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Geological Survey Branch

GEOLOGY AND METALLOGENY OF THE STEWART MINING CAMP, NORTHWESTERN BRITISH COLUMBIA

By Dani J. Alldrick

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Field research for this publication was carried out during the period 1982 through 1984.

SUMMARY

The Stewart mining camp in northwestern British Columbia is underlain by an Upper Triassic to Lower Jurassic island-arc complex. The subaerial volcanic pile is constructed of calcalkaline basalts, andesites and dacites with interbedded sedimentary rocks. Lateral variations in volcanic rock textures indicate that the district was a regional paleotopographic high with a volcanic vent centred at Mount Dilworth. Early Jurassic calcalkaline hornblende granodiorite plutons of the Texas Creek Plutonic Suite represent coeval, epizonal subsidiary magma chambers at depths of 2 to 5 kilometres below the stratovolcano. From these plutons, late-stage two-feldspar porphyritic dikes cut up through the volcanic sequence to feed surface flows. Following subsidence this succession was capped by Middle Jurassic marine-basin turbidites.

Mid-Cretaceous tectonism was characterized by greenschist facies regional metamorphism, east-northeast contraction, and deformation. It produced upright north-northwest-trending en echelon folds and later east-verging, ductile reverse faults and related foliation.

Mid-Tertiary calcalkaline biotite granodiorite of the Coast Plutonic Complex intruded the deformed arc rocks. The batholith, stocks and differentiated dikes of the Hyder Plutonic Suite were emplaced over a 30-million-year period from Early Eocene to Late Oligocene.

The 200 mineral occurrences in the district formed during two mineralizing events that were characterized by different base and precious metal suites. One ore-forming episode occurred in Early Jurassic time and the other in the Eocene. Both metallogenic epochs were brief, regional-scale phenomena. Some deposits from the younger mineralizing episode were emplaced adjacent to older deposits.

All Early Jurassic deposits were emplaced in andesitic to dacitic hostrocks at the close of volcanic activity, about 185 million years ago. They have regional zoning patterns that are spatially related to plutons of the Texas Creek suite and to their stratigraphic position within the volcanic-sedimentary sequence. The Early Jurassic hydrothermal system acquired its characteristic suite of silver, gold, zinc, lead and copper from magmatic fluids. Early Jurassic deposits include gold-pyrrhotite veins, veins carrying silver, gold and base metals, and stratabound pyritic dacites. Gold-pyrrhotite veins formed adjacent to the subvolcanic plutons during late magma movement. Epithermal base and precious metal veins and breccia veins were formed along shallower faults and shears, and in hydrothermal breccia zones along the contacts of subvolcanic dikes. Stratabound pyritic dacites are barren fumarole and hotspring-related deposits that formed on the paleosurface from shallow groundwater circulation within hot dacitic pyroclastic sheets.

Tertiary silver-rich galena-sphalerite veins are related to intrusion of Middle Eocene biotite granodiorite stocks of the Coast Plutonic Complex. All deposits are localized in brittle faults or fractures; most have southeast trends and subvertical dips. Likely sources for the silver in these Tertiary deposits are turbidite sequences within the Unuk River Formation and thicker, infolded turbidites of the Salmon River Formation. Tertiary skarns and porphyry molybdenum deposits are also genetically related to the Middle Eocene plutons.

All these deposit types can be selectively explored for by using diagnostic features such as stratigraphic and plutonic associations, alteration assemblages, gangue mineralogy and textures, sulphide mineralogy and textures, precious metal ratios and lead isotope signatures.

TABLE OF CONTENTS

TABLE OF CONTENTS — *Continued*

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

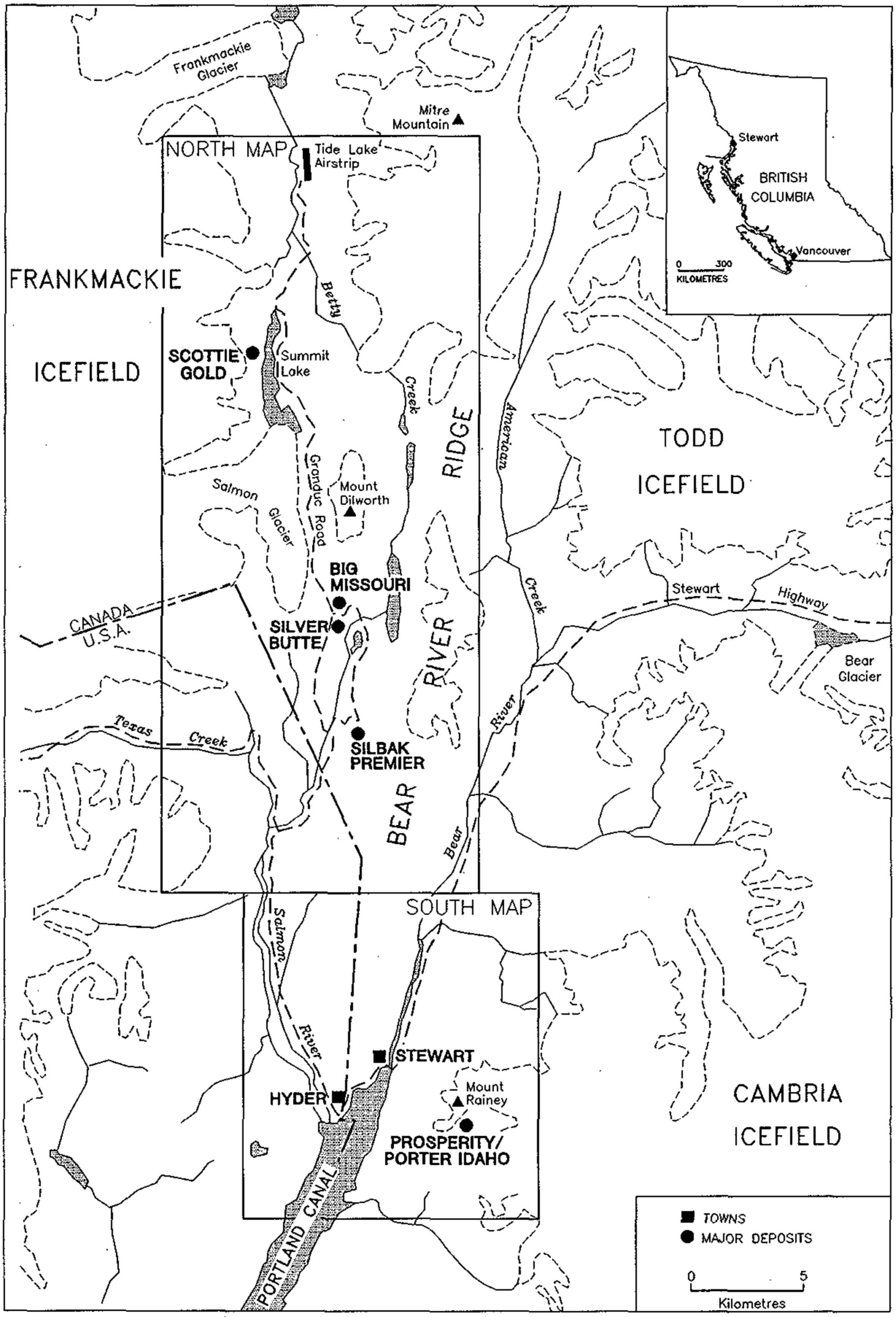

Figure 1. Location of study area.

CHAPTER 1 — INTRODUCTION

The Stewart mining camp has a long history of underground gold-silver production and is entering a new era of open-pit and underground precious metal mining. The district is abundantly mineralized, with over 200 widely distributed, varied mineral occurrences. This report documents the geologic setting of the mining camp and geologic features of the major mineral deposit types. New ideas about the tectonic setting and metallogenic history of the district are also presented.

LOCATION AND ACCESS

The area lies near the eastern margin of the Coast Mountains at the head of the Portland Canal, a fiord 115 kilometres long which marks the southeastern boundary between the Alaska Panhandle and northwestern British Columbia. The field area covers 750 square kilometres centred near the Silbak Premier mine; it includes the town of Stewart, British Columbia and the village of Hyder, Alaska (Figure 1). Stewart can be reached by road from Vancouver and has air service to Terrace and Smithers. The main access route within the area is the Granduc mine road, a gravel haul-road running north from Hyder to the Tide Lake airstrip.

TOPOGRAPHY

The study area is near the southern end of the Boundary Ranges of the Coast Mountains. Elevations range from sea level to 2544 metres on Mitre Mountain. Topography is rugged; the area is characterized by precipitous glaciated valley walls and rounded ridge crests. The dominant topographic pattern is north-trending ridges and intervening glaciated valleys (Figure 1).

HISTORY

There is no history or evidence of a permanent settlement at the head of the Portland Canal prior to 1898. However, the area was one of the main hunting grounds for the Nass (Naas) indians who traditionally encamped twice yearly to hunt bear and waterfowl and for berry-picking. Their name for this site, Skam-a-kounst, means safe-house or stronghouse, and the remote head of this long fiord probably served as a place of retreat when parties of Haida raided the mainland or when intertribal wars broke out. Although they were never openly antagonistic, the indians did not welcome the arrival of prospectors into their game preserve.

In 1896, a preliminary survey of the canal was undertaken by the United States Army Corps of Engineers, led by Captain D.D. Gaillard. They built four stone-and-concrete storehouses along the canal; the final one was constructed at Eagle Point near what is now the border crossing to Hyder, Alaska. This storehouse was constructed between September 4 and 21, 1896, and survives as an historic monument. This site was also the starting point for the international boundary survey that began in the summer of 1903 and was completed by the summer of 1905. Captain Gaillard later achieved fame as one of the senior engineers on the Panama Canal construction project, and the Gaillard Cut is named in his honour.

Mining history in the region also began with the Gaillard expedition when Lieutenant Mosier of the United States Navy discovered and staked the first copper showings in the Outsider mine area on Maple Bay (Magee Bay), along the southeast side of the Portland Canal. The Brown Alaska Company of Prince of Wales Island, Alaska, began major construction at this site in the summer of 1905 and 15 000 tonnes of copper-gold ore were shipped to the smelter at Hadley, Alaska between 1906 and 1908. The existence of this nearby smelter was an early incentive to prospectors and promoters alike.

During the fall and winter of 1897 a Seattle promoter named Burgess (Bruges) talked enthusiastically about the untapped placer gold that he had seen in the headwaters of the Nass River. By the early spring of 1898 a party of 64 'adventurers', few with any mining or prospecting experience, set sail aboard the chartered steamer Discovery, with six months' supplies aboard. They reached the head of the Portland Canal on May 4, 1898 and packed overland through the Bear River Pass in search of the rich placer ground that Burgess had reported in the area around Meziadin Lake. No gold was found and the party moved northward towards Bowser Lake, but by now the expedition had endured much physical hardship and still found no gold. Amid growing discontent Burgess stole silently away, and most of the rest of the party made their way back to civilization at intervals. Whether Burgess had ever visited the region before, or truly knew of placer gold in the headwaters of the Nass remains a mystery, but his objective was very specific. Ironically, if the party had turned south instead of north from Meziadin Lake, they could not have failed to find the placer gold beds in Nelson, Porter (Del Norte) and Willoughby creeks.

Relying on the abandoned supplies, three men wintered over, D.J. Rainey, James W. Stewart, and Ward Brightwell. They built a cabin at the foot of Mount Dolly, beside Rainey Creek. In the following seasons, their prospecting work concentrated on locating placer gold, but they noticed several mineralized outcrops while hunting for game on the mountains. At first these were not considered valuable; in 1899, only the Grizzley Bear claims (now the Roosevelt Group) were staked in Bitter Creek by Rainey, but gradually all of these showings were relocated and staked. The American Boy claims were staked on American Creek in 1900, and the first claims on Glacier Creek were staked in 1903. The general search for gold by prospectors straggling south from the overcrowded Klondike, and the recording of mineral claims at the head of the Portland Canal, slowly drew more prospectors to this remote location.

Two other Stewart brothers, Robert and John, came north from Victoria in 1902 and, although they spent a few seasons prospecting, their great vision was of a prosperous mining town with docks and railways serving mines in the hinterland. They established the post office in 1905, and founded the Stewart Land Company and incorporated the townsite in 1907, soon after the International Boundary was formally defined in 1906. It was standard policy that, in the absence of any other name, the post office was named Stewart after its founder and first postmaster, and the steadily growing settlement also became known as Stewart.

Discoveries continued, fueling increasing stock speculation in Victoria and Vancouver. In 1904, prospects known as the Big Missouri, later renamed Golden Crown, were staked by Harrison and Raerick, two experienced Alaskan prospectors. The first ore production, at the modest milling rate of 80 tons per day, was achieved by the Portland Canal Mining Co. Ltd. at its Glacier Creek property. The Red Cliff copper-gold deposit was the first major mine of this era, and the richest gold deposit in the district.

By 1910, the population had grown to nearly 2000. As in any prospecting centre and burgeoning mining camp, rumours and speculations were part of daily life. Expectations were heightened by the construction of a 12-mile railway to the Red Cliff mine, and by much publicised plans to extend it through the Bear River Pass to the anthracite coalfields of the Groundhog camp. In early June, two rival prospecting teams came down from Glacier Creek with rock samples containing coarse gold and stories of a "mammoth gold reef of free-milling gold. Unknown in extent, but traced for at least 20 miles, it is more than a mountain of ore – an entire range of it in fact." (The Portland Canal Press Ltd., 1910). The town became deserted overnight as the Glacier Creek area was blanketed with new claims. A young reporter who was in Stewart on an assignment to cover 'frontier life' for an English newspaper succumbed to the atmosphere and excitement. His enthustiastic "eye-witness" report of the discovery of this mountain of gold was reprinted round the world, and Stewart changed forever. By the end of the year the population reached 10000, with another 2000 settled in the neighbouring village of Hyder.

In the prospecting and staking frenzy that ensued, Charles Bunting and William Dilworth found a small gossanous knob in the woods overlooking the canyon of the Salmon River and staked the showing that would become the Silbak Premier mine. The discovery outcrop and original claim group were centred on the site of the small glory hole. Tunnelling on 1-level and 2-level by the Salmon-Bear River Mining Company Limited, began in 1912 and 1913 respectively, but no ore-grade rock was encountered until 1914 and the bonanza ore for which the Premier is justly famous, was not located until 1916. Limited production of direct-shipping ore began in 1918 and the mill was commissioned in 1921.

In the late spring of 1911, several hundred metres of the toe of the Silverado Glacier tore loose and a roaring ice-avalanche cascaded down into the bay, causing major waves. The steamer Camosun, tied up at dock, was badly shaken for a few minutes, producing broken dishes and tumbled cargo. Waiting only a few days for the veneer of crushed ice to melt, two brave or foolhardy prospectors climbed the avalanche route. Spurred on by the train of boulders and blocks of well-mineralized float, they soon located the outcrops of the veins that would become the Silverado mine workings.

In Stewart, plans for the railway extension were postponed, then the Red Cliff mine closed in 1912, and Stewart's population dropped to less than two dozen people during the First World War. Only three people wintered over in the town from 1917-1918. The opening of the Premier mine in 1918 began a new era of prosperity that continued through to the Second World War. A telegraph line connected Stewart to the outside world in 1919. By the late 1920s, the town had a population of 1500, with another 500 residents in Hyder. By 1929, before the stock market crash, there were over 40 mining companies and syndicates active in the district. The Premier mine provided stable employment until the outbreak of war in 1939. With the mine shut down during the war, Stewart's population again declined steadily, reaching 300 by 1950.

Hyder was settled by American prospectors returning from the Klondike gold rush. Originally Portland City, it was soon renamed in honour of geologist F.B. Hyder. Through the years of the First World War, Hyder was abandoned, but soon after the armistice of 1918, it returned to life as Stewart hit world headlines (again) as the site of the rich Premier mine. With the crash of 1929, and through to the end of the Second World War, Hyder was again deserted. Most of the town was destroyed by a fire in 1948.

The village of Hyder, British Columbia blossomed during the 1920s, partly because of the Premier mine tramway terminal and loading docks, but mainly because of its proximity to its American namesake during the years of prohibition. Within a few years Hyder, Alaska was connected to Stewart by road and Hyder, B.C. was soon reduced to pilings.

Readers particularly interested in the early history of the district are referred to the displays and archives of the Stewart Museum, and to the archives of the Legislative Library and Royal British Columbia Museum in Victoria.

PREVIOUS GEOLOGICAL WORK

Geologic work began in the Stewart area in 1906. Studies up to 1965 were reviewed by Grove (1971, p. 19). Detailed tables in Brown (1987) list all geological reports and maps for the Silbak Premier mine (p. 7) and for the whole of north-central British Columbia (p. 9). Thesis studies in the Stewart area have been completed by White (1939), Seraphim (1947), Grove (1973), Galley (1981), Brown (1987), McDonald (1990b) and Alldrick (1991). Comprehensive reference lists for every mineral property are included in recently revised MINFILE listings.

Prospecting and properties in the Stewart (Portland Canal) area have featured prominently in the British Columbia Department of Mines Annual Reports beginning with Carmichael's review in 1907. Mapping projects and deposit studies have been completed by Grove (1971, 1986) and Alldrick (this report). Several mapping programs by the Geological Survey of Canada include those of McConnell (1913), Schofield and Hanson (1922), Hanson (1935) and Anderson (1989).

Ongoing geological work includes regional-scale mapping by R.G. Anderson of the Geological Survey of Canada and studies in the Hyder area by the Geological Survey Division of the State of Alaska (Solie *et al.*, 1991) and the United States Bureau of Mines.

FIELDWORK

Fieldwork for this study was carried out during the summers of 1982, 1983 and 1984. Mapping traverses were recorded on 1:10 000-scale air photographs and compiled on 1:25 000-scale field maps. Four major deposits, representing significantly different deposit types, were selected for detailed examination.

The route to the present report was neither obvious nor direct. What started out as an exercise in mineral deposit classification ultimately required modification of accepted ages of major plutons, inversion of stratigraphic columns, and rotation of the dips of whole mountains of strata through as much as 90° from orientations established for decades.

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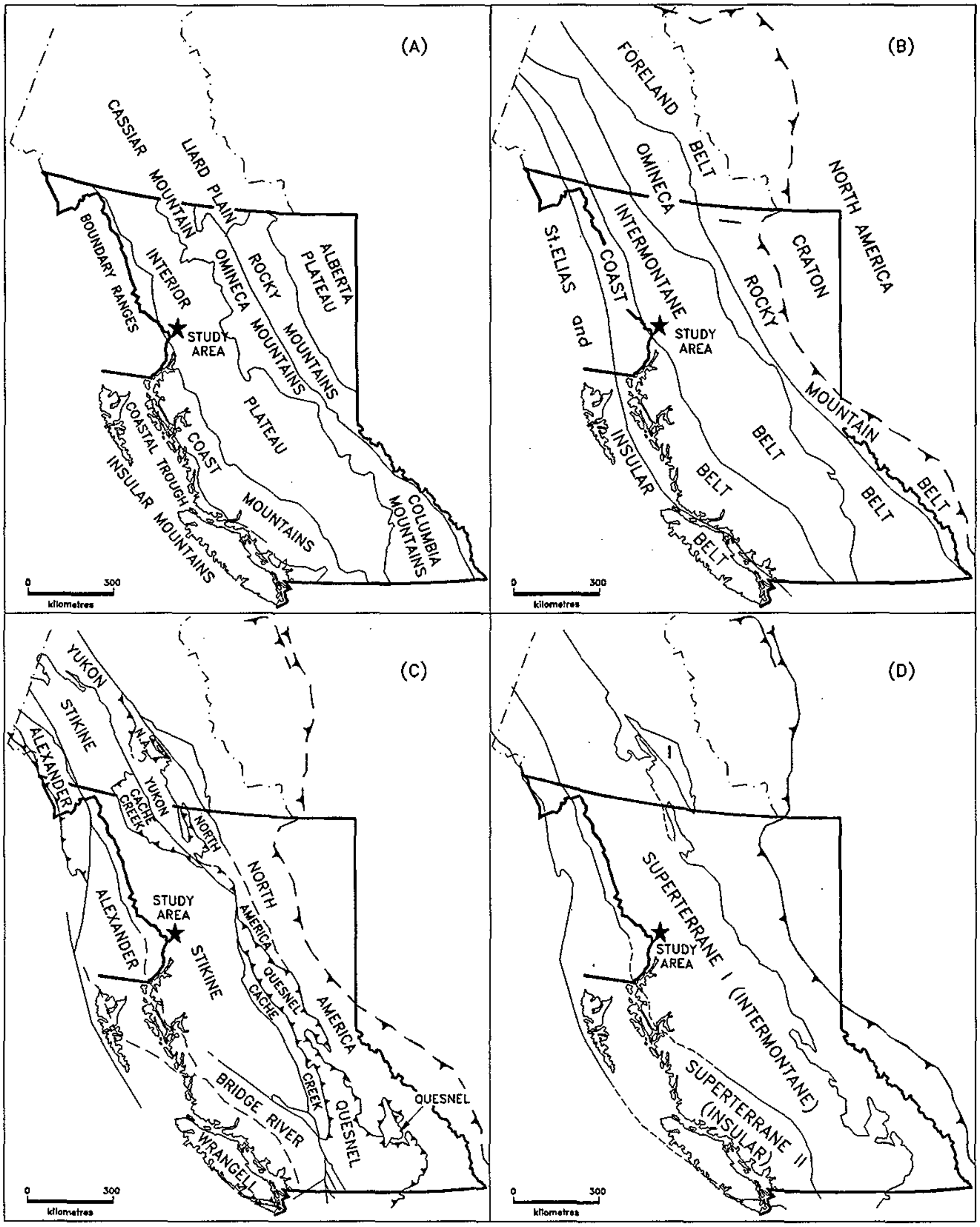


Figure 2. Physiographic and tectonic belts, terranes and composite terranes of the Canadian Cordillera (modified from Sutherland Brown, 1976, Armstrong, 1988 and Monger, 1984).

CHAPTER 2 — REGIONAL GEOLOGIC SETTING

The study area lies in the Coast Mountains along the western margin of the Intermontane tectonic belt, adjacent to the Coast Plutonic Complex (Figures 2a and 2b). According to terrane concepts it lies entirely within Stikinia (Figure 2c). The Intermontane Belt roughly coincides with the Intermontane Composite Terrane (Intermontane Superterrane or Superterrane I, Figure 2d) of Monger (1984).

STRATIGRAPHY

A simplified geological map of north-central British Columbia is presented in Figure 3 and the stratigraphy of Stikinia is shown schematically in Figure 4. A brief review of major stratigraphic units follows with emphasis on the regional divisions within the Hazelton Group.

PRE-HAZELTON STRATA

The oldest rocks within Stikinia, termed **Stikine assemblage** by Monger (1977) and **Asitka assemblage** by Wheeler and McFeely (1987), consist of Devonian to Permian sedimentary successions with interbedded volcanic strata. This regionally extensive assemblage is exposed around the northern periphery of the Bowser Basin along the Stikine Arch (Figure 3).

The **Stuhini/Takla Group** is a Late Triassic volcanic and sedimentary rock sequence of Carnian to Norian age that encircles the Bowser Basin. The Stuhini Group comprises pyroxene-porphyritic basalts to basaltic andesites, bladed feldspar porphyry volcaniclastic rocks and derived sedimentary rocks. The Takla Group consists of pyroxene and pyroxene-feldspar-porphyritic flows grading laterally to distal sedimentary facies, overlain by feldspar-porphyritic volcanic rocks with proximal volcaniclastic sedimentary facies.

HAZELTON GROUP STRATA

The Lower to Middle Jurassic Hazelton Group consists of calcalkaline basalt to rhyolite and derived volcaniclastic sedimentary rocks that are well exposed around the perimeter of the Bowser Basin (Figure 5). Historic subdivisions are compared to stratigraphic divisions defined in this study in Figure 6.

SMITHERS AREA (SOUTHEAST)

Tipper and Richards (1976) divided the Hazelton Group of the Smithers area into lower Telkwa Formation, middle Nilkitkwa Formation and upper Smithers Formation. Within the Sinemurian Telkwa Formation they recognized five distinct time-equivalent sequences, ranging from basaltic and rhyolitic volcanic rocks to laterally equivalent sedimentary rocks. Lower Pliensbachian to middle Toarcian Nilkitkwa Formation comprises interbedded shale, greywacke, andesitic to rhyolitic tuffs and breccias, and minor limestone. Middle Toarcian to lower Callovian Smithers Formation consists of an assemblage of poorly sorted, fossiliferous, fine to medium-grained clastic sedimentary rocks with minor intercalated tuffaceous shale, tuff and volcanic breccia.

STEWART AREA (WEST)

The large exposure of Hazelton Group rocks on the western rim of the Bowser Basin has been termed the Stewart Complex (Figure 5 and Grove, 1986). In the Stewart area, Grove divided the Hazelton Group into the lower Unuk River Formation, middle Betty Creek Formation and upper Salmon River Formation. Type areas for both the Betty Creek and Salmon River formations are in the northern part of the present study area. Grove defined the Hettangian to lower Toarcian Unuk River Formation as a predominantly andesitic sequence of lava flows, pyroclastic rocks and epiclastic and clastic sedimentary units. The Middle Toarcian to middle Bajocian Betty Creek Formation is characterized by bright red and green volcaniclastic sedimentary rocks with intercalated andesitic volcanic flows, pillow lavas, chert and carbonate lenses. Middle to Upper Jurassic, upper Bajocian to upper Oxfordian, Salmon River Formation is a thick sequence of complexly folded, colour-banded tuffaceous siltstones and lithic wackes. The base of the Salmon River Formation is marked by rhyolite, chert and carbonate lenses.

TOODOGGONE AREA (NORTHEAST)

Hazelton age sequences on the northeast rim of the Bowser Basin include the Toodoggone volcanic rocks, the Cold Fish volcanic rocks and the Spatsizi "Group".

Carter (1972) named the informal Toodoggone volcanic belt that crops out northeast of the Bowser and Sustut basins. Diakow (1990) formally defined the Toodoggone Formation and divided it into six stratigraphic units. The sequence is a thick pile of flat-lying subaerial dacitic tuffs and minor sedimentary rocks that is coeval with Lower Jurassic Telkwa and Nilkitkwa formations in the Smithers area.

Thomson *et al.* (1986) proposed the informal name, Cold Fish volcanics, for a volcanic sequence exposed along an 85-kilometre by 10-kilometre erosional window through overlying sedimentary rocks of the Bowser Lake Group. Thorkelson (1988) examined these rocks in detail and described them as a lower Pliensbachian to lower Toarcian succession of subaerial to submarine felsic to mafic lava flows and tuffs with minor shale and limestone. Cold Fish volcanics are therefore coeval with the Nilkitkwa Formation to the south and the upper Toodoggone volcanic rocks to the east.

Thomson *et al.* (1986) also defined the Lower to Middle Jurassic Spatsizi Group at the northern end of the Bowser Basin. This varied sequence of sedimentary formations and tuffs was interpreted as the basinward sedimentary facies that are the lateral equivalents of the nearby Cold Fish volcanics. The sedimentary Spatsizi Group ranges in age from early Pliensbachian to early Bajocian, and is therefore contemporaneous with the sedimentary Nilkitkwa and

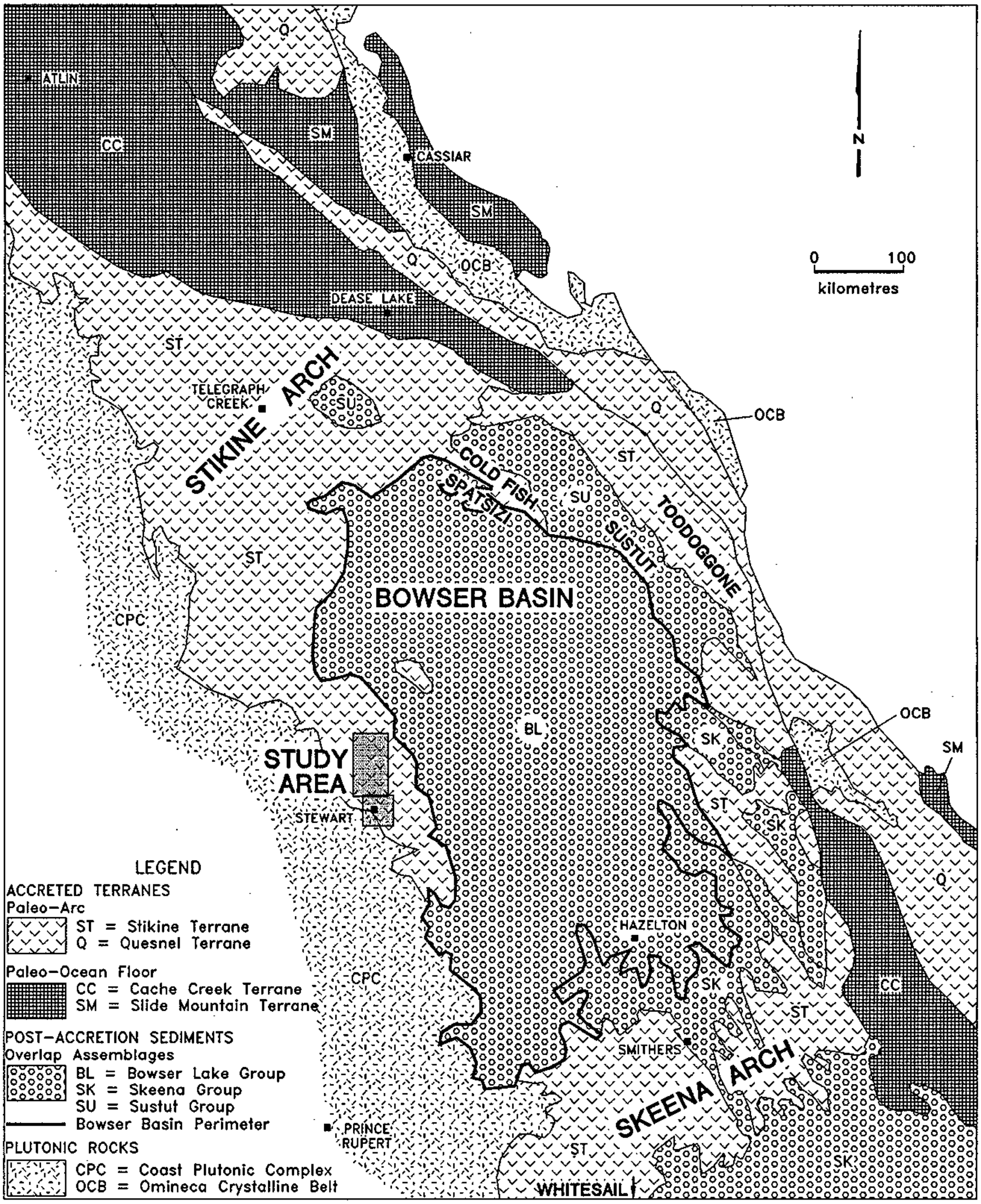


Figure 3. Tectonic elements of northern British Columbia (modified from Wheeler and McFeely, 1987).

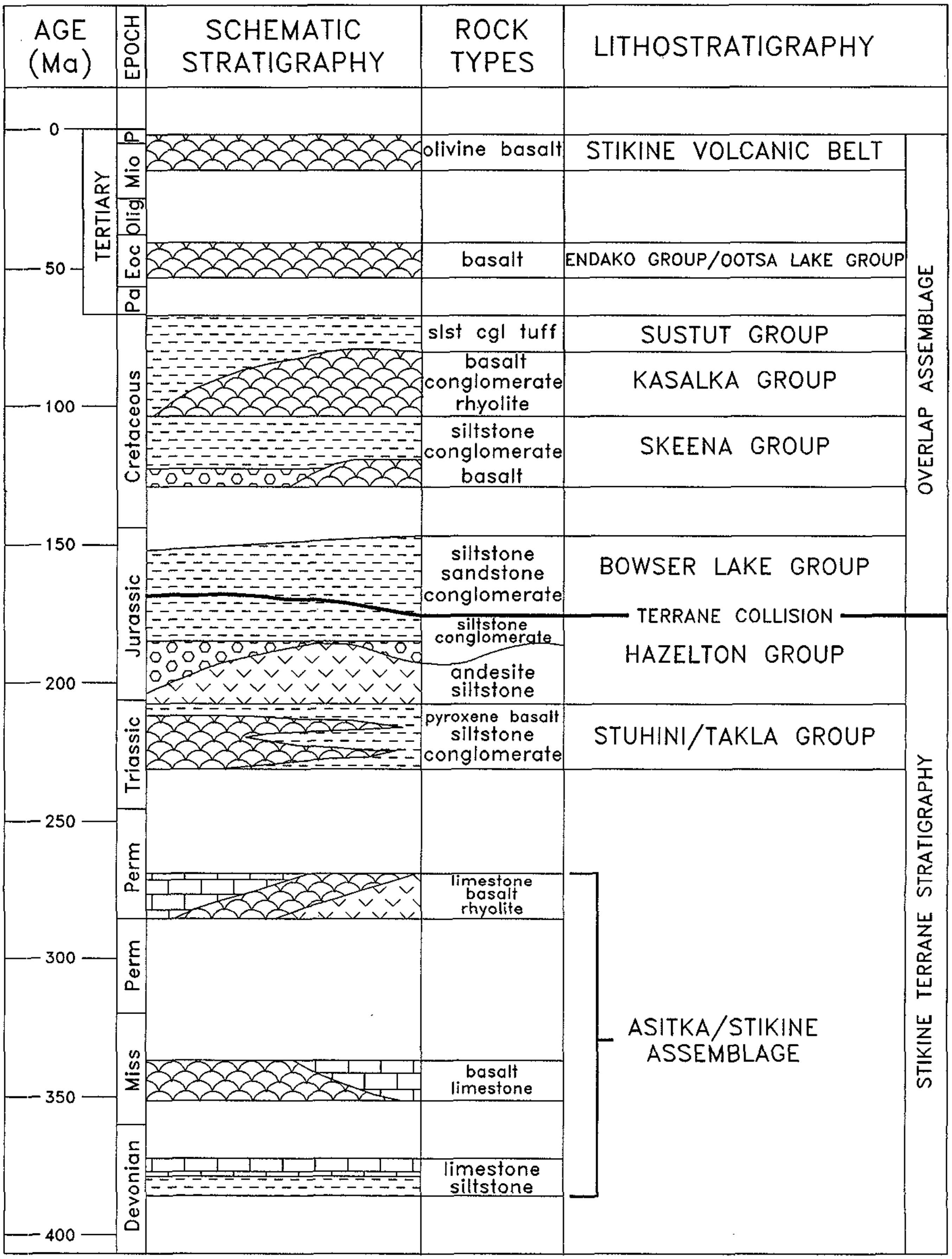


Figure 4. Stratigraphy of Stikinia and younger overlap assemblages.

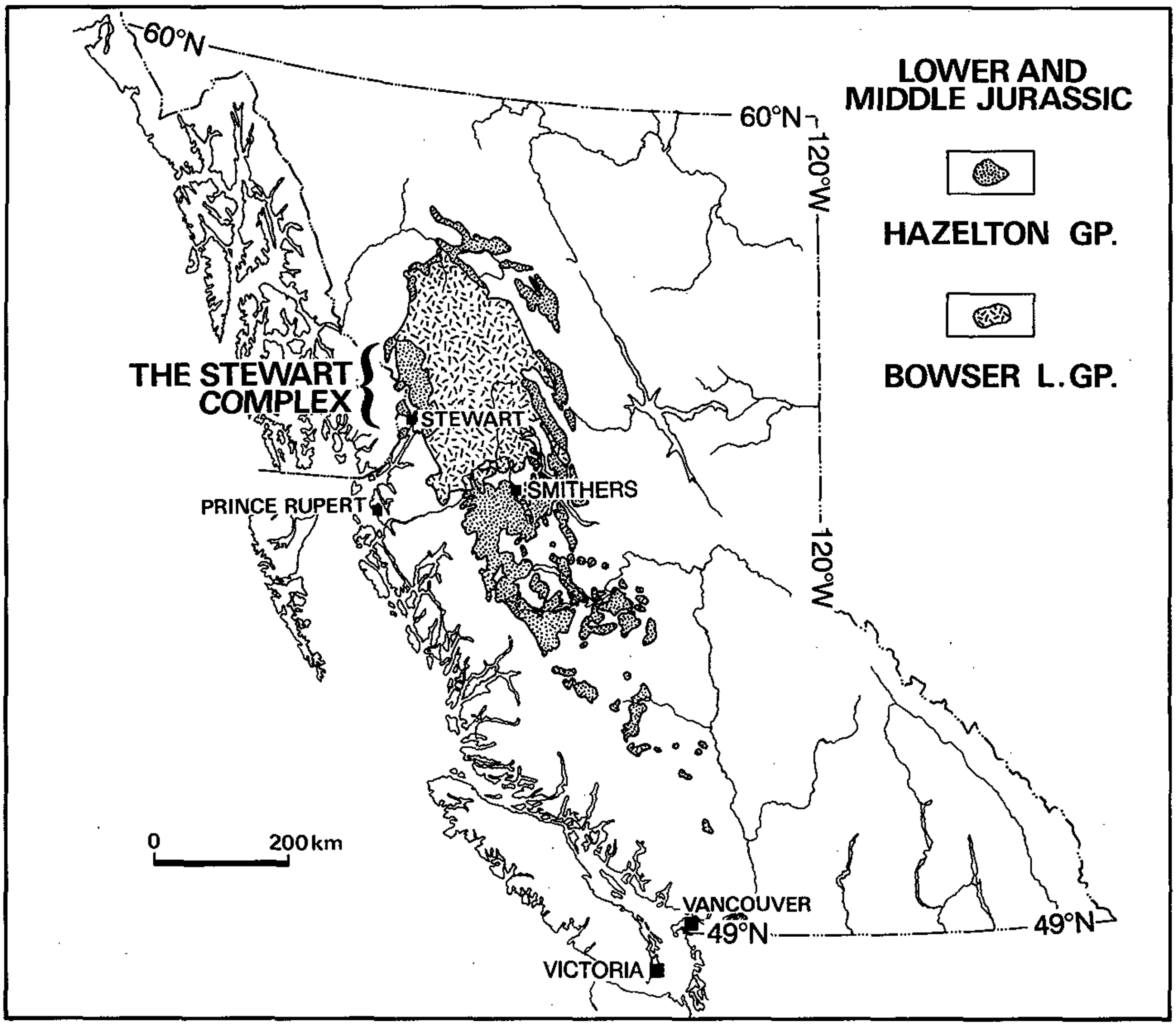


Figure 5. Distribution of the Hazelton Group, the Stewart Complex and Bowser Lake Group rocks in Central British Columbia.

Smithers formations of the Hazelton Group defined by Tipper and Richards (1976). Consequently, Anderson (personal communication, 1990) suggested redefining this sequence as the Spatsizi Formation.

WHITESAIL AREA (SOUTH)

The Whitesail Formation was defined by Woodsworth (1980), described in the Tahtsa Lake area by MacIntyre (1985), and dated at 184±4 Ma (van der Heyden, 1989, p.58-59). The unit has a gradational upper contact with thin-bedded argillites, siltstones and cherts similar to the Smithers and Salmon River formations. There are striking similarities between the Whitesail Formation (MacIntyre, 1985) and the Mount Dilworth Formation of the Stewart area, which is described in this report. MacIntyre's description of the Whitesail Formation follows:

"FELSIC VOLCANIC — CHERT UNIT (WHITESAIL FORMATION (?); LMjC)

Siliceous light grey, greenish grey, and dark grey volcanic rocks conformably overlie, and are, in part, interbedded with red and green volcanic units of the Telkwa Formation. These rocks are typically thin bedded, and in places are finely laminated. The predominant rock types are welded lapilli tuff, mottled cherty tuff, and banded or massive dacite and rhyodacite. Eutaxitic textures are common in the more siliceous fragmental rocks. These felsic volcanic rocks grade upward into alternating beds of mottled and banded grey chert, siliceous argillite, and siltstone which may be part of the Smithers Formation. Stratabound lenses of pyrite and pyrrhotite, up to several centimetres thick, are common in this part of the section."

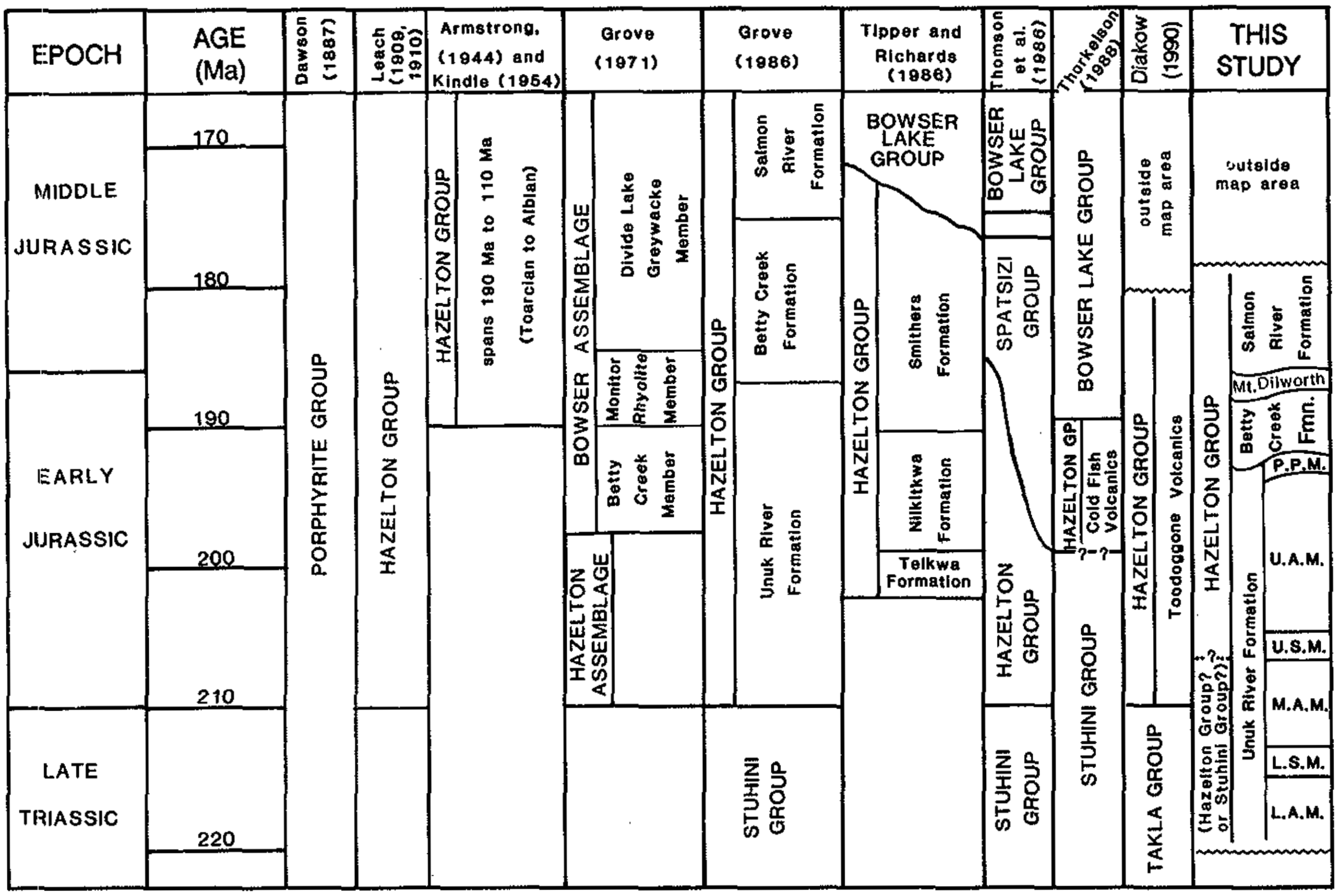


Figure 6. Evolution of stratigraphic nomenclature for the Hazelton Group (see also Figure 13). L.A.M.=Lower Andesite Member; L.S.M.=Lower Siltstone Member; M.A.M.=Middle Andesite Member; U.S.M.=Upper Siltstone Member; U.A.M.=Upper Andesite Member; P.P.M.=Premier Porphyry Member.

POST-HAZELTON STRATA

The **Bowser Lake Group** comprises a thick sequence of Middle Jurassic to Upper Jurassic sedimentary and rare volcanic rocks. The type area lies northeast of the study area. Chert-pebble conglomerates are diagnostic of the base of the group and these are overlain by shale, siltstone and intraformational conglomerates.

The Lower Cretaceous (Hautervian to Albian) **Skeena Group** consists of a sedimentary sequence of basal conglomerates overlain by a thick succession of distal turbidites. Minor amygdaloidal basalt flows are interbedded near the base of the sequence (MacIntyre, 1985).

MacIntyre (1985) defined the Middle to Upper Cretaceous (105 to 80 Ma) **Kasalka Group.** The predominantly volcanic sequence consists of basalts to rhyolites overlying a distinctive, maroon basal conglomerate. Tuffaceous members interbedded with Sustut Group sedimentary rocks are probably products of contemporaneous "Kasalka" explosive volcanism.

The **Sustut Group** consists of a thick sequence of middle Albian to Maastrichtian continental sedimentary rocks with minor conglomerates and air-fall ash tuffs.

Eocene volcanic rocks of the **Ootsa Lake Group** were first defined by Duffell (1959). Volcanic rocks of the **Endako Group** were defined by Armstrong (1949). The Ootsa Lake Group is a succession of continental calc-alkaline basalt to rhyodacite volcanic rocks. The Endako Group is preserved as scattered plagioclase-porphyritic basalt flows.

More than 100 volcanic centres have been recognized in northwestern Stikinia. Souther (1977) labelled this region of Miocene to Holocene cones and flows the **Stikine volcanic belt**. Lavas are mainly olivine basalt and range from 17 Ma to Recent, with the youngest age 130 years B.P. (Grove, 1986).

INTRUSIVE EVENTS

The magmatic evolution of the Canadian Cordillera was episodic, with distinct lulls between magmatic pulses. Episodes vary in location, intensity, duration, extent and character, and appear to be linked to changes in plate motion. Armstrong (1988) and Woodsworth *et al.* (in press) define eight magmatic periods in northern British Columbia (Figure 7). Magmatic events which affected the Stewart area are reviewed here.

Several plutons of economic significance were emplaced in the Canadian Cordillera during the **Early Jurassic (210 to 185 Ma)**: the Guichon Creek batholith, Copper Mountain intrusions, Iron Mask batholith and Island Plutonic Suite in southern British Columbia, and the Texas Creek Plutonic Suite in the Stewart area. All have been interpreted as the coeval subvolcanic magma chambers to Early Jurassic island-arc volcanic complexes.

Within Stikinia, Early Jurassic plutons are relatively small. All are interpreted as the sources of Hazelton volcanic rocks. The calcalkaline Texas Creek suite, within this study area, is represented by batholiths and stocks of distinctive coarse-grained hornblende granodiorite that contain potassium feldspar megacrysts.

Middle Cretaceous (110 to 90 Ma) granitic rocks are concentrated in two broad geographic belts that coincide with two zones of metamorphic rocks in the Canadian Cordillera: the Omineca crystalline belt and the Coast Plutonic Complex (Figure 2B). Mid-Cretaceous intrusive rocks are particularly abundant in the western part of the Coast Plutonic Complex. Within this small time span these I-type plutons are interpreted as pre-, syn- and post-tectonic with respect to the regional deformation and metamorphism (Woodsworth *et al.*, in press).

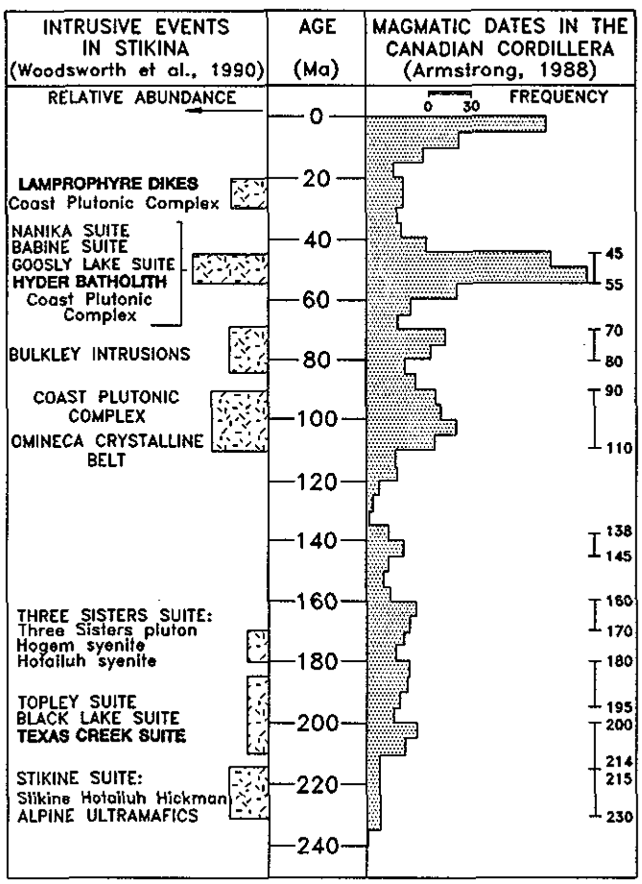


Figure 7. Intrusive events in Stikinia and the Canadian Cordillera.

Armstrong (1988) characterizes the **Early Tertiary (55 to 45 Ma)** magmatic episode as "a spectacular, short-lived event with rapid onset and equally rapid decline. The actual duration could not have been much more than 5 million years".

Within Stikinia, small high-level Eocene plutons and dikes mark a period of widespread intrusive activity. Woodsworth *et al.* have defined three suites: the granitic Nanika suite, granodioritic Babine suite and gabbroic Goosly Lake suite (Figure 7). Several stocks are related to major molybdenum and copper-molybdenum deposits: Berg, Kitsault, Ajax, Granisle and Bell. Intrusions are coeval with intermediate to felsic pyroclastic rocks of the Ootsa Lake and Buck Creek groups and mafic volcanic rocks of the Endako Group.

TECTONIC HISTORY

Subduction Zones

Prevailing tectonic models suggest there were two active subduction zones in the Triassic and Early Jurassic, providing magmas to the separate Insular and Intermontane terranes (Figure 8; Griffiths, 1977; Griffiths and Godwin, 1983; Armstrong, 1988). Polarity of Triassic-Jurassic subduction zones is uncertain (Marsden and Thorkelson, in press) but from Cretaceous time onward there is strong evidence for eastward-dipping subduction (Armstrong, 1988).

Polarity of the Eocene volcanic arc is well documented (Ewing, 1981; Armstrong, 1988): subalkaline quartz diorite bodies are present in the Coast plutonic belt; Intermontane rocks grade eastward from calcalkaline to alkaline; easternmost exposures are invariably alkaline, which is the normal pattern in wide subduction-related magmatic arcs (Gill, 1981).

Terrane Accretion

Relationships between terranes are summarized from Armstrong (1988) and illustrated in Figures 2, 3, 8 and 9. Earliest terrane linkage was between the Cache Creek and Quesnel terranes where Cache Creek rocks were caught up in an active accretion wedge (Monger, 1984; Paterson and Harakal, 1974). The timing of the connection between Stikinia and the Cache Creek is uncertain, but Upper Triassic rocks of both Stikinia and Quesnel terranes (Stuhini and Takla groups) are very similar and Early Jurassic (212-204 Ma) plutonic rocks are common to both terranes. Therefore these three terranes were probably linked when Early Jurassic arc-magmatism began in northern Stikinia (Monger, 1984).

Until Toarcian time, contrasting environments existed on the partially assembled Stikinia, Cache Creek and Quesnel terranes, and on the oceanic Slide Mountain Terrane to the east. But all four terranes, which were independent of each other in the Permian (Monger, 1977), had been at least loosely assembled by the end of the Early Jurassic to form Superterrane I (Figures 2c and 2d).

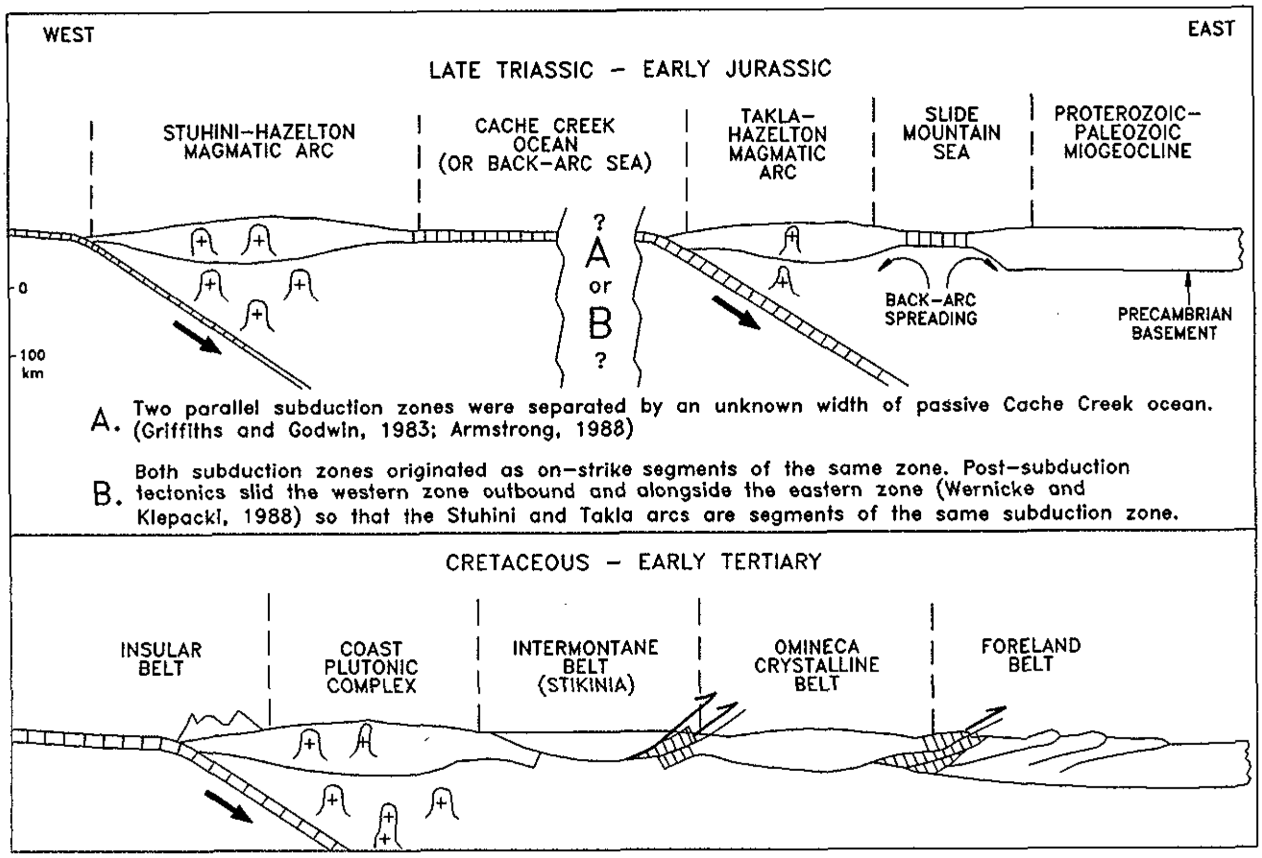


Figure 8. Subduction zone geometry of the Canadian Cordillera. A hypothetical cross-section through Stikinia.

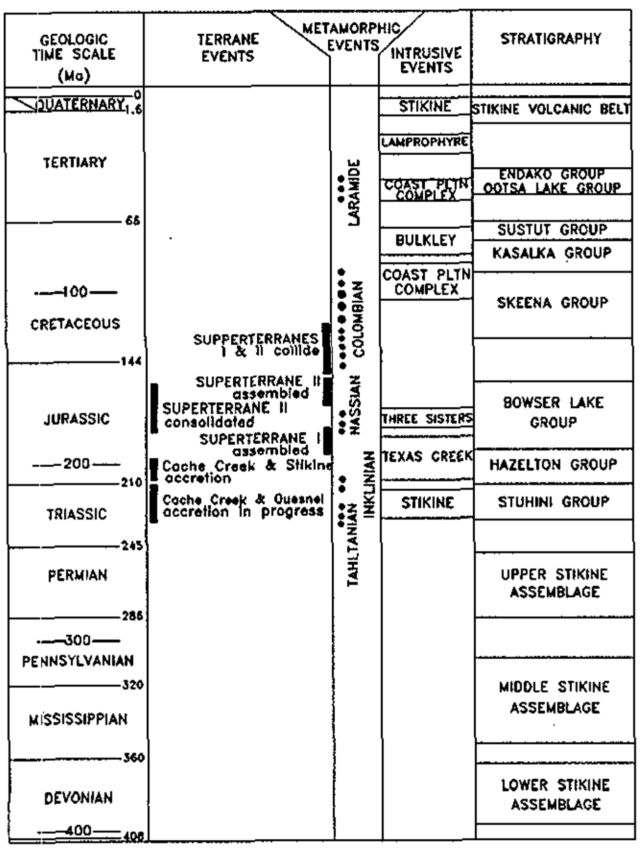


Figure 9. Geologic history of Stikinia.

As Superterrane I was thrust onto North America in Early to Middle Jurassic time, these four loosely assembled terranes collided sequentially with each other. All deformation within Superterrane I terminated before emplacement of late Middle to early Late Jurassic plutons. This large part of the Canadian Cordillera was therefore in place against North America by the mid-Jurassic, but perhaps not at its present latitude.

The overlap assemblage of the Gravina – Nutzotin belt (Berg *et al.*, 1972) links the Alexander and Wrangell terranes in Alaska by Late Jurassic time, to form Superterrane II (Coney *et al.*, 1980). Ongoing work suggests links between these terranes in the Paleozoic. The Jurassic Bridge River – Hozameen – Tyaughton – Taku ocean separating Superterranes I and II closed between Early to Middle Jurassic.

Thus, assembly of the Canadian Cordillera was largely complete by the Late Jurassic, and by mid-Cretaceous an Andean-type magmatic arc was established on the Cordilleran margin of North America.

GEOLOGIC HISTORY

A synthesis of the preceeding stratigraphic, plutonic and tectonic relationships is summarized in this section and illustrated schematically in Figure 9.

380 to 310 Ma: The lower and middle Stikine assemblages may represent remnants of two mid-Paleozoic volcanic arcs.

280 to 250 Ma: The unconformable, upper Stikine assemblage may record a third magmatic arc complex.

250 to 230 Ma: The Tahltanian orogeny deformed the Stikine assemblage prior to deposition of Upper Triassic volcanic rocks.

230 to 210 Ma: The volcanic arc assemblages of the Stuhini/Takla Group were produced by two subduction zones. The Cache Creek and Quesnel terranes were linked in the Late Triassic, but Stikinia was not yet linked to other terranes.

210 to 190 Ma: In the earliest Jurassic, plutons intruded and pinned the collision zone of the Cache Creek and Quesnel terranes. The partially assembled Superterrane I (Stikinia – Cache Creek – Quesnel) linked with the Slide Mountain Terrane in Toarcian time (190 Ma).

On Stikinia, Upper Triassic Stuhini/Takla mafic volcanic strata were gradational into Early Jurassic intermediate to felsic Hazelton Group units. Early Jurassic batholiths throughout the Intermontane Belt were coeval subvolcanic magma chambers within the "Hazelton" island-arc complex, analogous to modern arcs of the southwest Pacific.

190 to 155 Ma: One east-dipping subduction zone operated through the Late Jurassic. In the period 190 to 180 Ma the linked terranes of Superterrane I collided with North America. Starting in Toarcian time, Slide Mountain rocks were thrust eastward onto the North American continental margin. Between Toarcian and Bajocian time, Stikinia was overridden by the Cache Creek Terrane. Mid-Jurassic plutons pinned these consolidated terranes and then a prolonged magmatic lull began throughout the Canadian Cordillera.

The Smithers, Whitesail, Mount Dilworth, Salmon River and Spatsizi formations of the upper Hazelton Group accumulated between 190 to 180 Ma. The Bowser Lake Group was deposited in the Bowser Basin between 180 and 150 Ma (Cookenboo and Bustin, 1989). The Bowser Basin was a slowly sinking depression that accumulated clastic sediment from surrounding elevated areas. It has been devoid of magmatism since the Middle Jurassic, earning it the label "cold spot" (Armstrong, 1988).

155 to 125 Ma: From Early Cretaceous onward a single eastward-dipping subduction zone developed on the Cordilleran margin. The major magmatic lull continued throughout much of the Early Cretaceous. Sedimentary rocks of the Bowser Lake Group accumulated until 150 Ma. From 150 to 125 Ma the absence of both plutonic and volcanic rocks coincides with regional gaps in the stratigraphic record, indicating a time of emergence, erosion and external drainage (Armstrong, 1988; Cookenboo and Bustin, 1989). Renewed plutonism began about 130 Ma within the Coast Plutonic Complex.

125 to 110 Ma: The magmatic lull continued in the Intermontane Belt, but magmatic activity in the Coast Plutonic Complex increased. Deposition of Skeena Group sedimentary rocks and Kasalka Group volcanic rocks progressed throughout this period.

110 to 90 Ma: An Andean-type, continental-margin magmatic arc was fully established by the mid-Cretaceous. Renewed magmatism in the western part of the Coast Plutonic Complex and in the Omineca Belt peaked during this period. Accompanying tectonism, deformation and regional metamorphism within the western Intermontane Belt peaked from 110 to 100 Ma.

90 to 70 Ma: Transpression related to oblique subduction produced right-lateral transcurrent faulting, carrying displaced terranes northward (Monger, 1984). Right-lateral movement along the Tintina fault on the west side of the Omineca Belt displaced the Bowser Basin hundreds of kilometres northward (Eisbacher, 1981).

Plutonism, with extrusive phases, was abundant in Stikinia and in the western and central parts of the Coast Plutonic Complex. Sedimentary rocks and intercalated tuffs of the Sustut Group were deposited during uplift of the Omineca Belt to the east and the Coast Plutonic Complex to the west (Eisbacher, 1981).

70 to 60 Ma: No evidence of volcanism or sedimentation was preserved on Stikinia during this short magmatic lull.

60 to 40 Ma: This period spans the final major magmatic episode in the Canadian Cordillera. Within Stikinia, plutons were small, high-level stocks and dikes with contemporaneous volcanic sequences.

40 to 20 Ma: This period was characterized by localized plutonism in the Coast Plutonic Complex. High-level granite and granite porphyry intrusions include the stock hosting the Quartz Hill molybdenum deposit. The Oligocene was marked by widespread, but volumetrically small emplacement of lamprophyre dikes.

Cooling, uplift and unroofing of the Coast Plutonic Complex accompanied east-west extension represented by north-striking faults. North to northeast-striking faults and joints controlled distribution of Oligocene to Recent intrusive and volcanic rocks.

20 to present: East-dipping subduction has continued along our west coast until the present. Throughout the Miocene a flood of alkali-olivine basalt issued from a multitude of vents and fissures to form plateau lavas. Intermittent eruption has continued throughout Pliocene, Pleistocene and into Recent time.

CHAPTER 3 — LITHOLOGIC UNITS

A simplified geological map of the study area is presented on Figure 10; more detailed geology is presented at 1:50 000 scale on Figure 11 (in pocket). Regional stratigraphy presented in this report (Figure 12) is the latest step in the evolution of stratigraphic subdivisions started by McConnell (1913) and revised by Schofield and Hanson (1922), Hanson (1929, 1935) and Grove (1971, 1973, 1986) (Figure 13). Grove (1973, 1986) established the current stratigraphic nomenclature. Only one modification is made, the felsic volcanic sequence, Monitor rhyolite, which Grove included within the Salmon River Formation, has been raised to formational status in this study and has been renamed the Mount Dilworth Formation or Mount Dilworth dacite.

Fossil samples from the map area have been collected by Schofield and Hanson (1922), Hanson (1935), Grove (1971, 1986), Anderson (personal communication, 1986), and Brown (1987). All previously reported and newly located fossil exposures are shown on Figure 11.

HAZELTON GROUP

The Hazelton Group is a sequence of mixed volcanic and sedimentary rocks that spans the Lower Jurassic epoch. Volcanic units progressively change in composition from basalt through andesite to dacite over a total thickness of 5 kilometres. This compositional change is paralleled by a change in colour from dark olive-green to light grey, and by progressive changes in associated phenocrysts (Figure 14).

UNUK RIVER FORMATION

The Unuk River Formation is a thick sequence of massive green to greenish grey andesitic tuffs and lava flows with minor interbedded sedimentary rocks. This succession was defined during studies north of the present map area (Grove, 1973, 1986). This unit hosts all of the major gold deposits in the Stewart mining camp.

The formation is exposed along a north-trending belt through the centre of the map area. The base of this sequence lies to the west, engulfed in the Coast batholith, but the formation is at least 4500 metres thick within the map area. The upper contact is typically a sharp, ragged to smoothly undulating erosional boundary with significant paleorelief. Porphyritic andesite flows or tuffs are overlain by grits to conglomerates of the Betty Creek Formation.

STRATIGRAPHY

Significant revisions have been made to Grove's informal stratigraphic divisions. These follow from recognition of regionally distributed feldspar-porphyritic andesite flows and tuffs at the top of the formation, and two siltstone members within the succession. The siltstone units mark periods of volcanic quiescence and provide important stratigraphic and structural markers within the predominantly andesitic sequence. They permit determination of bedding attitudes, stratigraphic tops and fault offsets throughout the map area.

Overall, the Unuk River Formation is a thick, monotonous sequence of medium-green andesitic rocks that are preserved as weakly to moderately foliated greenschists. In more detail, the volcanic rocks range from dust to ash tuff, crystal tuff, lapilli tuff, monolithic pyroclastic breccia and lava flows. Plagioclase and, less commonly, hornblende or augite phenocrysts or crystal fragments characterize the volcanic rocks. Phenocryst distribution is illustrated in Figure 14. Individual tuff beds show little evidence of sorting or preferred orientation of crystals or lithic fragments, except in zones of ductile deformation.

Discontinuous exposures and abrupt lateral textural changes in the tuffs hinder tracing and correlation of individual beds along strike, but a general zoning pattern of clast size and crystal abundances within the sequence has been recognized (Figure 14). Lapilli tuffs are uniformly distributed but medium to coarse ash tuffs are most abundant in the lower part of the sequence and crystal tuffs and crystal-lithic tuffs are somewhat more abundant in the upper part. Tuff breccias are present near the top of both the middle and upper members of the sequence. Very coarse tuff breccias are known only at the top of the succession near the Mount Dilworth vent area.

LOWER ANDESITE MEMBER

The Lower Andesite Member is at least 500 metres thick, but the lower contact has not been defined. It is composed of massive to well-bedded ash tuffs. No lapilli were seen in outcrop and no phenocrysts were noted in hand samples, but a thin section of ash tuff collected near Flower Pot Rock has abundant fine-grained (~0.5 mm) pyroxene grains and crystals.

LOWER SILTSTONE MEMBER

The Lower Siltstone Member is a thin-bedded turbidite succession of dark grey to black siltstones that ranges from 50 to greater than 200 metres in thickness.

MIDDLE ANDESITE MEMBER

The Middle Andesite Member is at least 1500 metres thick and comprises dust tuff, ash tuff, lapilli tuff and minor tuff breccia with interbedded medium to coarse volcaniclastic sedimentary rocks. Massive pyroxene-porphyritic flows crop out near the top of the member around the Granduc millsite and along the road network to the Roanan vein and other deposits south of the Alaskan border. An isolated exposure of massive augite-porphyritic basalt in the Long Lake area (Dupas, 1985) may be the stratigraphic equivalent of the pyroxene porphyries of the Middle Andesite Member.

