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METALLOGENY OF THE GREENWOOD MINING CAMP

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Abstract

The majority of the 244 mineral localities and deposits recorded in the British Columbia mineral inventory file (MINFILE) for the Grand Forks sheet (82ESE) occur in the Greenwood mining camp. This is a relatively small area that preserves wide geologic and metallogenic diversity. Concentrations of precious metals and copper, lead and zinc are found in accreted Paleozoic and early Mesozoic arc, back arc and oceanic terranes. The Lexington-Lone Star copper-gold porphyry system, rooted in Proterozio cratonic basement rocks, was emplaced in the early Jurassic subsequent to the accretion of the Knob Hill - Attwood groups that are part of the Slide Mountain ophiolitic terrane. Reactivation of suture zones resulted in silver-lead-zinc mineralization such as found at the No.7, Skomac and Skylark mines. These and the famous copper-gold skarn deposits, such as the Phoenix, Greyhound, Mother Lode, Oro Denoro and Eholt deposits, associated with the Brooklyn arc rocks, are the focus of traditional and ongoing exploration. New exploration in the camp is centred on silicified limestone deposits with bulk tonnage gold potential (the PAC prospect), stratabound massive suphides (the Croesus property), and epithermal gold/ silver related to Tertiary faulting (the Tam O'Shanter prospect).

INTRODUCTION

The Canadian Cordillera is a collage of oceanic and arc terranes that were acereted to the western margin of the North American craton during the Mesozoic. After final docking in mid-Cretaceous the terranes were disrupted by major strike-slip faults (Price et al., 1985). Post-accretionary volcanism and block faulting was particularly widespread during the Tertiary in the Intermontane Belt (Souther, 1977; Monger et al., 1982).

The Grand Forks-Greenwood area is part of a well mineralized region of complex geology in the southern interior of British Columbia (Figure 1). The map-area (82ESE) straddles several important physiographic-tectonic domains. Much of the area west of the Christina Lake and the Arrow Lakes is part of the Interior Plateau; the Selkirk Mountains lie to the east, and the Okanagan Highlands are mostly west of the Kettle River.

The area is underlain principally by large Mesozoic and Tertiary granitic plutons that intrude the Proterozoic pericratonic Monashee Complex and the accreted Paleozoic and Mesozoic oceanic and arc rocks of the Slide Mountain and Quesnel terranes (Figure 2). Overprinting by Tertiary extensional structures has complicated the geology.

Lode mineralization was first recorded near Greenwood in 1884 and major deposits of copper and gold have been mined here since the turn of the century. Most of the mineral production from the Greenwood mining camp is from copper bearing skarn deposits and, to a lesser extent, polymetallic quartz veins and, less commonly, copper-gold porphyry deposits. A more detailed breakdown of the 244 mineral ocurrences in the broader Boundary area of 82ESE shows 12 vein-type producers related to granodiorite stocks, 4 vein producers in fault zones, 6 in skarns, 2 mineralized listwanites, 1 magmatic orebody and 1 porphyry copper deposit. Production to date from the 26 principal mines in the area stands at 32,044,173 tonnes of ore consisting of 38,278 kilograms of gold, 183,102 kilograms of silver, 270,945 tonnes of copper, 966 tonnes of lead, and 329 tonnes of zinc.

GEOLOGICAL SETTING

The Greenwood mining camp is a 400 km^2 area bounded on the north by the Coryell and Ladybird plutons, on the west by the Toroda Creek graben, on the east and south by the Granby fault and structures related to the Republic graben. The camp is underlain by more than a dozen mappable units comprising a variety of sedimentary, volcanic, metamorphic and intrusive rocks that range from Paleozoic to Tertiary age. The names of the formations used in this report are the same as those in current geological literature on the Boundary area of British Columbia and adjacent parts of Washington state.

Slide Mountain Terrane

The Permo-Carboniferous ophiolitic ultramafic rocks, basic intrusions and bedded oceanic suites of the Anarchist, Knob Hill and Attwood groups in the Greenwood area are similar to formations in the Slide Mountain terrane such as the Milford-Kaslo Groups in the Kootenays and the Fennell Formation in the Clearwater area (Figure 2). The Knob Hill Group is Permo-Carboniferous, and possibly as old as Devonian, and consists of banded metacherts, quartz-chlorite schist, amphibolitic schists and gneisses and a few recrystallized limestone bands. The Attwood Group is Permian and consists mainly of dark argillite, greywacke, conglomerate, some thick fossiliferous limestone lenses and metavolcanic units. The 'Anarchist Group' comprises mostly undivided Knob Hill and Attwood formations. These groups are significantly folded, overturned and faulted. The Chesaw thrust fault (Jurassic) is displayed at intervals near the international border where the ophiolites and Knob Hill Group are thrust over the Attwood Group (Cheney et al., 1996). In the Greenwood area, splays or imbrications of the Chesaw fault comprise at least 5 separte belts of serpentinite, listwanite and metagabbro (Fyles, 1990).

Quesnel Terrane

The Quesnel terrane is represented in the area mainly by the Brooklyn Group and the Nelson batholith and equivalent volcanic rocks that show evidence of penetrative deformation, chlorite grade regional metamorphism and important tectonic movements. The Brooklyn Group is mid-Triassic and basal Quesnellia. The group structurally overlies both the Knob Hill and Attwood sequences and is characterized by thick basal 'sharpstone' conglomerate, interfingering shales and limestones, and an upper sequence of volcanic breceias (Church, 1986). The 'sharpstone' typically contains abundant clasts derived from the older terranes composed largely of ribbon chert such as the Cache Creek and Knob Hill groups (Seraphim, 1956). The Nelson plutonic rocks (Jurassic) are believed to be feeders to the Rossland Volcanics that occur at the southern extremity of the Quesnel arc in the interior region of British Columbia (Hoy and Dunn, 1997).

Post-Quesnellian Terranes

The Laramide orogeny (late Cretaceous / early Tertiary) in the Greenwood area is marked by intrusion of the Ladybird granite, and followed by post-Laramide orogenic collapse (Eocene) that features graben development and late plutonism including emplacement of the Coryell batholith.

The Penticton Group (Eocene) is the youngest assemblage in the camp and consists of the Kettle River and Marron formations (Church, 1986). The Kettle River beds are fluvial and lacustrine feldspathic sandstones and siltstones; the Marron Formation comprises several alkalic and calcalkalic volcanic members fed in part by dikes and sills emanating from the Coryell batholith. These rocks have been titled by block faulting related to graben development and major detachment tectonics (Tempelman-Kluit and Parkinson, 1986).

METALLOGENY

The the most important metallic mineral deposits of the Greenwood mining camp are massive sulphides and disseminations related mostly to skarns, porphyry-deposits and veins. Other less common types of mineralization include volcanogenic massive sulphide deposits (VMS), magmatic/hydrothermal deposits, and unconformity and detachment related deposits. The following metallogenic interpretations are augmented by synoptic descriptions of the main deposit types in the Appendix of this report).

Skarn Deposits:

The history of the Greenwood mining camp is essentially the history of the Phoenix mine and the other large copper-gold skarn deposits in the area such as the Mother Lode, Greyhound and Oro Denoro mines. In the case of the latter examples, the proximity of these ore deposits to the Wallace Creek granodiorite pluton and the Brooklyn limestone fits the classical setting of skarn deposits (Sutherland Brown, 1969). Indeed, the combination of igneous intrusion, limestone and mineralization is frequently repeated throughout the camp. The Phoenix orebody is unusual, however, because it is almost exclusively of stratabound calc-silicate alteration of limestone with no known accompanying granitic intrusion. Nevertheless, the extensive deposits of grade copper ore, which have given rise to the mining industry at Phoenix have all the characteristics of metasomatic replacements. These replacements are composed essentially of chlorite-epidote skarns containing variable amounts of garnet, calcite and quartz, accompanied by blebs and disseminations of pyrite, chalcopyrite, magnetite and specularite. The skarn and copper minerals are localized in a band of impure Brooklyn limestone above a well defined foot-wall argillite. The thickness of mineralization varies from a maximum of 60 m to less than 1 m at the limits of mining. The ore beds are generally inclined downward to the east, but dips determined for individual beds vary somewhat because of a series of N-S faults that have produced irregularities.

In summary, the Phoenix ore body appears to be locallized by faulting, the footwall argillite and impurity of the overlying limestone. No igneous source rocks are known, nevertheless, it is assumed that a deep seated granitic body under the mine area produced the mineralizing solutions which were then channelled by faults to favourable facies sites in the Brooklyn limestone for replacement and deposition (Fahrni, 1966).

There is question, however, that other deposits in the area, such as Eholt and Emma skarns, are related to the nearby Wallace Creek pluton or Coryell batholith. Peatfield (1978) and others argue that the transitional argillaceous zone between the sharpstone conglomerate and limestone in the Brooklyn Group may have been the site of original copper-iron deposition and that subsequent metamorphism produced stratiform skarn-like deposits.

The Silvester-K deposit is a steep easterly dipping zone of massive sulphides (mostly pyrite with some gold values). The deposit is 160 m long, up to 2.5 m wide and appears to be concordant within the Brooklyn strata. A volcanogenic origin of the sulphides has been considered, however, no tuffs or vent rocks have been identified in the area, and the deposit is on strike with the nearby San Jacinto deposit which is a more typical skarn developed in Brooklyn limestone as the result of intrusion of the Providence Lake microdiorite body. At San Jacinto it is theorized that metasomitizing fluids followed microdiorite dikes into the stratigraphic pile then infiltrated bedding planes. Recrystallization of the carbonate units by these warm fluids produced granular or sugary textures that facilitated further infiltration and eventual wholesale replacement (Church, 1984).

