GUIDE TO MAJOR MINERAL DEPOSITS OF CENTRAL AND NORTHERN VANCOUVER ISLAND, SOUTHWESTERN BRITISH COLUMBIA, CANADA

A field guide for a GAC - MAC Victoria '95 field trip: 20 - 25 May 1995

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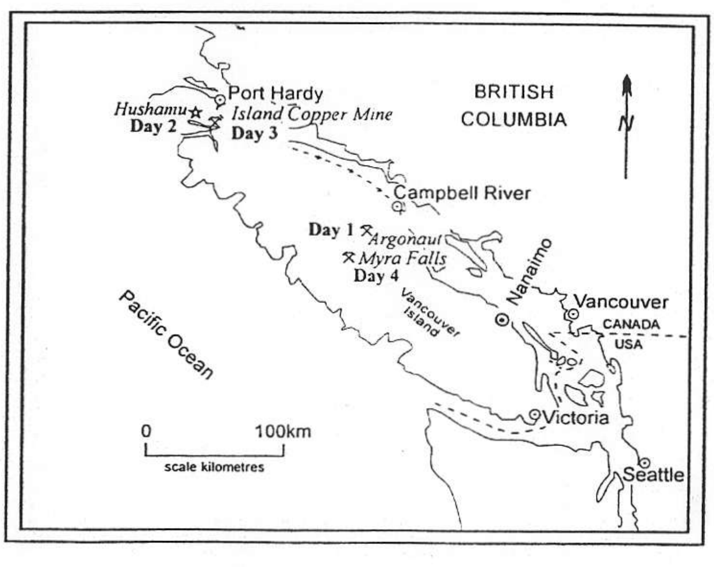

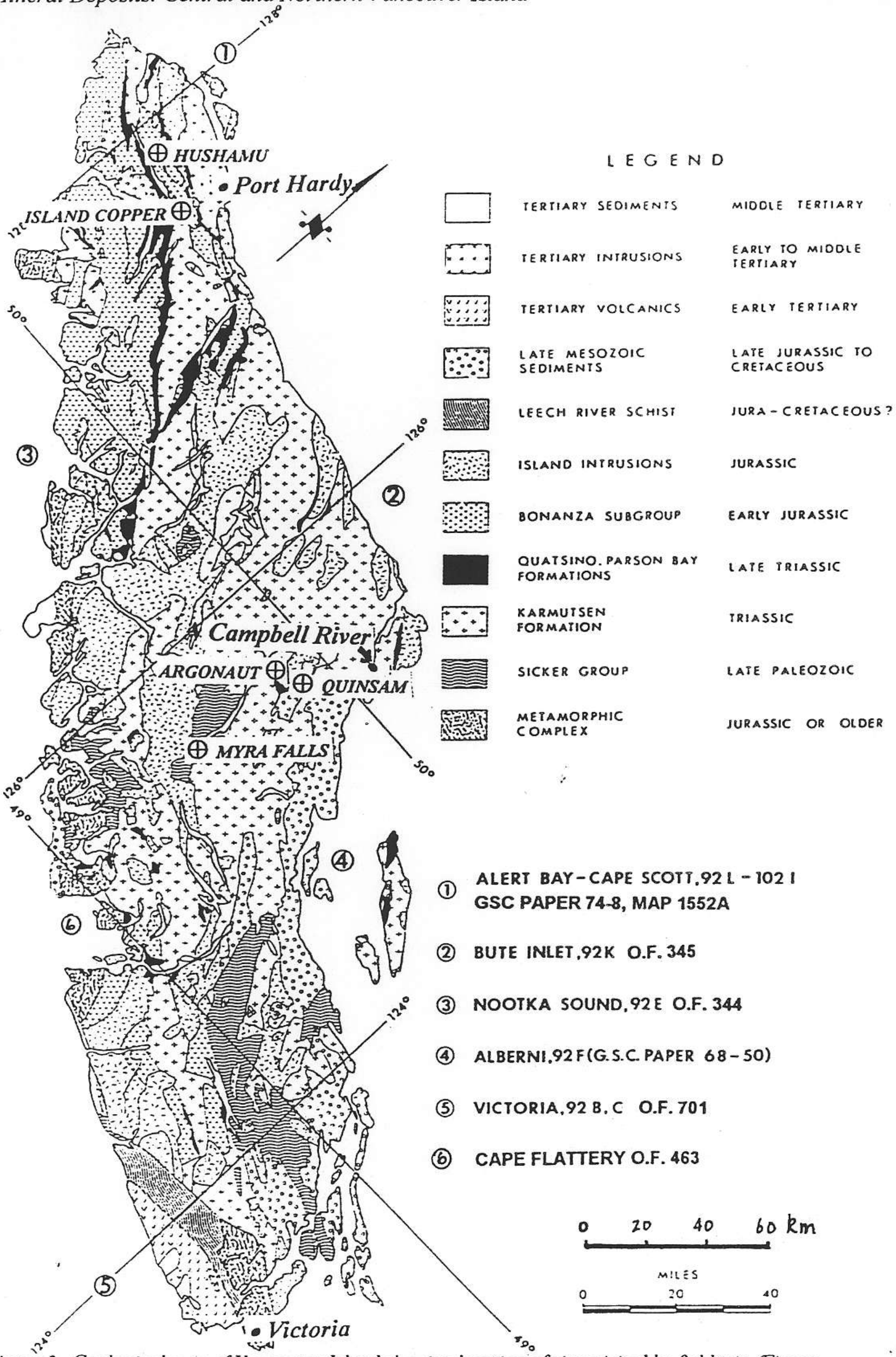

Figure 2. Geological map of Vancouver Island showing location of sites visited by field trip (Figure 1). Stratagraphic column is in Figure 3 (inside back cover). Mapping by the Geological Survey of Canada is as indexed and is after Muller, J.E., Northcote, K.E. and Carlisle, D. (1974): Geology and Mineral Deposits of Alert - Cape Scott Map-area (92L - 102I) Vancouver Island, British Columbia; Geological Survey of Canada, *Paper 74-8, 77 pages.*

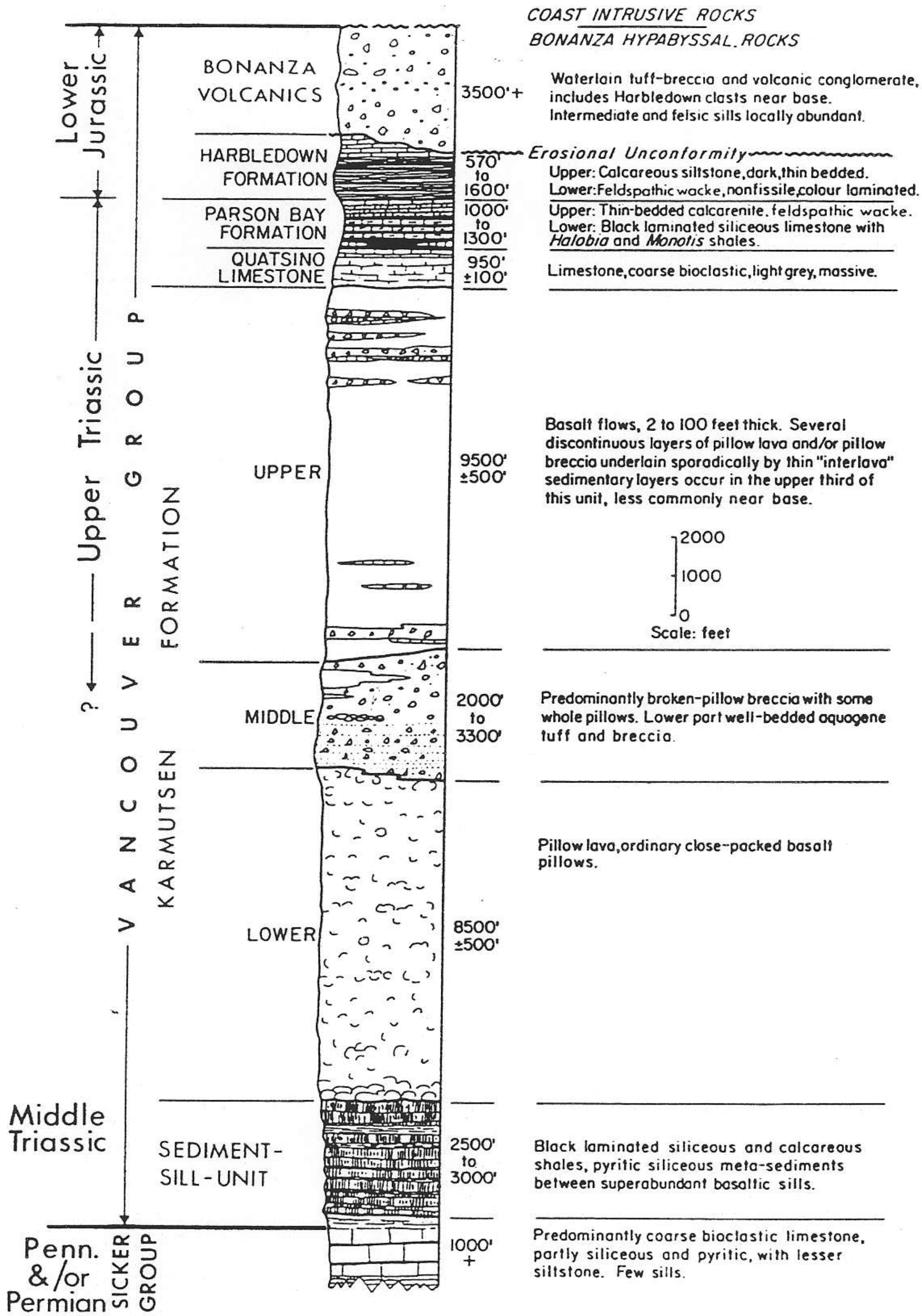

Figure 3. Major Paleozoic and Mesozoic straigraphic units of northeastern Vancouver Island according to Donald Carlisle, in *Muller* et al. *(1974). See geology map of Figure 2 (inside front cover).*

INTRODUCTION

Mining on Vancouver Island has had a long and colourful history. It began with the discovery of placer gold near Victoria in 1864. Mining flourished in the late 1800's, until the 1950's, with the large scale exploitation of major coal fields in the Cretaceous Nanaimo basin. During the 1950's and 1960's mainly copper -iron skarn deposits were mined. In 1966 Westmin's Myra Falls volcanogenic massive sulphide deposit came into production as the major mine on the island. It was first thought to be a shear zone replacement deposit and only later considered to be a Kuroko-type occurrence. Similar, more limited, VMS mineralization in equivalent hostrocks had been mined from 1898 to 1908, and again during World War II, at Mount Sicker, 150 kilometres to the southeast of Myra Falls. There the copper-zinc-lead-silver-gold-barite deposits supported a small smelter. The late 1960's saw the emerging pre-eminence of porphyry copper deposits culminating with the opening of the Island Copper mine in 1971. Currently there is exploration interest on the island for a broad spectrum of mineral deposits types and commodities. Major exploration interest is focused on gold and copper, magnetite, industrial minerals (limestone, marble, dimension stone, silica, pyrophyllite) and thermal coal.

The purpose of this field trip

This field trip will examine one past-producing mine and two active mines, shown on Figure 1. Each of these mines illustrate an important deposit type on Vancouver Island. The *Iron Hill (Argonaut) mine*, a past producer near Campbell River, is typical of island magnetite skarn deposits. *Island Copper mine,* near Port Hardy, is a porphyry copper-gold-molybdenum deposit; it is the seventh largest gold producer in the Province. *Westmin Resources' mine at Buttle Lake* in Strathcona Provincial Park is a volcanogenic polymetallic massive sulphide deposit. Successful exploration at the mine since 1980 has led to a ten-fold increase in ore reserves since mining began.

Each of the deposits occurs in a different stratigraphic group (Figures 2 and 3: inside front and back covers, respectively). The Westmin Resources massive sulphide deposits occur in Late Devonian rocks of the Myra formation, part of the Sicker Group. The Iron Hill (Argonaut) skarn deposit is found in altered Upper Triassic limestone of the Quatsino Formation of the Vancouver Group. Island Copper porphyry copper deposit is mainly in Jurassic volcanics of the Bonanaza Group, but is related to Early to Middle Jurassic intrusions of the Island Plutonic Suite.