UPPER SILTSTONE MEMBER

The Upper Siltstone Member varies in thickness from as little as 50 metres near the Indian mine to more than a

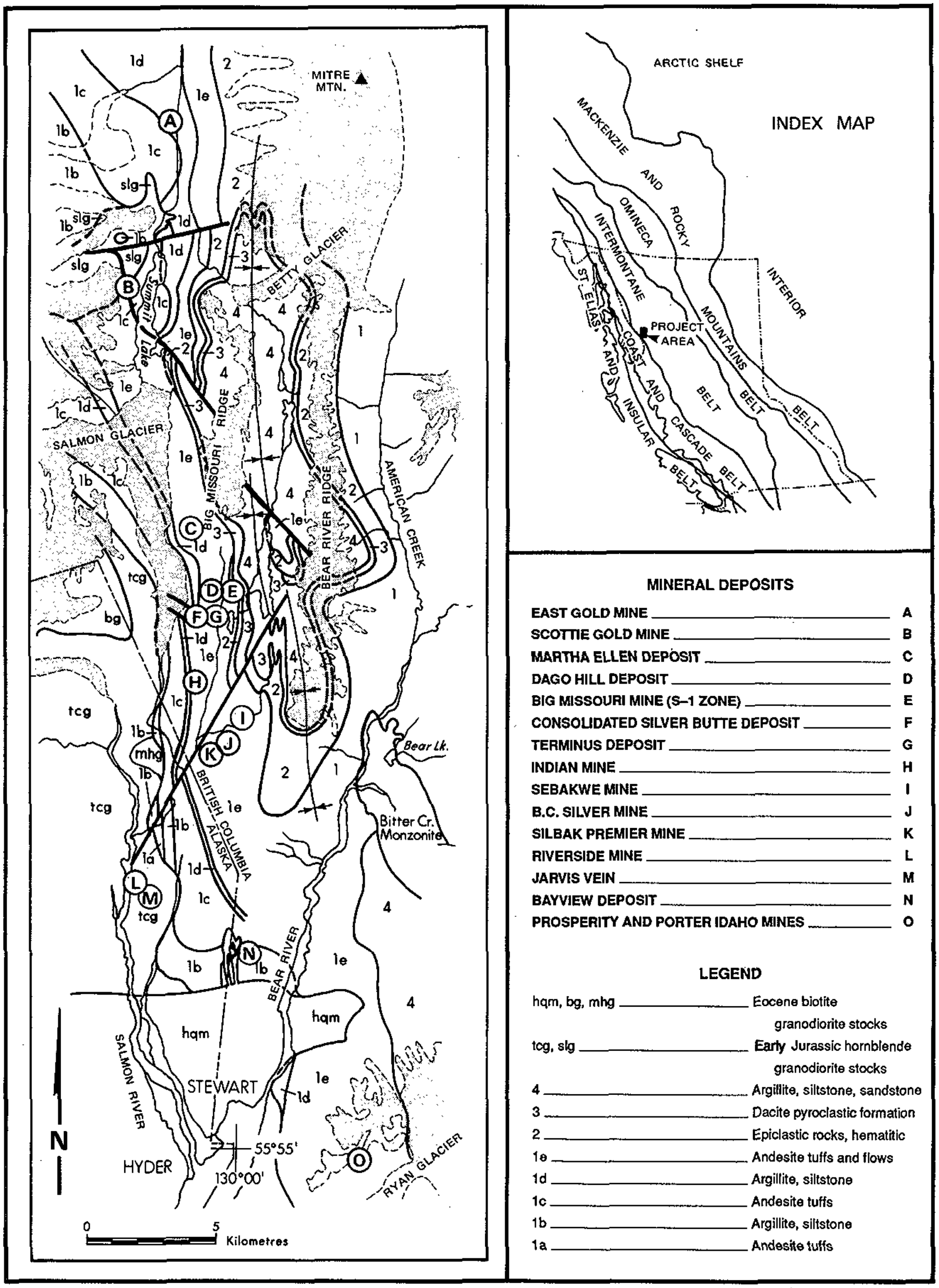


Figure 10. Geologic setting of the study area.

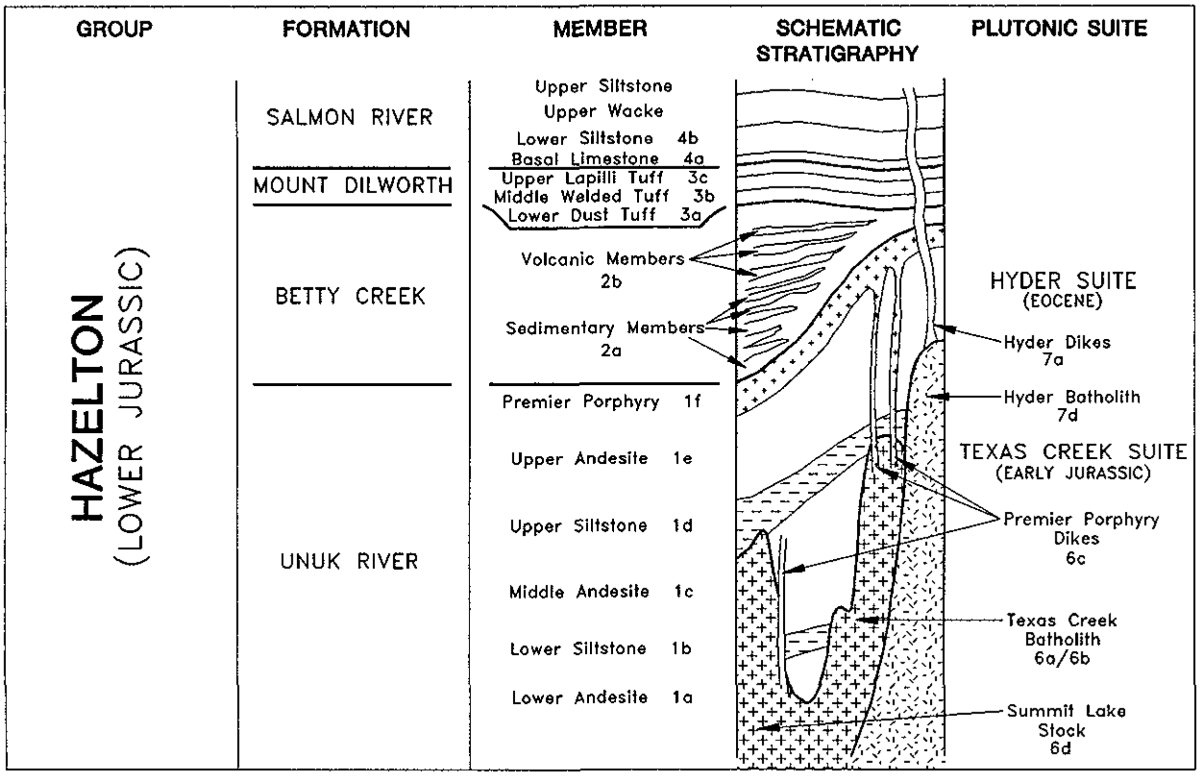


Figure 12. Schematic stratigraphy of the Stewart mining camp.

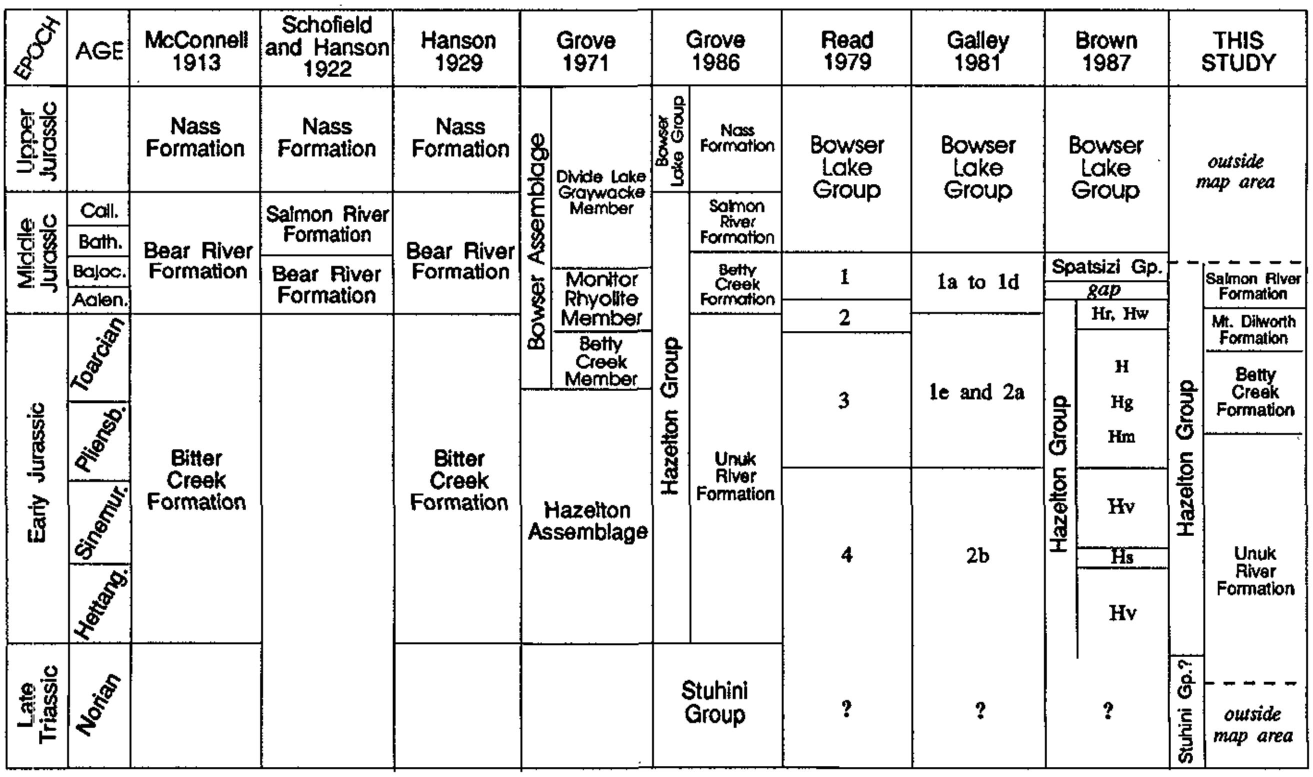


Figure 13. Evolution of stratigraphic nomenclature for the Stewart mining camp. (See also Figure 6.)

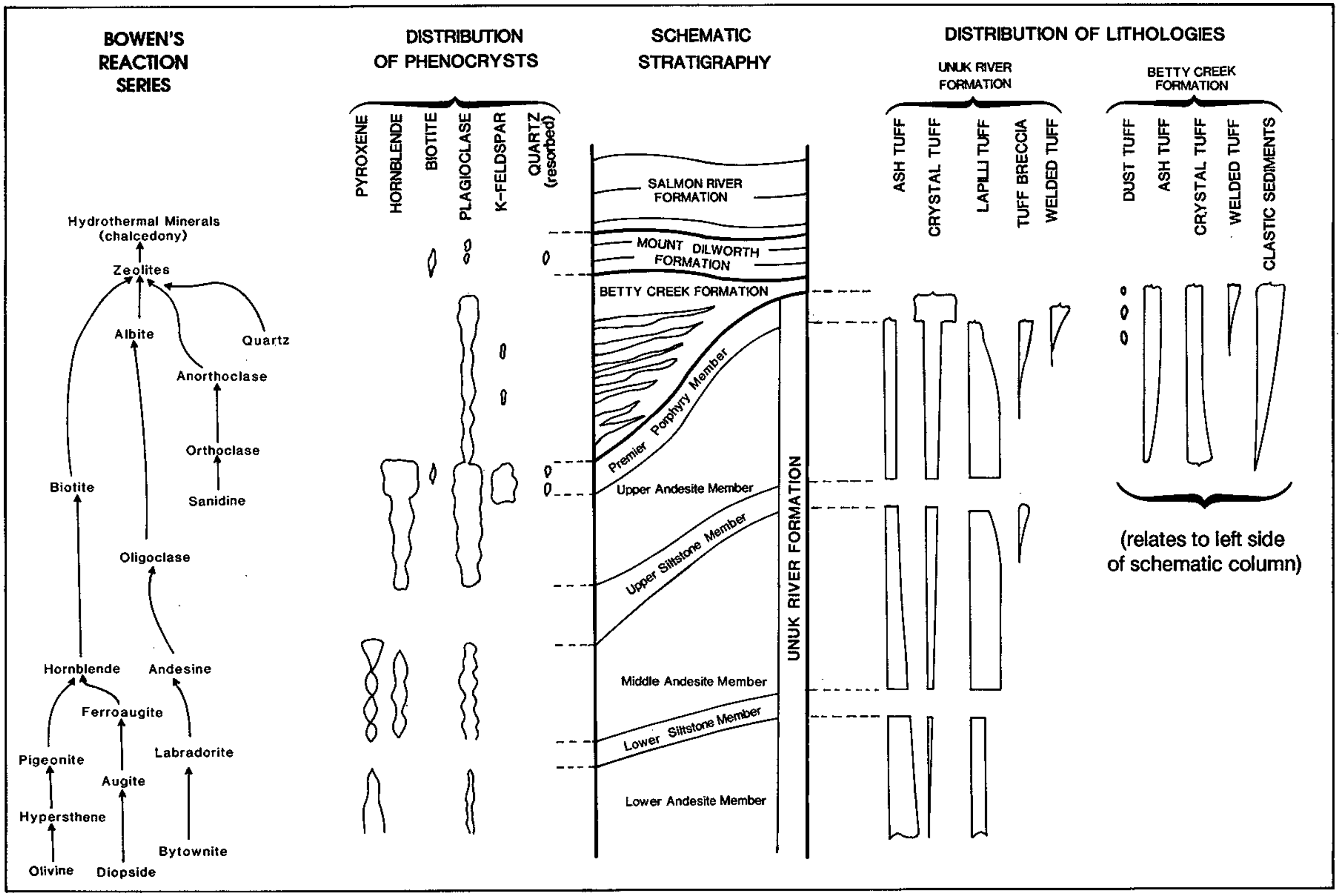


Figure 14. Phenocryst mineralogy and fragment size variations in Stewart stratigraphy.

kilometre in the northern part of the map area. The upper contact can be a sharp change from dark grey or black thin-bedded siltstone to massive green andesitic tuff, as along the western slope of Troy Ridge; but typically the thin-bedded strata are overlain with a sharp upper contact by the basal black-tuff facies of the Upper Andesite Member. Offsets of this unit provide evidence for major movement along the Millsite, Morris Summit and Slate Mountain faults.

On the west side of the Tide Lake Flats, the Upper Siltstone Member hosts precious metal veins at the East Gold mine. Pyritic areas in the siltstones produce brightly coloured, gossanous exposures that crop out from north of the mine southward to the Millsite fault (Figure 11). Rocks of the Upper Siltstone Member, preserved as purple-brown hornfelsed siltstones, host calcsilicate veins and minor sulphide mineralization in the Molly B, Red Reef and Oral M adits on Mount Rainey (Figure 11).

Upper Andesite Member

The Upper Andesite Member is a thick sequence of massive tuffs with minor flows and local lenses of sedimentary rock. It is about 2000 metres thick and capped by regionally extensive crystal tuffs of the Premier Porphyry Member.

Black Tuff Facies

The base of the upper andesite is marked by a massive, black, fine-grained to locally fragmental unit, 0 to 250 metres thick. Thin sections reveal that it includes not only layers of carbon-impregnated ash tuff, feldspar crystal tuff, and lapilli tuff, but also massive siltstone, feldspathic wacke and granule to pebble conglomerates of roughly rounded volcanic debris. Therefore the unit consists of intimately mixed massive sedimentary rocks and tuffs, transitional between underlying thin-bedded black siltstones and overlying massive green andesite tuff. Whole-rock analyses plot as andesite.

The upper contact of this unit grades over 10 to 50 centimetres into green chloritic tuffs. This gradational colour boundary undulates across large, texturally uniform outcrops. These relationships indicate that the black rocks are andesitic air-fall tuffs that were deposited on top of the thin-bedded silts in a very shallow anoxic basin. The tuff apparently accumulated until it built up to and above sea level, where it was preserved without carbon.

Main Sequence

A monotonous succession of greenstones and minor sedimentary lenses comprises the main sequence of the Upper Andesite Member. These rocks have previously been studied in detail by Grove (1971, 1973, 1986), Read (1979), Galley (1981) and Brown (1987). It is difficult to distinguish individual units because of the uniform green colour and pervasive foliation of the rocks. Rock types range from dust and ash tuffs to lapilli tuffs and tuff breccias; crystal tuffs display varying abundances of plagioclase and hornblende. The top of the Upper Andesite Member is andesitic lapilli tuff to coarse tuff breccia. Regionally, the largest angular fragments range up to 40 centimetres long. In one small area on Mount Dilworth a single bed contains blocks that are up to 1.5 metres across, including an intact hexagonal fragment of columnar-jointed andesite, 1.2 metres across. Overall variations in clast size and in phenocryst composition and abundance are illustrated by Figure 14.

Generally, massive fine-grained aphanitic ash tuffs have local fine plagioclase and hornblende phenocrysts set in an altered ash matrix. These rocks are pervasively chloritized and contain up to 5 per cent disseminated fine-grained pyrite. Chlorite defines the penetrative foliation of the rocks and gives a phyllitic sheen to some broken surfaces.

Fragmental rocks are open-framework volcanic breccias and may represent air-fall lapilli tuff, ungraded pyroclastic flow breccias, or lava flow breccias. Exposures are typically massive with no preferred orientation, but local zones of ductile deformation result in plate-like flattened fragments. Correlation of these fragmental units is difficult, even over the short distances between outcrops and drill holes. The apparent lack of continuity may be due to abrupt textural variations, slumping, postdepositional erosion or small-scale, postlithification faulting.

Deep green to greyish green fragmental rocks are typically monolithologic; fragments are generally matrix supported and textures are best displayed on recently glaciated or deeply weathered surfaces. Fragments are typically angular, but some exposures have subrounded and well-rounded clasts. Fragmental rocks contain lithic, pumice and crystal fragments. Lithic fragments consist of varieties of ash tuff, variable plagioclase and hornblende porphyritic rocks, and lithified fragmental rocks. The matrix is composed of fine lithic chips and glass shards in a groundmass of quartz, feldspar and sericite, chlorite and carbonate-altered ash and dust. Some weathered exposures show resistant fragments in a recessive matrix, others a resistant matrix with recessive fragments. Possibly the former represent air-fall lapilli tuffs and the latter either hot pyroclastic flows or flow-top breccias.

Pyrite is disseminated in both fragments and groundmass as angular subhedral grains to euhedral cubes. Typically it makes up about 2 per cent of these rocks, but within 2 kilometres of the Silbak Premier mine, local exposures of intense chlorite-pyrite alteration contain up to 5 per cent disseminated medium-grained pyrite.

Locally within the Upper Andesite Member, lenses of maroon to purple to grey siltstone, sandstone and conglomerate are preserved. Epiclastic rocks record periods of erosion and volcanic quiescence during the overall development of the andesitic volcano. These hematitic sedimentary units are distinctive and may be useful markers on a property scale.

A thin lens ($\leq$30 m) of black to dark grey sedimentary rock crops out high on the northwest slope of Troy Ridge (Figure 11, in pocket). The unit is exposed around the shore of a long, narrow pond and consists of thin-bedded siltstone and gritty limestone. It wedges out to the south but its northern extent is unknown. These rocks mark local subaqueous conditions on what is interpreted as a subaerial volcanic edifice; conditions of formation might be analogous to sediment accumulation in Spirit Lake at Mount St. Helens, Washington.

Premier Porphyry Member

The distinctive Premier Porphyry Member contains plagioclase, potassium feldspar and hornblende phenocrysts and marks the top of the Unuk River Formation throughout the map area. Regionally it can be divided into three units; on more local scales a variety of additional facies are preserved.

The rocks are texturally similar to dikes of Premier Porphyry which cut both the underlying strata (Plate 1) and the Texas Creek batholith. Brown (1987, pp. 113-118) renamed these units to avoid confusion between stratabound and intrusive phases. Here, the writer prefers to stress the genetic link between the intrusive and extrusive phases of these economically and stratigraphically important rocks. All gold deposits in and around the Silbak Premier and Big Missouri mines lie stratigraphically below this member.

Massive to Layered Plagioclase Porphyry

The basal unit of the Premier Porphyry Member is massive to crudely laminated plagioclase-hornblende-phyric rock. Plagioclase crystals (<6 mm) stand out clearly (Plate 2) but the hornblende crystals are smaller and only evident in hand sample with careful study. Layering reflecting variable grain-size sorting is typically 1 to 2 centimetres thick and the rock appears more indurated and less foliated than andesitic tuffs lower in the sequence. The definition of the layering is variable, some exposures are almost massive. This unit does not normally carry potassium feldspar crystals, but a few small or broken orthoclase rhombs were noted in widespread outcrops (arrow in Plate 2).

Premier Porphyry Flow

The Premier Porphyry flow unit is a dark green to medium greyish green or grey to black, massive, indurated, crystal-rich rock with megacrystic potassium feldspar and smaller plagioclase and hornblende crystals. An interlocking, felted groundmass of microlites indicates the rock is a flow. Phenocrysts include small (3 to 5 mm) white, subhedral to euhedral plagioclase and larger (1 to 5 cm) buff-coloured, euhedral orthoclase. Locally hornblende crystals 5 to 10 millimetres long are visible, but they are generally obscured by strong chlorite alteration. The matrix is fine grained and usually chloritized.

In thin section the rock has embayed, partially resorbed quartz grains. The large feldspar crystals are euhedral with little rounding or fracturing. Plagioclase may be present as glomeroporphyritic clusters and all feldspars have a thin, clear, inclusion-free rim. Both Read (1979) and Galley (1981) report minor amounts of biotite in thin section examination of samples collected near the Big Missouri deposit. No biotite was noted in samples examined in this study.

Premier Porphyry Tuff

The Premier Porphyry tuff is characterized by its maroon colour and by potassium feldspar megacrysts and plagio-

Plate 1. Chilled margin along irregular contact of Premier Porphyry dike cutting bedded tuffs of Lower Andesite Member, Unuk River Formation. Exposed in bank of Salmon River near Flower Pot Rock.

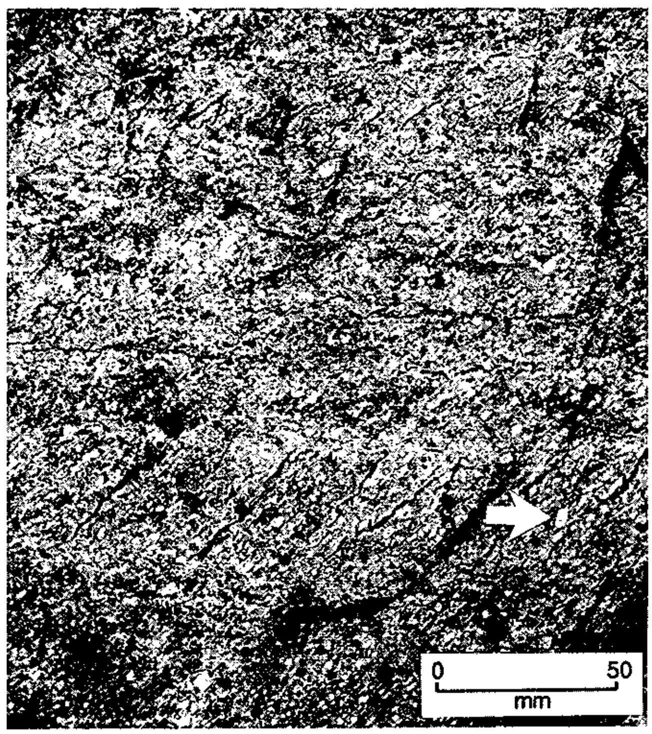


Plate 2. Bedded plagioclase-hornblende tuff, uphill from Premier glory hole. Note rare, coarse K-feldspar crystals (arrow). Massive to layered plagioclase porphyry, Premier Porphyry Member, Unuk River Formation.

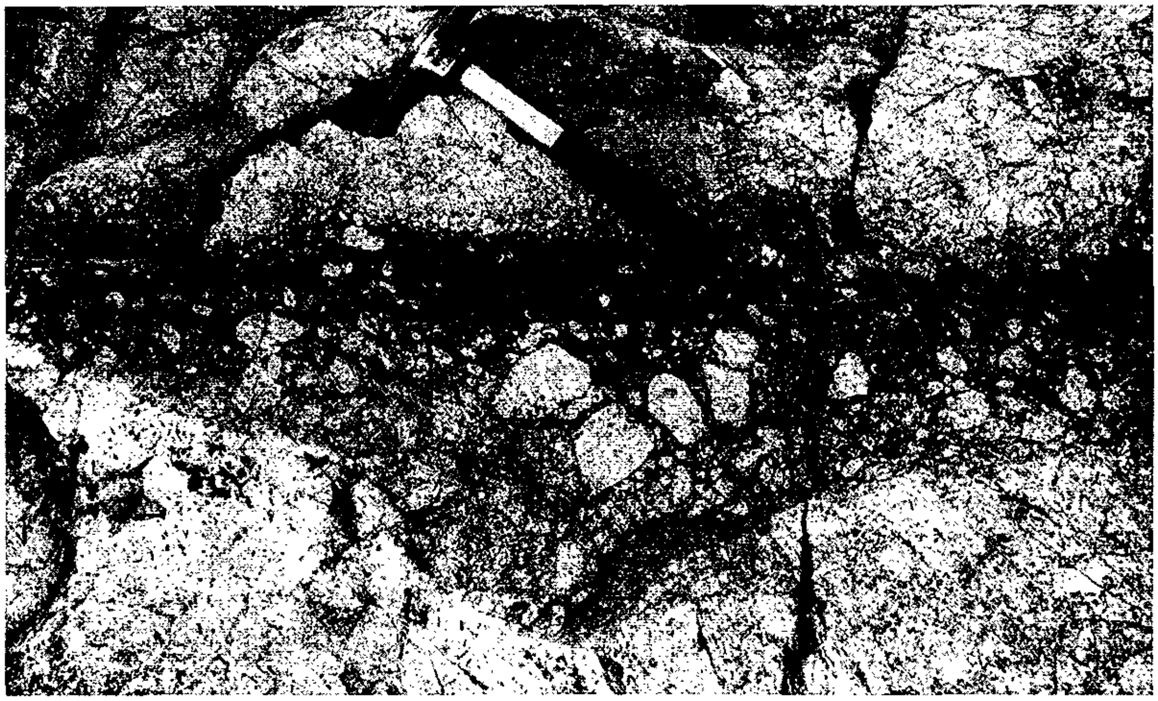


Plate 3. Mappable hematitic regolith layer between massive beds of K-feldspar-porphyritic flow, north end of 49 Ridge. Premier Porphyry flow, Premier Porphyry Member, Unuk River Formation.

TABLE 1
TEXTURAL DISTINCTIONS BETWEEN PREMIER PORPHYRY FLOW AND PREMIER PORPHYRY TUFF

Flow	Tuff
• rimmed feldspars	• no feldspar rims
• few or no lithic chips	• lithic clasts common
• euhedral phenocrysts	• broken and/or rounded phenocrysts
• interlocking crystalline matrix	• fine ash matrix
• glomeroporphyritic feldspars	

clase and hornblende crystals. It is distinguished from the underlying green Premier Porphyry flow by its hematite content, which produces a purple to greyish purple colour, and by its noncrystalline aphanitic matrix. Based on microscopic textural features summarized in Table 1 this rock is interpreted as a massive, subaerially deposited, air-fall crystal tuff. Distinction between tuff and flow textures is best made by thin section study, although Read (1979) felt slabbed samples were adequate.

Other Facies

In the Mount Dilworth area, the 100-metre section of Premier Porphyry flows is divided in the middle by a thin hematitic sandstone layer (Plate 3) parallel to the borders of the flow. The sandstone **regolith** was traced along the cliff face on the west side of 49 Ridge for 150 metres. This sedimentary layer records a brief period of subaerial weathering, followed by continued extrusion of similar flows.

A **vent** area has been mapped at the south end of 49 Ridge. The facies indicators are: a wedge-shaped bed of angular to well-rounded (milled) clasts of Premier Porphyry that is interpreted as a fall-back breccia in a vent area (Plate 4), and very coarse tuff-breccia at the top of the Upper Andesite Member. The fissure itself is exposed in the vertical cliff at the south end of 49 Ridge where blocks of black Premier Porphyry up to 3 metres in diameter are suspended in a matrix of massive to foliated ash and crystals of similar material (Plate 5). This vent area was probably a parasitic cone on the flanks of a large composite stratovolcano.

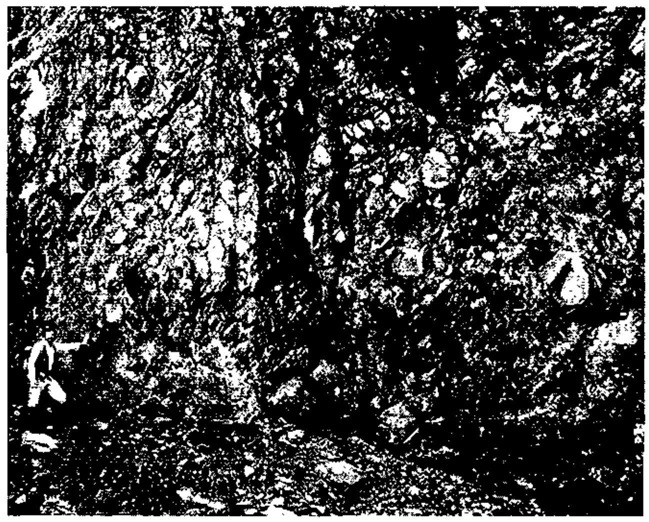


Plate 4. Milled fall-back breccia of dark green K-feldspar-megacrystic boulders, east cliff of 49 Ridge. Vent facies, Premier Porphyry Member, Unuk River Formation.

Plate 5. Large angular block of black K-feldspar-megacrystic flow-rock in similar groundmass. Megabreccia exposure in the south cliff of 49 Ridge. Vent facies, Premier Porphyry Member, Unuk River Formation.

PROVENANCE AND DEPOSITIONAL ENVIRONMENT

The Unuk River Formation represents an andesitic volcanic pile and intraformational epiclastic rocks. Volcanic rocks are subalkaline, calcalkaline, potassium and iron-rich andesites with minor basalts to basaltic andesites. The formation is regarded as a well-preserved composite stratovolcano, with paleotopographic peaks at or near Mount Dilworth (Upper Andesite Member) and at the north end of Long Lake (Middle Andesite Member). The stratovolcano was a predominantly subaerial structure with two brief periods of marine transgression recorded by the thin-bedded siltstone members (Table 2).

Rocks of the Unuk River Formation have not yielded diagnostic fossils within the map area, neither has the base of the formation been defined. Rocks low in the sequence have not been dated. Rocks of the uppermost Premier Porphyry Member are interpreted to be 195 million years old *based on correlation with U-Pb zircon ages from nearby* Premier Porphyry dikes. The entire formation is regarded as an Early Jurassic, Sinemurian(?) to mid-Pliensbachian, volcanic pile composed of onlapping to overlapping volcanic and derived sedimentary members from a series of nearby, actively erupting volcanic vents.

BETTY CREEK FORMATION

The Betty Creek Formation is a complex succession of distinctively coloured red and green epiclastic sedimentary rocks interbedded with andesitic to dacitic tuffs and flows. It was first defined by Grove (1971) as a member of the "Bowser assemblage". He redefined it (1973, 1986) as a formation *within the Hazelton Group with its type area* along the canyon of Betty Creek in the northern part of the map area.

The formation varies in thickness from 4 to 1200 metres. It is exposed continuously throughout the map area except for the 2-kilometre interval between Union Lake and Fetter Lake where it may be absent or overprinted and obscured by intense alteration.

Sections through the Betty Creek Formation from Daisy Lake to Slate Mountain have no interbedded volcanic rocks. In contrast, on Mount Rainey the andesites of the Unuk

TABLE 2

EVIDENCE FOR SUBAERIAL VERSUS SUBAQUEOUS DEPOSITION OF THE UNUK RIVER FORMATION

- Conspicuous absence of pillowed flows in seven decades of mapping
- Meteoric water component in fluid inclusions (McDonald, 1990a)

Key to Symbols in Following Lists

P=present; **A**=conspicuously absent;
?=insufficient data or not applicable

Characteristics of Subaerial Fallout Deposits (simplified from Fisher and Schmincke, 1984)

?	— Minor lenticularity close to source
?	— Ash layers wedge out against steep surface irregularities
?	— Grading may be normal and reverse
P	— Fabric in beds is commonly isotropic
P	— Elongate fragments are uncommon
P	— Bedding planes are generally gradational; bedding planes are distinct only where deposition is on weathered or erosional surfaces or different rock types
A	— Sorting is moderate to good
?	— Size and sorting vary with distance within single layers
P	— Silicic and intermediate compositions more common than mafic
P	— Intermediate composition commonly associated with large composite volcanoes
P	— Proximal facies include: lava flows, pyroclastic flows, domes, pyroclastic tuff breccias, avalanche deposits and debris flows
P	— Intermediate facies include: coarser grained tephra, some lava flows, pyroclastic flows, ash falls and reworked fluvial deposits
?	— Distal facies include: fine fallout tephra with no coeval coarse-grained pyroclastic rocks or lava flows
P	— Coarser grained pyroclastic deposits gradually decrease, reworked pyroclastic deposits gradually increase away from source

Characteristics of Submarine Fallout Tephra (simplified from Fisher and Schmincke, 1984)

A	— Plane parallel beds extend for hundreds of km^2
?	— *Normal grading; crystal and lithic-rich bases to shard-rich tops*
?	— Inverse grading only if pumice is present
A	— Basal contacts sharp, upper contacts diffuse
?	— Sorting: good to poor depending on bioturbation
P	— Sizes and sorting varies irregularly, but there is an overall size decrease with increasing distance from source
A	— Ancient layers in terrestrial geologic settings are altered to clays and zeolites; known as bentonites
A	— Tephra commonly interbedded with pelagic calcareous or siliceous oozes, or with muds and silts, depending on proximity to land. Commonly interbedded with nonvolcanic or tuffaceous shale or siltstone
A	— Terrigenous materials accumulate as interbedded turbidites

River Formation are capped by a thick sequence of dacitic volcanic rocks and there are few interbedded sedimentary rocks. The varying abundance of sedimentary and volcanic rocks is probably controlled by paleotopography and regional distribution of volcanic vents. The volcanic flows and tuffs may have been extruded from other nearby volcanic centres to form onlapping units that interfinger with a thick sedimentary wedge shed from the Mount Dilworth paleovolcano.

The basal contact is typically marked by a sharp colour change from greenish chloritic andesitic tuffs of the Unuk River Formation to maroon clastic sedimentary rocks. The basal sedimentary rocks are commonly conglomerates developed on lithologically similar underlying andesites. The contact varies from irregular to smoothly undulating. The upper contact is a sharp, smooth boundary between purple, hematitic grits or wackes and overlying aphanitic massive dust tuffs of the Mount Dilworth Formation.

STRATIGRAPHY

SEDIMENTARY UNITS

Brightly coloured sedimentary rocks range from mudstones, siltstones, sandstones, wackes and grits up to coarse boulder conglomerates. The bedding, textures and colouring of these beds are distinctive. The matrix is typically hematitic, brick-red to maroon to purple, but local greenish and mottled purple and green units are present near the base of the sequence. The iron oxide that gives the sandstones their strong reddish shades lies within the intergranular clay fraction (Plate 6).

Striking exposures of multicoloured, heterolithic boulder conglomerate are widespread. Rounded cobbles and boulders of volcanic rock within these beds range in colour from red to purple, green and grey. Most of the clasts are andesitic volcanic rocks similar in texture and composition to rocks in the underlying Unuk River Formation. Conglomerates are predominantly matrix supported (Plate 7), but clast-supported "boulder beds", with boulders up to 40 centimetres in diameter, crop out along Bear River Ridge. Individual conglomeratic beds are massive to crudely sorted. Crudely sorted layers may have either reversely graded or symmetrically graded beds, which are characteristic features of lahars (Fisher and Schmincke, 1984).

Monolithic cobble and boulder-conglomerate beds are common near the base of the sequence, particularly where the formation thins on Mount Dilworth and at the northeast end of Long Lake. The textures and mineralogy of the angular to subrounded clasts are identical to those of the immediately underlying andesitic rocks.

The general depositional environment is subaerial although some sedimentary units exhibit waterlain textures. Scattered exposures of grit to mudstone beds have normal grading (Plate 6), crossbedding (Plate 7), scour marks (Plate 8) and rhythmic bedding (Plate 6); they represent stream-channel deposits where debris-flow fans have been reworked on the lower flanks of a stratavolcano. On both limbs of the Dilworth syncline these sedimentary structures

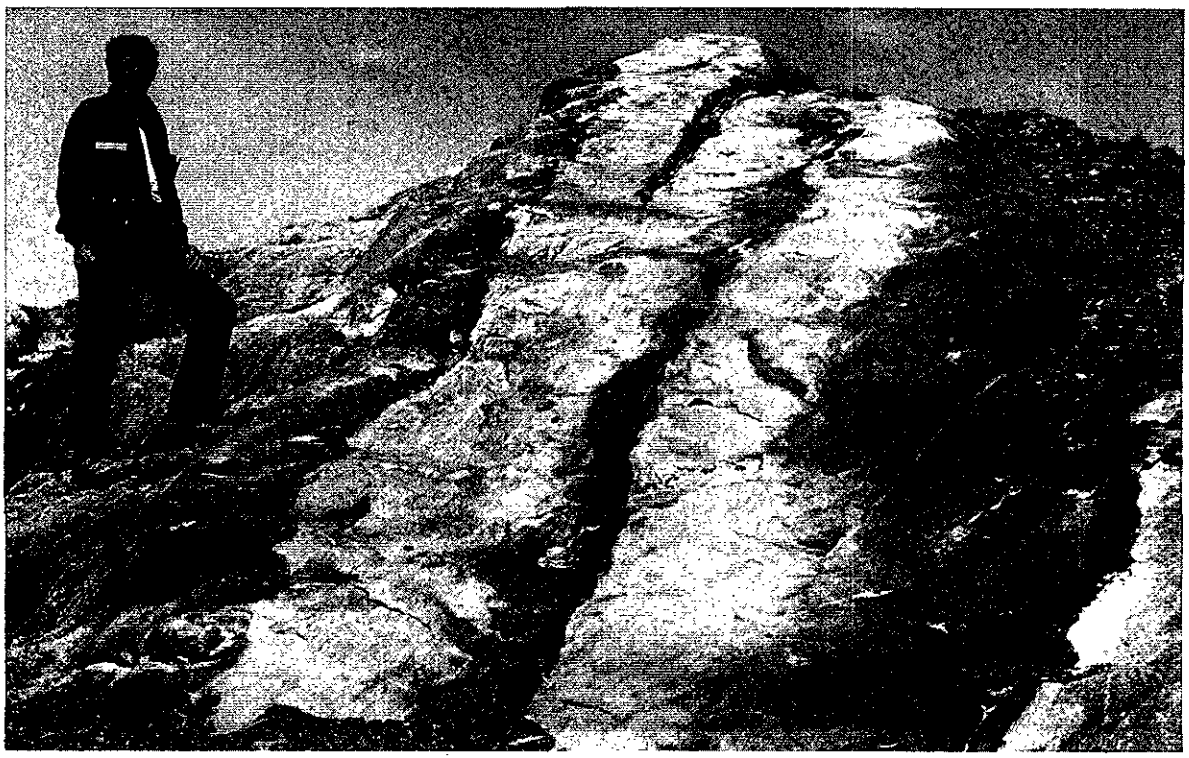


Plate 6. Rhythmic graded beds of coarse wacke (pale grey) to hematitic mudstone (dark grey), east shore of Daisy Lake. Strike north, tops to east towards Troy Ridge. Betty Creek Formation (*See* colour photo in back of report).

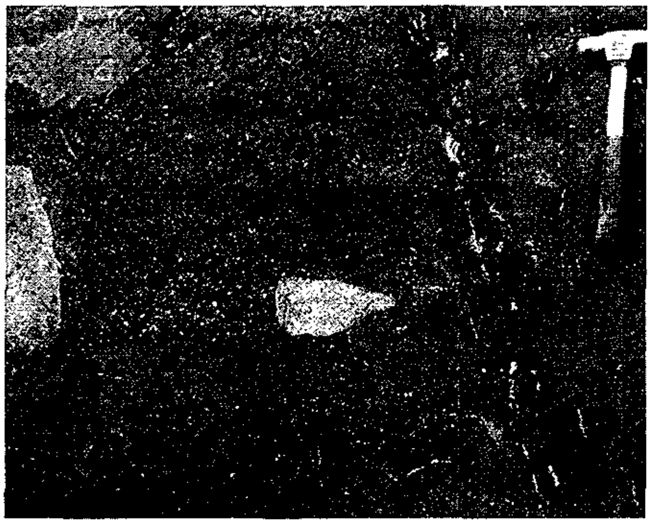


Plate 7. Medium-bedded hematitic wackes and pebble conglomerates, west side of Troy Ridge. Grading and crossbeds in layer below boulders and hammer show that beds are upright. Betty Creek Formation.

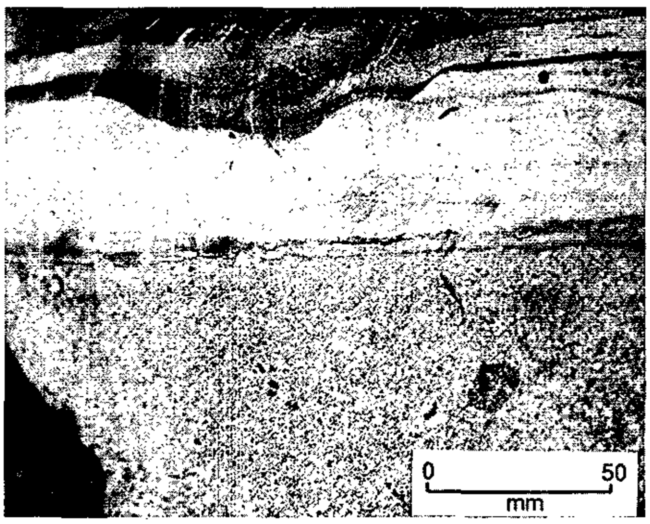


Plate 8. Bedded coarse wacke (grey) with finer sandstone (white) and siltstone (black), east and uphill from Premier glory hole. Scour channel indicates strata are upright. Betty Creek Formation.

have consistent stratigraphic tops toward the synclinal axis on Mount Dilworth (Figure 11).

Volcanic Units

Volcanic rocks interbedded with the sedimentary rocks include dust tuff, ash tuff, lapilli tuff, feldspar-crystal tuff and porphyritic lava flows. Units on the slopes of Mitre Mountain and along the northern Bear River Ridge are predominantly dacitic. Those exposed on the southern Bear River Ridge, uphill from the Silbak Premier mine, are a deeper green colour and seem more andesitic in character. As a generalization, within a single stratigraphic section, a series of volcanic units appears to change upward from andesitic to dacitic composition.

The dacitic tuffs range from pale waxy yellow or yellow-green crystal tuffs and welded tuffs to pale green, coarse ash tuffs and dust tuffs. Crystal tuffs host medium-grained (0.5 to 1.0 cm), white, subhedral to euhedral feldspar phenocrysts. No hornblende phenocrysts have been noted, but there are rare fine-grained ($\leq$5 mm) quartz crystals in some samples. Rare dacitic welded tuffs exhibit eutaxitic textures with flattened fiammé up to 12 centimetres long.

PROVENANCE AND DEPOSITIONAL ENVIRONMENT

The clastic sedimentary rocks are probably derived by weathering and erosion of Unuk River Formation tuffs and flows. Whole-rock analyses from interbedded tuffs plot near the dacite-andesite boundary. The Betty Creek Formation is interpreted as a subaerial clastic apron of poorly sorted lahars and reworked debris flows interbedded with andesitic to dacitic volcanic rocks on the flanks of an emergent andesitic stratovolcano constructed of Unuk River Formation rocks. Areas where the Betty Creek Formation thins or wedges out represent paleotopographic highs.

No fossils or isotopic dates have been obtained from the Betty Creek Formation, but constraints include the Early Jurassic, Toarcian fossil assemblage at the base of the overlying Salmon River Formation, and Early Jurassic U-Pb dates from underlying andesitic dikes (194.8$\pm$2.0 Ma). Thus, the most likely age range for accumulation of the sedimentary rocks, tuffs and flows of the Betty Creek Formation is mid-Pliensbachian to mid-Toarcian (195 to 190 Ma).

Mount Dilworth Formation

The Mount Dilworth felsic volcanic sequence is composed of dense, resistant, variably welded dacite tuffs. Individual members display distinct lateral textural variations and textural changes that can be related to volcanic centres, paleotopography and depositional environment.

In this study the unit has been raised to formational status and named the Mount Dilworth Formation or Mount Dilworth dacite. This felsic volcanic sequence is thin but continuous throughout the region. It is a resistant cliff-former and an important regional stratigraphic marker and thus deserves formational status. Mount Dilworth is the preferred type area because it offers several sections that are continuously exposed in outcrop and that are free from the complications of minor faults and folds. Additional attractions of the Mount Dilworth area are relative ease of access and a wide variety of discrete, mappable rock types and members.

The formation is exposed in a continuous, northerly elongated oval outcrop pattern within the map area. This distribution reflects the regional, doubly plunging "synclinorium" in the centre of the area. Thickness ranges from 20 to 120 metres, but appears even greater near Union Lake and Monitor Lake where outcrop patterns are complicated by faulting.

The basal contact is a sharp, gently undulating surface. Massive, aphanitic, grey to green to maroon dust tuffs

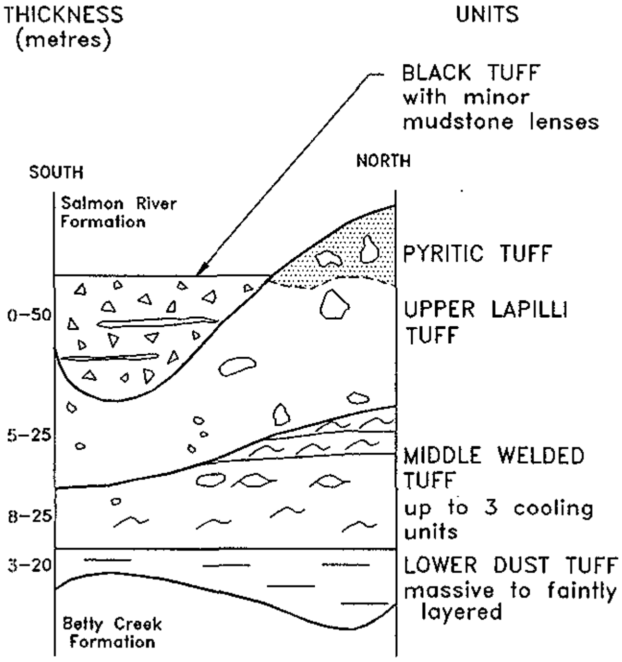


Figure 15. Stratigraphy within the Mount Dilworth Formation.

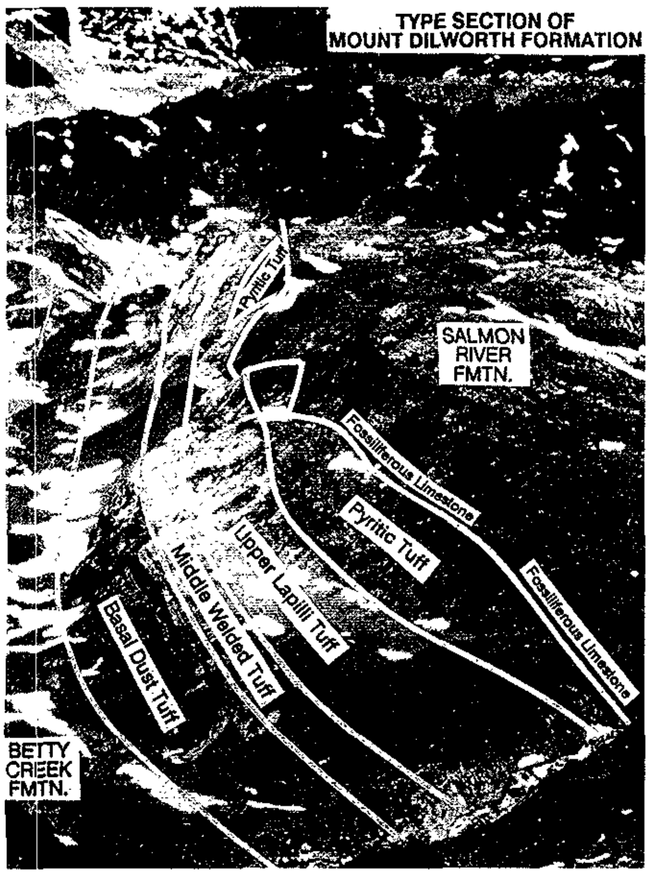


Plate 9. Complete stratigraphy of Mount Dilworth Formation exposed in cliff along east side of Daisy Lake. Overlying Salmon River Formation includes well-bedded shales, siltstones and wackes and basal fossiliferous limestone. Looking north from Windy Point to Scottie Gold minesite in background.

overlie purple to maroon clastic sedimentary rocks of the Betty Creek Formation. In some exposures the contact is marked by a 1 to 3-metre interval of interbedded hematitic sedimentary rocks and dust tuffs. The upper contact is typically a sharp but ragged surface between coarsely fragmental felsic lapilli tuffs and overlying calcareous grits of the Salmon River Formation. Where the uppermost member of the Mount Dilworth Formation is the Black Tuff Member, the upper contact of the formation is smooth with a sharp break between massive black tuffaceous mudstones and the overlying calcareous grits.

STRATIGRAPHY

Stratigraphic relationships within the Mount Dilworth Formation are shown schematically on Figure 15 and on Plate 9. Despite local heterogeneities and lateral textural variations, the three major members of the formation – the lower dust tuff, middle welded tuff, and upper lapilli tuff – can be distinguished in sections throughout the map area.

Lower Dust Tuff Member

The lowest member of the Mount Dilworth Formation is a massive aphanitic dust tuff (fine ash tuff) composed of volcanic dust and fine lithic particles. This unit is regionally distributed throughout the map area and beyond. It blankets underlying Betty Creek sedimentary rocks and ranges in thickness from 3 to 15 metres. The unit has sharp conformable contacts with adjacent units.

This rock is typically olive grey to grey, but bright turquoise-coloured zones are exposed near Summit and Divide lakes and local purple and bright maroon hematitic alteration zones give the rock a swirled or marbled pattern (Plate 10). At the southeast corner of Summit Lake, along the upper Granduc road, the dust tuff contains fine silica-filled vesicles and large euhedral pyrite crystals up to 1 centimetre across (Plate 11).

At microscopic scale the rock is predominantly (>70%) fine ash, with fine (<1 mm) lithic chips and crystal fragments of quartz, feldspar and hornblende. The groundmass may be massive to moderately foliated and is commonly extensively altered to carbonate and sericite. Samples collected along the east side of Monitor Lake contain glass shards and fragments of chalcedony.

Middle Welded Tuff Member

The middle welded ash flow tuff is the most variable of the three regionally extensive members of the Mount Dilworth Formation. It forms a series of laterally varying dacitic facies sandwiched between the other two members that are texturally more consistent. The lower contact is sharp and planar, the upper contact is sharp but irregular.

In the Mount Dilworth to Monitor Lake area, sections through this member show that mixed fiammé and angular felsic lapilli at the base are overlain by pumice-lapilli tuff. Well-exposed sections have progressively more intense welding and compaction down-section (Plate 12); equidimensional pumice clasts grade downward into black glassy fiammé. Outside the Mount Dilworth area sub-

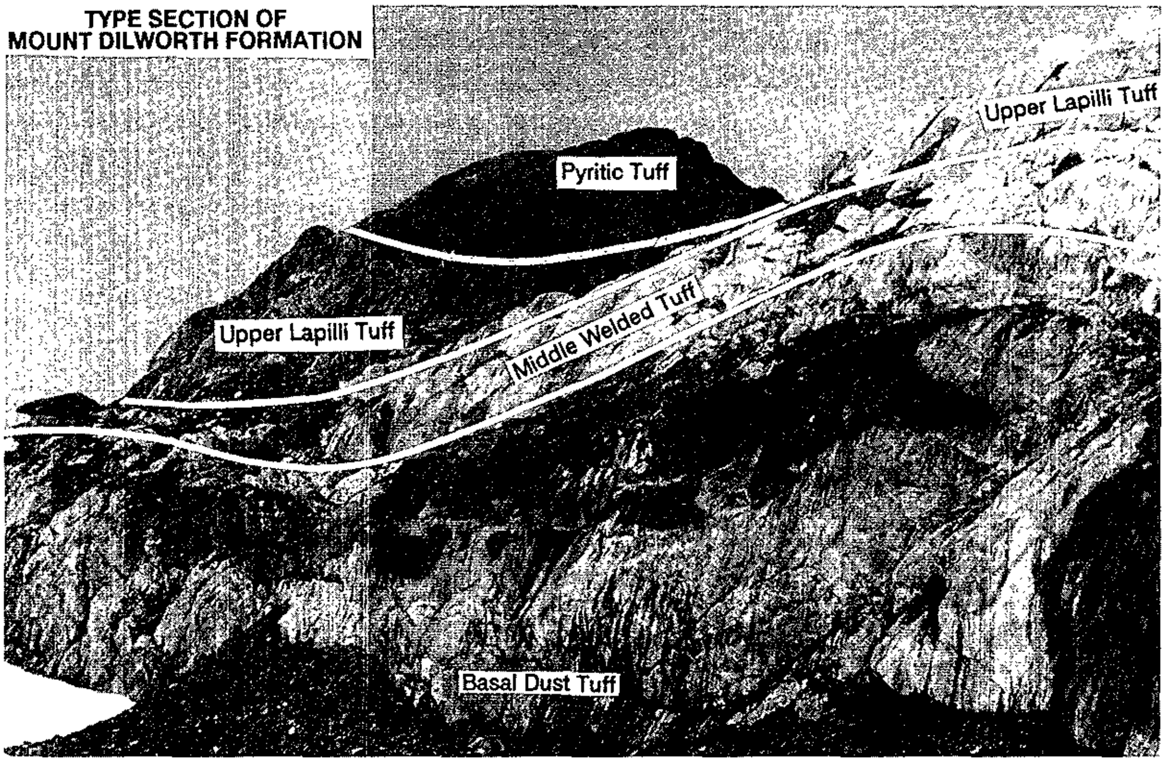


Plate 10. Stratigraphy in Mount Dilworth Formation, north end of 49 Ridge. Note colour-mottling of Lower Dust Tuff. Height from base of photo to top of pyritic knob is 30 metres (*see* colour photo in back of report).

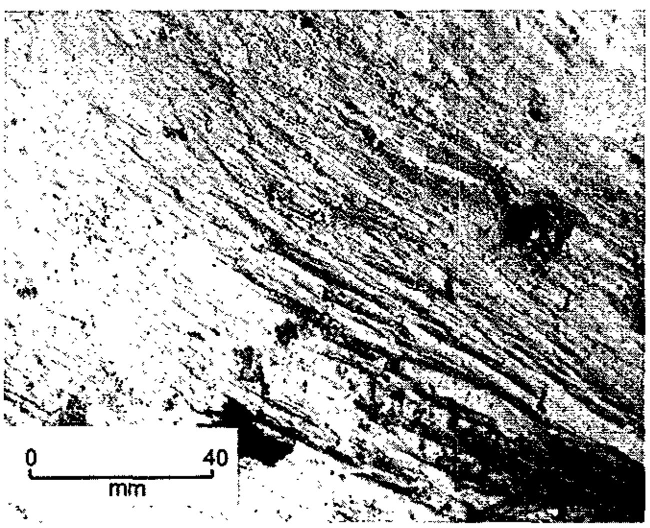


Plate 11. Lower Dust Tuff Member of Mount Dilworth Formation, Windy Point roadcut. Turquoise-grey colour is typical; fine lithic chips and large euhedral pyrite crystal are unusual variations.

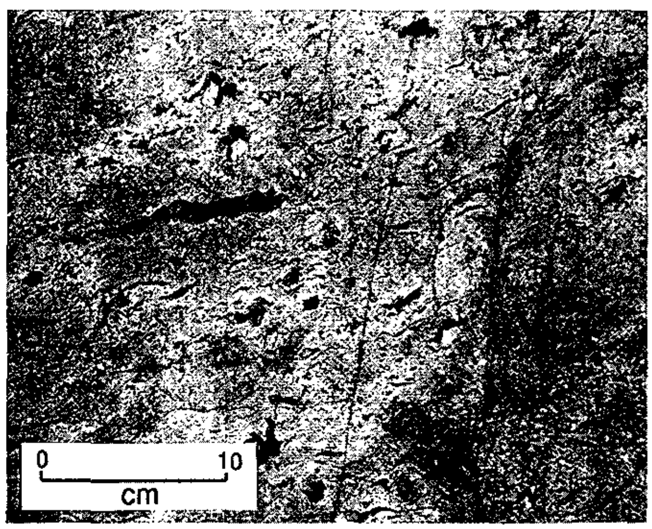


Plate 12. Middle Welded Tuff Member of Mount Dilworth Formation, north end of 49 Ridge. Fiammé in welded tuff. Largest clast is 10 centimetres long.

rounded pumice lapilli are mixed with varied siliceous lithic clasts, but the rocks are not obviously welded.

Midway between the south edge of the Mount Dilworth snowfield and Union Lake, one outcrop has bedding and small dune forms (10 cm amplitude) in fine creamy ash tuff at the base of this member. These dune forms are interpreted as base-surge features; no internal truncation of layers was noted but asymmetry indicates that the blast was from the north of the exposure. Along the northwest slope of Mount Dilworth a similar bed of white to cream-weathering massive fine siliceous ash tuff forms a thin (30 cm) resistant layer at the base of the Welded Tuff Member. At this location this bed is overlain by three ash-flow cooling units, each containing progressively less compressed pumice clasts up-section, all included within the Middle Member. Elsewhere along the Mount Dilworth ridge, only a single cooling unit has been noted within this member.

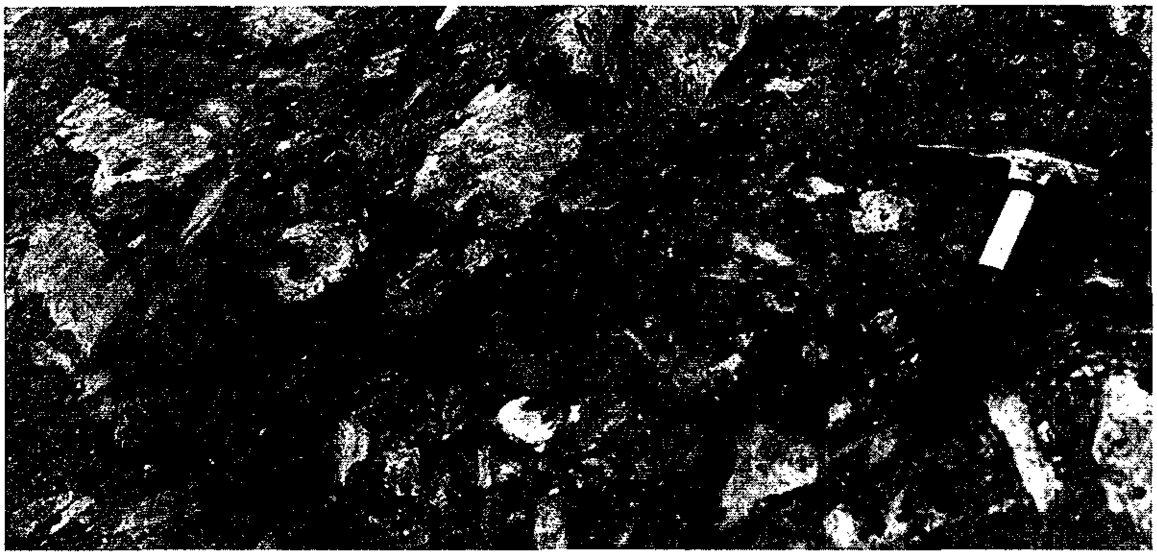


Plate 13. Upper Lapilli Tuff Member of Mount Dilworth Formation, south end of Mount Dilworth. Note swirled bombs of flow-banded dacite.

In thin section, rocks of this member contain fiammé-like wisps on all scales. Veinlets and fragments of microcrystalline quartz (chalcedony) are common, as are broken crystals of both plagioclase and potassium feldspar. In some samples, partially collapsed fiammé are wholly altered to aggregates of chlorite, quartz, calcite and epidote.

Upper Lapilli Tuff Member

The regionally extensive upper member of the Mount Dilworth Formation is a siliceous lapilli tuff to tuff breccia. The lower contact of this unit is generally sharp, irregular to undulating, but may be locally indistinct. The upper contact is gradational to sharp against the pyritic tuff, gradational into the black tuff, and irregular but sharp against the basal fossiliferous wackes and calcareous grits of the Salmon River Formation.

Fragments are predominantly swirled flow-banded dacite bombs or spatter (Plate 13), but clasts of other siliceous volcanic rocks are also common. Regionally, the fragment size ranges up to a maximum of 10 to 15 centimetres, and the overall size range is that of a lapilli tuff. However, along the southwest edge of the Mount Dilworth snowfield, large swirled flow-banded bombs up to 50 centimetres long are preserved. This local increase in fragment size suggests that the southern part of Mount Dilworth was a vent area for this member. The unit may be partially welded but contains neither pumice fragments nor fiammé. Along much of its strike length the groundmass is medium to dark grey.

In thin section the groundmass has a massive to subtly layered glassy or welded texture. Clasts are lithic chips, cryptocrystalline quartz and scattered feldspar crystals. Disseminated pyrite is often present in the matrix and in some lithic chips. Minor (1%) biotite is present in exposures along the southeast side of Summit Lake. North of Goat Creek many of the finer lithic chips are well rounded.

Pyritic Tuff Member

A prominently gossanous, pyritic, fragment-rich unit is exposed along the west side of Mount Dilworth (Plate 10) and the east side of Summit Lake (Plate 9). This member ends abruptly in a gossanous cliff at the south end of Mount Dilworth, but progressively thins northward, finally wedging out high on the western slope of Troy Ridge. Another area of exposure has been documented by Dupas (1985, p. 313) at the northeast end of Long Lake where it was appropriately termed the "Iron Cap" by early workers (Plumb, 1956). The upper and lower contacts of this unit are typically sharp but irregular. Locally the lower contact is gradational over less than a metre; the upper contact may be an interbedded sequence of sedimentary rocks and dacitic tuffs.

Along the southwest edge of the Mount Dilworth Snowfield the unit carries clasts of flow-banded siliceous volcanic rock, clasts of massive felsic tuffs or flows, and large rounded boulders (up to 0.5 m diameter) of coarse crystalline calcite aggregates. As in the underlying member, fragment size decreases progressively northward from rounded boulders to cobbles, then to lapilli.

In thin section, the unit contains lithic fragments, broken feldspar crystals and chips of microcrystalline quartz (chalcedony). Lithic fragments may have microscopic scale flow-banding. Disseminated pyrite comprises up to 50 per cent of the matrix, but is more typically 10 to 15 per cent. Pyrite is present in some lithic clasts but not in others. In samples from exposures north of Goat Creek, charcoal to black varieties of this unit are impregnated with up to 30 per cent fine pyrite, not carbon. Some samples are cut by fine veinlets of chalcedonic quartz and some of these veinlets have internal growth-layering in thin section.

The pyritic unit is not continuous along strike but is exposed as a series of discontinuous lenses of strong pyritic impregnation. Despite, or perhaps because of, careful mapping along its entire strike length, this unit seems complex and may represent penecontemporaneous but postdepositional impregnation of pyrite into a variety of rock types. Although the predominant rock type is lapilli tuff identical to the underlying Upper Lapilli Tuff Member, in some exposures the pyrite-rich unit is a carbonate-mudstone-cemented debris flow with heterolithic volcanic and carbonate clasts. For these reasons the Pyritic Tuff Member is interpreted to represent pyrite impregnation around fumarolic centres, possibly with related calcareous mud-filled brine pools. The host lithology is therefore the upper layer of the Upper Lapilli Tuff Member.

Black Tuff Member

The Black Tuff Member is a thick unit of carbonaceous crystal and lithic-lapilli tuffs with local mudstone and siltstone lenses. Lapilli consist of crowded feldspar porphyritic lava or crystal tuff, limestone, pumice and rare massive pyrite. The rock is well displayed in the waste dumps at the south end of the penstock tunnel near the Long Lake dam and in abandoned drill core near the Lakeshore workings south of Monitor Lake.

This member has been traced in outcrop from the south end of Mount Dilworth southward to the crest of Slate Mountain and is also exposed in a few discontinuous outcrops south and southeast of Monitor Lake. It overlies the Upper Lapilli Tuff Member and either overlies or is the stratigraphic equivalent of the Pyritic Tuff Member to the north. The contact between the black tuff and the underlying upper lapilli tuff is gradational. Both units host disseminated sulphides and pyritic lithic clasts, but the black tuff also carries angular clasts of massive, medium-grained pyrite aggregates. East of Silver Lakes, bluish grey chalcedony veins cut this unit in exposures in the Start adit and in outcrops to the north of the adit.

In thin section the crystal-rich tuffs are seen to contain up to 50 per cent feldspar crystals and up to 5 per cent ragged chlorite flakes after biotite, together with a few well-rounded quartz grains. Compositions for plagioclase in samples throughout the Mount Dilworth Formation range from An_{32} to An_{40} with most samples falling into the andesine range, An_{36} to An_{38}. The rock matrix is composed of volcanic ash, dust and fine carbon. Some samples have crude bedding caused by a slight change in overall matrix grain size. Fine chalcedony veinlets cut through some samples.

Two alternative interpretations might account for the limited strike extent of the thick, distinctive Black Tuff Member; it may represent an erosional remnant of an originally extensive unit,or deposition was restricted to the area it now occupies. The latter interpretation requires that the black tuff was deposited in a topographic low such as a volcanic crater or caldera. If this depression was an anoxic water-filled basin it would account for local sediment lenses and the intense carbon impregnation throughout the unit.

PROVENANCE AND DEPOSITIONAL ENVIRONMENT

All rocks of the Mount Dilworth Formation look highly siliceous in hand sample and have been identified as rhyolites during field examination by all workers. However, on the basis of all the analytical data this rock unit is dacite.

The formation represents fallout and pyroclastic flow deposits from a series of explosive subaerial felsic volcanic eruptions that proceeded in quick succession, apparently becoming progressively more violent. Based on clast size, one vent area was near the south end of Mount Dilworth. The formation was deposited subaerially on the flanks of an exposed volcanic cone. The general absence of sedimentary deposits between units confirms there was little or no time between eruptions. The uppermost Black Tuff Member was deposited under subaqueous conditions, perhaps in a fault-bounded caldera or crater lake. Interbedded sedimentary rocks within the Pyritic Tuff Member indicate that subsidence followed the final major eruption.

There are no fossils associated with the felsic volcanic rocks of the Mount Dilworth Formation but the unit is immediately overlain by Toarcian limestones and is underlain by the mid-Pliensbachian to mid-Toarcian Betty Creek Formation. Therefore it records a voluminous but short-lived volcanic event during middle to late Toarcian time (about 190-185 Ma).

Salmon River Formation

The Salmon River Formation is a thick assemblage of complexly folded, thin to medium-bedded siltstones and wackes with minor interbedded intraformational conglomerates, limestones and siliceous tuffaceous siltstones. Grove (1973, 1986) selected the summit, northern slopes and eastern cliffs of Mount Dilworth and Troy Ridge as the type area for the formation.

Salmon River strata are preserved as a large trough-like erosional remnant in the northeast part of the map area. The formation is at least 1000 metres thick, although its top has not been identified.

This thick sedimentary sequence has a rough to undulating, sharp contact with underlying felsic fragmental tuffs. The writer regards this as a paraconformable contact, formed during foundering and rapid subsidence of a subaerial volcanic edifice immediately after its last violent and voluminous eruptive event. Evidence that supports this interpretation includes minor interbedded wackes with ripple marks in the upper metre of the Pyritic Tuff Member at the northeast end of Long Lake, and interbedded tuffaceous and pyritic limestones, siltstones and cherty units in the lower part of the Salmon River strata.

