FILE

CORPORATION FALCONBRIDGE COPPER

MEMORANDUM

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DATE: February 11, 1987
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TO: L. D. Pirie
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DE
FROM: C. M. Burge
SUJET
SUBJECT: Wagner & Abbott Veins NTD 82K/11E

Owner/Operator:	Mikado Resources Ltd., 70%/Turner Energy and Resources, 30%.
Regional Geology:	Cambrian meta-sediments of the Index Broadview formations lie above the Badshot limestone within the Finkle Creek synform. These rocks are considered part of the Kootenay arc by Hoy, 1980.
Property Geology:	The Mikado ground is underlain by grey and light green phyllites with minor limestone and quartz grit. This sequence lies on the northeastern limb of the Finkle Creek synformal structure thought to be an overturned anticline. This structure is complexly folded.
Mineralization:	A number of silver-lead zinc occurrences are covered by the Mikado ground including Duncan knob, Bannockburn, Sheila but the main zones are Wagner and Abbott. The Wagner vein consists of quartz veins and massive galena-sphalerite in veins up to .7m wide. Serem (Ronning 1977) reported this mineralized zone to be stratabound and confined to one 40' thick distinct quartzite unit. Within this unit a 3 to 12 foot mineralized zone exists where galena, sphalerite and tetrahedrite form part of the cement in a calcareous quartzite. The Abbott mineralization consists of quartz and calcite veins carrying galena and sphalerite in

disseminations and clusters. Occasionally chalcopyrite occurs.

Claims:

AG 1	4297	Richard Watson	Expire/91
AG 2	4298		
AG 3	4299		
AG 4	4300		
Ban 1-7		Turner Energy Resources	Expire/91
Hall 2-4			
Abbott	4401	John Robertson	Freed of lien/86
Gertie 1-2		Mikado	
Lake 1-8			
Creek 1-8			
Gertrude 1-2		John Robertson	
SOB			

References:

Open file 432 GSC
Geology of Lardeau West Half
GSC Memoir 161
Assessment Reports to be examined in Victoria #13736, 12873.

Remarks:

Serem drilled a number of holes and blocked out a section, however they stated exploration costs were extremely high and benefits were not materializing. Mikado seems hesitant to release grade and tonnage figures together. Do the 250,000 tons referred to in the development release refer to grades reported in Oct 3/86 Stockwatch?

Further investigations should be directed toward more recent assessment reports in Victoria and G.S.C. Memoir 161.

The Kootenay Arc has undergone intense polyphase deformation. In general, the earliest recognized structures are tight to isoclinal, north-trending recumbent folds. In the Lardeau area in the northern Kootenay Arc, evidence indicates that these structures developed during the Caribooan orogeny in Devono/Mississippian time (Wheeler, 1968, 1972; Read, 1975, 1976).

More open but locally isoclinal, north-trending Phase 2 folds with upright to steeply west-dipping axial surfaces are superposed on the Phase 1 folds. These folds dominate the structure of the Kootenay Arc and account for the pronounced north/south structural grain. In the Lardeau area, radiometric dates restrict the second phase of deformation to an interval between 178 Ma and 164 Ma. The older limit is set by a K/Ar date from the core of the pre to syn-tectonic Kuskanax batholith, the younger by both the post-tectonic northern part of the Nelson batholith and the Mount Carlyle stock (Read and Wheeler, 1975). The latest discernible deformation in the arc caused faulting and gentle folding of the earlier structures.

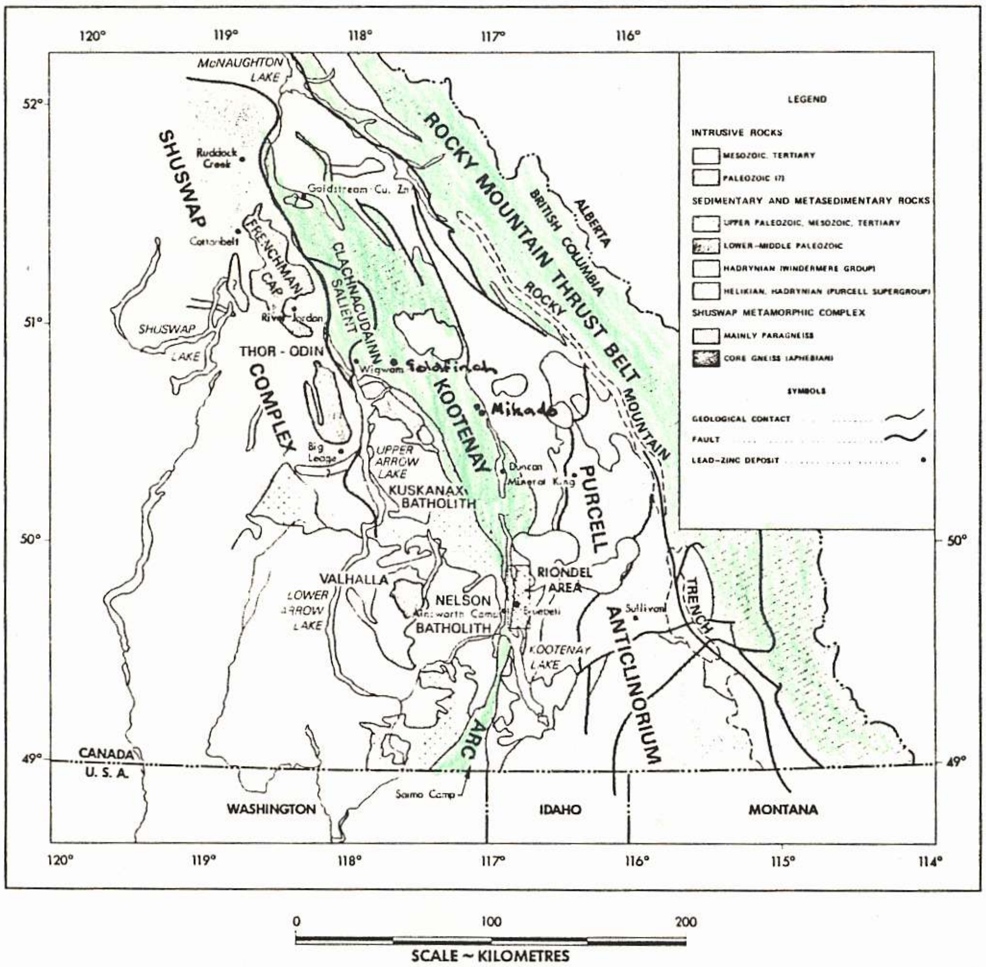
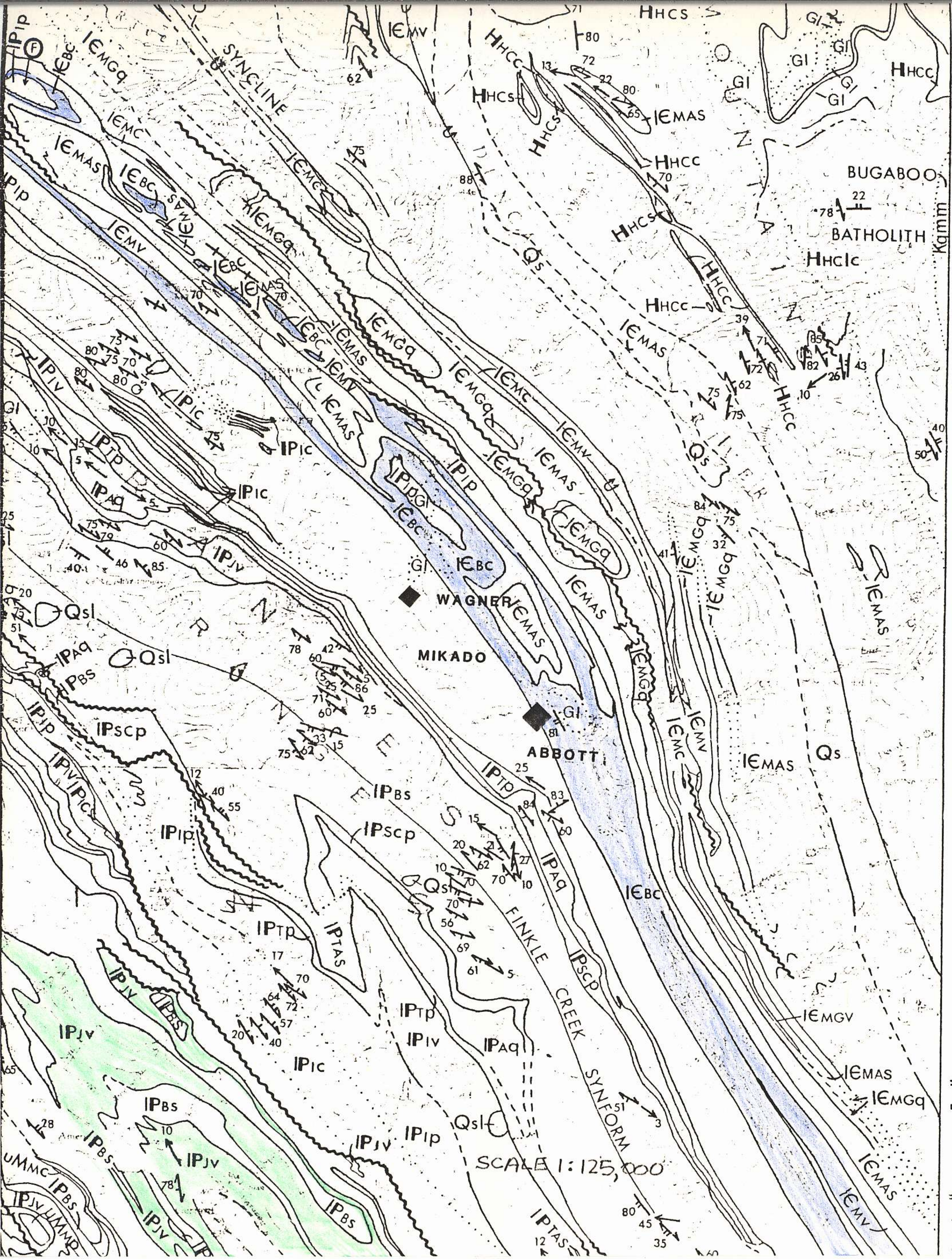