Volcanogenic Massive Sulphide Depnsits:

The Slide Mountain terrane in British Columbia contains a number of volcanogenic massive sulphide deposits (VMS). Some VMS examples include the Chu Chua deposit in the Fennell Formation, the Nina deposit in the Nina Creek Group and the Lang Creek occurrence in the Sylvester Allochthon (Figure 2). Similarly, the Slide Mountain equivalent rocks in the Greenwood area have VMS potential. For example, the Clearcut rhodonite occurrence is a stratabound deposit associated with what appears to be the metamorphic equivalent of volcanic rocks and siliceous and pelitic sediments of the Knob Hill Group. The absence of the primary detrital textures within the silica-rich host rocks is consistent with a chemical precipitate protolith, either of sedimentary or hydrothermal origin. Many similar manganese deposits are considered distal equivalents of volcanogenic massive sulphide deposits (Simandl et al., 1996).

The Overlook mine in Washington state is a VMS associated with the Attwood Group where overturned limestone forms the hanging wall of the deposit (Lasmanis, 1996). The Overlook, previously thought to be skarn-related, is similar in some ways to the Silvester K deposit at Greenwood that contains gold associated with magnetite and sulphides hosted by limestone.

The VMS model has also been applied to the Croesus occurrence in the Greenwood camp. This showing consists of an alignment of sulphide lenses, several hundred metres in total strike length, associated with Attwood limestone, greenstone and dark argillite. A cross-section of the main mineralized zone shows 7.5 m of massive sulphides consisting of massive pyrite, pyrrhotite, sphalerite and some fine grained chalcopyrite.

Porphyry Deposits:

The Lexington intrusion, accompanied by copper-gold porphyry-type mineralization, was emplaced in the early Jurassic, near the time of accretion of the Quesnel arc with the North American craton (Seraphim et al., 1996).

The Lexington-Lone Star Cu-Au deposits are part of a 3 km long linear porphyry system that straddles the U.S./ Canada border south of Greenwood . This 3 km long linear porphyry systems occurs in a northeast dipping belt of sheared quartz porphyry and serpentinite. Theories regarding the genesis of the copper-gold porphyry mineralization generally involve faulting and the Lexington intrusion which has been dated 200 Ma by U/Pb zircon methods. The serpentinite in the Lexington area was emplaced first, as a ductile body into the northeast dipping No. 7 fault zone, which is thought to be a splay or imbrication of the Chesaw thrust. Later, the Lexington magma, in one or several pulses, intruded the same fault zone dividing the serpentine into upper and lower limbs. The parental magma was contaminated by, or derived from, early Proterozoic basement rocks (2445 Ma). Continued movement on the fault zone resulted in penetrative deformation of the serpentinite and the Lexington quartz porphyry. Although the porphyry is generally sheared, the margins of the body are locally intact and contain disseminations of pyrite, chalcopyrite and minor molybdenite from the time of initial cooling and concentrations of sulphides and magnetite resulting from contact metamorphism of serpentinite and liswanitic wall rocks. Later movement fractured the margins of the intrusion allowing emplacement of the City of Paris vein system which was then itself sheared by younger movement.

Veins:

An extensive and intricate fissure system provided the necessary channelways for the metalliferous solutions that formed the vein deposits of the Greenwood mining camp. In many cases igneous intrusions served principally as heat engines in the process of convection and dispersion of the solutions. A linear lead isotope relationship that connects diverse deposit-types in the area appears to be the result of mixing within a well connected hydrothermal plumbing system (Church, 1986).

The oldest veins in the Greenwood camp are mesothermal quartz veins characterized by high silver values and variable amounts of gold, silver, copper, lead and zinc. The Providence and Dentonia (Jewel) veins systems have been worked intermittantly since the turn of the century. These veins are hosted mostly in the Knob Hill Group but originate in the adjacent Greenwood and Wallace Creek granodiorite stocks.

The workings of the Providence mine follow ore shoots within a narrow quartz vein. The ore minerals consist of pyrite, galena, sphalerite, chaleopyrite, tetrahedrite, proustite, native silver and free gold in quartz carbonate gangue. The vein strikes 050° and dips 40° to 60° southeast. It has been traced underground for more than 370 m and ranges from a fraction of a centimetre to 0.75 m in width. Unbroken quartz rarely extends from wall to wall, and more commonly strands of quartz are separated by thin, lenticnlar bands of altered country rock. The vein is irregular in size and attitude on the lower levels. In a few places these changes can be correlated with the passage of the vein from one rock to another. Thus, in the northeast part of the workings the vein pinches to a gouge filled fissure on passing from the relatively hard silicified rocks to soft chloritic schists. On the lower levels the vein appears to be more persistent in the silicified rocks than in the granodiorite.

The Dentonia vein, in the Jewel Lake area, trends northeasterly from margin of the Wallace Creek pluton cutting across greenstones, pelitic schists and chert of the Knob Hill Group. The vein averages about one metre wide and consists of grey disseminations and small pockets of sulphides in quartz. The ore minerals are pyrite and galena with minor amounts of sphalerite, chalcopyrite, tellurides and some native gold. Ore controls are attributed to several factors, the most important of which are deflections in the vein attitude and a response to abrupt changes in the composition of the host rocks. Tensional gash fractures developed attendant to compressional stress from the southwest, allowing the influx of quartz possibly during the cooling stages of Wallace Creek pluton. The amount of movement was small and the direction is believed to have been largely horizontal. The host rocks are not thought to have offered any special opportunity for chemical reaction with the ore bearing solutions, however, there was a tendency for the greenstone to split and fray under stress and the walls of the vein and septa show some evidenee of replacement. The age of the Dentonia vein is bracketed by the Wallace Creek granodiorite, which hosts the vein locally, and crosscutting young dikes. A sample of the granodiorite from the Denero Grande shaft area returned an early Cretaceous K/Ar date of 125 Ma. The numerous feldspar porphyry and pulaskite dikes found in the mine workings are feeders to volcanic rocks in the Penticton Group (Eocene).

Many of the producing veins in the Greenwood camp are Mesozoic or Tertiary age and hosted by the Attwood Group. The Skylark vein is a silver-lead-zinc, quartz-carbonate fissure filling deposit hosted by dark shales and greenstones of the Attwood Group. Similar veins found in the Mount Roberts Formation, Burnt Basin camp (35 km east of Greenwood), appear to be distally connected to the Nelson Batholith.

Other sulphide bearing veins, including the Winnipeg, Skomac, No.7 and Athelstan lodes, are related to dismembered ophioloitic rocks in fault zones and have no obvious granitic source. At the Winnipeg mine, mineralization consists of pyrite, pyrrhotite and pyrite occurring in discontinuous quartz veins and lenses hosted by Attwood greenstones, ultramafic rocks and asssociated gabbros. The veins are quartz-filled gash fractures developed as splays of a major southeasterly-trending fault. At the Athelstan and Jackpot mines the main units are serpentinite and listwanite, and the principal ores are gold and copper rich sulphides. A band of listwanite up to 168 m wide, extending between the Athestan and Jackpot adits, is traversed by an irregular system of fissures that served as channelways for the ore bearing solutions. The common ore minerals, pyrite and arsenopyrite, form replacements in the listwanite. The ore bodies are crescent shape in plan and section and plunge from 10° to 40° easterly. The bodies range in thickness from 1 to 7.6 m and were stoped over a length of 30 m. The foot and hanging walls of the ore bodies commonly follow well defined fissures. The composition of the wall rock has had a marked influence on ore deposition such that The rocks containing a high percentage of carbonates were most susceptible to replacement by the ore bearing solutions, whereas those composed of serpentine were the least susceptible.

Some of the youngest veins in the area are related to some of the oldest structures. For example, the City of Paris vein system is associated with the No. 7 fault zone and a belt of serpentinite that traverses the Lexington property on the Canada-United States border (Little, 1983). The fault zone is an ancient structure believed to be a continuation of the Chesaw thrust in Washington state (Cheney *et al.*, 1994). The associated serpentinite is interpreted to be part of a disrupted Paleozoic ophiolite composed primarily of peridotite (Fyles, 1990). Because of the ductile nature of these rocks, the belt became a tectonically active zone and the locus of much shearing, thrusting, igneous intrusion and vein mineralization. The common Mg-Fe carbonate-talc alteration (listwanite) and serpentinization are the product of major thrusting of the ophiolitic rocks.

The City of Paris veins are the result of reactivation of thrusting at the contact between the Lexington quartz porphyry and hangingwall serpentinite during the development of the Republic graben. An analysis of fuchsite obtained from quartz splays in the listwanitic wall rocks yielded a K/Ar age of 56.7 ±1.0 Ma (Church, 1997). In the early Tertiary these thrusts were reactivated by tectonic compression directed subparallel to the developing northerly elongated graben structures and igneous activity (Armstrong and Ward, 1991; Church, 1986). Carr et al (1987) interpreted of onset of extension (and overlapping compression) in the southern Interior of British Columbia to be 58 Ma (Paleocene\Eocene). The event is linked to interaction between the North American and the subducting Kula-Pacific plate boundaries (Struik, 1992).