STRATIGRAPHY

Basal Fossiliferous Limestone Member

Thin, pyritic, fossiliferous limestone crops out at the base of the formation throughout the area. The unit comprises dark grey to black carbonate-cemented grit with interbedded lenses, pods and nodules of fossiliferous, gritty limestone. Both the calcareous grits and fossiliferous limestones contain sparsely disseminated pyrite, which is more abundant where the unit is underlain by the pyritic tuff.

The calcareous grits locally contain scattered granules and pebbles of volcanic rock types. Thin conglomeratic

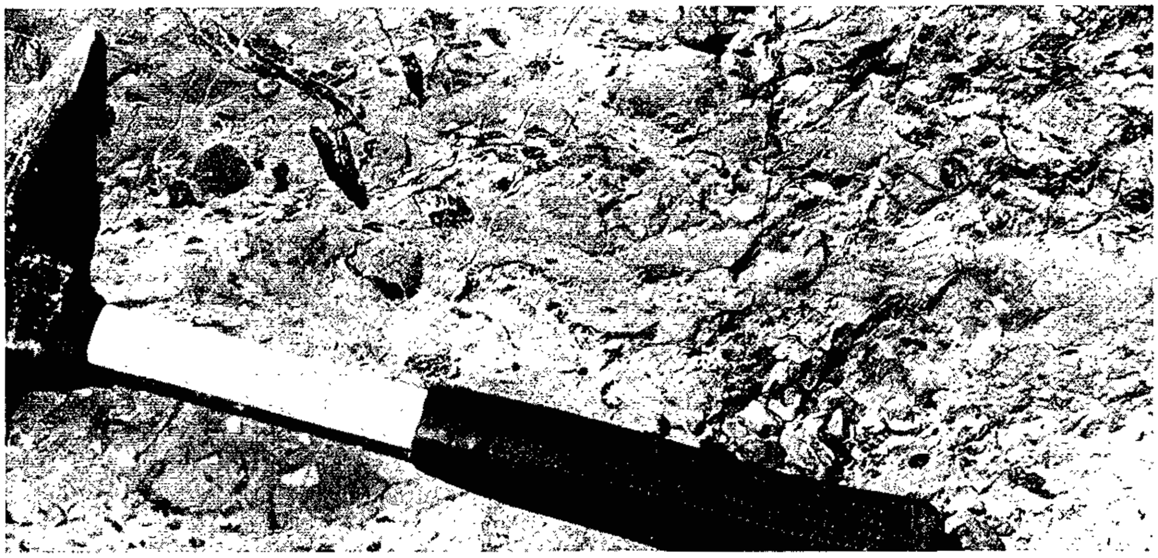


Plate 14. Fossil and mudchip-rich gritty limestone. Basal Fossiliferous Limestone Member of the Salmon River Formation. Southwest edge of Mount Dilworth snowfield.

layers at Summit Lake and on Slate Mountain contain rounded pebbles of pumice. These local pumice-conglomerate beds may represent rafted pumice, suggesting minor felsic volcanism continued during marine transgression. The grits also have up to 10 per cent fine-grained, angular, altered feldspar grains, indicating rapid erosion and deposition with little weathering and reworking of the sands.

The limestone is buff to grey, sandy to gritty with some black siltstone chips or rip-up clasts. The thin member is fossiliferous throughout the map area and locally contains up to 50 per cent fossil debris (Plate 14). The most precise fossil age comes from recent sampling of the Basal Limestone Member on Troy Ridge by Anderson (personal communication, 1986). Fossils include abundant belemnites and lesser pelecypods, including *Weyla*; many fossils are preserved as fragments. The key fossils form an overlap assemblage characteristic of Toarcian time.

The upper contact of this basal member is typically marked by a bedding-plane fault that separates this unit from overlying thin-bedded siltstones. The fault is marked by a massive quartz vein in some areas. Where the fault is absent, the upper contact is conformable.

Lower Siltstone Member

The lower 50 to 100 metres of the main sedimentary succession consists of black to grey, thin to medium-bedded calcareous siltstones and shales with minor intercalated limestones and siliceous tuffaceous beds. The rhythmically interbedded siltstones to fine-grained sandstones are exposed as beds 5 to 10 centimetres thick (Plate 15). Shale partings between these layers are a few millimetres thick. The siltstone is well bedded and finely laminated; shale is massive, intensely cleaved or weakly phyllitic. The siltstone sequence is characterized by abundant scour-and-fill structures, graded bedding and crossbedding; tops are toward the axis of the Mount Dilworth syncline.

The slates and siltstones locally contain minor amounts of disseminated pyrite, and pyrite seams outline some bedding planes producing characteristic banded, iron-stained weathered surfaces. The buff-weathering limestone lenses, pods and concretions are regionally distributed but thin, and are present near the base of the siltstone sequence. Grove (1986) and Anderson (personal communication, 1986) have recovered Middle Jurassic fossil suites from these strata. Siliceous beds, first reported by Grove (1973, 1986), were studied in detail by Brown (1987) who describes the beds as planar to undulating layers of siliceous, radiolaria-bearing shale less than 5 centimetres thick.

In thin section siltstones are composed of silt-sized quartz, feldspar and lithic chips in a carbonaceous, calcareous clay matrix. Tuffaceous beds contain glass-shard outlines, bubble-wall fragments, plagioclase microlites and quartz fragments, indicating that minor or distant pyroclas-

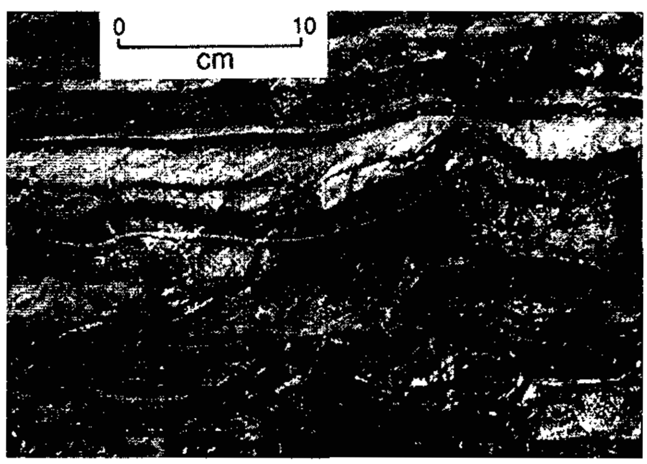


Plate 15. Rhythmically interbedded black limy siltstones and white siliceous tuffaceous siltstones, Lower Siltstone Member of the Salmon River Formation. (Brown photo.)

tic volcanism was contemporaneous with marine deposition (Brown, 1987).

This member is interpreted as a sequence of rhythmically bedded marine clastic sedimentary rocks derived from the erosion of a predominantly volcanic terrain. The lower contact is usually marked by a zone of intense deformation and quartz veining, 5 to 30 metres thick, adjacent to a bedding-plane fault.

Upper Wacke Member

Conformably overlying the Lower Andesite Member are medium to light grey wackes and intraformational conglomerates (Plate 16). Quartz greywackes, greywackes and arkosic wackes are included in this sequence. Most of these rocks form fairly massive beds a few metres to several metres thick with minor interbeds of thin-bedded siltstone. The conglomerates consist of subparallel, black siltstone slabs and cobbles in a grey sandstone matrix.

Still higher in the sedimentary succession the strata are rhythmically bedded dark grey siltstones. They were not examined in this study.

PROVENANCE AND DEPOSITIONAL ENVIRONMENT

The clastic rocks of this formation were derived mainly from weathering and erosion of a volcanic source area. Some beds may have formed by mixing of varying proportions of water-transported volcanic detritus and air-fall ash and crystals from distant felsic pyroclastic activity.

Sediment was deposited on the flanks of an extinct volcano in a shallow to moderately deep marine basin, relatively near subaerial source rocks. The thin rhythmic bedding suggests transport was predominantly by mass-flow processes such as turbidity flows. The general absence of fossils and bioturbation through most of the sequence indicates that the beds accumulated rapidly.

The basal fossiliferous limestone is Toarcian. Although an upper age cannot be demonstrated, the absence of the distinctive, basal chert-pebble conglomerate units of the Bowser Lake Group suggests that the youngest rocks in the succession predate Bowser time and are therefore Middle Jurassic, but older than upper Bajocian.

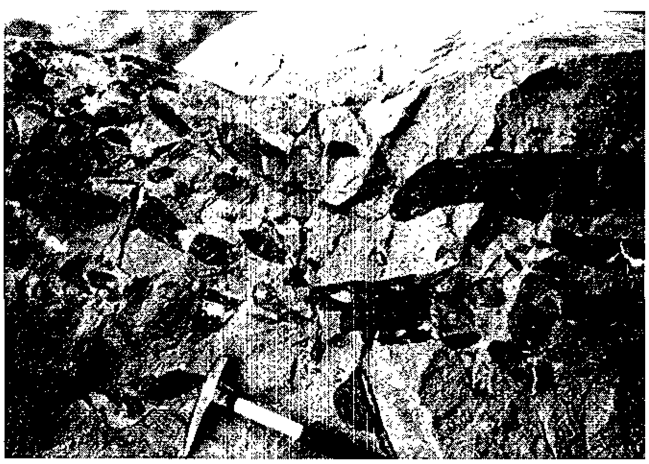


Plate 16. Intraformational conglomerate. Zone of rounded black slabs and blocks of siltstone within a thicker bed of coarse wacke. Upper Wacke Member of Salmon River Formation. Northwest edge of the Mount Dilworth Snowfield.

INTRUSIVE ROCKS

Plutonic rocks underlie about 100 square kilometres or 15 per cent of the map area. In the southwestern corner they form a continuous mass of superposed plutons; to the northeast, discrete stocks and a variety of dikes are scattered throughout the stratified rocks. Based on field relationships, modal and chemical compositions, textures and extensive dating, intrusive rocks of the region have been grouped into two plutonic suites in agreement with guidelines established by the North American Commission on Stratigraphic Nomenclature (1983). Both suites are represented by batholiths, stocks and a variety of dikes; the older suite also has sills and volcanic extrusive phases. Terminology conforms to the classification scheme of Streckeisen (1975).

The Early Jurassic Texas Creek granodiorite suite is characterized by an overall coarse grain size, abundant coarse hornblende and locally by very coarse potassium feldspar phenocrysts or megacrysts. The Eocene Hyder granodiorite suite is characterized by overall medium grain size, biotite, equigranular plagioclase and orthoclase, and trace amounts of fine-grained, golden sphene. The marked difference in hornblende versus biotite contents and the presence of alteration and foliation in the older Texas Creek suite are the most reliable field distinctions between the two.

Texas Creek Plutonic Suite

The Texas Creek Plutonic Suite or Texas Creek granodiorite suite includes the Texas Creek batholith, the Summit Lake stock, Premier Porphyry dikes and a variety of related dikes and sills within the map area. The Premier Porphyry Member of the Unuk River Formation is an extrusive equivalent of these plutonic rocks.

Major element analyses of five plutonic and dike-rock samples from the Texas Creek suite were completed in this study. These results are presented in detail later in this chapter and show that rocks of the Texas Creek granodiorite suite are subalkaline, calcalkaline intrusions with elevated potassium contents. Analyses from subvolcanic Premier Porphyry dikes fall within the andesite field on a total alkali versus silica plot.

TEXAS CREEK BATHOLITH

Buddington (1929, p. 22) defined the Texas Creek batholith. The pluton crops out in the southwestern part of the map area and extends far to the west. It is roughly 15 kilometres in diameter with a total area of about 205 square kilometres.

The Texas Creek batholith is composed of hornblende granodiorite to monzodiorite to quartz diorite. Two phases have been recognized: in the central and western areas, within Alaska, the batholith is a very coarse grained equigranular rock; along the eastern margin it is porphyritic with a medium to coarse-grained groundmass. The porphyritic phase has hornblende phenocrysts up to 2 centimetres long and large potassium feldspar phenocrysts from 3 to 5 centimetres long. Based on isotopic dates and field relationships, the equigranular phase was emplaced first, followed by the porphyritic phase. Similar phase relationships have been recognized in the Early Jurassic Lehto batholith on the Iskut River (Britton *et al.,* 1990).

Along the eastern contact, the coarsely porphyritic margin of the Texas Creek batholith usually displays a narrow zone, up to a few tens of metres wide, of medium to dark greenish grey chloritic alteration that is sometimes accompanied by a crude foliation. Shearing and broken grains indicate that this zone results from crushing along the granodiorite contact. There is a general absence of contact metamorphism in the adjacent country rocks that suggests that there was not a major thermal or chemical contrast between them and the intrusions, and that pressures from rising magma and late-stage fluid accumulations were relieved by faulting, dike injections or by regular venting of volatiles to surface.

The **main phase** in the core of the batholith was examined along the West Fork of Texas Creek, west of the map area. Core rocks are massive, equigranular, medium to coarse-grained hornblende granodiorite, with up to 15 per cent coarse euhedral hornblende. This hornblende-rich, coarse-grained texture is a characteristic feature of the Texas Creek batholith that can be recognized through all alteration and deformation.

In thin section, feldspar crystals have fine crystal inclusions of apatite and lesser zircon. Near the margins of the batholith, coarse inclusion-rich euhedral plagioclase grains show a thin inclusion-free overgrowth rim. Similar textures are present in Premier Porphyry dikes and in extrusive rocks of the Premier Porphyry Member. In many samples of the equigranular phase, anhedral quartz displays interfingering, sutured boundaries. Hornblende crystals are typically large, euhedral to subhedral, and are commonly twinned. Some hornblende hosts small zircon crystals. Many hornblende crystals have minor interlamellar biotite but no free biotite was noted. Chlorite alteration of the amphiboles varies in intensity, but is a characteristic feature. The granodiorite also contains accessory apatite, sphene and zircon.

Toward the eastern margin of the batholith much (60 to 100%) of the hornblende is altered to chlorite, the rock has subparallel microfractures filled by chlorite, and coarse inclusion-rich plagioclase grains are strongly altered to sericite. Even where plagioclase is intensely sericitized, potassium feldspar is fresh and unaltered. Quartz grains in these margin areas have moderately strained extinction.

The **porphyry phase** of the batholith lies along its eastern margin. The rock is generally a feldspar-porphyritic, coarse-grained hornblende granodiorite. This porphyritic margin is up to several hundred metres wide, but is locally absent, as near the wrecked bridge on the Texas Creek road at the south end of Mineral Hill. The rock is dull greenish grey to light grey and the large phenocrysts give outcrops a mottled appearance.

Phenocrysts comprise up to several per cent of the rock volume, and are 1 to 4 centimetres long, white to faintly pink to buff euhedral orthoclase crystals similar to those in Premier Porphyry dikes and extrusive rocks. Phenocrysts enclose small euhedral crystals of hornblende and plagioclase. Potassium feldspar in the groundmass is generally interstitial to hornblende and plagioclase. Plagioclase is present as euhedral to subhedral lath-shaped crystals of oligoclase-andesine.

Quartz has bimodal grain size. It is both coarse grained and contemporaneous with other coarse mineral phases, and fine grained and interstitial to the earlier formed minerals. Abundant hornblende is present as euhedral, columnar, black prisms up to 2 centimetres long. Accessory minerals, including sphene, zircon, apatite and magnetite, form about 1 per cent of the rock volume. Pyrite is rare.

The porphyry phase has varying degrees of alteration. Sharply euhedral hornblende and interlamellar biotite are partly to completely altered to chlorite, but quartz shows only slightly strained extinction. Plagioclase is extensively altered to fine sericite aggregates, but some crystals have thin, clear, unaltered rims. Potassium feldspar is fresh and unaltered.

SUMMIT LAKE STOCK

The Summit Lake stock is a remarkably fresh, medium to coarse-grained hornblende granodiorite. The rock is generally equigranular with rare potassium feldspar phenocrysts. Thin sections show there is a finer grained interstitial groundmass among the coarse-grained hornblende, biotite, plagioclase, potassium feldspar and quartz.

Potassium feldspar crystals are characteristically unaltered. Some large crystals display a ring of fine beads or blebs of quartz near the rim. Plagioclase (oligoclase) is 25 to 40 per cent sericitized. Plagioclase crystals display subtle, thin, clear rims but the texture is not as obvious as examples from the Texas Creek batholith to the south. Most quartz is in the fine-grained interstitial groundmass. The few large quartz grains are sutured.

Total mafic mineral content is 18 to 20 per cent. Coarse, sharply euhedral, green hornblende is commonly twinned. Inclusion-rich red-brown biotite composes 2 to 5 per cent of the rock. It is more readily chloritized than the typically fresh hornblende. The rock also contains rare tiny zircons and interstitial rosettes of chlorite.

Massive, unsheared textures at the intrusive contact indicate passive emplacement, but the granodiorite is somewhat altered. The hornblende is wholly altered to very pale green chlorite, quartz is only slightly strained, and plagioclase has minor (15 per cent) sericitization.

TEXAS CREEK DIKES

The Texas Creek Plutonic Suite includes a dike phase. Schofield and Hanson (1922) referred to these dikes as "Premier Sills". Brown (1987) proposed the descriptive term "potassium feldspar porphyry". The writer has used the term "two-feldspar porphyry" in past articles, but "Premier Porphyry" is preferred because of its current widespread use and the close relationship between these distinctive dikes and all the major ore zones at the Silbak Premier mine. The rock is characterized by potassium feldspar megacrysts and plagioclase phenocrysts in a fine-grained to aphanitic groundmass.

Premier Porphyry dikes cut all the five lower members of the Unuk River Formation and the eastern margin of the Texas Creek batholith. They do not cut the Premier Porphyry Member of the Unuk River Formation or any of the overlying strata. They are interpreted as subvolcanic feeder dikes coeval with the extrusive Premier Porphyry Member that marks the top of the Unuk River Formation (Figure 12).

In outcrop, Premier Porphyry dikes weather green to greyish green, have visible phenocrysts and are massive to weakly foliated. Outcrops are characteristically blocky weathering and less foliated than the country rock andesitic tuffs. In some exposures potassium feldspar megacrysts weather out, leaving large rectangular pits. Intrusive contacts are rarely found in outcrop, but good examples of chilled dike margins have been noted during underground mapping, drill-core examination, and mapping along the Salmon River.

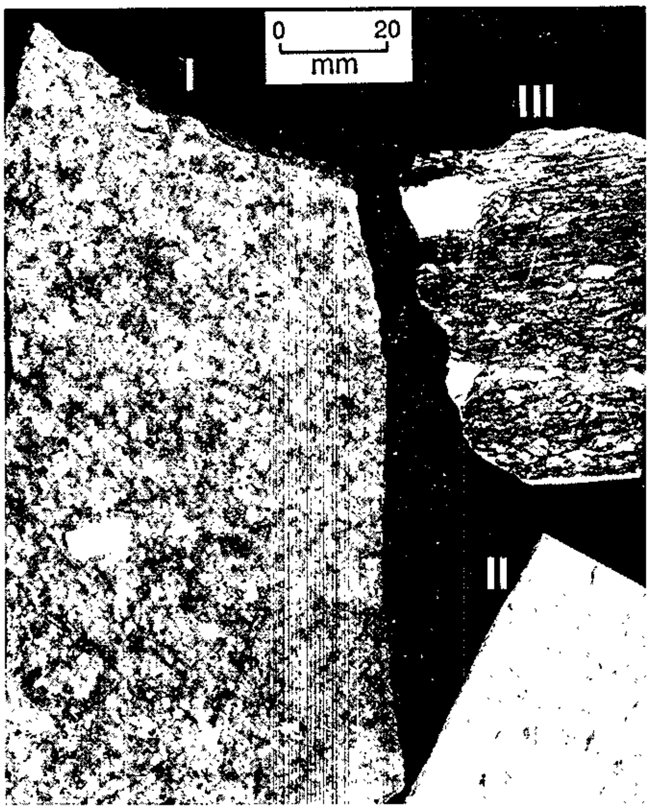


Plate 17. Three aspects of Premier Porphyry dike: (I) Type rock with moderate chloritic alteration; (II) Strongly sericite-carbonate-pyrite-altered dike-rock from south rim of Premier glory hole; (III) Strongly chloritized mylonite zone in Premier Porphyry dike adjacent to Lindeborg vein in underground workings of the Riverside mine.

Three varieties of Premier Porphyry dike are recognized based on detailed mapping and drill-core logging at the Silbak Premier mine[1] (Brown, 1987):

- **Potassium feldspar megacrystic, plagioclase hornblende porphyry** is the "typical" Premier Porphyry dike. The extrusive equivalents of this dike-rock are Premier Porphyry tuff and Premier Porphyry flow of the Premier Porphyry Member.
- **Plagioclase hornblende porphyry** is texturally similar to the potassium feldspar megacrystic porphyry, but contains few or no quartz and potassium feldspar phenocrysts. The extrusive equivalent of this dike-rock is the massive to layered Plagioclase porphyry of the Premier Porphyry Member.
- **Plagioclase porphyry** is hornblende poor, least abundant, and may be a gradational phase of plagioclase hornblende porphyry.

On both property and regional scales the megacrystic variety is the most abundant and will be described here as the type rock.

Typical Premier Porphyry dikes (Plates 1 and 17) are medium to dark green rocks with large (up to 5.0 cm) potassium feldspar megacrysts, plagioclase phenocrysts (up to 8 mm) and hornblende phenocrysts (up to 1.0 cm) in an altered fine-grained to aphanitic groundmass. The fine-grained groundmass, lower hornblende content, and presence of pervasive chloritic alteration distinguish hand samples of Premier Porphyry dike from the coarse-grained, hornblende-rich, generally less altered rocks of the Texas Creek batholith and Summit Lake stock.

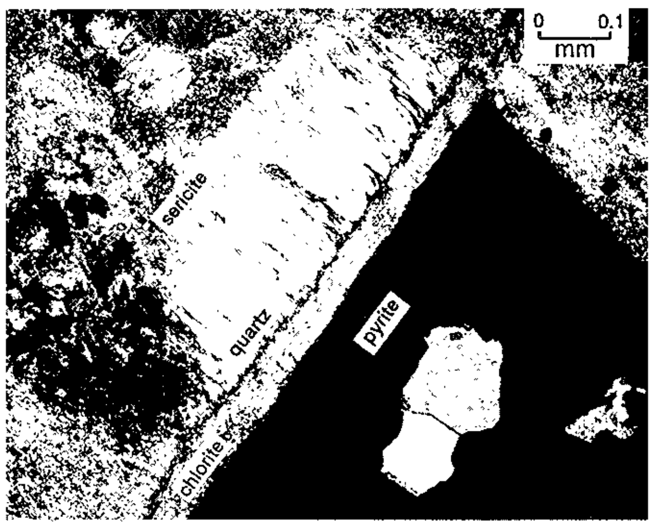


Plate 18. Photomicrograph of pressure shadow around pyrite crystal shows sequential (but penecontemporaneous?) growth of sericite, quartz and chlorite, indicative of lower greenschist facies metamorphism. Silbak Premier mine. Crossed nicols.

[1] Geologists at the minesite emphasize the difficulties of distinguishing between these rocks by respectively naming these same three dike types:
- Premier Porphyry proper.
- Premier Porphyry probable.
- Premier Porphyry problematic.

In thin section, typical Premier Porphyry consists of phenocrysts of orthoclase, plagioclase, hornblende and rounded quartz in a groundmass of quartz and potassium feldspar crystals. Potassium feldspar usually constitutes up to 4 per cent of the rock; crystals average about a centimetre long. Rocks with up to 50 per cent phenocrysts are called "crowded porphyry". Rare phenocrysts up to 5 centimetres long have been noted. Cores and rings of fine hornblende and plagioclase inclusions are common. Some megacrysts display simple twinning. Two x-ray diffractometer analyses of potassium feldspar megacrysts indicated compositions of 88 and 96 per cent potassium feldspar which were classified as "low sanidine" based on degree of Al/Si disorder (Brown, 1987). Grove (1971) concluded that the potassium feldspar phenocrysts were metasomatic. However, Vernon (1986) demonstrated primary igneous origins for potassium feldspar megacrysts and the megacrysts in rocks throughout the map area are regarded as primary igneous phenocrysts.

Plagioclase phenocrysts, mainly oligoclase, constitute 25 to 35 per cent of the rock and range from 2 to 8 millimetres long. Like equivalent extrusive and plutonic rocks, samples of Premier Porphyry dikes often contain plagioclase phenocrysts that have thin clear rims around sericitized cores. Scattered, small (<4 mm) quartz eyes are present in accessory amounts (up to 4%) in some dike exposures. They are typically nodular to lobate and strongly embayed, indicating substantial resorption. Analyses from subvolcanic Premier Porphyry dikes fall within the andesite field on a total alkali versus silica plot. This is consistent with the petrographic evidence of strongly resorbed quartz crystals; free quartz was metastable in this magma.

Euhedral hornblende phenocrysts make up 2 to 8 per cent of the rock and average 3 millimetres long, with local examples up to a centimetre long. Hornblende is pervasively altered to chlorite with or without pyrite and may only be preserved as chloritized remnants. Apatite, sphene, zircon, pyrite and magnetite are accessory minerals. The rock typically contains about 2 per cent very fine grained euhedral pyrite. Pyrite grains have pronounced quartz-chlorite-sericite pressure shadows, indicating a post-sulphide deformation event at elevated temperatures (Plate 18).

The groundmass is fine grained to aphanitic and is generally strongly altered. Rare fresh samples have fine-grained, interlocking to micrographic quartz and potassium feldspar. Alteration generally consists of abundant very fine grained sericite, lesser fine-grained carbonate, and minor chlorite and pyrite. In some dike samples carbonate flooding is the dominant alteration; in others chlorite alteration is dominant. Plagioclase is altered to sericite aggregates with some carbonate, and the hornblende is primarily altered to chlorite. Alteration is not pervasive or ubiquitous even within a single outcrop; some samples are fairly fresh with little alteration of the groundmass and with unaltered hornblende crystals.

AGE

Isotopic dates from a variety of plutonic rocks of the Texas Creek Plutonic Suite range from 211 to 186 Ma, spanning the Early Jurassic. The oldest dates come from the core (main phase) of the batholith, the youngest from dike phases.

SUMMARY

Rocks of the Texas Creek granodiorite suite were emplaced in a shallow subvolcanic setting below and within an Early Jurassic andesitic stratovolcano. Some dikes were volcanic feeders that produced extrusive units on the paleosurface. Intrusion and crystallization proceeded over a 25 million year period from the deepest, earliest batholithic rocks to the shallower, youngest dike phases.

Following emplacement, rocks of the Texas Creek suite were subjected to hydrothermal alteration and associated sulphide mineralization, episodes of both brittle and ductile faulting, and lower greenschist facies metamorphism. These rocks were deformed in the same regional deformation that affected stratified country rocks and were later cut by intrusions of the Tertiary Hyder Plutonic Suite.

HYDER PLUTONIC SUITE

In the Stewart region the continental-scale Coast Plutonic Complex trends northwest. Part of the main body lies along the southwest edge of the study area (Figure 10). Its eastern boundary is defined as the eastern limit of continuous Eocene plutonic rocks (Anderson, 1989). Buddington (1929) included the main Coast Range batholith and all the satellitic plutonic rocks to the east in the "Hyder Quartz Monzonite suite" or Hyder Plutonic Suite.

The Hyder Plutonic Suite includes a batholith, a large stock, several minor plugs and widespread dikes. The batholith lies within the eastern margin of the Coast Plutonic Complex. Smaller stocks in the map area are outlying satellites of the Coast Complex that are mineralogically and texturally similar to the main batholith. The varied dikes, collectively termed Hyder dikes, are exposed as prominent swarms of regional extent and as randomly distributed, isolated dikes in the intervening country rock. Although the plutons have associated dike phases, they lack preserved extrusive equivalents.

Major plutons range in composition from granite to tonalite to quartz monzonite. These plot as *calcalkaline* granites to granodiorites on a total alkali versus silica diagram. These rocks are characterized by overall medium grain size, biotite, equigranular white plagioclase and orthoclase, and trace amounts of fine-grained golden sphene. In comparison with Early Jurassic plutons, these Tertiary plutons are biotite rich, more siliceous and less altered. Associated dike phases range from aplite to lamprophyre. Emplacement of the Hyder suite has produced variable contact metamorphism, including mechanical, thermal and metasomatic effects. This regionally extensive suite hosts major molybdenum deposits and many minor silver, lead, zinc, gold and tungsten showings throughout the district.

HYDER BATHOLITH

The Hyder batholith extends along the eastern side of the Coast Plutonic Complex from the Unuk River area southeastward along the Alaska border through the head of the

Portland Canal at Stewart to Observatory Inlet and Alice Arm (Grove, 1986, p. 69). This overall length is 175 kilometres and the width averages 16 kilometres. The batholith is bordered on the west by the Central Gneiss Complex and on the east by stratified country rocks.

The batholith is well exposed along tidal zones of the Portland Canal and in roadcuts and quarries at Stewart, Hyder and northward along the Granduc mine road to the Fish Creek bridge. It ranges in composition from biotite granodiorite to quartz monzodiorite. The rock is fresh, light grey to pinkish grey, massive, medium grained, biotite rich with minor hornblende and is locally slightly porphyritic. Fine-grained, golden sphene crystals are characteristic. Large outcrops have blocky joint patterns. Intrusive contacts are marked by biotite hornfels of argillaceous country rocks, epidote disseminations and veins in tuffaceous and plutonic country rocks and local skarn development in calcareous sedimentary rocks.

Based on biotite K-Ar dates, the Hyder batholith is Eocene, 48.8 Ma (Smith, 1977). As none of the major Tertiary dike swarms in the region cuts the batholith, this date places an upper limit on the age of the dike swarms.

Locally, the batholith is spatially related to silver-rich galena-sphalerite-freibergite veins at the Porter Idaho, Silverado and Bayview mines near the town of Stewart. Regionally, discovery of the huge Quartz Hill molybdenum deposit in Alaska and the Molly May – Molly Mack molybdenite prospects south of Anyox spurred interest in the main batholith of the Coast Plutonic Complex as a setting for molybdenum deposits.

BOUNDARY STOCK

The Boundary granodiorite stock, which straddles the international border southwest of Salmon Glacier, was not examined in this study. The stock was described in detail by Buddington (1929) and Smith (1977).

The Boundary granodiorite is an inequigranular, hypidiomorphic, medium-grained, biotite hornblende granodiorite. Hand samples are fresh, dull white, with scattered grains of pale pink orthoclase and grey, glassy quartz; they are speckled with mafic crystals and tiny crystals of honey-coloured sphene are common. In contrast to the older Texas Creek batholith, which it intrudes, the Boundary stock is more massive, lighter coloured, with a pinkish hue, and contains conspicuous biotite. The Boundary granodiorite also resembles the Hyder batholith. However, the Boundary stock is generally finer grained; its hornblende needles are more euhedral, more abundant and more distinct; and all its minerals are slightly inequigranular.

HYDER DIKES

The Stewart Complex hosts an extensive array of Tertiary dikes and dike swarms, collectively termed the Hyder dikes. Textures and compositions are highly variable, ranging from aplite to lamprophyre, but plagioclase-porphyritic granodiorite with biotite-rich, fine-grained to aphanitic, light grey groundmass is common. Some workers have restricted the name "Hyder dikes" to refer only to the granodiorite porphyry dikes, but Late Tertiary aplite, microdiorite and lamprophyre dikes are considered as late phases of the Hyder plutonic episode in this study.

Hyder dikes have been grouped into four **dike phases** based on similar compositions, textures and relative ages. The oldest are massive, equigranular to porphyritic, fine to medium-grained, light grey biotite or biotite hornblende granodiorites that are up to 60 metres wide, and rarely, much wider. These are cut by buff to pinkish to white, massive to flow-banded, saccharoidal aplite or "rhyolite" dikes up to 5 metres wide. Aphanitic to fine-grained, greyish green microdiorite or "andesite" dikes range up to 10 metres in width. These, in turn, are cut by thin, dark brownish grey, variably porphyritic lamprophyre dikes that are generally less than 50 centimetres wide.

Pale **granodiorite porphyry dikes** vary significantly in both composition and texture. Modal compositions range from granite to diorite, but massive plagioclase-porphyritic biotite granodiorite is most common. In hand specimen the rock is characterized by pink to buff to white plagioclase phenocrysts, up to 5 millimetres long, that form up to 45 per cent of the rock. Equigranular dikes are fine to medium grained; plagioclase, biotite and less commonly hornblende, orthoclase or quartz can be recognized. The groundmass of the porphyritic dikes is aphanitic to fine grained. A single U-Pb zircon date of 54.8±1.3 Ma agrees with field relationships that show these dikes cutting all rocks except the younger plutons and dikes of the Hyder plutonic suite.

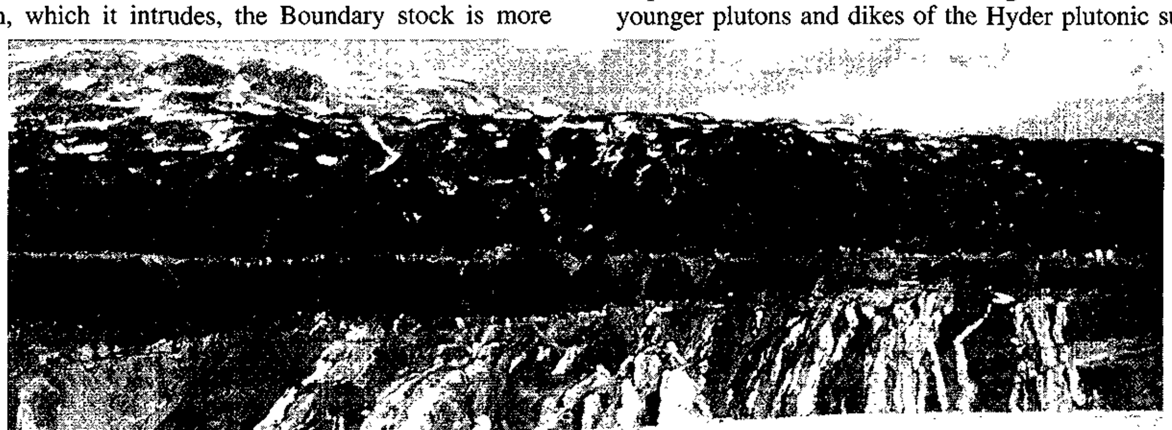


Plate 19. The Portland Canal dike swarm and the Granduc mine road.
Looking east from Mount Bayard across the Salmon Glacier to Mount Dilworth. (Hembling photo.)

Aplite dikes are sparsely distributed throughout the region. They seem to be more numerous within the two major southeast-striking dike swarms and within the Tertiary plutons, and are probably genetically related to them. Dikes generally range up to 5 metres wide and tend to weave or meander through the country rock, rather than have a rectilinear form. However, within the major dike swarms their trend is generally parallel to the resistant, bounding plagioclase porphyry dikes.

Aplite forms fine-grained to saccharoidal, white to cream to buff to pale pink dikes with distinctive flow banding and aphanitic chilled margins. Flow banding ranges from a few millimetres to a few centimetres thick, but is not present in all dikes. Some hand samples have distinct quartz eyes. Aplite dikes are extensively sericitized and generally lack mafic minerals.

Aplite dikes cut the Hyder batholith and the granodiorite porphyry dikes, but they are cut by younger lamprophyre dikes. Rubidium-strontium dates from aplite indicate a Middle Eocene age of 44±4 Ma (Brown, 1987).

Microdiorite dikes are greenish grey or medium to dark grey and sparsely porphyritic. They are distributed throughout the region and are the dominant lithology of the Berendon dike swarm. These dikes crosscut Tertiary Hyder plutons, but they are cut by younger lamprophyre dikes.

Microdiorite dikes range up to 10 metres wide and typically display chilled margins and blocky fractures. Hand samples have an aphanitic to fine-grained texture and may be porphyritic. Dikes are composed of small phenocrysts of plagioclase with or without hornblende, in a felted groundmass of interlocking plagioclase laths, lesser hornblende laths, and minor interlocking interstitial quartz and potassium feldspar (Buddington, 1929).

Lamprophyre dikes are sparsely distributed throughout the region. Most are less than 50 centimetres wide. Wide lamprophyre dikes rarely change attitude or thickness, but thinner dikes (<20 cm) change attitude or pinch out abruptly. Dike contacts are sharp, parallel surfaces. Chilled margins are common but quite thin. Closely spaced joints make the lamprophyres easily eroded, so that many dikes are marked by deeply incised clefts.

Lamprophyre dikes vary in mineralogy, texture and hand-specimen appearance. In outcrop, they are dark green, dark grey or dark brownish grey; fresh samples are charcoal to jet black. All these dikes are shoshonitic (Rock, 1977), but both biotite-rich minettes and hornblende-rich spessartites are present. Minettes are characterized by prominent biotite phenocrysts, up to 3 millimetres long, hosted in a massive, dark grey, aphanitic groundmass (Brown, 1987). Spessartite dikes are composed of 40 per cent, deep green, euhedral hornblende, 56 per cent subhedral plagioclase, minor magnetite and trace hypersthene.

Brown (1987) reported an Oligocene K-Ar date (25.2 ±1 Ma) for a biotite lamprophyre. Carter (1981, p.88) also reports Oligocene K-Ar dates (36.5±1.2; 34.4±1.5) from two lamprophyre samples in the Alice Arm area.

Rocks in the Salmon River valley are cut by two major southeast-striking **dike swarms** of felsic to mafic dikes and by a third, less dense, belt of intermediate to mafic dikes. Both major swarms are composed of four main dike rock types, the third is composed only of the two youngest, more mafic rock types. In the two major swarms intrusive rock comprises more than 40 per cent of the bedrock; locally, only narrow lenses and slices of country rock separate the anastamosing dikes. The cumulative thickness of intrusive rock in these two swarms represents a northeasterly crustal extension of at least 1.5 kilometres.

The Portland Canal dike swarm (Plate 19) is the longest of the three. It has been traced continuously southeastward from Mount Bayard to Mount Dickie and finally to Mount Trevor, in the centre of the Cambria Icefield. Major felsic dikes are exposed along the north wall of the Salmon Glacier northwest of Mount Bayard and farther northwest in the cliffs of Scottie Dog Mountain near the Granduc mine, for a total length of 67 kilometres. The swarm has an indicated width of 2 kilometres on the accompanying map (Figure 11), but its boundaries are somewhat arbitrarily drawn where dikes make up 40 per cent or more of the bedrock. Dikes crop out for up to 500 metres outside these boundaries.

Dikes in the swarm generally trend east-southeast to southeast and dip steeply southwest, but dips flatten to about 45° where dikes cross thin-bedded argillites of the Salmon River Formation south of Mount Dilworth. Individual dikes are up to 150 metres thick and can be traced to depths of hundreds of metres and lengths of thousands of metres. Myriad smaller dikes in the swarm, from a few to 60 metres wide, form a complex, anastamosing network. Dikes locally merge into small elongate stocks more than 400 metres wide. Toward these minor Tertiary plutons, dikes are progressively closer together, thicker and more numerous, ultimately coalescing into the stocks.

Variations in texture and composition have been noted within individual dikes as well as between dikes. The most abundant felsic dikes are equigranular or fine to coarse porphyries, and may be flow brecciated. Modal compositions range between granite, quartz monzonite, granodiorite and quartz diorite (Grove, 1986). Other dikes in the swarm include aplites, microdiorites and lamprophyres.

No absolute age determinations have been made on any of the dikes in this swarm, but Brown (1987) reported that the Portland Canal swarm was more differentiated than the Boundary dike swarm (54.8 Ma, R.G. Anderson, personal communication, 1985) and concluded that the Portland Canal swarm was slightly younger.

Several mineral occurences and a few deposits are located within this dike swarm. At some deposits, like the Martha Ellen orebody, post-ore dikes cut across the mineral zones but are not themselves affected by the mineralization. At other showings, the Portland Canal dikes were the locus for sulphide mineralization. Many dikes have been fractured and faulted, the spaces in the dikes and in adjacent country rocks are filled with coarse-grained quartz and silver-rich galena and sphalerite, for example: Outland Silver Bar, Silver Basin, Lion, Unicorn, Silver Hill, Silver Tip, Spider, Lois, M.J. and Silver Crown prospects. None of these occurrences have been major producers, although Silver Tip does have significant reserves (Plumb, 1957).

The Boundary dike swarm is the second major southeast-striking swarm and lies along the international border between Cantu Mountain and Mount Welker, passing through the Silbak Premier mine. It extends beyond the map area in both directions. The swarm has a length of at least 22 kilometres, from Mount Jefferson Coolidge to the Bear River, and a width of 3 kilometres. The Boundary swarm has the same general southeast strike and steep southwest dip (135°/70°SW) as the Portland Canal swarm and includes a similar variety of dikes. Granodiorite porphyry dikes are especially abundant within this belt. The most spectacular, continuous exposures are at the summit of Mount Welker.

The Berendon dike swarm is the third, narrower, less crowded belt of dikes. It trends south along the west side of Tide Lake Flats, and across the upper portal (3600-level) area at Scottie Gold mine to August Mountain. From August Mountain it swings southeast and continues over the crest of Mount Dilworth. Southeast of Mount Dilworth, toward Mount Bunting, it merges with the wider Portland Canal swarm.

This belt of dikes is significant because it is dominantly composed of microdiorite (andesite) dikes with many subparallel, thin lamprophyre dikes. Older, more felsic dikes are absent. These younger dikes clearly trend north to north-northwest. Therefore the northwesterly trend of younger, more mafic dikes in the two major swarms is due to deflection or 'capture' of these dikes by the resistant, thicker, felsic dikes of the two main swarms.

AGE

Granodiorite porphyry dikes cut all stratified rocks and all Early Jurassic plutonic rocks, but do not cut Tertiary plutons and dikes. Based on these field relationships and on age determinations, the emplacement of these dikes slightly preceded intrusion of the main Tertiary plutons. Thus the plutons obliterated the precursor dikes. Dikes of aplite, microdiorite and lamprophyre cut all other rocks and probably originated as late phases of the batholith. Tertiary plutons and dikes of the Hyder plutonic suite crosscut all regional folds, but are offset by most major and minor faults. In a few locations dikes are deflected along pre-existing fault zones.

Isotopic dates are available for most of the intrusive rocks of the Hyder suite and range from 55 to 25 Ma, a 30 million year period similar to the 25 million year span of dates from the Texas Creek suite. The general sequence of Tertiary intrusion is summarized in Table 3, based on field relationships and isotopic dates.

TABLE 3
HYDER PLUTONIC SUITE — SEQUENCE OF INTRUSION

Epoch	Age (Ma)	Lithodemes/Phases
late Oligocene	35–25	Lamprophyre dikes.
early Oligocene	45–35?	Microdiorite dikes.
mid-Eocene	44	Aplite dikes.
mid-Eocene	48–49	Hyder batholith/Bitter Creek stock.
mid-Eocene	52?	Precursor Portland Canal dike swarm.
mid-Eocene	51–52?	Boundary stock/Davis River stock.
early Eocene	55?	Precursor Boundary dike swarm.
early Eocene	55	Granodiorite porphyry dikes.

(Ages derived from isotopic dates and/or field relationships)

As the Boundary stock is slightly older than the Hyder and Bitter Creek plutons, their spatially associated precursor dike swarms (Boundary and Portland Canal respectively) are probably also slightly different in age. It is impressive that these small age differences were correctly deduced for the plutons (Buddington, 1929, p. 33) and for the dike swarms (Brown, 1987, p. 52) on the basis of petrographic studies alone.

SUMMARY

The main batholith of the Coast Plutonic Complex and outlying satellitic stocks and dikes are interpreted as subduction-related plutonic rocks emplaced above the eastward-subducting Pacific plate in early Tertiary time. Emplacement of major intrusions ended when relative plate motions changed from colinear (high-angle) to transcurrent (oblique) geometry about 42 Ma (Armstrong, 1988). The plutonic episode was followed by faulting, uplift and rapid erosion.

BASALTIC DIKES OF THE STIKINE VOLCANIC BELT

In Miocene time, alkali-olivine flood basalts formed plateau lavas. The lava issued from regional networks of vents and fissures (Souther, 1972; Smith, 1973). This volcanic activity culminated in the late Miocene to early Pliocene and continued intermittently through to the present day.

Basaltic dikes have been reported by Buddington (1929) and, under the classification of lamprophyres, by Smith (1973, 1977; *see* Rock, 1977, p.140). The dark porphyritic rock has augite, plagioclase and rare olivine phenocrysts in a subophitic groundmass of plagioclase and pyroxene. These widespread dikes may have been the feeders to Miocene volcanic flows that were eroded in this area, but are preserved elsewhere.

PETROCHEMISTRY

Chemical analyses have helped classify rock types, determine their type and degree of alteration, and establish their tectonic affinities.

VOLCANIC ROCKS

In this report, lithochemistry is compared and contrasted at formational scale. The patterns show a systematic chemical evolution that is parallelled by the colour index and phenocryst assemblage of the rocks (Figure 14).

The stratigraphic distribution of phenocrysts shows an evolution that closely resembles Bowen's reaction series (Figure 14). The significance of different phenocrysts in andesites is reviewed by Gill (1981, Chapter 6). **Plagioclase phenocrysts** may range in composition from An_{15} to An_{99}; plagioclase phenocrysts in the Unuk River Formation fall in the range An_{25} to An_{45}. Characteristic features of plagioclase phenocrysts in orogenic andesites are present in Stew-

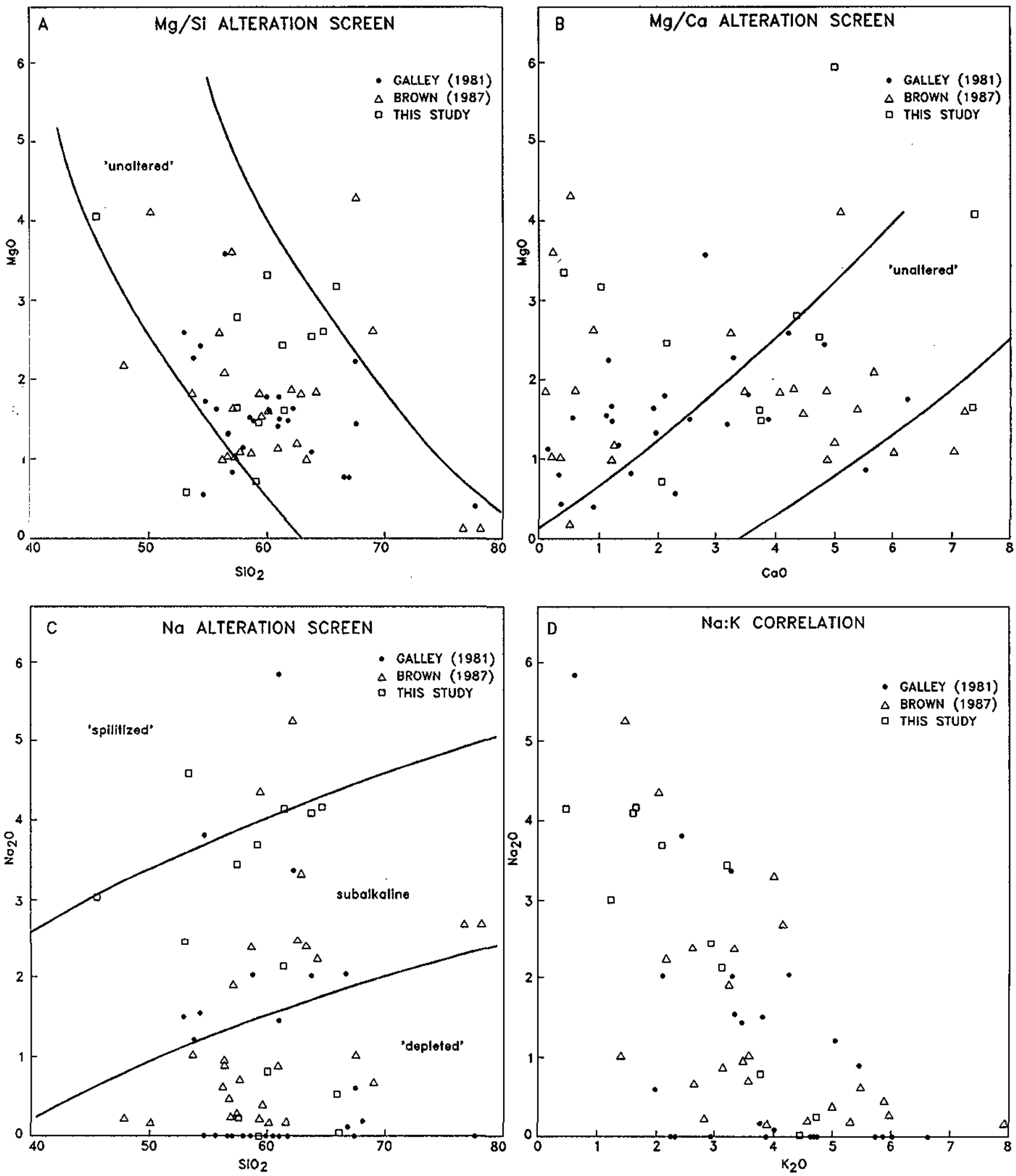


Figure 16. Major element data plotted on the alteration screening diagrams from de Rosen Spence (1976).

art rocks, for example, inclusion-rich zones, regions of oscillatory zoning, and clear, normally zoned mantles. Gill concludes that **hornblende phenocrysts,** which are conspicuously abundant in Stewart, are relatively uncommon in andesites and are largely restricted to medium and high-potassium andesites, to topographically and stratigraphically high levels of stratovolcanoes, and to formation in magma chambers at high crustal levels. Finally, he notes that **quartz phenocrysts** in andesites are almost always embayed. This presence of metastable quartz may reflect assimilation of sialic rock, mixing of mafic and acid magmas, or high-pressure crystallization.

Alteration is the principal cause of lack of concordance between classification by petrographic description and by the total alkali versus silica plot (Sabine *et al.,* 1985). Altered samples must be eliminated from the data set before chemical classification schemes can be applied to the remaining "unaltered" samples. Petrography is an essential step for classification of every volcanic rock and can readily identify all significantly altered rocks. Not only can altered rocks be screened and eliminated from the chemical data set by microscopic examination, but it is usually possible to reliably identify the original rock type despite its alteration overprint. To complement microscopic studies, de Rosen Spence (1976) developed three discriminant plots for separating chemically altered volcanic rocks from data sets. These plots identify alteration effects involving the most mobile elements: sodium, magnesium, calcium and silica.

TABLE 4
MAJOR ELEMENT ANALYSES FROM STRATIFIED ROCKS IN THE STEWART MINING CAMP

MOUNT DILWORTH FORMATION													
LbNo	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**	**LOI**	**TOTAL**
A-626	65.87	1.11	12.27		17.49	0.060	3.18	1.03	0.52	0.920	0.00	5.00	107.45
A-633	66.12	1.26	13.51		8.11	0.003	7.68	0.02	0.03	4.450	0.00	6.00	107.18
G-1	67.4	0.71	13.4		6.22	0.05	2.24	1.14	0.00	2.96	0.09	4.00	98.21
G-4	62.2	0.47	17.8		4.95	0.17	1.64	1.20	3.37	3.27	0.17	3.08	98.32
G-15	66.6	0.39	15.9		3.94	0.10	0.79	1.53	2.04	4.27	0.11	3.62	99.29
UNUK RIVER FORMATION (Premier Porphyry dikes. See also Table 5)													
LbNo	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**	**LOI**	**TOTAL**
A-405	59.38	0.49	14.98	4.60	0.00	0.360	1.47	3.74	0.00	8.100	0.20	0.00	93.32
A-624	57.54	0.52	14.47	4.86	2.08	0.270	1.65	7.34	0.24	4.740	0.10	3.10	96.91
B-70	59.6	0.50	14.8	0.7	3.6	0.28	1.55	4.46	0.39	4.96	0.19	7.86	98.89
B-15	62.5	0.51	15.0	0.9	3.4	0.15	1.20	4.96	2.47	2.83	0.22	6.40	100.54
B-366	61.6	0.49	15.1	0.8	3.4	0.30	1.49	3.83	0.17	7.89	0.22	5.72	101.01
B-524	62.8	0.55	16.0	0.6	3.9	0.14	1.82	3.49	3.31	3.99	0.26	2.80	99.66
B-546	60.1	0.52	14.5	0.6	4.0	0.26	1.60	7.20	0.16	3.89	0.19	8.93	101.95
UNUK RIVER FORMATION (Upper Andesite Member - Main Sequence)													
LbNo	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**	**LOI**	**TOTAL**
B-40	57.4	0.83	22.6	1.6	5.1	0.09	1.02	0.30	0.26	5.93	0.09	4.4	99.62
B-105	63.3	0.48	14.3	1.8	2.5	0.11	0.99	4.86	2.39	2.64	0.23	6.0	99.60
B-96	56.2	0.81	19.4	7.4	1.4	0.14	0.98	1.20	0.61	5.45	0.12	4.5	98.21
B-294	57.1	0.61	16.7	0.4	4.3	0.11	1.62	5.36	1.89	3.23	0.25	7.5	99.10
B-340	56.4	0.73	15.4	6.3		0.48	2.08	5.65	0.95	3.47	0.30	5.75	97.52
B-357	56.7	0.96	21.1	8.1	1.5	0.08	1.02	0.20	0.45	5.85	0.12	3.62	99.70
B-381	64.2	0.59	14.9	0.9	3.7	0.13	1.84	4.86	2.23	2.17	0.23	6.03	101.78
B-382	62.1	0.64	17.4	4.0	2.0	0.16	1.87	4.29	5.25	1.46	0.24	2.5	101.91
B-455	58.6	0.56	15.1	5.6		0.17	1.08	6.01	2.37	3.33	0.28	7.58	100.68
B-543	57.7	0.68	14.2	3.9	2.6	0.26	1.09	7.02	0.71	3.55	0.30	9.51	101.52
G-7	60.9	0.64	15.9		5.98	0.20	1.42	3.17	5.85	0.63	0.22	3.31	98.22
G-18	61.8	0.75	14.8		7.30	0.24	1.50	2.54	0.00	3.90	0.25	4.62	97.70
G-20	54.8	0.76	15.6		6.76	0.25	1.74	6.21	0.00	4.73	0.31	5.69	96.85
G-21	56.7	0.83	17.6		7.43	0.17	1.33	1.95	0.00	5.85	0.34	5.83	98.03
G-22	53.0	0.77	16.0		7.55	0.34	2.59	4.21	1.51	3.80	0.31	7.00	97.08
G-24	54.3	0.77	15.9		8.43	0.35	2.44	4.83	1.55	3.34	0.31	5.69	97.91
G-26	61.1	0.56	14.1		4.84	0.44	1.80	3.54	0.00	4.65	0.25	6.15	97.43
G-27	60.5	0.80	15.8		6.19	0.15	1.77	3.64	0.00	3.89	0.30	4.46	97.50
UNUK RIVER FORMATION (Middle Andesite Member)													
LbNo	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**	**LOI**	**TOTAL**
A-344	45.55	0.96	16.24		13.47	0.210	4.06	7.38	3.02	1.240	0.34		92.47

Data source: A = Alldrick (1991); B = Brown (1987); G = Galley (1981)

The plots separate unaltered subalkaline rocks from strongly altered samples and also separate unaltered subalkaline rocks from unaltered alkaline rocks.

Screening plots were applied to all the available data sets (Figure 16); the results were alarming. Only 22 per cent of the writer's data, 19 per cent of Galley's data and 33 per cent of Brown's data were retained as "unaltered" samples. A large proportion of the rejected samples fall in the "sodium-depleted" field on the Na_2O versus SiO_2 plot. Petrographic work indicates that these samples have been affected by replacement of sodium by potassium in plagioclase. Sericitization in the Stewart area is common in most rocks and particularly intense in plagioclase phenocrysts. A plot of Na_2O versus K_2O (Figure 16d) shows a strong 1:1 linear correlation between the two components, also implying selective replacement of sodium by potassium. Since selective Na:K replacement does not affect the discriminant plots of Figures 17, 18 and 19, samples showing only sodium depletion or enrichment with no significant calcium or magnesium alteration were also retained in the dataset. From a total of 68 wholerock analyses, 31 'least-altered' samples were retained for plotting (Table 4).

Three recommendations are proposed for dealing with variably altered volcanic rocks in Hazelton Group strata of the Stewart complex:

- Thorough petrographic description is an essential step that will identify all strongly altered samples and indicate alteration mineral assemblages.

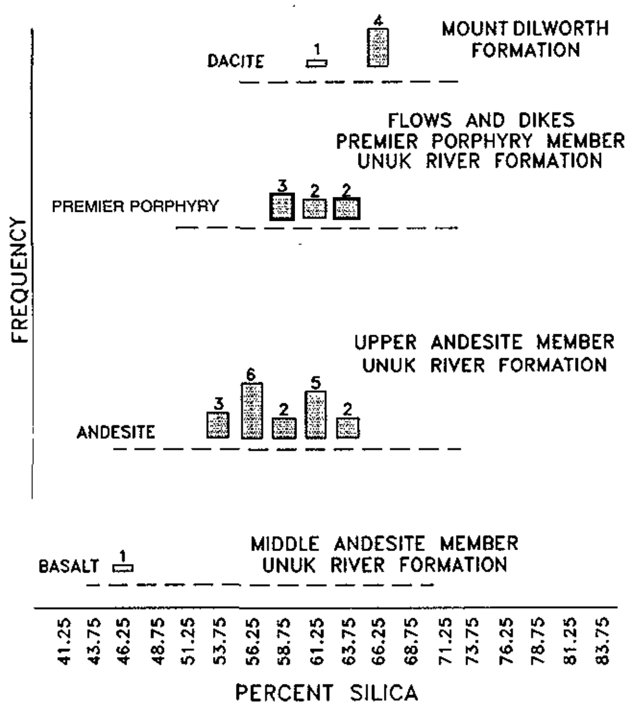


Figure 17. Silica histograms. Apparent bimodal andesite population is an artifact of histogram division points.

- Application of discriminant plots as alteration screens will help identify moderately altered samples that may have been overlooked, and will give important insight into the bulk chemistry of the alteration process.
- All iron-based discriminant plots must be interpreted with caution because most rock samples from the region contain some pyrite and many have hydrothermal chlorite alteration.

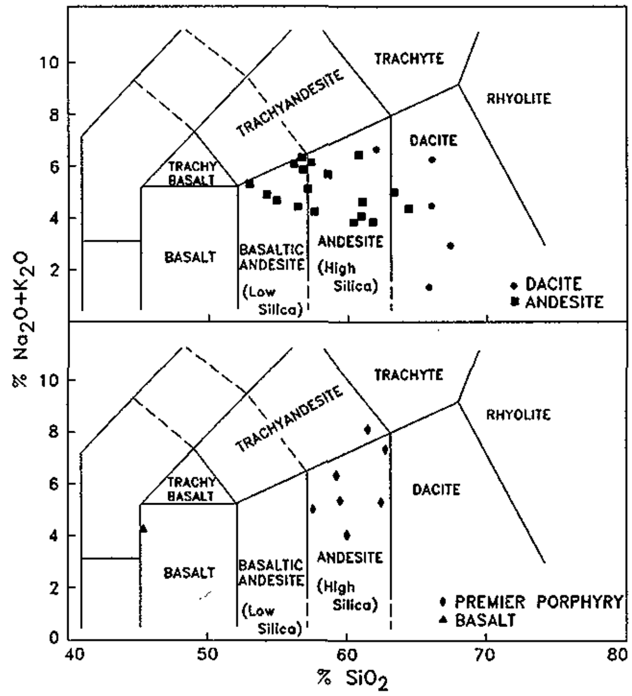


Figure 18. Major element data plotted on total alkali versus silica discriminant diagram of Le Bas *et al.* (1986).

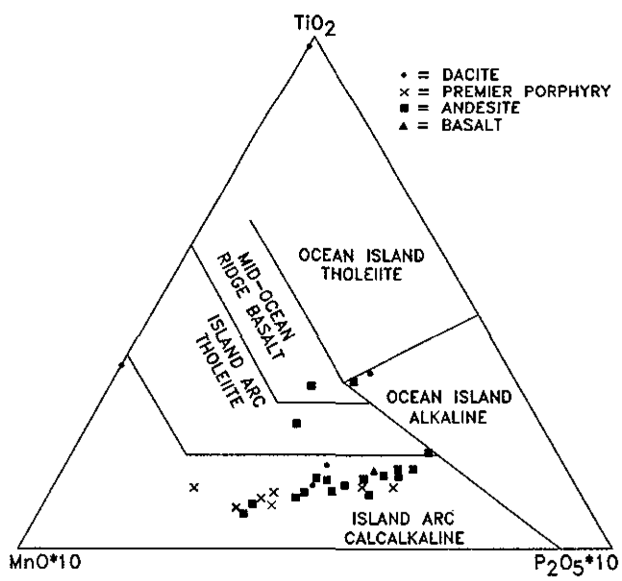


Figure 19. Major element data plotted on the tectonic environment discriminant diagram of Mullen (1983).

TABLE 5
MAJOR ELEMENT ANALYSES FROM INTRUSIVE ROCKS

	Lab #	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	
TEXAS CREEK SUITE (EARLY JURASSIC)														
Alldrick	A327	58.52	0.54	15.79	6.57		0.140	2.32	4.82	2.36	3.550	0.23		Texas Creek batholith (porphyry)
Alldrick	A325	60.59	0.53	15.83	6.24		0.120	1.83	4.26	2.80	2.970	0.18		Summit Lake stock
Alldrick	A624	57.54	0.52	14.47	4.86	2.08	0.270	1.65	7.34	0.24	4.740	0.10	3.10	Premier Porphyry dike
Alldrick	A405	59.38	0.49	14.98	4.60		0.360	1.47	3.74		8.100	0.20		Premier Porphyry dike
Brown	B366	61.60	0.49	15.10	0.80	3.40	0.300	1.49	3.83	0.17	7.890	0.22	5.72	Premier Porphyry dike
Brown	B70	59.60	0.50	14.80	0.70	3.60	0.280	1.55	4.46	0.39	4.960	0.19	4.86	Premier Porphyry dike
Brown	B15	62.50	0.51	15.00	0.90	3.40	0.150	1.20	4.96	2.47	2.830	0.22	6.30	Premier Porphyry dike
Brown	B524	62.80	0.55	16.00	0.60	3.90	0.140	1.82	3.49	3.31	3.990	0.26	2.80	Premier Porphyry dike
Brown	B546	60.10	0.52	14.50	0.60	4.00	0.260	1.60	7.20	0.16	3.890	0.19	8.93	Premier Porphyry dike
Brown	B360	78.10	0.31	10.00	3.00		0.050	0.15	0.51	2.70	4.150	0.01	1.43	Premier Porphyry dike
Alldrick	A326	58.20	0.51	14.66	7.63		0.120	1.86	3.58	2.96	3.240	0.19		Salmon River dike
HYDER SUITE (MIDDLE EOCENE)														
Carter	NC38	71.38	0.33	12.01	0.99	0.62	0.030	0.78	1.90	1.07	6.720	0.19	1.50	B.C. Moly stock (Alice Arm)
Carter	NC30	66.98	0.54	14.64	0.69	2.02	0.040	1.00	3.08	3.76	4.650	0.20	1.18	Bell Moly stock (Alice Arm)
Carter	NC33	65.78	0.52	13.56	1.29	2.22	0.030	1.32	3.53	3.97	4.250	0.38	1.27	Ajax stock (Alice Arm)
Carter	NC35	71.16	0.31	14.23	0.36	1.86	0.040	0.29	1.40	3.22	4.580	0.15	1.39	Roundy Creek stock (Alice Arm)
Carter	NC26	68.92	0.57	15.20	1.02	0.87	0.010	0.64	2.23	3.32	4.430	0.38	0.23	Valley stock (Alice Arm)

* samples A405 and B366 were collected independently from the same trench exposure.

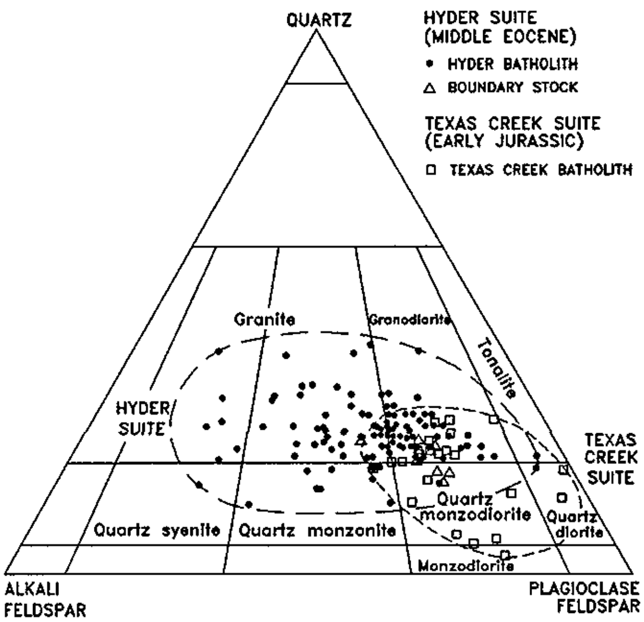


Figure 20. Modal compositions of plutonic rocks from studies by Buddington (1929), Smith (1977) and Grove (1986), replotted on the discriminant diagram of Streckeisen (1975).

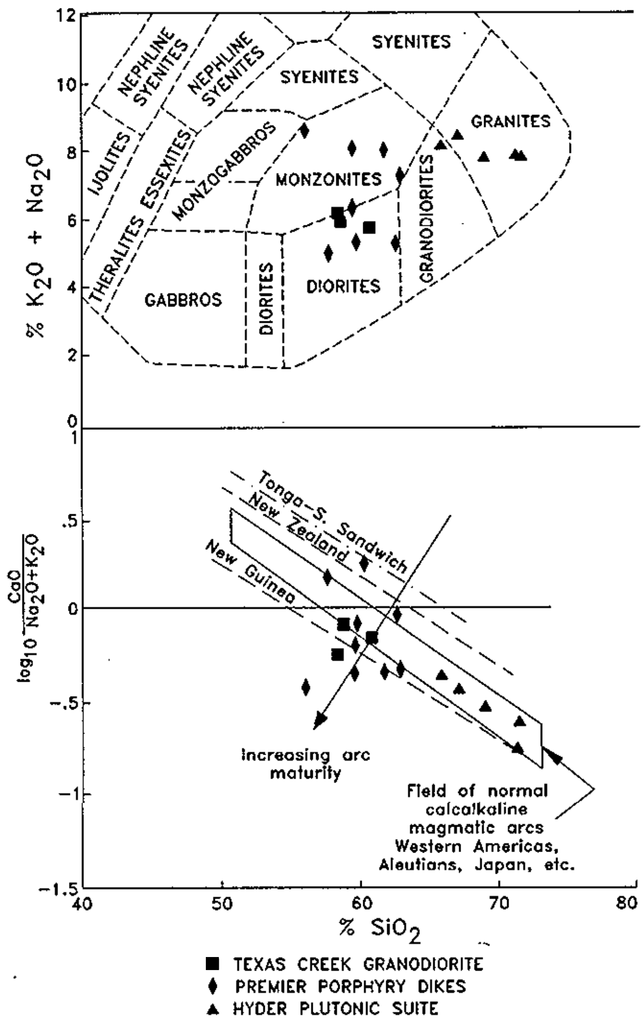


Figure 21. Major element data from plutonic rocks plotted on discriminant diagrams of Cox *et al.* (1979) and Brown (1982).

"Silica contents . . . are the best single discriminants for distinguishing andesites from basalts or dacites, they increase regularly relative to various differentiation indices and they have more immediacy to most people than do combinational parameters." — James B. Gill, 1981

Histograms of total weight per cent silica (Figure 17) are simple but effective diagrams that clearly separate the different lithological groups and show the progressive, more felsic evolution up-section.

The new I.U.G.S. classification scheme (Figure 18) shows that the "basalt" and "andesite" field terms are appropriate. Stewart andesites are dominantly high-silica andesites. Both the total alkali - silica plot (Figure 18) and the silica histogram (Figure 17) show that Premier Porphyry subvolcanic intrusive rocks are high-silica andesites. Finally, samples from the Mount Dilworth Formation plot as low-silica dacite, rather than rhyolite as concluded by Grove (1971), Galley (1981) and Brown (1987).