Figure 3. General geological map of southeastern British Columbia.



1326A "LARDEAU E/2"

PALEOZOIC

CAMBRIAN TO DEVONIAN OR OLDER

LOWER CAMBRIAN TO MIDDLE DEVONIAN OR OLDER

LARDEAU GROUP (lPBC to lPIgr)

BROADVIEW FORMATION (lPBC, lPBS):

lPBC	Limestone, grey phyllitic limestone and grey phyllite		
lPBS	Grey and green phyllitic grit and phyllite		
lPJV	JOWETT FORMATION: green phyllite, limy green phyllite, greenstone		
lPSCP	SHARON CREEK FORMATION: dark grey to black siliceous phyllite		
lPAq	AJAX FORMATION: massive grey quartzite		
lPTp	TRIUNE FORMATION: grey to black siliceous phyllite		
lPTAS	TRIUNE, AJAX, SHARON CREEK FORMATIONS: undivided		
l. Iv	INDEX FORMATION (lPIv to lPIgr) Green phyllite, limy green phyllite, greenstone		
lPIc	Phyllitic and arenaceous limestone;minor grey phyllite		
lPIp	Grey and light green phyllite; minor phyllitic limestone and quartz grit		
lPIgr	Quartz grit; minor gritty phyllite		
lPLs	Undivided: grey phyllite, siliceous phyllite, gritty phyllite, phyllitic grit, rare quartzite	lPLsb	Biotite sc
lPLv	Undivided: green phyllite, limy green phyllite, greenstone	lPLm	Amphibolit
lPLc	Undivided: limestone, phyllitic limestone	lPLsc	Calc-sili

CAMBRIAN

LOWER CAMBRIAN

lЄBC	BADSHOT FORMATION: Grey and white limestone	lЄBSC	Marble

PROTEROZOIC to PALEOZOIC

HADRYNIAN (WINDERMERE) AND/OR CAMBRIAN

HADRYNIAN (WINDERMERE) AND/OR LOWER CAMBRIAN

HAMILL GROUP (lЄMp to lЄMGq)

MOHICAN FORMATION (lЄMp, lЄMv, lЄMc):

lЄMp	Grey and brown phyllite, micaceous quartzite; minor limestone	lЄHsb	Grey and bro black phylli limestone
lЄMv	Green phyllite, minor grey phyllite and limestone	lЄHm	Amphibolite
lЄMc	White to light grey limestone		
lЄMAS	MARSH ADAMS FORMATION: white, grey and brown quartzite, phyllitic quartzite; minor grey and black phyllite	lЄHsab	Garnet-biotite micaceous quar
lЄMGq	MOUNT GAINER FORMATION (lЄMGq, lЄMGv): white quartzite	lЄHq	Tan and white micaceous quart
lЄMGv	Green phyllite, greenstone		

THE STOCKWATCH FRIDAY, OCTOBER 3, 1986 ISSUE

= NTS 82K/10

MIKADO / ABBOTT PC.F

Mikado Resources Ltd **MKO**
Shares issued: 3,250,001

News Release

Mr. Richard Watson reports:

Further assays have been recieved in addition to the previously reported 8 foot section that assayed 0.65 oz per ton Au, 3.64 oz per ton Ag, 0.31% Pb and 0.27% Zn. Additional sampling along strike gave an assay of 0.26 oz per ton Au, 4.9 oz per ton Ag, 0.31% Pb and 0.34% Zn over 5 feet. This zone is approximately 500 feet northwest of the Abbott ore horizon.

Two other massive sulphide zones were discovered at the upper Abbott below the gold bearing zone. Initial sampling of the high grade sections of these zones gave assays of 0.01 oz per ton Au, 46.5 oz per ton Ag, 0.71% Pb and 0.52% Zn to 0.015 oz per ton Au, 29.4 oz per ton Ag, .32% Pb and 28.5% Zn.

Hole 86-52 on the Abbott property in the Greenlaw zone has had an intersection at 500 feet of depth. The hole intersected 5 feet that assayed 32.6 oz per ton Ag, 9.19% Pb, 8.51% Zn and 2 feet of 5.77 oz per ton Ag, 10.9% Pb and 4.16% Zn.

About 90 tons of high grade ore from the Abbott have been hauled and await a test shipment to Trail. Samples taken from the ore stockpile assayed 0.052 oz per ton Au, 17.8 oz per ton Ag, 29.1% Pb, 18.9% Zn and 20.9 oz per ton Ag, 35.1% Pb, 15.3% Zn and 0.147 oz per ton Au.

Mining Journal 19-Dec-86

DEVELOPMENT

Mikado Secures Milling Facility

Vancouver-based Mikado Resources Ltd. has reached an agreement to acquire a 50% interest in the Ainsworth mill, owned by David Minerals (now bankrupt), which is the only milling facility in the Slocan area of British Columbia. The 50% interest cost to Mikado is $C278,000 and its share of the rehabilitation cost will be about $C45,000. The mill has a 110 t/d capacity which is easily expandable to 230 t/d. Production is scheduled to begin by summer 1987.

The mill will be used to treat lead-zinc-silver-gold ores from Mikado's joint venture Mt. Templeman tenements in the Lardeau region of British Columbia, where it has delineated a series of mineralized veins and replacement deposits in a mineralized belt 4 km in width with a strike length of 40 km. Two of the drill targets tested, the Wagner and Abbott zones, are estimated to contain a combined tonnage of over 250,000 t with further potential at depth and along strike. Mikado owns 70% of the property and Turner Energy & Resources 30% (*MJ*, September 19, p.201).

MIKADO RESOURCES LTD.(MKO-V)

RESERVE ESTIMATES CALCULATED FOR 1986 EXPLORATION RESULTS - Mikado Resources Ltd.'s consulting geologist, P.J.Santos, P.Eng. has reported the Abbott-Wagner property 60 miles southeast of Revelstoke, B.C. has measured and indicated ore reserves of 298,000 tons with a gross value of $50,613,000 and a net value of $17,160,000. Additional inferred ore reserves of 206,000 tons increased total reserves to 504,000 tons from the six high grade, massive sulfide ore bodies that are still open along strike and down dip, a significant increase from the 1985 exploration program, which showed no measured reserves, 40,000 tons indicated ore and 20,200 tons inferred ore.

A total of 14,149 feet of diamond drilling and 86 feet of development work were completed in 1986.

Eight additional massive sulfide occurrences on the property have the potential of developing into high grade ore bodies.

A five year multi-phase exploration, development and mining program is being proposed at a cost of $1,500,000 annually.

Mikado Resources Ltd. recently acquired 50% working interest in a 100 tons per day flotation mill which is suitable for treating the ore from the property. There is six years supply of ore for this mill. **TURNER ENERGY & RESOURCES LTD.**(TUN-V) is a partner in this project.

in the zone are black and grey schists and slates and quartzites, generally impure, belonging to the Lardeau group, and occasional dykes of greenstone. One great difference does exist within the belt and that is the amount of silver in the grey copper and the relative abundance of that mineral. The silver values at the Triune, Silver Cup, and adjoining properties are high, running up to several hundred ounces per ton of sorted ore. They are also good at the Nettie L and the Multiplex and at the Beatrice. On Great Northern mountain, however, the grey copper seems to be much lower in silver value, with the single exception of a rich ore-shoot developed on the St. Elmo claim.