Epithermal mineralization is best preserved in Tertiary structures. For example, the Knob Hill mine at Republic, Washington, exploits a significant epithermal gold-silver vein related to movement on the Bacon Creek fault at the west margin of the Republic graben (Lasmanis, 1996). In the Greenwood area, the Tam O' Shanter is an epithermal prospect on the Deadwood segment of the Greenwood fault that forms the east margin of the Toroda Creek graben. On the Tam O' Shanter prospect, the Greenwood fault divides the Penticton Group on the west and northwest from the Knob Hill Group to the east. The focus of exploration is a splay on the Deadwood fault that encloses a zone of the basal Tertiary sedimentary rocks which are clay altered and locally silicified. A portion of the zone along the fault forms a silicified ridge (sinter zone) that is characterized by brecciated fine grained mottled quartz with dark areas containing fine pyrite.

DISCUSSION AND CONCLUSIONS

Theories on the genesis of precious and base metal deposits in the Greenwood area generally involve igneous rocks. Epigenetic models, proposed by LeRoy (1912; 1913), Seraphim (1956) Fahrni (1966) and Sutherland Brown et al. (1971) hold that some deposits are related to the emplacement of granitic intrusions; A syngenetic model introduced by Peatfield (1978) argues that other deposits have a volcanic-sedimentary origin. There is little question that intrusion of the large granitic plutons provided not only the thermal engine driving the circulation of mineralizing solutions to produce pyrometasomatic and porphyry-type deposits but these intrusions also provided the structural setting for the development of vein fissures. The evidence is equally strong that concentration of metals in certain stratigraphic units occurred at the tine of sedimentation near volcanic vents or in backreef shale basins distal to volcanic sources.

A review of the magmatic history of southern British Columbia shows Carboniferous to mid-Triassic volcanism is obscure and granitic plutons are almost always younger than this time interval (Armstrong, 1988). The oldest plutonie rock in the accreted terranes of the area, referred to as 'Old Diorite' and dated by K/Ar at 258 ± 10 Ma (late Permian), is closely associated with the belts of ultramafic rocks and the Knob Hill and Attwood groups (Church, 1986). These ancient rocks are poorly explored but contain hints of important mineralization such as found elsewhere in the Slide Mountain terrane. For example, severai ehromite lenses and a nickel sulphide occurrence near Rock Creek, west of Greenwood, are associated with the ultramafic rocks (Enns, 1971). Also, the Clearcut rhodonite and the Croesus massive sulphide occurrences in the Knob Hill and Attwood groups, respectively, may be the first evidence of VMS deposits in the Greenwood area.

According to Armstrong et al. (1988) no granitic plutons of mid-late Triassic age are known in Quesnellia, although volcanic rocks of basic and intermediate composition are common. In the Greenwood area, the Providence Lake microdiorite body, dated by K/Ar at 206 ± 8 Ma, is thought to be consanguineous with the Eholt volcanics, the uppermost unit in the Brooklyn Group. The Providence Lake intrusion is weakly mineralized with disseminated pyrite and malachite and the body appears to be the source of the Silvester K and San Jacinto polymetallic skarn mineralization.

Southern Quesnellia stands out as a location of latest Triassic to early Jurassic granitic plutonism and accompanying porphyry Cu (Au, Mo) mineralization such as associated with the Guichon Creek batholith, the Granite Mountain stock and the Lexington intrusion. In the Greenwood area, the Lexington porphyry was intruded into thrusted oceanic terrane in the early Jurassic at 200 Ma, and inherited zircon fractions dated 2445 Ma indicate that the porphyry was contaminated by Precambrian basement rocks in the process. Intrusion of the Lexington body in the early Jurassic thus pins the position of the thrusted terrane at this date and suggests that at least the initial phase of accretionary docking of these oceanic rocks on the continental craton was completed at this time. (Church, 1992). Final suturing of Quesnellia and the adjacent Slide Mountain terrane to North America was apparently completed between the early and middle Jurassic magmatic episodes as represented by the Nelson batholith in southorn British Cohunbia (Armstrong, 1988).

There was little magmatism over the Cordillera from the latest Jurassic through the first half of the early Cretaceous. Notable exceptions to this are the Greenwood and Wallace Creek granodiorite plutons, dated by K/Ar at 128-143 ± 5 Ma. These intrusions are the most important mineralizers in the Greenwood camp, and are directly or indirectly related to at least 4 Cu/Au skarn deposits, including the Mother Lode and Greyhound deposits, and 12 gold quartz and polymetallic veins among which the Providence and Dentonia deposits are the chief ore bodies (Church, 1986).

From mid-Cretaceous onward the Cordilleran margin of North America was largely assembled, and there were no major sutures east of the Coast Plutonic Complex and no further terrane distinctions although important igneous and tectonic events continued (Armstrong, 1988).

Other post-Quesnellian events include the Laramide orogeny (late Cretaceous / early Tertiary) that was marked by intrusion of the Ladybird granite in the Greenwood area, and followed by post-Laramide orogenic collapse (Eocene) featuring graben development and plutonism (the Coryell batholith). The City of Paris vein system, dated by K/Ar at 56.7 ± 1.0 Ma, is the result of re-activation of a splay of the Chesaw thrust by tectonic compression directed subparallel to the developing northerly elongated Republic graben south of Greenwood (Church, 1997) In a similar stress regime, the somewhat younger Tam O' Shanter epithermal deposit formed on the east bounding fault of the Toroda Creek graben northwest of Greenwood. At about the same time, the grabens were filled by the Penticton Group and coeval Coryell magmatism (K/Ar, 49.9 ± 1.7 Ma) and hydrothermal activity contributed porphyry Cu-Ag-Au (PGE) such as Sappho deposit west of Greenwood (Church, 1986; Mutschler, 1991).

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Appendix:

The following synoptic descriptions of the principal mineral deposit types (arranged alphabetically) are based on the data currently available in the MINFILE data base of the B.C. Geological Survey Branch for the Greenwood-Grand Forks area.

Athelstan-Jackpot: (082ESE047; Lat.49° 3.8', Long.118° 33.7').

The Athelstan-Jackpot mine is 8.5 km southeast of Greenwood and 1.5 km northwest of the confluence of Skeff Creek and July Creek. Access to the mine is from an abandoned railway grade and connecting roads from the Winnipeg mine and Hartford Junction to the northwest and Highway 3 to the east.

The main production from the property during the period 1901 to 1930 was 33216 tonnes of ore containing 180 kg gold; 210 kg silver; and 7.2 tonnes of copper.

The Athelstan and Jackpot claims are underlain mainly by ultramafic rocks (including 'listwanite'). The 'listwanite', consisting of talc and serpentine with subordinate amounts of carbonate (ankerite and calcite) and mariposite, extends in an unbroken band up to 168 m wide between the Athelstan and Jackpot adits. These rocks are traversed by an irregular system of fissures that served as channelways for the ore bearing solutions. The common ore minerals are pyrite and arsenopyrite form replacements in the listwanites. Disseminations of chromite occur locally in the sheared listwanite such as on the adjoining Butte claim where 17.1 per cent chromium has been reported from a three metre wide open cut. Near surface the ore is oxidized to limonite and a white arsenous oxide which attained shipping grade locally. The shape and size of several ore bodies that were mined can be inferred from the accessible workings. At the Jackpot mine the two ore bodies that were mined from the adit crosscut were crescentric in plan and plunged from 10°to 40° to the east along their longest axis. They ranged in thickness from a few feet to 7.6 m and probably averaged 3 m. They were stoped over a length of at least 30.5 m and across a width of at least 12 m. At the Athelstan mine the only accessible stope is about 18 m long, averages about 12 m wide, and ranges from 1 to 2.4 m in height. A winze sunk in the floor of this stope to a depth of 3.6 m was entirely in ore.

The foot and hanging walls of the ore bodies commonly follow well defined fissures and within the mine workings segments of ore have been displaced by several northwesterly dipping normal faults. Sulphides extending beyond these fissures are commonly extremely erratic. The composition of the wall rock has also had a marked influence on ore deposition. The rocks containing a high percentage of carbonates were most susceptible to replacement by the ore bearing solutions, whereas those containing appreciable serpentine were the least susceptible.

Big Copper (82ESE053; Lat. 49°07.4', Long. 118°47'):

The Big Copper deposit, on the Copper Mine claim, straddles the NE-SW trending ridge on Copper Mountain at the head of Wallace and Ingram Creeks. Access to the property is by gravel road 8 km west of Greenwood.

The claim was located in 1887 and the earliest recorded development occurred in 1894 when a 5 m shaft was sunk and a 12 m tunnel was driven. In 1917 the Big Copper and King Solomon mines together shipped 860 tonnes. In 1953 and 1954 further work led to the diseovery of a body of sulphides, from which two carloads of ore were shipped.

On the Copper Mine claim (also known as 'Big Copper') the ore consists of an oxidized cap of red earthy hematite with a small amount of native copper, copper carbonate accompanied by masses of black chalcocite below. The original ore assayed several per cent copper and appreciable silver and gold. Re-sampling of the old workings has yielded grades ranging between 0.64 and 2.75 per cent copper over a width of 4 m.

The copper bearing unit is believed to be a pre-volcanic Tertiary regolith formed by weathering of mineralized limestone.