Composite **Harker silica variation diagrams** have been plotted for four main stratigraphic divisions (Alldrick, 1991) and correlate well with predicted patterns for calcalkaline orogenic andesites (Gill, 1981). The TiO_2 analyses are almost all less than 1.2 per cent, indicating a convergent margin, island-arc environment (Gill, 1981).

Application of the **tectonic environment discriminant plot** of Mullen (1983) in Figure 19 classifies most of the Stewart samples as calcalkaline rocks from a convergent margin, island-arc environment.

Trace element studies indicate that the rocks are calc-alkaline, high-potassium, high-silica, orogenic andesites (Brown, 1987). **Chondrite normalization diagrams** show patterns consistent with those of the convergent plate margin suites (Erdman, 1985; Brown, 1987).

In conclusion, Hazelton Group volcanic rocks are a subalkaline, potassium-rich, iron-rich(?), calcalkaline suite that ranges in composition from basalt through andesite to dacite over a stratigraphic thickness of 5 kilometres. This compositional change is paralleled by a progressive change in colour from dark olive-green to light grey and by progressive evolution of associated phenocrysts. Augite-porphyritic basalts are subalkaline. Intermediate volcanic rocks are medium to high-potassium, high-silica andesites and are chemically similar to modern andesites of the Chilean Andes. Premier Porphyry rocks are high-potassium, high-silica andesites. Felsic volcanic rocks of the Mount Dilworth Formation are low-silica dacites.

The subaerial volcanoes of the Stewart camp formed along the central axis of a volcanic arc and were established on crust approximately 30 kilometres thick. The topographic setting envisioned is an arc-island chain of major islands and isolated subaerial volcanoes (similar to Indonesian examples or the eastern Aleutians), resting on thickened or "continental" crust.

INTRUSIVE ROCKS

There are scores of modal composition determinations for medium to coarse-grained plutonic rocks of the Stewart camp, but major element chemical analyses are limited to 13 samples (Table 5).

No **modal composition** determinations were undertaken in this study. Earlier data from Buddington (1929), Smith (1977) and Grove (1986) are replotted here (Figure 20) using Streckeisen's (1975) nomenclature. Texas Creek rocks range from granodiorite to monzodiorite and quartz diorite whereas the Hyder suite ranges from granite (syenogranite) to tonalite and is slightly richer in quartz and alkali feldspar. Due to the large area of overlap in modal compositions, a Streckeisen diagram alone would not be a reliable discriminant plot for plutonic rocks in this area.

Major element analyses from the Texas Creek Plutonic Suite and from the Hyder Plutonic Suite in the Alice Arm area are plotted on discriminant diagrams from Cox *et al.* (1979) and Brown (1982) in Figure 21. All plots clearly show that the Texas Creek batholith, Summit Lake stock and Premier Porphyry dikes are chemically similar and likely comagmatic; the wider scatter of the dike analyses is attributed to alteration. The more siliceous rocks of the Hyder plutonic suite are chemically distinct.

Rocks of the Texas Creek suite are subalkaline, calc-alkaline, high-potash monzonites to diorites that are chemically identical and probably comagmatic with Hazelton Group volcanic rocks. Rocks of the Hyder suite are subalkaline, calcalkaline granites to granodiorites and have no preserved extrusive equivalents.

CHAPTER 4 — STRUCTURE, METAMORPHISM, ALTERATION AND GEOCHRONOLOGY

STRUCTURE

Rocks in the study area display a variety of fabric elements and structures on all scales. The map area lies in a single structural domain or sub-area. All rocks have been subjected to the same series of stress regimes, although different rock types have deformed differently. Structural elements include:

- primary bedding (S_0) measured in sedimentary rocks, felsic volcanic rocks and rare sedimentary intervals in massive andesitic sequences,
- northwest-trending folds (F_1) that vary from open in volcanic rocks, to tight to isoclinal in turbidites,
- minor axial-planar cleavage (S_1) related to small, tight folds formed during regional-scale folding,
- west-dipping foliation (F_2) of brittle to ductile origin
- west-plunging lineations (L_3) and geometrically related extensional quartz veins and joints (S_3) (Brown, 1987),
- southeastward-striking, subvertical ductile shear zones (F_4),
- brittle faults of many scales, orientations and ages.

FOLDS

Folding is the dominant structural feature of area. The main fold structure is a northerly trending **regional-scale fold system** of en echelon synclines. Individual synclines trend north-northwest with steeply dipping to vertical axial planes. Each syncline is an open to tightly folded, doubly plunging canoe-shaped structure. Volcanic and sedimentary rocks of the Hazelton Group are deformed into open cylindrical folds. Sedimentary rocks of the overlying Salmon River Formation occupy the synclinal cores and display disharmonic tight to isoclinal folds on many scales. Bedding-plane faults or décollement surfaces formed where ductility contrasts between the siltstones and underlying felsic volcanic rocks caused failure.

Intermediate-scale minor folds, tens of metres wide, have been noted in several areas and are related to the formation of the major fold system. **Outcrop-scale minor folds** have only been noted in siltstone units, and are grouped into two classes:

- Strongly contorted minor folds are varieties of drag folds, and can be found wherever siltstone beds are cut by faults or intruded by major dikes.
- Some outcrop-scale minor folds within the Salmon River Formation are disharmonic space accommodations of plastically deformed siltstones that maintain axial planar continuity with the regional fold pattern.

FAULTS

Faults are abundant on both local and regional scales, but there are unresolved questions about absolute and relative ages of displacement. Small-scale structures are ubiquitous and create difficulties in locating and correlating offset mineralized zones and in estimating dilution factors for ore reserve calculations. These brittle fractures are preserved as narrow fault breccias or pinching and swelling bands of gouge up to 30 centimetres thick.

Major faults are separated into five groups:

- regional-scale north-striking, subvertical shears
- northerly striking, west-dipping shears
- southeast to northeast-striking "cross structures" that cut the northerly structural grain
- décollement surfaces or bedding-plane slips that are present near the base of the Salmon River Formation
- mylonite zones.

Regional-scale faults form major topographic lineaments ,that control drainage. These northerly to north-northeasterly striking, subvertical to steeply west-dipping, ductile to brittle faults include the Long Lake, Fish Creek, Skookum Creek, Salmon River and Cascade Creek structures.

Examples of map-scale, **northerly striking moderately west-dipping normal and reverse faults** are the Harris Creek, Union Creek and Mineral Gulch faults, and the series of parallel shears around and south of the Silver Butte property. These structures probably originated as ductile, contractional reverse faults, and were reactivated as brittle fractures during later extensional episodes.

Easterly "cross structures" are brittle, subvertical faults that have strong, but narrow, foliation envelopes. They trend from northeast to southeast and have lateral offsets up to a kilometre. Examples are: the East Gold, Millsite, Morris Summit, Dumas Creek, Windy Point and Hercules faults.

Décollement surfaces or bedding-plane slips are common around the perimeter of the Salmon River Formation outcrop area. These slips indicate detachment during folding near the contact with underlying dacitic strata of lower ductility.

Intrusion of the **northwesterly striking dike swarms** was accompanied by at least 1.5 kilometres of northeastward extension. Many dikes have sharp, planar, brittle wall-rock contacts.

Buddington (1929, p.16) first reported east-striking "gneissic structures" or **mylonites** in granodiorites and noted that they are parallel to strong foliation zones in the greenstone country rock. Discrete mylonite bands, a few metres wide at most, have been identified from the southernmost exposures of the Texas Creek batholith to as far north as Cooper Creek. At the Silbak Premier mine, mylonite zones are exposed in the disrupted, clast-rich, banded sulphide zone at the 2-level portal and in bedrock trenches near the glory hole. There are at least three orientations to mylonite zones in the map area:

- North-striking subvertical faults like the Long Lake fault (Brown, 1987) and the Fish Creek fault (Smith, 1977).
- North-striking, west-dipping fault zones commonly contain ductily deformed, flattened clasts.
- Southeast-striking, steeply northeast-dipping mylonites deform and offset Jurassic ore at the Silbak Premier mine and provide the locus for the Tertiary ore veins at the Riverside mine.

Moderately west-dipping, flattened angular clasts and rounded cobbles are common in outcrops and underground exposures throughout the southern half of the map area; these exposures are all examples of ductile deformation. In the past, the orientation of flattened clasts has been recorded as bedding, but where continuous exposures are available, it is possible to walk out of the deformed zone into similar rock with equant angular or rounded clasts.

The extensive zones of **cataclasite** illustrated by Grove (1971, 1986) and the single zone indicated by Smith (1977) could not be located in the field or recognized in dozens of thin sections from these areas. Grove's photomicrographs are typical of foliated, sericitically altered, fine lapilli tuffs within the Unuk River Formation. The writer concludes that all the "cataclasites" of the Salmon River valley are actually moderately to strongly foliated, moderately altered andesitic lapilli tuffs and crystal-lithic tuffs.

Foliation

Secondary foliation is present as rare axial-planar slaty cleavage, as schistosity, as flattened clasts in conglomerates or fragmental tuffs, and as gneissic or mylonitic fluxion structures described in the preceding section. In andesitic rocks of the Unuk River Formation the dominant feature is a north-striking penetrative foliation dipping moderately westward (30° to 70°W). It remains one of the most readily observed yet difficult to explain phenomena of the Stewart mining camp. In this report it is interpreted as coalesced, overlapping, or superposed foliation envelopes surrounding most fault zones in the district. These envelopes extend into wallrocks adjacent to both brittle and ductile faults. Envelopes associated with minor brittle faults are narrower, a few tens of metres at most; those associated with major ductile faults may be well over 100 metres wide with foliation intensity becoming progressively stronger toward the core of the shear. Faults are so widespread that most outcrops in the region have some degree of foliation; but this mechanism for its development also explains the seemingly random, local areas of unfoliated, unstrained, massive tuffs that have been encountered during mapping – there is no fault zone nearby. In any single outcrop, the most prominent foliation represents the largest or youngest faulting in the area as foliation envelopes from younger faults overprint and obscure pre-existing envelopes.

The foliation envelope around a fault may be obvious even though the recessively weathered fault itself is hidden. In outcrops of andesite tuff near the junction of the Silbak Premier and Big Missouri mine roads, intense foliation is coplanar with a broad, multiple fault zone mapped in the 6-level adit at the Silbak Premier mine (P. Wodjak, personal communication, 1985), which is probably the Slate Mountain fault.

West-dipping foliation is emphasized by flattened angular volcanic fragments in the andesitic tuffs and similar flattened cobbles in the conglomerates. These flattened clasts indicate that many of the faults were ductile in nature and record east-west compression at the relatively elevated temperatures needed to produce semiductile to ductile deformation. Contraction was probably accommodated by a series of ductile reverse faults. Subsequent Tertiary doming due to batholith emplacement produced an extensional regime that reactivated many of these faults, producing west-dipping, extensional, normal faults with relict ductile fabrics in their wallrocks.

Structural History

The structural history of the area is summarized in Table 6. The undulating fold axes of the regional-scale folds

TABLE 6
STRUCTURAL HISTORY OF THE STEWART DISTRICT

Age (Ma)	Structural and Tectonic Events	Other Geologic Events
0–35	♦ Minor fault adjustments ♦ Reactivation of older faults ♦ Minor E-W extension (35)	flood basalts lamprophyre dikes microdiorite dikes
48–52	♦ Regional doming and extension ♦ Normal, west-dipping faults	Hyder batholith and satellite stocks
52–56	♦ NE-SW extension	Granodiorite dike swarms
56–100	♦ Tectonic and magmatic lull	No strata preserved (Probably none deposited) No intrusive rocks (56–150)
100–120	Regional metamorphism (greenschist facies) ♦ Folding, with décollements developed along base of Salmon River Formation (early) ♦ Reverse faults and west-dipping foliation ♦ Mylonites ♦ Pencil lineation (late)	
120–190	♦ Tectonic and magmatic lull (150)	
150–185		Turbidites
185		Subsidence
190	♦ Subduction terminates	
190–210	♦ Convergent margin subduction (190–230)	Subaerial arc volcanism
210–230		Subaqueous arc volcanism

can be attributed to inhomogeneous contraction along nearly horizontal, east-northeast stress/strain axes. The similar geometry of west-dipping ductile shear zones and foliation implies a common origin with the folds during east-west contraction. However, upright folds probably formed early, followed by sequential development of the foliation.

Eocene dike emplacement was accompanied by significant northeast-southwest crustal extension. The north-striking pattern of microdiorite and lamprophyre dikes indicates minor east-west extension in Late Tertiary time.

METAMORPHISM

Regional metamorphic grade throughout the area is lower greenschist facies. Two independent lines of evidence indicate that temperatures reached 290°C at pressures of 450 megapascals (4.5 kilobars) about 110 million years ago.

The key mineral assemblages preserved in the rocks, and other diagnostic minerals that are conspicuous by their absence, are listed in Table 7. Relevant mineral phase transitions are also listed. The pressure-temperature boundaries defined by these equations are plotted on Figure 22 and indicate that the rocks in the region have been metamorphosed to lower greenschist facies. Pressure was 450±150 megapascals (4500 bars ± 1500 bars); temperature was 300°±25°C.

From field relationships, the timing of metamorphism and deformation must lie between deposition of the youngest sedimentary rocks (Bajocian, 175 Ma) and the onset of intrusion of the unmetamorphosed Hyder Plutonic Suite (Early Eocene, 55 Ma). Microscopic textures indicate syndeformational mineral growth, indicating that the physical deformation and thermal metamorphism that affected the region were contemporaneous. Pressure shadows around euhedral pyrite are filled by chlorite or by quartz with minor sericite (Plate 18). Chlorite and quartz crystals are commonly curved, indicating rotation of the stress field, or rotation of the rock within a stress field, during mineral growth.

TABLE 7
METAMORPHIC MINERALS AND PHASE TRANSITIONS

TABLE 7A: Metamorphic minerals identified.

Albite	Leucoxene (?)
Carbonate/Calcite	Prehnite (Brown, 1987)
Chlorite	Pyrite
Epidote	Sericite

TABLE 7B: Metamorphic minerals conspicuous by their absence in petrographic studies.

Biotite (minor primary biotite altered to chlorite)	
Hornblende (abundant primary hornblende altered to chlorite)	
Ca-plagioclase	Glaucophane
Chloritoid	Magnetite
Cordierite	Pumpellyite
Garnet (locally present in small skarn zones)	

TABLE 7C: Bounding univariant equilibria for equations in Figure 22.

1. chlorite+white mica+quartz=cordierite+phlogopite+fluid
2. chlorite+white mica+quartz=cordierite+biotite+Al_2SiO_5+fluid
3. Fe-chlorite+quartz±magnetite=almandine garnet
4. chlorite+albite+tremolite=glaucophane+clinozoisite+quartz+fluid
5. chlorite+zoisite+quartz+fluid=lawsonite+pumpellyite

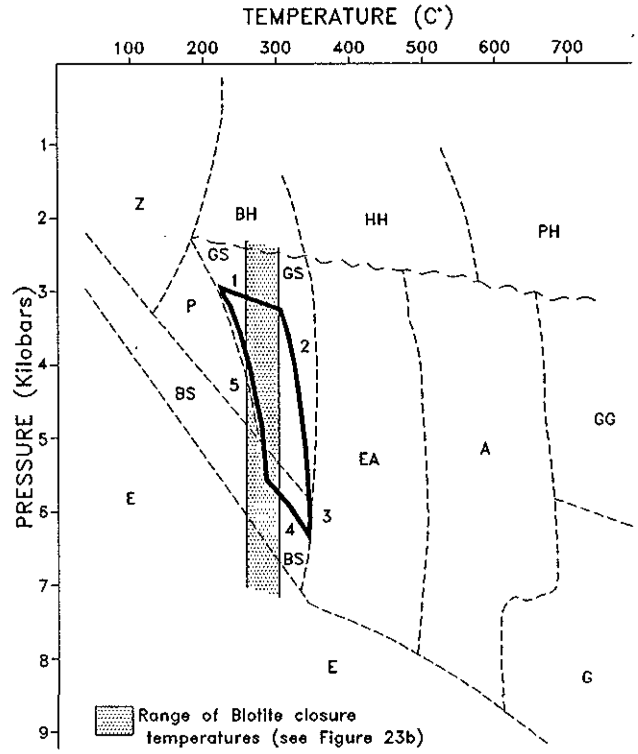


Figure 22. Metamorphic grade in the Stewart mining camp (adapted from Heitanen, 1967, Winkler, 1979, and Cho and Liou, 1987). Numbers refer to bounding univariant equilibria in Table 7C. Z=Zeolite; BH=Biotite hornfels; HH=Hornblende hornfels; PH=Pyroxene hornfels; P=Prehnite; GS=Greenschist; EA=Epidote amphibolite; A=Amphibolite; CG=Cordierite granulite; G=Granulite; BS=Blueschist; E=Eclogite.

One unexpected result of the geochronometry work in this study was determination of the age and maximum temperature of the regional metamorphic event (*see* under "Geochronometry", this chapter). Resetting of potassium-argon dates from biotite, sericite and feldspar indicates a thermal peak of 280°±20°C was reached 110±10 million years ago.

ALTERATION

Alteration is a conspicuous feature in hand samples of all andesitic rocks and some intrusive rocks in the area. At microscopic scale all rocks have alteration effects except some samples of the Hyder Plutonic Suite. This section summarizes the types of alteration assemblages so that they can be readily compared, and indicates their extent, interpreted age and process of formation.

"Alteration" is used in its broadest sense to include metamorphic and surface-weathering products, as some of these features were mapped as hydrothermal alteration in the past. This arrangement also allows comparison and contrast of chloritic assemblages formed by regional metamorphism and geothermal processes.

TABLE 8
CLASSIFICATION OF ALTERATION TYPES BY MINERALOGY, INTENSITY AND EXTENT

KEY: W=Weak; M=Moderate; S=Strong; I=Intense

DIAGNOSTIC MINERALS	REGIONAL (>15 km)	MINING CAMP (5-15 km)	PROPERTY (0.1-5 km)	LOCAL (<100 m)
Chlorite (+ *Pyrite*)	W	M	S	I
Hematite	S		S	
Carbonate	W-M			I
Sericite (+ *Carbonate*) (+ *Pyrite*)			M-S	S-I
Pyrite			M-S	M
Epidote			M-S	W-M
Biotite			S-I	
Hornblende				W-M
Skarn (*calcsilicates*)				S-I

Alteration types are listed according to their extent in Table 8, ranging from regional-scale phenomena affecting hundreds of square kilometres, down to small alteration patches affecting areas of less than 100 square metres. Alteration assemblages are then separated into groups according to interpreted age and process of formation in Table 9.

Alteration extent, intensity and mineralogy are often dependent on lithology, reflecting the permeability, chemistry or paleotopographic position of the host. In the case of focused or channelled hydrothermal fluids, alteration assemblages are primarily structurally controlled but may still have irregular distributions reflecting lithological changes in the wallrock of the structural conduit.

Lower greenschist facies regional metamorphism is indicated by a chlorite-carbonate-sericite-pyrite-epidote mineral assemblage (Table 7 and Plate 18). Macroscopic examination of slabbed rocks shows that metamorphic grade is roughly the same throughout the Salmon River area. Although it is a subjective distinction, regionally metamorphosed tuffs can be readily separated from the more intensely altered hydrothermal propylite zones. Metamorphic alteration is weak to moderate; the colour of fresh rock is medium greenish grey. Propylitized rock is greener, hosts coarser pyrite porphyroblasts and has more calcite and thus a more vigorous reaction to hydrochloric acid.

Strong hematitic alteration characterizes the sedimentary rocks of the Betty Creek Formation, part of the Premier Porphyry Member of the Unuk River Formation, and minor coarse clastic sedimentary lenses within the Upper Andesite Member of the Unuk River Formation. Hematitic alteration in these distinctive brick-red to purple rocks is attributed to subaerial oxidation by meteoric water on the exposed paleosurface.

The Lower Dust Tuff Member of the Mount Dilworth Formation displays **weak carbonate alteration** consisting of 10 to 15 per cent, evenly distributed, fine-grained carbonate. Overlying units are partially to strongly welded and acted as an impermeable cap to circulating groundwater. This carbonate flooding is interpreted as an extensive, shallow carbonate alteration that develops from circulating sulphate and bicarbonate groundwaters that characteristically overlie geothermal systems in andesitic stratovolcanoes (Henley and Ellis, 1983).

TABLE 9
CLASSIFICATION OF ALTERATION TYPES BY AGE AND GENETIC PROCESS

EARLY JURASSIC:

I. BROAD GEOTHERMAL PROCESSES
- At depth; strong chlorite + pyrite
- Shallow; moderate carbonate
- Local strong carbonate flooding

II. FOCUSED HYDROTHERMAL PROCESSES
- Strong; sheared chloritic margin of Texas Creek batholith
- Strong; sericite + carbonate + pyrite bleaching of turbidites
- Intense chlorite in andesites
- Intense sericite + carbonate + pyrite in andesites
- Moderate coarse pyrite in andesites
- Stratabound pyrite in dacites
- Hornblende metasomatism around Summit Lake stock

III. SURFACE WEATHERING
- Strong hematitic alteration of some tuffs and most coarse clastic sediments

MID-CRETACEOUS:

IV. REGIONAL METAMORPHISM
- Lower greenschist facies mineralogy

EOCENE:

V. CONTACT METAMORPHIC, METASOMATIC AND HYDROTHERMAL PROCESSES
- Biotite hornfels
- Skarn
- Epidote

Broad areas of **strong propylitic alteration** are common throughout the mineralized areas of the Unuk River Formation. Strong chloritic alteration and associated euhedral pyrite affect a large area of the Upper Andesite Member from well south of the Silbak Premier mine northwards to the 49, Lila and Harry prospects just south of Summit Lake. Clasts in fragmental volcanic rocks may be selectively epidotized. These large propylitic zones are attributed to deep circulation of chloride-rich brines characteristic of hydrothermal convection cells within recent island-arc andesitic stratovolcanos (Henley and Ellis, 1983).

Strong sericite-carbonate-pyrite alteration forms a distinctive gossanous horizon that extends northwards along Tide Lake Flats from the Millsite fault to the East Gold mine, gradually decreasing in intensity northwestward and fading out at Thomas Creek (Figure 11). The brightly coloured band is composed of thin-bedded black siltstones of the Upper Siltstone Member. It represents a relatively permeable unit that selectively channelled hot fluids northward and southward away from the Summit Lake stock, which intrudes the unit just downstream from the toe of Berendon Glacier.

The pyritic rock has been extensively sampled for assay and is generally barren, but hosts the high-grade veins of the East Gold mine near its northern end, just before the alteration intensity begins to diminish. The alteration process and chemistry are probably similar to structurally controlled sericite-carbonate-pyrite zones to the south, but this zone deserves special attention because of its stratigraphic control and its demonstration of a direct spatial association between the Early Jurassic stock, sericitic alteration and a high-grade gold deposit.

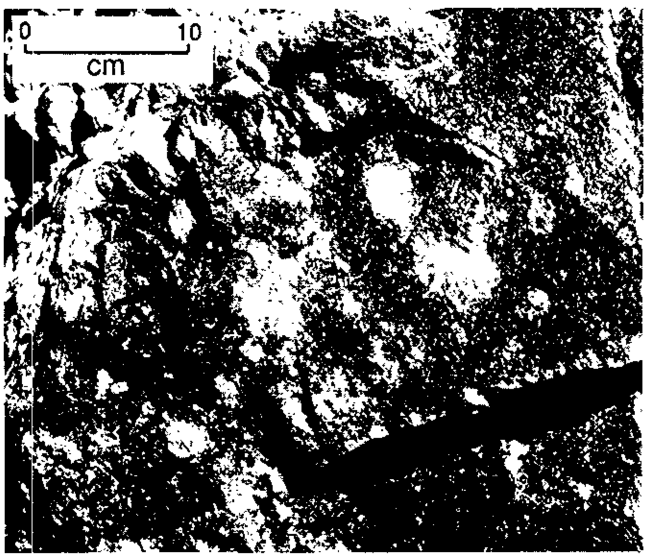


Plate 20. Andesite lapilli tuff. Strongly altered with clasts wholly replaced by yellowish green epidote. Exposure in Silverado Creek, 400 metres below Silverado millsite, Mount Rainey.

Strong chloritic alteration is locallized along much of the eastern contact of the Texas Creek batholith where the margin is crushed and crudely foliated. The alteration is interpreted as synvolcanic geothermal propylitic alteration concentrated in a strongly permeable zone along the margins of the pluton. The crushing and foliation are due to late-stage intrusion and to volume changes in the interior of the large pluton after the outer margin had crystallized.

Strong epidote alteration is pervasive in andesitic to dacitic country rocks around the perimeter of Tertiary plutons. Significant, but less extensive zones of epidote alteration are also common around Tertiary dikes, and are distributed along and around permeable faults or shear zones that have been cut by Tertiary plutons or dikes. Alteration along shears may extend more than 1 kilometre from the intrusion. Alteration is typically fine to medium-grained disseminated epidote that is preferentially weathered from outcrop surfaces, and is only evident in fresh rock and drill core. Close to plutons, lithic fragments may be wholly replaced by epidote (Plate 20). In both intrusive and country rocks, crosscutting narrow veinlets of epidote and minor specular hematite are common within a few metres of the contact.

Strong carbonate flooding is locally preserved within the broad propylitic alteration zones in the massive andesite tuffs. Hand samples are very pale green to off-white and have a bleached or 'silicified' appearance. The rock is quite soft however, and reacts vigorously with hydrochloric acid. Thin sections show groundmass, phenocrysts and fragments are flooded by up to 35 per cent fine-grained carbonate. This alteration is interpreted as remnants of early (shallow) hydrothermal carbonate flooding that have escaped subsequent overprinting by later (deeper) chloride-rich brines as the volcanic edifice grew.

Intense chlorite alteration is common in wallrocks of many ore shoots. It is most evident in the deeper levels of the Silbak Premier mine (Plate 21). At shallower levels this alteration is either absent or overprinted and obscured by

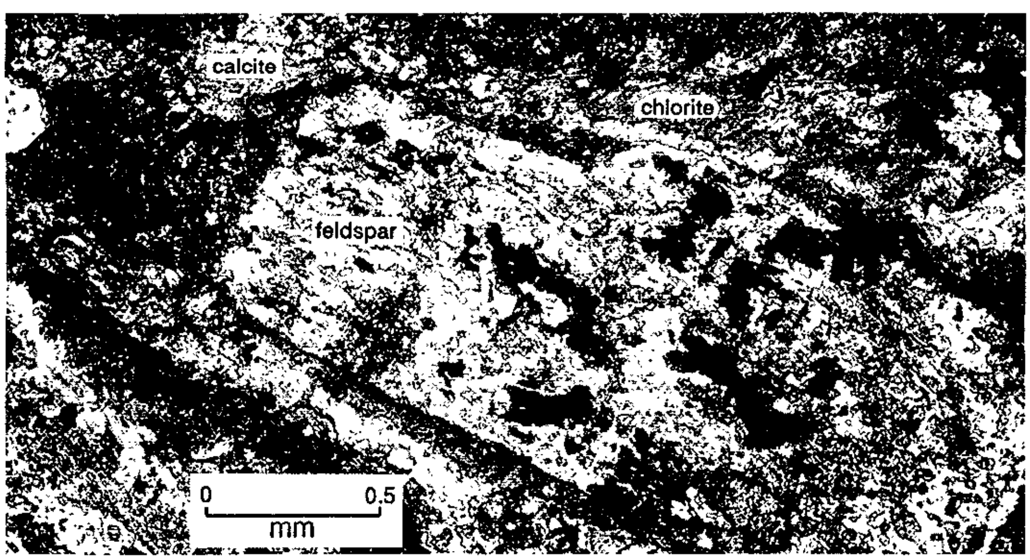


Plate 21. Photomicrograph showing strong chlorite-carbonate alteration in groundmass of Premier Porphyry dike rock. Silbak Premier mine. Plane polarized light (*see* colour photo in back of report).

subsequent sericite-carbonate-pyrite alteration. This classic propylitic alteration is accompanied by up to 5 per cent medium to coarse-grained disseminated euhedral pyrite. It is attributed to intense propylitzation along long-lived fluid channelways. The transition to the broader propylitic envelope of regional greenschist metamorphism is gradational, but the two differing intensities are readily distinguished in hand sample.

Strong sericite-carbonate-pyrite alteration is a characteristic feature of the wallrock at all the deposits in the Big Missouri area, and adjacent to ore shoots in the shallower levels of the Silbak Premier mine. The rocks are strongly bleached to an off-white color and have a silicified appearance, although they are not silicified. Altered wallrocks in the Big Missouri area show progressive alteration of andesitic tuffs (Plate 22). Original rock textures are commonly obscured. The carbonate component is generally more abundant than the white mica, but broken rock tends to fail along the micaceous foliation, creating the appearance of a strongly sericitized rock, sometimes termed sericite schist. Alteration may extend up to 50 metres outward from ore zones and grades abruptly into broad propylitic alteration over distances of only a few metres (Plate 22). This alteration preceeded, accompanied and followed sulphide deposition along long-lived or reactivated channelways within the stratovolcano. It is regarded as typical hydrothermal sericitic alteration introduced by hydrothermal brines at moderate to shallow depths. This assemblage is a common feature in the wallrocks of epithermal ore deposits (Silberman and Berger, 1985).

Dense mats of fine-grained **biotite hornfels** are common in siltstone units cut by plutons of the Hyder Plutonic Suite. Hornfels has a characteristic red-brown to purplish colour and is so fine grained that original bedding is well preserved in most exposures. Biotite hornfels rarely extends more than 100 to 200 metres from the intrusive contact. It is well exposed in the Molly B and Red Reef adits near Stewart, and in the Skookum (Mountainview) adit southeast of the Riverside mine.

Very **coarse grained disseminated pyrite** is distributed over a narrow zone in the wallrocks of ore shoots and subeconomic sulphide zones at the Silbak Premier mine, at many deposits along the Big Missouri Ridge, and at many other prospects and showings. Euhedral crystals range up to 1 centimetre across and have strongly striated surfaces. Quartz inclusions indicate porphyroblastic growth. This pyrite may be an integral part of the associated propyllitic and sericitic alteration in the wallrock, but has a more restricted distribution and may be a useful guide to ore within a broader propylitic or sericitic zone. The pyrite is interpreted to have formed by hydrothermal circulation around structural conduits in the stratovolcano.

Small **skarn** zones have formed where limy beds are cut by Tertiary plutons and dikes. They have limited extent, a few tens of metres long and a few metres thick at most, reflecting the thickness of the original limestone or limy siltstone that has been metasomatized. Zoning includes symmetrically layered coarse-grained garnet-quartz-diopside-tremolite. Good exposures are in the Molly B adit, in the Red Reef adit and elsewhere in scattered outcrops on the lower northwest slope of Mount Rainey. All skarn zones are enveloped by larger alteration zones of biotite hornfels.

In summary, complex, scattered and locally overprinted alteration records four processes that affected the rocks at

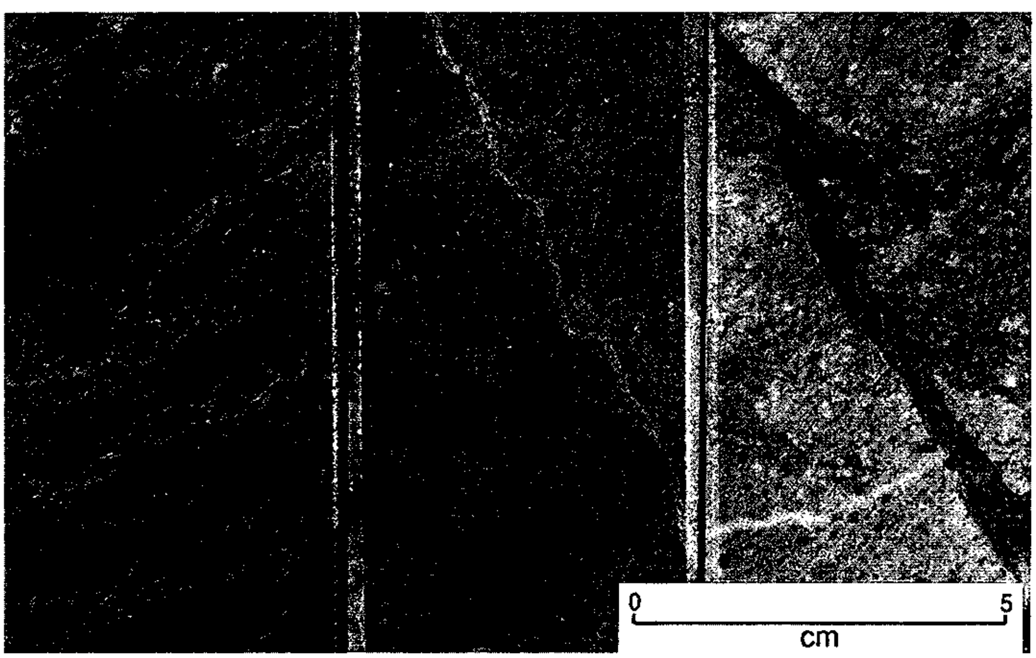


Plate 22. Progressive sericite-carbonate-pyrite alteration (bleaching) of chloritic andesitic lapilli tuff in Dago Hill drill hole at depths of 34, 36 and 37.5 metres respectively. Note variation in lapilli textures. Alteration has virtually obscured lapilli in the most altered sample which is cut by a blue-grey chalcedony and sulphide veinlet. Note abrupt transition from chloritic to sericite-carbonate bleaching in central core piece. Dago Hill deposit, Big Missouri area.

different times, at different intensities and in different volumes:

- Oxidation due to subaerial weathering
- Hydrothermal alteration and related mineralization due to a subvolcanic, synvolcanic geothermal convection system in an andesitic stratovolcano
- Lower greenschist facies regional metamorphism
- Contact metamorphism and metasomatism peripheral to plutons.

GEOCHRONOMETRY

This report presents a revised interpretation of the geologic history of the Stewart area based on new potassium-argon dates and all previously published geochronological data from the district. Isotopic dates from the Stewart mining camp are erratically distributed over a 186 million year range, from Triassic to Oligocene (Table 10). Dates from samples of the same rock unit vary significantly. However, when this broad array of dates is combined with field observations, closure temperatures for argon loss in minerals, and the concept of the "metamorphic veil" (Armstrong, 1966), a simple explanation emerges.

Isotopic dating near Stewart has been reported by Smith (1977), Alldrick *et al.*, (1986), Alldrick *et al.*, (1987a) and Brown (1987). Dates from Smith (1977) and Brown (1987) are listed in Table 10. New potassium-argon dates are listed in Table 11. Uranium-lead dates are presented with analytical data in Table 12.

DISCUSSION

It was hoped that the new potassium-argon analyses would reveal the age of mineralization at the Silbak Premier mine, the Dago Hill deposit near the Big Missouri mine, and the Indian mine. However, significantly different dates were obtained from two samples of altered wallrock from a single diamond-drill hole at the Dago Hill deposit. These results indicate that a simple interpretation of the dates, as direct measurements of the age of alteration and mineralization, is not valid. In addition, contrasting dates obtained by Smith (1977) for hornblende and biotite separates from samples of Texas Creek granodiorite prove that there has been argon loss from at least some mineral phases in these rocks.

Minerals will lose argon gas from their crystal lattices when heated to moderate temperatures over geologically short periods of time (Armstrong, 1966; Dodson, 1973; York, 1984). The lowest temperature at which minerals rapidly lose argon has been termed the "threshold temperature" (Armstrong, 1966), "closure temperature" (Dodson, 1973), and "blocking temperature" (York, 1984) and is largely dependent on mineral type and grain size. Parrish and Roddick (1984) have compiled closure temperatures for mineral phases and mineral groups (Table 13).

Armstrong (1966) argued that temperature increases during regional metamorphism would drive off argon from

TABLE 10
DATES FROM THE STEWART MINING CAMP IN CHRONOLOGICAL ORDER

Apparent Age (Ma)	Rock Unit	Rock Type	Mineral	Analytical Method
*211 ± 6	tcg	Hornblende granodiorite stock	Hornblende	K-Ar
*202 ± 6	tcg	Hornblende granodiorite stock	Hornblende	K-Ar
195.0 ± 2.0	tcg	Hornblende granodiorite stock	Zircon	U-Pb
194.8 ± 2.0	tcg	Premier Porphyry dike	Zircon	U-Pb
192.8 ± 2.0	tcg	Hornblende granodiorite stock	Zircon	U-Pb
189.2 ± 2.2	tcg	Hornblende granodiorite dike	Zircon	U-Pb
186 ± 6	tcg	Hornblende lamprophyre dike	Hornblende	K-Ar
*130 ± 3	tcg	Hornblende granodiorite stock	Biotite	K-Ar
*108 ± 3	tcg	Hornblende granodiorite stock	Biotite	K-Ar
101 ± 3	le	Sericite-flooded andesite tuff	Whole-rock	K-Ar
89.0 ± 3.0	tcg	Sericite-flooded Premier Porphyry	Whole-rock	K-Ar
87.2 ± 3.0	tcg	Sericite-flooded Premier Porphyry	Whole-rock	K-Ar
81.9 ± 2.8	vein	K-feldspar in quartz vein	K-feldspar	K-Ar
78.5 ± 2.8	le	Sericite-flooded andesite tuff	Whole-rock	K-Ar
62.9 ± 2.3	tcg	K-feldspar flooded Premier Porphyry	Whole-rock	K-Ar
54.8 ± 1.3	hqm	Biotite granodiorite dike	Zircon	U-Pb
* 53.8 ± 2.0	hqm	Biotite granodiorite stock	Hornblende	K-Ar
* 52.2 ± 4.0	hqm	Biotite granodiorite stock	Biotite	K-Ar
* 51.6 ± 2.0	hqm	Biotite granodiorite stock	Hornblende	K-Ar
* 50.5 ± 2.0	hqm	Biotite granodiorite stock	Biotite	K-Ar
* 50.4 ± 2.0	hqm	Biotite granodiorite stock	Biotite	K-Ar
* 49.9 ± 2.0	hqm	Biotite granodiorite stock	Hornblende	K-Ar
48.4 ± 1.7	hqm	Biotite granodiorite stock	Biotite	K-Ar
* 47.3 ± 1.0	hqm	Biotite granodiorite stock	Biotite	K-Ar
45.2 ± 1.6	tcg	Hornblende granodiorite stock	Biotite	K-Ar
* 44.8 ± 1.5	hqm	Biotite granodiorite stock	Biotite	K-Ar
42.7 ± 1.5	le	Sericite-flooded andesite tuff	Whole-rock	K-Ar
25.2 ± 1.0	dike	biotite lamprophyre dike	Biotite	K-Ar

* Dates from Smith (1977), recalculated with IUGS decay constants.

TABLE 11
POTASSIUM-ARGON DATES FROM THE STEWART MINING CAMP

Sample No.	Location (Minfile No.)	Mineral or Concentrate	%K	^{40}Ar rad. 10^{-6} cc/gm	$\frac{\%^{40}\text{Ar rad.}}{^{40}\text{Ar total}}$	$\frac{^{40}\text{Ar rad.}}{^{40}\text{K}} \times 10^{-3}$	Apparent Age (Ma) ($\pm 1\sigma$)
Premier G.H.[1] Lat. 56°03.1′ Long. 130°00.7′	Southeast rim of Silbak Premier glory hole (MI 104B-54)	Whole-rock, sericite flooded	6.38±0.09 n=3	22.624	93.1	5.301	89.0±3.0
PM84-29-232′[1] Lat. 56°03.1′ Long. 130°00.7′	Core sample from Premier glory hole area (MI 104B-54)	Whole-rock, sericite flooded	4.92±0.02 n=3	17.079	95.2	5.189	87.2±3.0
PM84-25-369′[1] Lat. 56°03.1′ Long. 130°00.7′	Core sample from Premier glory hole area (MI 104B-54)	K-feldspar, from quartz vein	11.44±0.03 n=3	37.268	94.3	4.870	81.9±2.8
81-58-25′[1] Lat. 56°06.4′ Long. 130°00.7′	Dago Hill zone, Big Missouri camp (MI 104B-45)	Whole-rock, sericite flooded	4.13±0.07 n=3	16.681	89.8	6.038	101 ±3
81-58-68′[1] Lat. 56°06.4′ Long. 130°00.7′	Dago Hill zone, Big Missouri camp (MI 104B-45)	Whole-rock, sericite flooded	4.52±0.03 n=3	14.087	86.0	4.659	78.5±2.8
IM-10[1] Lat. 56°04.6′ Long. 130°01.9′	Galena Cuts zone, Indian mine (MI 104B-31)	Whole-rock, sericite flooded	5.68±0.05 n=5	9.542	87.4	2.511	42.7±1.5
L-2[1] Lat. 56°14.8′ Long. 130°04.3′	Blueberry vein (MI 104B-133)	Hornblende, from lamprophyre dike	0.847±0.017 n=5	6.433	90.9	11.359	186 ±6
A84-1-8[1] Lat. 56°02.0′ Long. 129°55.0′	Roadside quarry on Stewart Hwy.	Biotite, Bitter Creek granodiorite	6.75±0.06 n=5	12.878	79.7	2.852	48.4±1.7
DB-84-25[2] Lat. 56°03.3′ Long. 130°00.5′	Trench 2190 at Premier glory hole	Whole-rock K-feldspar flooded	5.92±0.05 n=2	14.721	82.2	3.717	62.9±2.3
B-383[2] Lat. 55°59.3′ Long. 130°03.8′	Roadcut 2.0 km south of Riverside mine	Biotite, Texas Creek granodiorite	4.17±0.02 n=2	7.416	84.4	2.659	45.2±1.6
AT84-27-5[2] Lat. 56°04.4′ Long. 130°02.4′	Roadcut on east side of Indian Lake	Biotite, lamprophyre dike	7.22±0.01 n=2	7.133	68.0	1.477	25.2±1.0

[1] K analyses by P.F. Ralph and B. Bhagwanani, Ministry of Energy, Mines and Petroleum Resources; D. Alldrick samples.
[2] K analyses by K. Scott, The University of British Columbia; D. Brown (1987) samples.
All Ar analyses by J.E. Harakal, The University of British Columbia.

TABLE 12
URANIUM-LEAD ZIRCON DATES FROM THE STEWART MINING CAMP

Sample No.	Location [UTM]	Sample Properties	Weight (mg)	Concentration Observed (ppm) U	Pb	$\frac{^{206}Pb}{^{204}Pb}$	Atomic Ratios[3, 4] $\frac{^{206}Pb}{^{238}U}$	$\frac{^{207}Pb}{^{235}U}$	$\frac{^{207}Pb}{^{206}Pb}$	Model Ages (Ma)[4] $\frac{^{206}Pb}{^{238}U}$	$\frac{^{207}Pb}{^{235}U}$	$\frac{^{207}Pb}{^{206}Pb}$	Concordia Age (Ma)[4]
A84-1	(130°05′55″W 56°14′00″N)	nm, 150-215µm	16.3	459	13.6	8841	0.03035±16	0.2092±11	0.04998± 07	192.8±1.0	192.9±0.9	194.2± 3.3	192.8±2.0
	[09-432250E 6232320N]	m, <45µm	1.3	1908	55.6	8473	0.02952±16	0.2041±11	0.05014± 09	187.5±1.0	188.6±0.9	201.4± 4.0	
		m, <45µm	1.5	887	26.2	6499	0.02962±16	0.2048±11	0.05015± 13	188.2±1.0	189.2±0.9	202.0± 5.8	
A84-2	(130°03′13″W 56°05′28″N)	nm, >150µm	14.2	349	10.2	8110	0.02979±17	0.2049±11	0.04990± 06	189.2±1.1	189.3±0.9	190.3± 2.8	189.2±2.2
	[09-434400E 6216475N]	m, <75µm	0.3	898	27.8	1278	0.03056±17	0.2101±73	0.04987±162	194.1±1.1	193.7±6.1	189.1±76.0	
A84-3	(130°03′13″W 56°05′28″N)	nm, >150µm	10.5	596	18.6	1839	0.03062±17	0.2113±15	0.05006± 25	194.4±1.0	194.7±1.3	197.7±11.7	195.0±2.0
	[09-434400E 6216475N]	nm, >150µm, abd	4.3	510	15.6	6189	0.03072±16	0.2117±11	0.04999± 09	195.0±1.0	195.0±0.9	194.4± 4.1	
		m, <45µ	1.3	1272	38.3	6639	0.03004±16	0.2078±11	0.05016± 09	190.8±1.0	191.7±0.9	202.6± 4.1	
A84-5	(130°00′50″W 56°03′06″N)	nm, >150µm	5.3	343	10.84	1081	0.03020±16	0.2090±12	0.05018± 17	191.8±1.0	192.7±1.0	203.5± 7.6	194.8±2.0
	[09-436760E 6212240N]	nm, >150µm, abd	2.9	378	11.7	1864	0.03067±16	0.2120±13	0.05013± 19	194.8±1.0	195.2±1.1	201.2± 8.9	
AT-34-3[2]	(130°01′22″W 56°03′02″N)	nm, >150µm	5.0	362.2	4.14	629	0.01064±06	0.0702±05	0.04789± 02	68.2±0.4	68.9±0.5	93.7±10.1	54.8±1.3
	[09-436300E 6212130N]	m, <75µm	1.0	431.2	4.34	226	0.00853±12	0.0554±14	0.04713± 93	54.8±0.8	54.8±1.3	55.6±46.0	

[1] All analyses by J.K. Mortensen, Geological Survey of Canada, Ottawa.
[2] Data provided by R.G. Anderson, Geological Survey of Canada, Vancouver.
[3] The errors apply to the last digits of the atomic ratios.
[4] All errors shown are 1σ errors, except for 2σ errors in final column.
Isotopic composition of blank: 6/4:17.75, 7/4:15.5, 8/4:37.3.
Isotopic composition of common lead is based on the Stacey and Kramer (1975) model: 6/4=11.152, 7/4=12.998, 8/4=31.23 at 3.7 Ga with $^{238}U/^{204}Pb=9.74$, $^{232}Th/^{204}Pb=37.19$. Decay constants: 6/4=0.155125, 7/4=0.98485, 8/4=137.88.

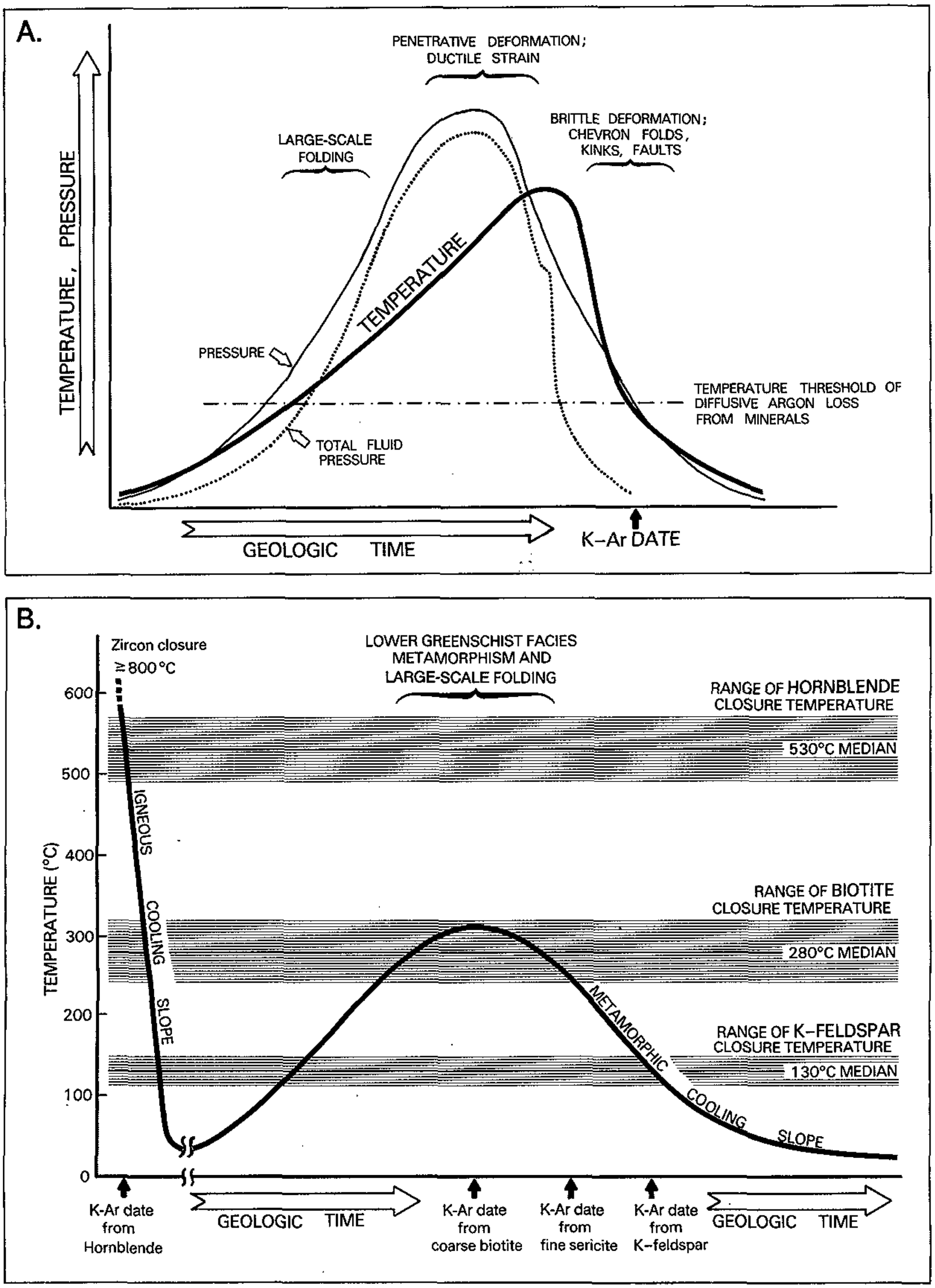


Figure 23. Relationships between temperature, deformation and argon loss versus geologic time, for potassium-argon samples. **A**. Relationships between temperature, deformation and argon loss from minerals in the metamorphic interior of an orogenic belt (from Armstrong, 1966). **B**. Relationships between temperature, deformation and argon loss for minerals dated in the Stewart mining camp.

TABLE 13
CLOSURE TEMPERATURES FOR ARGON LOSS IN MINERALS

Mineral	Closure Temperature
Hornblende	530° ± 40°C
Muscovite	~350°C
Biotite	280° ± 40°C
K-feldspar	130° ± 15°C
Microcline	~110°C

(From Parrish and Roddick, 1984)

many minerals whose potassium-argon dates would then be reset to record only the time of the final cooling of the orogen. If the temperatures were high enough, all potassium-argon dates relating to the pre and syn-metamorphic history of the rocks would be lost or degraded to younger values. This concept of a "metamorphic veil" is illustrated schematically for a high-grade region in Figure 23a. Regional metamorphic grade in the Stewart area was lower greenschist facies indicating a thermal peak of 300°C. From the closure temperatures listed in Table 13, only certain mineral groups should have argon loss during lower greenschist facies metamorphism. Figure 23b shows a schematic diagram which predicts the effects of lower greenschist facies temperatures on potassium-argon dates for a variety of minerals.

Interpretation

Radiometric dates are displayed on Figure 24. This diagram includes uranium-lead dates from zircons which are estimated to have closure temperatures of greater than 500°C and thus are not susceptible to thermal resetting at greenschist facies temperatures. The "date" of a mineral represents the last time the mineral cooled through its closure temperature, whether that temperature drop resulted from original cooling of an igneous magma or from cooling after a metamorphic event.

The broad band on Figure 24 represents the interpreted thermal history of the Stewart mining camp. The fine black lines represent the interpreted thermal history of discrete igneous bodies such as dikes and stocks. The cooling curve after each thermal peak is drawn through the data points, but the thermal peak itself represents the probable age of emplacement. The temperature rise to each thermal peak, and details of any prior, cooler interval, cannot be exactly reconstructed. For igneous bodies the temperature rise can be considered virtually instantaneous – a vertical line, but for the regional metamorphic event the temperature rise is

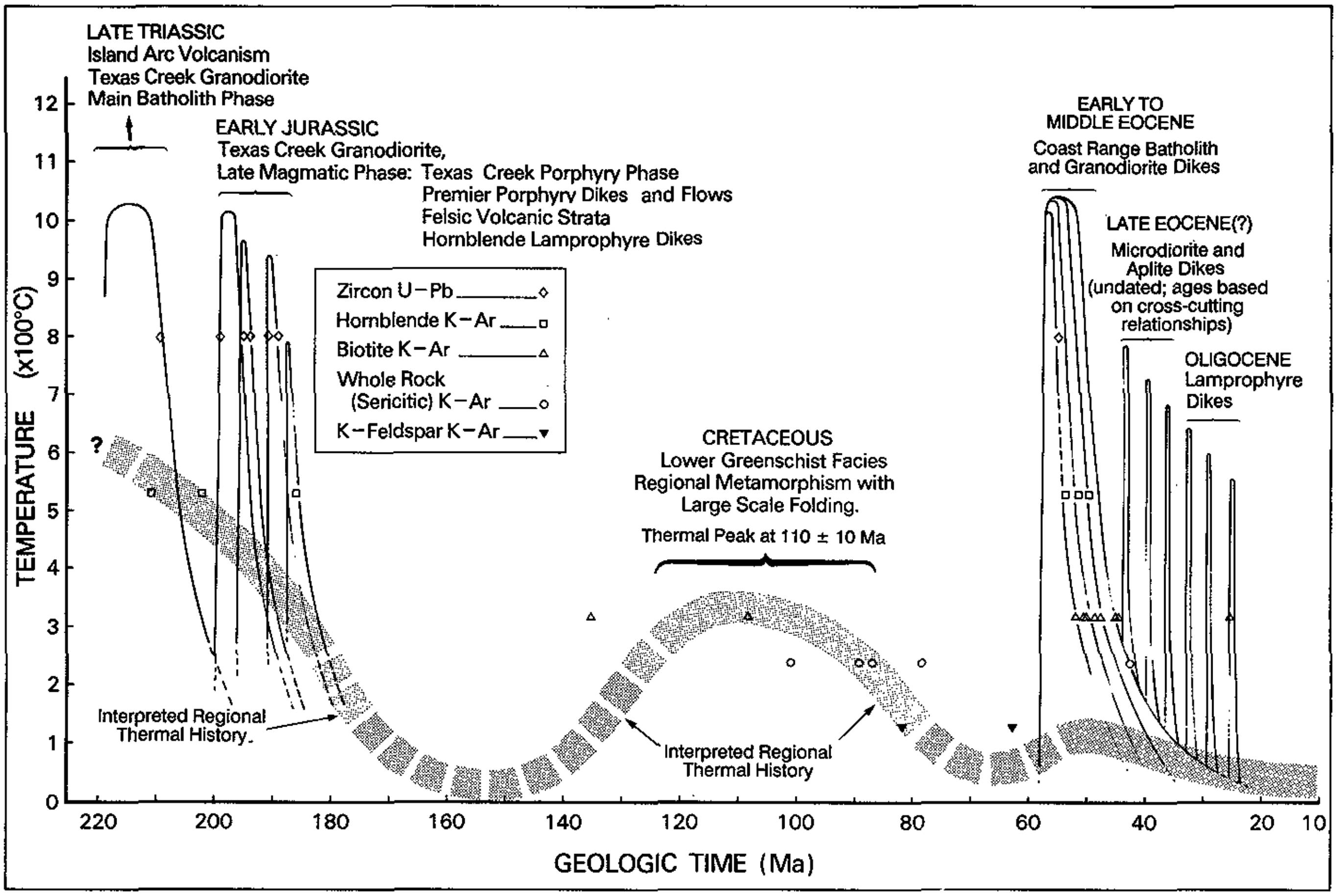


Figure 24. Igneous, metamorphic and thermal history of the Stewart district is revealed in this plot of isotopic dates versus closure temperatures for the minerals dated. All data are listed in Tables 10, 11 and 12.

hidden behind the metamorphic veil and must be hypothetical – a dashed grey band.

Biotite separates from the Texas Creek granodiorite are clearly reset because their potassium-argon dates do not match those for hornblende separates from the same samples (Table 10). Also, the potassium-argon dates for the reset biotites differ by 22 million years even though the dates for the two hornblende separates lie within analytical error of each other. This is interpreted as the result of only partial argon loss from the older biotite (Sample 3S-008 of Smith, 1977). Partial argon loss occurs either when the thermal peak is short lived, such as country rock intruded by a narrow dike, or when it barely reaches a temperature equal to the closure temperature for the mineral. Coarse-grained igneous biotites are estimated to have closure temperatures of 240°C to 320°C and, as the thermal peak of regional metamorphism was probably not a short-lived event, the temperatures during regional metamorphism are inferred to have reached, but not exceeded 300°C. It is also possible that the two biotites had slightly different closure temperatures, or that the maximum temperature during regional metamorphism varied between the sample locations, which were 3 kilometres apart (Smith, 1977). A third biotite separate from the Texas Creek granodiorite, sample B-383 in Table 11, has been dated at 45.2 Ma. This sample was collected near the northern contact of the Hyder stock and the potassium-argon ratio of the biotite has been thermally reset by the Tertiary intrusion.

Two dates for sericite-rich altered dike-rock from the Silbak Premier mine, 87.2 and 89.0 Ma, fall within analytical error of each other and are considered the most representative values for thermally reset sericite dates. The potassium feldspar date from the Silbak Premier mine, 82 Ma, gives a reasonable additional control for the cooling curve after regional metamorphism.

The dates for two sericite-rich altered andesite samples from a single drill-hole at Dago Hill are different, 78.5 Ma and 101 Ma. Thin section study of these two samples reveals that the deeper core sample, which yields the younger date, is composed of sericite and carbonate-altered andesitic ash tuff. The shallower sample is similarly altered andesitic crystal tuff containing large laths of hornblende that have been extensively altered to coarse sericite (Alldrick *et al.*, 1987a). The closure temperature for hornblende is well above the thermal peak reached during regional metamorphism (Figure 23) so the remnant hornblende would probably retain some of the radiogenic argon generated since its original magmatic crystallization. The older date is thus attributed to a mixture of argon from older (Jurassic) hornblende and younger (reset to Cretaceous) sericite.

The formation of the Dago Hill and Silbak Premier deposits must predate the 110±10 Ma regional metamorphic event. Black stylolites of insoluble residue are common within the coarsely crystalline carbonate gangue at several mineral deposits in the Big Missouri camp. These stylolites are pressure-solution features that indicate that the deposits predated regional deformation. Fine to medium-grained euhedral pyrite crystals associated with the alteration envelopes at the Big Missouri deposits exhibit well-developed pressure shadows in thin section (Plate 18), also indicating that the mineralization and alteration predate metamorphism. The age of ore deposition at the Big Missouri, Silbak Premier, Silver Butte, Scottie Gold and similar deposits is estimated at 185 Ma (Chapter 4).

Conclusions

The new data and interpretations presented in this report allow significant revisions to the geologic history of the district (Table 14). When isotopic dates are plotted against mineral closure temperatures, a simple thermal history can be deduced:

1. Late Triassic to Early Jurassic volcanism and coeval subvolcanic intrusion (211 to 190 Ma) was followed by dike emplacement (190 to 185 Ma) and then by turbidite deposition (Toarcian to Callovian, 185 to 160 Ma).
2. Moderate deformation associated with lower greenschist facies metamorphism reached its thermal peak about 110±10 Ma.
3. Stocks and dikes of the Coast Plutonic Complex intruded the deformed rocks in early to middle Eocene time, 55 to 45 Ma, followed by a 20 million year period of aplite, microdiorite and biotite lamprophyre dike emplacement.

TABLE 14
GEOLOGIC HISTORY OF THE STEWART MINING CAMP

Age (Ma)	Event
35-25	Emplacement of biotite lamprophyre dikes.
45-35	Emplacement of microdiorite or 'andesite' dikes along NNW trend, locally deflected by biotite granodiorite dikes.
48-43	Formation of argentiferous galena-sphalerite-freibergite vein deposits and spatially associated MoS_2 and WO_3 deposits.
55-45	Intrusion of Hyder, Boundary, Davis River, Bitter Creek and Mineral Hill stocks of the Coast Range batholith. Biotite granodiorite to biotite quartz monzonite. Continuing dike intrusion.
55	Crustal extension and intrusion of major WNW-trending biotite granodiorite dike swarms marked onset of emplacement of stocks at depth.
110-90	Lower greenschist facies regional metamorphism reaches a thermal peak. Moderate deformation along north-trending fold axes. Major folds and slaty cleavage formed.
190-160	Marine transgression, flysch sedimentation with minor intraformational conglomerates (Unit 4). Relative quiescence.
190-185	Waning magmatic activity marked by emplacement of hornblende lamprophyre dikes at depth.
~190	Subaerial felsic volcanism (Unit 3). Emplacement of dikes at depth. Formation of gold-silver vein and breccia deposits. Deposition of barren pyrite around fumarolic centres at surface.
195-190	Deposition of subaerial epiclastic sediments and interbedded andesitic to dacitic tuffs and flows (Unit 2). (Emplacement of minor dikes at depth?)
195	Intrusion of porphyry phase of Texas Creek granodiorite, Premier Porphyry dikes, and extrusion of Premier Porphyry flows and tuff breccias.
215-195	Andesitic volcanic activity (Unit 1), predominantly subaerial with two periods of marine transgression; coeval intrusion of main phase of Texas Creek granodiorite

SUMMARY GEOLOGIC HISTORY

This section highlights the tectonic processes that have affected the Stewart camp, by combining elements of the geologic history of the study area, established in this report, with the tectonic evolution of Stikinia (Armstrong, 1988).

Basaltic volcanic and sedimentary rocks of the Stuhini Group were laid down on a metamorphosed platform of Stikine assemblage rocks. This was the first phase in the evolution of a single Late Triassic to Early Jurassic arc that evolved from basaltic flows (Stuhini Group) through andesitic volcanism (Unuk River Formation) to dacitic pyroclastics (Betty Creek and Mount Dilworth formations). Each volcanic phase was accompanied by emplacement of subvolcanic intrusions that are preserved as suites of progressively shallower, more siliceous plutons. Compositional evolution over this 40 million year period is attributed to progressive thickening of the crust.

Early Jurassic volcanism was predominantly subaerial. Intervolcanic periods were marked by subsidence, submergence and deposition of turbidites. Re-emergence of each new volcanic edifice was due to swelling over recharged magma chambers and to aggradation of the volcano above sea level. Topographically, the volcano was part of a semicontinuous chain of large and small volcanic islands, similar to the central and eastern Aleutians and to many examples in the southwest Pacific such as the New Ireland - Solomon Islands chain.

Bulk chemistry and prominent hornblende phenocrysts of the Unuk River Formation andesites suggest these lavas erupted along the main axis of an arc. A general northwest trend to Hazelton volcanic centres is suspected (Alldrick, 1989). The arc was established over a Mesozoic subduction zone that is poorly constrained, but probably dipped northeasterly.

Volcanism terminated abruptly in Toarcian time (187 to 185 Ma) with the deposition of the thin, widespread, dacite pyroclastic blanket of the Mount Dilworth Formation. The end of volcanism was followed by subsidence of the subaerial volcanic arc. Sedimentation was initially gritty, shallow-water fossiliferous limestones at the base of the Salmon River Formation, followed by a thick accumulation of carbonaceous turbidites and wackes.

As sedimentary rocks accumulated in the Bowser Basin through the Late Jurassic, final amalgamation of the two superterranes was completed to the west of Stikinia. From 150 to 125 Ma there is a lull in plutonism and volcanism and region-wide gaps in the stratigraphic record that indicate a period of tectonic and magmatic quiescence and widespread emergence and erosion.

In the Early Cretaceous an eastward-descending subduction zone was established well west of Stikinia. The arc was fully developed by the mid-Cretaceous (110 to 90 Ma) when magmatism peaked. Accompanying tectonism was characterized by greenschist faces regional metamorphism, east-northeast contraction, and deformation that produced a north-northwest-trending undulating fold system. Folds were overprinted by east-verging ductile reverse faults that began in the Stewart area and propagated eastward across the Bowser Basin.

Transpression related to oblique subduction during the Late Cretaceous (90 to 70 Ma) may have initiated large, north-striking fault structures such as the Long Lake fault. These faults remained intermittently active into late Tertiary time.

No significant magmatic activity or sedimentation was recorded in Stikinia over the period 70 to 55 Ma, but the following 10 million years, 55 to 45 Ma, spans the final major magmatic episode in the Canadian Cordillera. Plutons emplaced in the Stewart area include the batholith, satellitic stocks and extensive dike swarms of the Hyder suite. Intrusion was preceded and accompanied by northeast extension. Waning magmatism between 45 and 25 Ma was marked by a succession of aplite, microdiorite and lamprophyre dikes, and by reactivation of old faults.

CHAPTER 5 — MINERAL DEPOSITS

The Stewart mining camp is abundantly mineralized, with widely distributed, texturally and mineralogically varied, precious and base metal deposits. Past production data and ore reserves are listed in Table 15.

In the first section of this chapter, empirical geologic criteria are used to sort these numerous mineral occurrences into groups of similar deposit types. The first impression when looking at a mineral deposits distribution map is of the unusually large number of mineral occurrences in the 750 square kilometre study area (Figure 11) and the wide distribution of these showings. The geologic map shows no clear stratigraphic or plutonic controls to distribution. If

TABLE 15
MINE PRODUCTION AND ORE RESERVES IN THE STEWART MINING CAMP
(To January 1, 1992)

Property	Minfile No.	Date	Past Production (tonnes)	Reserves (category)	Au g/t	Ag g/t	Pb %	Zn %	Cu %	WO_3 %
EAST GOLD	104B 033	1939–1954	44		1207.00	3 313.00	4.80	1.30	0.07	
SCOTTIE GOLD	104B 034	1981–1985	197 522		16.50	16.00				
		1985(U)		132 000 (g)	19.20	17.00				
		1990(U)		28 992 (m)	18.51					
SPIDER	104A 010	1925, 1933–1936	22.2		14.20	8 238.00	3.50	3.90		
MARTHA ELLEN	104B 092	1987		1 576 449 (g)	2.26	27.43				
SILVER TIP	104B 043	1915, 1950, 1951, 1957	26		11.80	2 610.00	14.00	19.00		
		1956(U)		816 (g)	4.80	970.30	4.20	6.20		
NORTHSTAR	104B 146	1987		47 078 (g)	4.29	20.57				
S-1	104B 084	1987		1 209 709 (g)	2.71	7.20				
		1990	304 000		2.40	10.00				
		1991		800 000 (g)	2.20	10.00				
CREEK	104B 086	1987		7 529 (g)	2.40	116.23				
BIG MISSOURI	104B 046	1938–1942	768 943		2.37	2.13				
DAGO HILL	104B 045	1934, 1950	14		48.00	3 952.00	0.46		0.12	
		1987		557 141 (g)	2.54	38.06				
		1988-1989	384 000		1.20	10.00				
		1991		150 000 (g)	1.20	10.00				
PROVINCE	104B 147	1987		286 734 (g)	2.43	12.69				
		1990	33 300		2.46	21.88				
		1991		100 000 (g)	1.50	20.00				
SILVER BUTTE	104B 150	1991(U)		96 209 (m)	9.91	65.90	0.67	3.85	0.32	
		1991(U)		279 387 (g)	17.31	36.69				
		1991	102 539		8.89	55.50				
INDIAN	104B 031	1925, 1952	12 870		3.40	119.70	4.40	5.50		
SILBAK PREMIER (includes SEBAKWE and B.C. SILVER)	104B 054, 104B 153, 104B 155	1919-1953, 1959–1968,	4 276 714		13.00	274.00	0.66	0.20		
		1989(O)		6 500 000 (m)	2.16	80.23				
		1990(O)		3 388 900 (m)	2.51	67.73				
		1990(U)		851 000 (m)	7.50	34.84				
		1991(O)		945 000 (m)	2.80	41.30				
		1988-1991	1 060 593		2.27	67.00				
		1992(U+O)		4 900 000 (g)	2.00	20.00				
RIVERSIDE	104B 073	1925, 1927, 1941–1950	26 437		2.89	102.10	3.90		0.13	0.12
DUNWELL	103P 052	1926–1941	45 710		6.72	224.40	1.83	2.43	0.03	
UNITED EMPIRE	103P 050	1925 1934, 1936	163		2.10	1 136.70	7.40			
MOLLY B	103P 085	1940, 1941	290		2.36	12.01			0.72	
SILVERADO	103P 088	1927	13			3 662.40				
PROSPERITY/ PORTER IDAHO	103P 089	1922 1924–1932, 1938, 1939, 1947, 1950, 1981	27 268		1.00	2 692.97	5.10	0.03	0.10	
		1989(U)		826 400 (g)		668.50	2.50	2.50		

U = underground
O = open pit

g = geological
m = mineable

stratigraphy, plutonic associations or structural settings are used to separate out 'groups' of deposits, deposits of different ages are present within most of these divisions (Table 16, in pocket). Deposit classifications based solely on ore mineralogy, stratigraphic position, plutonic association or structural setting do not work in the Stewart mining camp and are probably not reliable anywhere in the region.