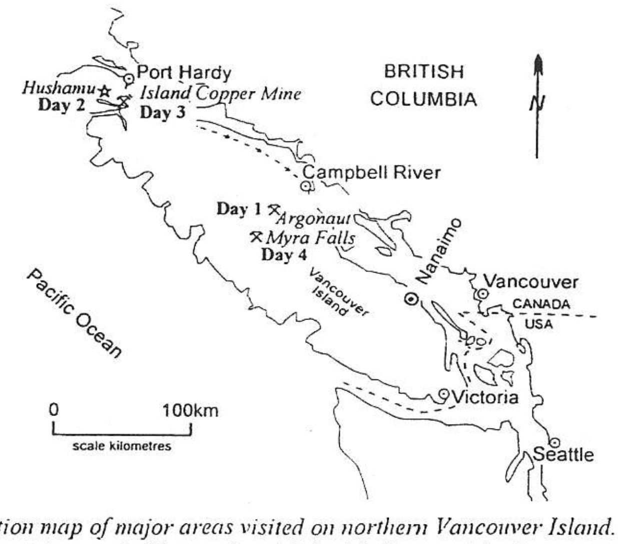

Figure 1. Location map of major areas visited on northern Vancouver Island. Geology and stratigraphic section are in Figures 2 and 3 (inside front and back cover, respectively).

Itinerary

DAY 1 [SATURDAY 20 MAY]

STOP PURPOSE [FIGURE 1, PAGE 2]

Drive Victoria to Campbell River
1-1 Examine Iron Hill (Argonaut) Fe-skarn (page 4)
Drive Campbell River to Port Hardy
Stay at Port Hardy Inn (604)949-8525

DAY 2 [SUNDAY 21 MAY]

STOP PURPOSE [FIGURE 5, PAGE 10]

2-1 Follow road log: Coal Harbour to Hushamu area (pages 8-9)
Examine Hushamu/Mt McIntosh porphyry copper gold prospects
Examine Pemberton Hills high sulfidation, advanced argillic epithermal prospects
Stay at Port Hardy Inn (604)949-8525

DAY 3 [MONDAY 22 MAY]

STOP PURPOSE [FIGURE 5, PAGE 10]

3-1 Follow road log: Island Highway to Island Copper mine (page 31)
3-2 Visit Island Copper porphyry copper-gold-molybdenum mine (page 31)
Drive Port Hardy to Campbell River
Stay at Coast Discovery Inn (604)287-7155

DAY 4 [TUESDAY 23 MAY]

STOP PURPOSE [FIGURE 17, PAGE 41]

4-1 Underground tour of the H-W and/or Battle VMS mine(s) (page 40)
4-2 Follow road log: Buttle Lake camp to Campbell River (page 40)
Drive Campbell River to Nanaimo: ferry to Vancouver is available at Departure Bay
Drive Nanaimo to Victoria

Acknowledgments

Participation in this field conference has been supported by the British Columbia Geological Survey Branch, Ministry of Energy, Mines and Petroleum Resources, and the Department of Geological Sciences, The University of British Columbia.

We acknowledge the permission to tour the Island Copper minesite by BHP Minerals Canada Ltd.; the EXPO (Hushamu) property by BHP Minerals Canada Ltd. and Jordex Resources Incorporated; and the Buttle Lake minesite by Westmin Resources Limited.

We thank the staffs at the visited mines for their professional contributions and hospitality, notably: John Fleming, Chief Geologist, Island Copper mine, BHP Resources Canada Ltd., and Cliff Pearson, Chief Geologist and Steve Juras, Exploration Geologist, Myra Falls Operations, Westmin Resources Limited.

Victor Koyanagi, B.C. Geological Survey Branch, prepared some of the figures for this field guide.

DAY 1: IRON HILL (ARGONAUT): A MAGNETITE - GARNET SKARN DEPOSIT

STOP 1-1: IRON HILL MINE

The abandoned site of the Iron Hill (Argonaut) mine (Figure 4) is about 25 km southwest of Campbell River. The deposit, visible from and immediately east of Upper Quinsam Lake, is situated on Iron Hill. It may be reached from Campbell River by: (i) going west about 16 km on highway 28, (ii) turning south on the logging/mining road that passes the Quinsam Coal mine, (iii) traveling southward on this road for about 13 km to the east side of Upper Quinsam Lake to a point just before Mine Creek where the pits are visible directly ahead, and (iv) traveling about 500 m east on a subsidiary logging road to a track on the right that allows convenient access to Mine Creek near the northeast corner and base of the main dumps. A short field traverse follows:

1. Park the vehicles just before and immediately north of Mine Creek.
2. Cross the creek. While crossing it, note the well exposed, I-type, xenolithic hornblende granodiorite of the Jurassic Island Intrusions. Metallogeny of copper-iron skarn is closely linked to this granitic type (*cf.* tungsten skarn and S-type granite association).
3. Climb the dumps that are in front and slightly to the right. The dumps provide good examples of skarn mineralogy and texture. Hematite-magnetite balls, apparently replacing garnets, locally are spectacular. Crossing the dumps allows access to the lower bench on the southwest side of the open pit lake.
4. At the northwest end and start of the traverse along the lower bench, you are in marble of the Quatsino Formation. Layering is said to be bedding.
5. Near the center of the lower bench you are in massive magnetite and massive brown garnetite. The pit on your left was mainly a pod of massive magnetite. The size of this is impressive.
6. Near the slide that crosses the bench towards its southeast end there are breccias with margins of jig saw garnetite fragments in a matrix of massive magnetite.
7. Beyond the slide, altered Karmutsen volcanics occur.
8. The road beyond the lower bench and to the left makes a loop that can be followed to return to the vehicles.

IRON HILL (ARGONAUT): A MAGNETITE - GARNET SKARN DEPOSIT

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The Iron Hill magnetite - garnet skarn deposit (Figure 4) occurs at the contact of Quinsam granodiorite of the Jurassic Island Intrusions with basalt of the Triassic Karmutsen Formation and recrystallized limestone/marble of the Upper Triassic Quatsino Formation. This is the classical setting of Fe-Cu skarns in Wrangellia. The deposit is in central Vancouver Island (NTS: 092F13; 49.863° N, 125.544° W, 457 m elevation).

The abandoned mine site is about 25 km southwest of Campbell River. The deposit, visible from and immediately east of Upper Quinsam Lake, is situated on Iron Hill.

Comments

Deposit Type

Skarn, contact metasomatic, pyrometasomatic, magmatic(?).

Owners and Production

The deposit was discovered in the early 1900's. In 1948 a limited drill program was initiated by the Coast Iron Company and in 1949 they shipped about 0.9 million tons of direct shipping ore to Wenatchee, Washington, U.S.A. The mine was subsequently leased to the Argonaut Mining Company (a subsidiary of Utah Mining and Construction Co. Ltd.), which mined the deposit from 1951 to 1957. Over this period 3.7 million tonnes of mined ore produced 2.0 million tonnes of magnetite concentrate with 56% total iron (Hancock, 1988; BCMEMPR MINFILE: 092F-075), which was shipped to Japan. Recent owners, unknown to writer, have investigated the possibility of recovering garnet from the tailings and waste pile.

Ore

Magnetite was mined; potential of limestone and garnet has been considered. Skarn has preferentially replaced the marble with respect to the basalt. Ore varies from coarsely crystalline massive magnetite at its core to a mixed, crystalline magnetite/garnetite near the margin (Figure 1) next to a boundary phase of nearly pure crystalline garnetite.

Host rocks

Figure 4 shows an elliptical pendant, about 400 m northwest by 300 m northeast, that is floored and surrounded by Jurassic Quinsam granodiorite of the Island Intrusions. The pendant has a core of fetid, massive to well bedded, Upper Triassic Quatsino recrystallized limestone that marks a northwest trending syncline overturned to the southwest (Black, 1952). The marble is surrounded by Triassic Karmutsen basalt. Magnetite - garnet skarn is concentrated along the contact of the basalt and the marble, but is most pronounced in the keel of the syncline near its intersection with the granodiorite.

Age

Jurassic: The skarn deposit was generated by the I-type, hornblende granodiorite of the Jurassic Island Intrusions (Quinsam intrusion).

Mineralogy

Opaques in the ore are mainly magnetite with minor hematite. Skarn includes: andradite (commonly zoned), calcite, hedenbergite-diopside, johannsenitic proxene, grossularite, idocrase, ilvaite, hematite and maghemite. Wall rock alteration includes actinolite, epidote and chlorite. Minor discontinuous, late veins cross-cut the skarn and commonly are pyrite in a gangue of abundant rhodochrosite associated with lessor quartz and iron carbonate. The veins also contain trace sphalerite, cobaltite and chalcopyrite.

Zonation

A distinct zonation of skarn away from contacts with the volcanic and carbonate rocks is common (*cf.* Meinert, 1984). Zonation also reflects protolith composition. Hood (1989) named nine skarn types. Major ones include: (i) pyroxene-ilvaite in a limestone protolith; it occurs within 1-2 m of the skarn-marble contact, (ii) massive magnetite-garnet in a limestone protolith; it is the most extensive replacement skarn and occurs in contact with the marble or separated from it by a narrow border of pyroxene-ilvaite skarn, (iii) garnet-magnetite-carbonate in a volcanic protolith; it is extensive over several meters in the basalt away from the marble contact, and (iv) pyroxene-garnet in a volcanic protolith; it occurs toward fresher volcanics adjacent to the garnet-magnetite-carbonate skarn.

Genetic origin

Mineralogy and textures within the Iron Hill deposit generally can be attributed to successive replacement by infiltration of, and replacement by, progressively iron enriched hydrothermal solutions. Locally, a magmatic origin is indicated by (Hood, 1989, *cf.* Clapp, 1912): (i) breccia in garnetite with garnetite jig-saw fragments apparently inflated by a matrix of magnetite, (ii) massive and featureless nature to the large pods of pure magnetite, and (iii) a magnetite 'dike' that does not have a skarn border.

Selected annotated references

Black, J.M., 1952. Iron Hill. B.C. Dept. Mines, Annual Report, 1952, pp. A221-A228. *Produced general map of the deposit (Figure 1). Suggested that magnetite was concentrated in the nose of an overturned syncline.*

Clapp, C.H., 1912. Southern Vancouver Island. Geological Survey of Canada, Memoir 13. *Concluded that iron was emplaced as magnetite magma.*

Eastwood, G.E.P., 1966. Iron deposits of British Columbia. In 'Tectonic History and Mineral Deposits of the Western Cordillera', Canadian Institute of Mining and Metallurgy, Special Volume No. 8, pp. 329-333. *Presents tabulated data for skarns on Vancouver Island.*

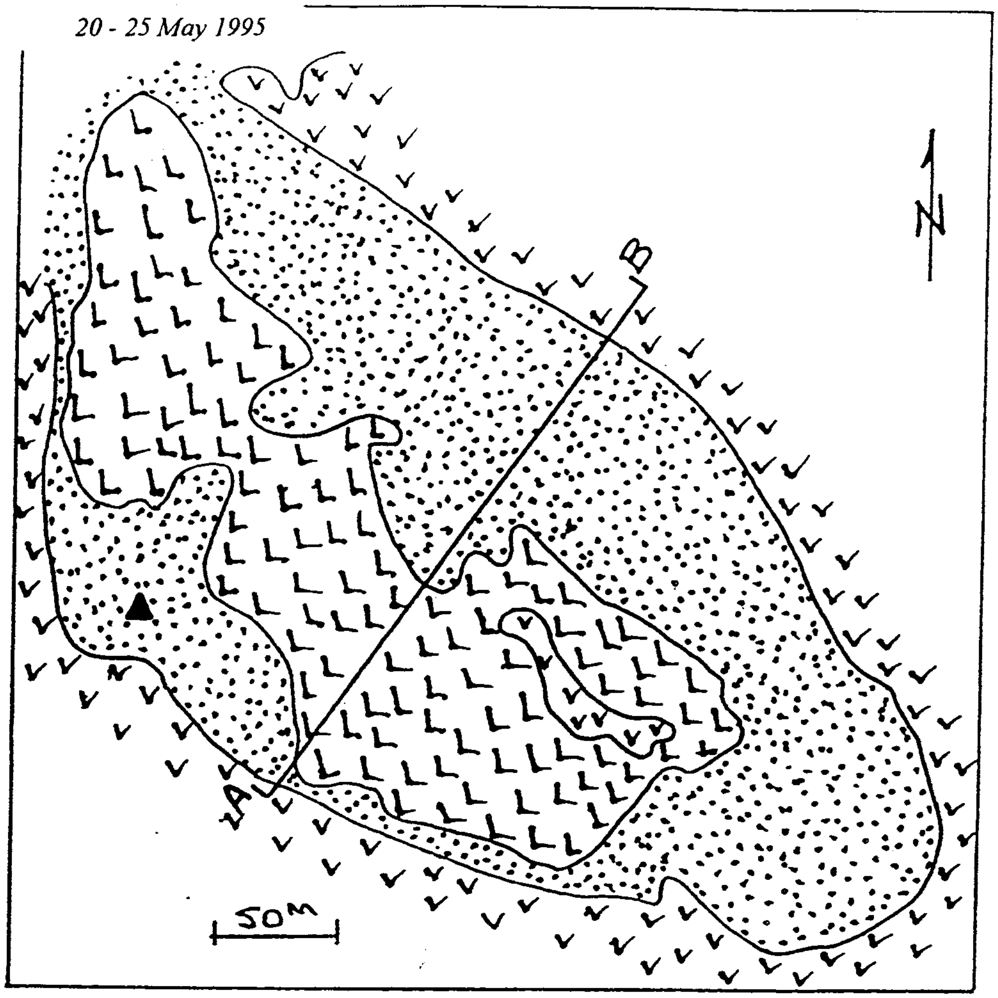
Einaudi, M.T., Minert, L.D., and Newberry, R.J., 1981. Skarn deposits. Economic Geology, 75th Anniversary Volume, pp. 317-319. *Classifies Vancouver Island magnetite skarns as island arc calcic magnetite type.*