A diamond drill hole just west of the west boundary of the Copper Mine claim, encountered skarn mineralization associated with Brooklyn limestone after penetrating 170 m of Tertiary volcanic rocks. The last 16 m of the hole were in skarn including an interval from 179-180 m of green epidote breccia in fine grained dense purplish hornfels with 1-2 per cent disseminated pyrite.

City of Paris (082ESE042; Lat.49°00.6', Long.118°36.6').

The City of Paris mine is 10 km southeast of Greenwood and 1.1 km north of the International Boundary. Access to the mine is from the Boundary road 1 km west of the Phoenix - Lone Star haulage road.

Production from the City of Paris mine from 1900 was 1,926 tonnes of ore containing 27 kg gold; 139 kg silver; 60 tonnes of copper and a small amount of lead and zinc. Subsequently, an additional 8 tonnes of ore was produced from the adjacent Lincoln claim yielding 12 kg silver, 373 kg lead and a minor amount of gold and zinc.

The City of Paris mine is on a vein system near the south contact of a major ultramafic lens. The vein system consists of two locally discontinuous, subparallel veins developed along the margin of a narrow serpentinite appendage flanking the main ultramafic body. The veins trend northwest at about 160° and vary in width from 5 m to mere stringers of ore. The vein system dips 55° degrees northeast and has an exposed strike length of 460 m. The City of Paris vein, which follows the northeast side of the serpentinite appendage, is the source of much of the mined ore. The Lincoln vein occurs on the south side of the serpentinite appendage. The lithologies in this area are impregnated with and traversed by stringers of quartz and calcite carrying sulphides, which diminish in amount with distance from the main lead. The ore on northwest occurs in chutes and consists of argentiferous galena, sphalerite, tetrahedrite, chalcopyrite and pyrite, while in the southeast drift the ore is almost massive pyrite and chalcopyrite. Some of the best assay results were obtained from the Lincoln shaft and portal area. The metal values are unevenly distributed, running in pay streaks. A grab sample from the vein near the Lincoln shaft assayed 2.1 g/t gold, 182 g/t silver, 1.84 per cent copper, 3.98 per cent lead, 0.12 per cent zinc, 0.073 per cent arsenic, and 0.93 per cent antimony.

The origin of the vein system is related to reactivation of thrusting at the contact between the Lexington quartz porphyry and hangingwall serpentinite during the development of the Republic graben. The veins clearly existed prior to emplacement of the Tertiary dikes, as evidenced by the damming of these dikes adjacent to the veins. However, the veins are also younger than the penetrative deformation that is commonly seen in the surrounding country rocks. An analysis of fuchsite obtained from quartz stringers in listwanite, immediately north of the Lincoln workings, yielded a K/Ar age of 56.7 ±1.0 Ma.

Clearcut (082ESE241; Lat. 49°12', Long. 118°37')

The Clearcut rhodonite prospect is on the road leading to the microwave tower on Mount Roderick Dhu, 13 km northeast of Greenwood.

The main exposure is a 10 m long road cut that displays pink pyroxmanganite and rhodonite coated with black manganese oxide. This rock has a sugary texture and grades into quartz-rich rock containing spessartine garnet and light coloured mica.

The host rocks are part of the Knob Hill Group that outcrops in an southeast trending belt extending from the lower course of Clement Creek to Jewel Lake and thence to the area northwest of Mount Roderick Dhu. The Knob Hill Group consists of a variety of volcanic and sedimentary rocks converted to amphibolite and quartz-mica schists by regional metamorphism. The rocks are medium to fine grained, medium to dark coloured. Primary structures, such as bedding, are often confused with foliation and gneissosity. The metasedimentary rocks consist of quartz (15 to 90 per cent), plagioclase, biotite and some garnet and magnetite, and less commonly amphibole, chlorite, muscovite and occasionally andalusite. Because of recrystallization, metaquartzites and metacherts cannot be distinguished. The amphibolites generally occur as massive lenses - possibly derived from basaltic lava flows and pyroclastic rocks. Typically the amphibolites consist of 40 to 70 per cent green amphibole, and smaller amounts of plagioclase, quartz, magnetite and titanite. Epidote, calcite and quartz are present in abundance associated with small veins and fissures.

The Clearcut pyroxmanganite/rhodonite occurrence is a stratabound deposit associated with what appears to be the metamorphic equivalent of volcanic rocks and siliceous and pelitic sediments. The absence of the primary detrital textures within the silica-rich host rocks is consistent with a chemical precipitate protolith, either of sedimentary or hydrothermal origin. Many similar manganese deposits are considered distal equivalents of volcanogenic massive sulphide deposits.

Croesus (082ESE123; Lat.49°03.7', Long.118°40').

The Croesus claim is located on the lower slopes of Monnt Attwood, 2.5 km south of Greenwood. Access to the area is from Highway 3 via the Lind Valley road and an old logging road that skirts the northwest spur of Mount Attwood.

The showings consist of an alignment of sulphide lenses (~400 m in length) associated with limestone, greenstone and black argillite formations of the Attwood Group. The claim is bisected by a major southeast-trending fault along which units of the Attwood Group and serpentinite from the northeast are thrust over Knob Hill rocks, mostly chert, on the southwest. A cross-section of the main mineralized zone shows 3 m of limestone and 7.5 m of massive sulphides and calc-silicates intruded by a 15 m dike. The principal sulphide minerals are massive pyrite and pyrrhotite, sphalerite and fine grained chalcopyrite.

Eholt (82ESE239; Lat. 49°09.5', Long. 118°32.2').

The Eholt property includes the reverted Princess Louise, Delamar and Orient claims located in the headwater area of Eholt Creek, 11 km northeast of Greenwood and 16 km northwest of Grand Forks. Access to the property is from several logging roads and the abandoned Kettle Valley Railway line through the settlement of Eholt located just north of Highway 3.

The Eholt property is underlain by moderately deformed Paleozoic and Mesozoic volcanic and sedimentary rocks and somewhat tilted but relatively fresh Tertiary beds. The rocks are cut by a offshoots of the Wallace Creek granodiorite pluton and numerous small syenite and monzodiorite bodies related to the nearby Coryell batholith.

Two types of mineralization occur on the Eholt property. These are (1) massive sulphide and/or magnetite replacements within or associated with skarn occurrences and (2) sulphide stringers and disseminations within the metavolcanics and sharpstone conglomerate beds. The principal deposits are the 'Dead Honda' sulphide-rich skarn on the Orient claim, the 'Eholt Mountain' skarn containing disseminated sulphides on the Delamar claim, and the 'Brown Creek' skarn on the Princess Louise claim. The shallow working at these localities expose garnet (± epidote, pyroxene) replacements in Brooklyn limestone / volcanic rocks containing pyrrhotite, pyrite, magnetite and chalcopyrite in varying ratios and abundance. Drilling at Dead Honda tested a 200-300 m wide, 1.5 km long northerly trending mineralized zone containing sulphide-rich intersections of more than 25 m grading up to 2.7 g/t gold and 0.28 per cent copper. On Eholt Mountain., disseminated pyrrhotite occurs in tremolite altered Brooklyn sharpstone conglomerate on the southwest slope; and southeast of Eholt Mountain disseminations of pyrite, in concentrations up to 3 per cent with traces of gold and copper, is common in fragmental metavolcanic rocks.

Numerous dikes and sills, related to the Coryell batholith, occur in an intricate fissure systems cutting the mineralized areas.

Greyhound (082ESE050; Lat.49°6.1', Long.118°42').

The Greyhound and Ah There claims are centred just northwest of the confluence of Motherlode and Greyhound Creeks and approximately 2.5 kilometres northwest of Greenwood. The adjoining claims are readily accessible from the Motherlode Creek road.

Production from the Greyhound open pit in the brief period of mine operations from 1970 to 1971 amounted to approximately 221,200 tonnes of ore having 15.6 kg gold; 349 kg silver; and 597 tonnes of copper.

Work began on the Greyhound claim in 1900 with some underground exploration which included a shaft, 60 m deep, and a crosscut driven from the bottom. At about the same time a shaft, approximately 45 metres deep, was put down on the adjacent Ah There claim. This activity resulted in a trial shipment of 24 tonnes of ore in 1903. Except for a number of brief exploration projects, such as some diamond drilling in 1912, 1916 and 1956, the property remained more or less dormant until open pit mining on the Greyhound claim began in 1969 and continued through 1971. This excavation amounted to about 900,000 tonnes of ore and wasterock.

The property is underlain by altered Brooklyn formations, mostly skarn rocks, and granodiorite which forms the west boundary of the Greenwood pluton. Pulaskite dikes, feeders to the Marron volcanic rocks, are common. Mineralization consists of pyrite, chalcopyrite, pyrrhotite, magnetite and specularite occurring on fractures and interstitially near the contact of the carbonate rocks, skarn and the granodiorite.

Jewel (082ESE055; Lat.49°10', Long.118°31').

The Jewel claim and four additional Crown granted claims, including Denero Grande, Enterprise, Anchor and Ethiopia, comprise what is known as the Dentonia property. This is centred approximately 10.5 km east of Jewel Lake on the west slope of Mt. Pelly. Access is by the Jewel Lake road which joins Highway 3 a few kilometres north of Greenwood.

Production in the period 1900 to 1980 from this property totals 123,294 tonnes of ore having 1,219 kg gold; 7,193 kg silver; 163 tonnes of lead; and 3 tonnes of zinc.