Examples from each deposit-type group are described in the second section of this chapter. These are good *examples* of the different deposit types, but they should not be regarded as "type deposits". Comparison of the features of the Big Missouri and Silbak Premier deposits shows that there can be variations between deposits within one deposit-type group.

LEAD ISOTOPE STUDIES

In 1986, a suite of galena samples, representing ten deposits on eight properties, was submitted for lead isotope analysis. The results of this work, reported in Alldrick *et al.*, (1987b), were so unexpected and definitive that additional samples were immediately processed. This section presents galena lead isotope data from 21 mineral occurrences on 18 properties in the Stewart area.

Occurrence locations are shown on Figure 11. Table 17 presents a summary of the galena lead isotope data. The complete data set of 88 values is tabulated and plotted in Alldrick (1991).

Small lead isotope data sets are useful for indicating relative age relationships among deposits, and between deposits and hostrocks. Such 'fingerprint' interpretation of lead isotope data is a simple but powerful tool when combined with other geological data. The following interpretations are derived in Figures 25 and 26:

- The position of the data clusters in Figures 25 and 26 indicates that all deposits sampled in this study are Phanerozoic, and probably post-Paleozoic.
- Comparing relative positions of the two data clusters with the progressive evolution of lead isotope ratios shows that the galena from deposits in Cluster 2 are significantly younger than galena from Cluster 1 deposits. This relative age relationship is consistent with interpretations based on geological evidence.
- The two clusters of data shown in Figure 26 clearly define two separate metallogenic events in the Stewart area.
- The tightness of the two data clusters indicates that each ore-forming event was a short-lived episode in geologic time, drawing homogeneous lead from a uniform or well-mixed or well-sampled source rock(s).
- Both data clusters represent deposits that are distributed over a 30-kilometre strike length, thus the two metallogenic events that formed these deposits were both regional-scale phenomena.
- Although the Indian and Silbak Premier mines are less than 2 kilometres apart, the data indicate these deposits formed at significantly different times, with the Indian mine being the younger of the two.

The lead isotope data support the interpretation of Jurassic and Tertiary metallogenic epochs based on field studies and geochronology reported in Chapters 3, 4 and 5. The two ore-forming episodes were not closely related genetic processes. Specifically, Cluster 1 deposits formed cogenetically with calcalkaline Hazelton Group volcanic

TABLE 17
GALENA LEAD ISOTOPE DATA

B.C. MINFILE Number	Deposit or Camp Name	Mineral Occurrence	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	B.C. LEADFILE Number
104B-086	BIG MISSOURI GROUP	Creek	18.820	15.615	30415-006
104B-148		Calcite Cuts	18.858	15.646	30415-002
104B-002		Terminus	18.823	15.609	30415-007
104B-092		Martha Ellen	18.826	15.615	30415-AVG
104B-092		Hercules, Dumas	18.734	15.612	30415-013
104B-147		Province	18.824	15.604	30415-AVG
104B-136		Province West	18.781	15.643	30415-005
104B-034	SCOTTIE GOLD		18.804	15.608	30493-001
104B-054	SILBAK PREMIER GROUP	Glory hole	18.836	15.617	30494-006
104B-053		Northern Lights	18.828	15.607	30494-AVG
104B-054		2-Level portal	18.837	15.619	30494-AVG
104B-095	CONSOLIDATED SILVER BUTTE	Silver Butte	18.820	15.612	30495-AVG
			18.82	**15.62**	**CLUSTER AVERAGE**
103P-089	PROSPERITY/PORTER IDAHO		19.121	15.622	30492-AVG
104A-010	SPIDER		19.085	15.609	30616-001
104B-095	CONSOLIDATED SILVER BUTTE	Packer fraction	19.177	15.629	30720-001
103P-051	BAYVIEW		19.152	15.620	30765-AVG
103P-088	SILVERADO		19.159	15.640	30766-AVG
104B-369	START		19.134	15.638	30923-AVG
104B-031	INDIAN		19.155	15.623	30939-AVG
103O-001	JARVIS (HOWARD)		19.168	15.625	50055-AVG
104B-073	RIVERSIDE		19.176	15.639	50058-AVG
			19.15	**15.63**	**CLUSTER AVERAGE**

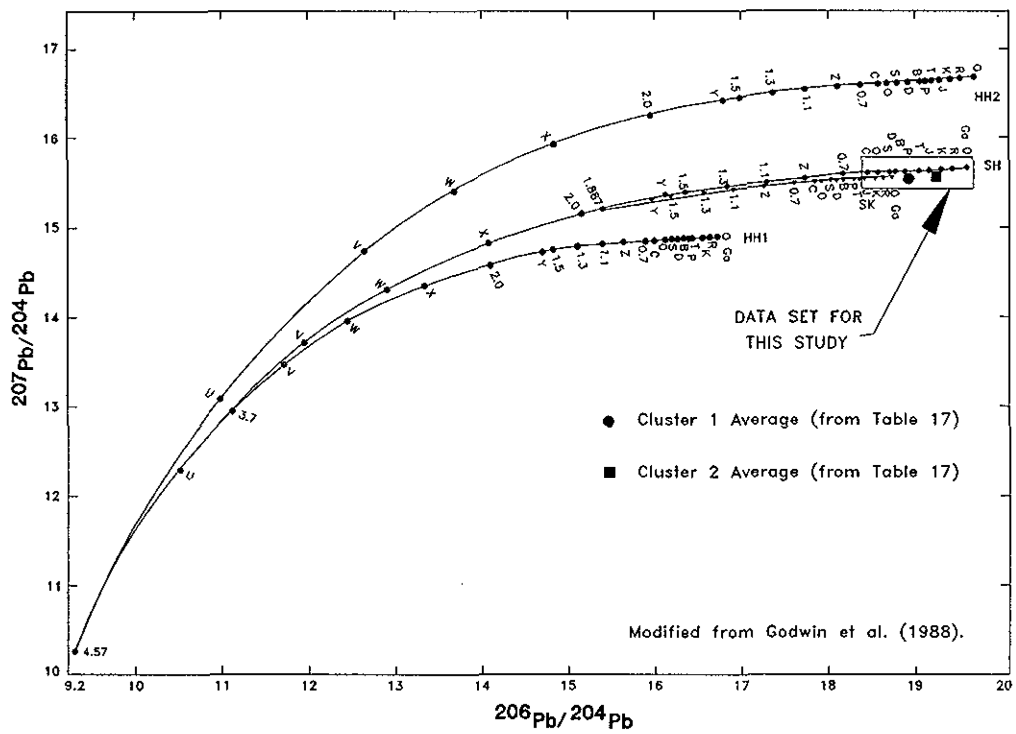


Figure 25. Growth curve for lead isotope evolution suggests relatively recent ages for the data in Table 17 and Figure 26. Lead evolution curves are for the models of Holmes (1946, 1947) and Houtermans (1946) (HH1 and HH2), Stacey and Kramers (1975) (SK), and Godwin and Sinclair (1982) (SH). Ages are $\times 10^9$ years. Note that curve SK evolves from 3.7×10^9 years on curve HH1, and that curve SH departs from curve SK at 1.887×10^9 years.

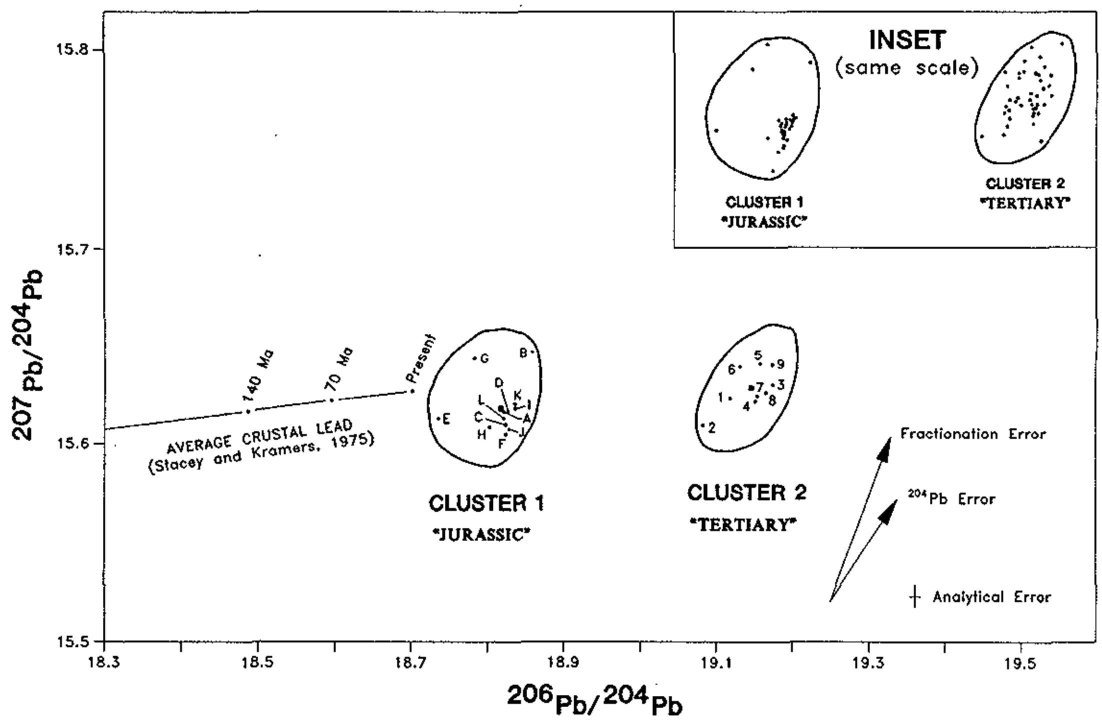


Figure 26. Lead isotope plot of averaged galena lead isotope analyses for each mineral occurrence listed in Table 17. Inset shows plot of all galena lead isotope analyses. Lead evolution "growth curve" is from the model developed by Stacey and Kramers (1975). Ages are in millions of years. Analytical error is 2σ. Square symbols represent group means. A-Creek; B-Calcite Cuts; C-Terminus; D-Martha Ellen; E-Hercules; F-Province; G-Province West; H-Scottie Gold; I-Glory Hole; J-Northern Lights; K-2 Level Portal; L-Silver Butte; 1-Prosperity/Porter Idaho; 2-Spider; 3-Packer Fraction; 4-Bayview; 5-Silverado; 6-Start; 7-Indian; 8-Jarvis; 9-Riverside.

rocks of the Stikinia Terrane about 190 million years ago. Cluster 2 deposits are epigenetic veins related to Eocene intrusion of dominantly granodioritic plutons. The deposits of Cluster 1 include both gold-silver-pyrrhotite veins, such as the Scottie Gold deposit, and silver-gold-lead-zinc-copper deposits such as Silbak Premier orebodies. In contrast, deposits of Cluster 2 are silver-lead-zinc veins characterized by high silver grades and by spatially associated molybdenum (Mountainview) or tungsten (Riverside) occurrences.

Both data clusters are enriched in ^{206}Pb relative to average crustal growth curves such as the Stacey and Kramers (1975) model curve (Figure 26), consequently the positions of the 'Jurassic' and 'Eocene' clusters of data from this study are substantially at odds with 'absolute' ages indicated on the Stacey and Kramers (1975) model growth curve. This is an example of the local inadequacy of the various world average lead isotopic growth curves for absolute dating of mineral deposits. The Stewart leads have evolved in a uranium-rich environment for a significant portion of their recent history.

For prospect classification, lead isotope analysis from galena in a small exposure or in a weakly mineralized vein would indicate whether the mineral occurrence was related to the earlier gold-silver (±base metal) event or to the later silver-lead-zinc(-molybdenum-tungsten) mineralizing episode. In the Stewart area, routine lead isotope analysis would be a practical aid for exploration programs focused on specific metals. The method is an effective technique for evaluating the commodity potential of a mineral showing or for setting exploration priorities on large claim groups that cover several varied mineral occurrences.

Lead isotope data from the Stewart mining camp do not provide absolute age dates for the formation of mineral deposits, but are consistent with dates determined by other methods. The formation of 21 varied mineral deposits can be attributed to just two mineralizing events: one in Early Jurassic time and one in Eocene time. Both metallogenic epochs were brief, regional-scale phenomena. Deposits from the younger mineralizing episode may be emplaced adjacent to or superposed on older deposits.

DEPOSIT CLASSIFICATION TABLE

A variety of geological parameters were applied as classification criteria for the sorting of mineral occurrences (Table 16). The criteria were necessarily empirical – it was essential to first separate out groups of similar deposits before an attempt was made to summarize the distinctive characteristics of each group and to deduce processes of formation for each deposit type.

Twenty-one occurrences were first sorted into two groups using lead isotope data as a "primary" diagnostic characteristic, but the lead isotope signature is just one of several distinctive geological features of the two deposit groups (Table 18). For these same 21 deposits, "secondary" diagnostic or characteristic features of the Jurassic and Tertiary deposit groups were identified (Tables 16 and 18). Ultimately, 45 secondary diagnostic features were recognized. Once these other characteristic features were determined, all 186 remaining showings in the area could be categorized as Early Jurassic or Eocene deposits without resorting to additional lead isotope work. Analysis of these features allowed separation of the 207 mineral occurrences into five groups with similar characteristics. The resulting sorted chart is presented as Table 16 (in pocket) and summarized in Table 18. Features and genesis of deposits from each of the five deposit-type groups are described in the next section.

Empirical classification criteria do not indicate genetic processes but they do divide the wide variety of mineral deposits in the Stewart mining camp into only a few groups, each with readily recognizable diagnostic features. Once deposits had been sorted into groups with common characteristics, other more complex, poorly documented features also proved to be diagnostic. For example, the style, intensity and mineralogy of associated alteration envelopes seemed too variable; too erratic and too poorly documented to be useful diagnostic criteria during this study, but there are characteristic alteration minerals or mineral assemblages associated with each of these deposit-type groups.

EARLY JURASSIC DEPOSITS

Early Jurassic deposits have lead isotope ratios consistent with a Jurassic age; other geologic features of these deposits indicate a more specific late Early Jurassic age. Some of these deposits have been identified as Triassic, Jurassic, Eocene and even Oligocene age deposits prior to this study, most were not categorized.

GOLD-PYRRHOTITE VEINS: SCOTTIE GOLD MINE

The Scottie Gold mine lies on the east side of Morris Summit Mountain at 1100 metres elevation (Figure 11). The showings were first staked in 1928. Trenching, diamond drilling and several phases of underground development were carried out between 1931 and 1948. There was no further physical work until the Northair Group optioned the ground in 1978. Production started on October 1, 1981 and continued until February 18, 1985.

GEOLOGIC SETTING

Ore zones are hosted in andesitic volcanic rocks near the eastern edge of a large hornblende granodiorite stock. Host-rocks are matrix-supported andesitic tuff breccias and lapilli tuffs with intercalated ash tuffs, volcanic sandstones and volcanic conglomerates of the Middle Andesite Member of the Unuk River Formation. Massive tuffs vary from coarse ash tuffs to fine-grained crystal-rich tuffs composed of plagioclase and plagioclase-pyroxene-hornblende phenocrysts. Two kilometres northeast of the mine, thin-bedded siltstones trend north, dip vertically and have tops to the east; two kilometres west of the mine, several outcrops of thin-bedded wacke strike southeast, and dip steeply northeast with tops to the northeast. No bedding has been recognized within the mine workings.

The mine sequence is intruded on the northwest by the Summit Lake stock, a coarse-grained equigranular to subtly

TABLE 18
DIAGNOSTIC FEATURES OF STEWART MINERAL DEPOSITS (From Table 16)

DIAGNOSTIC FEATURE CATEGORIES	DEPOSIT TYPES				
	EOCENE DEPOSITS		JURASSIC DEPOSITS		
	Skarns	**Ag-Pb-Zn Veins**	**Au-Pyrrhotite Veins**	**Au-Ag-Base Metal Veins**	**Stratabound Pyritic Dacites**
Pb:Pb Ratio		'Eocene' cluster	'Jurassic' cluster	'Jurassic' cluster	
Au:Ag Ratio		>1:200, <1:10,000	>1:1, <1:5	>1:5, <1:200	
Ore Minerals		scheelite dominant galena-sphalerite minor pyrite	massive pyrrhotite-pyrite arsenopyrite trace chalcopyrite electrum	dominant pyrite minor chalcopyrite electrum gold polybasite	
Gangue Minerals		ankerite	calcite chlorite	calcite chlorite K-feldspar chalcedony carbon	
Ore Textures		medium to coarse-grained massive aggregates	metamorphic overprint	cryptocrystalline to fine-grained zones laminated comb quartz book structure colloform vuggy growth zones (cockade) metamorphic overprint	
Vein Textures		massive veins rare vugs	metamorphic overprint	coarse quartz-calcite intergrowths chalcedony clasts ore clasts vein clasts vuggy abundant primary fluid inclusions chalcedony veinlets metamorphic overprint	
Alteration	skarn hornfels epidote	hornfels epidote rare minor pyrite	pyrite envelope chlorite envelope silica	pyrite envelope broad chlorite envelope silica sericite K-feldspar carbonate	
Structures	stratabound	massive, tabular veins (southeast strike, subvertical) dike margin (granodiorite)	en echelon veins metamorphic overprint	vein stockworks, breccia veins dike margin (Premier Porphyry) disseminated metamorphic overprint	stratabound disseminated metamorphic overprint
Hostrock	? Lower Slst. Mbr. Hyder batholith ? Boundary stock	Salmon River Fm. Mount Dilworth Fm. Betty Creek Fm. Premier Porphyry Mbr. Middle And. Mbr. Lower Slst. Mbr. Hyder batholith ? Boundary stock Portland Canal dike swarm Boundary dike swarm granodiorite dikes	Middle And. Mbr. Premier Porphyry dike Blueberry dike Summit Lake stock	Premier Porphyry dike Blueberry dike	Mount Dilworth Fm.

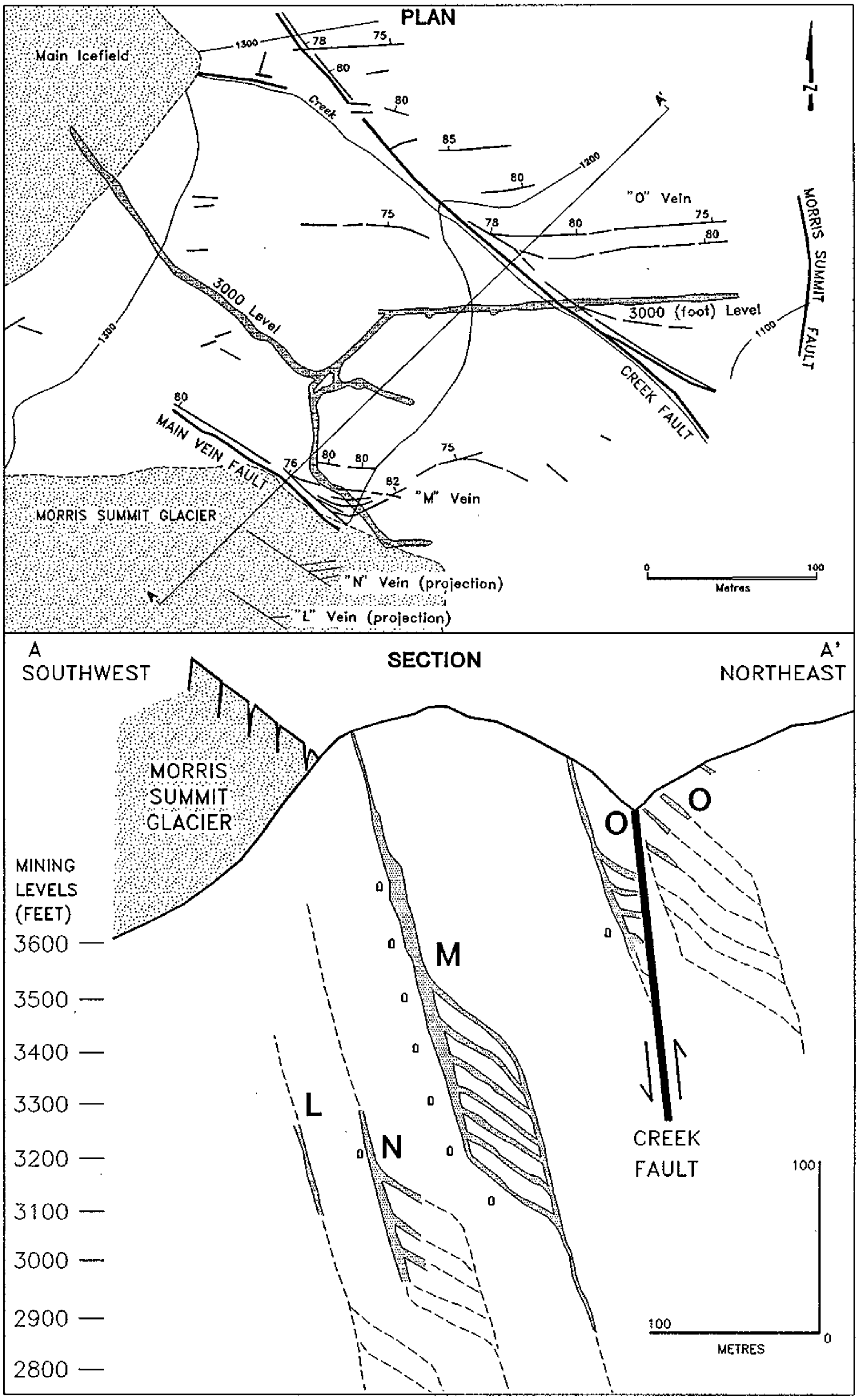


Figure 27. Geologic map and cross-section through the Scottie Gold mine. Map shows the distribution of veins on surface. Country rock is massive andesite tuffs. 3000-level underground workings for reference. (Simplified from company plans.)

potassium feldspar porphyritic hornblende granodiorite. It crops out 500 metres to the west of the mine workings. The pluton has not been intersected in drill holes or underground workings so the closest approach to the ore zones is unknown, but is probably less than 500 metres. Contact relationships indicate relatively passive emplacement, but the pluton has produced a distinctive metasomatic alteration assemblage. Near the contact with the stock, andesites are bleached and impregnated with fine to very coarse grained accessory hornblende (up to 3 cm long) and minor fine pyrite. Bleaching is due to carbonate±sericite flooding.

Country rock and ore zones are cut by green microdiorite dikes and dark brown lamprophyre dikes of the Berendon dike swarm. Lamprophyre dikes are spessartite with fresh, fine hornblende phenocrysts and calcite-filled amygdules.

The Morris Summit fault is a regional-scale structure (Figure 11) that trends north-northwest through the mine area between the 3000-level and 3600-level portals, dipping southwest at 30° to 45°. The fault lies east of the ore zones. There is no consensus about the absolute displacement across this major fault. Specific geological features support arguments for normal, reverse and dextral strike-slip movement. In plan, the relative sense of offset is dextral. Resolution of this problem is an important key to exploration along its eastern side. Several small crosscutting faults mapped in the mine workings do not significantly displace mineralization.

OREBODIES

Ore zones on the Scottie Gold property are vein networks locallized within four complex, subparallel shear or fracture zones (Figure 27). The vein networks are major structures striking about 130° and dipping 75° to 80° northeast. The L, N and M Zones have a horizontal separation of about 50 metres; the O Zone is roughly 110 metres farther to the northeast. The greatest ore production has come from M Zone which is described here. Other zones had similar sulphide and gangue mineralogy and ore grades, but were generally narrower with less complex structure.

M Zone is two parallel vein structures: the West Vein (Main Vein West, West Mine Vein, McLeod West Zone), and the East Vein (Main Vein East, East Mine Vein, McLeod East Zone). These two major veins are connected by 'rungs' of many narrower veins, called the Sixties Veins (Figure 28). Local flexures or rolls are common; the attitude of the West Vein averages 130°/75°NE overall, but orientation in the 36-95 stope is 145°/63°NE. Sixties Veins trend and dip 060°/80°NW. The M zone extends vertically at least 450 metres from surface at 1280 metres elevation to the deepest drill-hole intersections at 830 metres elevation. It is at least 150 metres long, but along its northwestern 100 metres, the Main Vein West is 10 centimetres to 1 metre wide with only erratic gold values. The productive section of the M Zone is roughly 40 metres long on every mine level.

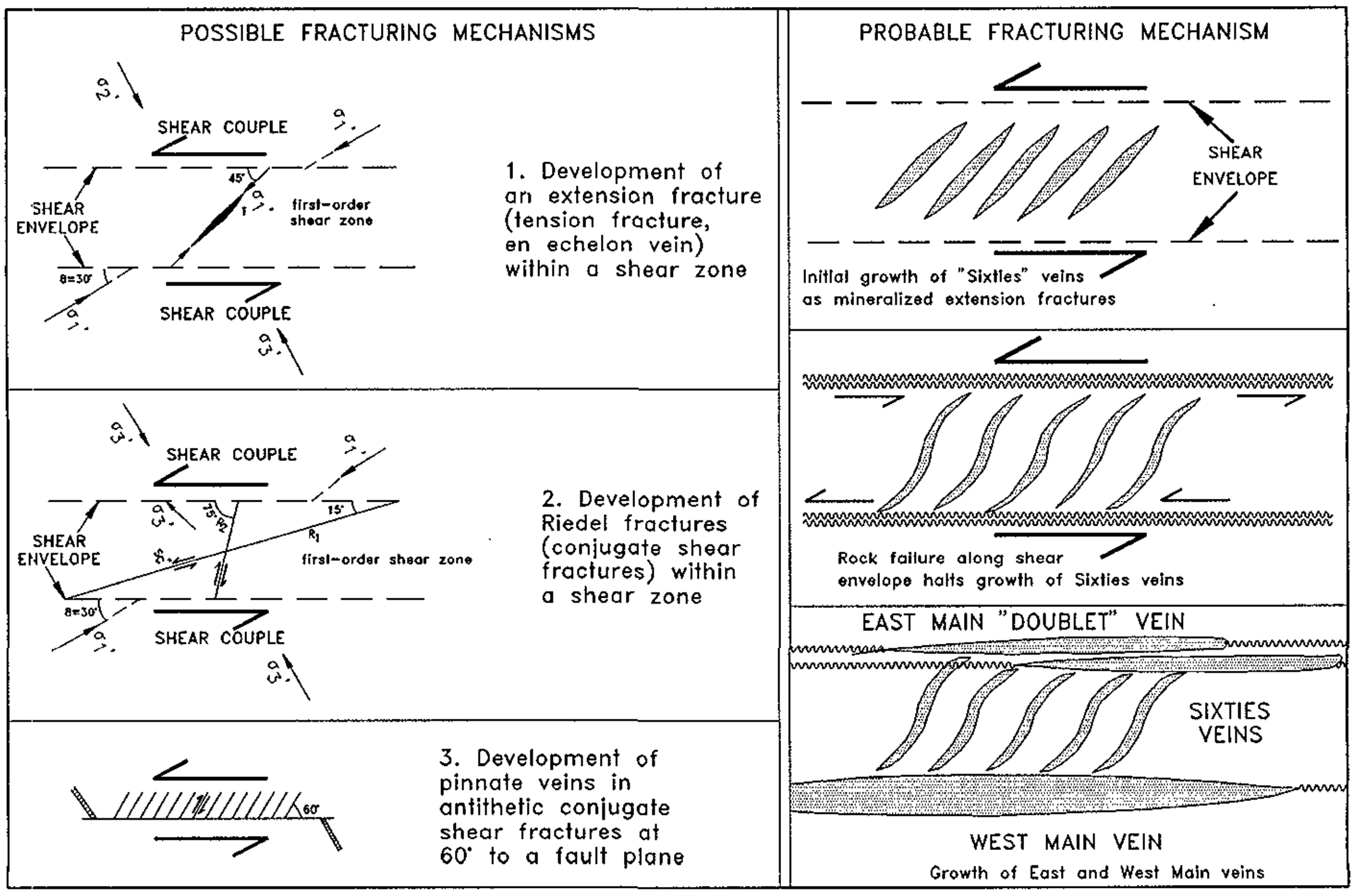


Figure 28. Possible and probable fracturing mechanisms controlling vein formation at Scottie Gold mine (modified from Hancock, 1972 and Hodgson, 1989).

West Vein is a simple, massive vein deposit with a moderate alteration envelope, whereas the East Vein is more complex, showing small-scale structural control and a more intense alteration envelope (Figure 28 and Plate 23). The minor but mineralized Sixties Veins, connecting the two major veins, commonly constitute ore. There are enough differences among the West Vein, East Vein and the interconnecting Sixties Veins that they are described separately.

The West Vein is the most massive, regular vein in the mine (Plate 24), averaging 5 metres in width and locally reaching 7 metres. On every mine level, it trends southeastward until it rolls away to a 110°-trend at the southeast end of the mine where gold values abruptly decrease and the vein breaks up into horsetails and disappears. The northwest limit of the West Vein has not been determined, but the vein is at least 150 metres long.

The core of the vein is massive, fine-grained, distinctly pinkish to bronze-coloured, nonmagnetic pyrrhotite with little or no associated pyrite. The only other component is minor scattered knots or blebs of quartz, calcite and chlorite. This core zone ranges from 4 to 6 metres wide along the productive part of the vein. The immediate margins of this

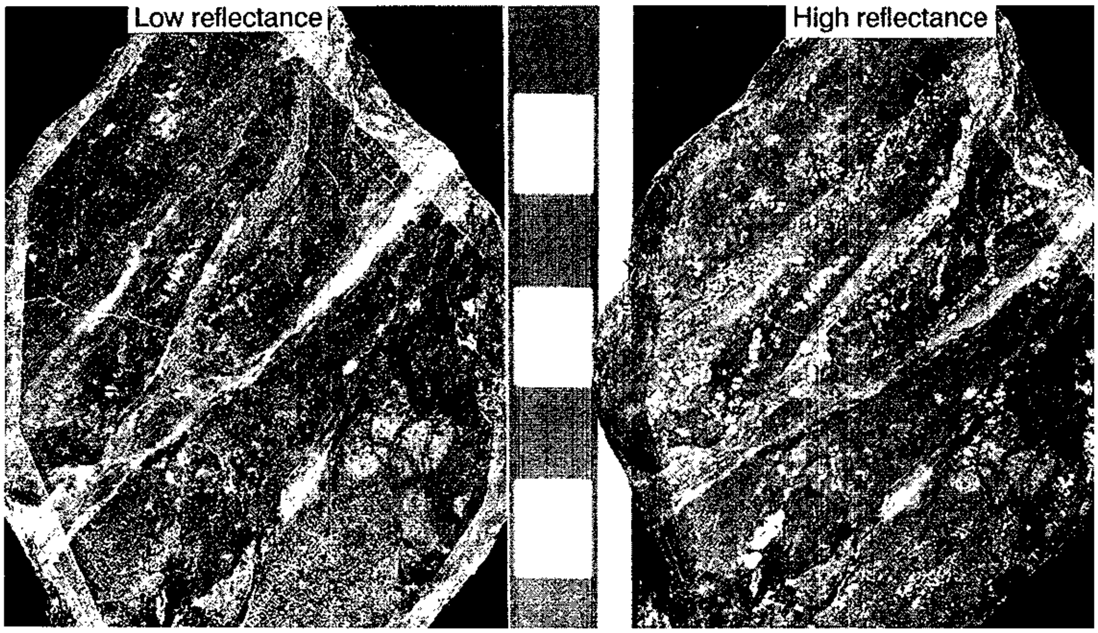


Plate 23. Sheared and altered wallrock, Scottie Gold mine. **A.** Low reflectance view of strongly sheared wallrock shows rich pink to coral manganese carbonate alteration (rhodochrosite). **B.** High reflectance view shows distribution of sulphide trains, mainly pyrite, within this sheared, altered wallrock (*see* colour photo in back of report).

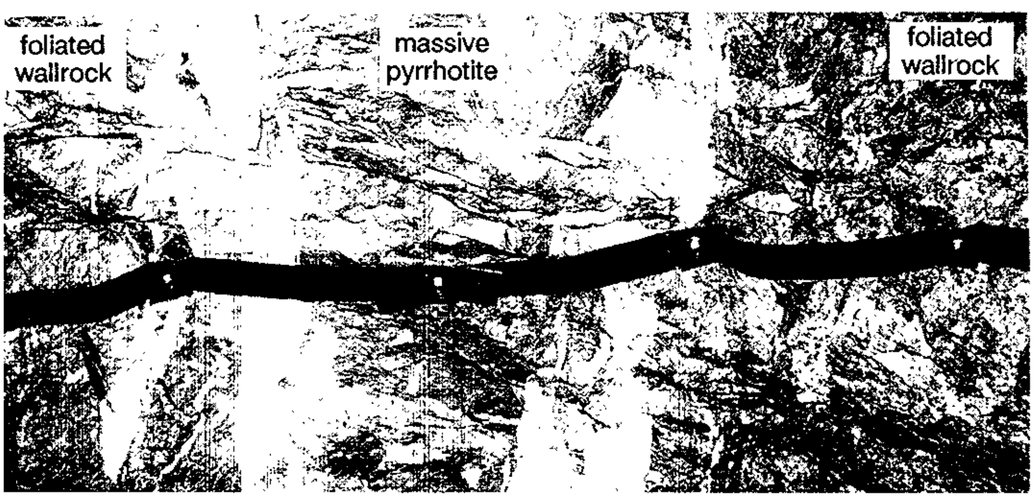


Plate 24. The M Vein (Main Vein West) in the back (roof) of a drift along 3600-level, Scottie Gold mine. Note perfect symmetry of the massive pyrrhotite core and quartz-sulphide marginal zones. Pods, blebs and lenses of pyrrhotite are also present in foliated wallrock. Strapping is 15 centimetres wide.

pyrrhotite core consist of overprinted swarms of quartz-carbonate veins and veinlets hosting accessory to minor pyrrhotite, pyrite, sphalerite and galena with intervening wallrock fragments or inclusions that are intensely altered to sericite, carbonate and chlorite. These marginal vein swarms are typically 0.5 to 1 metre wide on both sides of the massive pyrrhotite core. Gold values within this marginal rock are erratic and only locally make ore.

The East Vein is narrower and more erratic than the West Vein and can be seen to pinch and swell, and bifurcate, along its overall 130° trend, parallel to the West Vein. In detail this vein is two adjacent, parallel vein structures with screens of strongly altered wallrock sandwiched between them. Both veins make ore. Each consists of a massive sulphide core that is narrower but similar to the West Vein. The sulphide core is composed of roughly equal amounts of fine-grained pyrrhotite and pyrite, in contrast to the West Vein which is dominantly pyrrhotite. Quartz-carbonate margins of the East Vein are similar to the West Vein, but wider, and have veins and veinlets penetrating into the country rock. These quartz-carbonate vein swarms contain galena, sphalerite, pyrrhotite and pyrite with fragments of altered country rock. They are erratically gold bearing, locally constituting ore. The East Vein trends southeastward to outcrop.

The intervening Sixties Veins connect the West and East veins. The Sixties Veins trend 060° and dip 80° to the northwest. They are individually much thinner than either of the main veins, locally pinching down to 2 to 3 centimetres. However, they commonly make ore due to consistently high grades of better than 70 grams per tonne gold. Sixties Veins are either miniature copies of the larger veins (massive pyrrhotite cores with quartz-carbonate-sulphide margins) or they consist only of quartz-carbonate gangue with substantial disseminations, blebs and seams of fine-grained pyrrhotite. All country rock between the Sixties Veins is variably altered as a result of overlapping alteration envelopes from adjacent veins.

The abrupt mineralogical change between the pyrrhotite core and the symmetrical quartz-carbonate margins suggests that these ore zones originated as composite veins. Subsequent shearing and recrystallization has obscured any evidence of a median suture and original fibrous growth.

Prior to this study, the form and distribution of the gold had not been determined; rare free gold required a hand lens for detection and was noted only within the marginal quartz-carbonate vein zones. Gold values are distributed erratically across and along all veins, even though veins are continuous and the pyrrhotite cores appear homogeneous. Whole stopes on the West Vein grade up to 50 grams gold per tonne, locally exceeding 70 grams per tonne, but sections of the East Vein and Sixties Veins may be either very high grade or virtually barren in exposures that appear identical. Distribu-

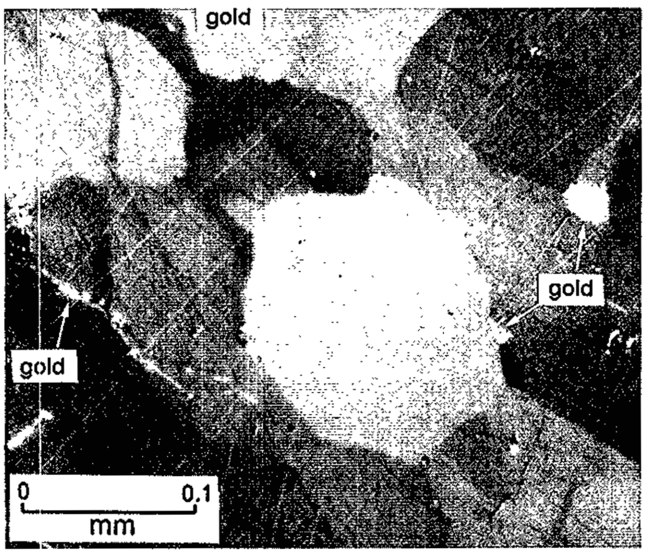


Plate 25. Photomicrograph showing typical form and size for disseminated gold within massive pyrrhotite, Scottie Gold mine. Crossed polars show that gold blebs are locallized along pyrrhotite grain boundaries. Sample of M Zone ore from a working face that averaged 69 grams per tonne gold.

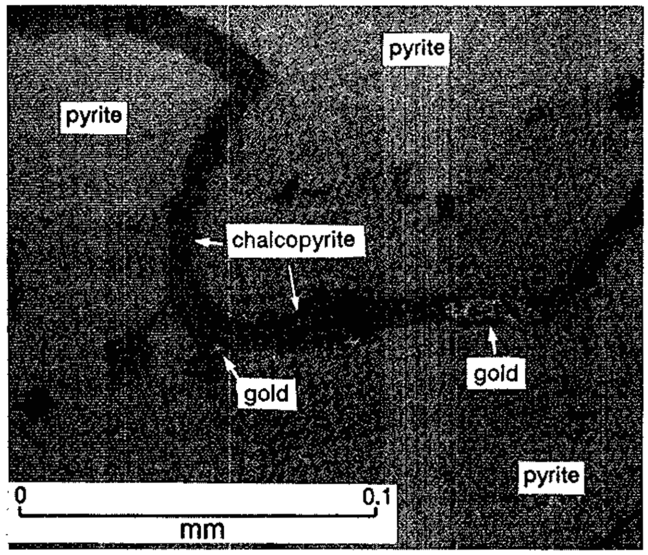


Plate 26. Photomicrograph of two gold grains within a chalcopyrite 'veinlet' filling a fracture through a pyrite grain, Scottie Gold mine.

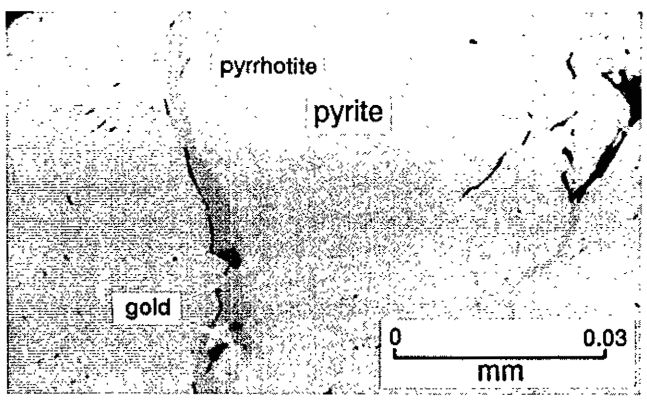


Plate 27. Photomicrograph of gold grain within pyrrhotite 'veinlet' cutting large, round, fractured pyrite grain, Scottie Gold mine.

tion of silver values also appears to be random, but silver was not routinely assayed.

Mineralogy

In order of abundance, opaque minerals include pyrrhotite, pyrite, sphalerite, chalcopyrite, galena, arsenopyrite, native gold, tennantite and rare chalcocite.

Pyrite commonly shows evidence of cracking, crushing and shearing. Pyrrhotite, however, has totally annealed with roughly 120° triple junctions (Plate 25). Cracks within pyrite are filled by trace copper minerals (Plate 26) or by pyrrhotite (Plate 27). The chalcopyrite along these cracks represents crystalline growth along the fracture, the pyrrhotite represents recrystallization along the walls of the crack that has turned a thin selvage of the host pyrite grain into pyrrhotite. Pyrite and pyrrhotite also are present as blebs and patches and as sheared streaks or strings of crushed grains in the quartz-carbonate marginal zones and in adjacent, intensely altered wallrock.

Chalcopyrite is present in trace to minor amounts in both the pyrrhotite core zone and marginal quartz-carbonate zone, but is more abundant in the core zone where it is distributed along fractures in pyrite (Plate 26), commonly with associated gold, and along grain boundaries in massive, recrystallized and annealed pyrrhotite (Plate 25). Tennantite and tetrahedrite, distinguished by their respective greenish and bluish tints, have been noted in the core zone as late fracture fillings in pyrite, with associated chalcopyrite and gold.

Sphalerite and galena are common in the quartz-carbonate envelope, but are virtually absent in the pyrrhotite core. Arsenopyrite is present locally within the pyrrhotite core as fine to coarse-grained euhedral, commonly cracked crystals. Broken crystals are enveloped by pyrrhotite. Zones of arsenopyrite are not associated with the highest gold grades, but generally assay in the 15 to 20 grams gold per tonne range.

Native gold is ubiquitous as fine blebs and grains in the pyrrhotite core zone. Gold grains are typically 10 to 40 micrometres in diameter, the largest grain observed measured 120 micrometres across. Gold is most commonly associated with chalcopyrite (Plate 26). Free gold is also scattered throughout massive pyrrhotite (Plate 25). It is much less abundant and more erratically distributed in quartz-carbonate envelopes where it may be associated with pyrrhotite-pyrite blebs or quartz-carbonate gangue.

Gangue minerals include quartz, carbonate, sericite, chlorite, minor epidote and trace clinozoisite. The four most abundant gangue minerals display both massive and sheared forms, suggesting they were all deposited prior to shearing. Major shear structures in the quartz-carbonate margin zone and in the immediately adjacent wallrock are dominantly replaced by sericite and carbonate with lesser amounts of chlorite and quartz. Some large quartz chips floating in massive pyrrhotite are aggregates of long fibrous crystals indicating growth prior to brecciation and shearing. Thin sections show elongate strings of quartz granules resembling mylonitic ribbon grains.

Alteration

Andesitic volcanic rocks on the property have strong propylitic alteration with pervasive chlorite, minor epidote and trace disseminated pyrite. Alteration intensity increases progressively within 10 metres of the ore zones. Pyrrhotite, pyrite and chalcopyrite are present as fine disseminations and hairline-fracture coatings adjacent to the main mineral deposits and seem to be associated with the most abundant chloritization.

Within the underground workings, wallrock alteration immediately adjacent to the quartz-carbonate vein margin is abundant chlorite alternating with two lighter coloured alteration types that have been described in hand samples as silicification and as hematization producing a pink chert. Thin sections show that the light, colourless alteration is dominantly sericite and calcite with grains of crushed quartz. The pinkish alteration type (Plate 23) is entirely

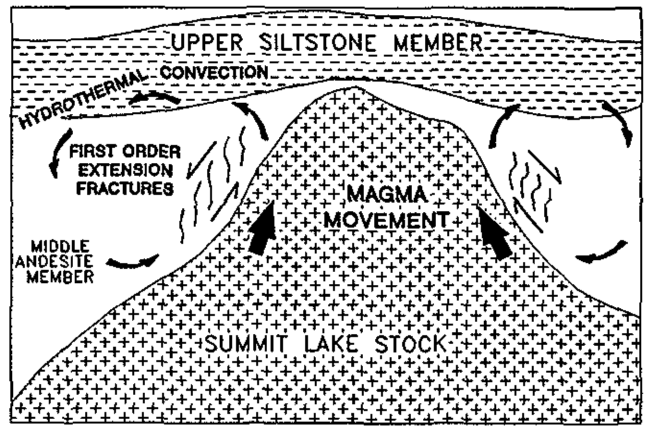


Figure 29. Genetic model for the Scottie Gold mine.

composed of fine to coarse-grained carbonate aggregate that is free of hematite even under high magnification, and is therefore probably rhodochrosite.

Wallrock alteration ranges from massive, unfoliated, alternating patches of chlorite, sericite-carbonate, and pink carbonate with scattered knots or blebs of sulphide aggregate, to strongly foliated, banded segregations of alternating green, white and pink alteration types with scattered streaks of sulphides.

Genesis

Veins at the mine are locallized along complex, subparallel shear or fracture zones. They have been called shear veins, cymoid veins and loops, sigmoidal veins, extension veins, tension gashes and ladder veins. The zones have undergone post-ore ductile and brittle shearing that complicates structural studies, nevertheless en echelon distribution of the Scottie Gold ore zones is evident in both plan and section (Figure 27).

Outcrop patterns and underground geometry of the Sixties Veins suggests they are a series of en echelon tension gash veins. However, the formation of the massive, planar "Main Veins" requires a more complex process. The ore-

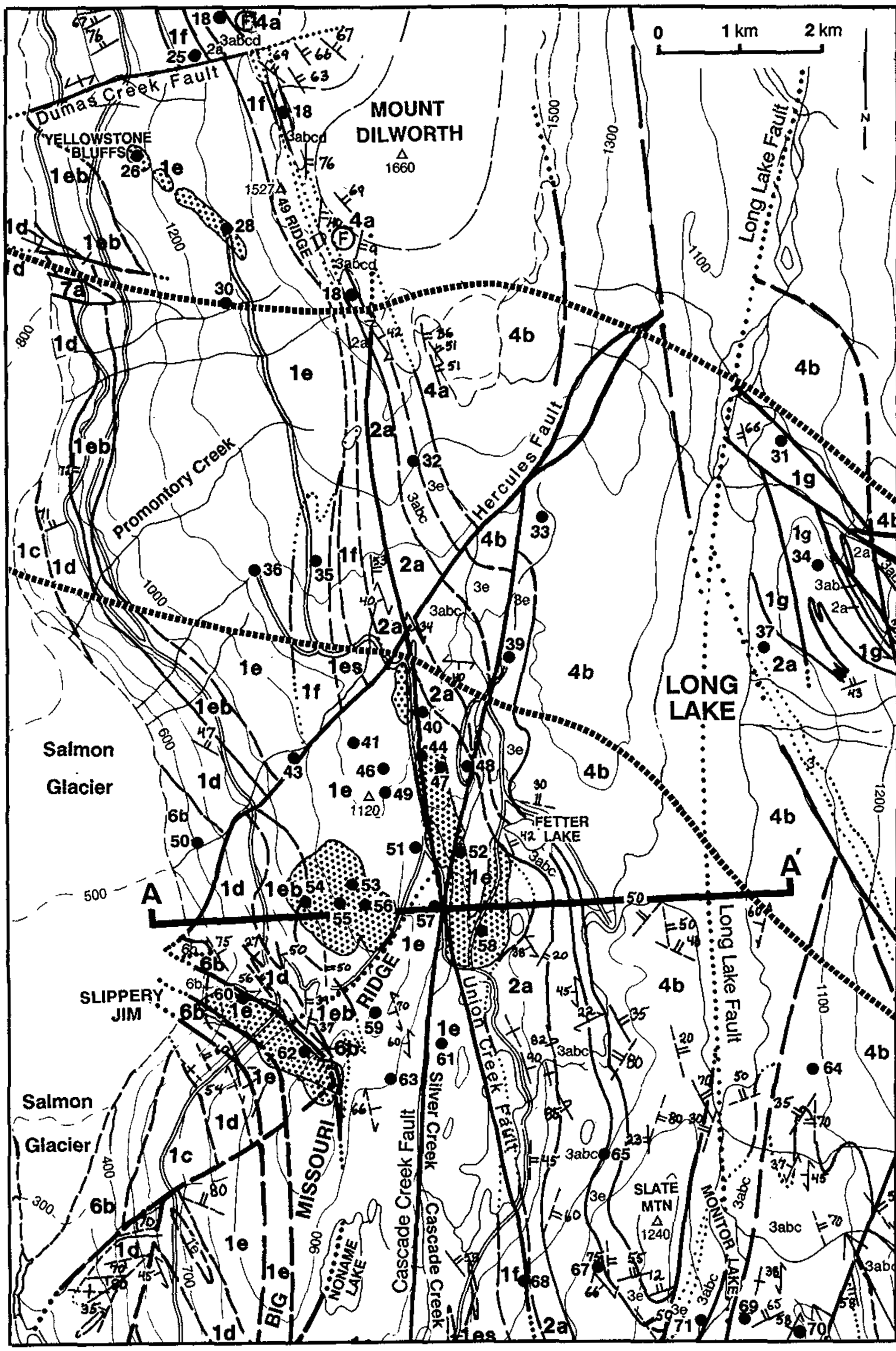


Figure 30. Geology and mineral deposits in the Big Missouri mine area. (See Figure 11 or 12 for legend.)

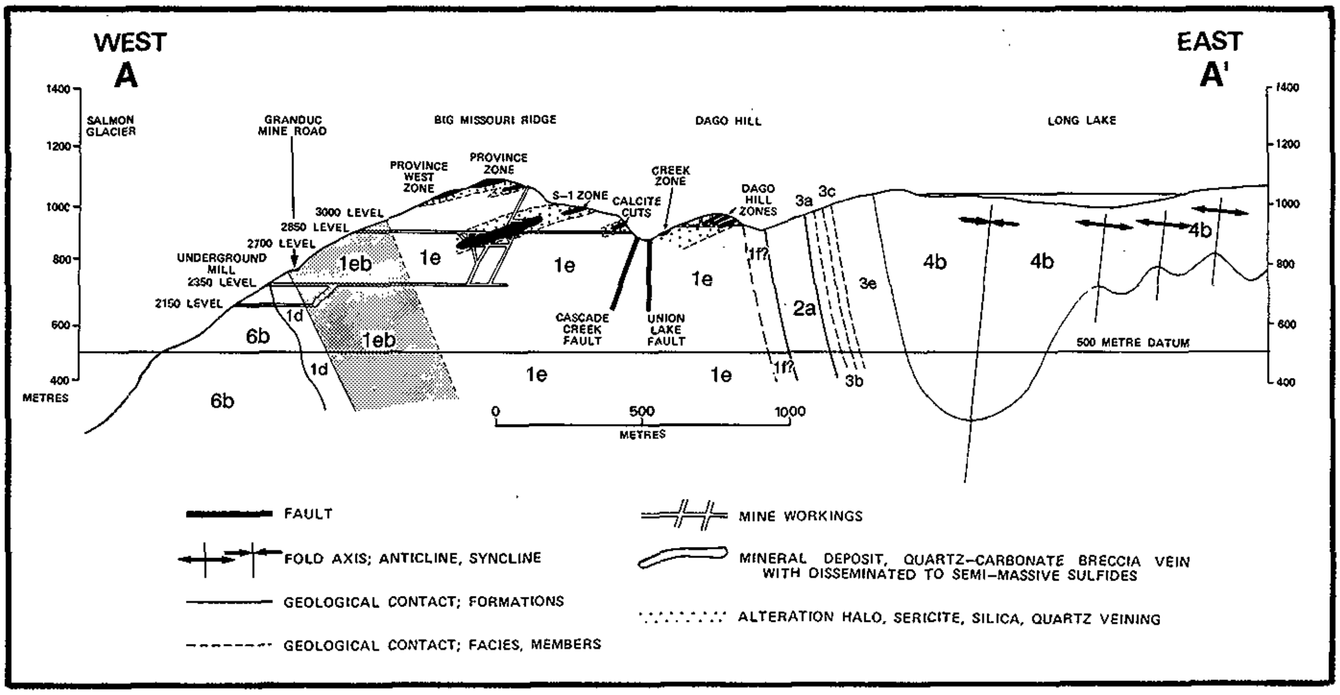


Figure 31. Cross-section through the Big Missouri mine area.
(*See* Figures 11 or 30 for section location and Figure 11 or 12 for legend.)

hosting structures at Scottie Gold mine began as a series of en echelon tension veins, the Sixties Veins, within a shear envelope that became a locus for subsequent shearing (Figure 28). The tensional structures developed in the country rock around the Summit Lake pluton during late magma movement (Figure 29). Many variables affect the equilibrium stability fields of pyrite and pyrrhotite, but in general these minerals indicate crystallization under low oxygen fugacity with temperatures in the range 250°C to 350°C (Nguyen *et al.*, 1989).

SILVER-GOLD-BASE METAL VEINS: THE BIG MISSOURI AREA

The Big Missouri mine and several other nearby orebodies and prospects lie on or adjacent to Big Missouri Ridge at an average elevation of 900 metres (Figure 30).

GEOLOGIC SETTING

All gold-silver occurrences in the Big Missouri area are hosted by the Upper Andesite Member of the Unuk River Formation. It is similar to descriptions in Chapter 2 and includes the basal black tuff facies that is well exposed on the hillside along and above the Granduc mine road. The main sequence includes typical medium-green andesitic ash tuffs and lapilli tuffs, abundant plagioclase-hornblende-phyric crystal tuffs, and minor tuff breccias.

The Upper Andesite Member is underlain on the west by the Upper Siltstone Member. The contact is commonly sheared, but locally is exposed as an unsheared, undisrupted, "welded" contact of thin-bedded siltstones overlain by massive tuffs. Graded, rhythmically bedded turbidites have tops to the east. Dips along the Granduc mine road and in nearby outcrops above and below the road range from 27° to 72° eastward and average about 55° east.

The Upper Andesite Member is overlain on the east by the maroon and green Premier Porphyry Member which has been traced along the eastern side of Dago Hill and seems to mark the eastern limit and stratigraphic cap to all the mineral zones on the hill (Figure 31).

Near the northeast end of Silver Lakes, the Betty Creek Formation shows bedding dipping from 82° west to vertical with tops to the east. The formation thins down to only a

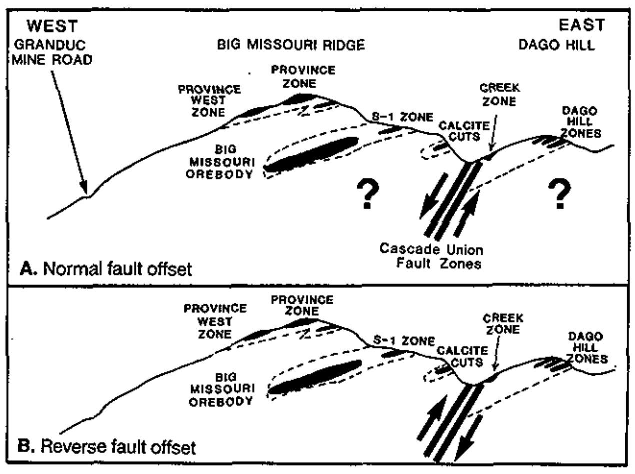


Figure 32. Net fault offset in the Big Missouri mine area. Combined offsets along the Cascade Creek and Union Creek faults may be normal or reverse. **A.** If normal, ore zones on the west and east sides of the faults are unrelated and faulted-off extensions of known zones may exist at depth. **B.** If reverse, ore zones on the west and east sides of the faults may have originally been continuous ore shoots.

few metres near Tunnel Lake. To the north, between Tunnel Lake and Union Lake, it is either absent, recessively weathered, or obscured by intense hydrothermal alteration.

All members of the Mount Dilworth Formation have been identified in the Dago Hill area except the pyritic tuff which ends abruptly at the south end of Mount Dilworth. Orientation of distinctive fiammé in the Middle Welded Tuff Member and subtle bedding in the Lower Dust Tuff Member range from shallow to moderately eastward dips. Fiammé at the north end of Dago Hill strike south-southeastward and dip 42° east-northeast. The fiammé are at the base of a single 10-metre-thick cooling unit of welded tuff that displays progressively more compressed pumice clasts downsection. Base-surge dune forms exposed in this member north of Union Lake also have tops to the east.

Based on all bedding attitudes noted in adjacent units, massive andesitic tuffs of the Upper Andesite Member are interpreted to dip eastward on Big Missouri Ridge. No bedding has been reported within this unit, despite several programs of detailed, property-scale mapping. A thin lens of well-bedded hematitic wackes, exposed along Big Missouri road south of Silver Lakes, lies within the Upper Andesite Member and dips steeply eastward (Figure 11).

Intrusive rocks along Big Missouri Ridge range from batholiths to dikes. The floor of the portal into the Silver Butte workings shows the eastern contact of potassium feldspar porphyritic Texas Creek batholith intruding andesitic tuff; this is the highest stratigraphic level of intrusion known for these rocks. Road construction north of the Silver Butte deposit has exposed an irregular dike of Premier Porphyry which cuts thin-bedded turbidites of the Upper Siltstone Member. The southern end of the Martha Ellen orebody is cut by a Tertiary granodiorite porphyry dike.

Faulting is abundant on a range of scales. The Silver Butte deposit lies within a fault-bounded, stratigraphically down-dropped block. Bounding faults have steep westerly dips. Two other major north-striking faults on the east side of the ridge, the Union Creek and Cascade Creek faults, dip moderately to steeply westward (Figures 30 and 32). Distribution of outcrop patterns across the faults suggests relative normal offset of up to several tens of metres. Determination of direction and amount of offset on these two faults is a key to resolving the number of ore zones and the exploration potential on the property (Figure 32).

In summary, the general structure on Big Missouri Ridge is an upright, steeply to moderately eastward-dipping strat-

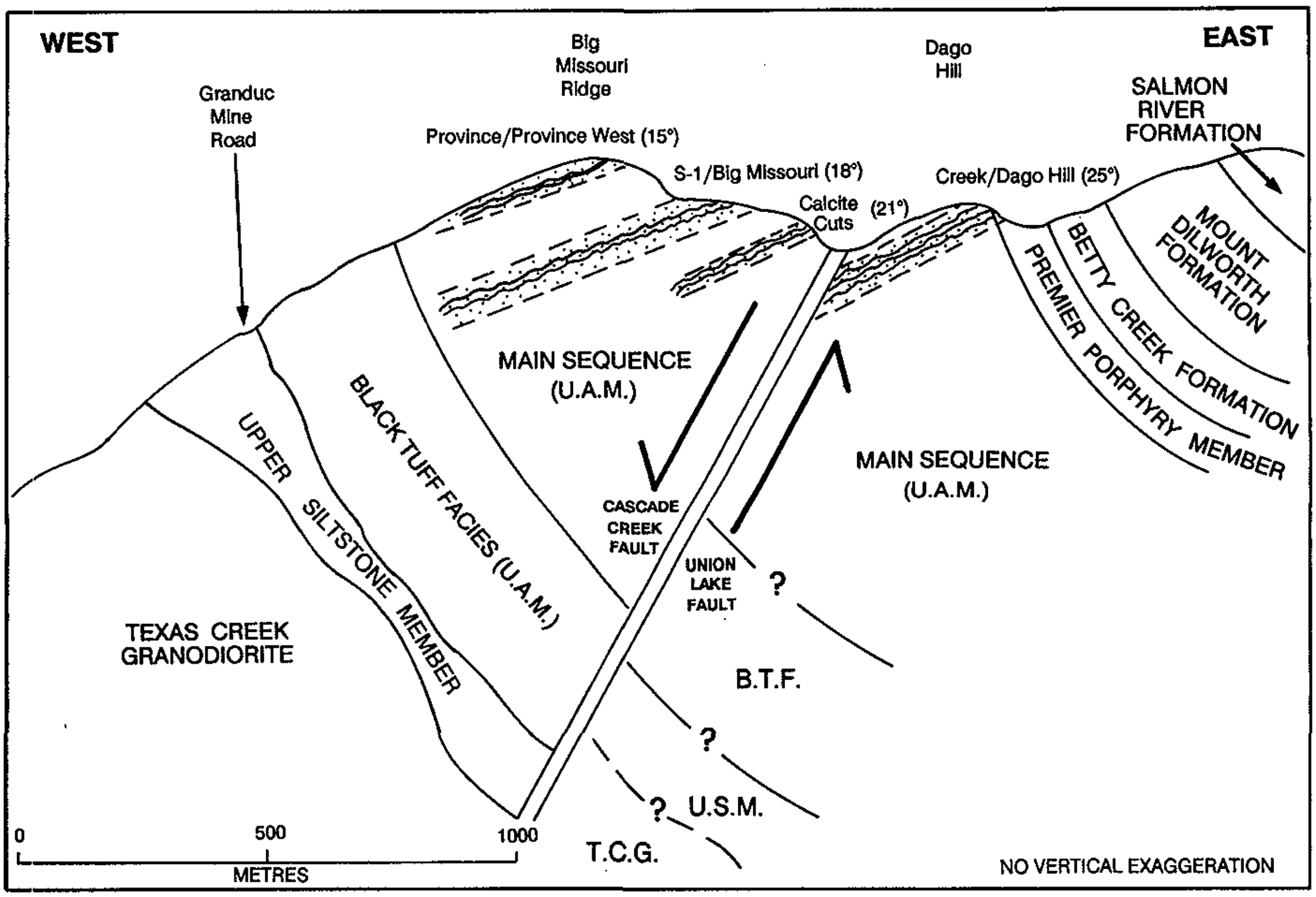


Figure 33. Ore deposit model for Big Missouri mine. This interpretive cross-section shows the dip of each ore zone in parenthesis. Note that progressive steepening of ore zone attitudes coincides with the curvature of the folded hostrocks, so that each ore zone must have formed roughly perpendicular to the paleosurface. Stippled areas are alteration envelopes around the breccia veins. Broad outcrop exposures of alteration (e.g. Galley, 1981, and Grove, 1971, Figure 25) represent areas where the topographic slope roughly parallels the dip of an ore zone. Normal fault offset implies that additional ore zones could exist at depth.

igraphic sequence lying on the western limb of a major north-trending syncline (Figures 30 and 31). There are no features that indicate the existence of minor folds within the Upper Andesite Member; the mineral deposits are tabular bodies that are well delineated by drilling and underground workings and clearly show no evidence of small-scale folding.

OREBODIES

There are 25 deposits and prospects within a 2.5-kilometre radius of the Big Missouri mine (Figure 30). Five of these have been classified as Tertiary silver-lead-zinc deposits in this study, the remainder are classified as Early Jurassic gold-silver-base metal deposits (Table 16). This section reviews the structural and textural features of the Early Jurassic deposits.

All but one of these 20 deposits have a northerly strike and a gentle westward dip (~20°), and thus are oriented roughly perpendicular to stratigraphy (Figures 30 and 33). Based on their crosscutting attitude and the many distinctive textures and structural features described in this section, these Early Jurassic mineral deposits are all interpreted as epigenetic veins.

Deposit dimensions range from impressively large to surprisingly small. The S-1 vein system and its down-dip continuation (the original Big Missouri orebody) have a dip length of 700 metres and a strike length of 120 metres. The Creek deposit, composed of semimassive to massive sul-

Plate 29. Cross-cut through the main orebody of the Big Missouri mine shows ringed wallrock clasts representing classic cockade texture in the quartz-calcite gangue. 2816 cross-cut. Big Missouri area.

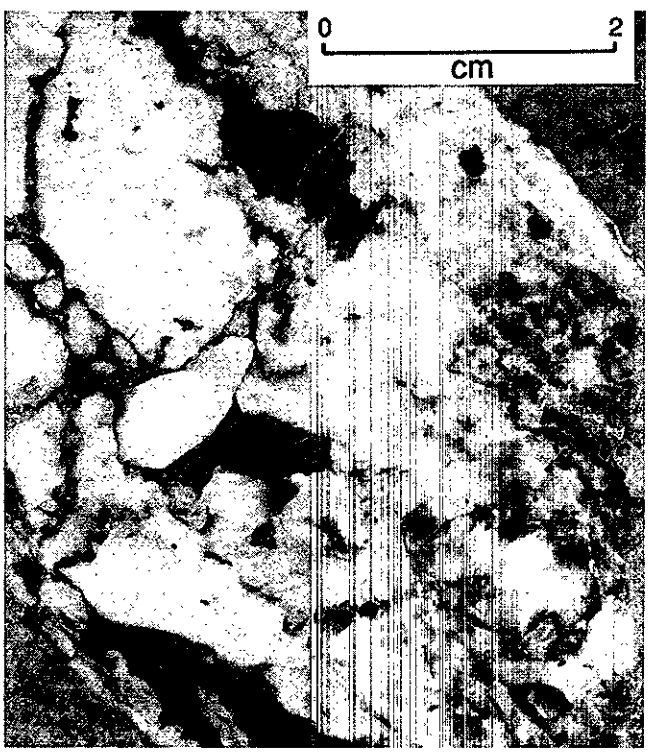


Plate 28. Crudely symmetric vein growth of coarse-grained quartz and calcite with late infilling of grey chalcedony. DDH 81-58 at 34 metres depth. Dago Hill deposit, Big Missouri area. BQ drill core.

Plate 30. Slabbed ore sample from the Province Zone shows clasts of early, sulphide-poor banded vein rock preserved in more sulphide-rich quartz-carbonate vein material. Big Missouri area.

phide, is at the opposite end of the size scale. This zone is 2 metres thick with a strike length of only 35 metres and an up-dip length of only 15 metres (thought to terminate against a fault).

Average thicknesses and drill intersections on all showings are in the 1 to 3-metre range. Maximum thicknesses are more difficult to determine, but sections of the original Big Missouri underground orebody were at least 6 metres thick and may have been wider.

In general, the strike length of ore shoots is significantly less than dip length, so that their longest dimension is consistently east-west, or in terms of the original (prefolding) depositional setting, vertical. Certainly this is the case for S-1 zone and Dago Hill. Drill information indicates a small but real southward rake to these zones, so that the trend of their long dimension is close to west-southwest (Figure 10b in Dykes *et al.*, 1988).

Different veins have slightly different dips (Figure 33). The Dago Hill deposits dip 25° west, Calcite Cuts dips 21° west, S-1 dips 18° west and Province and Province West dip 10° to 15° west. These differences are real and measurable, but are perhaps too small to be significant. Nevertheless it seems more than a coincidence that the variation is systematic. This radial or fan pattern is exactly what would be expected from a series of originally vertical and parallel veins after the host stratigraphy had been deformed in the manner that this region has been folded (Figures 11, 31 and 33).

Vein contacts are sharp, but complicated by extensive fracturing and peripheral quartz-carbonate and chalcedony vein networks that criss-cross shattered, altered wallrocks (Plates 28 and 29). Some ore zones have distinctive changes in lithology between structural footwall and hangingwall rocks. However, some vein intersections, such as the interval from 10.7 to 12.5 metres in drill-hole 82-42 on the S-1 zone, have exactly the same lithology in the hangingwall and footwall.