Hancock, Kirk D., 1988. Magnetite occurrences in British Columbia. BCMEMPR Open File 1988-28, 153p. *See excellent location map on p. 28 and description pp. 29-30.*

Hood, Chris T.S., 1989. Geology of the Iron Hill calcic iron skarn, central-east Vancouver Island. Unpublished BSc thesis, University of B.C., 48p. *Defined nine skarn types, based on bulk mineralogy and textural properties, that are controlled by proximity to contacts and composition of protolith.*

Meinert, L.D., 1984. Mineralogy and petrology of iron skarns in western British Columbia, Canada. Economic Geology, vol. 79, pp. 869-882. *Describes zoning in skarns.*

Sangster, D.F., 1969. The contact metasomatic magnetite deposits of southwestern British Columbia. Geological Survey of Canada, Bulletin 172, 85p. *See especially: figure 8 (Figure 1) and pp. 54-56.*



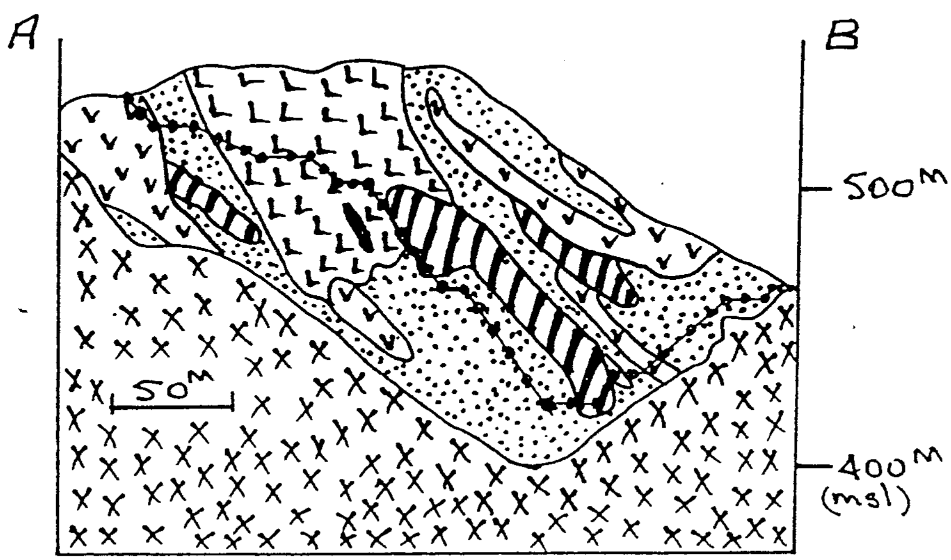


Figure 4. Plan and cross-section of Iron Hill (Argonaut) magnetite-garnet skarn deposit, central-east Vancouver Island, southwestern British Columbia. Plan and cross-section are after Black (1952) and Sangster (1969), respectively. (See also Hancock, 1988.) V = basalt of Triassic Karmutsen Formation. L = recrystallized limestone of Upper Triassic Quatsino Formation. X = Quinsam granodiorite of the Jurassic Island Intrusive Suite. Dots = skarn and magnetite. Slashes = massive magnetite. Line with dots = approximate pit cross-section. Solid triangle = Iron Hill.

DAY 4: BUTTLE LAKE VMS CAMP

STOP 4-1: UNDERGROUND TOUR OF H-W AND/OR BATTLE ZONE (FIGURE 17)

In the very early morning we drive from Campbell River to the south end of Buttle Lake in Strathcona Provincial Park. The tour starts at the Myra Falls operation site, approximately 80 km from Campbell River (Figure 1). Basic underground gear will be provided (hard hats, belts and steel-toed boots with a limited size range, *etc.*).

We will view ore-hosting lithologies of the Myra formation and examples of the main ore types. See the following papers in this field guide: (i) Pearson, (ii) Barrett *et al.*, and (iii) Robinson *et al.*

STOP 4-2: ROAD LOG (FIGURE 17)

In the afternoon we retun to Campbell River and make four stops to view examples of the stratigraphic sequence overlying the Myra formation in the Sicker Group. The following notes refer to Figure17 (refer also to the stratigraphic columns in Figure 3 [inside back cover] and Table 2):

1. 0.0 km. H-W headframe.

2. 2.5 km (southwest end of Buttle Lake). Thelwood formation (sharp banded tuff). Turbiditic, thin to medium bedded tuffaceous mudstone to sandstone with chert interbeds. Intercalated with synsedimentary mafic sills. This unit probably unconformably overlies the Myra formation that hosts the ore zones.

3. 4.0 km (southeast end of Buttle Lake). Flower Ridge formation (scoria clast unit). Bedded mafic tuffs, lapilli tuffs and pyroclastic breccias with prevalent and distinctive scoriaceous (amygdular) clasts. This unit has a lower contact that is gradational with the Thelwood formation. Its upper contact is abrupt against Buttle Lake Limestone. From this stop point a clear view of Price hillside is available; its geology is detailed in Juras (1987, unpublished PhD thesis, The University of Brisish Columbia). The original VMS discovery in the Buttle Lake camp was in the creek immediately to the left of the Price adit near the middle of the hillside.

4. 16.1 km (Karst Creek day area and boat ramp, east side of Buttle Lake). Buttle Lake Formation is characterized by crinoidal limestone with abundant chert nodules and beds.

5. 31.4 km (central-eastern side of Buttle Lake). Karmutsen Formation in this area is characterized by pillowed and hyaloclastite basalt. Exposures near Campbell Lakes (Figure 17) are columnarly jointed, indicating subaerial deposition. Native copper is common in the Karmutsen basalt. For example there are native copper showings on Quadra Island, immediately east of Campbell River.

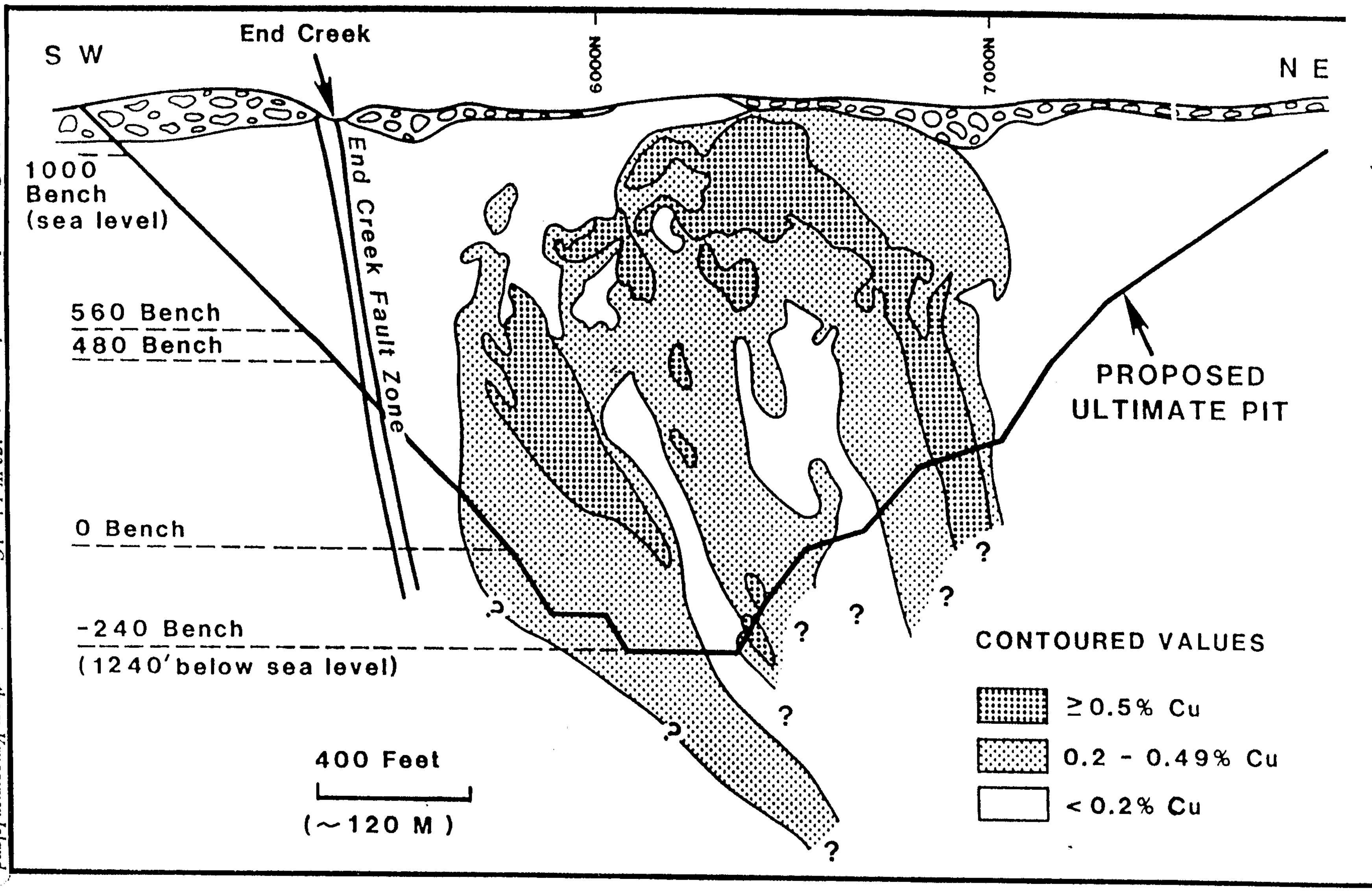


Figure 16. Contoured copper values, section 173 W, Island Copper mine, northern Vancouver Island.