The claims are underlain by greenstones, pelitic schists and chert of the Knob Hill Group intruded by the Wallace Creek granodiorite pluton. The Dentonia quartz vein cuts northeasterly (020°) across the strike of these formations averaging about 1 m in width. Mineralization consists mostly of disseminations and small pockets of sulphides in quartz. The ore minerals are mostly pyrite and galena with minor amounts of sphalerite, chalcopyrite, tellurides and some native gold. Ore controls are attributed to several factors, the most important of which are deflections in the vein attitude and the response of the main fissure zone to sudden changes in the composition of the host rocks. Both of these features are present in the Jewel ore body. Here the vein is enlarged and somewhat refracted at the intersection of brittle granodiorite and the less competent schistose volcanic rocks. A major deflection in the strike of the vein is not so apparent in the case of the Anchor shoot at the greenstone / metaquartzite contact, although the vein is generally less steeply inclined. The great width of quartz in the main part of the Enterprise section appears to be solely the result of a major variation in the direction of the fissure zone caused by stresses acting on rather homogeneous greenstone.

The origin of the vein structure is the result of regional stresses. Apparently, tensional gash fractures developed attendant to north trending shears in response to compressional stress from the southwest, allowing the influx of quartz. The amount of movement was small and the direction is believed to have been largely horizontal. The host rocks are not thought to have offered any special opportunity for chemical reaction with the ore bearing solutions, however, there was a tendency for the greenstone to split under stress, the walls of the vein and septa showing some evidence of replacement. The age of the Dentonia vein is bracketed by the Wallace Creek granodiorite, which locally hosts the vein, and crosscutting young dikes. A sample of the granodiorite from the Denero Grande shaft area returned an early Cretaceous K/Ar date of 125 Ma. The numerous feldspar porphyry and pulaskite dikes found, cutting across the mine workings, are clearly feeders to the Marron lavas of the Penticton Group (Eocene).

Lexington (082ESE041; 49°00.7', 118°36.9').

The Lexington adit is 50 m east of Goosmus Creek near the US border, 10 km south of Greenwood. Access to the claim is 1.5 km by dirt road west of the main Phoenix - Lone Star haulage road.

Much of the recent exploration has focussed on the widespread, low grade copper mineralization associated with the quartz porphyry inrusion on the Lexington, City of Paris, Lincoln and adjacent claims. This 'porphyry' mineralization is mostly contained within a 900 m long, 300 m wide segment of the quartz porphyry exposed between the main ultrabasic intrusion and a smaller subparallel serpentinite splay near Goosmus Creek. The principal mode of occurrence of the main ore minerals, pyrite and chalcopyrite, is in fractures and disseminations and, to some extent, in quartz stockworks. Anomalous copper values have also been obtained in the serpentinite splay adjacent to the quartz porphyry intrusion near Goosmus Creek just below the Lexington portal. This sheared serpentinite contains interfoliated impregnations and massive lenses of pyrite, chalcopyrite and magnetite.

Ore reserves for this property, base on the most recent work (1981 estimates), indicate 313,527 tonnes grading 5.44 g/t gold and 1.96 per cent copper; calculated using a 15 per cent dilution factor. An additional 110,000 tonnes grading 1.99 g/t gold and 0.92 per cent copper; is amenable to possible open pit mining.

Mother Lode (082ESE034; Lat.49°06.7', Long.118°42.9').

The property comprising the Mother Lode and Sunset mines is centred four kilometres northwest of Greenwood at the elevation of 1,050 m. Access is by all weather gravel road which connects the property to the Mother Lode Creek road and Greenwood.

Production from this property totalled 4,245,875 tonnes of ore yielding 5,391 kg gold; 21,406 kg silver; and 34,915 tonnes of copper.

Mineralization consists principally of pyrite, chalcopyrite, magnetite and specularite which are erractically distributed throughout the skarn rocks. Chalcopyrite was most abundant in the Sunset mine but tonnage was relatively small. The host rocks for the ore at the Mother Lode mine are steep, easterly dipping conglomerates and limestones of the Brooklyn Group. In the area of the open pit, the limestone is mostly converted to garnet skarn which is locally interbedded with epidote and actinolite. These rocks are intruded by relatively fresh pulaskite porphyry dykes, feeders to the Marron lavas, and older, somewhat altered granodiorite offshoots of the Wallace Creek pluton. A granodiorite dike, about 30 m thick, is visible in the pit, and another occurs in the underground workings. The Mother Lode orebody is flanked by limestone on the northwest and by a northerly trending normal fault on the southeast. The ore has a warped configuration trending northeast and then east at the north end of the body and steepening in inclination from 45° southeast to nearly vertical at depth.

The geology of the Sunset mine is similar to the Mother Lode except there are two relatlvely flat lying ore bodics at Sunset that have developed in skarnified Brooklyn rocks on the limbs of a northerly trending anticlinal structure. A thrusted plate of Knob Hill chert passes only a short distance under the floor of the Sunset mine and at a slightly greater depth under the Mother Lode.

No.7 (082ESE043; Lat.49°01.5'; Long.118°38.3').

The No.7 mine is on the claim of the same name on a ridge crest 3.3 kilometres east of the confluence of McCarren and Gidon Creek, 7.5 kilometres southeast of Greenwood. Access to the property is 2.4 km travelling southerly and up hill by winding dirt road from the McCarren Creek road.

The intermittant operations of the No.7 mine from 1901 to 1945 producted a total of 13,748 tonnes of ore yielding 92.4 kg gold, 3,110 kg silver, 97 tonnes of lead, and 6.2 tonnes of zinc.

The mine is developed on a quartz vein on a major southeasterly trending fault that extends through the City of Paris mine and on to the US border. The vein has been traced for a strike length of more than 300 m. The vein ranges from 10 cm to 1.5 m wide and dips 40°to 65° northeast, having dike rocks or chloritic schists of the Knob Hill Group on the hanging wall and highly sheared talc-carbonate rocks of the serpentinite body on the footwall.

Mineralization consists of pyrite, sphalerite and some galena dispersed in blue - grey quartz along the central portion of the vein. The most productive part of the vein was southeast of the inclined shaft above the 55 m level. Evidence of some pre-mineral movement is furnished by unbroken vein quartz seams and lenses in the fault zone exposed at the southeast end of the 90 m level. Subsidiary faults of small displacement are part of this same fault zone, and offset both vein and the post mineral quartz trachyte dikes.

The No.7 fault zone is an ancient structure believed to be a possible continuation of the Chesaw thrust in Washington state. The serpentinite is part of a disrupted Paleozoic ophiolite complex. Because of the ductile nature of these rocks, the belt has become a tectonically active zone and the locus of much shearing, thrusting, igneous intrusion and vein mineralization. The common Mg-Fe carbonate (listwanite) alteration and serpentinization are believed to be related to major thrusting of the ophiolitic rocks during the Jurassic. In the early Tertiary these thrusts were re-activated by a tectonic compression directed subparallel to the developing northerly elongated graben structures. Igneous activity at the same time is believed to be related to numerous vein deposits.

Oro Denoro (082ESE063; Lat.49°07.6'; Long.118°32.9').

The Oro Denoro and Emma mines are centred 10.2 kilometres northeast of Greenwood at the elevation 1,200 m on the divide between Ehoit Creek and Fisherman Creek. Access to these adjoining properties is about 0.6 kilometres southwest from Highway 3 by level gravel road along an old railway bed.

Production from Oro Denoro totals 124,001 tonnes containing 117 kg gold; 954 kg silver; and 1,691 tonnes of copper (which does not include several thousand tonnes of ore shipped to the Phoenix mill in 1978). From the Emma mine a total of 240,948 tonnes of ore was produced containing 212 kg gold; 2,434 kg silver; and 2,350 tonnes of copper..

The Oro Denoro mine is centrally located within a 2.4 km-long N-S alignment of skarn deposits which includes the Emma and Jumbo on the north and the Cycops and Lancashire Lass on the south. Mine development at Oro Denoro cover an area of about four hectares in the central part of the claim.

The orebody at the Emma mine is vertical and strikes northerly, roughly parallel to bedding in the Brooklyn limestone, near the eastern contact of the Wallace Creek granodiorite body. Mineralization, consisting mostly of pyrite, chalcopyrite and magnetite impregnations in garnetite, is mostly confined to a narrow zone about 8 m wide and 100 m long.

In the early period of mining at the Oro Denoro mine, 1903 to 1910, ore was drawn from a number of large stopes on two underground levels and five open pits. The two southernmost quarrys, Nos.1 and 2, were the principal source of copper ore. These are interconnected and have a general east-west elongation. The trend of the excavations appears to follow the course of a number of large steeply dipping calcite lenses in the skarn by the granodiorite contact which is near the north wall. Quarry No.3, centred about 60 m north of Nos.1 and 2, is the second largest pit. Here the mineralization was concentrated in a tongue of skarn projecting deep into the granodiorite mass. Quarries Nos.4 and 5, centred about 45 m northwest of No.3, are relatively small. The magnetite rich ore was situated between a small remnant of limestone in the skarn and the granodiorite. Control of the mineralization appears to be east-west cross fractures trending approximately perpendicular to bedding in the limestone host rocks.