To the east of the above-mentioned zone is a wide belt of sedimentary rocks belonging to the Lardeau group. There are slates, schists, crystalline limestones, and quartzites, with irregular areas of chlorite schist and greenstone, particularly on the western side. The belt is bounded on the east by the prominent Badshot formation—a broad band of crystalline limestone—which forms the highest peaks in the district. In the sediments are numerous prospects and showings of mineralization which once more exhibit a pronounced tendency to preserve their similarities along the strike of the rocks. Several of the smaller bands of limestone are in part replaced, most commonly near their contacts, by pyrite, sphalerite, and galena. An excellent example is the bed of marble in which are the Surprise, Mollie Mac, and Hidden Treasure deposits. The Alma group, near the head of Pool creek, is probably on the northwesterly continuation of the same bed. The mineralization on all these properties is very similar. At the head of Ferguson creek the Big Five and the Elsmere show replacement bodies in a similar but larger bed of crystalline limestone lying a little farther east. On Duncan lake, at the south end of the district, similar replacement bodies have been found on the east shore in about the same stratigraphic horizon. Every bed of limestone west of the Badshot formation merits careful prospecting for similar deposits.

Immediately west of the Badshot formation is a belt, about half a mile wide, of carbonaceous sediments in which exists a somewhat less distinct type of deposit. The Wagner, part of the Abbot, the Jewell, Mohican, and the Black Warrior at the head of McDonald creek, are in it. They are all fissure veins valuable for their content of lead, zinc, silver, gold, or copper. Similar deposits might be expected at any place in the belt.

Within the Badshot formation several small fissure deposits have been worked for lead and silver, but the ruggedness of the ground makes prospecting extremely difficult.

East of the Badshot formation there are numerous properties in the prospect stage, but, on the whole, they are practically unknown to the writer. Some of them are described elsewhere in this report.

RELATION OF ORE DEPOSITS TO COUNTRY ROCKS

The broad, irregular belts of greenstone and chlorite schist have evidently been distinctly unfavourable to the formation of mineral deposits. Where veins do occur within these rocks they are in most cases extremely irregular and of low grade or very erratically mineralized. In several cases veins have been observed to end abruptly where they encounter chlorite schists. This, however, does not mean that no mineral deposits will be found in chlorite schists or massive greenstone. Where these rocks are extensively carbonated some important deposits have been found, as for example, those on the Multiplex group, an ore-body in the Silver Cup mine, and many of the gold-quartz veins in the vicinity of Camborne. All these deposits occur, however, near the edges of prominent masses of greenstone, where intercalations of sediments of the Lardeau group are abundant, or where the greenstones are relatively small dykes in the sediments. No important mineral deposits have as yet been found within the larger areas of greenstone. The grey carbonated rocks may be taken as a general guide to mineralization, but it does not follow that ore deposits accompany every case of carbonatization.

The beds of crystalline limestones are much the most favourable horizons for replacement bodies of sulphides. Replacement has proceeded with greatest ease along or near the contacts of the limestones with adjoining rocks. The smaller beds of limestone appear to hold more promise of containing replacement bodies than the larger ones. Fissure veins that crosscut the strike of the sediments have in several cases been observed to form replacement deposits along the strike of limestone bands which they traverse.

For fissure deposits containing lead, zinc, and silver the slates and argillaceous or carbonaceous schists, black or grey in colour, seem to be most favourable. Graphitic schists have been developed along many of the mineralized shear zones, but it is doubtful if they have had any effect on the ascending solutions that might tend to cause deposition of the sulphides. In some cases the predominance of graphitic material near and in the veins may seem to indicate that they had so affected the solutions, but detailed examination of many inclusions in the veins failed to confirm such a theory. The only bearing that the graphite has on the location of ore deposits seems to be that the soft carbonaceous sediments, from which the graphite was most probably formed, was easily sheared and crushed, during premineralization movements, to form zones along and up which the mineralizing solutions might travel.

The massive beds of quartzite contain few mineral deposits. On the whole they seem to have behaved during premineralization movements as rather competent members against which the softer beds were crushed and sheared. On the Nettie L group and adjoining claims they have been considerably fractured and probably faulted and parts of the veins lie in them.

VERTICAL EXTENT OF THE ORE DEPOSITS

In a district where little deep mining has been done the evidence bearing on the vertical extent of the ore deposits is necessarily meagre. The fact that ore deposits occur throughout the Lardeau from the tops of the mountains to the bottoms of the valleys does not indicate that individual ore-bodies should persist through similar vertical ranges.

The Silver Cup mine is the chief property on which deep exploration has been done. The veins on that property have been developed to a depth of about 1,200 feet below the outcrops. Unfortunately the lower 500 feet of the mine is now flooded. It is reported, however, that commercial ore was encountered in the lower levels. It is known that good ore continued to 700 feet below the outcrops, and, from the plans of the mine workings, one may safely conclude that it persisted to greater depths. At the surface on the Silver Cup and adjoining claims, the veins nearly parallel the strike of the formation, cutting across it at very small angles, and occur in a zone of fracturing and shearing. This zone strikes northwest down the hillside, from an elevation of 7,000 feet at the Free Coinage to 4,700 feet at the Yuill claim in the bottom of Cup creek. Between the two elevations, veins in the zone have been developed on the Silver Cup, Sunshine, and Towser claims. Although it cannot be said that all the showings from the Free Coinage to the Yuill are on the same lead, they are certainly in the same zone of mineralization. Although the deposits, so far developed at the lower elevations—on the Towser and Yuill claims—are not as extensive as those encountered in the upper workings of the Silver Cup mine, yet they are by no means unimportant, and, what is more important, the type of mineralization is practically identical. The silver values at the Yuill and Towser are apparently equally as good as those at the higher elevations. The horizontal distance between the upper and lower showings is about 4,500 feet. The above facts naturally do not indicate that there is continuous mineralization in the Silver Cup zone between the limits observed. They do support the expectation that ore-bodies, similar to those already developed, may occur between the limits observed. The type of mineral deposit to which the Silver Cup belongs is such that the ore-bodies may be expected to be quite erratic in size and distribution in the mineralized zone.

On the Wagner group a quartz vein occupies a shear zone in carbonaceous sediments. It is mineralized with pyrite, sphalerite, galena, and argentiferous grey copper. The strike of the vein is such that it trends directly up and down a steep mountain side. At the upper workings, elevation 7,700 to 7,950 feet, bands and bunches of galena-sphalerite ore occur in the vein within a short horizontal range. Below 7,700 feet a glacier covers the vein. At 7,000 feet elevation, below the glacier, and to the southeast of the upper workings, a similar vein, which may be a continuation of the same one, outcrops and appears at intervals to an elevation of 6,000 feet. It is slightly mineralized in several places. Between 6,000 and 6,200 feet elevation the vein is well exposed. With the quartz is a considerable amount of calcite and ankerite and at one place the vein is heavily mineralized with pyrite, sphalerite, and a little galena. The evidence is not indisputable, but it suggests that at the lower elevations carbonates, pyrite, and sphalerite are more abundant than they are above and that galena is relatively less abundant.

The lead-zinc replacement deposits in limestone have not been extensively developed at any place. At the Mollie Mac, on Gainer creek, however, sulphides are exposed at intervals on the surface of a steep hillside, at the southwestern contact of the limestone, through a vertical range of at least 500 feet. The mineralization is not proved to be continuous throughout this distance, but, where observed, it shows no change. It is reported that the best showings on the property are still higher than those visited by the writer. Here, then, is good evidence that the sulphides persist for at least 500 feet vertically. The writer believes that this type of deposit, which is well represented in the Lardeau, will prove to be more persistent both vertically and horizontally than the other types in the district.

Wagner Group

The Wagner group, owned by C. T. Porter and associates, is on the divide between Cariboo creek and the head of Hall creek. The highest outcrops, at an elevation of nearly 8,000 feet, occur on a knob of slate that protrudes above the top of the glacier (Plate III B). The approach is over the top of the ice. A fair trail leads to the property from Gerrard, following Healy creek for some 11 miles. The claims have been worked in a somewhat desultory manner since 1896. Reports on the property may be found in the Annual Reports, Minister of Mines, British Columbia, 1897 and 1909, and in the Summary Report, Geological Survey, Canada, 1904.

At the time of the writer's visit, in July 1926, C. T. Porter and three men were camped at the Jewell cabin on the summit between Hall and Healy creeks. From there the claims are reached by a tortuous trail which climbs the steep front of the glacier. The workings are on the Duncan claim, and consist of open-cuts, one adit, and a shaft therefrom.