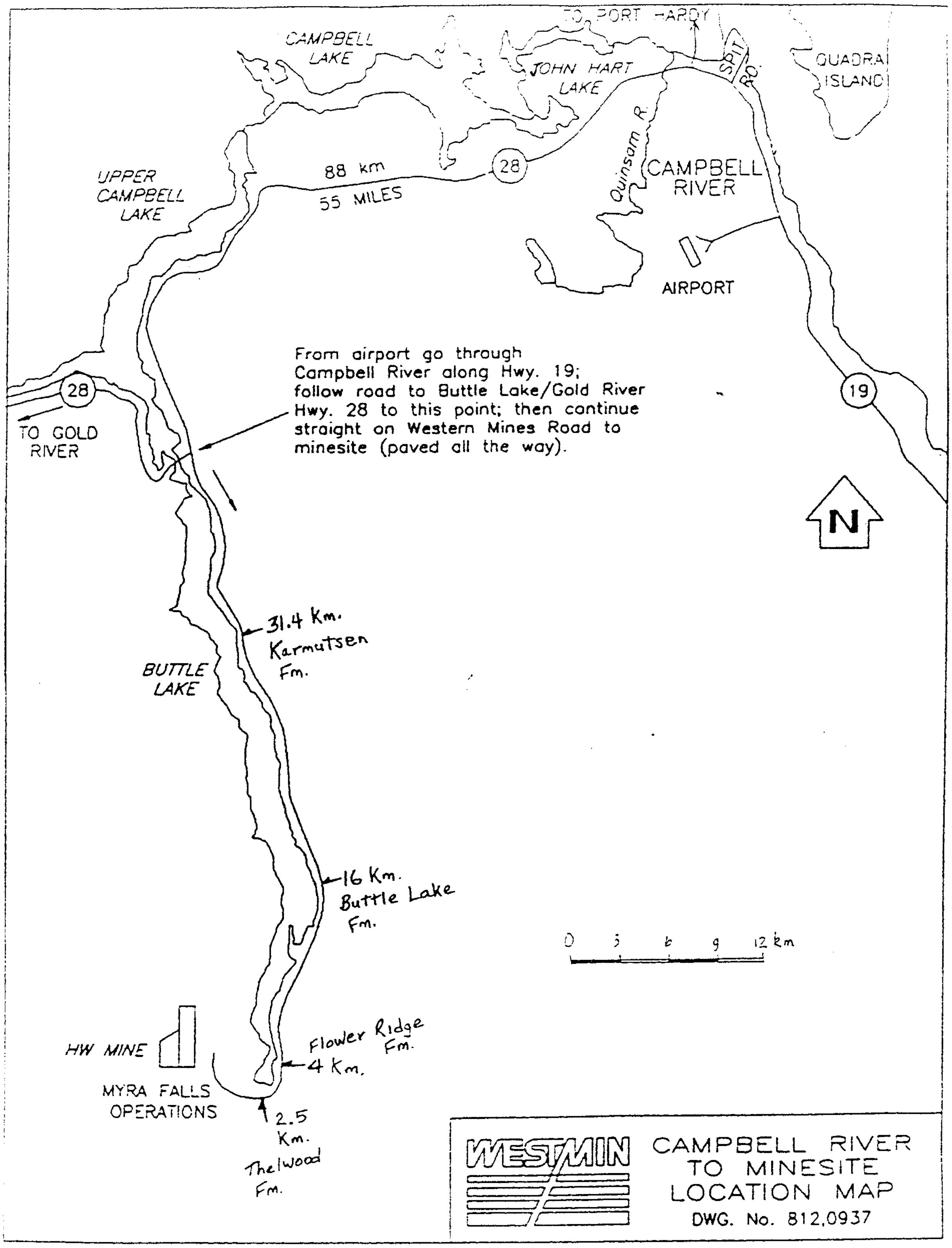


Figure 17. Fourth day travel route Campbell River to Myra Falls. Locations of field stops are shown.

MINING ZINC-RICH MASSIVE SULPHIDE DEPOSITS ON VANCOUVER ISLAND, BRITISH COLUMBIA

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Abstract

The Myra Falls Minesite, of Westmin Resources Limited, is located at the geographic center of Vancouver Island, within the confines of Strathcona Provincial Park (Figures 1 and 17). The Operation includes two active underground mines, H-W and Lynx, together with a modern 3,650 tpd milling facility. Recent exploration successes will lead to the commissioning of a third mining area in late 1993 - The Battle/Gap Mine.

These ore deposits are complexly metal-zoned volcanogenic massive sulphides of Devonian Age, hosted in the Myra Formation of the Sicker Group volcanic assemblage. Three distinct felsic volcanic units are defined within the 450 metre thick Myra Formation. They are, from oldest to youngest, the H-W Horizon, the LMP Horizon and the Upper Rhyolite Unit. Massive sulphide mineralization occurs throughout the property in the H-W and LMP Horizons. There are a number of orebody types, including polymetallic massive sulphides, polymetallic disseminated sulphides, zoned pyritic massive sulphides, clastic sulphide zones and stringer sulphide zones. Individual orebodies range in size from 10,000 tonne zinc-rich polymetallic lenses to the 10 million tonne, zoned massive sulphide H-W main lens.

The property has been in continuous operation for 26 years, producing over 13 million tonnes of ore averaging 2.2 g/t Au, 64.0 g/t Ag, 1.9% Cu, 0.6% Pb, and 5.6% Zn. Current Geological reserves stand at 12.5 million tonnes at a comparable grade, including 4 million tonnes of recently discovered high grade ore in the Battle and Gap Zones.

Mining and milling methods have evolved over time to enable successful extraction and milling of these complex ores. Change is ongoing with the recent conversion of the H-W Mine to large-scale bulk mining methods, and the development of effective computerized ore reserve calculation and mine planning tools. These changes, in concert with successful exploration techniques that led to recent high grade ore discoveries, have breathed new life into the Operation and should assure its' present and future viability.

Several other noteworthy aspects of the operation will be briefly addressed, including the challenges inherent in operating a mine within a Provincial Park setting.

Introduction

The Myra Falls Operations of Westmin Resources Limited are located in steep, mountainous terrain near the south end of Buttle Lake on Vancouver Island (Figures 1 and 17). Westmin's claim block, seven km long by two to three km wide, is situated in Strathcona Provincial Park, one of British Columbia's oldest and largest parks. The first claims in the area were staked in 1917, when Strathcona Park was opened for prospecting. Three massive sulphide showings were located then; two in Myra Creek Valley and the third in adjacent Thelwood Creek Valley. These showings became, in time, the Lynx, Myra and Price Mines (Figure 18).

Sporadic exploration work continued through to 1961, when Western Mines Limited (the precursor to Westmin Resources Limited) acquired the claims and concentrated its efforts on the Lynx claim group. Ore definition drilling quickly indicated a mining reserve of 1.9 million tonnes, part of which could be mined by open pit. Mining started in the pit in 1966, proceeded rapidly underground and has continued to the present day.

The open pit phase was completed in 1975 with 1.6 million tonnes mined. The Lynx Mine operated at production rates of 600 to 900 tonnes per day until 1985, at which time

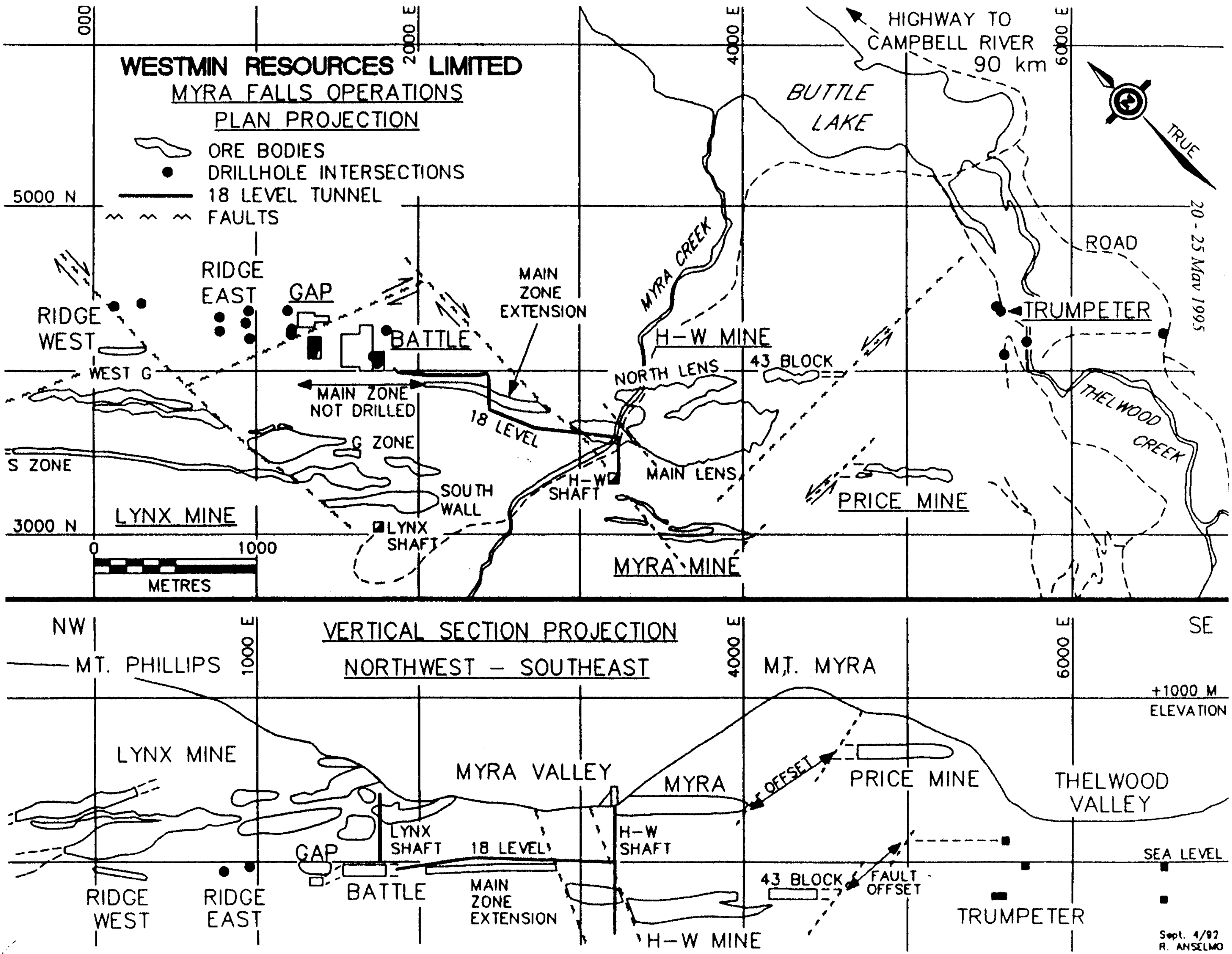

Figure 18. Plan and vertical projections of ore bodies, Buttle Lake camp, central Vancouver Island.

production gradually decreased to the current 300 tonnes per day. Production to date at Lynx has been 5.3 million tonnes grading 2.5 g/t Au, 90 g/t Ag, 1.6% Cu, 1.0% Pb, and 7.5% Zn. There is excellent potential for additional reserves and mine exploration continues unabated.

In 1969, with production and reserves comfortably established at the Lynx Mine, exploratory drilling turned to the Myra claims directly across Myra valley. A series of high grade, precious-metal-rich ore intersections led quickly to a production decision and the Myra Mine came on-stream in 1972. This mine operated for 13 years, at prodnction rates ranging from 200 to 400 tonnes per day, until reserve depletion in 1985. Total production was 1.0 million tonnes grading 3.0 g/t Au, 160 g/t Ag, 1.0% Cu, 1.5% Pb, and 9.5% Zn.

The Price claims, in Thelwood valley, received serious attention in 1979, resulting in the discovery of the Upper Price Zone. Underground development and drilling subsequently has defined a geological reserve of 185,000 tonnes grading 1.5 g/t Au, 66 g/t Ag, 1.4% Cu, 1.3 % Pb, and 10.4% Zn. The location of this zone in Thelwood valley, as well as its distance from existing workings, has precluded any early development but its day will come.

Concurrent surface drilling in 1979 resulted in the discovery of the H-W orebodies, at a depth of 400 m below the floor of Myra valley (see Fig. 18). Accelerated exploration drilling on this zone in 1980 indicated the potential for a major massive sulphide deposit, of unprecedented size for the camp, and a favourable production decision was soon forthcoming. The H-W Mine was commissioned in 1985 and has operated since then at production rates of 2,700 to 4,000 tonnes per day. Total production to January 1st, 1993 was 7.5 million tonnes grading 1.9 g/t Au, 30 g/t Ag, 2.1% Cu, 0.3% Pb and 4.2 % Zn. Remaining mining reserves at that date were calculated at 6.2 million tonnes grading 1.9 g/t Au, 32 g/t Ag, 1.6% Cu, 0.4% Pb, and 3.8% Zn.

Mine exploration is ongoing, with expenditures of (Cdn) $3 to $4 million per annum. This commitment has resulted in several recent high-grade ore discoveries, revitalizing the operations. These new zones now total 3.6 million tonnes proven and probable geological reserves, grading 1.8 g/t Au, 55 g/t Ag, 2.2% Cu, 0.6% Pb, and 11.2% Zn. In addition, there are 2.7 million tonnes of possible reserves at a similar grade. The first of the new ore zones to reach production will be the Battle Zone, in July 1993 - opening a new chapter in the history of the Myra Falls mining operations.

Property-wide production to January 1st, 1993, has been 13.8 million tonnes grading 2.2 g/t Au, 64 g/t Ag, 1.9% Cu, 0.6% Pb, and 5.6% Zn, mined over 26 years of continuous production. Current geological reserves in all categories are 15.2 million tonnes, at 2.0 g/t Au, 48 g/t Ag, 2.0% Cu, 0.5% Pb, and 7.1% Zn. These figures certainly reflect a major zinc resource.

