic fine tuff and epidote-rich mudstone.

Mixed sedimentary and pyroclastic deposits are found in the middle to lower parts of the Upper Mafic unit. They are only sporadically present in the southwest region, but are equal to or greater in abundance than the hydroclastic deposits towards the northeast area. The deposits are 2 to 7 m thick and consist of thinly bedded, massive to laminated cherty tuff, jasper and chert, and epidote-rich mudstone. Fine to coarse tuff and fine lapilli-tuff deposits are also present. Primary sedimentary structures, such as scours and flames, are common.

Thelwood Formation (Sharp Banded Tuff)

The Thelwood Formation is a 270 to 500 m thick bedded sequence of siliceous tuffaceous sediments, subaqueous pyroclastic flow deposits and penecontemporaneous mafic sills (Juras, 1987). This unit is present throughout the mine property but the best exposures occur on the west side of the mouth of Thelwood Creek and around Myra Falls. The rock units can be grouped into three general, repetitive lithologies: (1) tuffaceous sediment units, (2) pyroclastic deposit units, and (3) mafic sills. Components of all three occur within each generalized unit. Tuffaceous sediment units range from 5 to 30 m in thickness and consist of massive to thinly bedded tuffaceous mudstone and siltstone, mudstone, and vitric ± crystal fine tuff. Minor chert layers occur locally. Also present are up to 20 percent coarse grained subaqueous pyroclastic deposits. Pyroclastic deposit units, intermediate in composition, range from 4 to 25 m in thickness and consist of vitric-lithic, lapilli-tuff to coarse tuff beds intercalated with up to 50 percent tuffaceous sediment deposits. Tuffaceous mudstone rip-up clasts are common and generally are concentrated in the lower portions of a deposit mafic sills consist of 1 to 90 m thick, massive basaltic to basaltic andesite sills. They are found throughout the Thelwood Formation but are generally more common in the lower portions. They also seem to be associated with the tuffaceous sediment units. Contacts of sills can be finer grained than the interiors and reflect chilled margins. Locally, flame-like protrusions of tuffaceous sediment into sills and hyaloclastitic margins are observed, and are interpreted to be the result of intrusion into wet unlithified sediment (Juras, 1987).

Flower Ridge Formation

The Flower Ridge Formation is the uppermost Paleozoic unit exposed in the mine-area. The unit is basaltic in composition and consists mainly of moderately to strongly amygdaloidal feldspar + pyroxene porphyritic basaltic lapilli-tuff, tuff-breccia and pyroclastic breccia deposits (Juras, 1987). Other rock types of this formation are fine to coarse tuffs, basalt flows and flow breccias, and bedded tuffaceous mudstone. The top of the Flower Ridge Formation is not on the mine property where only the lower 650 m can be observed. The contact with the underlying Thelwood Formation is conformable and characterized by the first appearance of abundant scoriaceous volcanic clasts in either pyroclastic or sedimentary beds.

Intrusive Rocks

Intrusive phases on the mine property, from oldest to youngest, are: (1) Paleozoic or Triassic diabase dikes, (2) Triassic basaltic sills and dikes related to the Karmutsen Formation, (3) Jurassic feldspar porphyry and quartz diorite dikes related to the Island Intrusions, and (4) Jurassic or younger quartz + feldspar porphyritic rhyolite and hornblende gabbro dikes. Paleozoic or Triassic diabase dikes are the second most abundant intrusive unit. They are usually less than 1 m wide, dark brown, aphyric and always strongly carbonate altered. There are several sets of dikes, but all have been affected by the major Jurassic deformational event, which constrains the age of their intrusion as Paleozoic, Triassic or both. certain mafic sills and dikes in the Thelwood and Flower Ridge Formations are inferred, on the basis of lithologic similarity, to represent dikes related to the Triassic Karmutsen Formation. These basaltic sills and dikes are thick (up to 300 m), coarse to very coarse grained, and contain relatively unaltered pyroxene and plagioclase grains. Jurassic feldspar porphyry and quartz diorite dikes are the most abundant intrusive phase on the mine property. They are intermediate in composition, up to 25 m wide, and crosscut all Sicker Group lithologies and fold-related fabrics in the mine-area. The latest event (Jurassic or younger) is represented by rare quartz + feldspar porphyritic rhyolite dikes, and a coarse to very coarse grained hornblende gabbro dike. These dikes crosscut all other intrusive rocks as well as most faults.