About 200 yards east of the showings lies the western contact of the so-called "lime dyke", a massive band of grey to white marble dipping steeply to the southwest. This member forms the highest peaks in the Lardeau, of which mount Templeman, just east of the Wagner, has an elevation of about 10,200 feet. West of the "lime dyke" is a broad belt of black slates and carbonaceous schist with quartzitic varieties also dipping steeply west, in which the ore occurs. The only igneous rock in the immediate vicinity is a sill about 160 yards northeast of the Wagner adit. It is about 4 feet wide and light grey in colour, speckled green with shreds of chlorite. It weathers to a rust brown surface due to oxidation of disseminated pyrite. In thin section it consists of a fine-grained, crystalline intergrowth of feldspar—largely albite with a 10 degrees maximum extinction angle—and quartz, the latter forming about 10 per cent of the whole. Chlorite is present and some remnants of muscovite. Considerable calcite and sericite have developed and minor quantities of apatite, zircon, and pyrite appear. It is an aplite of quartz-syenite composition and does not appear to have had any connexion with the formation of ore.

On the top of the knob, above the adit near the corner post of the Duncan claim, is a showing of rusty quartz in slates. Between it and the adit, along the strike of the vein (south 20 degrees east) the lead is up to 10 feet wide, consisting of quartz with bands and small inclusions of schist. The dip is steep to the west. Towards the hanging-wall is a band of heavy galena-sphalerite ore about 2 feet wide. Fifty feet west is a small band of galena with some pyrite in the schist.

The adit, at 7,880 feet above sea-level, is driven 93 feet, in a northerly direction, on a strong quartz vein, presumably the same as that above mentioned. From its end a crosscut runs 42 feet to the west. The last 32 feet of this crosscut is in hard, slaty material in places converted to graphite schist. Numerous small quartz veins and much disseminated pyrite can be seen. The first 10 feet of the crosscut is in vein material, white quartz, slate inclusions, and some sulphides. For 2 feet beyond the foot-wall side the quartz is fractured and replaced or cemented by pyrite, sphalerite, and galena, the galena showing small areas of tetrahedrite under the microscope. West of this is about one foot of white quartz with disseminated zinc blende and little galena or pyrite. The mineralization continues for 10 feet towards the portal, on the west side of the drift. Below the vein is up to one foot of mashed quartz and slate and irregular veinlets of milky quartz are found in the slates on the east side of the drift.

Thirty-seven feet out from the crosscut, a small cut has been made into the vein and a shaft sunk. It is now filled with water, but Mr. Porter states that it goes down 50 feet at which point a drift was run 15 feet to the northwest and then a crosscut made for 20 feet to the west. He says that 10 feet or more of good concentrating ore has been exposed. At the top of the shaft a fair amount of disseminated pyrite, galena, and sphalerite occurs in the quartz near the foot-wall, and near the hanging-wall is a foot or so of irregular stringers of coarse cubic galena. The vein is finely banded and contains pyrite throughout. From the shaft to the portal, 55 feet, a small amount of sulphide is irregularly scattered throughout the quartz.

The vein can be traced on the surface 60 feet down to the top of the glacier. Good, fine-grained ore, largely galena, occurs as a band up to 18 inches wide along the foot-wall side. At the level of the top of the ice and 25 feet southwest of the main lead is another quartz vein up to 5 feet wide. Lens-shaped bunches of galena and pyrite occur in it, but the whole is much more irregular than the other vein. Anastamosing quartz stringers cut the slates. One hundred and fifty feet farther west is a large, irregular quartz vein slightly mineralized with pyrite and galena.

Several specimens of the ore were polished and examined under the microscope. The gangue is quartz and a little carbonate. Many clear, glassy quartz crystals are embedded in the galena which may be coarse, cubical, or fine grained. The ore minerals are rounded residual grains of pyrite, dark brown or black sphalerite which is cut and replaced by argentiferous tetrahedrite and galena, and chalcopyrite. The grey copper undoubtedly accounts for the high silver values which are obtained (up to 240 ounces according to Mr. Porter). It is found as irregular areas of microscopic size scattered throughout much of the finer grained galena and can only occasionally be seen in a hand specimen. An azure blue copper stain, probably azurite, on the ore, appears to be a good guide to it. The chalcopyrite is found in very small amounts, generally as disseminated specks in the sphalerite. The quartz is in many cases much fractured and cut by the sulphides.

Below the glacier, at an elevation of 7,000 feet, southeast of the adit and approximately along the strike of the vein, a large outcrop of quartz with slate inclusions was seen. The quartz is rusty and contains specks and small bands of pyrite, sphalerite, and galena. Mr. Porter states that a better showing occurs in the vicinity and is of the opinion that it is the continuation of the vein on which the adit is driven. This point is not proved, as the glacier intervenes between the two showings. Still farther southeast, between elevations 6,200 and 6,000 feet, a strong vein of quartz up to 20 feet wide stands out like a wall on the east side of a small stream. It is rusty, due to disseminated pyrite. In one place heavy mineralization of pyrite and sphalerite with a little galena was found. Calcite and ankerite are present in the vein in important amounts.

The characters of the vein are thus somewhat different from those at the upper showings. The meagre evidence points to an increase of pyrite and sphalerite relative to galena and to more carbonate. This may be due to increased temperature and pressure resulting from nearly 2,000 feet deeper burial at the time of formation.

The property has one of the best surface showings seen in the Lardeau and undoubtedly deserves careful development. Its location is against it as the trail from Gerrard is about 18 miles long, is poor, and must cross a summit nearly 7,000 feet high to reach the property. The only other outlet is via Hall creek and Duncan river to Howser—some 35 miles by trail and water. The great vertical range of the outcrops described leads to the hope that mineralization would be persistent in depth, probably as separate lenses of ore in the vein. A tremendous expenditure would be required before any extensive development could be undertaken.

Abbot Group

The Abbot group lies at the foot of mount Abbot, at the head of a south fork of Healy creek, a mile southeast of the Jewell. In 1926 it was acquired from C. T. Porter and associates by E. B. and A. E. Brown and development work was pushed forward in 1927. The property was visited in July, 1926.

The main showing is at an elevation of about 6,700 feet on a steep slope below which lies much loose talus (Plate III A). A short adit exposes, practically at the surface, an irregular 2 to 3-foot vein of coarse galena, sphalerite, and pyrite striking north 25 degrees west and dipping steeply west. Just above it mineralization has extended into the limestone several feet to form a flat body of coarse galena. Ten feet inside the adit is a 3-foot irregular zone paralleling the main vein, of pyrite, sphalerite, galena, and some quartz replacing a dull grey, siliceous, finely crystalline limestone. The pure pshalerite contains small quantities of chalcopyrite. Small amounts of grey copper can be seen by the naked eye in the coarse galena. Black slates and schists lie a short distance west of the limestone (part of the "lime dyke"). To the north west ofthe adit large quartz veins occur in the slates a short distance west of the limestone and continue at intervals for several thousand feet to an elevation of 7,600 feet, almost to the Jewell claims. They are very slightly mineralized with pyrite, sphalerite, galena, and a little chalcopyrite. Their strike is north 25 degrees west and the dip practically vertical. No work has been done on them. If these veins continue to the southeast they should pass just below the adit where the ground is covered by talus.

Other Occurrences

According to report, many isolated, high-grade bunches of galena occur high up on the limestone peaks east of the Abbot. Work has been done on some of these and some of the locations were pointed out to the writer, but the approaches were too dangerous to attempt. Similar bodies occur near the head of Ferguson creek.[1] They are rich, discontinuous pockets in the limestone and in most cases no fissure or other means of access for the ore-bearing solutions is discoverable. This is

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[1] Ferguson creek in Geographic Board report; North Fork of Lardeau river on map.