During its life to date Myra Falls Operations has continually evolved by embracing new mining and milling methods. Hence, successful application of innovative geological thinking to the search for new orebodies has resulted in discovery of ore to be extracted and processed by methods that are continuously under review and improvement.

Minesite facilities now comprise: two operating underground mines, the Lynx and H-W; a modern 3,650 tpd concentrator, assay lab, mine offices and shops, surface tailings disposal system, and two hydroelectric power plants totalling 11 mW. A 180 person camp is in operation, but the majority of the 450 employees commute daily 90 km from Campbell River via bus transportation provided by Westmin.

Geological setting

Regional geology

The Insular belt of the Canadian Cordillera underlies most of Vancouver Island. The lower members of this belt, including the Palaeozoic Sicker and Buttle Lake Groups, the Triassic Vancouver Group, and the Jurassic Bonanza Group (Figure 2, inside front cover) are postulated to be part of an allocthonous terrane. This terrane has been named Wrangellia by Jones, Silberling, and Hillhouse (1977), and is thought to have been accreted onto North America some 150 million years ago.

Volcanic hosted massive sulphide (VHMS) mineralization is present in the oldest member, the Palaeozoic Sicker Group. Sicker Group rocks are exposed on Vancouver Island in fault-bounded structural uplifts and the Buttle Lake uplift hosts the Myra Falls massive sulphide orebodies. Massive sulphide ore was also mined intermittently by others in a smaller uplift area, near Duncan, British Columbia, 160 km to the south. Four formations are identified (Juras, 1987) in the Sicker Group at Myra Falls: the late Devonian Price and Myra Formations, the early Mississippian Thelwood Formation and the Mississippian Flower Ridge Formation.

The Price Formation (Footwall H-W Andesite in Mine terminology) is greater than 400 m thick (base unexposed) and consists of a sequence of massive basaltic andesite flows and volcaniclastics. These rocks are poorly exposed on the mine property and are recognized mainly in drillcore.

The Myra Formation (Mine Sequence), which hosts all known ore occurrences at Myra Falls, conformably overlies the Price Formation. This Formation is up to 450 m thick and is subdivided into ten stratigraphic units that are described later under Mine Geology. These units show remarkable continuity along their NW-SE trend but exhibit abrupt facies changes, across strike in a NE-SW direction, reflecting their depositional environment. The environment of deposition is interpreted to be related to rifting within an oceanic island arc system.

Conformably overlying the Myra Formation is the Thelwood Formation, a 270 to 500 m thick thin-to-medium-bedded sequence of siliceous volcaniclastic rocks and subaqueous pyroclastic flows intruded by mafic sills.

The uppermost formation in the Sicker Group is the Flower Ridge Formation. It is also the youngest Palaeozoic stratigraphy exposed in the mine area. This Formation is up to 1,000 m thick, is basaltic in composition and consists mainly of fine to coarse submarine volcaniclastic deposits.

The Sicker Group, within the Buttle Lake uplift, has undergone regional greenschist facies metamorphism. This resultant metamorphic veil appears to have overprinted most evidence of submarine hydrothermal alteration.

Mine geology

Stratigraphy within the Mine Sequence has been used as perhaps the most critical exploration tool, and will therefore be discussed in considerable detail. Other areas of Mine Geology described include the sulphide deposits, alteration and structural geology.

THE MINE SEQUENCE (MYRA FORMATION)

The Mine Sequence (Myra Formation) is subdivided into ten informal litho-stratigraphic units (Juras and Pearson, 1990; Figures 19 and 20). These units are described below in order of decreasing relative age:

1. The H-W Horizon is the lowermost unit (up to 200 m thick), and consists mainly of felsic tuffs and flows, with subordinate argillites, mafic flows, volcaniclastics and massive sulphides. These rocks are widespread throughout the mine area and represent the thickest and most extensive rhyolite sequence seen. In general, argillites and felsic tuffs predominate in the SW part of the property; above the H-W Main Lens for example, whereas felsic flows are more common in the NE, above the H-W North Lens position. The mafic flow component typically is present in the central region, associated with argillite. These mafic flows consist of aphyric to pyroxene-phyric komatiitic basalt and hyaloclastite (Juras 1987). Massive sulphides are present as clasts, stringers, laminae and lenses (see Figures 19 and 20).

   The bulk of the massive sulphide mineralization was deposited at the base of the H-W Horizon. This position is represented by the H-W Main Lens, H-W North Lenses, and the Battle Zone, which together total some 25 to 30 million tonnes of pyritic massive sulphides. Stratigraphically higher in the H-W Horizon are the Upper Zone massive sulphides, consisting of small baritic, precious-metal-rich polymetallic ore zones represented by the H-W Mine Upper Lenses and the Gap Zone. Higher again, Hanging Wall Zone sulphide deposits occur at the top of the H-W Horizon; in the Ridge Zone

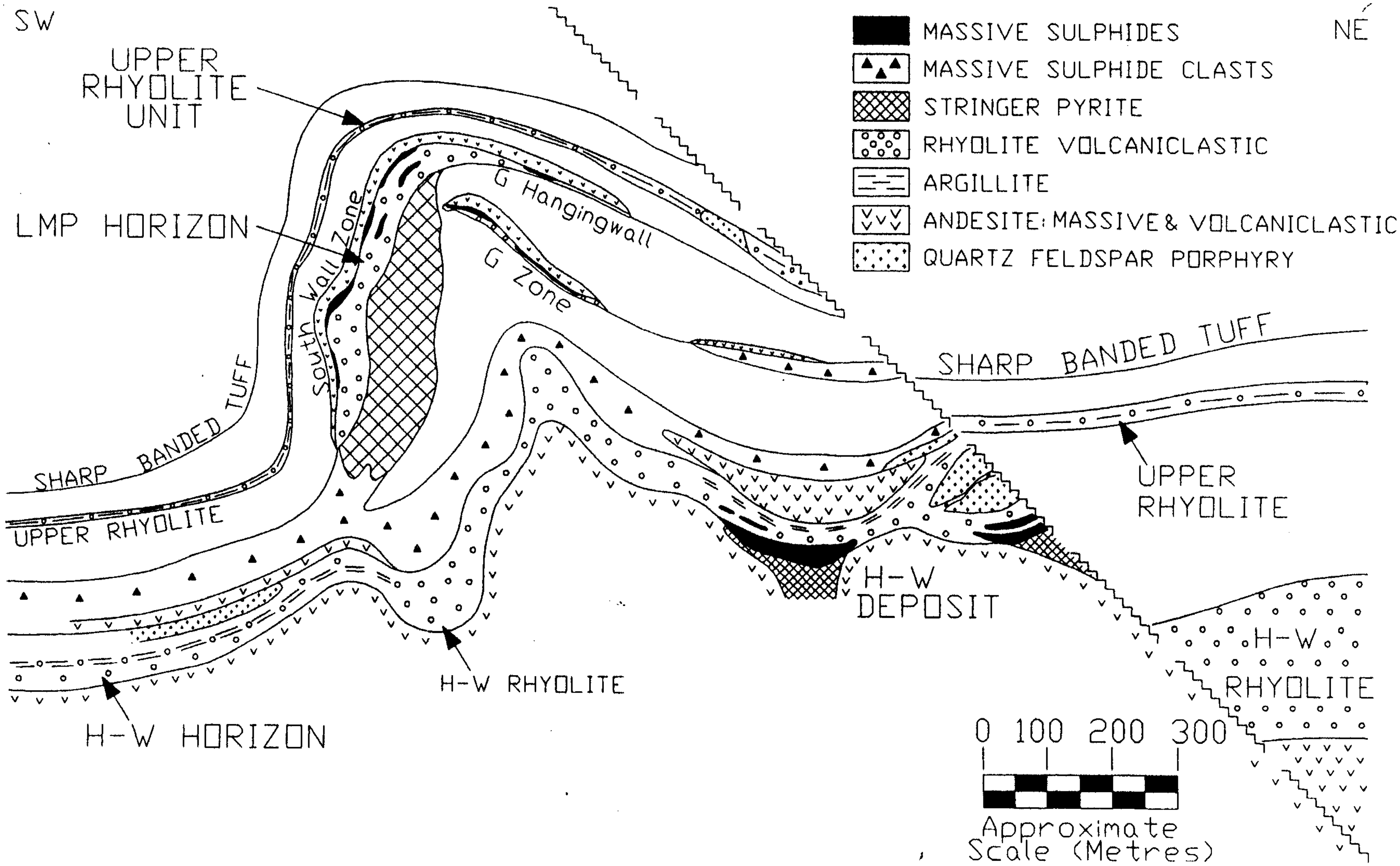

Figure 19. Composite cross-section of the mine sequence, Myra formation, Buttle Lake camp.

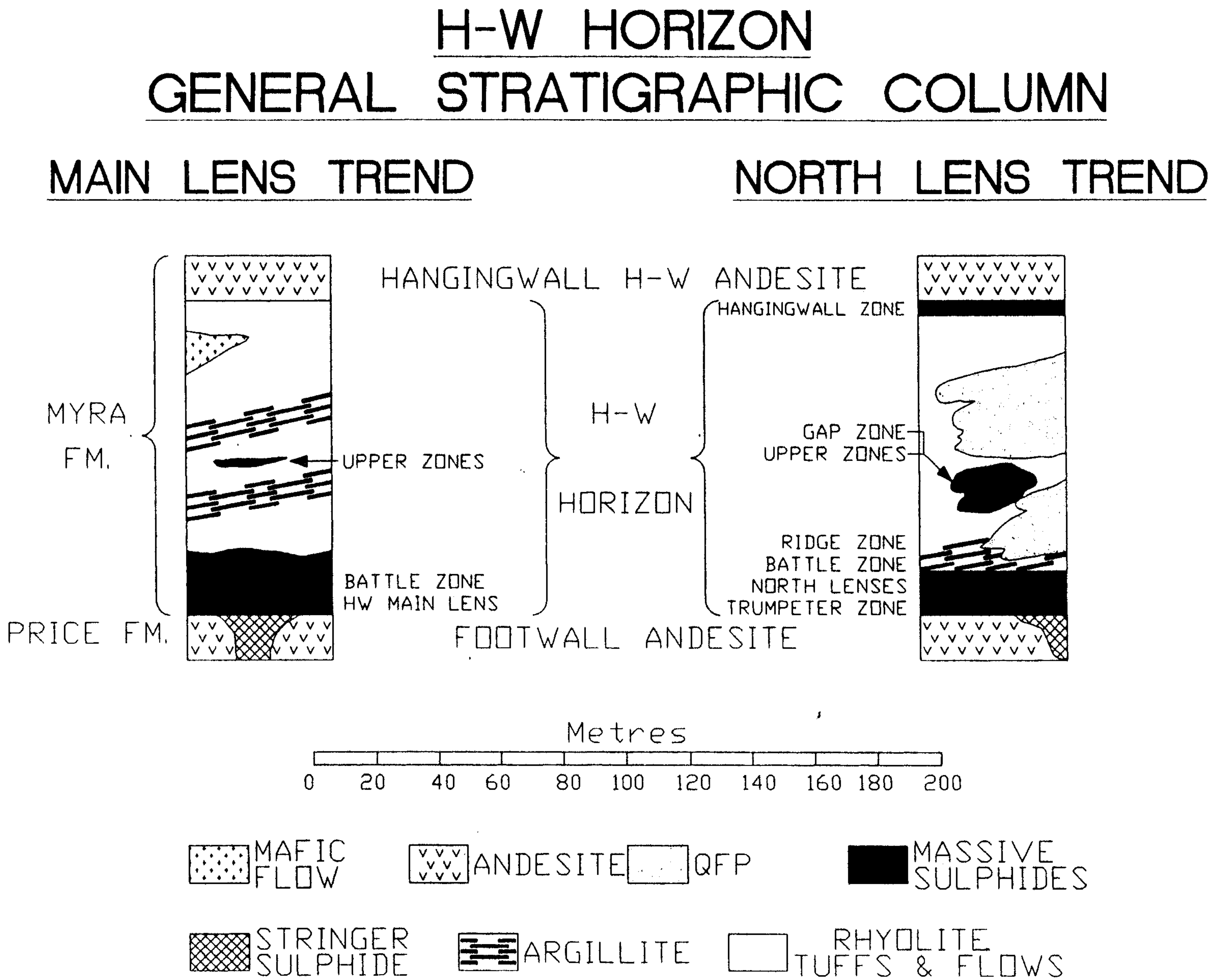

Figure 20. General stratigraphic column for the H-W horizon, Buttle Lake camp, central Vancouver Island, southwestern British Columbia.

area. Massive sulphide clasts are observed throughout the Horizon, but are rarely of economic significance.