DEFORMATIONAL HISTORY OF THE MINE-AREA

The main deformational event in the Buttle Lake Camp is mesozoic in age and affected all pre-Mesozoic stratigraphy in the area. It is expressed in the Thelwood Formation as northwest trending, horizontal to shallowly northwest plunging, upright open folds. No foliations or lineations attributable to this event are recognized in Thelwood Formation lithologies. However, there is a distinct northeast striking, vertical joint set perpendicular to fold axes defined by bedding. Effect of the Mesozoic event on the Myra and Price Formations resulted in the development of second-order or parasitic folds relative to folds in the Thelwood Formation. The resultant structures, confined largely to the anticlinal cores (defined by folds in the Thelwood Formation), are northwest trending asymmetric open folds with steep southwest- to northeast-dipping axial surfaces, and, less commonly, symmetrical, tight to isoclinal folds with vertical axial planes. This is reflected by the range of steep northeast to steep southwest dips in the predominant foliation on the mine property. Plunges of these structures are shallow and vary in direction from northwest (Lynx area) to southeast (Price area) . Relative to the folding style in the Thelwood Formation, myra Formation structures can be classified as disharmonic, reflecting contrasting ductilities between the two units (Myra Formation was more ductile: Juras, 1987).

Lithologies in the Buttle Lake Camp also experienced at least two deformational phases after the main mesozoic episode. The first is characterized by rotation of bedding due to later intrusion of batholiths of the Jurassic Island Intrusions. The second phase might be represented by the north-northeast and east-northeast trending joint sets observed in the mine-area. These joints may have formed as a result of Cretaceous to Tertiary tectonics related to uplifting of the Buttle Lake area.

Faulting

Most of the numerous mine property faults are high angle, normal faults; some are strike-slip. Flat dipping thrust-like structures are also present. Though the faults occur with many different orientations, the main trends are northeast, north, northwest and east-southeast. Many of the more significant faults are associated with schistose zones commonly characterized by gouge, breccia, schistosities parallel to the fault, and abundant kink bands. Bedding, foliations and joints have been rotated near some faults. Fault displacements range from centimetres to hundreds of meters. Most offsets are less than 100 M. The largest measured offset occurs on the Myra-Price fault with an estimated net slip of 850 m (Walker, 1985).

Metamorphism

Rock units in the Price and myra Formations are characterized by lower greenschist mineral assemblages similar to those attributed to regional submarine hydrothermal metamorphism (cf. Reed, 1983, 1984). The metamorphic mineral assemblages are diverse, reflecting the bulk composition of rock types (ultramafic to rhyolite) in the Myra Formation and whether the unit is flow dominant or clastic dominant. Alteration of ultramafic to intermediate volcanic flowe and clasts generally formed either epidote-dominant or chlorite-dominant assemblages of which the former is more common. Additionally, ultramafic volcanic rocks contain actinolite. Variations in epidote and chlorite in the ultramafic to intermediate volcanic rocks generally can be explained by the presence of multiple water/rock ratios in the hydrothermal system (Reed, 1983). Alteration and metamorphism of felsic volcanic rocks in the myra Formation formed numerous mineral assemblages that generally comprised varying proportions of sericite, albite and quartz.

Later superimposed burial metamorphism or dynamothermal metamorphism recrystallized phyllosilicate phases to coarser grain sizes and created local pressure shadow development. These effects are most pronounced in the hinge areas of Mesozoic structures and in schist zones related to faulting. Best evidence that the area experienced a later event is in reset K -Ar and, to a lesser degree, Rb- Sr isotopic dates (Juras, 1987).

Rock units in the Thelwood and Flower Ridge Formations are characteristically metamorphosed to sub-greenschist and lower greenschist facies. The Thelwood Formation contains a lower greenschist metamorphic mineral assemblage of chlorite, clinozoisite/epidote, quartz and albite. Flower Ridge Formation units contain similar assemblages except for the presence of actinolite and pumpellyite. The latter phase, indicative of a sub-greenschist facies, is present only in the mid- to upper parts of the formation.