Mineral deposits range from quartz-carbonate veins containing trace to minor amounts of sulphides, to zones of semimassive sulphide veins with accessory quartz-carbonate gangue. The dominant vein type is a complex quartz-carbonate±sulphide-cemented breccia vein. Clasts are typically present (Plates 29 and 30), locally absent, and vary from sharply angular to smoothly rounded, but are not spherical. Clasts are wallrock andesite, quartz-carbonate vein material (indicating a rebrecciated vein), blue-grey microcrystalline to cryptocrystalline quartz (chalcedony) and sulphide chips.

Wallrock clasts may be strongly bleached and sericite, carbonate and silica-altered. Some fragments are medium to dark green and moderately chloritized. Clasts are massive ash tuff, lapilli tuff and crystal tuff and are interpreted to have formed by plucking or 'spallation' of fractured wallrock. Lack of significant rounding and abrasion in most clasts suggests they have not moved great distances within the vein.

Quartz, carbonate and quartz-carbonate clasts vary from irregular ragged chips in the Dago Hill veins, to smoothly rounded "pebbles" in at least some locations in the Province deposit. These clasts typically contain only minor to trace amounts of sulphides and no carbon, and may represent early (presulphide) brecciation episodes. Internal textures are medium to coarse-grained crystal aggregates although some clasts have coarse comb quartz and others show segments of cockade texture as alternating bands of quartz and carbonate (Plate 30).

Blue-grey microcrystalline quartz clasts are interpreted as fragments of chalcedony vein material. Blue-grey chalcedonic veins and veinlets are common in outcrop, trenches and drill core adjacent to deposits of the Big Missouri area (Plates 22 and 28). Clasts are small (<3 cm), sulphide free and subrounded. **Sulphide clasts** are rare, small angular chips of fine-grained pyritic aggregate.

Vein material consists of variably textured quartz and chalcedonic quartz, calcite, sulphide minerals, carbon, sericite and chlorite. Gangue minerals are commonly distinctly laminated (Plates 28 and 30), with bands of fine to medium to coarse-grained crystalline quartz, crystalline calcite and, less commonly, blue-grey microcrystalline quartz, carbon and sulphides. Undulating to arcuately banded or crustified gangue alongside vein walls ("dish structures" of Galley, 1981, pp.68-71) drape around original irregularities of the vein walls and clasts incorporated in earlier deposited layers. Quartz textures range from cryptocrystalline chalcedonic quartz, through fine to medium-grained and locally coarse-grained crystalline comb quartz rich in primary fluid inclusions. Quartz of differing textures may grow in adjacent layers. Cockade texture, consisting of distinctive rings of alternating, variably textured quartz-calcite-sulphide layers may completely envelope wallrock clasts (Plate 29).

Documented features such as symmetric growth-layers (Plate 28), colloform growth (Plate 31), cockade texture (Plate 29), rebrecciated veins (Plate 30), coarse, elongate comb quartz (Plate 28), fluid-inclusion trains and drusy

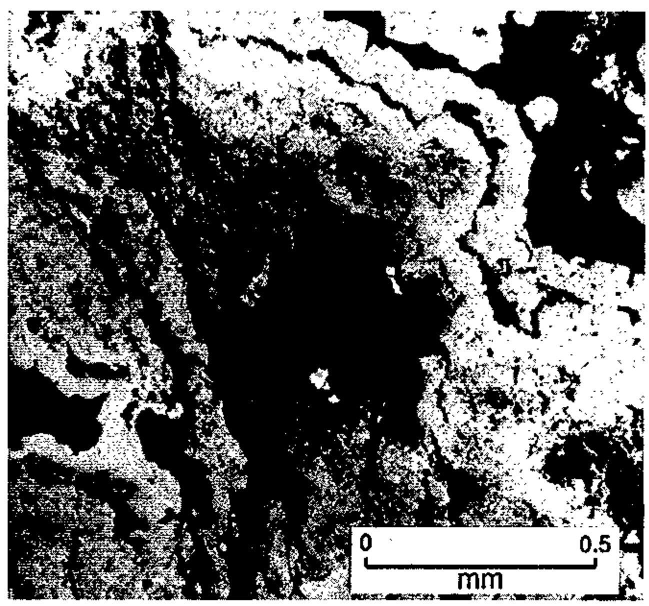


Plate 31. Photomicrograph of colloform pyrite growth layers with gangue-filled spaces. S-1 deposit, Big Missouri area.

cavities are characteristic of vein growth and open-space filling in the subvolcanic environment (Dowling and Morrison, 1989).

Carbon, as amorphous carbon, is present in the veins as thin seams between adjacent quartz and quartz-carbonate layers. Carbon is fine grained, powdery and charcoal to jet black in colour. Granules range up to 2 millimetres in diameter with lustrous, conchoidally fractured surfaces. Carbon locally comprises up to 15 per cent of the vein volume at Dago Hill where recent mining has exposed large blebs and pods up to 15 centimetres across. It also occurs in fine veinlets and small patches and commonly is associated with pyrite. Open cavities containing euhedral, drusy quartz and pyrite may be coated with a film of carbon (Galley, 1981, p.76). The most probable source for this material is the strongly carbonaceous turbidites of the Upper Siltstone Member which stratigraphically underlie this area.

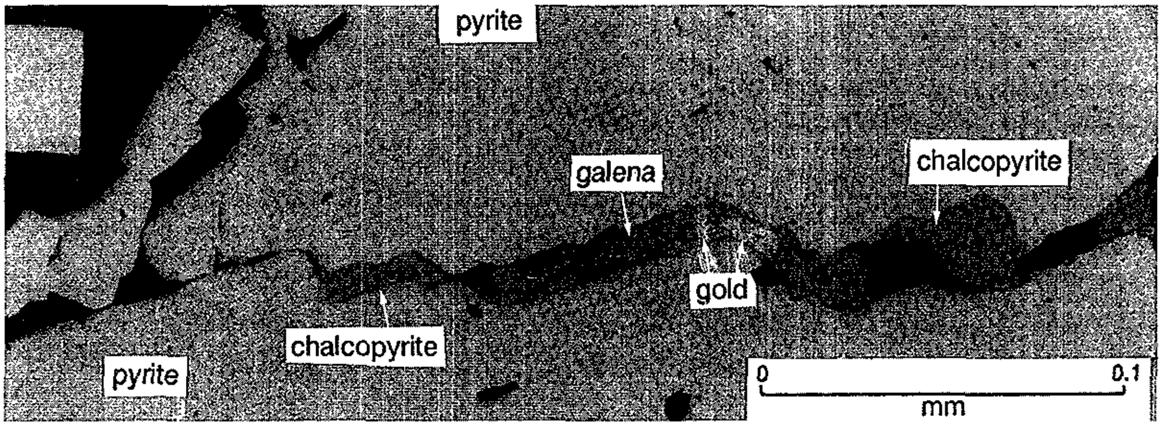


Plate 32. Photomicrograph of fracture through pyrite grain hosting chalcopyrite, galena and two grains of electrum. Dago Hill deposit, Big Missouri area.

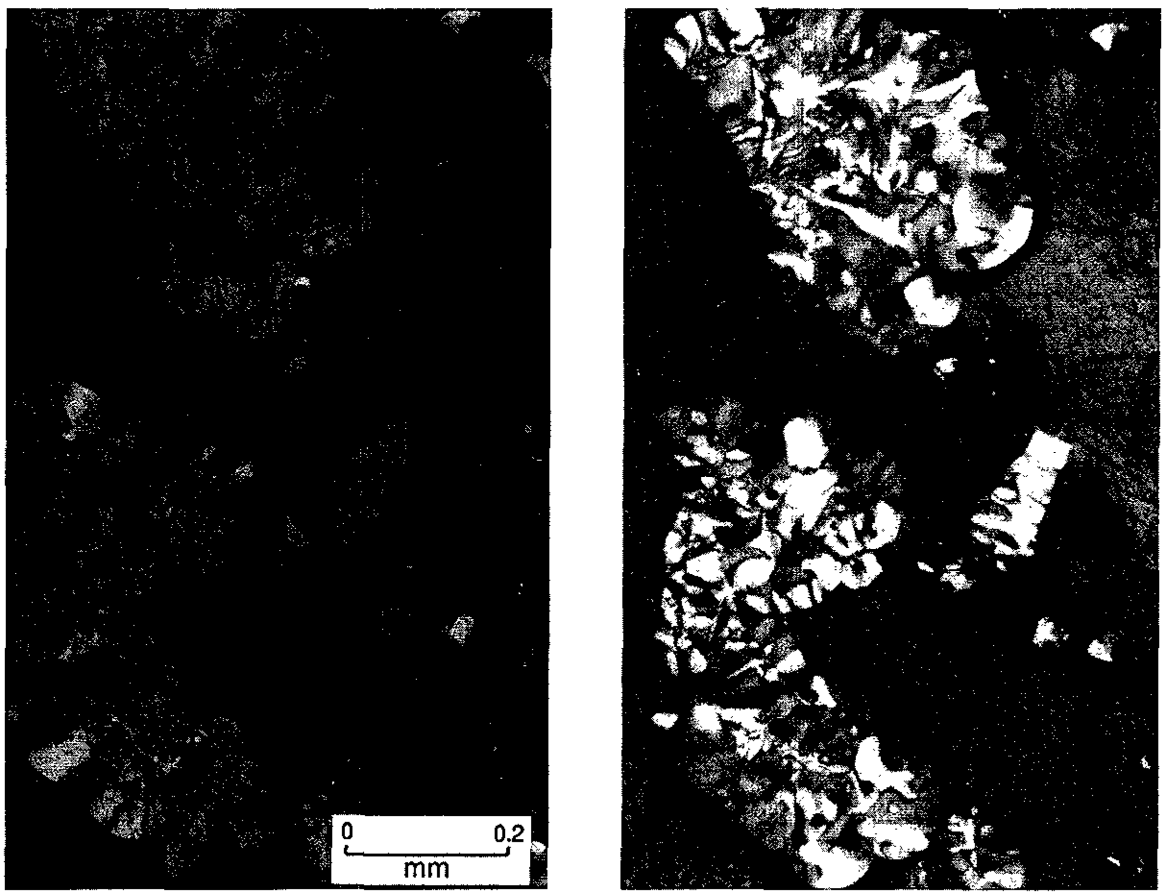


Plate 33. Photomicrograph of characteristic features of delafossite: botryoidal texture, moderate pleochroism and strong anisotropy. S-1 deposit, Big Missouri area (*see* colour photo in back of report).

Fine to medium-grained semimassive sulphides are characteristic of the Silver Butte, Province West, Creek and Martha Ellen zones. Sulphides display crude book-structure (interlayered sheets of gangue) at centimetre-scale. These zones generally have higher base metal values but lower precious metal values relative to sulphide-poor sections of veins. Pyrite is the most abundant sulphide; other sulphides noted in drill core and hand samples include sphalerite, galena and chalcopyrite.

Altered wallrocks are cut by multiple generations and orientations of variably textured veins and veinlets of chalcedony, crystalline quartz, quartz-calcite and calcite. Mine geologists have documented up to five generations of crosscutting veinlets at Dago Hill (S. Dykes, personal communication, 1984). All these wallrock veins contain trace to minor sulphides, but late calcite veins carry the least sulphides. No obvious asymmetry was noted in the distribution of these complex overprinted vein networks in the structural hangingwall and footwall rocks.

Broad patterns of mineralogical zoning have been documented by Galley (1981) and Dykes *et al.* (1986, 1988). These include abundant galena and carbon at Dago Hill versus more abundant sphalerite, calcite and iron carbonate, and a general absence of carbon, at the Province deposit. Figure 31 shows that these deposits may have formed at significantly different paleodepths and pressure-temperature conditions within the major fractures that cut the Upper Andesite Member.

Plate 34. Photomicrograph of pyrite encrustations around coarser gangue crystal (quartz). S-1 deposit, Big Missouri area.

Mineralogy

In order of abundance, opaque minerals include pyrite, sphalerite, minor to accessory chalcopyrite and galena, trace tennantite and pyrrhotite, and rare electrum (Plate 32), covellite and delafossite (Plate 33). Holbek (1983) identified trace amounts of electrum, acanthite, native silver, freibergite and chalcocite. Galley (1981) also reported rare pyrargyrite and polybasite. Mineral paragenesis deduced by Galley and Holbek indicates an overall simple sequence of sulphide precipitation that is consistent with progressively lower temperatures with time.

Sulphide mineral textures range from disseminated euhedral crystals to irregular crystal aggregates of mixed sulphides. Grains range from micron size up to coarse euhedral pyrite crystals and large sphalerite blebs or aggregates up to 2 centimetres long. Many samples have cracked and shattered grains of pyrite with remobilization of other sulphides among these fragments, suggesting post-ore deformation by local faulting or regional tectonism. In undeformed samples most sulphide minerals are closely associated with each other, indicating contemporaneous deposition, although there is clearly an early pyrite phase. Galena and chalcopyrite are mostly included within sphalerite but also are present as fine blebs. Chalcopyrite is also distributed as sinuous grains along fractures (Plate 32).

Pyrite is present as disseminations, veinlets and thin bands interlayered with gangue. It is the most abundant mineral in semimassive sulphide zones and also occurs as veinlets and disseminations in surrounding wallrocks. Disseminated pyrite in wallrocks has strongly striated surfaces and may be of a different generation than vein-hosted pyrite. Most vein-hosted pyrite is earlier than other sulphides which enclose or partially replace it. Holbek (1983) reports minor post-ore pyrite, so that as many as three generations of pyrite may be present in these deposits.

Vein-hosted pyrite is present as sharply euhedral crystals, sharply angular fragments and "crushed" ragged chips. Some grains have internal crystalline skeletons, with later overgrowths in crystallographic continuity. Local, thin arcuate bands of pyrite grains and aggregates conform to thicker crustiform layers of enclosing gangue minerals (Plate 34). Some large pyrite grains have internal rings or diffuse bands of encapsulated gangue and sulphide grains indicating oscillating pulses of inclusion-rich growth (Fleet *et al.*, 1989; Barton *et al.*, 1977; Barton and Bethke, 1987). Tiny internal blebs of pyrrhotite, tennantite and chalcopyrite were noted. Pyrite grains are commonly cracked with the fractures filled by chalcopyrite, sphalerite and galena.

Sphalerite is present in both low-sulphide and semimassive sulphide zones. It is locally more abundant than pyrite. Colour ranges from red to red-brown to purple to black. Typical textures are medium to coarse-grained subhedral to anhedral aggregates. Individual grains vary from anhedral to amoeboid shapes that suggest remobilization. Galley (1981) reports sphalerite at the Northstar-Lindeborg prospects that forms rims up to 1 centimetre thick around andesite fragments; these in turn are enveloped by thin crusts of galena, forming cockade texture of alternating sulphides. The writer has identified atoll sphalerite at microscopic scale in samples from the underground workings that may represent skeletal growth or an early stage of development of cockade texture.

Galena is most common as bands of grains within semimassive sulphides but also occurs in minor amounts in low-sulphide vein sections. Intergrowths with chalcopyrite or sphalerite indicate coprecipitation. Blebs of tetrahedrite-tennantite are scattered through some galena crystals.

Chalcopyrite has been noted in all deposits of the area in minor to accessory amounts. The mineral is present as intergrowths with other sulphides, as microscopic exsolution blebs in sphalerite and in late fine veinlets, presumably due to remobilization. Secondary copper minerals, chalcocite, covellite and delafossite, are intimately associated with, or entirely replace, chalcopyrite.

Precious metal values are contained in electrum, acanthite, freibergite and native silver and extremely rare pyrargyrite and polybasite. In low-sulphide vein sections silver sulphides and native silver are present as free disseminations in gangue. In semimassive sulphide vein sections, they generally form aggregates with galena and chalcopyrite or inclusions in pyrite. Freibergite/tetrahedrite/tennantite is present as minute blebs within sphalerite, galena and pyrite. Gold occurs only as electrum and has been reported only from the S-1 and Dago Hill zones. Consequently, it may be useful as a depth-dependent mineral phase (Figure 33). Electrum is present as tiny rounded grains entirely contained within chalcopyrite, sphalerite or pyrite (Plate 32), as coarser elliptical blebs along sulphide grain boundaries or fractures, and as free grains within gangue. Grain size varies from 2 to 70 microns. The average gold:silver ratio for electrum is 1:1 (Holbek, 1983).

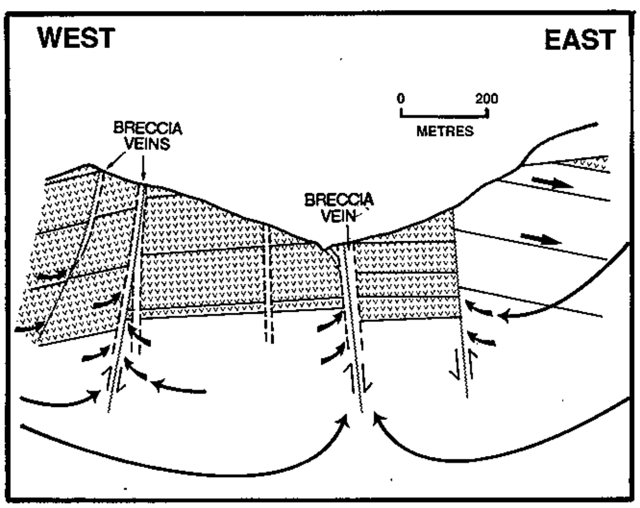


Figure 34. Genetic model for the ore deposits of the Big Missouri ridge area shows their prefolding configuration as a series of subparallel epithermal breccia veins emplaced along minor faults in a crater or caldera-like setting (*see also* Figure 35). This diagram is an actual cross-section through the Mount Skukum epithermal ore deposits (MacDonald, 1987).

Gangue is primarily quartz with lesser carbonate, sericite, oxides and carbon. Holbek (1983) has documented minor barite.

Alteration

Andesitic volcanic rocks become progressively more bleached toward each major vein (Plate 22). No apparent asymmetry, either in thickness or mineralogy, was noted in the alteration zones examined in core. These envelopes of bleached, foliated pyritic rocks were mapped as rhyolite during early exploration work. Light coloured rocks are still commonly referred to as "siliceous" or "silicified", but they are dominantly affected by sericite flooding with lesser, patchy carbonate alteration. The bleached rock is generally quite soft; powdered material has a moderate to strong reaction to dilute hydrochloric acid.

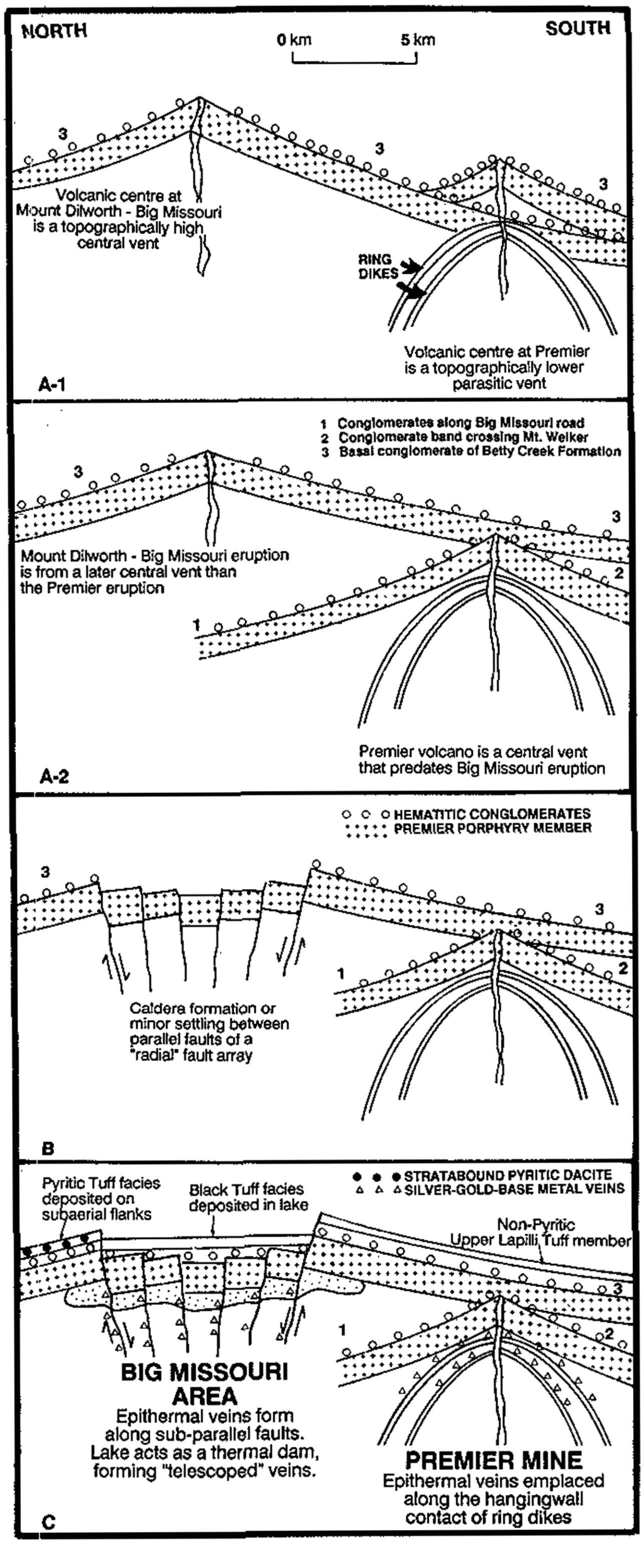
Several metres from major veins, core samples show weak to moderate chlorite alteration (Plate 22). This propylitic alteration may be overprinted by irregular zones of fine sericitic alteration. Closer to the main veins the zones of sericitic alteration coalesce and the rock is bleached and moderately to strongly sericitized with ragged patches of remnant chlorite alteration. Similar patches of later carbonate alteration overprint sericite. Closer still to the veins (<2 m), fine calcite is the most abundant alteration mineral and areas of pervasive calcite flooding are common. Adjacent to the veins (<0.5 m), alteration may be intense sericitization, calcite flooding or silicification, or mottled patchy combinations of all three alteration minerals. Fine to medium-grained disseminated pyrite accompanies all alteration types, but is most abundant (up to 15%) in strong sericitic alteration.

Genesis

The subtle, but real, progressive steepening of dip in the Big Missouri ore zones (Figure 33) is an important clue to the prefolding orientation of these deposits. Prior to mid-Cretaceous deformation, ore zones in the Big Missouri area formed as parallel epithermal breccia veins emplaced in a series of parallel, vertical, brittle faults (Figure 34). There was relatively minor offset across these faults, on the order of a few tens of metres at most; offset between blocks was more a matter of differential settling rather than major tectonic disturbance (Figure 35c). Faults formed as part of a series of synvolcanic radial fractures around an active volcanic centre. 'Radial' fracture sets may appear to be truly radial on a regional scale, but in detail are commonly composed of several parallel sets, for example Spanish Peaks and Dike Mountain, Colorado (Knopf, 1936; Johnson, 1961).

Hydrothermal fluids were concentrated above a local dome in the underlying Texas Creek batholith, exposed near the mill portal of the Big Missouri mine and in underground workings at the Silver Butte deposit. Dikes of Premier Porphyry that crop out along the Granduc mine road may have penetrated up into the mineralized region. Fluids precipitated breccia veins into several parallel fault zones. A series of fluid pulses deposited ore and gangue repeatedly along each fault. Possibly only one fault structure at a time served as a fluid conduit; other faults becoming conduits as the 'active' fault sealed due to precipitating ore and gangue minerals.

Metal and mineral distribution is less well documented at Big Missouri than at Silbak Premier, and post-ore faulting has disturbed the continuity of individual ore shoots (Figure 33). However, two Silbak Premier patterns – elevated precious metal grades in low-sulphide ores, and deposition of high-sulphide ore shoots at depth versus stratigraphically shallower deposition of low sulphide-ores – fit present Big Missouri data.



Silver-Gold-Base Metal Veins: Silbak Premier Mine

The Silbak Premier mine is located 17 kilometres by road from Hyder and 20 kilometres by road from Stewart, below treeline on the western slope of the Bear River Ridge. Brown (1987, pp.8-13) provides a detailed history of ore production.

GEOLOGIC SETTING

Like the Big Missouri area to the north, Silbak Premier mine and several nearby showings are all in the Upper Andesite Member of the Unuk River Formation (Figures 11 and 47a). The member is similar to the detailed descriptions in Chapter 3 except that the basal black tuff facies has not been identified in this area. The main sequence includes medium to dark green, moderately to strongly foliated andesitic ash tuffs, lapilli tuffs and crystal tuffs with abundant plagioclase±hornblende crystals. Andesite is noticeably darker green and more strongly chloritized than elsewhere in the region. Local beds of hematitic and chloritic conglomerate with well-rounded volcanic cobbles crop out north and northwest of the mine workings between the glory hole and the Cooper (Lesley) Creek bridge. Conglomerates are purple, green, and mottled purple and green in colour.

No sedimentary bedding has been noted in the immediate mine area (200 m radius). Ductile deformation has produced moderately westward-dipping (40°) penetrative foliation and ductile shear zones characterized by spectacularly stretched clasts of angular lapilli and rounded cobbles that have all previously been recorded as evidence of west-dipping bedding in these strata (Langille, 1945). Many bedding measurements shown in the immediate mine area (Brown, 1987) were taken from elongate cobbles that may have been deformed (D.A.Brown, personal communication, 1987).

Figure 35. Sequence of development of Early Jurassic subvolcanic settings in the Stewart mining camp. The Big Missouri and Silbak Premier epithermal ore deposits likely formed penecontemporaneously, but stratigraphic and facies evidence suggests that their geological settings formed sequentially. Case **A-1:** the thicker section of Betty Creek Formation strata that overlies the Silbak Premier deposits suggests the Silbak Premier setting represents a later parasitic vent on the flank of a major stratavolcano that was centred at the Big Missouri area. Case **A-2:** the setting for the Silbak Premier ore deposits formed beneath an early central vent that was later buried by pyroclastic and epiclastic debris from a later, but nearby, central vent in the Big Missouri area. Case **A-2** seems to fit the detailed lithostratigraphic evidence best. **B.** Subsequent caldera formation in late 'Mount Dilworth' time creates block faults and a basin for deposition of the Black Tuff facies. **C.** Main period of epithermal mineralization coincides with formation of Pyritic Tuff facies and accumulation of Black Tuff facies.

To the west, the Upper Siltstone Member underlies the Upper Andesite Member. The sedimentary unit is offset in this area by major faults and thus provides a useful indication of relative direction and amount of offset that can be used to reconstruct fault-truncated ore zones and guide exploration. From north to south:

- The Upper Siltstone Member crops out west and downslope from the Indian mine workings where it dips moderately eastward (57°) with tops to the east.
- Exploration work in 1988 located an exposure on the hilltop south of Indian Lake and west of the Woodbine prospect. Strata here are vertical; no tops indicators were noted (A. W. Randall, personal communication, 1988).
- Southeastward, the next area of outcrop is at the confluence of Cascade Creek and Salmon River where a large well-washed outcrop area of thin-bedded siltstones is disrupted by the Boundary dike swarm. Dips range from 60° west to vertical; no tops indicators were noted.
- Nearby, Brown (1987) mapped siltstones in Logan Creek just upstream from the Granduc mine road. Beds here dip steeply westward, averaging 80°, but show tops to the east, indicating that strata are overturned.
- Farther south, geologists from Esso Minerals Canada measured dips averaging 80° east, with tops to the east, on outcrops in Cabin, Boundary and Daly creeks.

Therefore the Upper Siltstone Member in the Silbak Premier area has dips ranging from steeply westward to moderately eastward but dominantly subvertical; tops indicators are consistently to the east, so that westward-dipping exposures represent overturned strata.

Overlying the Upper Andesite Member to the east, the Premier Porphyry Member has its three facies exposed on the wooded slopes eastward and uphill from the Silbak Premier glory hole. Layering in the lowest massive to laminated tuff unit dips gently eastward (20°).

Farther east and uphill, bedded wackes and siltstones of the Betty Creek Formation dip moderately eastward (30° to 50°). Scour channels indicate tops to the east. Along the crest of the Bear River Ridge, abundant bedding exposures indicate a broad synclinal trough with local minor folds developed in interbedded sedimentary rocks and tuffs (Figure 11).

In summary, the general structure is a vertical to moderately eastward-dipping sequence lying on the western limb of a north-trending syncline (Figure 36). This structural setting fits observed sedimentary bed orientations and tops indicators, and is critically important for resolving the intrusive history of the dikes in the mine and the genesis of the mineral deposits.

Volcanic rocks at the mine are intruded by a variety of dikes and other irregular intrusive bodies. Dikes of Premier Porphyry, a potassium feldspar megacrystic plagioclase-amphibole porphyry, are the most abundant intrusive rock and they are spatially associated with most, and possibly all, ore zones. Premier Porphyry dikes are described in Chapter 3 from their type exposures at the Silbak Premier mine. The dikes have a variety of forms including:

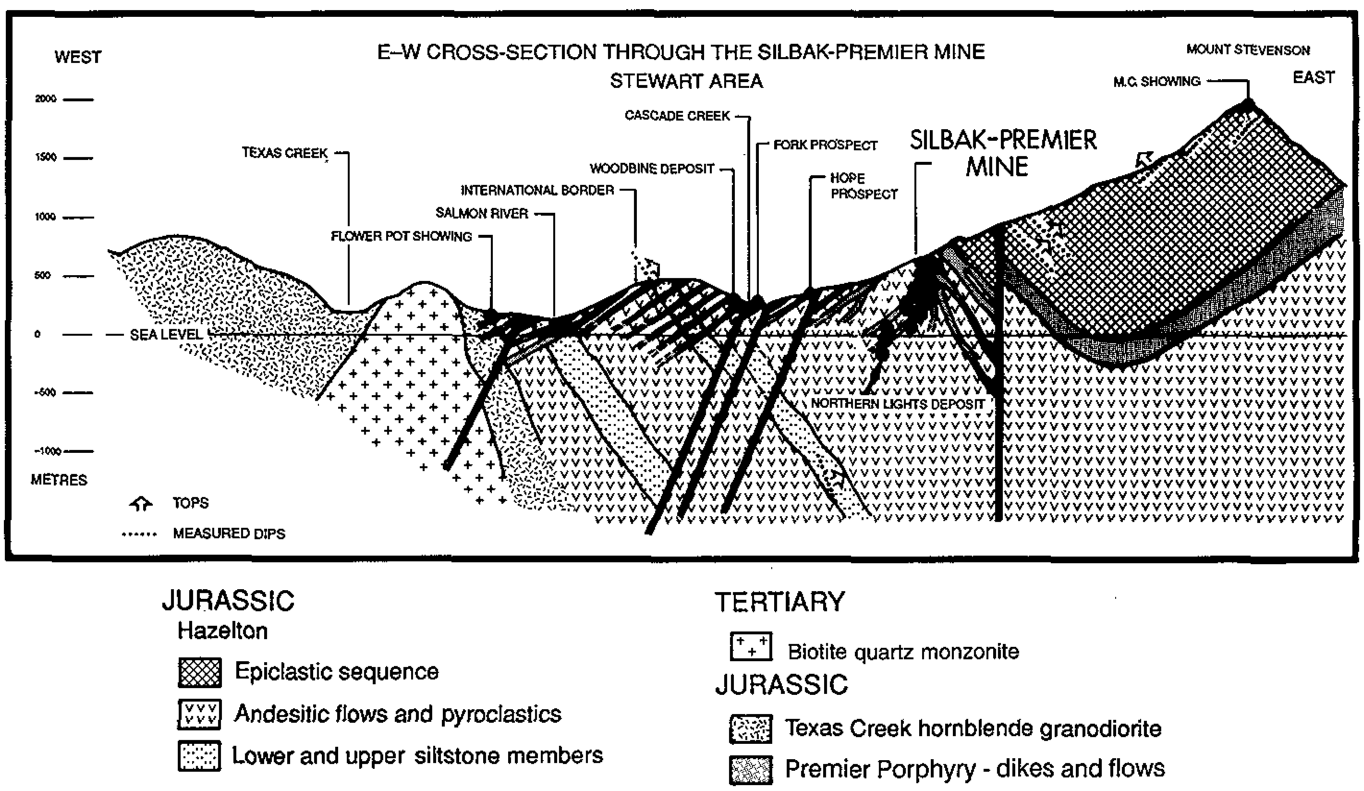


Figure 36. Geologic cross-section through the Silbak Premier mine area. (See Figure 11 for cross-section location.)

- branching or anastomosing dikes which incorporate screens of country rock or brecciated mineral zones,
- fan-like radiating patterns of a few to several dikes, and
- large-scale curved dikes.

No process or model has accounted for the varying forms and the range of textures of these important intrusive rocks. They are generally regarded as folded and unfolded subvolcanic dikes, sills and possible extrusive flows, without an explanation of how folded and unfolded examples co-exist within a few hundred metres of each other.

Other intrusive rocks in the mine area are dikes and a small stock of the Hyder plutonic suite. One major granodiorite porphyry dike, the 100-metre-wide "Main Dike", cuts through the centre of the Sebakwe ore zone. Tertiary microdiorite and lamprophyre dikes also cut through the mine workings.

Small-scale faulting has been a major problem in underground exploration in the mine area. Many ore shoots are offset a few tens of metres or less, but locating the continuing ore shoot can be a major delay and expense. Dikes, altered wallrock and mineralized zones are so abundant that it is difficult to be certain that the same ore shoot has been found.

Regional-scale faults have important implications for exploration. The location of the Upper Siltstone Member west of the Woodbine prospect indicates that relative normal offset occured along the Slate Mountain fault and Cascade Creek lineament (Figure 36). Deposits such as Woodbine, Fork, Power and Hope, in the hangingwall block, may have been emplaced at a similar stratigraphic level as the West zone in the footwall block and the mineralized dike contact in each fault block may be the same structure (Figure 37).

The most enigmatic structure in the mine area is a ductile to brittle shear that trends subparallel to the West zone and deforms ore at many sites, including a spectacular exposure at the 2-level portal. This structure is well exposed in trenches on the south edge of the glory hole as bleached, ductily deformed Premier Porphyry. It is interpreted as a post-ore ductile shear, with later superimposed brittle fracturing, that developed subparallel to the long linear dike of Premier Porphyry because of the high resistance of the massive dike and relative ductility or instability of the sulphide and breccia zones.

A hematitic, ductile shear zone crops out north of the mine workings and has been intersected in drilling in the glory hole area (McDonald, 1990a). The zone shows pronounced stretching of both angular and rounded clasts that have been mapped as bedding by early workers. Consequently it has been regarded as a stratigraphic marker for decades, for example Langille's (1945) "purple tuff", and it was a key piece of evidence for west-dipping strata in the mine area. This shear zone is certainly an important planar marker, but it is not a stratigraphic unit.

OREBODIES

The historic Silbak Premier underground operation produced ore from eighteen separate shoots (Grove, 1971), many small, previously subeconomic ore shoots are recovered in current open-pit mining. Past production and published reserves for the Silbak Premier mine are listed in Table 15.

Production from two distinct breccia and vein stockwork trends, the Main and West zones, came from ore shoots distributed along a combined strike length of 1600 metres (Figure 37a), but roughly 80 per cent of that production was recovered within 500 metres of the intersection of these two trends. The intersection area contained the widest ore shoots (up to 20 m) and those with the highest gold and silver grades.

The new open pit is located in the richest part of the old Premier underground workings where the Main and West zones intersect (Figure 37a). This area also corresponds to a concentration of converging Premier Porphyry dikes (Figures 38 and 37a). The many small, subparallel ore shoots have an aggregate thickness of 20 to 50 metres.

The **Main zone** trend of ore deposits strikes 050° and extends 2000 metres northeast from the glory hole area. The trend includes the original Premier, B.C. Silver and Sebakwe ore deposits and the Bush showings. The Main zone dips about 60° northwest at surface and progressively curves and flattens to a dip of about 30° near 6-level (Figures 38 and 37d).

Convergence of the Premier Porphyry dikes from depth toward surface means that continuous ore shoots are localized between Premier Porphyry dike and andesite country rock at depth, but lie between separate but similar Premier Porphyry dikes near surface (Figure 38). Ore shoots at the southwest end of the Main zone trend were composed of two extensive subparallel sheets Langille (1945), but in the Sebakwe workings at the northeast end of the trend, ore zones consisted of many small, en echelon shoots.

At its southern end the Main zone is abruptly truncated at the **West zone** which trends 290°. The West zone is vertical to steeply dipping throughout its extent. Mineralization and alteration are localized along the southern contact of a large subvertical Premier Porphyry dike (Figure 37a). The zone is 350 metres long and is exposed as a single breccia zone, 5 to 10 metres thick, open to depth. The northwestward extension of this trend includes the Hope, Power, Fork and Woodbine prospects over a total strike length of 1500 metres.

Northern Lights is a blind orebody in the structural hangingwall of the Main and West zones. It displays the same two distinct zone orientations (Figure 37a).

Ores of the Silbak Premier mine are hosted in massive breccia veins and in peripheral vein networks or stockworks. Ore was deposited during one part of an extensive history of hydrothermal brecciation and veining that has been divided into three stages (McDonald, 1988): pre-ore breccias and veins, ore-stage breccias and veins, and post-ore veins.

Pre-ore breccia is a hydrothermal breccia confined to andesitic volcanic rocks immediately adjacent to massive unbrecciated Premier Porphyry dikes. It consists of rounded to angular fragments of country rock andesite ranging from 1 to 15 centimetres across. Fragment abundance ranges

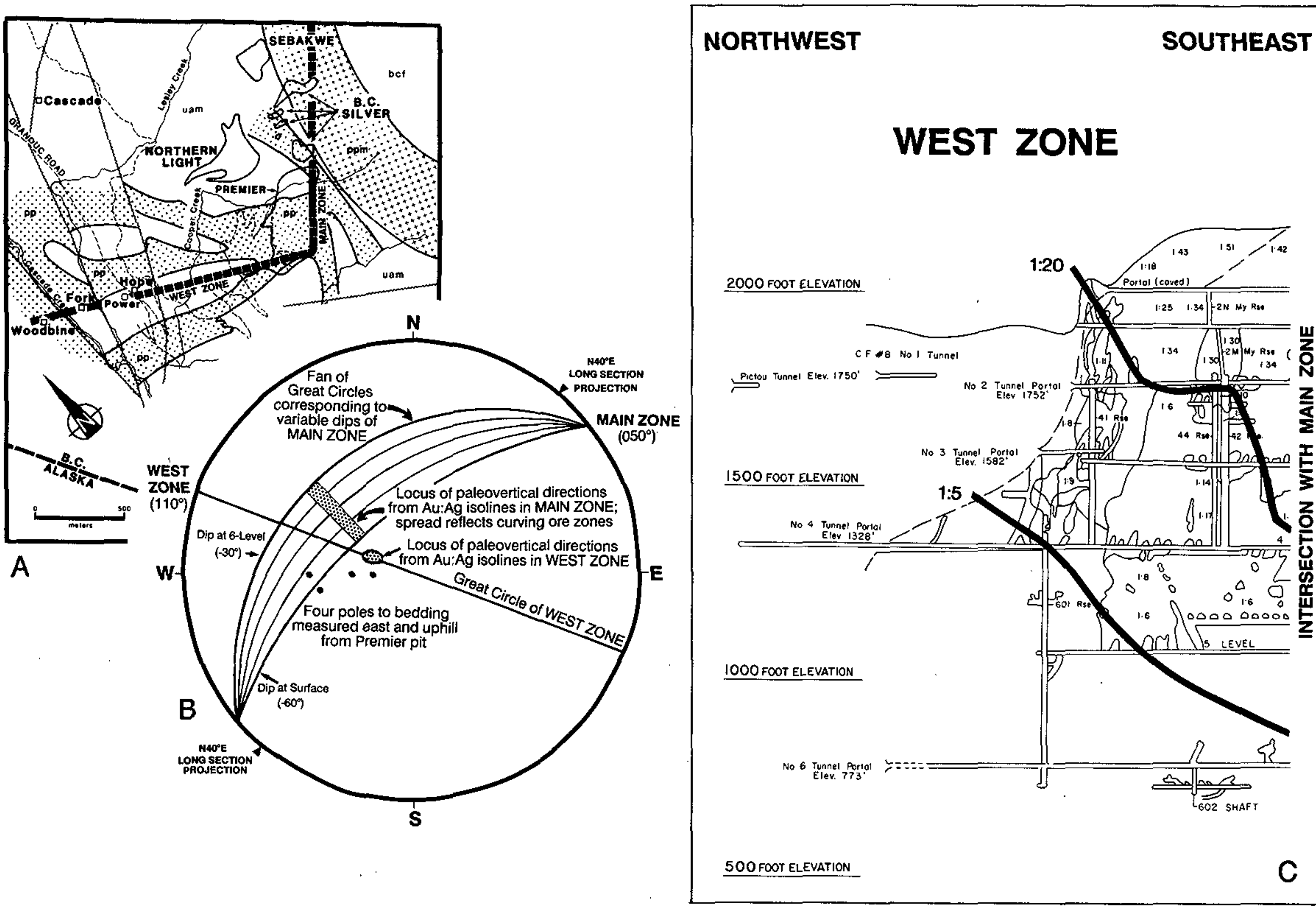


Figure 37. Three-dimensional distribution of ore zones at the Silbak Premier mine. **A**. Simplified geology map of the Silbak Premier mine area. (Modified from Alldrick, 1987 and Brown, 1987.) **B**. Stereonet shows good correlation between "paleovertical" directions obtained from bedding measurements, and from probable "paleovertical" precious metal zoning in the ore shoots. **C**. Longitudinal section through the West Zone orebodies shows zoning of gold:silver ratios. (Modified from Grove, 1986.)

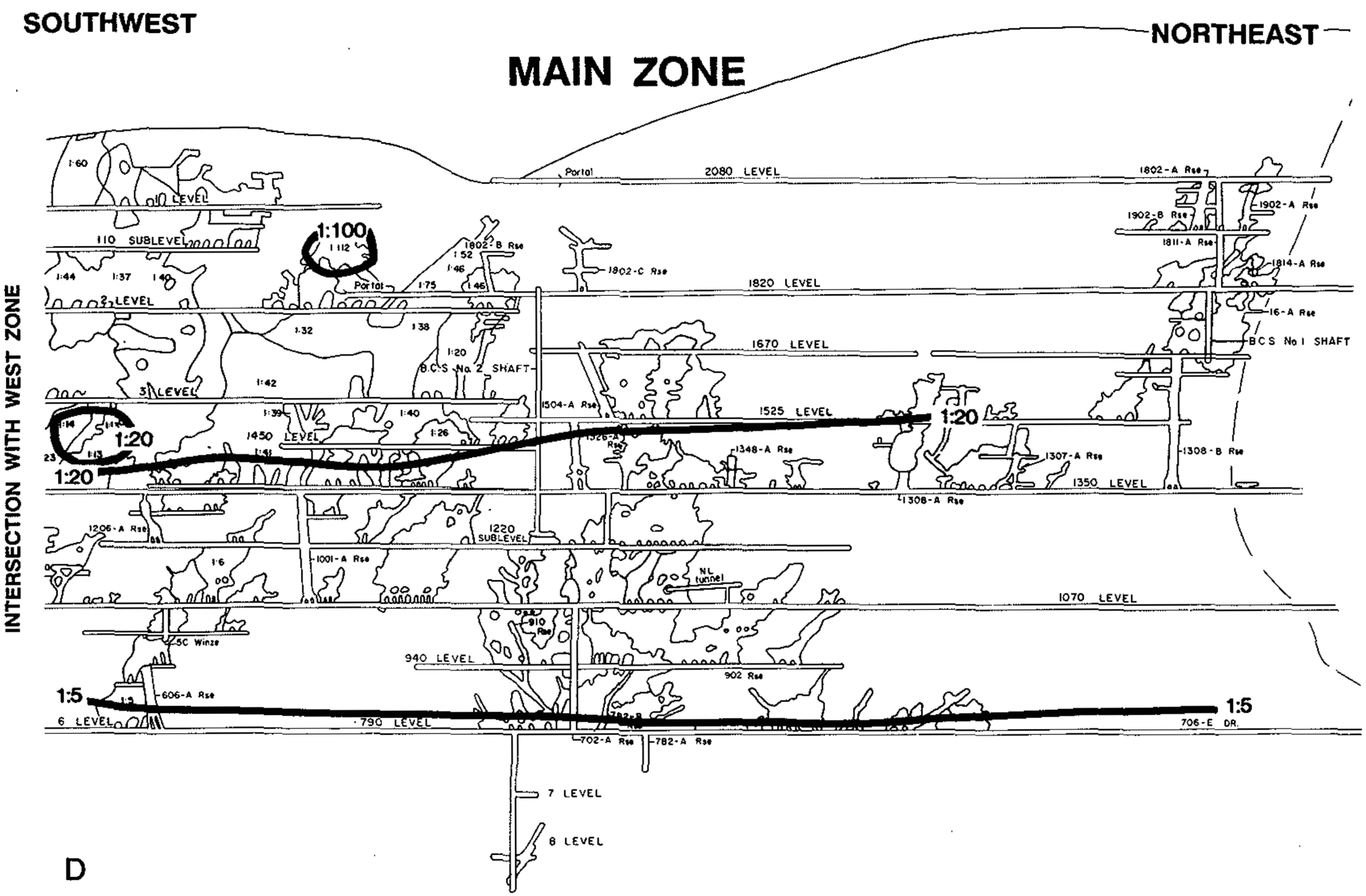


Figure 37. Three-dimensional distribution of ore zones at the Silbak Premier mine. D. Longitudinal section through the Main Zone orebodies shows zoning of gold:silver ratios. (Modified from Grove, 1986.)

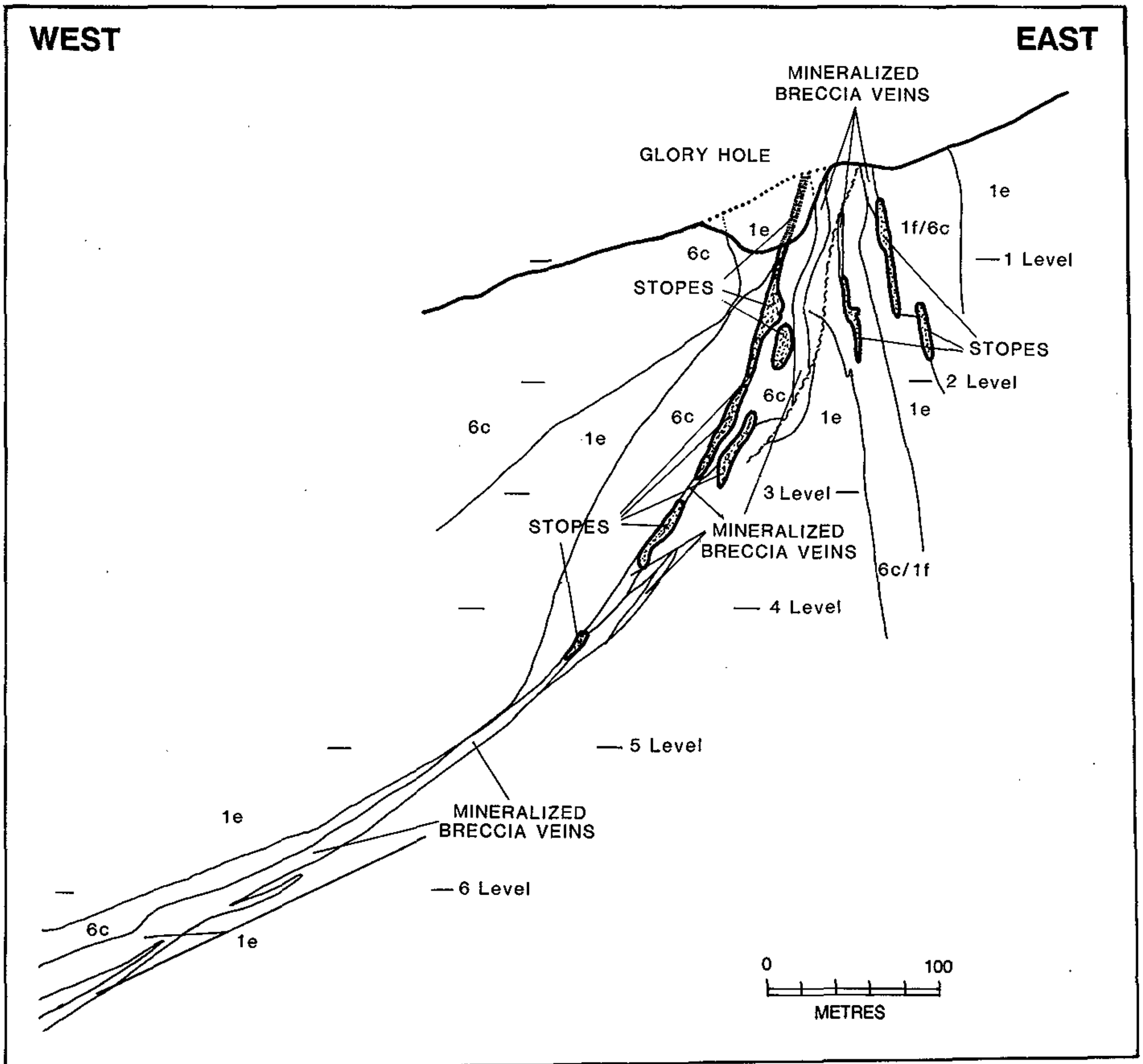


Figure 38. Geologic cross-section through Main zone, Silbak Premier mine. Mine Section 2245N. (Modified from P. Wojdak, written communication. *See* Figure 11 or 12 for legend.)

from 25 to 90 per cent (McDonald, 1988). Breccia matrix is medium to dark green and consists of pyrite, chlorite, sericite, quartz and carbonate. Pre-ore breccia may have been overprinted by later veining and brecciation; large clasts of pre-ore breccia are found within the ore breccias of the 602 ore zone. Quartz-carbonate and quartz-chlorite **pre-ore veins** cut pre-ore breccia, but are cut, in turn, by all later vein and breccia types.

Ore-stage veins and breccias contain most of the base metal sulphides and host all the precious metal ore of the mine area. They seem to record an extended period of multiple, superimposed ore-bearing vein and breccia formation. Veins and minerals display internal structures and textures indicating several pulses of mineral deposition and growth, and these are transected by veins of later generation. The ore types are best considered as four styles of mineralization that can be shown as an inter-related matrix (Table 19).

Brown (1987) puts the dividing line between low-sulphide and high-sulphide categories at 15 per cent sulphide content; McDonald (1988) defines low-sulphide veins and breccias as those with less than 5 per cent sulphides, high-sulphide veins and breccias as those with 20 to 45 per cent sulphides. Vein stockworks are areas of overprinted vein patterns that, together with zoned sulphide grains and layered sulphides, provide evidence for multiple mineralizing episodes. Breccias are areas of even greater dilation than the veins, so that these descriptive categories for veins, vein stockworks and breccias are gradational. The distinction between low-sulphide and high-sulphide ore types is more sharply defined than the textural divisions. Even so, large low-sulphide breccia bodies may have local pods of high-sulphide breccia within them.

A vertical zoning pattern is indicated by the general distribution of these ore types (McDonald, 1988); high-sulphide veins and breccias are more prominent in the lower levels of the deposit and in the West zone, low-sulphide veins and breccias are more prominent near surface and in the Main zone. All styles of mineralization constitute precious metal ores.

Breccias and veins are characterized by distinctive gangue textures indicating deposition in a subvolcanic environment, for example, cockade structure, comb-textured quartz, chalcedonic quartz, crustiform banding and open vugs lined with quartz, pyrite and sphalerite. Fluid inclusion studies indicate ore deposition occurred at an average depth of 600 metres (McDonald, 1990a,b). These important veins and breccia bodies are described and compared below in the same numerical order used in Table 19.

Plate 35. Shattered wallrock with vein network or 'stockwork,' 602 orebody, 6-level, Silbak Premier mine.

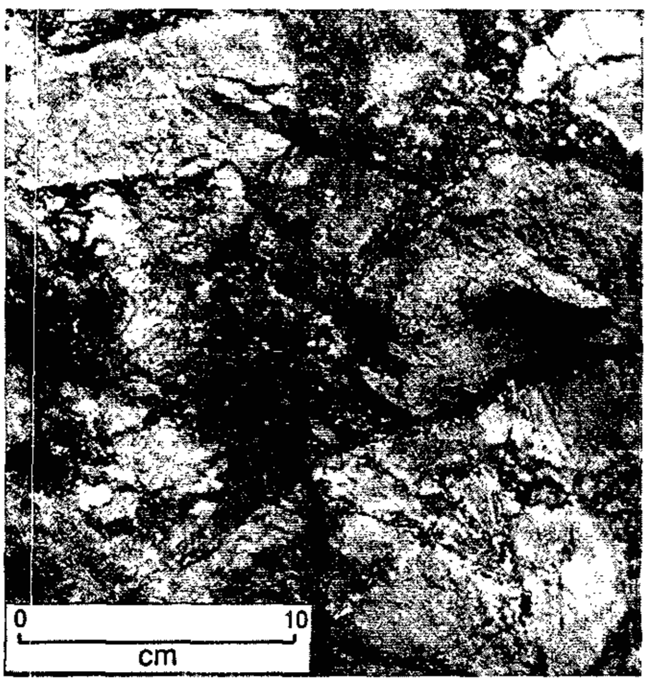


Plate 36. Sulphide-cemented breccia of bleached, rounded wallrock clasts exposed in the floor of the Silbak Premier glory hole, south wall.

(1) Vein Stockworks and Veins. Vein stockworks are irregular networks of banded to massive veinlets that vary from 0.5 to 4 centimetres in width (Plate 35). Stockworks are generally peripheral to breccia zones and appear to be lateral, gradational extensions outward from the breccia bodies.

(2) Breccias. Breccia bodies are extremely irregular, with subsidiary arms or splays off the main body. Breccia zones range up to 20 metres wide and have been located throughout the entire extent of Main and West zones, from surface to the deepest mine workings. Most breccias pass gradually into vein stockwork zones, but some are bounded by faults. Breccia matrix comprises up to 70 per cent of the rock and hosts most of the precious metal minerals. Clasts include wallrock and ore fragments. Wallrock clasts are composed of either andesite or Premier Porphyry, but the original lithology of strongly altered clasts can be difficult to determine (Plate 36).

(3) Low-sulphide Veins and Breccias. There is a progression from weakly altered hostrock, to strongly altered hostrock cut by minor quartz veins, to intensely altered hostrock criss-crossed by low-sulphide vein stockworks, to low-sulphide breccias (siliceous breccias) (Figure 39).

(4) High-sulphide Veins and Breccias. High-sulphide veins, vein stockworks, and the matrix to breccia may contain up to 45 per cent pyrite, galena, sphalerite, chalcopyrite, pyrrhotite, tetrahedrite, native silver and electrum. Quartz, chalcedony, calcite, barite and albite gangue minerals are either randomly intergrown with the sulphides or locally form crude bands (McDonald, 1988).

(5) Low-sulphide Veins. Low-sulphide veins and stockworks are preferentially localized in Premier Porphyry and along porphyry-andesite contacts. They are more abundant

TABLE 19
STYLES OF MINERALIZATION
AT THE SILBAK PREMIER MINE

	1 VEIN STOCKWORKS AND VEINS	2 BRECCIAS
3 LOW SULPHIDE (<5% sulphide)	5 Precious metal veins Siliceous stockworks Low-sulphide veins	6 Precious metal breccias Siliceous breccias Low-sulphide breccias
4 HIGH SULPHIDE (>20% sulphide)	7 Base metal veins Sulphide veins	8 Base metal breccias Sulphide breccias

(Numbers refer to sections in text)

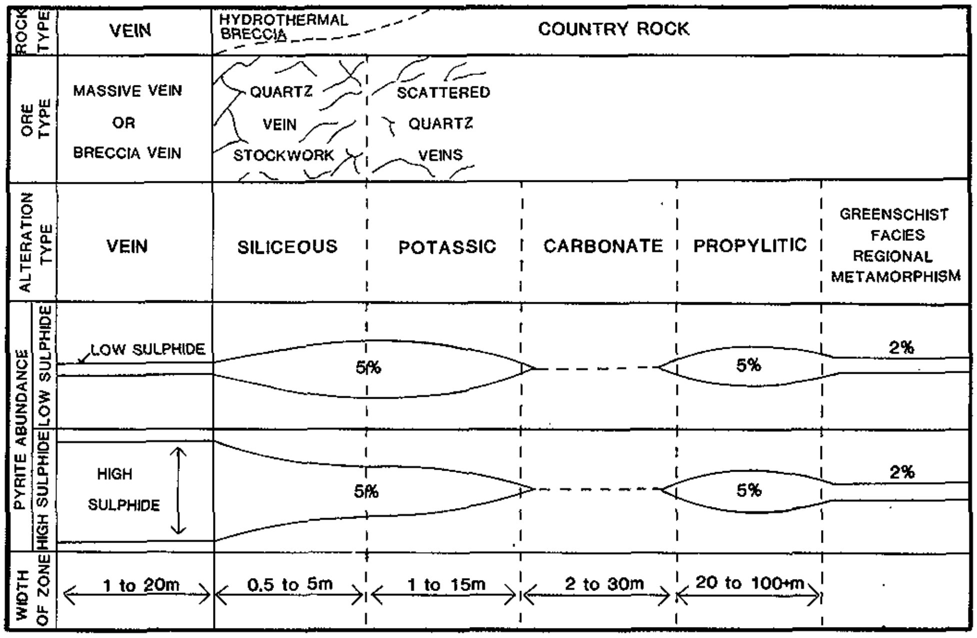


Figure 39. Distribution of ore structures and alteration zones in the Silbak Premier mine. Note variation in horizontal scale.

Plate 37. Low-sulphide breccia shows late, coarsely intergrown calcite-quartz gangue. Clasts are locally ringed by early sequential layers of pyrite and mixed base metal sulphides (dark grey). Note single clast of blue-grey chalcedony. 2-level trench, Silbak Premier mine (*see* colour photo in back of report).

closer to surface and in the Main zone and generally constitute ore with the highest silver:gold ratios (Randall, 1988). Low-sulphide vein stockworks contain disseminations and patches of pyrite, sphalerite, chalcopyrite, pyrrhotite, tetrahedrite, native silver and electrum in quartz-rich gangue with associated calcite.

(6) Low-sulphide Breccia. Low-sulphide breccia is the most extensive of the four "end-member" ore types and also the highest grade ore. Alternate names are: precious metal breccia, siliceous breccia, bonanza ore and breccia veins. Total sulphide content is less than 5 per cent, composed mainly of pyrite with minor sphalerite and galena. Precious metal bearing minerals are polybasite, pyrargyrite, acanthite, tetrahedrite, freibergite, native silver, gold and electrum (Randall, 1988). Gold and silver values are not distributed uniformly within these zones. Higher grade "bonanza" sections consist of local concentrations of silver sulphosalts with electrum and native silver in later fractures (Brown, 1987).

Clasts are predominantly bleached, altered porphyry and andesite with rare chalcedonic clasts (Plate 37). Near the margins of the breccia, clasts are sharply angular and more distinct, closer to the centre they are rounded and less distinct due to intense silicification. Breccia matrix is mainly chalcedonic quartz with patchy sulphide aggregates. Local high-sulphide zones have been discovered within these low-sulphide breccias.

(7) High-sulphide Veins. High-sulphide veins and vein-stockworks are restricted to the immediate margins of high-sulphide breccias, extending only 2 to 3 metres from the breccia contact. They are most common in the lower parts of the deposit and in the West zone.

(8) High-sulphide Breccias. High-sulphide breccias are the most visually striking ore type (Plate 36) although precious metal content is consistently lower than low-sulphide ores. Sulphides are dominantly pyrite with accessory sphalerite and galena, and minor chalcopyrite and pyrrhotite. Base metal sulphides are massive textured, medium to coarse grained and commonly vuggy. Breccia boundaries may be sharp fault contacts, a gradation into a high-sulphide vein stockwork, or gradational contacts into volcanic wallrock with scattered large patches of sulphide aggregate grading outward into a disseminated pyritic halo. This ore type is characteristic of West zone and deeper levels of Main zone.

A different variety of high-sulphide breccia ore is exposed at the 2-level portal, the Ladder trench and the Hope prospect. Striking surface exposures of semimassive to massive polymetallic sulphides are distinctly layered. Layering is regarded as post-ore, tectonically induced foliation within and adjacent to the major ductile shear that parallels the West zone.

Post-ore veins are quartz-carbonate and quartz-chlorite en echelon sets. They resemble pre-ore veins, so crosscutting relationships must be noted before classification is possible.

Evidence for **post-ore deformation** includes: fractured and dislocated pyrite enveloped by more ductile chalcopyrite, galena and sphalerite; pressure shadows around pyrite in gangue (Plate 18); porphyroblastic growth of coarse-grained, striated pyrite; and parallel foliation in sulphides and wallrock along the West zone.

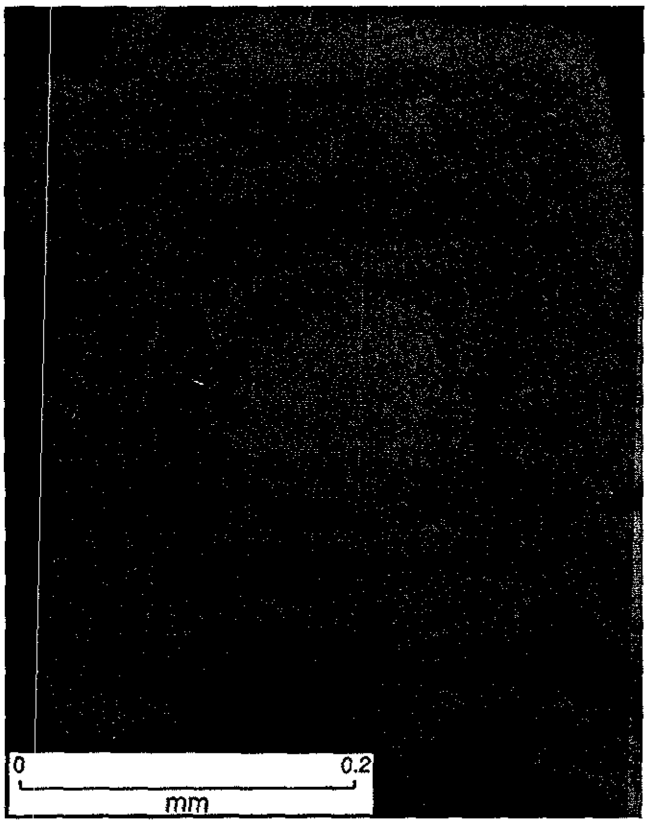


Plate 38. Photomicrograph of concentrically-zoned pyrite and pyrite aggregate record episodes of inclusion-rich mineral growth interspersed with inclusion-free layers. This oscillatory zoning or growth banding is attributed to periodic changes in the physical and chemical conditions of the depositing system (Fleet *et al.*, 1989). 2-level, Silbak Premier mine.

Mineralogy

There are significant variations in mineral textures, gangue and sulphide mineralogy, gangue and sulphide abundances, precious metal contents and precious metal ratios both within and among ore zones. Sulphide minerals include pyrite, sphalerite and galena with accessory to minor chalcopyrite and pyrrhotite and rare arsenopyrite. Silver and gold-bearing minerals include tetrahedrite/freibergite, polybasite, pyrargyrite, acanthite, native silver and electrum (Brown, 1987; McDonald, 1988). McDonald distinguishes between tetrahedite (0 to 20% contained silver) and freibergite (greater than 20% contained silver). Gold is present mainly as electrum whereas silver occurs primarily within tetrahedrite, polybasite and freibergite.

Base metal sulphides, tetrahedrite, electrum and native silver are present in both low-sulphide and high-sulphide ores. Polybasite, pyrargyrite, freibergite and acanthite are specific to low-sulphide breccias and veins (McDonald, 1988) where total metallic mineral content is less than 5 per cent. High-sulphide breccias and veins contain 20 to 45 per cent pyrite, sphalerite, galena, chalcopyrite, pyrrhotite, arsenopyrite, tetrahedrite, native silver and electrum.

Pyrite is the most abundant sulphide mineral; grains range from microscopic dust up to 1 centimetre in diameter. Larger grains may host complex rings of inclusions of other sulphides (Plate 38) indicating a sequence of pulses of inclusion-rich crystal growth (Fleet *et al.*, 1989; Barton *et al.*, 1977; Barton and Bethke, 1987). Fractured grains are enveloped by more ductile sulphide minerals. Pyrite aggregate typically forms monomineralic layers in book structure or banded veins.

Sphalerite is the next most abundant sulphide mineral with irregular grains ranging up to 8 millimetres across. Microscopic study shows most sphalerite is inclusion-rich with chalcopyrite and rare galena and sulphosalts. Sphalerite is typically brown, but McDonald (1988) also reports amber, deep red and black varieties. Galena is mostly a minor component but locally comprises up to 10 per cent of the vein material. Chalcopyrite is present in trace to minor amounts, generally as minute inclusions within sphalerite. Some high-sulphide ore contains as much as 4 per cent chalcopyrite McDonald (1988).

Pyrrhotite is present in minor amounts in most high-sulphide ores, associated with the more abundant pyrite. High-sulphide breccias exposed in the 6-level workings contain up to 8 per cent pyrrhotite as large intergranular blebs. It may be significant that these zones are among the deepest exposures in the mine as pyrrhotite crystallizes at higher temperatures than pyrite.

McDonald (1988) has identified small (0.1 to 0.3 mm) rectangular to subhedral crystals of arsenopyrite in high-sulphide ores. Arsenopyrite has also been reported peripheral to the low-sulphide ore zones (Phillips, 1989).

Tetrahedrite and argentiferous tetrahedrite are present in low-sulphide and high-sulphide ores. The mineral forms irregular grains or occurs as inclusions within galena and sphalerite. Silver content of tetrahedrite increases with elevation and the mineral becomes freibergite above 2-level (McDonald, 1988).

Polybasite is present only in low-sulphide ores where it is the most abundant silver mineral. It forms both irregular aggregates and minute inclusions in tetrahedrite. Pyrargyrite is a minor component of low-sulphide ores, forming irregular grains that are intergrown with polybasite (McDonald, 1988). Acanthite is present in trace amounts, always in contact with galena.

Native silver is present as minute inclusions in pyrite, galena, tetrahedrite and polybasite or as free grains in quartz. It also forms replacement rims around, and fine veins within, grains of polybasite, pyrargyrite and tetrahedite.

Electrum is present in both low-sulphide and high-sulphide ores as irregular blebs within pyrite and galena. The composition of electrum varies within individual grains and throughout the deposit; gold contents range between 35 to 56 weight per cent (McDonald, 1988). Grains are more silver-rich toward the rims.

McDonald (1988) determined a primary paragenetic sequence for metallic minerals. Both low-sulphide and high-sulphide veins and breccias have a sequence from sulphides to sulphosalts to native metals. In general, low-sulphide ores are earlier than high-sulphide ores; low-sulphide veins and breccias are cut by high-sulphide veins and breccias.

Gangue minerals include chalcedony and quartz, together with carbonate, potassium feldspar, albite, barite and rare anhydrite.

ALTERATION

A sequence of four distinctive alteration envelopes is developed around Silbak Premier ore zones and is an important exploration guide at mine scale. Spatial distribution of these alteration zones is shown on Figure 39. Widths of the different alteration zones vary with depth; widths of the silica, sericite and carbonate alteration all increase toward surface. These zones are locally discontinuous in the lower mine levels. The mineralogy, evolving fluid chemistry, and spatial and chronological sequence of the alteration envelopes is consistent with deposition in a subvolcanic, epithermal environment (Heald *et al.,* 1987; Siems, 1984).

Siliceous alteration (silica). Wallrock immediately adjacent to breccia orebodies and within vein stockwork ore zones is silicified (silica-flooded) and hosts accessory disseminated fine-grained potassium feldspar, and disseminations and patchy aggregates of mixed sulphides. Feldspar and sulphides together do not exceed 10 to 15 per cent of the rock volume. Sulphides locally have enough precious metal content to make ore. Alteration is sufficiently intense that original rock features are obscured in hand sample, but polished slabs or thin sections reveal the volcanic or Premier Porphyry dike textures. Silica flooding extends only a few metres outward from major siliceous breccia bodies and may fade out within a vein-stockwork zone as the overall vein density decreases outwards (Figure 39). However, precious metal mineralization is everywhere bounded by at least a thin envelope of siliceous alteration.