The most recent excavation, which is located immediatelty west and south of the old quarries, is an open pit, 150 metres long and 45 metres wide, developed mainly in garnetite skarn at the summit of Oro Denoro's 'Mine Hill'. The target of these workings was a mineralized zone near the south end of the pit. The mine is traversed by a number of ore controlling faults. The most significant is a pronounced shear that strikes 120° from the north end of the main pit and through No.1 quarry. Important movement on this zone has resulted in the emplacement of exotic formations in the skarn such as a wedge of carbonaceous schist in the main pit and epidotized volcanic breccia along the south wall of No.1 quarry. Of less importance are two minor faults dipping 80° east and 75° southeast causing local displacements in the skarn - granodiorite contact.

PAC (082ESE194; Lat.49°06.7', Long.118°31.3').

The PAC showing and adjoining R. Bell and Cordick mineral occurrences are situated 11 kilometres northeast of Greenwood, just east of Highway 3 and 2.5 km south of Wilgress Lake.

The first recorded work in the area was on R. Bell claim in 1896 when a shaft was sunk to a depth of about 30 m on a seam of high grade chalcopyrite in eruptive rocks. The claim was Crown granted in 1900 and by 1902 ore was shipped by the owners, the Granby Smelting Company. Total underground development at this time was 120 m of shaft sinking and 180 m of cross-cutting and drifting. Exploration of the property continued intermittantly after the production period and in 1927 a tunnel was driven connecting the R. Bell and Cordick claims following a southeaserly striking vein. The face of this tunnel displayed pyrite and hematite associated with quartz and calcite gangue minerals across a vein-width of more than 1 m. The host rock in the area is greenstone stained locally with copper carbonate minerals and cut by a large 30 m wide, barren, pulaskite porphyry dike.

In 1995, after many years of inactivity, the discovery of a Carlin-type gold occurrence 150 m from the R. Bell and Cordick copper skarn workings, sparked renewed exploration activity by Kettle River Resources Ltd. Trenching has exposed 30 m of intensely silicified limestone similar to the discovery outcrop where two chip samples of 2.4 and 1.8 m across structure returned assays of 19.5 and 32 g/t gold, respectively. The mineralization is hosted within an interbedded sequence of Brooklyn limestone and sharpstone conglomcrates.

Phoenix (082ESE020; Lat. 49°05.4', Long. 118°36').

The Phoenix mine, centred on the claim of the same name, is located six kilometres east of Greenwood at the elevation of 1,370 m. Access to Phoenix is by paved road east from Greenwood and by an all weather gravel road west from the Grand Forks section of Highway 3.

Production from Phoenix is 26,956,525 tonnes of ore containing 30,225 kg gold; 92,055 kg silver and 230,050 tonnes of copper. Most of this production was derived from the Old Ironsides, Knob Hill and Victoria claims in the period 1900 to 1976. Also contributing to this total, 1,600,582 tonnes of ore was shipped from the Gold Drop mine up to the end of operations in 1919; and 855,634 tonnes of ore from the Rawhide mine between 1904 and 1916; plus 545,129 tonnes from Snowshoe between 1900 and 1911; and 292,834 tonnes from the Brooklyn, Idaho and Stemwinder operations between 1900 and 1960.

Systematic development on the Old Ironsides, Knob Hill, and Victoria claims began in 1895. The first ore, consisting of about 270 tonnes, was shipped in 1900. Under management of the Granby Consolidated Mining, Smelting and Power Company Ltd., an extensive system of tunnels and stopes was subsequently developed comprising three adit levels on the Old Ironsides and Knob Hill claims and five levels to the east on the Victoria and Aetna claims, serviced in part by the Victoria shaft.

At the close of the first period of operations in June 1919, a total of 12,434,620 tonnes of ore had been mined from stoped areas, exceeding 48,000 m^2 in lateral extent, accessed by a 37-km long network of interconnected tunnels. Intermittent mining from 1920 to 1942 produced 47,1004 tonnes of ore. Renewed operations by the Granby Mining Company Ltd. in 1959 began excavations which, by the final close of mining activity in 1976, resulted in removal of almost the entire old underground workings. This created a large elliptical 425 x 800 m open pit from which 9,070,560 tonnes of residual low grade ore was extracted.

The geology of the Phoenix area is complex. The mine is underlain by an intricately folded, faulted, metamorphosed and mineralized sequence of Paleozoic and Mesozoic volcanic and sedimentary rocks that are overlain in turn by Eocene volcanic and epiclastic rocks. Paleozoic rocks at Phoenix include the Knob Hill Group that consists mostly of chert, cherty argillite, greenstone and a minor amount of limestone. Scanty fossil evidence indicates that the Knob Hill rocks may be as old as Devonian, although of some geologists suggest a Permo-Carboniferous age. These rocks are unconformably overlain by Brooklyn limestone, sharpstone conglomerate, argillite and the Eholt volcanics believed to be Middle-Upper Triassic age. Small microdiorite intrusions together with possibly coeval andesites of the Eholt Formation, overlie and intrude Brooklyn limestone and sharpstone conglomerate units. North trending fold axes and a series of north dipping thrusts, associated with serpentinite slices, have been identified within the pre-Tertiary assemblages. Locally, sedimentary rocks of the Kettle River Formation unconformably overlie the older rocks. These are feldspathic sandstones and conglomerates containing interbeds of rhyolite ash and minor carbonaceous seams. Overlying and intruding these beds are pulaskite and augite porphyry dikes and sills, and trachyte and mafic phonolite volcanics of the Marron Formation.

The ores of the Phoenix area are almost exclusively the result of limestone alteration. The extensive deposits of low grade copper ore, which have given rise to the mining industry at Phoenix, occur in mineralized areas of the Brooklyn limestone which have all the characteristics of metasomatic replacements. These replacements are composed essentially of chlorite -epidote skarn rocks with variable amounts of garnet, calcite and quartz, accompanied by blebs and disseminations of pyrite, chalcopyrite, magnetite and specularite. The skarn and copper minerals are localized in a band of impure limestone above a well defined foot-wall argillite. The thickness of mineralization varies from a maximum of 60 m to less than 1 m at the limits of mining. The ore beds are generally inclined downward to the east, but dips vary and a series of N-S faults has produced irregularities.

The main ore body outcrops on the Knob Hill and Old Ironsides claims on the south side of a ravine that is the headwater area of Twin Creek. In its downward and eastward extension the ore body passes onto the Victoria and Aetna claims. The mountain in this area is divided by a 'great' pulaskite porphyry dike which is traceable southerly for 1200 m from the Victoria claim through the Aetna and War Eagle claims. The dike is relatively fresh, has not been cross-fissured by any subsequent geological events, and continues at depth for at least a few hundred metres as proven by diamond drilling. The main body of ore, on the Knob Hill, Ironsides and other westerly claims, is composite in character and consists of two lenses which coalesce about their central portions. The western lens is at least 750 m long, from 12 m to 38 m thick, and from 112 m to over 275 m wide. The eastern lens is apparently not so long, but approaches the magnitude of the former in width and thickness. The combined thickness of the two at their point of junction is about 57 m. In its southern extension this composite ore body appears to break up into subordinate ribs and wedges of ore separated by complementary ribs of almost barren gangue rock. A similar condition also appears to occur to the east of the main ore body and the 'great' dike, where a rather flat lying zone, consisting in part of pay ore, has been found on about the same level as No.3 tunnel. The general strike of the outcrop of the ore body is 010° with dips to the east ranging from 45°to 60°. The dip flattens with depth and on the lower levels averages from 15° to 30°. A downfaulted block of Tertiary rock, viewed in the 1000-m long Victoria to Gold Drop tunnel, separates the east side of the Phoenix pit from an eastern extension of the Old Ironsides-Knob Hill skarn zone.

The Gold Drop mine (082ESE028) develops only part of an extensive and practically continuous ore body, which outcrops on the Gold Drop claim, swings down and across the Rawhide and Curlew, and terminates on the Snowshoe claim. The whole, when broadly viewed, has, on a horizontal plan, the form of a compressed crescent with northward trending horns, broken by the occurrence of the detached Gold Drop No.1 ore body and the north Snowshoe body. The ore body rests on a floor of sharpstone beds and in the Gold Drop proper there is an entire absence of Brooklyn limestone and Tertiary intrusives. The ore body of the Gold Drop proper is developed in the southeast part of the Gold Drop, and the northeast part of the Monarch claim. The strike varies from 013° to 032°, with and easterly dip, which averages about 40°, but flattens to about 25° below the level of the Monarch drift.

The known length of the ore body along the strike of the Monarch (082ESE027) drift is over 320 m, and its width to the boundary of the claim is about 96 m. The thickness probably averages about 9 m, the diamond drill logs showing a range from 2 to 17 m.

The Rawhide mine (082ESE026) develops the continuation of the Gold Drop-Monarch ore body. The mine workings, underlying about three hectares on the western part of the Rawhide claim, consists of several large stopes and glory holes accessed by approximately 1,400 m of tunnelling on seven levels. The ore body, which attains a maximum thickncss of 23 m near the northwest boundary of the claim, rests on Brooklyn sharpstone conglomerate beds dipping 13° to 25° north and northeast.

The Snowshoe mine (082ESE025) consists of two main mineralized zones worked to a depth of about 65 m. Development to the end of operations in 1911 included several open cuts, glory holes, two shafts and a series of stopes accessed by 3,000 m of tunnelling. Surface excavations, including a 70 x 120 m pit, completed between 1957 and 1964, resulted in the production of about 270,000 tonnes of low grade ore from the southern part of the claim.