MINERALIZATION AND ALTERATION H-W

The massive sulphide member of the H-W Horizon consists of a number of massive sulphide deposits (Main Zone, North Lenses, Upper Zones) that are collectively known as the H-W deposit (Figs. 4, 7). The H-W massive sulphide bodies are typical fine grained, massive to thin bedded assemblages of pyrite,

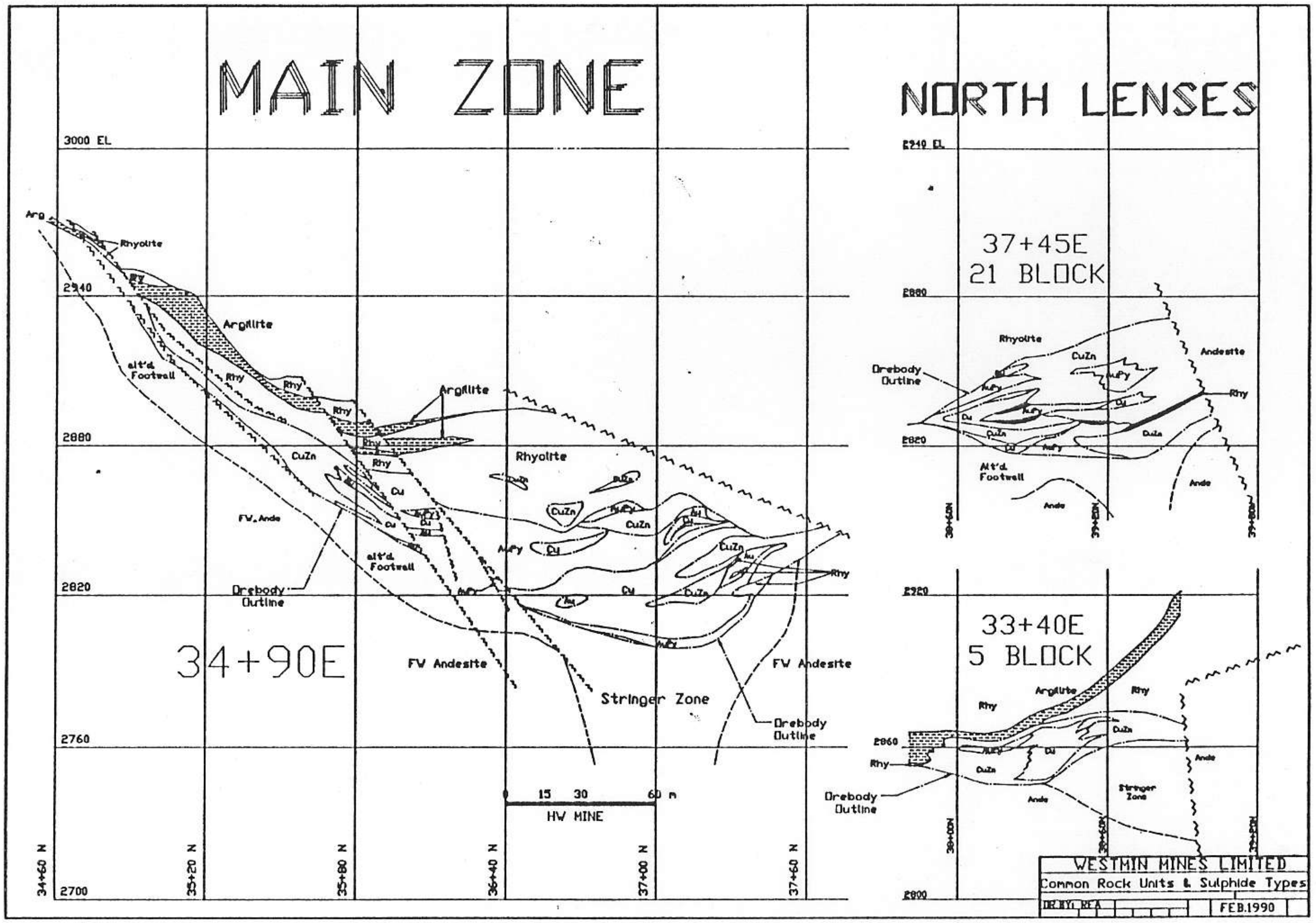

Figure 7. Sections through typical H-W Horizon massive sulphide deposits (coordinates are in meters). Sulphide and rock type symbols are: Au, AuPy = auriferous pyrite; Cu = pyrite + chalcopyrite; CuZn = sphalerite + chalcopyrite + pyrite; Rhy = rhyolite; Ande = andesite; alt'd = altered.

sphalerite and chalcopyrite with subordinate bornite, tennantite, galena. Trace native gold and argentite are recognized. Non-sulphide phases include barite, quartz and sericite. The deposits are commonly located at the base of the H-W Horizon.

The H-W Main Zone massive sulphide body, the largest of the H-W deposits, is an elongate, essentially flat lying lens some 1200m long by up to 500m wide. Thicknesses range from 3m along the 40° north dipping "fringe" zone to 80m in the flat lying central zone (Fig. 7) . The Main Zone sulphides exhibit a strong lateral zonation from the pyrite-rich central zone, having chalcopyrite and sphalerite-rich areas, to the barite-rich and pyrite-poor fringe zone containing significant sphalerite, chalcopyrite, galena and bornite. Cu/Zn ratios mimic the mineral zoning and define a copper-rich central region and a zinc-rich fringe area. mineral zonation on a smaller scale is more complex necessitating seven discrete sulphide types for mine planning purposes. Also within the Main Zone are regions of barren pyrite. However, because of relatively uniform gold distribution throughout the deposits (Walker, 1985), these base metal-poor areas contain mine average gold values and are consequently called auriferous pyrite.