Sericitic alteration (potassic). Intense sericitic alteration with accessory pyrite, silica and minor potassium feldspar characterizes the next alteration envelope outward from the ore. This alteration may develop within the outer part of a vein-stockwork ore zone (Figure 39). In these areas, margins of individual veins and veinlets may have a silicified wallrock envelope up to one centimetre thick.

Carbonate alteration. Carbonate alteration bleaches still-recognizable country rocks. Altered rock has an overall pale grey or bone colour but original textures, fragments and phenocrysts can still be seen. Pyrite is present only in trace amounts or is absent in this zone, suggesting selective dissolution and replacement by calcite. This alteration type has been mapped as potassic or even as siliceous alteration in the past, but carbonate-flooded rocks are quite soft and powdered rock reacts strongly with dilute acid. Although the inner boundary seems gradational or patchy, the outer boundary of this alteration zone is marked by a relatively abrupt colour change over as little as a few centimetres or a more gradual change over a metre or less.

Chlorite alteration (propylitic). Propylitic alteration consists of pervasive chloritization of wallrock, producing a distinctive deep green colour (Plate 39). Associated with this alteration is up to 5 per cent fine to coarse-grained euhedral pyrite and minor to trace carbonate, sericite and epidote that are usually only noticeable in thin section. This alteration is distinct from the much less intense regional metamorphic greenschist facies alteration. Differences in alteration should be routinely documented during reconnais-

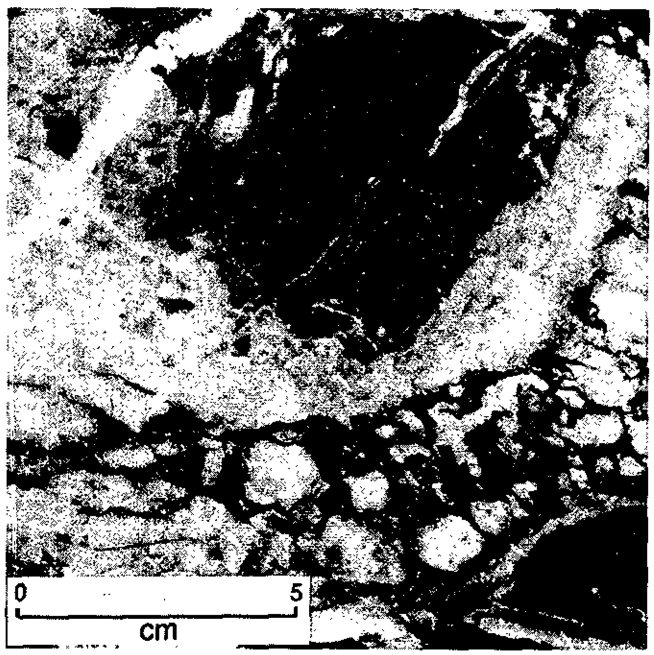


Plate 39. Chlorite-altered wallrock clasts host early disseminated sulphide mineralization. Chlorite-altered wallrock was then cut by thick, coarse-grained quartz-calcite veins, subsequently cut by bright white quartz veinlets, and then rebrecciated and cemented by a base-metal-rich sulphide phase. Silbak Premier glory hole.

sance mapping in the region. Propylitic alteration should be regarded as a distal indicator of ore potential, defining an area worthy of follow-up prospecting or geochemical surveys.

Pyrite alteration. McDonald (1988) concluded that the pyritic envelope or halo around both the low-sulphide and high-sulphide ore types may be independent of spatially associated silica and potassic alteration envelopes. In contrast, the writer has noted slightly varying pyrite textures that seem to be characteristic of each alteration zone (Figure 39). In either case, the pyritic envelope could be mapped as an independent alteration phenomenon and regarded as yet another proximal indicator of ore.

Silica alteration hosts very fine to fine-grained anhedral to granular disseminated pyrite resembling dust or fine-ground pepper. Potassic alteration is associated with generally coarser, more abundant (up to 8 to 10%), fine to medium-grained euhedral disseminated pyrite that is more distinctive and produces a shotgun-pellet or coarse-ground pepper size pattern. Pyrite is virtually absent from the carbonate-altered zone and the propylitic alteration zone hosts fine to coarse-grained euhedral disseminated pyrite with smooth faces. Pyrite in the propylitic alteration zone is distinctly coarser and more abundant (5% versus 2%) than in the regionally metamorphosed greenschist facies country rocks.

Zoning. As elevation increases, the decline in the total amount of sulphide minerals (Brown, 1987) coincides with an increase in silver sulphosalt minerals (McDonald, 1988), an increase in the silver to gold ratio (Hanson, 1935; Grove, 1971, 1986), and a decrease in fluid inclusion homogenization temperatures (McDonald, 1990a,b).

Low-sulphide veins and breccias are dominant in the upper levels of the deposit and in the northwest-striking Main zone. High-sulphide veins and breccias are dominant in the lower part of the deposit and in the west-northwest-striking West zone.

Metallic minerals display strong vertical zonation within the mine. Minerals change from sulphosalt assemblages in the topographic top of the deposit to more base-metal-rich assemblages at the bottom. Below 3-level, ore minerals are predominantly pyrite, galena, sphalerite and minor chalcopyrite. Silver-bearing minerals are present mainly between 3-level and surface (polybasite, pyrargyrite, acanthite and freibergite). Tetrahedrite, native silver and electrum maintain relatively constant abundances. Tetrahedrite is found throughout the deposit but above 2-level the content of silver exceeds 20 per cent, indicating a change to freibergite. In addition, the greater abundance of silver sulphosalts near the top of the deposit means silver grades and silver:gold ratios increase with elevation (Figure 37).

This mineralogical and metal zoning may provide a way-up indicator and correlates well with homogenization temperature isotherms of fluid inclusions that indicate that temperatures decreased upwards within the ore zones from 250°C to 205°C (McDonald, 1990a).

Higher ore grades near surface suggest that secondary or supergene enrichment may have affected the upper levels of the Silbak Premier deposits. This has been considered by Burton (1926), White (1939), Grove (1971, 1986) and Barr (1980). Burton felt that some supergene enrichment of native silver and polybasite was probable, but White and all subsequent workers up to McDonald (1990a) concluded that the ores are primary, based on their examinations of mineral textures and determination of paragenesis. Silbak Premier ores were emplaced at a considerable depth; McDonald concluded 600 metres depth based on fluid inclusion studies. The deposit was subsequently covered by many hundreds of metres of volcanic and sedimentary rocks. There is no lithostratigraphic evidence of a downcutting Jurassic erosional episode that could have exposed the uppermost ores to weathering or supergene enrichment. Burial was followed by regional metamorphism. Mid-Cretaceous deformation textures postdate the entire paragenetic sequence of ore minerals, including the paragenetically late polybasite (McDonald, 1988). Therefore there was no time in the history of the deposit that it was unroofed, until its very recent exposure by Quaternary glaciation, and there was no period when supergene processes could have generated the paragenetically youngest minerals in these ores.

GENESIS

A simple intrusive sequence relates the different Premier Porphyry dike rock types to stratigraphically stacked extrusive equivalent rocks. This intrusive 'model' accounts for all the types of intrusive rock and predicts that hydrothermal breccia veins will be concentrated in exactly the same position (relative to dikes and the paleosurface) as many of the Silbak Premier ore zones. The model resolves the problems of:

- 'folded' and 'unfolded' subvolcanic dikes and sills and extrusive flows
- the phenomenon of "telescoped" epithermal deposits (Barr, 1980; Grove, 1986)
- apparent lateral mineralogical zoning (McDonald, 1990a,b).

In addition it accounts for unusual features such as the hematitic rock-flour dikes first documented by Grove (1971).

Premier Porphyry dikes in the mine area record three subvolcanic intrusive events that each produced extrusive equivalent rocks now preserved as the three mappable units of the Premier Porphyry Member. The events must have occurred over a relatively short period of time as little or no sediment accumulated between them. The volcanic edifice was emergent and the mine area represented a local topographic high (Figure 35). The peculiar dike pattern at Silbak Premier can be projected into a pre-erosional cross-section (Figure 40) that emphasizes the difference in orientation between early subvertical plagioclase hornblende porphyry dikes and later, curving potassium feldspar megacrystic dikes.

The intrusive sequence and genetically related hydrothermal brecciation and veining are illustrated schematically in Figure 41. The initial subvolcanic magma (Figure 41a) was composed of plagioclase hornblende porphyry, texturally similar to the 'type' Premier Porphyry dikes but lacking the characteristic potassium feldspar megacrysts. The accompanying extrusive unit was deposited as a thinly laminated to thin-bedded, rhythmically bedded, crystal-rich tuff (massive to laminated plagioclase porphyry, Plate 5). The original conduit may have been a single elongate fissure. A large body of this plagioclase hornblende porphyry lies structurally above the main ore zones at the Silbak Premier mine. It is an apparently homogeneous mass that has little brecciation, alteration or mineralization and has consequently been a disappointing exploration target despite its similarities to the thinner, curving potassium feldspar megacrystic dikes.

Pressure release was followed by adiabatic cooling within the subvolcanic magma chamber during a period of quiescence (Figure 41a) that initiated growth of potassium feldspar megacrysts and quartz crystals. Seismic activity or magma subsidence caused a new fracture to form near the existing volcanic neck, allowing injection and extrusion of the potassium feldspar megacrystic magma. Magma crystallized in the fracture as massive subvertical dikes, including the one that now forms the northern contact of the West zone (Figure 37).

This second eruption produced the Premier Porphyry flow and was the most voluminous of the three eruptions. It was followed by a second period of quiesence and magma subsidence. This created increasing stress in rocks overlying the magma chamber (Figure 41b). The hemispherical distribution of this stress field is governed by decreasing lithostatic pressures as the surface is approached. As stress increased, shear fractures propagated through the caprock along a parabolic trace due to the hemispherical shape of the tensile stress field. This mechanism, originally proposed by Anderson (1937), has been presented with modifications by Phillips (1986). Magma, now rich in newly formed potassium feldspar and quartz, intruded the opening shear fractures to form ring dikes, and extruded at surface (Figure 41c). These ring dikes were thinner but more numerous

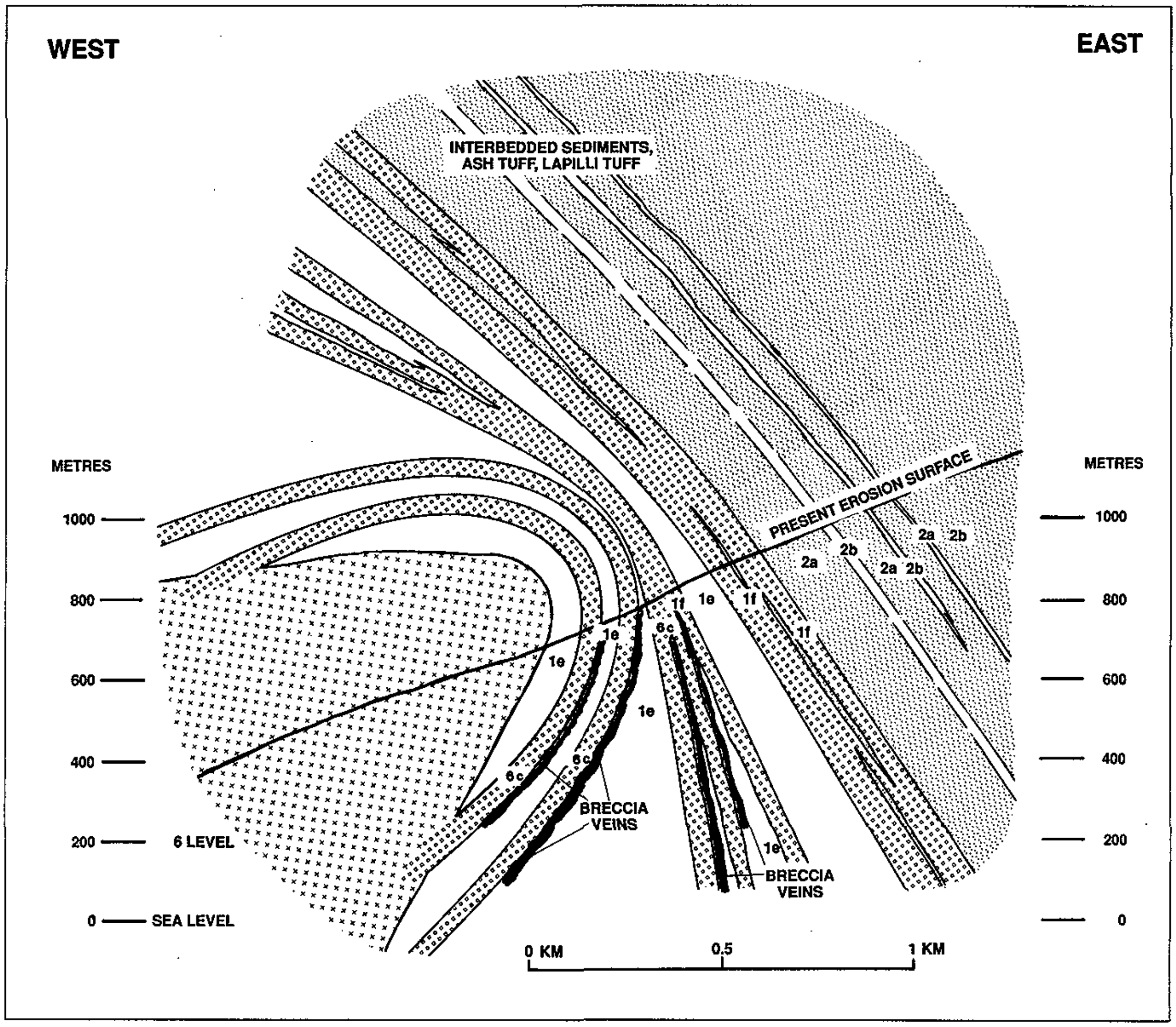


Figure 40. Ore deposit model for Silbak Premier mine. Pre-erosional geologic reconstruction in the Silbak Premier mine area. Compare with Figures 38 and 41. 1e=Upper Andesite Member; 1f=Premier Porphyry Member (undivided); 2a=Betty Creek Formation sedimentary strata; 2b=Betty Creek Formation tuffs; 6c=Premier Porphyry dikes.

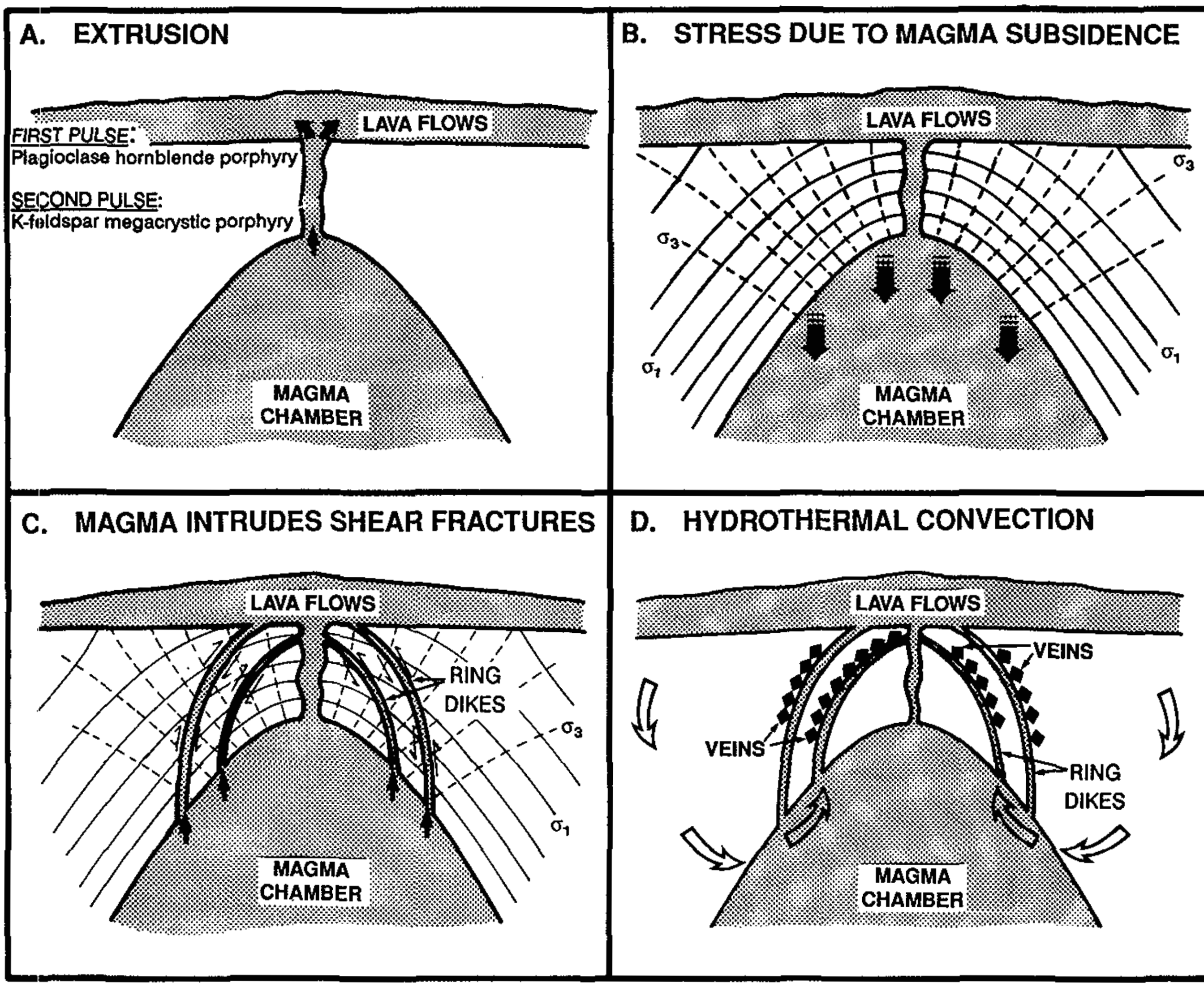


Figure 41. Genetic model for the Silbak Premier mine (modified from Anderson, 1937 and Phillips, 1986).

than the earlier central feeders. The extrusive equivalent is maroon Premier Porphyry tuff, and perhaps the upper part of the Premier Porphyry flow, which represent the last phases of this eruptive event.

An integral part of the final intrusive-extrusive event was the formation of hydrothermal breccia zones on the hangingwall sides of the curved shear fractures (Phillips, 1986). Hydrothermal solutions derived from late magmatic volatiles rose upward from the area of the top of the magma chamber (Figure 41d). Pathways to surface were intermittently sealed due to mineral deposition and lithostatic load so that fluids accumulated in lower pressure, dilational spaces above the magma chamber. These spaces existed along the hangingwall side of the ring dikes due to minor contraction during crystallization and cooling. In contrast, the footwall of a ring dike was a closed, high-pressure environment because the dike itself provided a dome-shaped impervious cap.

Hydrothermal solutions gradually accumulated, producing a fluid sheet that progressively precipitated minerals. As fluid pressure increased and exceeded lithostatic load, major and minor fractures popped open abruptly. These fractures extended the existing fluid-filled fracture network both upward along the dike contact and outward into the wallrock. Each new fracture opening caused a small, abrupt drop in fluid pressure which resulted in mineral precipitation that reflected the chemistry of the solutions at that moment. Mineral layers in ore display textures reflecting periods of slow, static high-pressure mineral precipitation during cooling, alternating with periods of mineral 'dumping' during abrupt pressure drops.

Fractures occasionally propagated to the surface and resulted in breaching, flash boiling and catastrophic pressure drop throughout the system with considerable mineral precipitation and accompanying chaotic wallrock spalling into the evacuated and unsupported fluid chambers. As the chambers closed, rock fragments in the centre of the zone were crushed and ground in a natural autogenous mill. Consequently, older clasts in the core of the breccia veins are crudely rounded in contrast to sharply angular, younger clasts near the breccia-vein margins. The shallow fractures that were open to surface sealed quickly; then the more typical cycle of moderate to high-pressure fluid accumulation and propagation of minor fractures resumed.

A rock cut along the old track between the B.C. Silver and Sebakwe portals sits stratigraphically above (eastward and uphill from) the 'blind' B.C. Silver ore shoots. The rock consists of green ash tuff shattered into a sharply angular mosaic breccia with a matrix of red, hematitic rock-flour (Grove, 1971, Plate IXc). This feature was formed by a gas blast and is a monolithologic equivalent of a hydrothermal pebble-dike. Such structures characteristically cut the barren caprock that overlies the mineralized interval of an epithermal vein system (Sillitoe, 1985, Figure 14).

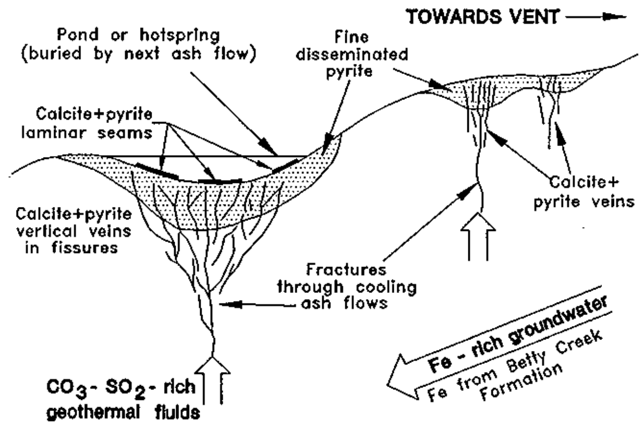


Figure 42. Genetic model for the stratabound pyritic dacite of the Mount Dilworth Formation.

Stratabound Pyritic Dacite: Mount Dilworth and Iron Cap

The stratabound pyritic dacite tuff exposed along the western edge of the **Mount Dilworth** Snowfield has been described in detail in Chapter 3. This unit forms a striking gossan that has attracted attention for decades. No other sulphide minerals have been noted in this area and no significant precious or base metal values have been reported.

As part of this study, samples of the unit were collected for assay at 300-metre intervals between its southern termination and Summit Lake. It was hoped that results might indicate an anomalously high zone of base or precious metals that would warrant additional sampling and ultimately drill testing of the down-dip extension. Base metal and precious metal values from 14 samples were uniformly low; 'peak' values are: less than 3 ppm gold, less than 10 ppm silver, 0.006 per cent copper, 0.07 per cent lead and 0.016 per cent zinc. Iron ranges up to 14 per cent and the rocks are relatively high in vanadium, thallium, germanium, chromium, barium, beryllium and fluorine when compared to most other ores and altered rocks in the district (Table 16).

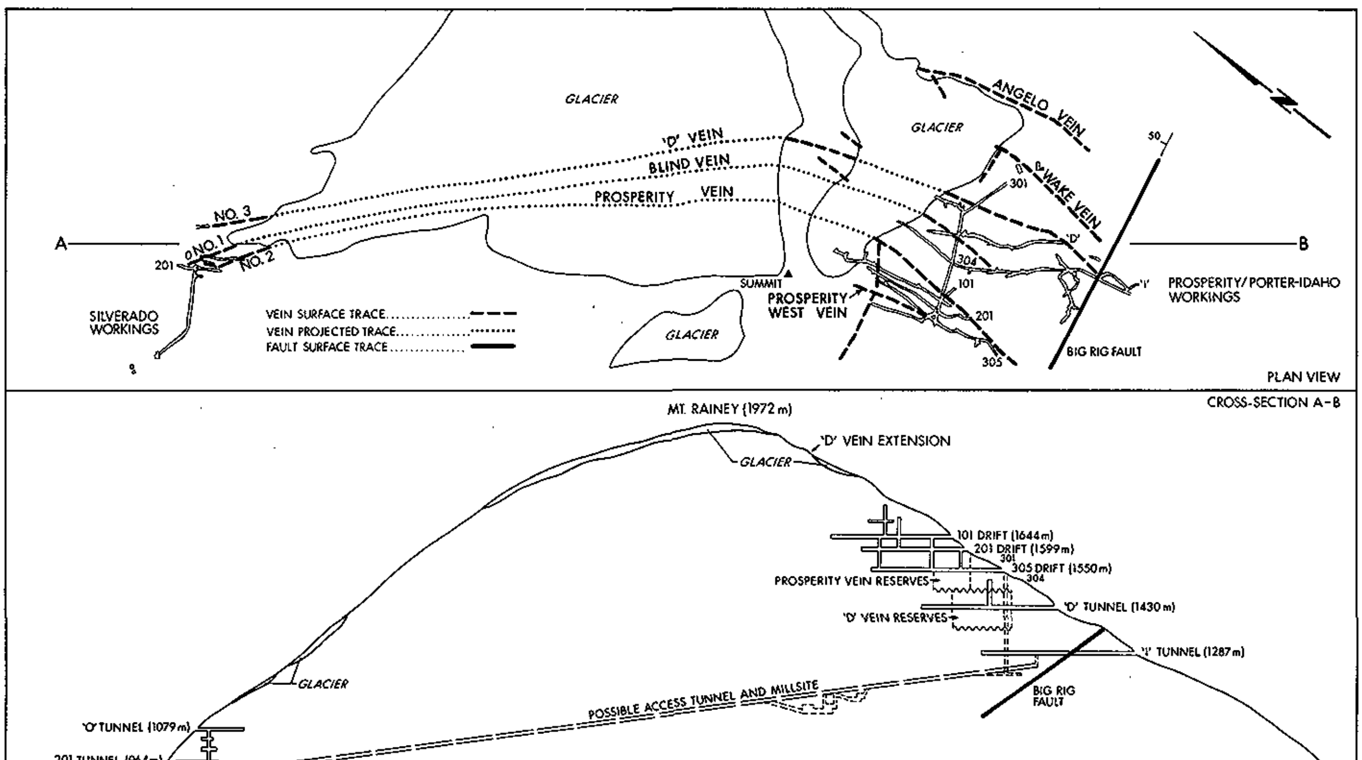


Figure 43. Distribution of veins at the Prosperity, Porter Idaho and Silverado mines near the summit of Mount Rainey. (From plans of Pacific Cassiar Limited. *See* Figure 11 for topographic and geologic setting and latitude/longitude.)

The **Iron Cap** prospect at the northeast end of Long Lake is another exposure of the same lithology in the same stratigraphic position. The showing has been described by Dupas (1985, p.313) and Plumb (1956, p.8). Because Plumb's report is unpublished the relevant section is reproduced here in full:

"This name derives from the iron-stained erosion surface of a single gently-dipping basaltic volcanic flow exposed for 3,000 feet along the south side of Joan Creek. It forms the uppermost horizon of the Bear River volcanic rocks and dips at about 20° conformably under the lowest sedimentary beds of the Salmon River Formation. The upper four feet or so is heavily impregnated with fine-grained iron pyrite that appears to fill vesicles in the dense, black, fine-grained rock. In addition to pyrite this rock contains a little chalcopyrite, galena and sphalerite as well as minute blebs and veinlets of opaque, pale blue chalcedony. While the gossan is widespread, no economic concentrations of the base or noble metals were found.

"Two open cuts had been blasted by the owners near the top and bottom of the zone, and they report low but consistent values in silver, lead and zinc. One sample, No. 326, was channeled by the writer across eight feet in the upper cut (elevation 4,420 feet) and assayed 0.20 ounces in silver with a trace of gold. No other areas worthy of sampling were observed and nothing further was done with this zone."

At both the Mount Dilworth and Iron Cap occurrences, pyritic dacite caps a blanket of dacitic pyroclastic rocks. This represents penecontemporaneous or postdepositional impregnation of pyrite into a variety of rock types, although the predominant rock type is dacitic lapilli tuff. In some exposures the pyritized rock is a carbonate-mudstone-cemented debris flow with heterolithic volcanic and carbonate clasts. The pyritic tuff is interpreted as local pyrite impregnation around fumaroles, hotsprings and calcareous-mud-filled brine pools that were scattered about on the cooling volcanic sheet (Figure 42).

EOCENE DEPOSITS

Eocene deposits have lead isotope ratios consistent with a Tertiary age; other geologic features of these deposits indicate a more specific Eocene age. Some of these deposits were regarded as Tertiary prior to this study, others were regarded as Jurassic or Cretaceous, most were not categorized. The Prosperity/Porter Idaho mine was examined in detail.

SILVER-LEAD-ZINC VEINS: PROSPERITY/PORTER IDAHO MINE

High-grade silver-lead-zinc veins of the Prosperity and Porter Idaho mines crop out on the upper slopes of Mount Rainey, 4.5 kilometres southeast of Stewart (Figure 11). Mine workings are on the south face of the mountain at 1550 metres elevation (Figure 43). Published reserves are 826 400 tonnes at 668.5 grams silver per tonne with 5 per cent combined lead-zinc (Canadian Mines Handbook, 1989, p.355). The Silverado deposit is exposed on the north face of the mountain, 2.5 kilometres northwest of the Prosperity/Porter Idaho mine.

GEOLOGIC SETTING

Silver deposits on Mount Rainey are hosted within an andesitic to dacitic volcanic sequence that is the stratigraphic extension of rock types hosting precious metal deposits in the Salmon River valley to the north (Figures 10, 11, 44 and 47c). The Hyder batholith intrudes these volcanic rocks on the west and north sides of Mount Rainey (Figure 11). The pluton is medium to coarse-grained biotite granodiorite; the core is unaltered but the outer 100 metres of the batholith is cut by a network of widely spaced (50 to 100 cm apart) epidote veinlets. Volcanic rocks at the contact are sheared and cut by epidote and chlorite veinlets.

The intruded volcanic section comprises a thick sequence of green andesitic coarse ash tuffs interpreted as the top of the Unuk River Formation (Figure 11). A section of massive purple epiclastic conglomerate, 100 metres thick, crops out as a prominent knob on the ridge top, 700 metres east of the intrusive contact and is interpreted as the base of the Betty Creek Formation. The overlying volcanic sequence farther east (Figure 44) is a complex succession of andesitic crystal and lithic tuffs, including lapilli tuffs and medium to coarse tuff-breccias, and interbedded dacitic crystal tuffs, lapilli tuffs, welded and thinly bedded tuffs, with local thin epiclastic conglomerate beds, black siltstones and argillaceous limestones. A thick section of massive felsic tuffs and interbedded coarse tuff-breccias is exposed on the arête at the head of Barney Glacier to the northeast of the mine workings. The arête continues eastward to the peak of Mount Magee. Beyond the peak, siltstones of the Salmon River Formation have been identified, so the unmapped peak area is the expected location of the stratigraphic extension of the Mount Dilworth Formation and the basal fossiliferous limestone of the Salmon River Formation (Figure 11).

The overall strike of volcanic units in the mine area is north-south with dips moderately to steeply westward to vertical, but large variations in the strike have been noted. No tops indicators were found. In order to correlate the rocks in the mine area with the stratigraphic sequence established to the north, the sequence at the mine would have to be overturned to the east (Figure 11).

Hostrocks to mineral zones at Prosperity/Porter Idaho are predominantly dacitic volcanic rocks, varying from lapilli and crystal tuffs to welded tuffs with minor units of thinly bedded tuff. In contrast, hostrocks at Silverado to the northwest are underlying andesitic lapilli tuffs and coarse tuff-breccias. Various felsic and lamprophyre dikes crop out in and around the Silverado deposits but are less evident in the Prosperity/Porter Idaho workings.

Silver mineralization on Mount Rainey is present as veins within a set of major subparallel brittle fault zones or "shears" (Figures 44, 45, 46 and 47c). Six of these shear structures, spaced roughly 175 metres apart, have been explored at Prosperity/Porter Idaho whereas four fault structures are known at Silverado. At Prosperity/Porter Idaho the main shear zones trend 165° and dip 60° westward. These

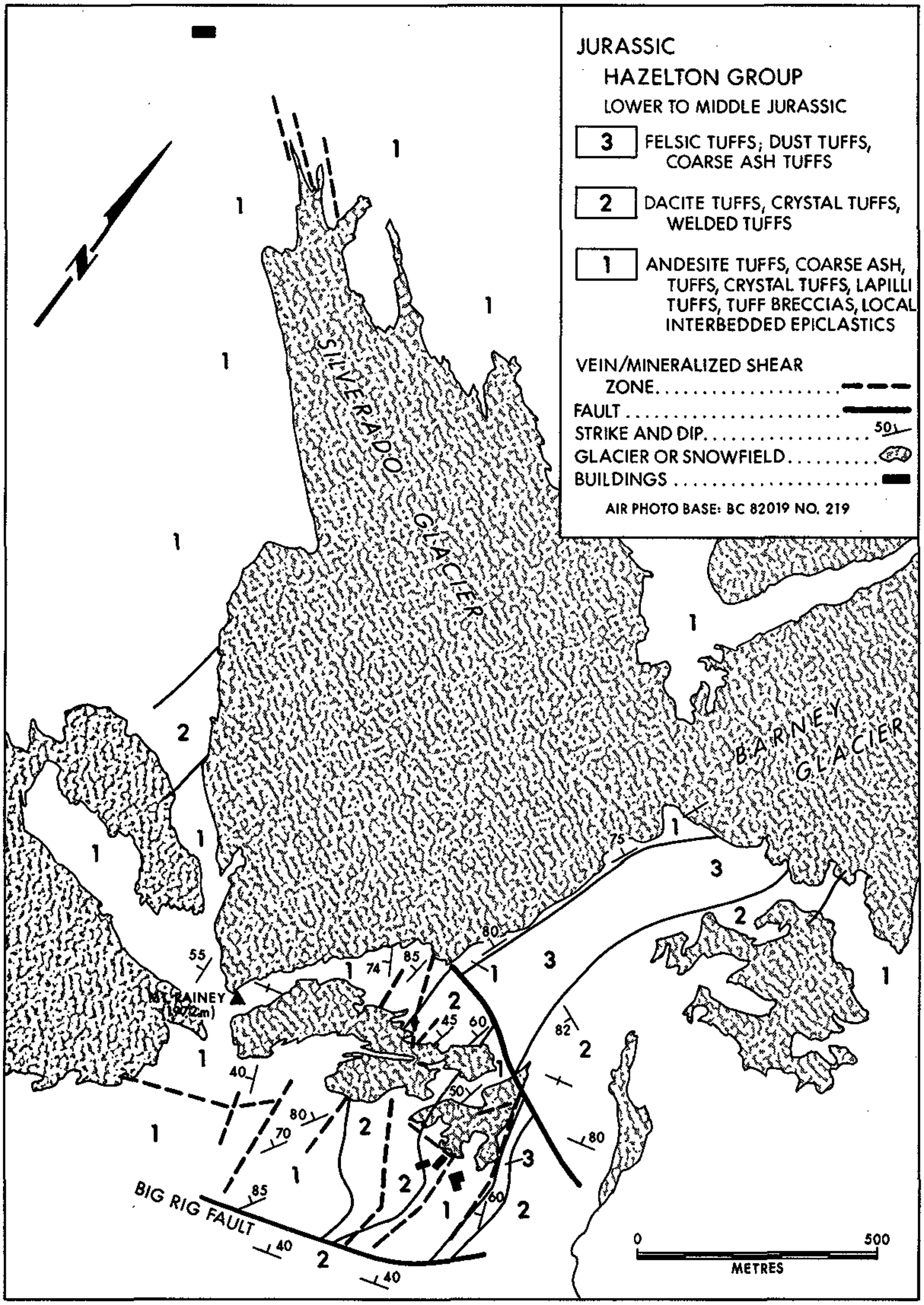


Figure 44. Geological map of the Mount Rainey summit around the Prosperity, Porter Idaho and Silverado mines.

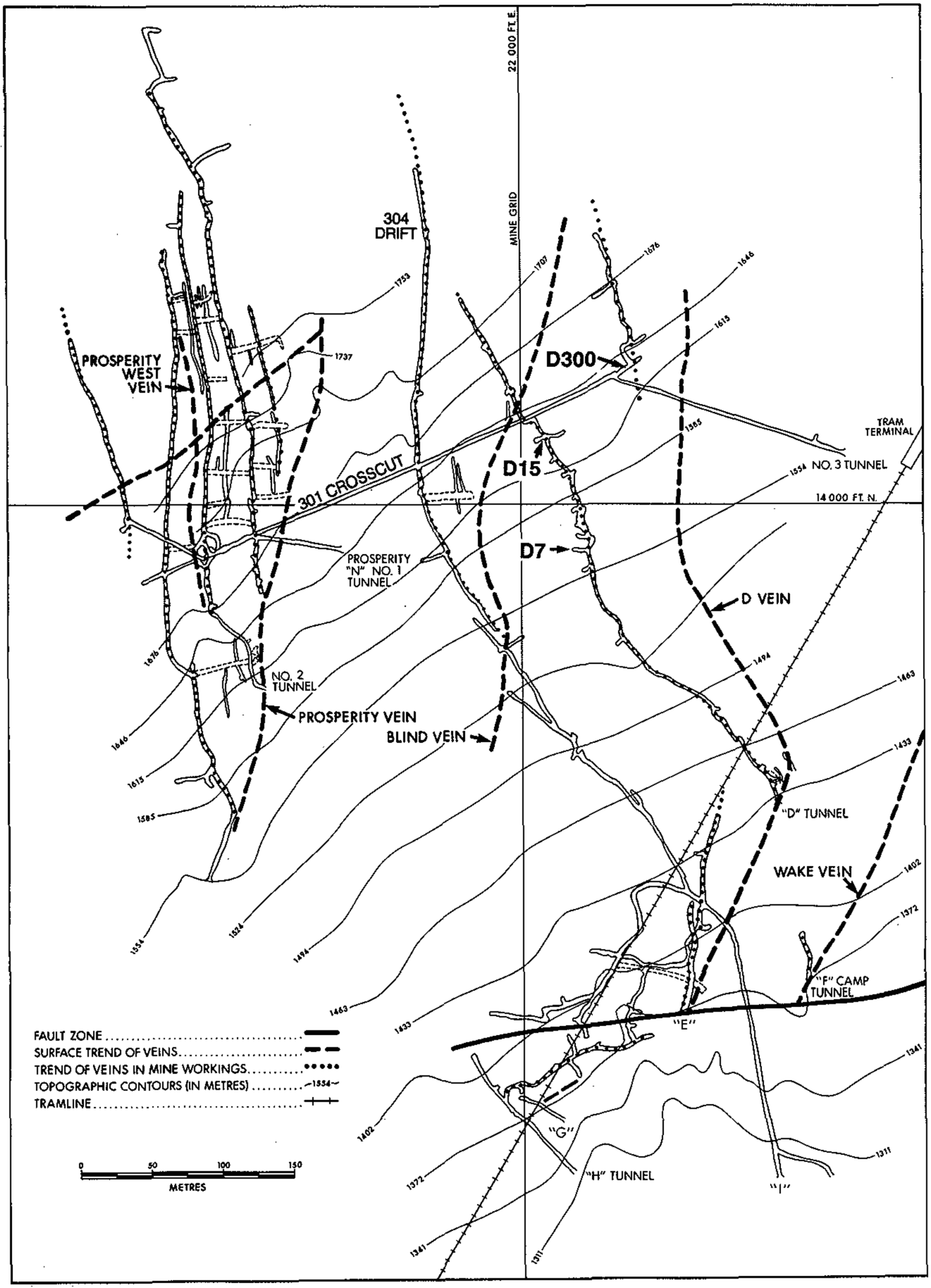


Figure 45. Plan of the Prosperity/Porter Idaho mine workings. Plan shows the surface trace of the veins, the underground mine workings, the location of the veins within the main levels, and the location of the three channel sample sections for this study.

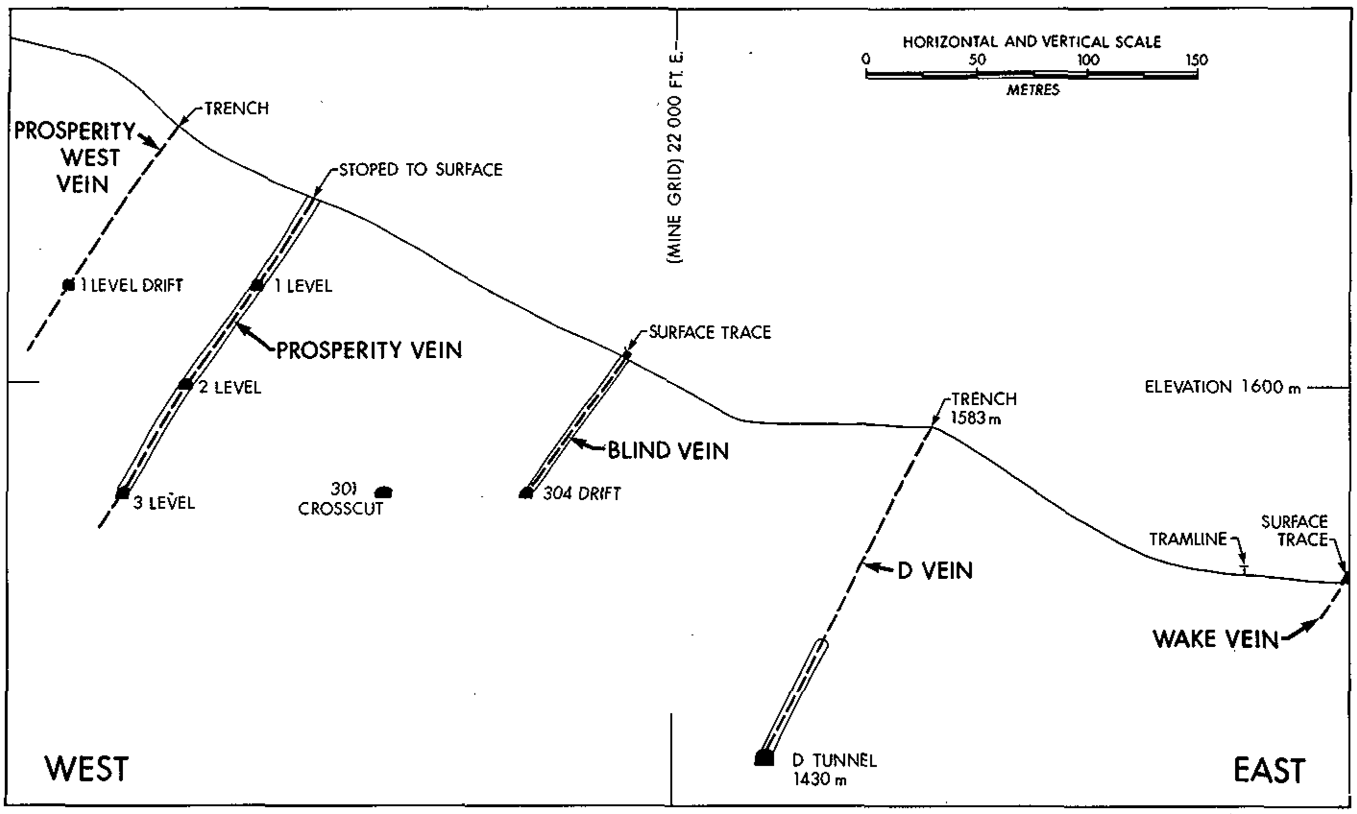


Figure 46. Cross-section through the Prosperity/Porter Idaho mine workings, along map section 14,000 N. (*See* Figure 45.)

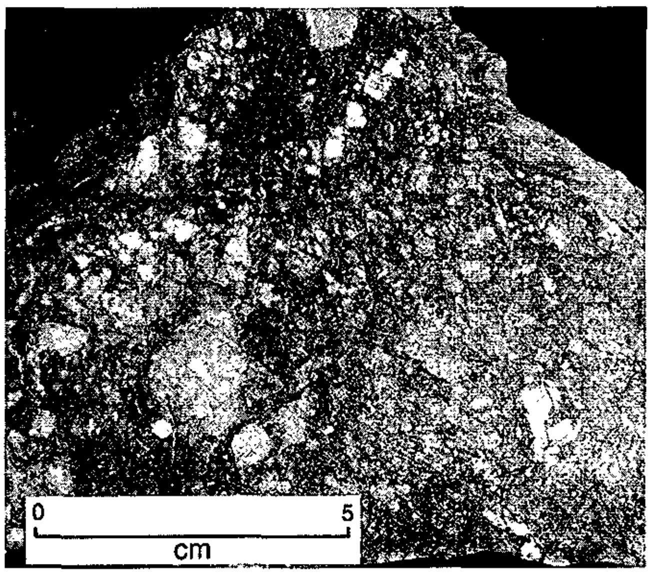


Plate 40. Polished slab shows weakly mineralized, lithified fault breccia. Fragments are country rock dacite tuff and bull quartz chips from pre-ore quartz veins. Prosperity vein, Prosperity/Porter Idaho mine.

zones do not splay and are cut but not offset by lamprophyre dikes in the underground workings. All shear zones continue northward until covered uphill by talus or ice. Southward, they terminate at, or are displaced by, a major north-dipping east-west fault zone called the Big Rig fault. At Silverado, the main mineralized shears trend 155° and dip 65° westward and the structures split along horse-tail-like splays.

The direction of offset along the shears has not been determined. Slickenside orientations range from horizontal to directly downdip. As there are no marked lithological changes across the shears, and in one area no lithological change at all, even on a microscopic scale, total offset is probably minor, 200 metres or less.

OREBODIES

The Porter Idaho shear zones are continuous structures, up to 13 metres wide, hosting discontinuous mineralized lenses or shoots. In unmineralized or weakly mineralized areas material within shear structures consists of varying amounts and sizes of intensely sheared wallrock fragments and blocks set in a gouge or clay matrix. Some shear zone sections are silicified, others are carbonate-cemented (Plate 40), still others are soft unlithified gouge. Mineralized zones pinch and swell within shear zones resulting in well-mineralized shoots up to 13 metres wide and 250 metres long. High-grade ore shoots extend from surface to a depth of 200 metres where old mine workings end, still in mineralization. There is no mineralization in the country rock between the parallel shears.

The distribution of sulphides is complex in the high-grade sections. Ore lenses consist of one or typically two veins of massive sulphide, each about 60 centimetres wide. Veins are hosted in recemented fault gouge and in screens of sheared, altered and mineralized country rock. Massive sulphide veins typically follow, or are near, the footwall and hangingwall of the main shear structure. They locally converge and swell to form a single vein, up to 2 metres wide, anywhere within the shear. These larger veins are composed of argen-

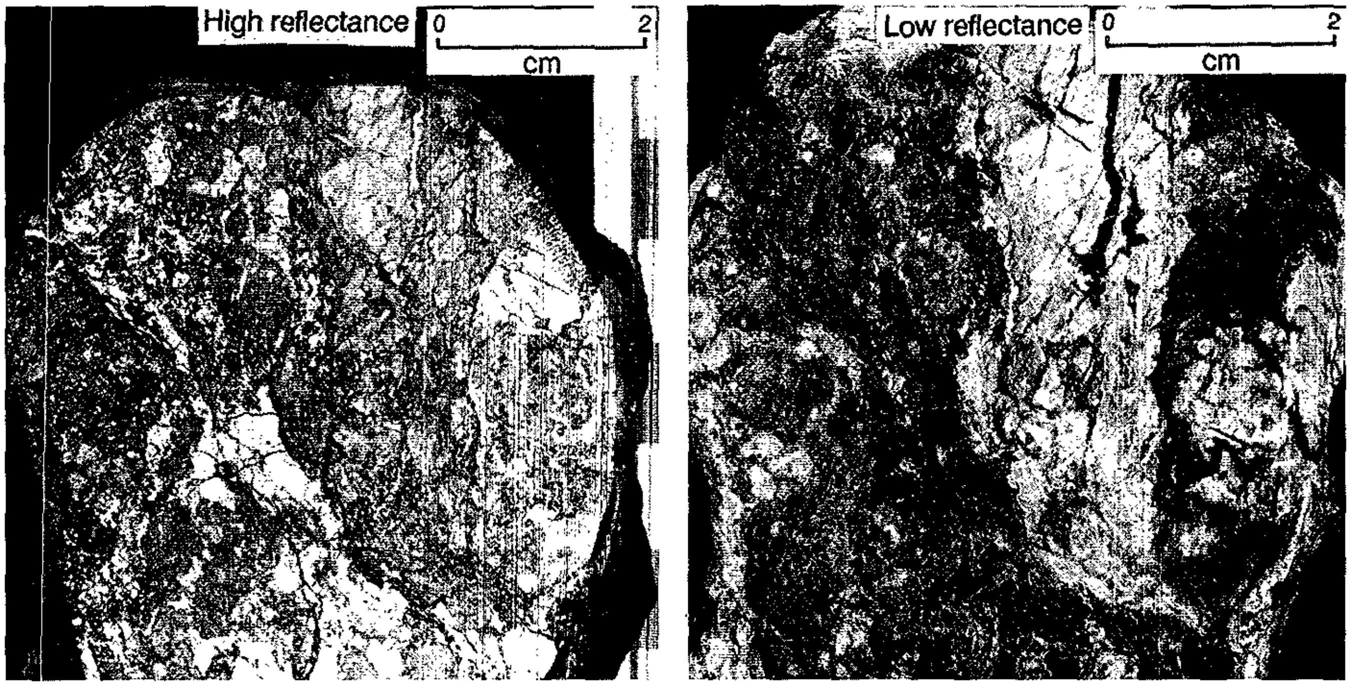


Plate 41. Well-mineralized fault breccia. **A.** High reflectance view shows sphalerite (white). Minor galena and pyrite and trace chalcopyrite are also present. **B.** Low reflectance view shows strongly bleached and fractured wallrock clasts. Blind vein, Prosperity/Porter Idaho mine.

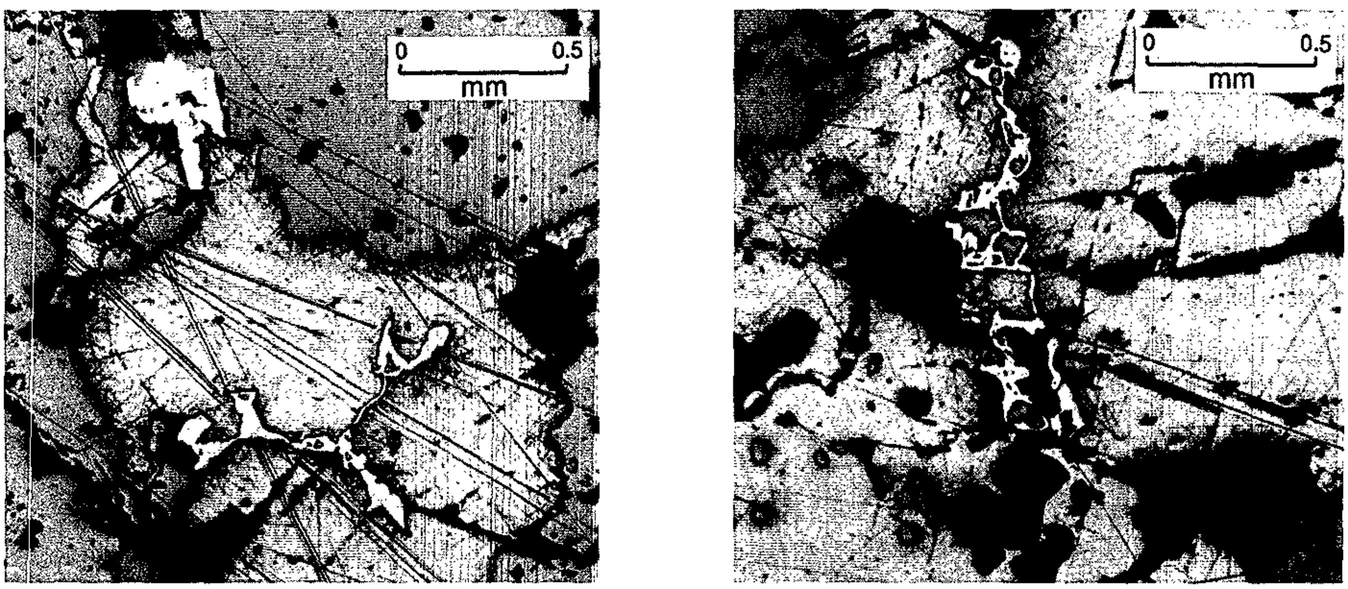


Plate 42. Photomicrograph of native silver within and adjacent to galena, enveloped by sphalerite with trains of chalcopyrite exsolution blebs. D vein, Prosperity/Porter Idaho mine.

tiferous galena, minor brown to black sphalerite and quartz. Adjacent to the massive sulphide veins, the shear zone is mineralized with disseminations, blebs and veinlets of quartz, buff-weathering carbonate, black manganese oxide and sulphides.

On surface, shear zones are recessive and exposures are sparse. A typical outcrop is a well-sheared zone containing distinctive black and orange coarsely mottled rock. This colour is due to manganese and carbonate alteration. In some outcrops manganese alteration predominates, producing massive to sheared sooty black gossan; in other exposures alteration is predominantly buff-orange-weathering carbonate. Sulphide minerals are partially preserved in some shear zone outcrops, but are leached from others, leaving a limonitic boxwork. Shear zones exposed by recent glacial retreat have less oxidation of sulphides; galena and sphalerite are exposed at surface and traces of yellowish, powdery greenockite have been noted.

TABLE 20
SEQUENCE OF ORE DEPOSITION AT THE PROSPERITY/PORTER IDAHO MINE

STAGE	RELATIVE TIMESPAN AND [AGE]	GROUND PREPARATION	SULPHIDES	GANGUE	ALTERATION
V	Long	? Minor reactivation of shears		Surface Weathering: carbonate; manganese oxides; hematitic mud.	Minor carbonate
IV	Long [45-20 Ma]	Minor reactivation of shears; Late cross-faults; Late dikes		Coarse banded calcite, coarse quartz, quartz+calcite, quartz+hematite+chlorite, qtz/chlor/qtz+chlor/ qtz+chlor+calcite	Patchy carbonate overprint
III	Short [~45 Ma]		Silver-bearing base metal sulphides	Sericite flooding, minor fine-grained quartz knots, ser>>qtz>>chlor+carb	Intense sericitic overprint of chlorite, local wallrock silicification
II	Short [~50 Ma]	Major brittle shear (cataclasis)			
I	Moderate [~55 Ma]	Extensional cracks	Disseminated euhedral pyrite	Quartz veins	Chloritized wallrocks

Snowfields and glaciers on Mount Rainey have retreated substantially in recent years, exposing extensions of known veins and reinforcing the concept that the shear structures are continuous through the mountain between Prosperity/ Porter Idaho and Silverado (Figure 43). Discovery of new vein outcrops has increased the mineralized strike length to a horizontal distance of 750 metres with a vertical extent of 335 metres. Icefield retreat also exposed other areas on the mountain for prospecting.

Mineralogy

In hand sample, massive sulphide veins consist of an aggregate of coarse galena and black sphalerite (Plates 40 and 41) with accessory pyrite and quartz; wire silver has been noted with the aid of a hand lens (Plate 42). Accessory amounts of tennantite (freibergite) are often suspected in hand sample examination, particularly in high-silver samples, but if the trace amounts of these minerals noted in all microscopic studies are typical, then the grains seen in hand sample are probably sheared or anhedral galena.

Early workers reported a mineral suite of galena, sphalerite, native silver, ruby silver, tetrahedrite, and minor amounts of pyrite, chalcopyrite and acanthite. A petrographic description of a grab sample of massive sulphide vein material adds polybasite, arsenopyrite and trace electrum to the mineral suite (J. McLeod, personal communication, 1982). Petrography from this study identified galena, sphalerite, pyrite, chalcopyrite, tennantite, tetrahedrite and native silver, adding only ubiquitous trace tennantite to the established list of minerals.

Gangue minerals include early quartz veins, now preserved as angular chips; synmineralization sericite flooding with associated knots of fine prismatic quartz crystals and minor chlorite and carbonate; and a later phase of quartz-chlorite-calcite veining that additional work might resolve into different pulses. Crosscutting all of these, the final vein phase is an episode of ribbon veins of coarse-grained calcite. Overprinted patches of fine carbonate, manganese oxide and hematitic mud are attributed to recent surface weathering and redeposition from groundwater.

The sequence of ground preparation, veining, mineralization and alteration has been determined from underground mapping and microscopy. This is summarized on Table 20. There was only one main pulse of sulphide mineralization; local areas of physical sulphide remobilization along narrow, reactivated shear planes may account for descriptions of late crosscutting sulphide veins.

Alteration

The sequence of alteration is schematically represented on Table 20. Shear zones have sharp borders against the country rock. Extensive zones of intense chloritization up to 10 metres wide and local zones of silicification up to 0.5 metre wide can be seen in hand sample. Both alteration types are accompanied by minor disseminated fine to medium-grained pyrite. Thin section study shows that all chloritized rocks are dacite, although in places they are mapped as andesite. Some 'silicified' wallrock has up to 20 per cent pervasive sericite; the rock is not so much silicified as bleached and sericitized.

Epidote weathers from surface exposures and had not been recognized as an alteration mineral at Prosperity/Porter Idaho, although it is conspicuous at Silverado (Plate 20). Drill core shows abundant fine to medium-grained disseminated epidote in dacitic wallrocks for several metres distance away from the shears, but it is replaced or overprinted by chlorite or sericite and silica alteration immediately adjacent to the shears.

Genesis

The geologic setting of Eocene deposits is remarkably consistent even though hostrocks vary from the oldest rocks of the stratigraphic column through to the youngest, and include Early Jurassic to Eocene plutonic rocks (Table 16). All occurrences are localized in brittle faults or fractures and there is a dominant trend for most of these veins, southeastward with a subvertical dip. Economic concentrations of argentiferous sulphides appear to be restricted to the part of the mineralized shear that transects more brittle, resistant rocks. For example, deposits are hosted in dacitic volcanic rocks of the Mount Dilworth Formation (Silver Tip, Lion, Start, Unicorn), or the Betty Creek Formation (Prosperity/Porter Idaho), or in massive granodiorite of the Texas Creek batholith (Riverside). There is a close spatial association between silver-lead-zinc deposits and Early to Middle Eocene igneous rocks, both earlier dikes (55 Ma) and later plutons (52-48 Ma).

A less obvious correlation, but one that is critical for explaining the difference between Jurassic and Eocene metal suites, is a close spatial association between Tertiary ore deposits and Jurassic turbidite sequences. Reduced, carbonaceous turbidite sequences characteristically have elevated silver contents. Contents of 20 to 30 ppm silver represent a geochemical concentration factor of the order of 100 to 500 (Laznicka, 1985). The minor turbidite units within the Unuk River Formation near the Indian, Silverado, Silver Basin and Riverside deposits, and the thicker, infolded turbidite sequence of the Salmon River Formation near the Prosperity/Porter Idaho, Unicorn, Lion, Silver Tip and Start deposits, are probably the main source beds for the metals of these Tertiary deposits.

Skarns:

Molly B, Red Reef and Oral M Prospects

Three 'skarn' deposits and several small showings crop out on the lower northwest slope of Mount Rainey. All three deposits on Mount Rainey are veins or vein stockworks cutting across country rock that is variably hornfelsed or skarned. The deposits were not examined as part of this study, and questions remain about the age and genesis of these mineral occurrences. The following summary is compiled from references listed in MINFILE.

GEOLOGICAL SETTING

Bedrock on the mountainside consists of volcanic and sedimentary rocks of the Unuk River Formation. Strata of the Upper Andesite Member crop out on much of the mountain, but the deposits are hosted by the turbidites of the Upper Siltstone Member. In this area the turbidites are distictly limy, with minor limestone interbeds, and lapilli tuffs within the overlying Upper Andesite Member contain clasts of thin-bedded limestone. Intrusive rocks on the mountainside all belong to the Hyder Plutonic Suite and include medium-grained biotite granodiorite of the Hyder batholith and scattered examples of all the main rock types of Hyder dikes: plagioclase-porphyritic granodiorite, aplite, microdiorite and lamprophyre.

Intense alteration zones are developed where the batholith cuts the limy turbidite sequences. Biotite hornfels imparts a purplish colour to the altered turbidites, but bedding is preserved. Calcsilicate skarn zones consist of concentric zones of medium to coarse-grained red garnet, green diopside and white tremolite that obscure the original rock type and fabric.

MINERAL DEPOSITS

The Molly B prospect consists of two separate calcsilicate skarn zones. One hosts disseminated scheelite, molybdenite, pyrite, chalcopyrite, pyrrhotite and sphalerite. Three hundred metres to the south, a second mineralized zone consists of pyrrhotite, chalcopyrite, pyrite and trace sphalerite. Between 1940 and 1941, the southern skarn zone produced 290 tonnes of ore grading 2.36 grams per tonne gold, 12.01 grams per tonne silver and 0.7 per cent copper.

The Red Reef prospect, staked in 1904 by pioneer prospector D.J. Rainey, consists of large patches, blebs, disseminations and stringers of pyrrhotite, pyrite, minor chalcopyrite and trace bornite in calcsilicate skarn. The highest reported assays from an array of grab and chip samples are 3.0 per cent copper and trace gold and silver.

The Oral M prospect was discovered in the early 1930s and named in honour of the wife of Harry Melville, manager of the Premier mine. Oral M is an auriferous, sulphide-rich quartz vein hosted by a brittle shear zone that cuts hornfels and skarn. The vein strikes 130° and dips 75° southwest. Disseminated, patchy to locally semimassive sulphides in the vein are pyrrhotite, pyrite and chalcopyrite. Exploration work from 1936 to 1941 comprised adits and open cuts on the surface together with several drill holes. Limited production was achieved in 1939 when 4.68 tonnes of hand-cobbed ore was shipped, grading 28.5 grams per tonne gold, 68.6 grams per tonne silver and 3.5 per cent copper. In 1941, 7.26 tonnes of ore was shipped assaying 28.1 grams per tonne gold, 163.9 grams per tonne silver and 11.84 per cent copper. Recent chip samples across the adit face returned values of 23.0 grams per tonne gold, 27.8 grams per tonne silver and 2.04 per cent copper (Davis, 1990).

Elsewhere on the claim groups, narrow veinlets of coarse-grained silver-rich galena-sphalerite, similar to the Silverado deposits, cut andesite tuffs.

Genesis

These veins have a similar strike and dip to the silver-rich Tertiary veins and a close spatial relationship to the Eocene Hyder batholith. Sulphides are hosted in massive bull quartz, and sulphides and gangue show no sign of post-ore shearing. Although they are not skarn deposits *sensu strictu*, the veins are locallized within strongly hornfelsed and strongly skarned rocks that were certainly more brittle than the unrecrystallized extensions of these units, exposed in the area. Preferential mineral deposition in more brittle country rock types is also a characteristic of Eocene vein deposits.

However, these veins have the higher gold contents and higher gold-silver ratios of the Early Jurassic deposits. In particular, the veins at Oral M have gold-silver ratios that are characteristic of the gold-pyrrhotite veins like the Scottie Gold deposits. Moreover, these veins on Mount Rainey have a close association between gold and copper that was noted at a microscopic scale in the Scottie Gold ores. Finally, the pyrrhotite-dominated sulphide assemblage is also characteristic of the Early Jurassic gold-pyrrhotite veins. These features suggest the Mount Rainey skarn deposits might be Early Jurassic.

A third possibility is that these deposits represent Early Jurassic gold-pyrrhotite veins that were remobilized during emplacement of the Eocene batholith, but no remnant of an Early Jurassic stock remains.

Although the skarn-hosted veins on Mount Rainey present problems to deposit classification, they also demonstrate the potential usefulness of a technique like lead isotope analysis.

CHAPTER 6 — METALLOGENY AND EXPLORATION

REGIONAL GENETIC MODELS

Regional genetic models for each metallogenic epoch compare and contrast the different geologic settings and genetic processes that formed the distinctly different, but penecontemporaneous, deposit types. Determination of genetic relationships among Early Jurassic deposit types is more complex because the effects of mid-Cretaceous deformation and metamorphism must be understood and 'removed' before developing these conceptual models.

EARLY JURASSIC

For Jurassic deposits, Figure 47a emphasizes the stratigraphic position of the mineral deposits, and indicates that all deposits except pyritic dacites crosscut stratigraphy, that is, they are epigenetic. The interpreted paleotopographic setting for the Early Jurassic deposit types is shown in Figure 35. Figure 48 emphasizes the variety of structural conduits and depositional sites that were available in and around the Early Jurassic volcano. Subvolcanic shear-hosted vein deposits (Figure 48) are: deposits that are transitional in setting beween the settings for porphyry copper and epithermal deposits; deposits that are transitional in depth of emplacement and in mineralogy and textures between mesothermal and epithermal deposits ("leptothermal" of Lindgren, 1933; "telescoped" of Buddington, 1935); and deposits emplaced along the thermal transition between the ductile and brittle shearing regimes (Nesbitt, 1988; Colvine, 1989; Foster, 1989).

Many features of the geologic setting and ore deposits of the Stewart district are depicted in Figure 49, which was originally developed for island-arc porphyry and epithermal systems in the southwest Pacific (Branch, 1976).

MIDDLE EOCENE

The genetic model for Eocene deposits emphasizes: the black turbidite source-rocks, the hydrothermal heat-source provided by the Middle Eocene intrusive rocks, and structurally and stratigraphically controlled deposition in well-shattered brittle rock units. Figures 47c, 50 and 51 show the spatial relationships between deposits and igneous rocks, the range of hostrock types, and the most favourable host-rocks. Figure 51 illustrates geologic settings that have concentrated economic quantities of metals.

METALLOGENY

Metallogenic models for the Early Jurassic and Middle Eocene are presented in Figure 52. Tectonic settings are remarkably similar. Differences in pluton composition, in depth of ore emplacement, and in textures, mineralogy and metal content of deposits are attributed to differences in crustal thickness, crustal composition and effects of regional metamorphism.

This specific tectonic setting of 'stacked arcs' – a young (Eocene) arc constructed on a foundation or crust consisting of a much older (Mesozoic) arc – has been recognized as the metallogenic association with the greatest variety of accumulated metals and mineralization styles. Laznicka (1985) provides examples which include the Cretaceous volcanic belt of Puerto Rico, the "Green Tuff" belt of Japan, and the Hazelton Group of British Columbia. Modern analogues exist in the New Ireland – Solomon Islands chain and the eastern Aleutians.

EARLY JURASSIC METALLOGENY

Eastward-plunging subduction generated arc volcanism on crust 25-30 kilometres thick (Gill, 1981), consisting of the metamorphosed Paleozoic rocks of the Stikine assemblage (Figure 52a). Volcanism continued through 40 million years, evolving from basalt to dacite. Hydrothermal convection cells developed around cooling subvolcanic plutons and dikes and deposited ores at depths ranging from as much as 4 kilometres up to the paleosurface. The hydrothermal systems at different depths should be regarded as separate and independant convection cells with separate chemical, thermal and pressure characteristics. There are broad horizontal bands with little or no record of mineral deposition or major hydrothermal alteration that separate the three roughly horizontal zones of distinctly different mineral deposit types (Figure 47b).

Hydrothermal fluids may have derived their characteristic suites of silver, gold, zinc, lead and copper from the dominantly andesitic country rocks (Gill, 1981; Laznicka, 1985), but Gill argues that most of the metals in deposits hosted by andesitic volcanic rocks are of primary magmatic origin. There is a relatively high volatile content in magmas in volcanic arcs; in orogenic andesites this vapour lies in the H-C-O-S-Cl-F system. Exsolution of vapour from the residual andesite liquid causes magma depletion in the elements which partition strongly into the vapour. Although H_2O is the most abundant volatile constituent in an orogenic andesite magma, the magma is more likely to become first saturated with CO_2 or a sulphur species than with H_2O. Orogenic andesite magmas typically contain 200 to 2000 ppm sulphur, and could be sulphur-saturated, coexisting with a sulphide liquid, or solid, or an S-species vapour. Subaerially erupted andesites lose much of this excess SO_2 by exsolution during eruption.

Once the vapour phase forms in chlorine-rich systems, the vapour is an effective solvent for alkalis, metals and silica (Gill, 1981). Chloride complexes remove metals from the source regions and transport base metals throughout the range of temperatures of formation for subvolcanic shear-hosted veins and epithermal deposits. Chloride complexes will also transport gold and silver at the upper end of this temperature range, but at the lower temperatures of epithermal ore deposition, precious metals will be transported by bisulphide complexes $(HS)^{-2}$ (Berger and Henley, 1989). Berger and Henley predict that the total precious metal content of epithermal deposits is proportional the concentration of H_2S in the hydrothermal system.