2. Overlying the H-W Horizon is the Hangingwall H-W Andesite. This unit is up to 100 m thick and consists of basaltic andesite to andesite flows and pyroclastics. These rocks are thickest over the H-W Main Lens, perhaps because that lens was deposited in a restricted palaeotopographic low.
3. The Ore Clast Breccia Unit contains a series of volcaniclastic submarine debris flows and subordinate subaqueous pyroclastic deposits, up to 90 m thick. This unit is characterized by subangular massive sulphide clasts, ranging from 1 cm to 1.5 m in diameter, but these clasts are never abundant enough to make ore grade.
4. The Lower Mixed Volcaniclastic Unit is also up to 90 m thick and is composed of andesitic volcaniclastic deposits, ranging from breccias to fine tuffs. These rocks are thickest to the southeast (Price Zone) and thin to the northwest (Lynx Mine area).
5. The Upper Dacite/5E Andesite/North Dacite Units represent three approximately contemporaneous, yet different, eruptive events exposed throughout the mine property in this stratigraphic position. These units are discontinuous and non-overlapping and consist mainly of andesitic and dacitic flows and pyroclastic deposits.
6. The Lynx-Myra-Price (LMP) Horizon, occupying the middle of the Mine Sequence, contains the G-Zone and G- Hangingwall Zone massive sulphide mineralized rhyolite members. Both members consist mainly of massive to thick-bedded vitric rhyolite tuff to lapilli tuff, capped by massive sulphide ore lenses; the G-Zone, S-Zone and G Hanging Wall Zone orebodies. The LMP Horizon ranges in thickness from ten to 150 m.
7. Hangingwall to most Lynx ore bodies is the G flow unit. It consists of several two to 15 m thick basalt flows and flow breccias, thickest in the Lynx Mine area above the Lynx G Zone ores. Jasper fragments and lenses are noted in this unit, as are amygdules filled with epidote or calcite. Total thickness of this unit ranges from five to 50 m.
8. The Upper Mixed Volcaniclastics Unit, which is up to 50 m thick, consists of volcaniclastic rocks of mafic to intermediate composition, ranging from fine tuff to tuff-breccia deposits. Mafic clasts predominate and are most abundant to the SW. Intermediate clasts, although everywhere subordinate, are most common toward the NE, especially in the Lynx Mine area.
9. The Upper Rhyolite Unit, the stratigraphically uppermost felsic unit in the Mine Sequence, is up to 50 m thick and is characterized by an association of Quartz Feldspar Porphyritic (QFP) rhyolite, argillite, chert and jasper. These units consist of intercalated rhyolite coarse tuff to tuff breccia and laminated beds of grey to black siliceous argillite, white to pale green chert and minor jasper.
10. The uppermost litho-stratigraphic unit in the Mine Sequence, the Upper Mafic Unit, is up to 200 m thick. The main rock types present are basaltic in composition and occur mainly as hydroclastic and pyroclastic deposits. Subordinate sedimentary deposits are present in the lower part of this unit, range from two to seven m thick, and are composed of thin-bedded to massive cherty tuff, chert and mudstone.

Sulphide deposits and alteration

Massive sulphide deposits (here defined as deposits of 50% or greater sulphide by volume) are known to occur within two of the three felsic volcanic units described above, namely the H-W Horizon and the LMP Horizon. These deposits are generally conformable, fine-grained, massive-to-layered lenticular beds of massive sulphides, commonly disrupted by folding and faulting. Stringer and disseminated sulphide zones are present but rarely are of mineable grade. Sulphide clasts are widely distributed throughout the Mine Sequence, and several ore grade clastic sulphide zones are developed in the H-W Horizon.

Metal distribution is complex, both laterally and vertically, and results in a large range of base and precious metal grades. In decreasing order of abundance, the main sulphide minerals present are: pyrite, sphalerite, chalcopyrite, galena, tennantite, and bornite. Minor amounts of electrum, stromeyerite, chalcocite, and argentite are are also present. Non-sulphide gangue minerals are barite, quartz and sericite. The typical metal zonation pattern consists of a copper-rich core, flanked by increasingly zinc-rich zones and culminating in a baritic zinc-lead-precious metal rich fringe. (Figure 21). The massive sulphide bodies range widely in size, from 10,000 tonne high grade polymetallic lenses to the strongly metal zoned, heavily pyritic H-W main lens of 10 million tonnes.

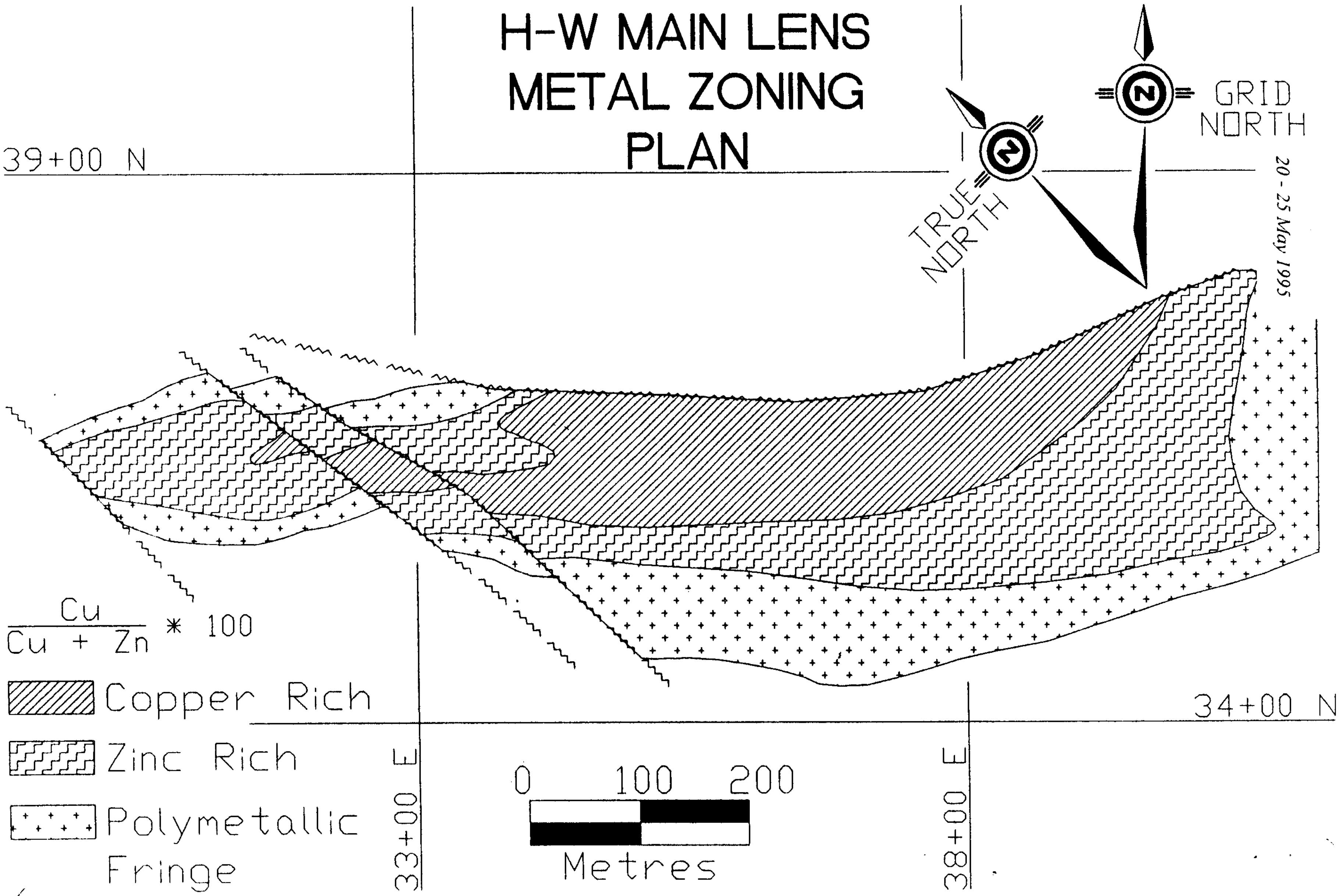

Figure 21. H-W main lens metal zoning plan, Buttle Lake camp, central Vancouver Island.

These sulphide bodies are generally massive to weakly layered. Layering, where present, is characterized by millimetre to metre thick layers of recrystallized coarse grained sphalerite, chalcopyrite-pyrite and pyrite. Individual layers can be traced up to tens of metres, particularly along strike.

Grain size in the massive sulphides is variable, ranging from fine grained to very fine grained in the massive pyritic sections and medium to fine grained within the polymetallic zones. Pyrite grain size is much coarser in the stringer zones, and coarse grained sphalerite and barite occurs in the polymetallic ores. Remobilized chalcopyrite is common in both the massive sulphides and the wallrock.

Non-sulphide clasts, ranging from several millimetres to approximately one metre in their longest dimension, are common in the massive sulphides, especially in the fringing polymetallic zones. Rhyolite, barite, chert, jasper and argillite clasts are present in varying abundance and relative proportions.

Barite is generally restricted to the fringe areas of the H-W Main and North Lenses, but is a common constituent of the Upper Zone and the Lynx-Myra-Price Horizon (LMP) polymetallic orebodies. Massive barite beds are rare but are present in both the H-W and LMP Horizons.

Syn-depositional, diagenetic and post-depositional structures and resulting textures are seen in or adjacent to massive sulphides at a scale of millimetres to metres. Development of layering, soft sediment slumping or folding, and extensional growth faulting took place during deposition. Growth faults and asymmetrical slump folds are observed in ore. Piercements (or diapirs) of dense, ductile massive sulphides, which are found in the overlying brittle hangingwall, may have developed during compaction, or more likely, during later folding. These piercements resemble sedimentary flame structures in their morphology, and range up to ten metres in height and a few metres in width.

Hydrothermal alteration, synchronous with massive sulphide mineralization, occurs as both discrete crosscutting zones in the footwall and as haloes around the orebodies. Two main pyritic feeder systems are known, one below the H-W Main Lens and the other associated with the Lynx and Myra deposits. Both systems exhibit NW-SE linear trends, parallel to the direction of least facies variation. Several smaller feeder zones are recognized, associated with the H-W North Lenses, the Price Mine and the Battle and Gap Zones. These feeder zones typically are developed in footwall andesitic volcanic rocks and have completely replaced them by assemblages of quartz, sericite and pyrite. Pyrite content ranges from one to 30%. Chalcopyrite and sphalerite are also present, in generally sub-economic amounts. The large H-W feeder system also has a zone of moderate to strong albitization and silicification. This zone flanks the quartz-sericite-pyrite assemblage and is composed of albite and quartz and/or sericite.

Structural geology

A period of NE-SW compression, during the Mesozoic, resulted in both ductile and brittle deformation. Cylindrical, closed, symmetrical folds, with NW-SE trending axial traces, developed in conjunction with mineral lineation and a subparallel cleavage. Groups of NE, N and E striking, intermediate to high angle, faults are ubiquitous and display both normal and lateral movement. These appear to cut-off the lesser developed NW striking NE dipping thrust faults and minor extensional faults. Fault zones may be from several millimetres to tens of metres thick, and their composition varies from sericite-chlorite-quartz schist to sericite with or without clay gouge and breccia. Measured displacements range from centimetres up to 350 m.

Mine exploration and ore reserves

As in most successful mining operations, mine exploration has played a vital role in the survival and profitability of the Myra Falls Operations. Exploration history, tools and techniques, and recent discoveries are examined below.

History

Mine exploration has been a constant at Myra Falls over the 26 years of its mining life. The minimum expectation has been to annually replace mined-out ore reserves in existing working areas, and in most years that objective has been met. Beyond that, exploration over the years has been successful in periodically enlarging the ore reserves base by finding new mining areas and "widening the playing field".