The H-W North Lenses are a diverse group of commonly overlapping massive sulphide, semi-massive sulphide and clastic sulphide lenses north of the main Flat Fault (Figs. 4 and 7). The lenses range from precious metal-rich, pyrite-poor sphalerite, chalcopyrite and galena deposits, to precious metal-poor sphalerite and pyrite deposits, to strongly metal zoned pyritic lenses similar to the H-W Main Zone. The clastic sulphide deposits comprise massive sulphide clasts (all ore types) amongst varying types of rhyolite clasts. Individual clasts are up to one meter in size.

L-M-P

The Lynx-Myra-Price Horizon massive sulphides are composed of banded sphalerite, chalcopyrite, pyrite, galena and minor tennantite. Bornite was present in the Southwall Zone. Non-sulphides include barite, quartz and sericite. The deposits are largely located on or near the uppermost contact of the horizon. The L-M-P massive sulphide deposits do not vary greatly in composition and are not significantly zoned. Precious metal grades vary between the various L-M-P ore zones, from a high in the Myra deposit and the G and West-G Zones, to a comparative low in the S-Zone and Price orebodies.

Alteration

The Price and Myra Formations contain two main zones of hydrothermal alteration associated with massive sulphide mineralization. One occurs below the H-W deposit and a smaller one is found beneath the Southwall Zone of the L-M-P Horizon in the Lynx Mine. Both feeder zones lie in andesitic volcanic rocks which have been completely altered to assemblages of quartz + sericite + pyrite ± chlorite. Pyrite content varies from several to over 30 percent (Walker, 1985). it is distinctly coarser grained relative to the overlying massive sulphides. Chlorite-bearing rocks appear to be more common in less intensely altered areas, marginal to the central parts of the zones. The H-W alteration zone has an additional flanking zone consisting of moderate to strong albitization and silicification, such that the final assemblage consists of albite + quartz + sericite. This alteration assemblage also occurs irregularly within the upper units of the Price Formation outside the feeder zone areas.