galena and sphalerite. At the Silver Cup mine pyrite crystallized first and was followed by sphalerite, tetrahedrite, and galena, with the latter two perhaps in part contemporaneous (Plate IV). Quartz crystallized largely before the sulphides, but continued to form until towards the end of mineralization. Galena was found to have clearly replaced the sphalerite on the Bannockburn claim and the same thing was noticed at the True Fissure mine (Plate VII A). At the Wagner, chalcopyrite, grey copper, and galena are closely associated in age, the galena probably continuing to form after the other two minerals, and all three are later than sphalerite which in turn followed pyrite. Good evidence of the same succession was obtained in ores from the Multiplex mine, where chalcopyrite is generally absent. Arsenopyrite in small amount probably followed pyrite in time of crystallization. At the Beatrice mine sphalerite, which was later than pyrite, is replaced by galena which is intimately associated with grey copper. At the Teddy Glacier property the succession was pyrite, sphalerite, and galena. Tetrahedrite and chalcopyrite were intimately associated with both sphalerite and galena. Polished surfaces of the ores from the Surprise group on Surprise creek indicate that magnetite was the first mineral to form during mineralization, that it was partly replaced by ankerite, and that the latter was replaced by sphalerite and galena. Galena replaced sphalerite and pyrite crystallized later than magnetite and earlier than sphalerite. Pyrite crystallized first in the Big Five ores and was accompanied or succeeded by sphalerite. Tetrahedrite followed sphalerite and was succeeded by boulangerite and bournonite, bournonite being the latest mineral to form. Examination of hand specimens and polished surfaces of ore from the Surprise group on Glacier creek shows that the quartz of the veins was fractured and crushed before the sulphides were deposited. Also, that the general sequence of crystallization was sphalerite (earliest), tetrahedrite, and galena. The relation of pyrite and chalcopyrite to the other sulphides was not established. In one specimen chalcopyrite in one place definitely cuts grey copper and in another place the order is reversed. This perhaps might be expected as the two minerals are believed to be practically contemporaneous in most of the Lardeau deposits. In the same specimen grey copper and chalcopyrite occur as fine veinlets in galena. This is the only instance in which either of these two sulphides have been found cutting galena and the reversal may be due to rearrangement of the sulphides under local conditions of pressure and chemical reaction.

In addition to the ore minerals mentioned above, certain others can be placed more or less definitely in the sequence of crystallization. Pyrrhotite, when it occurs, is an early mineral. It generally succeeds pyrite and precedes sphalerite and galena. The evidence, however, points to pyrrhotite and dark brown sphalerite as being very closely related in time of crystallization. This seems to be particularly true in the case of replacement bodies in limestone when both minerals are present. Complex sulpho salts such as boulangerite and bournonite which are mentioned above, and perhaps complex silver minerals, are present in a few examples. The evidence is hardly sufficient to place these minerals in a general sequence of crystallization, but where they have been found they appear to be as late or later than the galena.

Exploration implications of production and location data for Ag-rich vein deposits, Trout Lake mining camp, southeastern B.C.[1]

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Ore tonnage production data from 43 former producers in the Trout Lake mining camp are examined using plots of spatial density of deposits and statistical methods. Outlines of mineral belts are established from spatial density with the 0.5 deposit per 4 km^2 contour. Probability plots of ore tonnages distinguish two lognormal populations of deposits. Probablity plots of metal grades show four lognormal populations of silver and two of gold. A metal content versus ore tonnage graph draws attention to the similarity in proportions of metals produced from high-tonnage and from medium- + low-tonnage deposits. Triangular graphs of metal contents emphasize the direct relationship between silver and lead; metal ratios suggest some relationships that may be dependent upon host rocks. Linear correlation coefficients of tonnage and metal content show an inverse relationship between tonnage and precious metals and a direct relationship between silver and lead. Multiple regression models established between production tonnages and average grades can estimate deposit size within one order of magnitude.

Systematic evaluation of quantitative production and location data can augment exploration decisions.

Les données de production en tonnes de minerai de 43 anciennes exploitations du camp minier du lac Trout ont été examinées par une mise en graphique de la densité spatiale des gîtes et également par des méthodes statistiques. Les limites des ceintures minéralisées ont été tracées à l'aide de la densité spatiale en utilisant comme ligne de contour 0,5 gîte par 4 km^2. Les courbes de probabilité des tonnages de minerai permettent de distinguer deux populations lognormales de gîtes. Les courbes de probabilité des teneurs de minerai présentent quatre populations lognormales pour l'argent et deux pour l'or. Un graphique de la teneur en métaux versus le tonnage du minerai fait ressortir la similitude dans les proportions de métaux produits par les gîtes à tonnage élevé et à tonnage médium + faible. Les diagrammes ternaires des concentrations de métaux mettent en évidence une relation directe entre l'argent et le plomb; les rapports des métaux suggèrent l'existence d'une certaine relation, laquelle pourrait dépendre des roches encaissantes. Les coefficients de corrélation linéaire entre le tonnage et la concentration des métaux montrent qu'il existe une relation inverse entre le tonnage et les métaux précieux et une relation directe entre l'argent et le plomb. Des modèles de régression multiple établis entre les tonnages de production et les teneurs moyennes peuvent permettent d'évaluer la dimension de gîtes avec une précision meilleure qu'un ordre de grandeur.

Les décisions en exploration peuvent bénéficier de l'évaluation des quantités de minerai produites et des données sur la localisation des gîtes.

[Traduit par la revue]

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Introduction

Trout Lake mining camp is in southeastern British Columbia, about midway between Revelstoke and the north end of Kootenay Lake (Fig. 1). In broad outline the boundaries of the camp measure 52 km northwesterly by 26 km northeasterly (32 mi × 16 mi), covering an area of approximately 1350 m^2 (510 mi^2). Within this area three principal mineral belts (Southwest, Central, and Lime Dyke) are defined (Figs. 3, 4, and 5). The history, general geology, and property descriptions have been summarized by Emmens (1915*a*), Walker *et al.* (1929), Fyles and Eastwood (1962), and Read (1973, 1975, 1976, 1977). Discoveries of lode deposits of silver and gold were made in the early 1890's and sporadic exploration and production have continued to the present. The most recent exploration success is the Trout Lake porphyry molybdenum deposit in the Southwest mineral belt.

This study is designed to examine the contribution that can be made by vein location and production data (quantity and average grades of ores produced) to the development of an effective approach to exploration (cf. Sinclair 1979; Sinclair and Goldsmith 1980). Only polymetallic vein deposits are considered; the metals of interest are lead, zinc, silver, and gold. Historically, silver has been the most important commodity economically.

Precious-metal vein deposits are contained chiefly in the lower Paleozoic Lardeau Group and to a lesser extent in the Lower Cambrian Badshot Formation. The Badshot is an archaeocyathid-bearing limestone that underlies a 3000–5000 m thick sequence of grey and green siliceous or calcareous phyllite, gritty phyllite, quartz grit, metavolcanic rocks, and minor limestone (Table 1). The units strike northwesterly and regionally young to the southwest (Fig. 2). Although three phases of northwesterly trending coaxial folds have deformed the succession, second-phase folds of Middle Jurassic age dominate the structure of Trout Lake mining camp (Fig. 2). The second-phase folds are overturned to the southwest and pass from gentle northwesterly plunges northeast of Trout Lake to southeasterly plunges in the northwest corner. The metavolcanic rocks of the Jowett Formation outline the

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[1] This paper was presented at the "Silver–Sulpharsenide Vein Deposits Symposium," part of the Geological Association of Canada – Mineralogical Association of Canada Joint Annual Meeting, held in London, Ontario, in 1984.

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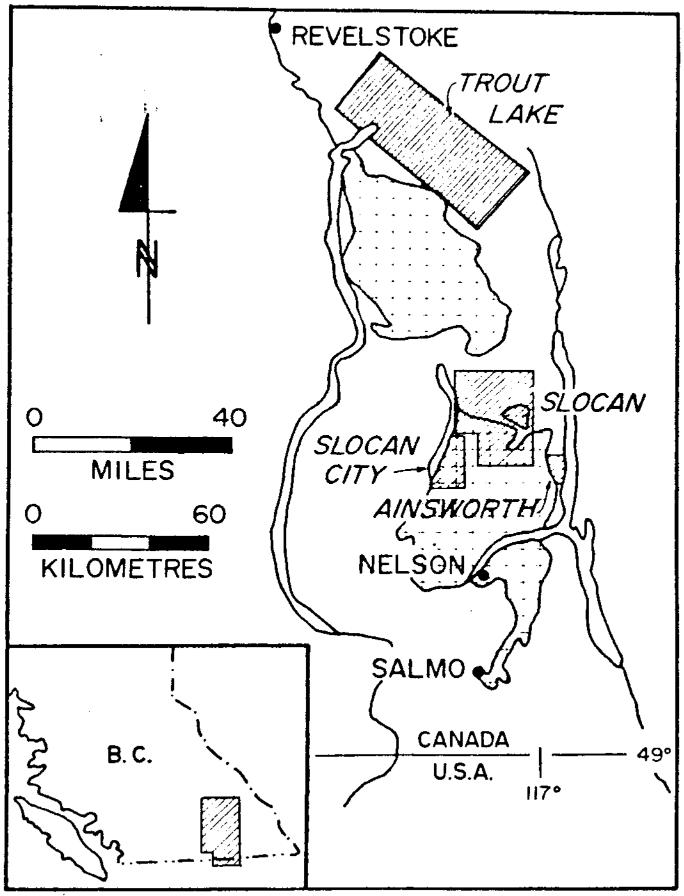

FIG. 1. Location of Trout Lake mining camp relative to other nearby vein camps in southern British Columbia. "+" signs indicate the Kuskanax batholith on the north and the Nelson batholith on the south.

two most important folds, Finkle Creek synform and Silvercup antiform, which pass through the mining camp. An anastomosing zone of fault slivers forms the steep, northeasterly dipping Cup Creek and Bonanza fault zones. In Cup Creek fault zone, rocks on the northeast sides are downthrown by at least several hundred metres, but the magnitude of strike-slip displacement is unknown (Fyles and Eastwood 1962, p. 43). The northwesterly trending structures and stratigraphy result in northwesterly trending belts of mineral deposits which are described in order from northwest to southwest.