The south ore body (Snowshoe mine) is a continuation of the one developed in the Curlew, Rawhide, and Gold Drop mines. It is broadly considered as one ore body, though bands, wedges, and ribs of slightly mineralized gangue rock break its continuity. These are removed or left in stopes depending on their size and structure. Along the Snowshoe-Curlew boundary the foot wall dips north at about 40°. To the west it has a curving strike to the north with easterly dips ranging from 30°to 65°. North of fhe main shaft at the first cross-cut, the strlke is northeasterly with southeast dips from 40° to 50°. In its downward extension, the ore body apparently swings to the northeast, which brings it adjacent to, or in contact with the north ore body. The north and south axis of the ore body is about 180 m and the east and west axis is about 80 m long. The thickness of the ore according to the cross sections varies from 8 m to 11 m with occasional local swells giving a greater thickness over small areas.

The foot wall rocks are sharpstone conglomerate beds, tuffs, red and grey argillites with local patches of quartzose crystalline limestone. The hanging wall consists of the garnet and epidote rocks of the mineralized zone into which the ore either insensibly fades, or from which it is separated by a gouge filled fissure. The ore body in depth terminates abruptly against the quartzose rocks of the Knob Hill group, on the plane of a presumably pre-mineral fault or contact plane, which dips west at from 15° to 38°. The ore body throughout is cut by numerous fissures which in places have a marked influence on the character of the ore, and which were the main channels of circulation of the ore bearing solutions. Many of these have been filled during the closing stages of deposition with quartz, calcite, chalcopyrite, and pyrite in banded arrangement.

The north ore body was probably at one time connected surficially with both the South Snowshoe and Gold Drop No.1 bodies, but has been separated by subsequent erosion. From the mine plans and sections the main part of the north ore body has a north-south length of 110 m on the surface, a width ranging from 34 m to 46 m, and is from 2 m to 17 m thick, the average being about 11 m. The dip of the foot wall varies from 18°to 56° east. A fault dipping 12° west cuts the ore off. To the north this fault steepens to 47° and with a displacement of about 12 m brings the lower part of the ore body to surface. The ore at this point lies on an augite porphyry dike which has been intruded along the foot wall. In its northern extension, the strike of the ore body swings to the northeast and the sharpstone foot wall gives place to the quartzose rocks of the Knob Hill Group. The dip is to the southeast from 22° to 65°, averaging about 45°. The ore in this portion of the body was of higher grade than the average mined in the camp, particularly in the copper content.

The Brooklyn and Idaho mines (082ESE013) are situated on a mineralized zone crossing the valley of Twin Creek about 700 m northwest of the Phoenix pit. The zone is an elongated pear shaped form, broad and shallow at the south, narrowing and becoming steeper to the north until it is enclosed by almost vertical walls of limestone, as exposed by the Brooklyn 'glory hole', and the sharpstone beds to the east, and limestone to the west. The floor is mainly limestone with some sharpstone conglomerate in the southern part. The length is 564 m, and the width varies from about 122 m in the south to less than 15 m in the extreme north.

The Brooklyn mine, at the north end of the mineralized zone, was developed from two glory holes at surface and a number of underground stopes serviced by a 130 m inclined shaft with 5 working levels. The total recorded ore production is 258290 tonnes, which includes the two main periods of operation from 1900 to 1908 and 1937 to 1940.

The Idaho mine, at the south end of the mineralized zone, includes and inclined shaft and two levels, the deepest of which connects with the 76-metre level of the Brooklyn mine. A total of approximately 2300 metres of tunnelling was completed at the Brooklyn and Idaho mines by the first closing of operations in 1908. In the period 1963 to 1964 open pit excavations in a 75 x 150 m area near the Idaho shaft yielded an additional 130,000 tonnes of ore. Subsequently the area became the main tailings pond for the Phoenix mine.

The Stemwinder mine (082ESE014) is 300 metres east of the Brooklyn and Idaho workings and 500 metres north of the Phoenix pit. Production from the Stemwinder began with a trial shipment of 4.5 tonnes of ore in 1895, seven years after the claim was first located by prospectors. Intermittent production between 1900 and 1949 yielded 32,014 tonnes of ore from workings consisting of an open stope and glory hole connected to 450 metres of tunnelling on two levels, at 32 and 61 metres depth, serviced by an inclined shaft and two portals. These workings were the focus of later excavations, in the period 1964 to 1967, which produced a 55 x 146 metre open pit from which 73,322 tonnes of ore was supplied to the Phoenix mill. A total of 718,475 tonnes of waste rock from this operation aided in the construction of tailings pond and water reclamation site in vicinity of the Idaho workings.

The most widespread rock around the Brooklyn and Stemwinder is a peculiar aggregate of subangular to subrounded fragments of white, red, and green chert; various types of volcanic and coarse grained rocks; and occasionally, finely crystalline limestone. The rock may be called chert breccia. It is one type of cherty material comprising the sharpstone unit.

Two northerly trending, curved, lenticular bodies of another peculiar rock, which will be referred to as limestone breccia, occur near and in the Stemwinder mine. It consists of subangular fragments of greyish white finely crystalline limestone ranging in size from one to several centimetres, together with a few smaller fragments of chert, set in a fine grained matrix of carbonate, chlorite, quartz, and clay minerals. Where faults are absent, the contact with the chert breccia is abrupt rather than gradational. Westward, near the Brooklyn mine, the chert breccia is in sharp contact along a northerly trending line with finely crystalline, thin bedded, siliceous or argillaceous limestone. The distinct and regular bedding of the latter strikes north and dips 75° to 80° eastward. Although the bedded limestone is more than 300 m thick on the north side of Twin Creek, it appears to be absent a short distance to the south, on the opposite side of the drift filled valley bottom.

In the old part of the Stemwinder mine, faults are the most conspicuous feature. Two important fault sets strike variably west of north. Faults of one set dip moderately to steeply east, and faults of the other set dip 25° to 40° westward. Faults of a third set appear to cnt those of the other two sets. The third set strikes northeasterly and dips moderately or steeply to the northwest or to the southeast. They are characterized by much gouge and by fluting that is close to horizontal. Although on the surface the limestone breccia appears to be fairly continuous, in the workings it is found to be cut into isolated blocks by the numerous faults. The blocks, ranging in size from a metre to several metres, are in fault contact with chert breccia on all sides. On No. 1 level the segmentation occurs in a northerly trending belt roughly 60 m wide. This belt is bounded on the west, almost directly below the glory hole, by a fault, beyond which the rock is all chert breccia.

All of the ore in the old part of the Stemwinder mine occurs in this belt. The ore bodies are fault blocks of limestone breccia which have been partly recrystallized as coarse grained grey calcite containing irregular veinlets and larger masses of chalcopyrite and pyrite. Usually the mineralization ends at the faults bounding the limestone breccia blocks, but in a few places the chert breccia for about a metre beyond such a fault is brecciated and moderately well mineralized. The ore is striking different to that of the Brooklyn mine. It contains no garnet or other lime silicate gangue minerals, no specularlite, and no quartz. However, it is similar to the Brooklyn ore in its virtual restriction to carbonate rocks and in its relation to faults which may well be pre-ore in age. The orebody mined in the Stemwinder glory hole was a block of mineralized limestone breccia bounded on both sides and below by faults. The lower bounding fault dips 25° westward and contains a thin sheet of pulaskite porphyry. The intensity of the mineralization of the limestone breccia shows a marked increase near this fault.

In summary, the Phoenix ore body appears to be localized by the fault system, the footwall argillite and impurity of the overlying limestone. No igneous rock source rocks are known, nevertheless, it is assumed that deep seated granitic rocks under the mine area produced the mineralizing solutions which were then channelled by faults to favourable facies sites in the Brooklyn limestone for replacement and deposition.

Providence (082ESE001; Lat.49°06.6'; Long.118°40').

The Providence mine is situated immediately north of Providence Creek 2.5 km north of the Greenwood post office. A short access road, along north boundary of Greenwood municpality, connects the mine directly to Highway 3, located 0.5 km to the west.

The mine operated intermittently from 1893 to 1973. A total of 10476 tonnes of ore have been mined yielding 183 kg gold; 42552 kg silver; 183 tonnes of lead; and 260 tonnes of zinc.

The Providence claim is almost entirely underlain at surface by greenish grey quartz chlorite schists of the Knob Hill Group at the northern boundary of the Greenwood granodiorite pluton. The schists dip 30° to 70° northeast and are cut by a northeast-trending Coryell-related feldpar porphyry dike, which is exposed between the two main shafts. The granodiorite is encountered in the southwest part of the miue below the fifth level.

The workings mostly follow ore shoots within a narrow quartz vein. The ore minerals consist of pyrite, galena, sphalerite, chalcopyrite, tetrahedrite, proustite, native silver and free gold in quartz carbonate gangue.

The vein strikes 050° and dips 40° to 60° southeast. It has been traced underground for more than 370 m, and ranges from a fraction of a centimetre to 0.75 m in width. Unbroken quartz rarely extends from wall to wall, and more commonly strands of quartz are separated by thin, lenticular bands of altered country rock. The vein is irregular in size and attitude on the lower levels. In a few places these changes can be correlated with the passage of the vein from one rock to another. Thus, in the northeast part of the fourth level the vein pinches to a gouge filled fissure on passing from the relatively hard silicified rocks to soft chloritic schists. On the No.5 level the vein appears to be more persistent in the silicified rocks than in the granodiorite.