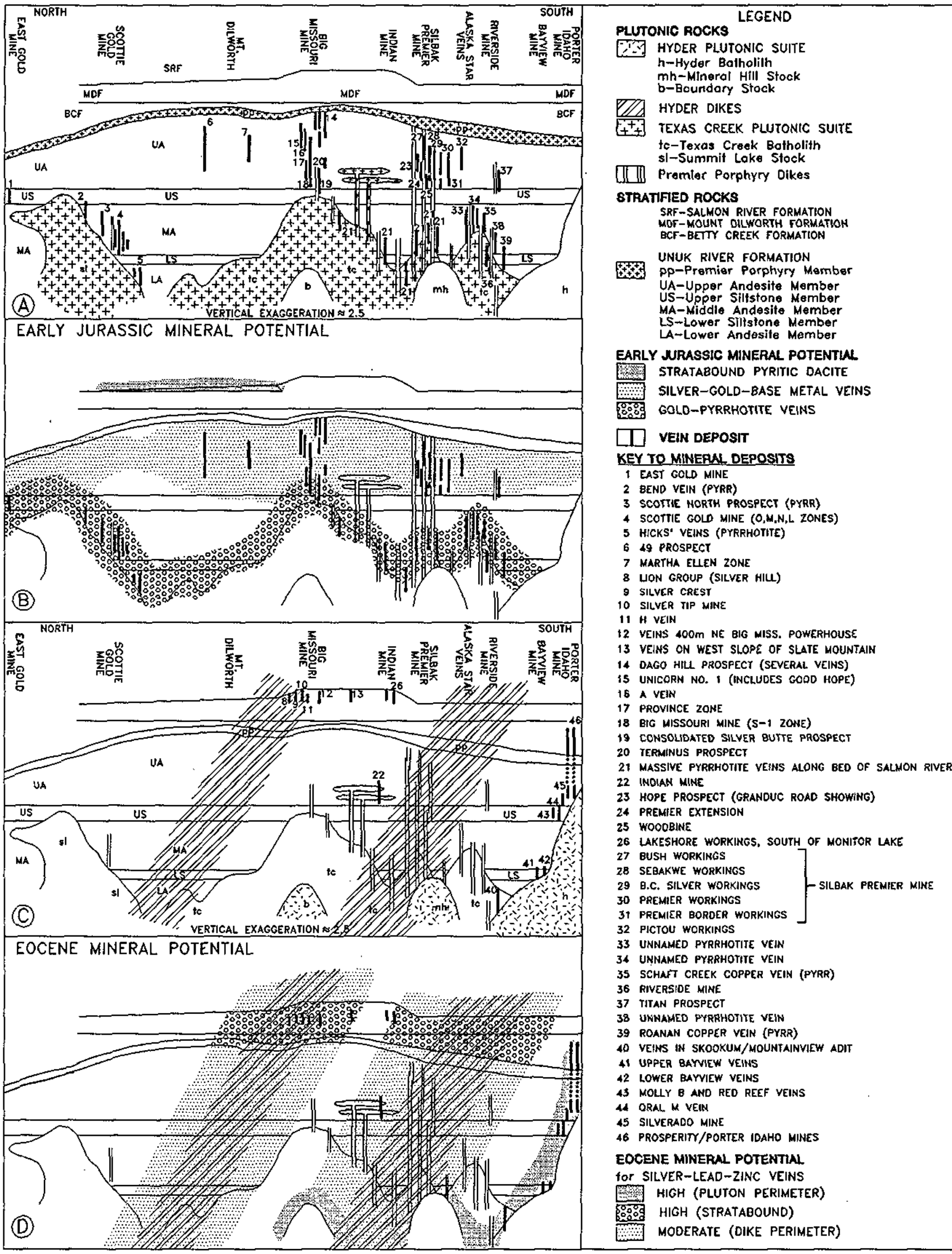


Figure 47. Schematic north-south longitudinal section showing the distribution of Early Jurassic and Eocene ore deposit types and prospective areas within the Stewart mining camp. **A.** Distribution of Early Jurassic mineral deposits. **B.** Prospective areas for Early Jurassic mineral deposit types. **C.** Distribution of Eocene mineral deposits. **D.** Prospective areas for Eocene mineral deposit types. Vertical exaggeration ~2.5:1.

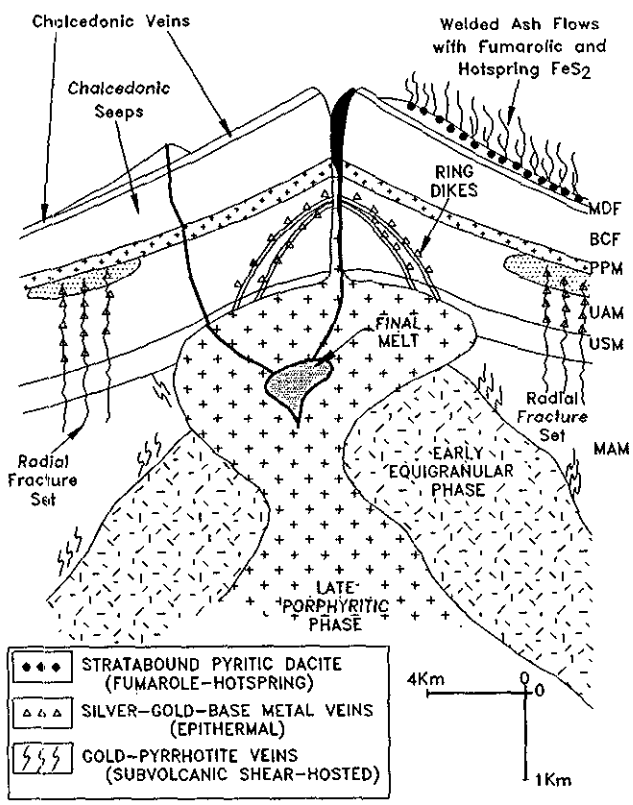


Figure 48. Genetic model for Early Jurassic mineral deposit types.

Subvolcanic shear-hosted gold-pyrrhotite veins formed in en echelon tension gashes developed in the immediate country rock around the plutons during late magma movement. These veins were locallized along the thermally controlled brittle-ductile transition envelope that surrounded each subvolcanic stock.

Epithermal silver-gold-base metal veins and breccia veins were deposited at critical pressure-temperature transitions in shallower subvolcanic faults and shears and in hydrothermal breccia zones along dike contacts. These deposits formed from many pulses of mineralizing fluid. Mixing of cool, meteoric groundwater with hot sulphur, chlorine, and metal-bearing magmatic fluids is the most likely mechanism for base and precious metal deposition, because there is no evidence of boiling (Brown, 1989; Seward, 1989; McDonald, 1990b). Base-metal-rich deposits of the Stewart camp are similar to low-sulphidation epithermal vein deposits (adularia-sericite type) that are common in the Phillipines (Sillitoe, 1989).

Stratabound pyritic dacite tuffs formed when residual trapped volatiles and magma erupted in a final series of violent dacitic pyroclastic blasts. Venting fumarolic fluids and hotspring pools scattered on this cooling volcanic sheet impregnated local areas with abundant fine disseminated pyrite. The area subsided beneath sea level before subaerial erosion could dissect the composite volcano or remove any of the deposits.

Middle Eocene Metallogeny

Eastward-plunging subduction generated the plutons of the Coast Plutonic Complex that were emplaced within a

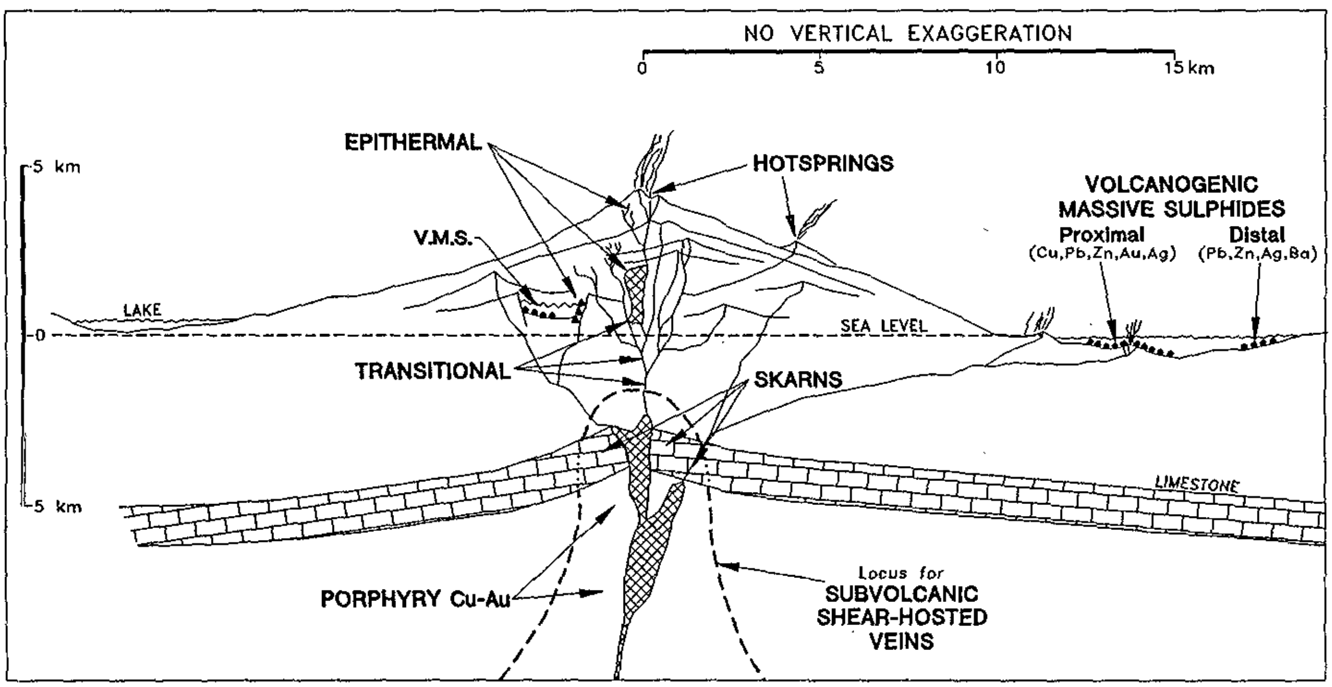


Figure 49. *Mineral potential in an andesitic stratovolcano (modified from Branch, 1976).*

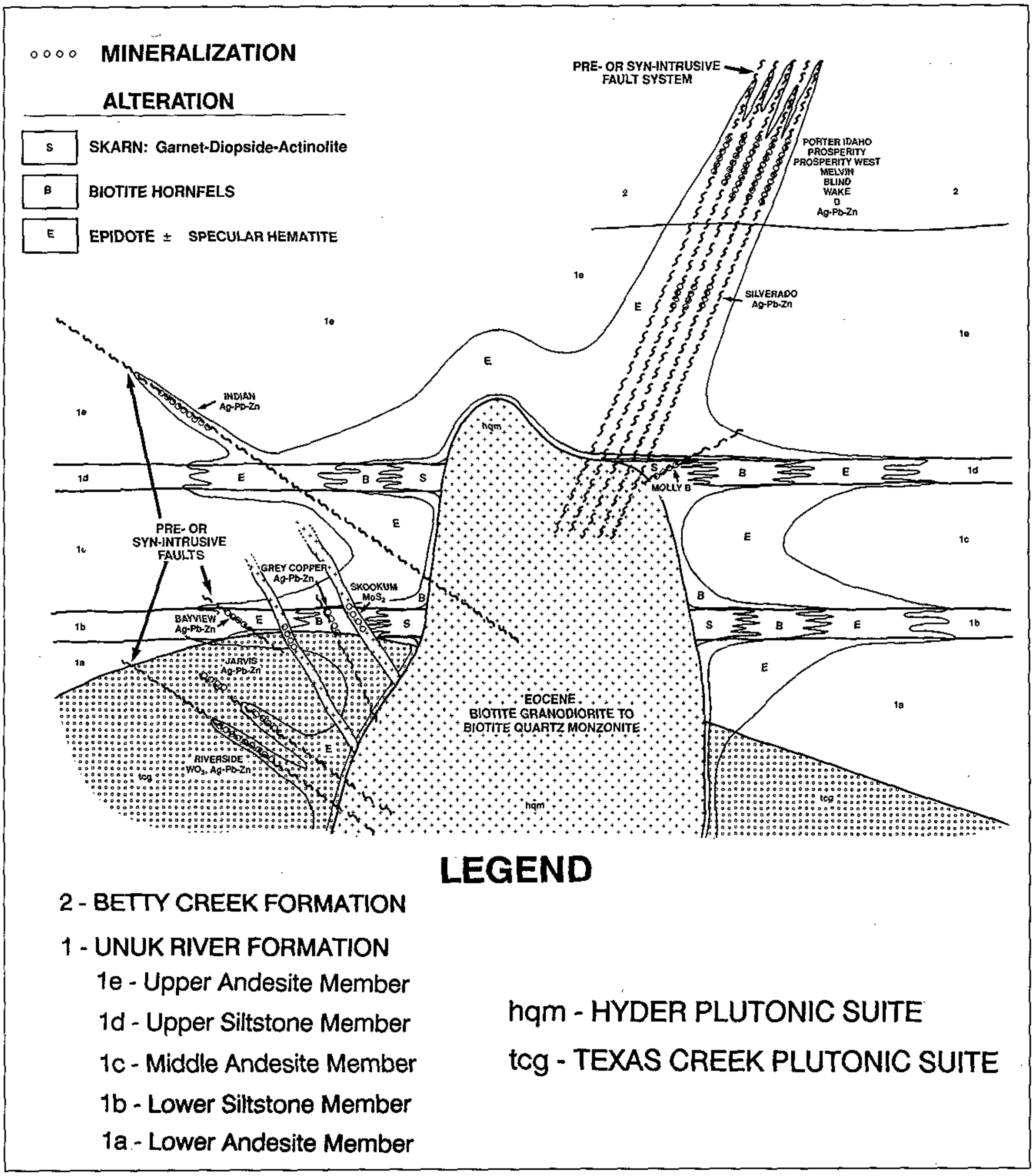


Figure 50. Ore deposit model for the Middle Eocene.

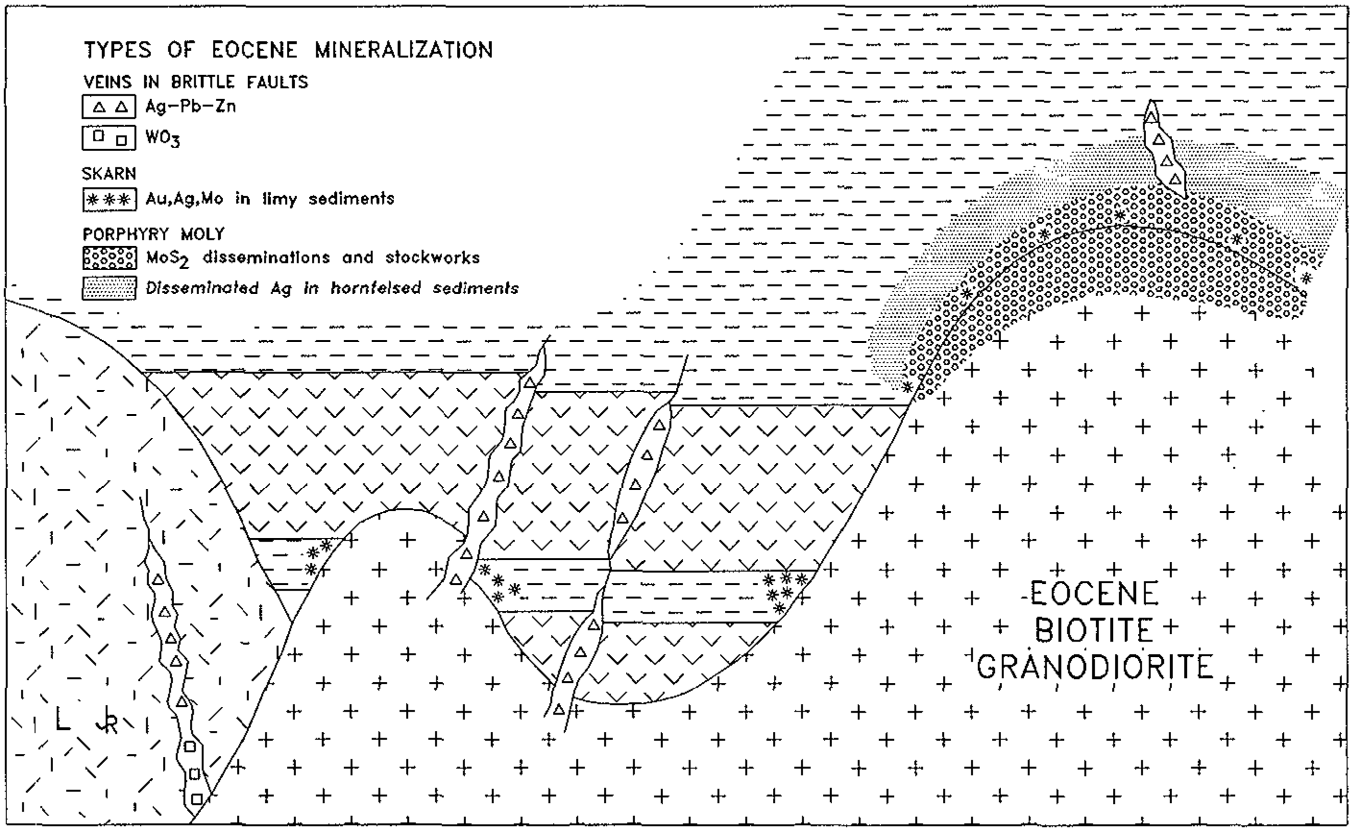


Figure 51. Genetic model for Middle Eocene mineral deposit types.

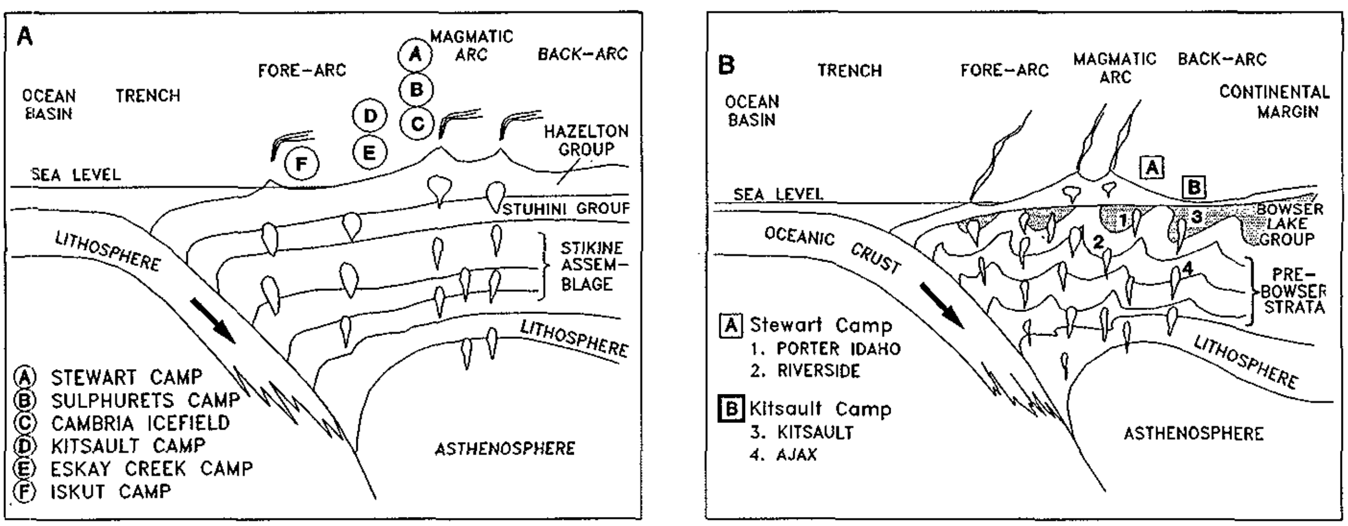


Figure 52. Early Jurassic and Middle Eocene metallogenic models for the Stewart camp. **A.** Early Jurassic tectonic setting and ore deposits. **B.** Eocene tectonic setting and ore deposits. Width of diagram=200 kilometres. Vertical exaggeration ~4:1.

plate of continental crust 50 to 70 kilometres thick (Gill, 1981), consisting of Paleozoic and Mesozoic sedimentary and volcanic rocks (Figure 52b). Brittle dacitic units and Jurassic plutons, shattered by mid-Cretaceous tectonism, provided local sites of extensive fracturing favourable for mineral deposition in Eocene time.

The Eocene magmatic pulse began with dike swarms followed by intrusion of the main batholith and satellitic hypabyssal plutons. Hydrothermal convection cells developed around these cooling intrusions; the volume of country rock affected was proportional to the size of the igneous body. Associated mineral deposits vary in size according to the amount of circulating fluid and the cooling period for the pluton.

The thick turbidite sequence of the Salmon River Formation and minor turbidite members of the Unuk River Formation contributed silver, lead and zinc to the Eocene hydrothermal system. The metals precipitated out as coarse-grained **galena-sphalerite-pyrite veins** adjacent to dikes or in fractures and shear zones some distance away from larger plutons. **Skarn** zones developed where plutons cut through limy turbidites and silver-rich **porphyry molybdenum** deposits formed around the apices of smaller stocks.

Molybdenite is probably magmatic in origin. The last plutons of this magmatic pulse are rare stocks emplaced in late Oligocene time within the main Coast Range batholith. These include the more highly evolved stock that generated the molybdenite-rich, silver-depleted Quartz Hill ore deposit (27-30 Ma, Hudson *et al.,* 1979). In this geologic setting, in the heart of the Coast Range batholithic complex, no turbiditic sedimentary rocks were available to supply silver, lead or zinc to the hydrothermal system.

EXPLORATION

Areas favourable for exploration for the six main deposit types are highlighted on Figures 47b and 47d. Local geological settings within these broad zones will be more highly prospective.

Gold-Pyrrhotite Deposits

The perimeter of the Early Jurassic plutons and the inner margin of the pluton should be the exploration focus for deposits similar to the Scottie Gold mine. A zone extending from 100 metres inside the pluton to 400 metres beyond the contact should be thoroughly prospected or covered by soil-sampling grids. The outer exploration limit can be extended if dikes or alteration distributions suggest a hidden apophysis of the pluton.

Gossans are strong but small. Areas where dozens of small veins and veinlets are clustered, such as the Shasta prospect or the banks of the Salmon River downhill from the Lower Daly-Alaska workings, should be carefully investigated and mapped. A series of samples of high-sulphide rock may return widely varying gold values; this should not discourage a thorough evaluation.

Silver-Gold-Base Metal Deposits

Although the entire thickness of the Upper Andesite Member of the Unuk River Formation is prospective for base and precious metal deposits, the strata immediately underlying the Premier Porphyry Member should be specifically targeted. Large pyritic alteration halos usually provide extensive gossans that are proximal indicators of mineralization. Thorough prospecting will be the single most productive tool, although soil geochemistry can be expected to work well. Geophysical surveys have not been particularly helpful. Low-sulphide veins may yield consistently higher precious metal values than the visually more impressive high-sulphide veins.

Specific prospects that deserve reassessment are: High Ore, several showings in the Stoner-Clegg-O'Rourke area, showings on the Silver Coin and Dan claims, the belt of gossans 2 kilometres long between Dago Hill and Union Lake, the Oxedental-49-Yellowstone trend and the nearby Dumas, Lila and Harry showings, and Rainbow.

Stratabound Pyritic Dacites

Although the pyritic dacites in the Mount Dilworth area were subaerially deposited, the Mount Dilworth Formation has both subaerial and submarine depositional settings on a regional scale. In their subaqueous setting, these rocks represent the classic stratigraphic and paleotopographic environment for formation of volcanogenic massive sulphide deposits. At the Eskay Creek property in the Unuk River valley, high-grade massive sulphide ore lenses are hosted in thin-bedded pyritic siltstones, immediately overlying stockwork style mineralization in pyritic dacites at the top of the Mount Dilworth Formation (Alldrick *et al.,* 1989; Britton *et al.,* 1990). Consequently, the Iron Cap zone deserves a thorough re-examination in view of reported minor base metals and anomalous silver values (Plumb, 1956).

Extensive pyritic intervals recur in this unit regionally: at the toe of Frankmackie Glacier, at the head of D.C. Glacier, at the toe of Knipple Glacier, along the south wall of Knipple Glacier, along the north arm of Treaty Glacier, along the upper canyon of Storie Creek, on the Unuk River near the mouth of Coulter Creek and at the Eskay Creek property east of Tom MacKay Lake (Alldrick and Britton, 1988; Alldrick *et al.,* 1989). These regionally distributed pyritic zones are favourable sites for subaerial hotspring-related deposits or for submarine volcanogenic massive sulphide deposits, both along the upper dacite contact and in the immediately overlying pyritic sedimentary rocks.

Silver-Lead-Zinc Deposits

Prospective settings for these deposits are the perimeters of Eocene plutons and the interiors and perimeters of the major Eocene dike swarms. The greatest potential lies alongside the Hyder batholith, especially where the pluton cuts brittle units (dacites, Texas Creek batholith, skarns). The exploration potential in the dike swarms is also greatest where dikes cut these same resistant units.

Deposits do not provide strong or large gossans. The mineralized shears are recessive weathering, making them difficult prospecting targets, and they do not generate geophysical anomalies. Peripheral epidote alteration in country rocks is a subtle but important proximal indicator.

Southeast-striking mineralized structures are persistant and may host up to four widely separated mineral zones over a distance of a few kilometres. The intersections of these southeast-striking structures with the few north-striking structures that are known to host mineralization should be specific prospecting targets.

Skarn Deposits

Skarn mineralization may be present wherever the Eocene batholith or stocks cut turbidite sequences, consequently the perimeters of Eocene plutons are also the most prospective area for skarn deposits. Limestone and limy siltstone beds will be selectively converted to skarn; siltstone beds will be recrystallized to biotite hornfels. As pyrite is relatively minor, and acid generation is buffered by abundant carbonate, these deposits do not produce striking gossans.

Skarn and hornfels are not associated with the plutons of the Lower Jurassic Texas Creek suite in the Stewart camp, but a molybdenite-bearing skarn is well exposed in a rock quarry adjacent to the Bronson stock in the Iskut mining camp, and the nearby McLymont Creek gold prospect has been identified as an Early Jurassic skarn deposit (Ray *et al.*, 1991). The potential for similar skarn mineralization in the Stewart camp has not yet been investigated; the eastern tip of the rock spine that separates the North and South arms of the Berendon Glacier (Figure 11) deserves a careful look.

Porphyry Molybdenum Deposits

Silver-rich porphyry molybdenum deposits in the Alice Arm – Kitsault mining camp are developed around the contact, at the apices of small to moderate-size Eocene stocks where they intrude turbidite sequences (Carter, 1981). No showings of this type have been identified in the Stewart camp but the optimum setting, around the perimeters of the Eocene batholith and stocks, is also the most prospective area for Eocene veins and skarns. Prospecting work for any of these deposit types should proceed with an awareness of the potential for all Eocene deposit types.

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Plate 6. Rhythmic graded beds of coarse wacke (grey) to hematitic mudstone (maroon), east shore of Daisy Lake. Strike north, tops to east towards Troy Ridge.

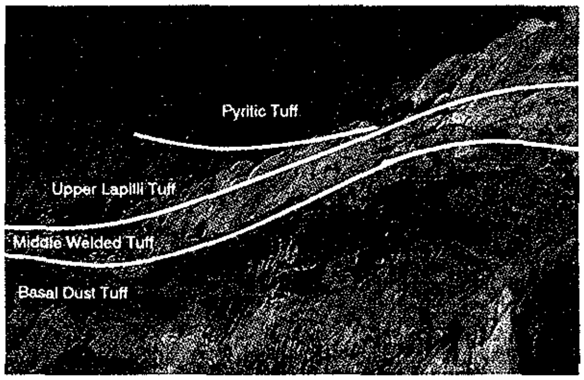


Plate 10. Stratigraphy in Mount Dilworth Formation, north end of 49 Ridge. Note colour-mottling of Lower Dust Tuff and spectacular gossans of the Pyritic Tuff. Height from base of photo to top of pyritic knob is 30 metres.

Plate 21. Photomicrograph showing strong chlorite-carbonate alteration in groundmass of Premier Porphyry dike rock. Silbak Premier mine. Plane polarized light. Feldspar crystal is 2.4 mm long.

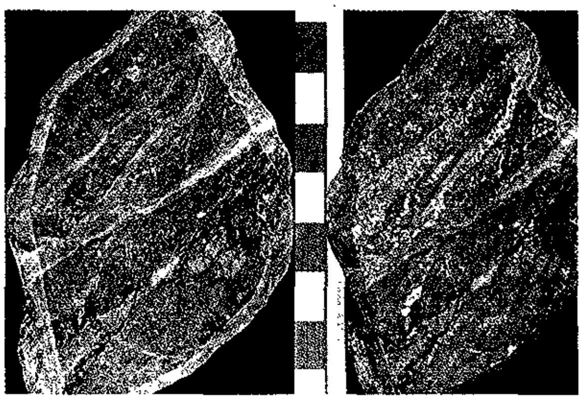


Plate 23. Sheared and altered wallrock, Scottie Gold mine. **Left.** Low reflectance view of strongly sheared wallrock shows rich pink to coral manganese carbonate alteration (rhodochrosite). **Right.** High reflectance view shows distribution of sulphide trains, mainly pyrite, within this sheared, altered wallrock. Scale bar in centimetres.

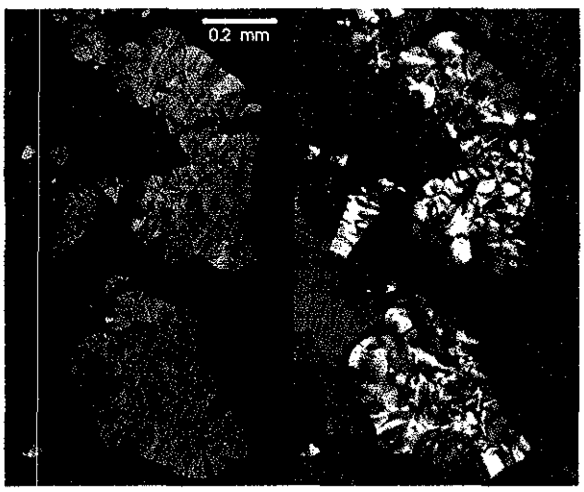


Plate 33. Photomicrograph of characteristic features of delafossite. **Left.** Botryoidal texture, rose-brown colour, moderate pleochroism. **Right.** Strong anisotropy in shades of blue or greenish blue. S-1 deposit, Big Missouri area.

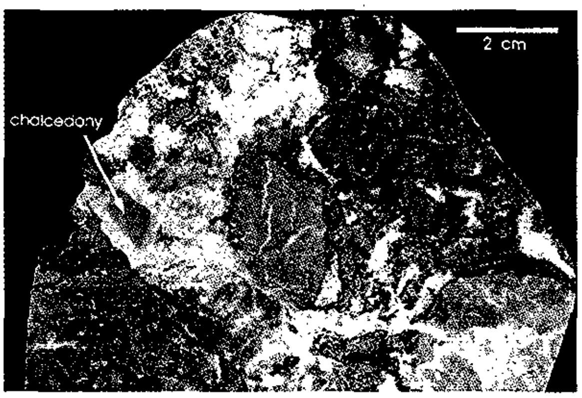
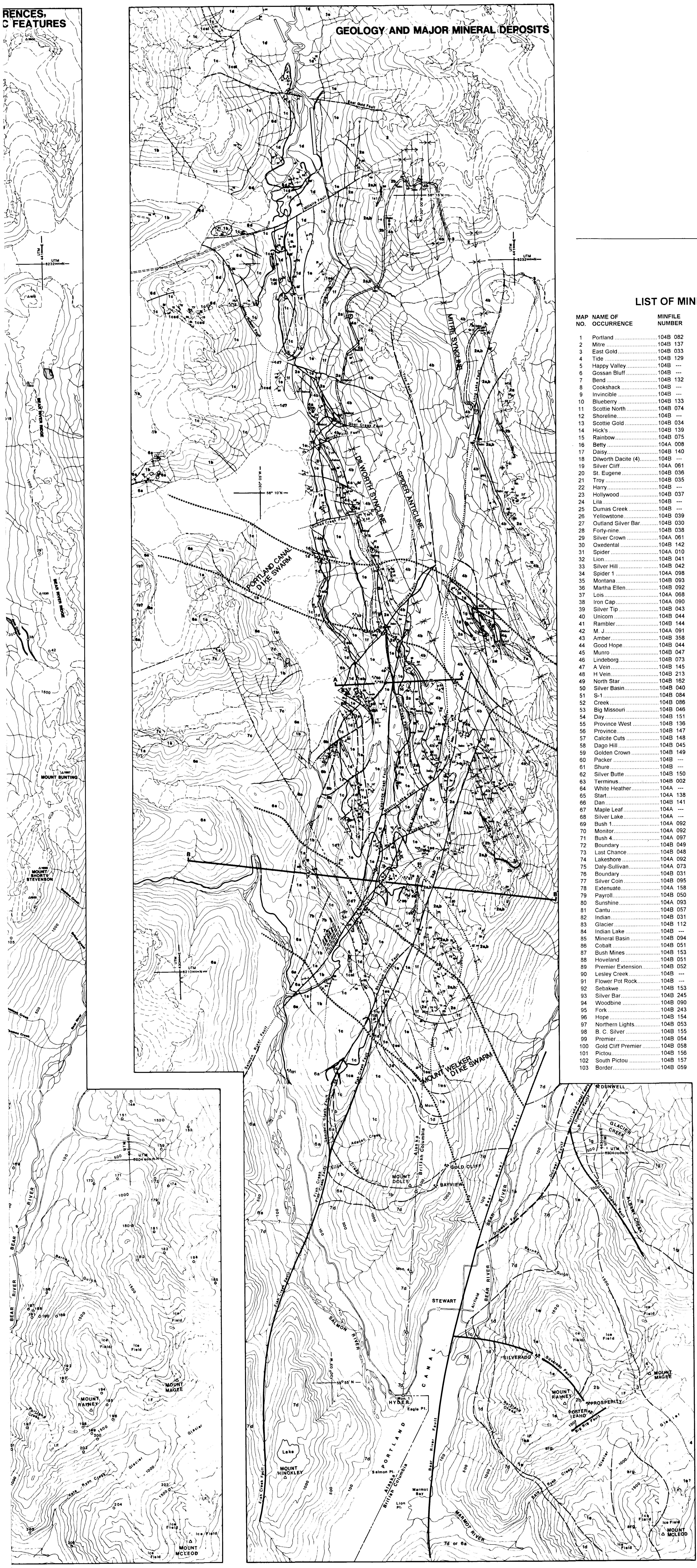


Plate 37. Low-sulphide breccia shows late, coarsely intergrown calcite-quartz gangue. Clasts are locally ringed by early sequential layers of pyrite and mixed base metal sulphides (dark grey). Note single clast of blue-grey chalcedony. 2-level trench, Silbak Premier mine.


MINERAL OCCURRENCES, GOSSANS AND TOPOGRAPHIC FEATURES
TIDE MOUNTAIN
MITRE MOUNTAIN
Phillips Glacier
Outre Glacier
North Berendon Glacier
South Berendon Glacier
Betty Glacier
SUMMIT MOUNTAIN
SUMMIT LAKE
TROY RIDGE
August Glacier
AUGUST MOUNTAIN
Salmon Glacier
MOUNT DILWORTH
BEAR RIVER RIDGE
LONG LAKE
MOUNT BAYARD
Mineral Glacier
Texas Glacier
CANTU MOUNTAIN
MOUNT BUNTING
MOUNT SHORTY STEVENSON
MINERAL HILL
NINEMILE MOUNTAIN
MOUNT WELKER
MOUNT DOLLY
STEWART
BEAR RIVER
SALMON RIVER
HYDER
PORTLAND CANAL
MOUNT RAINEY
MOUNT MAGEE
MOUNT HINCKLEY
Lake
Salmon Pt.
Lion Pt.
Marmot Bay
MARMOT RIVER
MOUNT MCLEOD
Alaska
British Columbia

GEOLOGY AND MAJOR MINERAL DEPOSITS
MITRE SYNCLINE
DILWORTH SYNCLINE
SPIDER ANTICLINE
PORTLAND CANAL DIKE SWARM
MOUNT WELKER DIKE SWARM
GOLD CLIFF
MOUNT DOLLY
BAYVIEW
STEWART
BEAR RIVER
SALMON RIVER
SILVERADO
HYDER
PORTLAND CANAL
MOUNT RAINEY
MOUNT HINCKLEY
Lake
MARMOT RIVER
Alaska
British Columbia

#85 (1a)



BC
Ministry of Energy, Mines and Petroleum Resources

Geological Survey Branch
BULLETIN 85

Figure 11

GEOLOGY AND MINERAL DEPOSITS OF THE STEWART MINING CAMP

NTS 104A and 104B

By D.J. ALLDRICK

Scale 1:50 000

0 1 2 3 4 5
kilometres

LIST OF MINERAL OCCURRENCES

MAP NO.	NAME OF OCCURRENCE	MINFILE NUMBER
1	Portland	104B 082
2	Mitre	104B 137
3	East Gold	104B 033
4	Tide	104B 129
5	Happy Valley	104B ---
6	Gossan Bluff	104B ---
7	Bend	104B 132
8	Cookshack	104B ---
9	Invincible	104B ---
10	Blueberry	104B 133
11	Scottie North	104B 074
12	Shoreline	104B ---
13	Scottie Gold	104B 034
14	Hick's	104B 139
15	Rainbow	104B 075
16	Betty	104A 008
17	Daisy	104B 140
18	Dilworth Dacite (4)	104B ---
19	Silver Cliff	104A 061
20	St. Eugene	104B 036
21	Troy	104B 035
22	Harry	104B ---
23	Hollywood	104B 037
24	Lila	104B ---
25	Dumas Creek	104B ---
26	Yellowstone	104B 039
27	Outland Silver Bar	104B 030
28	Forty-nine	104B 038
29	Silver Crown	104A 061
30	Oxedental	104B 142
31	Spider	104A 010
32	Lion	104B 041
33	Silver Hill	104B 042
34	Spider 1	104A 098
35	Montana	104B 093
36	Martha Ellen	104B 092
37	Lois	104A 068
38	Iron Cap	104A 090
39	Silver Tip	104B 043
40	Unicorn	104B 044
41	Rambler	104B 144
42	M. J.	104A 091
43	Amber	104B 358
44	Good Hope	104B 044
45	Munro	104B 047
46	Lindeborg	104B 073
47	A Vein	104B 145
48	H Vein	104B 213
49	North Star	104B 162
50	Silver Basin	104B 040
51	S-1	104B 084
52	Creek	104B 086
53	Big Missouri	104B 046
54	Day	104B 151
55	Province West	104B 136
56	Province	104B 147
57	Calcite Cuts	104B 148
58	Dago Hill	104B 045
59	Golden Crown	104B 149
60	Packer	104B ---
61	Shure	104B ---
62	Silver Butte	104B 150
63	Terminus	104B 002
64	White Heather	104A ---
65	Start	104A 138
66	Dan	104B 141
67	Maple Leaf	104A ---
68	Silver Lake	104A ---
69	Bush 1	104A 092
70	Monitor	104A 092
71	Bush 4	104A 097
72	Boundary	104B 049
73	Last Chance	104B 048
74	Lakeshore	104A 092
75	Daly-Sullivan	104A 073
76	Boundary	104B 031
77	Silver Coin	104B 095
78	Extenuate	104A 158
79	Payroll	104B 050
80	Sunshine	104A 093
81	Cantu	104B 057
82	Indian	104B 031
83	Glacier	104B 112
84	Indian Lake	104B ---
85	Mineral Basin	104B 094
86	Cobalt	104B 051
87	Bush Mines	104B 153
88	Hoveland	104B 051
89	Premier Extension	104B 052
90	Lesley Creek	104B ---
91	Flower Pot Rock	104B ---
92	Sebakwe	104B 153
93	Silver Bar	104B 245
94	Woodbine	104B 090
95	Fork	104B 243
96	Hope	104B 154
97	Northern Lights	104B 053
98	B. C. Silver	104B 155
99	Premier	104B 054
100	Gold Cliff Premier	104B 058
101	Pictou	104B 156
102	South Pictou	104B 157
103	Border	104B 059
104	Simcoe	104B 158
105	M. C.	104A 045
106	96 Group	104B 159
107	Virginia	104B 060
108	Boundary	104B 055
109	International	104B 055
110	Salmon River	104B ---
111	Stoner	104B 160
112	Daly-Alaska (Lower)	104B 061
113	Stoner-Clegg-O'Rourke	104B 062
114	Hoosier	104B ---
115	Daly-Alaska (Upper)	104B 063
116	High-Grade	104B ---
117	Alaska-Premier	104B 064
118	Cripple Creek	104B 067
119	Portland	104B 066
120	Hobo	104B 065
121	High Ore	104B 056
122	Butte	104B 068
123	Kline	104B 244
124	Zebra	104B ---
125	Blue Ribbon	104B 069
126	Hyder Skookum	104B 070
127	Titan	104B 071
128	No.3 Iron	104B ---
129	No.2 Iron	104B ---
130	Monarch	104B 162
131	No.4 Iron	104B ---
132	Shasta Iron	104B 163
133	Riverside	104B 073
134	Roanan	104B 164
135	No.1 Iron	104B ---
136	Ronnie	104B ---
137	Judy	104B ---
138	Roanan Copper	104B ---
139	Riverside Extension (2)	103O ---
140	CC3	103O ---
141	Jarvis (Howard)	103O 001
142	Olympia	103O 005
143	Jarvis Extension	103O ---
144	Dunwell	103P 052
145	Fish Creek (Upper)	104B ---
146	Onlione	103O ---
147	Prince John	103P 049
148	Sixmile	103O 002
149	Last Shot	103O 003
150	Fish Creek (Lower)	103O 005
151	George E	103P 054
152	Lakeview	103P 059
153	Nabob	103P 060
154	Gray Copper	103O 007
155	Ruby Silver	103O 007
156	Bishop	103O 004
157	Marsh	103O ---
158	Davies	103O ---
159	Riverside	103P 166
160	Tom	103O ---
161	Mountainview	103O 007
162	Lucky Boy (Adanac)	103O 008
163	Rampart	103O ---
164	Canyon	103O ---
165	Big Boulder	103O ---
166	Cliff Vein	103O ---
167	Silver Falls	103O ---
168	Victoria	103O ---
169	Chalmers	103P ---
170	Gold Cliff	103P 050
171	Portland Canal	103P 068
172	Mimico	103P 064
173	Phoenix	103P 058
174	Albany	103P 071
175	Lucille	103P 050
176	67	103O ---
177	Bayview (Upper)	103P 051
178	Bayview (Lower)	103P 051
179	Silver Bar	103P ---
180	Mobile	103P 069
181	Chicago	103P 081
182	Ben Bolt	103P 080
183	Red Hill	103P ---
184	Never Sweat	103P ---
185	Black Hill	103P 084
186	pyrite	103P ---
187	Molly B (Lower)	103P 085
188	Molly B (Upper)	103P 085
189	Monroe	103P ---
190	Oral M	103P 085
191	Red Reef	103P 094
192	Silverado	103P 088
193	Flat Vein	103P ---
194	View	103P ---
195	Tacoma	103P ---
196	Melvin	103P 090
197	Silver Bell	103P 095
198	Silver Key	103P ---
199	Prosperity	103P 089
200	Porter Idaho	103P 089
201	Coast Silver	103P 092
202	Aberdeen	103P ---
203	Dominion	103P 099
204	North Fork Basin	103P 098
205	Wire Gold	103P 096
206	Marmot Consolidated	103P ---
207	Emma Gordon	103O 010

LEGEND

INTRUSIVE ROCKS

TERTIARY

OLIGOCENE

9 Lamprophyre dikes (narrow, not shown) Age: 25.2 ± 1 Ma (K/Ar, Biotite, UBC)

LATE OLIGOCENE

8 Microdiorite dikes (narrow, not shown)

EARLY TO MIDDLE EOCENE

HYDER QUARTZ MONZONITE SUITE

7d HYDER BATHOLITH: Biotite quartz monzonite to granodiorite, golden sphene, ± hornblende, medium grained to coarse grained, locally feldspar porphyritic. (Crops out to southwest of map area) Age: 48.8 ± 2 Ma (K/Ar, Biotite, USGS)

7c BOUNDARY STOCK: Biotite granodiorite, golden sphene ± hornblende, medium grained. Age: 50.8 ± 2 Ma (K/Ar, Hornblende, USGS)

7b MINERAL HILL STOCK: Plagioclase porphyritic, biotite hornblende quartz monzonite

7a HYDER DIKES: Plagioclase porphyritic, biotite or biotite hornblende granodiorite. Age: 54.8 ± 1.3 Ma (U/Pb, Zircon, GSC)

JURASSIC

EARLY JURASSIC

TEXAS CREEK GRANODIORITE SUITE

6e TEXAS CREEK DIKES: Orthoclase hornblende porphyritic granodiorite coarse-grained groundmass (narrow, not shown). Age: 189.2 ± 2.2 Ma (U/Pb, Zircon, UBC)

6d SUMMIT LAKE STOCK: Coarse-grained hornblende granodiorite. Age: 192.8 ± 2 Ma (U/Pb, Zircon, UBC)

6c PREMIER PORPHYRY DIKES: Orthoclase ± hornblende porphyritic granodiorite, fine-grained chloritic groundmass. Abundant in Premier Mine area (narrow, not shown). Age: 194.8 ± 2 Ma (U/Pb, Zircon, UBC)

6b TEXAS CREEK BATHOLITH (PORPHYRY PHASE): Orthoclase ± hornblende porphyritic granodiorite, coarse-grained groundmass. Age: 195.0 ± 2 Ma (U/Pb, Zircon, UBC)

6a TEXAS CREEK BATHOLITH: Coarse-grained hornblende granodiorite. Age: 206.5 ± 6 Ma (K/Ar, Hornblende, USGS)

VOLCANIC AND SEDIMENTARY ROCKS

QUATERNARY

RECENT

5 Alluvium, glacial outwash and glacial lake sediments

TRIASSIC-JURASSIC

HAZELTON GROUP

MIDDLE JURASSIC (TOARCIAN TO BAJOCIAN)

SILTSTONE SEQUENCE (SALMON RIVER FORMATION)

4b Carbonaceous and calcareous thin to medium bedded siltstone, shale, argillite and sandstone with minor conglomerate and limestone. Fossil age: Toarcian to Bajocian

4a BASAL MEMBER: Grey to black grits; ash-rich siltstone, sandstone, argillite and limestone, with minor fossiliferous limestone, pumice conglomerates and weakly pyritic units, ≤10 metres thick. Fossil age: Toarcian

LOWER JURASSIC (TOARCIAN)

FELSIC VOLCANIC SEQUENCE (MOUNT DILWORTH FORMATION)

3e BLACK TUFF: Lateral equivalent to 3d; felsic carbonaceous tuff, crystal tuff and lapilli tuff with limestone, pumice and pyrite clasts,minor interbedded sediments.

3d PYRITIC LAPILLI TUFF: Lateral equivalent to 3e; siliceous airfall lapilli tuff to tuff breccia with 5% to 15% disseminated pyrite. Strong gossan development.

3c UPPER LAPILLI TUFF: Siliceous massive airfall lapilli tuff to tuff breccia, partially welded, cream to dark grey.

3b MIDDLE WELDED TUFF: Variable welded felsic ash flows with lapilli, fiammé-to-pumice gradations; single and compound cooling units, cream to maroon.

3a LOWER DUST TUFF: Aphanitic felsic airfall tuff, strongly coloured cream, grey, olive-grey, turquoise, maroon and purple.

LOWER JURASSIC (PLIENSBACHIAN TO TOARCIAN)

COARSE CLASTIC SEQUENCE (BETTY CREEK FORMATION)

2b ANDESITE TO DACITE TUFFS AND FLOWS: Interbedded with 2a; ash tuffs, crystal tuffs, lapilli tuffs, tuff breccias; minor porphyritic flows and welded ash flows, green to grey.

2a SEDIMENTARY ROCKS: Interbedded with 2b; hematitic conglomerate, grit, sandstone, siltstone, mudstone, minor limestone; maroon to purple.

UPPER TRIASSIC TO LOWER JURASSIC (NORIAN TO PLIENSBACHIAN)

ANDESITE SEQUENCE (UNUK RIVER FORMATION)

1g AUGITE PORPHYRY FLOWS: Massive pyroxene-porphyritic andesite; dark green.

1f PREMIER PORPHYRY FLOWS: Orthoclase megacrystic, plagioclase hornblende porphyritic andesite, fine-grained groundmass; green, maroon, purple, grey, black; local tuff breccia facies.

1e UPPER ANDESITE TUFFS: Dust, ash, crystal and lapilli tuff and tuff breccia, with local welded tuff, intercalated hematitic sediment lenses 1es. Basal unit is black, carbonaceous andesite ash tuff and lapilli tuff 1eb. Age: 210 ± 7 Ma (U/Pb, Zircon, UBC)

1d UPPER SILTSTONE MEMBER: Carbonaceous thin bedded argillite, siltstone, sandstone, with local basal conglomerate (1dc) and coral limestone (1dl).

1c MIDDLE ANDESITE TUFFS: Mainly ash tuffs, lesser dust and lapilli tuffs, interbedded augite porphyry (1ca) and two-feldspar porphyry flows, minor gradational sandstone (1csd) and siltstone (1csl).

1b LOWER SILTSTONE MEMBER: Carbonaceous thin-bedded argillite, siltstone.

1a LOWER ANDESITE TUFFS: Ash tuffs

ALTERATION

SERICITE + CARBONATE + PYRITE (gossanous)

DISSEMINATED PYRITE (gossanous)

SYMBOLS

GEOLOGICAL CONTACT: Defined, approximate, assumed

BEDDING, TOP KNOWN: Inclined, vertical, overturned

BEDDING, TOP UNKNOWN: Inclined, vertical

BEDDING: Compiled from other studies

FOLD AXIAL TRACE: Syncline, anticline

Minor folds

Lineation — 0, 30, 90

FOLIATION: Inclined, vertical

FOLIATION: Compiled from other studies

FAULT: Defined, approximate, assumed

Margins of major swarms/dike

Air photo linear, (assumed fault)

Fossil locality — F

MINERAL PRODUCER: Past production > 10 tonnes (Map 1, Table 1)

MINERAL OCCURRENCE: Outcropping, blind (Map 2, Table 2)

Placer workings

Topographic contour (100-metre intervals) — 500

Surveyed elevation (metres)

ROADS: In use, abandoned

#85 (1)(b)

TABLE 16

Mineral Deposit Classification for the Stewart Mining Camp

Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources
GEOLOGICAL SURVEY BRANCH

CHEMISTRY — MINERALOGY — TEXTURES — ALTERATION — STRUCTURAL SETTING — HOST ROCK

KEY TO DIAGNOSTIC FEATURES
- ● = Diagnostic
- ○ = Possibly diagnostic
- E = Criterion for Eocene deposits
- J = Criterion for Jurassic deposits
- E/J = Criterion sorts deposit types

Column groups: ORE METALS (Ag ppm, Au ppm, Cu %, Pb %, Zn %); TRACE ELEMENTS (As, Ba, Cd, F, Ge, Hg, Mn, Sb, Sn, W ppm); ORE MINERALOGY (Pyrite, Pyrrhotite, Sphalerite, Galena, Chalcopyrite, Bornite, Arsenopyrite, Tetrahedrite, Malachite, Chalcocite, Covellite, Electrum, Native Silver, Pyrargyrite, "Freibergite", "Argentite", Polybasite, Gold, Proustite, Stibnite, Acanthite, Naumannite, Molybdenite, Hematite, Scheelite); GANGUE MINERALOGY (Quartz, Calcite, Chlorite, Barite, Ankerite, K-Feldspar, Epidote, Chalcedony, Garnet, Diopside, Carbon, Pyrolusite); ORE TEXTURES (Cryptocrystalline, Fine Grained, Medium Grained, Coarse Grained, Laminated, Massive, Comb Quartz, Colloform Banding, Growth Zones); VEIN TEXTURES (Massive Vein, Breccia Vein, Chalcedonic Clasts, Mineralized Clasts, Wallrock Clasts, Vein Clasts, Ribbon Vein, Vuggy Vein, Chalcedonic Vein); ALTERATION (Chlorite, Epidote, Sericite, K-Feldspar, Silica, Carbonate, Pyrite, Hornfels, Skarn); STRUCTURAL SETTING (Brittle Fracture, Brittle Fault, Ductile Fault, Dike Margin, Stratabound, Stockwork, Disseminated); STRATIGRAPHY (Salmon River Formation, Mount Dilworth Formation, Betty Creek Formation, Unuk River Formation, Premier Porphyry Member, Upper Andesite Member, Upper Siltstone Member, Middle Andesite Member, Lower Siltstone Member, Lower Andesite Member); INTRUSIVE ROCK (Texas Creek Suite, Texas Creek Batholith, Summit Lake Stock, Premier Porphyry Dikes, Hyder Suite, Hyder Batholith, Boundary Stock, Portland Canal Dike Swarm, Boundary Dike Swarm, Granodiorite Dikes, Aplite Dikes, Microdiorite Dikes, Lamprophyre Dikes)

NAME OF OCCURRENCE	MAP NUMBER	MINFILE NUMBER	LEAD ISOTOPE RATIO	GOLD-SILVER RATIO	Ag ppm	Au ppm	Cu %	Pb %	Zn %
Au-Pyrrhotite Veins (Early Jurassic)									
SCOTTIE GOLD	13	104B-034	J	1:8.1	10.14	18.62	.11	.03	.04
SCOTTIE NORTH	11	104B-074		1:1.4	58.30	51.00			
BEND	7	104B-132		1:2.1	51.40	61.8			
COOKSHACK	8	104B							
BLUEBERRY	10	104B-133		1:2.1	21.83	26.56			
HICKS	14	104B-139		?					
INDIAN LAKE	84	104B		?					
FLOWER POT ROCK	91	104B							
SALMON RIVER	110	104B							
SHASTA IRON	133	104B-161		?	?	?			
ROANAN COPPER	139	104B							
No.1 IRON	136	104B							
No.2 IRON	129	104B							
No.3 IRON	128	104B							
No.4 IRON	132	104B							
Au-Ag-Base Metal Veins (Early Jurassic)									
MARTHA ELLEN	36	104B-092	J	1:6.5	25.05	2.78	1.18	5.11	13.32
CREEK	52	104B-086	J	1:48	116.23	2.40	3.47	11.54	12.9
PROVINCE WEST	55	104B-136	J	?					
PROVINCE	56	104B-147	J	1:5.3	13.57	2.50	0.36	2.56	5.61
CALCITE CUTS	57	104B-148	J	?					
DAGO HILL	58	104B-045	J	1:17	49.71	2.85	<0.01	0.05	0.07
SILVER BUTTE	62	104B-150	J	1:2.1	36.59	17.31	0.69	3.33	6.36
TERMINUS	63	104B-002	J	1:71	99.43	1.4	2.0	11.79	5.06
NORTHERN LIGHTS	97	104B-053	J	?					
PREMIER	99	104B-054	J	1:21	274.00	13.00	0.13	1.96	2.67
PORTLAND	1	104B-082		3:1	20.57	4.11			
EAST GOLD	3	104B-033		1:3.1					
TIDE	4	104B-129		1:1.4	28.11	18.55			
GOSSAN BLUFF	6	104B		1	low	low			
RAINBOW	15	104B-075		1:42	72.00	1.70			
HARRY	22	104B		?					
LILA	24	104B		?					
DUMAS CREEK	25	104B		?					
YELLOWSTONE	26	104B-039		1:116	5.50	651.00			
FORTY-NINE	28	104B-038		low					
OXEDENTAL	30	104B-142		low					
RAMBLER	41	104B-144		?					
AMBER	43	104B-358		1:30					
GOOD HOPE	44	104B-044		5:1-1:20					
LINDEBORG	46	104B-073		1:4.6	20.57	4.28			
NORTH STAR	49	104B-162		1:4.6	20.57	4.28			
S-1	51	104B-084		1:2.1	8.23	3.94			
BIG MISSOURI	53	104B-046		1:7					
DAY	54	104B-151		?					
GOLDEN CROWN	59	104B-149		?					
DAN	66	104B-141		~1:14					
BOUNDARY	72	104B-049		1:61					
PAYROLL	79	104B-050		1:4580	2589.28	13.71	1.7	4.8	16.12
MINERAL BASIN	85	104B-052		1:56	576.00	10.30		16.00	6.00
COBALT	86	104B-051		1:22	274.20	12.30			
BUSH MINES	87	104B-153		low	~100.00				
HOVELAND	88	104B-051		?					
PREMIER EXTENSION	89	104B-052		1:15	10.26	0.69			
SEBAKWE	92	104B-154		1:21	274.00	13.00		0.66	0.20
WOODBINE	94	104B-090		1:15					
FORK	95	104B-243		?					
POWER	96	104B-154		1:9.6	107.40	11.2			
HOPE	96	104B-154		1:9.2	157.00	17.00	2.4	2.04	27.78
B.C. SILVER	98	104B-155		1:21	274.00	13.00		0.66	0.20
GOLD CLIFF PREMIER	100	104B-058		1:4.0	137.12	34.29			
PICTOU	101	104B-156		1:4.1	173.11	0.27	<0.01	0.10	0.56
SOUTH PICTOU	102	104B-157		1:107	298.70	2.50	<0.01	0.05	0.05
SIMCOE	104	104B-158		1:212	152.89	0.72			
STONER	111	104B-160							
STONER-CLEGG-O'ROURKE	113	104B-062		?					
HOOSIER	114	104B		?					
HIGH ORE	121	104B-056		1:75	22.90	0.31			
BUTTE	122	104B-068		1:34	706.17	20.57			
Stratabound Pyritic Dacites (Early Jurassic)									
DILWORTH	18	104B		?	<10	<0.3	0.01	0.07	0.06
IRON CAP	38	104A-090		low	8.86				
Ag-Pb-Zn Veins (Middle Eocene)									
SPIDER	31	104A-010	E	1:750	466.27	0.66			
PACKER	60	104B	E	?					
START	65	104A-138	E	low	68.00			1.6	7.0
INDIAN	82	104B-031	E	1:40	119.70	3.04	0.15	8.85	25.08
LESLEY CREEK	90	104B							
RIVERSIDE	133	104B-073	E	~1:50	118.29	3.26	0.14	4.13	
JARVIS (HOWARD)	141	103O-001	E	?					
BAYVIEW (UPPER)	177	103P-051	E	1:4605	5848.30	1.27		16.99	16.53
SILVERADO	192	103P-088	E	1:4154	2968.00	0.69	0.20	8.90	8.30
PROSPERITY	199	103P-089	E	1:2714	2684.2	0.96	0.45	6.56	7.74
PORTER IDAHO	200	103P-089	E						
MITRE	2	104B-137		low					
HAPPY VALLEY	5	104B		?					
BETTY	16	104A-008		1:737	2025.0	2.74			
DAISY	17	104B-140		1:4242	848.00	.20			
SILVER CLIFF	19	104A		?					
ST. EUGENE	20	104B-036		low	384.00				
TROY	21	104B-035		1:25	13.00	0.7			
HOLLYWOOD	23	104B-037		?					
OUTLAND SILVER BAR	27	104B-030		1:116	186.00	1.40		2.17	2.29
SILVER CROWN	29	104A-061		1:600					
LION	32	104B-041		1:2368	5885.00	2.4	0.18	4.71	13.98
SILVER HILL	33	104B-042		low					
SPIDER 1	34	104A-098		1:40	418.30	10.30			
MONTANA	35	104B-093		?					
LOIS	37	104A-068		?					
SILVER TIP	39	104B-043		1:200	570.00	4.80			
UNICORN	40	104B-044		1:2370					
M.J.	42	104A-091		1:500					
MUNRO	45	104B-047		?					
A VEIN	47	104B-145		1:96					
H VEIN	48	104B-213		1:415					
SILVER BASIN	50	104B-040		low	102.90			7.8	4.8
SHURE	61	104B		?					
WHITE HEATHER	64	104A							
MAPLE LEAF	67	104B		?					
SILVER LAKE	68	104B		?					
MONITOR	70	104A-092							
BUSH 4	71	104A-097		low	20.57				
LAST CHANCE	73	104B-048		?					
LAKESHORE	74	104A-092		?	52	<0.3	0.06	2.72	1.96
DALY-SULLIVAN	75	104A-073		?					
SILVER COIN	77	104B-095		?					
EXTENUATE	78	104A-158		?	nil	nil			
SUNSHINE	80	104A-093		1:430	294.86	0.69	1.1	0.1	
CANTU	81	104B-097		1:176	1060.00	6.00		44.0	12.2
GLACIER	83	104B-112							
SILVER BAR	93	104B-245							
BORDER	103	104B-059							
M.C.	105	104A-045		1:1690	1690		0.15	10.90	20.0
96 GROUP	106	104B-159							
VIRGINIA	107	104B-060							
BOUNDARY	108	104B-055							
INTERNATIONAL	109	104B-055							
DALY-ALASKA (LOWER)	112	104B-061			1071.20				
DALY-ALASKA (UPPER)	115	104B-063							
HIGH-GRADE	116	104B							
ALASKA-PREMIER	117	104B-064							
CRIPPLE CREEK	118	104B-067							
PORTLAND	119	104B-066							
HOBO	120	104B-065							
KLINE	123	104B-244							
ZEBRA	124	104B							
BLUE RIBBON (CREST)	125	104B-069							
HYDER SKOOKUM	126	104B-070							
TITAN	127	104B-071							
MONARCH	130	104B-162		1:196	9120.00	46.40			
ROANAN	134	104B-164		1:71					
RONNIE	135	104B							
JUDY	137	104B							
RIVERSIDE EXTN. (2)	139	103O							
CC-3	140	103O							
OLYMPIA	142	103O-005		1:854					
JARVIS ENTN. (2)	143	103O							
DUNWELL	144	103P-052		~1:500					
FISH CREEK (UPPER)	145	104B							
ONLIONE	146	103O							
PRINCE JOHN	147	103P-049							
SIXMILE	148	103O-002		1:3.6	297.95	23.31		8.7	
LAST SHOT	149	103O-003		1:141					
FISH CREEK (LOWER)	150	103O-005		1:854					
GEORGE E.	151	103P-054		~1:50	•	•	•	•	•
LAKEVIEW	152	103P-059		~1:750	•	•	•	•	•
NABOB	153	103P-060		?	?	?	•	•	•
GRAY COPPER	154	103O-007							
RUBY SILVER	155	103O-007							
BISHOP	156	103O-004		?	?	?	•		
MARSH	157	103O							
DAVIES	158	103O							
RIVERSIDE	159	103P							
TOM	160	103O							
MOUNTAINVIEW	161	103O-007							
LUCKY BOY EXT/ADANAC	162	103O-008		?	?	?	•	•	•
RAMPART	163	103O							
CANYON	164	103O							
BIG BOULDER	165	103O							
CLIFF VEIN	166	103O							
SILVER FALLS	167	103O							
VICTORIA	168	103O							
CHALMERS	169	103P							
GOLD CLIFF	170	103P-050		1:671	2280.00	3.40	?	11.00	9.00
PORTLAND CANAL	171	103P-068		1:94	208.8	2.23	•	•	•
MIMICO	172	103P-064		low	5345.00	?		87.20?	•
PHOENIX	173	103P-058		1:53	200.00	3.80	•	•	•
ALBANY	174	103P-071		low	247.00	•	?	•	•
LUCILLE	175	103P-050		1:671	2280.00	3.40	?	11.00	9.00
67	176	103O							
BAYVIEW (LOWER)	178	103P-051		1:4340	8679.70	2.00	•	20.30	20.20
SILVER BAR	179	103P							
MOBILE	180	103P-069		1:1591	363.00	•?	•	•	4.20
CHICAGO	181	103P-081		?	?	?		•	
BEN BOLT	182	103P-080		1:80	193.00	2.4	0.90	15.01	3.16
RED HILL	183	103P							
NEVER SWEAT	184	103P							
BLACK HILL	185	103P-084							
pyrite	186	103P							
MONROE	189	103P							
FLAT VEIN	193	103P							
VIEW	194	103P							
TACOMA	195	103P							
MELVIN	196	103P-090		1:2327	72.15	0.03	•	0.15	0.46
SILVER BELL	197	103P-095		low	141.00	?		•	•
SILVER KEY	198	103P							
COAST SILVER	201	103O-092							
ABERDEEN	202	103P							
DOMINION	203	103P-099		?	?	?	•	•	•
NORTH FORK BASIN	204	103P-098		low	3840.	?	•	14.40	4.41
WIRE GOLD	205	103P-096		1.5:1?	9.90	15.30	?	•	?
MARMOT CONSOLIDATED	206	103P							
EMMA GORDON	207	103O-010							
Skarns (Middle Eocene)									
MOLLY B (LOWER)	187	103P-085		1:3	10.30	3.40	0.80	?	?
MOLLY B (UPPER)	188	103P-085		1:3	10.30	3.40	0.80	?	?
ORAL M	190	103P-085							
RED REEF	191	103P-094		?	•	•	3.00	•	•

SUMMARY

Although ore chemistry (assays and trace metal analyses) and ore mineralogy are of most interest to exploration geologists, these features seem to be the least reliable indicators of age and deposit type. Virtually any other feature about a deposit will give more insight into deposit type, including gangue mineralogy, ore textures, vein texture or 'structure', alteration minerals, and stratigraphic and plutonic associations.

SOURCES

Information for preparation of this table was compiled from MINFILE, provincial and federal government reports, public and private company reports, and field examination of several dozen showings.

SYMBOLS

● = present (no amounts or textures known or implied).

●? = presence reported but unlikely (based on later reports or field examination)

? = presence not reported, but probable.

DISCUSSION OF COLUMNS

Every column shows exceptions to the general patterns, with the notable exception of the lead isotope data. Therefore, for most deposits, several diagnostic criteria must be satisfied before classification can be completed with confidence.

Au-Ag Ratios
Vintage assay data are always suspect. On a property with dozens of available assays, those with the highest gold values were preferentially reported, regardless of silver grades. Reported gold-silver ratios are therefore sometimes biased towards gold.

Ore Chemistry
There are too few data available from most showings to determine any diagnostic patterns.

Ore Minerals
Only iron and base metal sulphide minerals are regularly reported. Relative abundances of these minerals are potential diagnostic features but most reports fail to indicate amounts.

Gangue Minerals
Half of the gangue minerals are diagnostic, which demonstrates the value of careful tabulation of all deposit data in chart form. For calcite, abundances less than 5% can be found in both Jurassic and Eocene deposits, but amounts over 5% are characteristic of Jurassic deposits.

Ore Textures
Ore textures are rarely discussed or illustrated in reports, yet these features can be diagnostic and are visually distinctive. Careful study of core or sawn samples is usually necessary.

Vein Textures
Vein textures or small-scale structures are described frequently, but the literature suffers from poorly defined terms. Consequently some reported textures are suspect.

Alteration
Altered wallrock usually has greater volume than the ore zone it surrounds, but it is rarely described in preliminary property examinations. Alteration minerals are strongly diagnostic and deserve careful attention and documentation.

Structural Setting
Structural features suffer from being 'interpretive' and terminology is poorly defined. Some similarities between Jurassic and Eocene structural sites for ore deposition should be expected since deposit types of both epochs were likely generated by hydrothermal convection around plutons and related dikes.

Host Rock
Most stratigraphic members are dominated by single lithologies or limited lithological ranges. Therefore the "stratigraphy" divisions also indicate host lithology.

To accompany Bulletin 85 by D.J. Alldrick