Mineral belts

Numerous vein deposits and occurrences have been reported in the area. A recent compilation by Read and Wheeler (1976) documents 43 past producers (Table 3) and about 180 occurrences from which no production has been obtained. The character of these deposits differs somewhat from one mineral belt to another.

In the Lime Dyke mineral belt, most of the mineral occurrences are galena–siderite replacements of carbonates of the Badshot Formation and in particular those of the lower part of the Index Formation. Shear and tension fractures cutting the limestone control its replacement by galena, pyrite, and minor Silver contents are generally about 1 oz/ton for ead. No major fault system lies within the mineral e past producers are related to the intersection of s with limestone and phyllite. Of the 10 small producers in the belt, eight are vein deposits with silver contents of about 300 oz/ton for every 5% Pb.

The essentially unfaulted, northeastern limb of Finkle Creek synform underlies the Mollie Mac mineral belt. Many mineral showings of galena–pyrite–sphalerite replacements of calcareous horizons in the Index Formation occur within the belt, but they are small, and none has produced.

In the economically important Central mineral belt, past producers lie close to the Cup Creek and Bonanza fault zones, which cut near the crest and on the flanks of Silvercup antiform (Fig. 2). The mineral occurrences and past producers are dominantly veins along fault splays located within several hundred metres of their major fault zones. The veins develop in the faulted competent units of the Lardeau Group, such as the phyllitic grits of the Broadview Formation or metavolcanic rocks of the Jowett Formation. Near Incomppleux River, where the northwestern end of Cup Creek fault zone truncates metavolcanic rocks of the Jowett Formation and associated metadiorite, gold–silver deposits occur.

The Central mineral belt contains the most important past producers within the camp, with Silver Cup (164), Nettie L (112), and True Fissure (101) mines accounting for most of the production from Ag-rich veins (Table 3) and the Eva (34) and Meridian (36) representing relatively large tonnage gold deposits with low base metal and Ag contents. Spider (45), the largest past producer in the camp, is intermediate between the Ag-rich producers to the southeast and the Au-rich past producers to the northwest.

None of the individual lodes of the Ag-rich veins of the Central mineral belt is continuously mineralized (Fyles and Eastwood 1962). Quartz is the main gangue, but siderite is present. Pyrite, sphalerite, and galena are the most abundant sulphides, although tetrahedrite is widespread and chalcopyrite and pyrrhotite occur locally. Silver grades are in excess of 100 oz/ton in some ore shoots (Table 3). A generalized paragenetic sequence from oldest to youngest is quartz–carbonate – pyrite – (gold) – sphalerite – tetrahedrite – chalcopyrite – galena. Tetrahedrite and chalcopyrite are locally contemporaneous or reversed in order, and quartz deposition apparently continued intermittently to the final stages of mineralization. The larger production veins commonly attained widths of 1–2 m and rarely up to 5 m. Veins are sinuous in both plan and section, with substantial thickening and thinning.

At the northern end of the Central mineral belt, the "large"-tonnage, grade gold deposits consist of either subparallel principal veins with intervening cross-veins and stringers, or massive veins, which give way to reticulated, quartz-filled fractures in the surrounding phyllite (Emmens 1915*b*). Thicknesses of individual veins are commonly 0.5–2.0 m. Most main veins strike northwesterly, the remainder strike northeasterly, and all have a moderate northerly dip. Quartz is the dominant gangue mineral, with minor siderite and sulphides consisting of pyrite, galena, and sphalerite. Visible gold occurs locally, especially along selvedges of the vein or at the margin of wall-rock inclusions. At the Oyster property (37), the "Criterion" vein is cut by a galena-rich vein. This is the only known indication of relative age relations of the Ag-rich deposits and the Au-rich deposits and shows that the Ag-rich deposits are apparently younger.

The few past producers in the Southwest mineral belt lie within a zone of northeasterly dipping faults that slivers competent units of the Broadview Formation west of Trout Lake

TABLE 1. Generalized stratigraphic section of the Trout Lake mining camp

Age	Group	Formation	Lithology
Jurassic (?)	Mafic intrusives		Diorite
Pennsylvanian to Permian (?)	Milford		Slate, argillite, chert, limestone, and pebble conglomerate
Stratigraphic relationship not established within the map area			
Cambrian to Mid-Devonian	Lardeau	Broadview	Grey and green grit and phyllite; minor pebble conglomerate and pyroclastic rocks
		Jowett	Mafic lavas, pyroclastic rocks, argillite, minor limestone
		Sharon Creek	Dark grey to black siliceous argillite; slate, phyllite, and minor grit
		Ajax	Massive grey quartzite
		Triune	Grey to black siliceous argillite
		Index	Dark grey and green phyllite; dark grey argillite; minor limestone and volcanic rocks; includes Molly Mac limestone
Probable conformity; relationship uncertain in map area			
		Badshot (Lade Peak)	Grey limestone (Grey limestone and argillaceous limestone)
Apparent conformity; relationship uncertain in map area			
Late Proterozoic to Cambrian (?)	Hamill	Mohican	Dark grey and green phyllite; minor limestone
		Marsh-Adams	Grey, brown, and white quartzite; micaceous quartzite; minor phyllite
		Mount Gainer	White to pinkish quartzite
Base not exposed			

(Psutka *et al.* 1982). The northern three deposits are gently dipping quartz veins cutting skarn that surrounds Trout Lake stock. The skarn contains coarse quartz, carbonate, epidote, diopside, and garnet, which is heavily mineralized with pyrrhotite and locally contains chalcopyrite and scheelite. Locally, quartz veins are silver rich and contain minor amounts of sphalerite, galena, scheelite, tetrahedrite, chalcopyrite, and pyrite. Native silver has been reported by Fyles and Eastwood (1962). Veins range up to 2 m thick but are mostly 10–20 cm thick; they have been traced for up to 150 m horizontally. Sulphides with silver occur very sporadically with veins.

Based on lead-isotope abundances and the relationship of vein-filled faults to the 76 Ma Trout Lake stock in the Southwest mineral belt, the age of mineralization in Trout Lake camp is probably Late Cretaceous to early Tertiary. Two deposits, Spider (45) and Silver Cup (164), have been analyzed for lead-isotopic abundances that have been reproduced in Table 2 (LeCouteur 1973). These limited data indicated that the leads are substantially enriched in a radiogenic component, more so than in the Mesozoic deposits of the Slocan camp to the south (Andrew *et al.* 1984). Consequently, the deposits of the Trout Lake camp are thought to be of late Mesozoic or early Tertiary age. From a detailed study of the structure and metamorphism around the mineral deposits of the Southwest mineral belt, Psutka *et al.* (1982) concluded that the movement of the northwesterly trending fault zones was both before and after the intrusion of the Trout Lake granodiorite stock radiometrically dated at 76 Ma (K–Ar, biotite) (Boyle and Leitch 1983). The northwestward extension of the fault that the Ethel (153) and Copper Chief (147) lie in or near does not offset the contact aureole. The combination of similar lead-isotope data from producers in the Southwest and Central mineral belts, the pre- and post-76 Ma movements on vein-filled faults, and the similar mineralogy among Ag–Pb–Zn veins in all the belts support a Late Cretaceous to early Tertiary age of mineralization.

Data evaluation procedure

MINDEP computer files for National Topographic System (NTS) map area 82 K NW prepared originally by Read and Wheeler (1976) contain much of the numerical and geological data on which this study was based.[2] This initial computer file was thoroughly edited and augmented to provide the final data base for evaluation. The resulting file contains information on 43 past producers and 180 additional vein prospects. Geological information for the file was also colleted from various reports, bulletins, and maps. Geological Survey of Canada *Open File Map 462* (Read and Wheeler 1976) should be examined in conjunction with this evaluation. A summary of production data is given in Table 3. Evaluation procedures considered are largely those of Sinclair (1972, 1979) and Orr and Sinclair (1971). These include cumulative percentage probability plots and machine-contoured plots of vein orientation and spatial density of deposits (Goldsmith and Sinclair 1983), a graph of metal content versus production tonnage, triangular graphs of metallic elements, and multiple regression techniques.