Four periods of significant new ore discovery are described below:

1. From 1964 to 1966, surface mapping and diamond drilling, along with subordinate underground work, resulted in the definition of a mining reserve base of 1.9 million tonnes of good grade ore. This reserve was sufficient to initiate mining at the Lynx Mine in 1966, starting with the open pit and moving quickly into underground operations.
2. From 1969 to 1971, exploration efforts spread to the Myra Claims, across Myra valley from the Lynx Mine. Underground development and diamond drilling resulted in the discovery of the Myra high grade lenses in late 1969 and the remainder of the Myra Mine deposits in 1970-1971. These reserves proved to be invaluable in the mid-1970's as their high grade nature carried the operations through a period of low metal prices and high taxation.
3. By 1978, Myra Mine reserves were completely defined and exploratory work in the immediate mine area had proved negative. In addition, at the Lynx Mine, the productive G ore horizon had been traced up to, but not across, the major right-lateral Lynx-Phillips Fault and new discoveries in the rest of the mine had for several years been insufficient to replace reserves. To address this situation, a complete review and revitalization of the exploration program was undertaken and new target areas established. This effort was soon rewarded in 1979-1980, with the discovery of: (a) the Upper Price Zone - a small (185,000 tonne) extension of the Myra Mine. It was discovered in Thelwood valley, across the major left-lateral Myra-Price fault; (b) the West G orebodies at Lynx - the fault offset of the Lynx Mine G Zone; and (c) the H-W Mine, a comparatively very large deposit in the H-W Horizon, located some 400 m below Myra valley.
4. By 1987 the H-W Mine was in full production; the Myra Mine was exhausted; and the Lynx Mine was in decline and operating at only 300 tonnes/day. Exploration strategy was again reviewed and an aggressive program was re-established to assure replacement of the property ore reserve base, which was being depleted at rates of up to 4,000 tonnes/day. This program has been very successful, with a string of new ore discoveries starting in 1989 and continuing to the present day.

Recent ore discoveries

The exploration program review in 1987 developed a number of scenarios which would lead to complete, broad-scale, minesite coverage in specific time frames. The chosen scenario aimed at property coverage in six years, i.e. by 1993. This plan was duly initiated, with expenditures in the range of (Cdn) $3-4 million per year, and has resulted in a series of remarkable new ore discoveries (see Figure 18). These new ore zones have revitalized the operations and more than replaced losses to the reserve base through mining and declining metal prices.

The new discoveries are predominately within the H-W Horizon, and in order of discovery, are:

1. H-W Mine 42 and 43 Blocks (H-W Horizon). These are the continuation of the H-W North Lens trend eastward towards the Myra-Price fault. 43 Block is a new type of ore zone, consisting of mineable grade fragmental sulphides interbedded with thin massive sulphide beds. This zone is equidimensional in cross-section, being some 35 to 45 m wide by 30 to 40 m thick, and has a strike length of 320 m. Current geological reserves on the zone are 750,000 tonnes grading 2.7 g/t Au, 55 g/t Ag, 1.9% Cu, 0.5% Pb, and 5.8% Zn. 42 Block occurs as a two to four metre thick massive sulphide bed about 60 m northeast of 43 Block. Drilling positions to test this occurrence are poor and reserves have been not calculated to date, but it remains a prime exploration target.
2. Ridge Zone (H-W Horizon). Exploration in 1988 focused on the trend of the H-W Horizon, northwest from the H-W Mine. This target lay 300 m below and 200 to 300 m

to the northeast of the existing Lynx Mine workings. Crosscuts were driven on the Lynx Mine lower levels to provide drill positions on 150 m spacing, along the H-W Horizon trend. Subsequent drill programs in 1989-1990 resulted in over 50 ore grade massive sulphide intersections, ranging from 0.2 to 22.5 m thick. Three mineralized stratigraphic positions were recognized here in the H-W Horizon - Hangingwall Zone, Upper Zone and Contact Zone, and ore intersections were obtained in all three. This effort did not lead to a production decision due to distance from existing workings, structural complexities and questionable ore continuity. A geological reserve has been calculated and is 668,000 tonnes grading 2.3 g/t Au, 91 g/t Ag, 1.2% Cu, 1.2% Pb, and 9.6% Zn.

3. Lynx Mine Targets (LMP Horizon). Concurrent with exploratory efforts in the new areas, exploration in the Lynx Mine was refocused in 1989 to examine parts of the mine that had been missed in the first pass of ore definition and mining. Two general targets were chosen: areas in close proximity to major faults, and untested stratigraphy up-dip and down-dip from known G and S zone lenses. This work was successful and has reversed the declining ore reserve picture. The new lenses are generally small in size (10,000 to 50,000 tonnes each), and are structurally complex, but commonly are high grade. Because they occur within the framework of mine development, access costs are comparatively low and these orebodies can have real economic impact. An example is 10-G-54 ore lens, defined in the fall of 1992 as 27,000 tonnes grading 4.1 g/t Au, 95 g/t Ag, 1.8% Cu, 1.2% Pb, 10.8% Zn, and already in production.
4. Gap Zone (H-W Horizon). Mine exploration in 1991 concentrated on tracing the H-W Horizon from the Ridge Zone discoveries back toward the H-W Mine workings - an area heretofore inaccessible from either surface or underground. In May of 1991, the Gap Zone discovery hole on this program intersected 33.1 m grading 3.6 g/t Au, 365.0 g/t Ag, 4.5% Cu, 0.5% Pb and 18.5% Zn. Exploratory stage drilling has recently been completed and delineates the Gap Zone as a high grade polymetallic ore lens, with dimensions of 20 to 30 m high by 40 to 50 m wide, and 250 m strike length. Geological reserves are now 1.0 million tonnes grading 3.0 g/t Au, 149 g/t Ag, 1.7% Cu, 1.1% Pb, and 12.8 % Zn. This lens is within the Upper Zone stratigraphic position, which is also represented by high grade polymetallic ore lenses above the H-W Main Lens and in the Ridge Zone area. Mineralogically, the Gap Zone is distinct, containing significant bornite, chalcocite and electrum, in addition to the more common sphalerite, chalcopyrite, tennantite, and pyrite.
5. Extension Zone (H-W Horizon). Development from the H-W mine started toward the Gap Zone in late 1991. Exploration diamond drilling from this access soon intersected and traced the Extension Zone, the faulted off and structurally complex westward extension of the H-W Main Lens. Grades are marginal to moderate and it is thus not an immediate mining target. Drilling to date is on 100 to 120 m spacing along strike and much definition drilling remains to be done. A geological reserve has been calculated, and totals 414,000 tonnes grading 1.2 g/t Au, 51 g/t Ag, 1.8% Cu, 0.3% Pb, and 3.7% Zn.
6. Battle Zone (H-W Horizon). Attempts to trace the Gap Zone east were generally unsuccessful but the drilling did intersect mineralization on the Contact Zone position of the H-W Horizon, some 30 to 50 m stratigraphically below the Gap Zone. This stratigraphic position is represented elsewhere on the property by the H-W Main Lens and H-W North Lenses, which are large tonnage and show excellent strike continuity. With this in mind, the Battle Zone became our prime target and remains so today. Drilling to date indicates a number of high grade, metal-zoned massive sulphide lenses ranging up to 35 m thick. The zone has been tested over 700 m of strike length on 100 to 110 m spaced exploration sections. Ore definition drilling started in late 1992 and has added significant ore tonnage to the south of the expected limits of the Battle Zone ore. Geological reserves have been calculated, and at January 1st, 1993, they were 3.4 million tonnes grading 1.1 g/t Au, 24.5 g/t Ag, 2.7% Cu, 0.5% Pb, and 12.9% Zn.
7. Trumpeter Zone (H-W Horizon). This new ore zone was discovered in early 1992, through surface drilling in Thelwood valley. The drill program leading to discovery was conceived as a test of the postulated fault offset position of 42 and 43 Blocks, across the Myra-Price fault. Surface drilling is an economical exploration technique for the mine property only in the deeply incised valleys - Myra and Thelwood. Drilling in Thelwood valley had been suspended for some 10 years and it took an extensive public information

and government approval process to re-establish the program. This program encompassed a number of initiatives to ensure protection of the environment. These initiatives included the use of vegetable oil for hydraulics, extra mufflers and mast "socks" to ensure that a nearby herd of elk would not be disturbed by the noise, and the capture and removal of all drill cuttings to the tailings disposal area. This program was quickly rewarded with the discovery of the Trumpeter Zone, a copper-rich pyritic massive sulphide lens that is believed to be the faulted off continuation of H-W 42 Block. Geological reserves for this Zone are calculated at 122,000 tonnes grading 3.2 g/t Au, 69 g/t Ag, 6.3% Cu, 0.3% Pb, and 4.6% Zn. The Trumpeter Zone lies at the same elevation as the H-W Mine workings, but approximately 1,500 m towards the southeast. Underground development is not expected to reach this zone for a number of years, but it remains an active and exciting exploration target.

Ore reserves

Ore Reserves are calculated annually, at year end, by an ore reserve team of geologists and engineers. Reserves are calculated initially as geological reserves in the Proven, Probable, and Possible categories. Engineering and geological constraints are combined with economic factors to define Mining Reserves - the basis for mine planning. In addition, the Geology team calculates a Resource category of marginal grade material (where economics are the decisive factor), and a Potential Reserve (where information is insufficient to allow reportable reserves to be calculated). The geological categories, including resources and potential, can be combined as a Mineral Inventory to help direct long-term planning. Tonnes and grades are reported for the Geological Proven/Probable Reserve and Mining Reserve categories and tonnes only for the Geological Possible Reserves category. Geological Resources and Geological Potential numbers are not published.

The reserves are calculated by classical sectional methods, using Net Smelter Return (NSR) values to define cut-off grades. Increasingly, calculations are computer-assisted using "Medsystem" software, developed by Mintec, Inc.

Future exploration

The Myra Falls Operations claim block, seven km long by two to three km wide, is a challenge to explore and well over half of the property remains to be tested. Much of it is accessible only through underground development. Surface drilling, for over 90% of the property, would require 2,000 to 3,000 m deep drillholes to reach the H-W Horizon targets. However, surface drilling is economically feasible in the lower levels of Myra and Thelwood valleys and is continuing in those areas.

As described previously, mineralization is present over a 450 m thick stratigraphic interval, in two mainly felsic volcanic horizons - the LMP Horizon, and the H-W Horizon (Figures 19 and 20). In addition, there is sketchy evidence of another felsic horizon in the Footwall H-W Andesite Formation - a possibility that warrants evaluation.

Exploration targets are defined by favourable stratigraphy, as noted above. Within the right stratigraphic unit, paleotopography (as indicated by facies and thickness distribution), mineralization, alteration and structure further define favourable areas.

The main exploration tools in use to date have been our experience base and knowledge of mine stratigraphy, supplemented by intensive diamond drilling programs. Westmin does most of its own underground drilling, using ten company-owned drills that range from 150 m depth capacity Gopher drills to a 1,000 m depth capacity Longyear 38. Drilling rates per year have ranged from 20,000 m to 60,000 m, depending on the need for ore definition and exploration work. Surface drilling is sporadic and is therefore contracted. Diamond drilling in areas of high potential is based on a pattern that fully tests the linear nature of the orebodies. Drill sections are spaced at 120 to 150 m intervals along the NW-SE trend, and drillholes on section are spaced only 30 to 50 m apart to ensure the narrow, linear ore trends are adequately tested.

This property has a vast exploration potential. To test this potential is a time consuming and expensive business and continuous exploration is essential. The new ore discoveries are the tangible results of Westmin's consistent exploration effort and expenditure, augmented by on-site expertise and commitment.

Westmin is an integral part of a Mineral Deposits Research Unit (MDRU) at the University of British Columbia in Vancouver. MDRU is a joint Industry-Government-University initiative, and is sponsoring graduate research to help ensure that our future exploration programs make the best possible use of the data recovered, so that we continue to find new orebodies.

Mining and milling

Mining and milling of these widely distributed, metal zoned and mineralogically complex orebodies is both challenging and rewarding. Methodologies have evolved over time in response to changing conditions and continue to do so today to ensure that the operations remain viable.

MINING

Myra Falls Operations provides a good example of the evolution of mining methodology to meet changing conditions. The orebodies in all three Mines have been, and continue to be, challenging to extract. In the Myra and Lynx Mines, challenge lay in orebody size, shape and structural disruption. The H-W Mine is characterized by much larger massive sulphide bodies, hence orebody size is rarely a concern; but the complex distribution of metal grades presents its own problems. The currently producing Lynx and H-W Mines will be discussed separately.