DEPOSITIONAL HISTORY

Tha Price and Myra Formations represent volcanism and volcanogenic sedimentation in an intra-arc rift environment within an oceanic island arc system (Juras, 1987). More specifically, most of the preserved Price and myra stratigraphy in the mine property indicates that deposition occurred in a northwest-southeast trending rift basin (minimum dimensions being 2 to 3 km wide and 10 km long), named here as the Buttle Lake Camp basin (BBSN). The rifted nature is implied by the marked linear distribution of many of the lithologic units in the Myra Formation, including the ore deposits and the presence of rift related volcanic rocks (komatiitic basalts and basalts). Deposition into the rift basin followed a general sequence of events: (1) mafic to intermediate arc volcanism, (2) rifting, hydrothermal convection and sulphide mineralization, (3) felsic arc volcanism, (4) ultramafic to mafic rift volcanism, and (5) volcanogenic sedimentation. This sequence was repeated at least twice forming two massive sulphide mineralized horizons: H-W and Lynx-Ryra-Price.

The first series of events in the development of the Buttle Lake deposits involved periods o f mafic to Intermediate arc volcanism (e.g. Price Formation and 5E Andesite). Rifting, marked by high-angle normal faults, created complex patterns of ridge and trough structures along the rift basin floor (based on topography necessitated by drawing of reconstructed cross sections). Little if any volcaniclastic or epiclastic sedimentation occurred during the opening of the rift basin. This initial lack of sedimentation on basin or trough floors could indicate that a subaqueous environment existed for the entire island arc system and that rifting took place in a marginal region of the volcanic arc (Hawkins et al., 1984) instead of in the topographically higher central area (Karig, 1971; Carey and Sigurdsson, 1984). As a consequence of numerous faults (documented normal fault spacing in modern rift basins can average 50 m: Arcyana,1975) and a relatively high thermal regime, submarine hydrothermal convection occurred. The driving mechanism for hydrothermal fluids could be from shallowly emplaced magma chambers or cupolas (Cathles, 1983; Alabaster and Pearce, 1985). Locally, hydrothermal fluids discharged along high angle faults onto the sea floor. The discharge or vent areas were within trough structures and are characterized by development of crosscutting, conically to cylindrically shaped, moderately to strongly altered zones. These evolved hydrothermal fluids ponded in existing depressions giving rise to the characteristic elongate nature of the Buttle Lake massive sulphide lenses (lateral extent much greater than thickness: cf. Lydon, 1988). Explosive and effusive felsic arc volcanic activity accompanied the mineralization events, resulting in formation of massive sulphide hosting, rhyolite-rich units. Timing of the felsic volcanism played an important role in determining the thickness of massive sulphide bodies. If the concomitant felsic volcanism preceded the ponding of the ore solutions and deposited pyroclastic material within the trough structures, relief was decreased. Subsequent ponding of the hydrothermal fluids was thinner and more spread out (L-M-P Horizon orebodies). The much thicker H-W deposits, for the most part, formed before significant deposition of felsic pyroclastic material.

The final events of a general sequence consisted of ultramafic to mafic rift volcanism (e.g. G-Flow unit), and volcanogenic sedimentation. The rift-related lavas, if voluminous enough, influenced the life of contemporaneous sulphide-generating geothermal systems. Sudden covering by the flows prevented further sulphide mineralization by choking hydrothermal activity (e.g. G-Zone and G-Hanging Wall Zone, Lynx area) or filling in existing depressions. Volume of the ultramafic to mafic lavas, which increased in successively younger cycles, was governed by the growth of the intra-arc rift zone. Volcanogenic sedimentation commonly coincided with another phase of mafic to felsic arc or mafic rift volcanism. Resulting mixtures of volcaniclastic debris and flows buried previously deposited massive sulphide deposits and generally preserved them.

Thelwood and Flower Ridge Formations indicate a major change in depositional style and environment from the underlying Myra Formation (Juras, 1987). The Thelwood Formation is a sediment-sill complex consisting of siliceous tuffaceous sediments, subaqueous pyroclastic deposits and penecontemporaneous mafic sills. The Flower Ridge Formation, the final main Sicker Group volcanic phase in the Buttle Lake Camp, represents basaltic explosive to effusive activity from a back-arc (?) spreading centre system. The Thelwood sills are probable early, intrusive equivalents to the Flower Ridge units.

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