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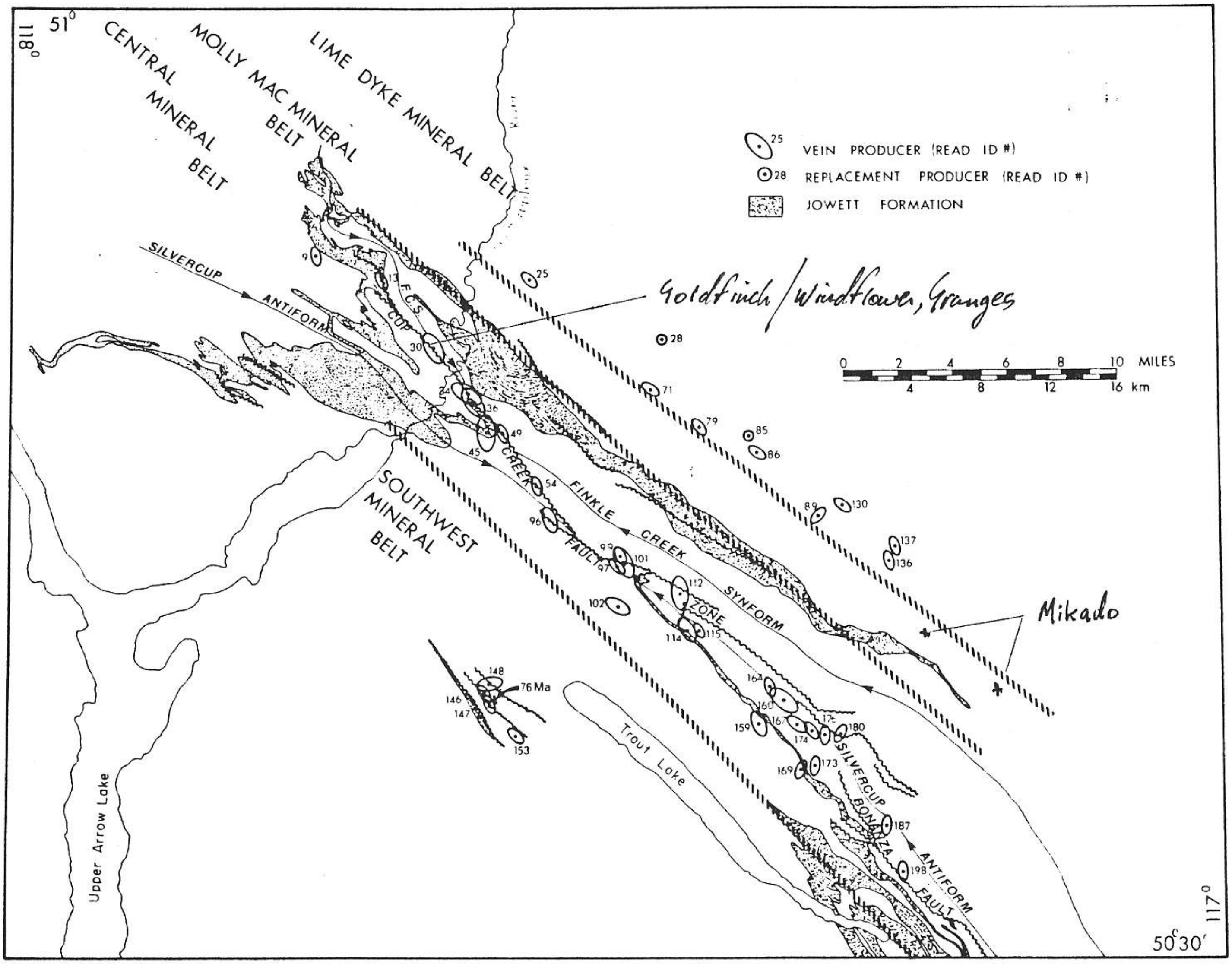
[2] These computer-based mineral deposit files are available, in large part, on magnetic tape and computer listings under the name MINFILE, from the Mineral Resources Division, Ministry of Energy, Mines and Petroleum Resources, Victoria, B.C.



Goldfinch/Windflower, Granges

Mikado

FIG. 2. Regional geology, Trout Lake area.

TABLE 2. Lead-isotope ratios for galenas, Trout Lake mining camp

Deposit	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Spider	19.157	15.732	39.260
Silver Cup	19.322	15.710	39.269

NOTE: Data from LeCouteur (1973).

Spatial plots of deposit locations and various geological characteristics were machine generated at a scale of 1 : 125 000 for the map area (NTS sheet 82 K NW). Each map was produced with one set of numerical information printed per deposit location. Maps with identification numbers, elevations, production tonnages, all metal grades, and all metal contents were generated and examined in relationship to available geological information. The most significant of these maps are shown as Figs. 3, 4, and 5.

Spatial density

Figure 3 is a hand-contoured spatial density map of all known vein deposits and occurrences in the Trout Lake camp (i.e., 223 separate reported occurrences and producers). Deposits that have produced one or more short tons of ore are shown individually by numbers keyed to Table 3. For contouring purposes, a window of 2 km × 2 km with a 50% overlap was used. The number of deposits per counting cell (window) was assigned to the cell centre, and the resulting regular grid was hand contoured at intervals of 0.5, 2, 4, and 6 mineral occurrences per 4 km², to define three areas of high concentrations that correspond with three long-established "mineral belts", which are, from east to west, Lime Dyke, Central, and Southwest mineral belts. The western part of the Lime Dyke belt of Fig. 3 is referred to as the Mollie Mac belt.

The principal advantages of contouring spatial densities of deposit locations are that arbitrary boundaries to mining districts can be determined and various aspects of the "structure" of deposit locations within individual belts can be examined (Goldsmith and Sinclair 1983). In this case, it is apparent that nearly all past producers are located near highs of the spatial density contours.

The advantage of an empirical approach to determining areal extent of mining camps is that quantitative comparisons among camps then become possible. Limits to various mineral belts

TABLE 3. Production data (to 1976)

Read No.	Name	Recorded production (short tons)	Average metal grades: Ag (oz/ton)	Au (oz/ton)	Pb (%)	Zn (%)	Host rock: Formation	Rock type
9	Ritchie Group (Teddy Glacier)	6	12.330	0.667	15.70	24.82	Index	Limestone
13	Lead Star	13	47.770	0.077	26.32	10.71	Broadview	Chlorite schist
25	Mammoth	83	187.337	0.101	30.77	5.82	Index	Limestone (chlorite schist)
28	Kootenay Chief	21	50.000	ND	68.05	ND	Badshot	Limestone
30	Camborne/Goldfinch	1 450	0.124	0.463	ND	ND	Broadview	Chlorite schist (phyllite)
34	Eva	31 656	0.097	0.219	ND	ND	Broadview	Chlorite schist (phyllite)
36	Meridian	56 086	0.067	0.148	ND	ND	Broadview	Chlorite schist (phyllite)
37	Oyster	10 102	0.059	0.160	ND	ND	Broadview	Chlorite schist (phyllite)
45	Spider	141 169	12.180	0.084	8.47	9.00	Jowett (Broadview?)	Chlorite schist
49	Mohawk	9	48.220	ND	16.63	20.81	Broadview	Phyllite
54	Gilman	1	2.600	2.040	2.90	3.10	Broadview	Phyllite
71	Metropolitan	6	202.670	0.167	16.47	ND	Index	Limestone (chlorite schist)
79	Little Robert	3	114.000	ND	24.00	ND	Index	Limestone (schist)
85	Silver Queen; Silver King	26	50.000	ND	40.00	ND	Badshot	Limestone
86	Old Gold	28	90.530	ND	18.29	ND	Index	Phyllite
89	Badshot	50	146.259	ND	48.84	4.60	Badshot	Limestone
95*	Mike	2	12.500	ND	10.75	36.20	Below Index (Milford?)	Phyllite (quartzite?)
96	Beatrice	585	77.620	0.102	30.72	ND	Broadview	Chlorite schist (phyllite)
97	St. Elmo	206	80.058	0.092	26.41	9.07	Broadview	Phyllite
99	Blue Bell	66	46.470	0.150	29.95	8.92	Broadview	Phyllite
101	True Fissure	5 077	6.450	0.039	5.25	2.98	Broadview	Phyllite
102	Broadview	275	36.080	0.070	34.51	16.66	Broadview	Phyllite
112	Nettie Lake	12 820	36.389	0.061	5.11	28.24	Sharon Creek, Ajax	Phyllite, quartzite
114	Ajax	539	35.070	0.028	51.27	ND	Sharon Creek, Ajax	Phyllite, quartzite
115	Raven	4	42.750	ND	36.65	6.25	Ajax	Quartzite
130	Lade	13	ND	1.000	ND	ND	Index	Chlorite schist (phyllite)
136	Mohecan	9	55.000	0.010	27.19	ND	Index	Phyllite (schist)
137	Black Prince	30	154.770	ND	14.22	ND	Badshot	Limestone
146	High Grade (Ruffled Grouse)	14	171.780	ND	11.94	ND	Below Index	Phyllite
147	Copper Chief	14	138.285	ND	9.54	14.52	Below Index	Phyllite
148	Lucky Boy	421	206.306	0.008	25.80	ND	Below Index	Phyllite
153	Ethel	76	121.720	ND	8.33	ND	Below Index	Limestone
159	Winslow	1 788	0.172	0.333	0.02	0.001	Broadview	Chlorite schist (phyllite)
160	Towser	25	56.000	0.200	40.23	ND	Triune	Phyllite
164	Silver Cup	23 091	62.110	0.220	12.52	2.26	Triune, Index	Phyllite, tuff
167	Triune	653	221.940	0.529	37.89	6.68	Triune, Index	Phyllite
169	Foggy Day	9	13.880	4.333	4.60	ND	Broadview	Phyllite (schist)
173	Cromwell	15	14.867	4.267	0.22	0.32	Triune	Phyllite
174	IXL Fraction	7	55.710	1.143	26.98	ND	Index	Phyllite (schist)
176	Noble Five	11	72.184	0.273	17.53	6.83	Triune	Phyllite, limestone
180	Silver Belt	1	33.000	1.000	76.85	ND	Index	Limestone, chlorite schist
187	American	14	63.710	ND	64.84	ND	Index	Phyllite
198	Fidelity	44	65.159	0.718	27.48	ND	Broadview	Phyllite, schist