Lynx mine

The Lynx Mine has been in continuous operation for 26 years, at production rates ranging from 900 to the current 300 tonnes per day. Mineable reserves have rarely exceeded five years planned production so exploration for, definition of, and development to new orebodies has always been aggressive. Lynx ore lenses are developed on both limbs of the NW-trending asymmetrical anticline within the Lynx-Myra-Price Horizon. S Zone and South Wall Zone ore is developed on the SW limb as steeply dipping lenses, with typical dimensions of three to ten m thickness, 30 to 60 m in height and 60 to 120 m strike length. G Zone orebodies are found along the more gently dipping NE limb, are of similar dimension, and have provided the bulk of the Lynx Mine production.

These ore bodies are developed along a known 2,750 m strike length and unfolded dip length of 750 m. An estimated 120 individual ore lenses have been mined to date, with total production from the Lynx of 5.3 million tonnes. Detailed definition drilling, with 15 m drillhole spacing, and sound geological interpretation are essential for stope planning and grade control. Ore grade is reasonably constant within individual lenses and throughout the Mine as a whole, but structural complexity and small scale faulting makes interpretation and mining a challenge. Ground conditions vary widely, from poor to excellent, with the SW limb ore zones exhibiting poorer conditions in general.

Lynx Mine has been developed from a 335 m deep internal shaft, situated just sonth of the south limb orebodies. To date, total underground development comprises 56 km of drifting, on 12 levels. Seven of these levels are accessed by the internal shaft and are spaced 45 m apart. The remaining levels are developed from adits on the steep mountainside. The various development levels are connected, for ventilation and access, by 18 km of raises.

In the initial 10-12 years of mine life, the bulk of production came from classical cut and fill mining, with subordinate room and pillar mining in the flatter G Zone ore lenses. As mining moved further and further away from the Lynx shaft, the cost of backfill became prohibitive and non-fill mining methods came to the fore. Room and pillar mining proved to be a very productive alternative, with mining recoveries averaging 85% or more. Most of the G and West G Zone orebodies were mined that way. The steep dipping SW limb ore zones are more difficult to mine, with poorer ground conditions a big factor. They are now mined by longhole retreat or "Avoca" methods, with mixed results. Ongoing experimentation is improving productivities but engineering profitable extraction of these lenses will always be a challenge.

Over the past two years, the Lynx Mine staff have had great success in cutting costs and improving productivity. That effort, in conjunction with the discovery and development of new orebodies, has enabled the mine to stay competitive despite its small size.

H-W mine

The H-W Mine was commissioned in September 1985. Access to it is from a 715 m deep, six compartment, vertical shaft. Five main levels are developed, at 45 m and 90 m spacing. The uppermost level, 18 Level, is actively advancing toward the new Battle and Gap Zones. 20 and 21 Levels were driven to provide definition drilling platforms to test the H-W Main and North Lenses. 23 Level is the main stope access level and is interconnected to 21 Level above and 24 Level below through internal ramps. These ramps provide access to the various stopes and the 21 Level maintenance shop. 24 Level is a track haulage level, and connects with all main ore and waste passes. It is also being advanced westward to the Battle and Gap area, in concert with 18 Level above. Ore haulage on 24 Level is accomplished with 15 tonne ore cars, pulled by electric locomotives on 914 mm gauge track. All ore is crushed underground in a 1.2 m Kenco jaw crusher, and is transported to surface in 11 tonne skips. A two km long covered conveyor belt transports ore from the H-W headframe to the concentrator for processing.

The H-W Main Lens and North Lenses are generally flat lying, thick, strongly metal zoned pyritic massive sulphide beds. H-W Main Lens dimensions are 300 m wide by 1,200 m long, with massive sulphide thicknesses ranging from 3 m along the fringes to 60 m in the core areas. Metal grades range widely, from $200 Net Smelter Return (NSR) fringe polymetallic ore to less than $20 NSR massive pyrite zones in the core areas. Detailed diamond drilling is necessary to define ore grades, both for economics and for blending to achieve consistent mill feed. The North Lenses comprise many types, from small, high-grade polymetallic lenses to large variable grade pyritic bodies. This set of ore zones has been traced over a strike length of 1,200 m and is still being explored both NW and SE along trend.

Initial mining in the H-W Mine emphasized room and pillar methods, favoured because of quick access to the ore and good productivity. Other mining methods used were cut and fill, on the more steeply dipping polymetallic fringes to the Main Lens, and longhole stoping in thick sections of the core area.

A major change to predominantly longhole mining was initiated in 1991, in response to the declining productivities and increasing costs of room and pillar mining. That change was completed during 1992 and 85% of production tonnes now come from longhole mining. In 1992, 25 longhole panels were mined, ranging in size from 8,000 to 114,000 tonnes, with an average of 34,000 tonnes. Computerized scheduling techniques were developed to ensure continuous production and backfilling. Five yard and seven yard scooptrams are used to move blasted ore to the ore passes. Backfill is classified mill tailings, cemented if necessary.

In concert with the change in mining methods, increased attention is paid to ore block grades and NSR's, using the Mintec Medsystem mine planning software. This computer modeled estimate of ore block value is compared against estimated block mining costs to ensure a positive cash flow.

MILLING

Myra Falls Operations produces copper and zinc concentrates for shipment throughout the world. Mill feed from mining operations averages 3,650 tonnes per day at mill head grades that range from 1.5 to 3.0 g/t Au, 20 to 30 g/t Ag, 1.2 to 4.5% Cu, and 2.5 to 6.5% Zn. Blending in the production system generally results in relatively constant or smoothly varying mill head grades, but pronounced spikes and troughs can occur for each metal.

The Myra Falls Concentrator has a name plate capacity of 4400 dry metric tonnes per day (dmtpd) and is capable of producing roughly 400 dmtpd each of copper and zinc concentrates and roughly 15 kg/d of gold concentrate. The copper concentrate grades roughly 26% Cu, 1.5% Pb, 3.5% Zn, 0.5% As, 10 g/t Au, and 250 g/t Ag. The zinc concentrate grades roughly 54% Zn, 1% Cu, 7% Fe, and 3 g/t Au. The gold concentrate grades roughly 2.5% Au and 1% Ag, from two Knelson Concentrators.

Lynx mine ore is crushed on surface with a primary jaw crusher and moved by conveyor belt 100 m to the mill coarse ore bin where it is combined with ore from the H-W Mine. The mixed ores are crushed in the secondary crushing plant, which is a conventional circuit employing one standard cone and one short head cone in closed circuit with a vibrating screen. The Lynx crusher is operated remotely from the secondary crusher. Two fine-ore bins feed two conventional rod mill/ball mill circuits. The flotation circuit is a non-conventional design (Mular and Veloo, 1991). Cyclone overflow is conditioned and feeds the copper roughers, and the copper rougher concentrate feeds the copper regrind circuit. The copper regrind overflow feeds the first cleaners, and the first cleaner tail feeds the cleaner scavengers. First cleaner concentrate feeds the copper column. Copper column tail combines with copper rougher concentrate and copper cleaner scavenger concentrate and reports to the copper regrind. Copper cleaner scavenger tail is conditioned with copper rougher tail and reports to the zinc roughers. Copper column concentrate reports to de-watering as final concentrate.

The zinc circuit is identical to the copper circuit (the zinc rougher tail combines with zinc cleaner scavenger tail and reports to mill final tail). Mill final tail is cycloned to produce backfill sand and the fines are thickened and distributed by spray bar in the tailing pond. All the water from the mill proeess, mine drainage, and surface runoff is treated with lime. The resultant sludge is removed in settling and clarifying ponds. Water is recycled to the mill and the excess is discharged to Buttle Lake. Both concentrates are thickened and filtered with pressure filters and the concentrates are trucked 90 km to an ocean port in Campbell River where they are shipped to varions Japanese and North American smelters.

The Westmin flotation circuit is unique in that conventional counter current flotation is not used. The only recycle stream is through the regrind. This circuit is easy to operate, has low cleaner circulating loads, and responds quickly to operator action.

Environmental controls

Our location is in the center of a Provincial Park, on a drinking water reservoir and at the headwaters of a river system important to the recreational, native and commercial salmon fisheries.

This has given environmental operations at the mine an important public profile and an opportunity to demonstrate that mining and nature can co-exist. An innovative tailings disposal and water treatment system is combined with on-going reclamation efforts and public information displays, tours and forums to document Westmin's commitment to that goal.

Tailings disposal

Tailings disposal in the 1967 to 1984 period was sub-aqueous deposition in Buttle Lake, some 3 km downstream from the mill. Tailings flowed by gravity through a 25 cm diameter high density polyethelene pipe to a raft on the north shore of the Lake and deposited on the lake floor beneath 30 metres of water. An emergency tailings pond near the mill was an alternate site which was used whenever tailings flow to the Lake was interrupted. This system operated essentially trouble-free during its life. However, the discovery of the large, pyritic H-W deposit and the gradual increase of metal concentrations in Buttle Lake in the late 1970's resulted in a partly politically mandated decision to develop an on-land facility to replace the sub-aqueous system. Subsequent study of the rising metal concentrations in Buttle Lake has shown that this was not due to sub-aqueous tailings deposition but was caused by ground water leaching metals from the extensive waste dumps. This acid drainage was reaching Myra Creek, which transported it to Buttle Lake.

The new tailings disposal had, then, to serve two purposes: intercept the acid drainage from waste dumps and, secondly, provide a storage area for decades of tailings production. An area below the waste dump was chosen and cleared; Myra Creek was diverted and an extensive outer embankment built to contain the tailings. Finally, collection drains were placed at the toe of the waste dump to capture the acid drainage for treatment.

The tailings are deposited using a subaerial technique. In this method, a thickened slimes slurry, approximately 50% solids, is distributed through spray bars along the outer embankment. Under the spraybars rapid settlement takes place, while finer particles travel some distance further, thus forming a sloping beach. Water "rolls" off the beach and is collected in a pond beyond the beach, to be drawn off through decant pipes to the pumphouse. After a three to six cm layer of tailings has been deposited, another set of spray bars is used and the initial deposit is allowed to drain and air dry. This causes thin, virtually impervious layers to deposit, resulting in the formation of an unsaturated, stable deposit.

Water treatment facilities are extensive and effective, collecting and treating contaminated groundwater, mine water, concentrator effluent, yard drainage and discharge from two sewage plants. Normal effluent quality from the system is less than 0.01 mg/L dissolved Zn, up to 0.20 mg/L total Zn, less than 0.01 mg/L Cu; and Pb and Cd levels below detection limits.

Reclamation

Since the H-W Mine start-up, reclamation efforts have emphasized removal of obsolete facilities and installations, such as the tailings line and road to Buttle Lake. Hydroseeding and landscaping work has been extensive to enhance the appearance of the site and work has started on reclaiming the old Lynx open pit. Surface diamond drilling set-ups are quickly cleaned up and re-seeded. Drillholes are plugged and casings are cut off below ground level so no trace remains of drilling activity. A sizeable and increasing, ($4.0 million and expected to rise to $22.0 million by 1995), reclamation bond is posted with the Provincial Government to address post-closure reclamation and remediation.

Public involvement

In recent years there has been growing public concern regarding the environment and a decline in support for extractive industries, in general, and mining in particular. Westmin's case is even more sensitive because the Myra Falls Operations is the only mining operation in a British Columbia Provincial Park and it is of onmost importance that the Company maintain strong public support for its continued activities.

Westmin's approach to public involvement is to be open and proactive. The Company tries to maintain a positive public image and a high community profile through advertising, community events, school contacts, open houses, tours and public meetings. Westmin and its employees take an active role in charities, community events, team or event sponsorships, displays, etc. In terms of the mining operations the Company regularly hosts community open houses and site tours where the operations are reviewed, changes are discussed and questions are answered.

In the case of operational initiatives which would be perceived to have an impact on the community or the public, Westmin sponsors community meetings to explain the initiative (concept or problem), the reason for it and possible outcomes. The Company seeks community feedback in terms of ideas, suggestions, concerns, etc. which it can bring to the problem before finalizing a solution. In this manner a solution to a problem is generally well thought out, with plenty of public input and usually no surprises or public apprehensions when a new program is finally announced.

Westmin's experience with this approach to public involvement has been positive. While it can be time-consuming and more expensive to work through the public process, there are many benefits. The public process forces the Company to carefully consider each initiative from various perspectives, which helps to avoid mistakes caused by hasty decisions. Secondly there is a high level of public awareness and understanding of the Company and its Myra Falls Operations and a good deal of community support for Westmin's position. This is a benefit which can not be bought, only earned over a number of years, but it is of immense value when Westmin or the mining industry in general is under attack. Mining companies have very little intrinsic political support, particularly in large urban centres distant from mining operations and the approval of local communities encourages urban politicians to be responsible.

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