Faults of at least two ages displace the mineral bearing fissure. The older group, which is pre-mineral in age, strikes 030° to 050° and dips gently northwest. Local dip reversals were seen along several low angle faults, and rolls in the fault plane were noted in every case where an individual fault could be traced for any distance. In each case the hanging wall has moved down with reference to the footwall, thus indicating normal faulting. Offsets along these faults range from 1 to 24 m. The maximum offset was measured along a fault that is now occupied by a post mineral feldspar porphyry dike.

Veins are, in places, slightly enlarged where they intersect these pre-mineral faults, and at other places narrow quartz stringers may follow the fault plane. The younger group of faults strikes north 30 degrees west to north 10 degrees east and dips at high angles. Displacements along these faults are small. They are post mineral and offset the vein as well as the older group of faults.

Republic, Nonsuch, Last Chance: (082ESE045; Lat.49°03.6', Long.118°42.4').

This property, also known as the Skomac mine and previously operated by Robert Mines Ltd., is centred on a treeless south facing hill side 4 km southwest of Greenwood. Access to the mine is about 3 km by dirt road travelling north from Highway 3 near Boundary Falls.

Production from this property has been intermittant. The total ore amounts to 2513 tonnes having 21 kg gold; 3709 kg silver; 50 tonnes of lead and 26 tonnes of zinc.

The mine is situated near the base of a diorite bluff between the elevations 850 and 1000 metres. The upper levels of the mine are almost entirely within the black phyllitic argillite formation of the Attwood Group. The lowest two levels follow a sheared ultrabasic intrusion occupying the contact between argillites and the large diorite body to the north. The several quartz veins in the mine have been emplaced on closely spaced en echelon fractures dipping about 50 degrees northeast on a total strike length of about 180 metres. An important set of younger cross fractures strike 020 to 040 degrees - a direction on which there has been intrusion of Tertiary dikes and some faulting of the veins.

The mine development began in 1894 after which a number of adits and shafts were worked. In the upper tunnel the vein is persistent, but varies from 0.35 to 1.8 metres in width, and contains iron sulphides carrying gold and silver. The gangue is quartz with oxides of iron in the fractures. Below the collar of the main shaft, the lead is split in three veins hosted in black argillite. The vein on the hanging wall is 20 centimetres wide, the one in the centre 0.45 metres, and on the foot wall 0.66 metres wide. The ore minerals are galena, ehalcopyrite, and pyrite in a gangue of quartz.

Origin of the vein structures is thought to be the result of regional shearing stress deflected into and taken up by the incompetent formations along the diorite contact. The ore shoots appear to be aligned gash structures, striking 015 and plunging 40 degrees northerly, almost at right angles to the principal shear direction.

Sappho (082ESE147; Lat.49°0.3'; Long.118°42.3').

The Sappho claim is centred 9.6 km south of Greenwood and 0.6 km north of the International Boundary. Access to the property is 2.7 km on a winding dirt road southeast of the Norwegian Creek road.

Production from this property is 102 tonnes of ore containing 6.1 kg silver; and 13.6 tonnes of copper. The old workings consist a short adit and mostly of a cluster of pits and shafts in the central part of the claim. A grab sample of ore taken from one of the pits assayed 3.2 per cent copper and 0.9 ppm platinum.

The principal rock types underlying the claim are a microdiorite intrusion (Jurassic ?), exposed in the central area and southeast corner of the claim, and younger crosscutting Coryell syenomonzonite - shonkinite intrusion. Greenstones, of uncertain age, hosting these intrusions are well exposed near the east boundary of the claim and in the south central area. Mineralization consists mostly of pyrite and chacopyrite disseminations in shears and blebs and pods of these minerals in biotite shonkinite and pegmatoid phases of the Coryell intrusion. Sulphides are also found locally in skarns of epidote, chlorite, garnet and magnetite near intrusive contacts.

Skylark (082ESE011; Lat.49°05.3', Long.118°38.3').

The Skylark claim is centred 2.7 km east of Greenwood and 0.8 km southeast of Twin Creek. Access is 1.8 kilometres easterly by winding dirt road from the main Greenwood to Phoenix road.

Mining on the Skylark claim has been intermittent since 1893. Total ore shipped amounts to 1931 tonnes containing 22.4 kg gold; 5283 kg siver; 3.7 tonnes of copper; 26.2 tonnes of lead and 4.8 tonnes of zinc.

The focus of interest on the Skylark claim is a mineralized quartz-carbonate vein in argillite and greenstone units of the Attwood Group. The vein dips dips 52° southeast and has a strike length of about 200 m. From two inclined shafts the vein has been followed to a depth of 24 m where it is displaced easterly about 9 m by a flat lying fault. The ore readily breaks free from the wall rocks and is easily mined. The vein averages 15 to 20 cm wide and the best values are found in 'pay streaks' along the hanging and foot walls. The mineralization consists of galena, sphalerite, tetrahedrite, arsenopyrite, stibnite, ruby silver and pyrite.

Sylvester K (082ESE046; Lat.49°06.3', Long.118°32.4').

The Sylvester K claim and adjoining Marshall claim are centred near Providence Lake 1.7 kilometres northwest of Phoenix and 5.8 km northeast of Greenwood. Access is via the Providence Lake road which runs north from the Phoenix mine site.

The principal rocks underlying the Sylvester K and Marshall claims are sedimentary units of the Brooklyn Group and offshoot apophyses and dikes of the Providence Lake microdiorite stock.

The Brooklyn beds are steep, mostly easterly dipping, comprising a thick basal sharpstone conglomerates overlain by a relatively thin transitional argillaceous facies, and a thick upper limestone unit. The Providence Lake microdiorite stock, dated 206 Ma, intrudes the limestone and conglomerate feeding the somewhat younger volcanic rocks of the Eholt Formation.

Mineralization comprises stratabound massive sulphides in limestone lenses and sulphide disseminations in the accompanying sharpstones and argillaceous rocks of the Brooklyn sequenee. The ore mineralogy consists principally of pyrite and smaller amounts of pyrrhotite and marcasite, and traces of chalcopyrite accompanied by carbonates, quartz, and chlorite. The drilling program on Silveter K delineated approximately 50 000 tonnes of mostly low-value pyritic ore in a zone 245 m long and 1 to 6 m wide. Spot gold grades within this zone locally exceed 10 grams/tonne.

Tam O' Shanter (082ESE130; Lat.49°05.4', Long.118°43.7').

The property, consisting of a large number of recorded claims and mineral leases, including the Tam O' Shanter and Bengal claims, is located about 4 km west of Greenwood in the headwater area of Buckhorn Creek.

The Tam O' Shanter claim two old shafts from the turn of the century and a more recent adit that follows a 'lead' of crushed country rock and soft gouge containing galena, chalcopyrite and pyrite with gold and silver values in a quartz gangue. From this a 3 ton ore sample was obtained assayed 13.7 g/t gold and 22.5 g/t silver.

The epithermal mineralization discovered on this property is related to Tertiary faulting and the associated alteration tends to be restricted to the Kettle River Formation. The dominant geological feature of the property is the steep northeast trending Deadwood fault that forms the eastern margin of the Toroda Graben. The fault separates the Penticton Group on the west and northwest from the Knob Hill Group to the east. The major area of alteration and focus of exploration is at a splay in the Deadwood fault that encloses a zone of the basal Tertiary Kettle River sedimentary rocks which are clay altered and locally silicified. The northern portion of this zone, called the Bengal Zone, is a silicified ridge of outcrops on which there are a series of trenches and an old shaft (the Bengal shaft). The fine grained quartz that comprises the ridge is commonly breceiated and contains up to 10 per cent fine grained pyrite. The mineralization here appears to be controlled by a small, steeply dipping, north-northeast trending fracture related to the main fault. A similar zone of alteration occurs in a conglomeratic facies of the Kettle River Formation 200 metres south of the Bengal Zone where the Deadwood fault splays into two subparallel structures. Several backhoe trenches have been dug at this point exposing strongly clay altered conglomerate between, and east of the main fault structures, and a zone of massive, fine grained, banded quartz which is referred to as the 'Sinter Zone'.

Winnipeg (082ESE033; Lat.49°04.5', Long.118°34.3').

The adjoining Winnipeg and Golden Crown claims are centred 7.5 kilometres east of Greenwood and 3.2 km southeast of the Phoenix mine. Access to the property is 1.2 km east from Hartford Junction by dirt road on an old railway grade.

Production from the Winnipeg and Golden Crown claims is reported to be 55804 tonnes of ore yielding 402 kg gold; 1207 kg silver; 1245 tonnes of copper and 0.38 tonnes of lead.

The Winnipeg and Golden Crown claims were staked in 1891 on a number of small copper and gold bearing veins. Mineralization consists of pyrite, pyrrhotite and chalcopyrite occurring in discontinuous quartz veins and lenses hosted in greenstones of the Attwood Group, the 'Old Diorite' and associated ultramafic bodies. The Golden Crown claim is underlain mostly by the greenstones except locally along the east boundary of the claim and the southeast end of the underground workings where diorite is encountered. The Winnipeg claim is underlain mostly by diorite on the east and greenstones on the west. The claims are traversed by an important southeasterly trending fault, from which the many quartz filled gash factures containing the ore, were developed.