NOTES: ND, no data. Parentheses indicate host rock to subordinate amount of ore. Total number of deposits, 43.

are defined arbitrarily with the 0.5 deposit per 4 km^2 contour (Sinclair 1979; Goldsmith and Sinclair 1983), and on this basis, various features of the three belts of Figs. 3, 4, and 5 are compared in Table 4. Note the variation in spatial density of mineral occurrences. Productivity as measured by mean spatial density of deposits that have produced and mean spatial density of tonnage produced (tons per square kilometre also vary considerably (see Table 4).

The geographic distribution of the mean silver grades of past producers and the strike or strikes of individual veins are shown in Fig. 4. In general, silver grades are highest in the Lime Dyke and Southwest mineral belts, with one high value in the southeastern part of the Central mineral belt. The highest silver values in the Southwest and Central mineral belts are spatially associated with diorite or granodiorite dykes (Read and Wheeler 1976). High-tonnage silver deposits occur in the northwestern and central portions of the Central mineral belt. Strikes of productive veins tend to be parallel or subparallel to

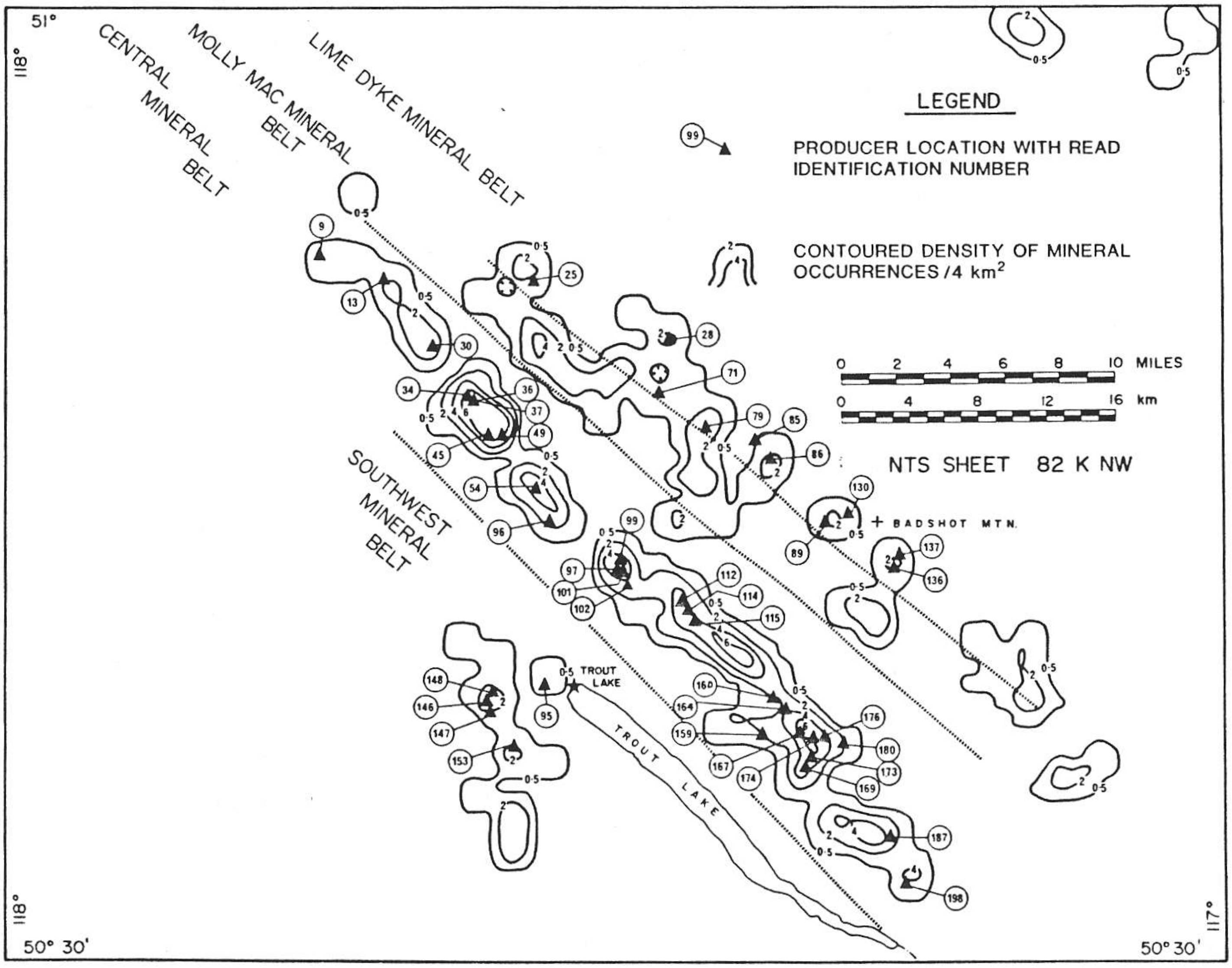


FIG. 3. Manually contoured spatial density map (number of mineral occurrences per 2 km × 2 km cell) for vein deposits in the Trout Lake area. Filled triangles are past and present ore producers, with circled numbers (Read No.) providing cross reference with tabulations in Read and Wheeler (1976) and in Table 3.

the strike of the host rocks; divergences appear to be caused by local variations in fold attitudes or to represent small transverse fissures extending outward from concordant or subconcordant veins.

Figure 5 shows gold grades of ore-tonnage producers. The Central mineral belt contains all of the deposits that have significant gold content and significant production. Four of five high-tonnage orebodies (more than 99 000 tons of the 101 000 tons total production) cluster in the northwestern end of the belt. Deposits with gold as the primary metal seem to occur at lower elevations than do deposits with silver as the primary metal.

Probability plot of ore production tonnage

Extracted ore tonnages are biased measures of sizes and relative values of deposits (Sinclair 1974, 1979). Consequently, the probability density function of production tonnages is of interest for use as an exploration guide. The histogram for vein "sizes" in a single camp can be commonly approximated by lognormal populations or mixtures of log-ability graph of production tonnages cumulated individually (from high to low tonnage) as suggested by Sinclair (1976) for small data sets ($n = 43$ in this case). The ND curve (cumulated number of deposits) shows the presence of two lognormal-size populations. A threshold of approximately 600 short tons separates the populations into large and small categories. The 13 largest producers (30% of total) are included in the upper population, and approximately 70% of all past producers are contained in the low-tonnage group. It is appreciated that some of the small past producers may have high-tonnage potential that has not been explored adequately, but the segregation into two classes focuses attention on the large deposits and their characteristics.

The CT curve of Fig. 6 is also constructed for individual deposits but depicts cumulative tonnage as a function of decreasing size of a deposit (Sinclair 1979). For comparison purposes, at a size corresponding to the smallest ore producer in the high-tonnage population (13th cumulated deposit: Lucky Boy, 421 tons produced) it may be seen that the 13 largest deposits account for more than 99% of the total tonnage pro-

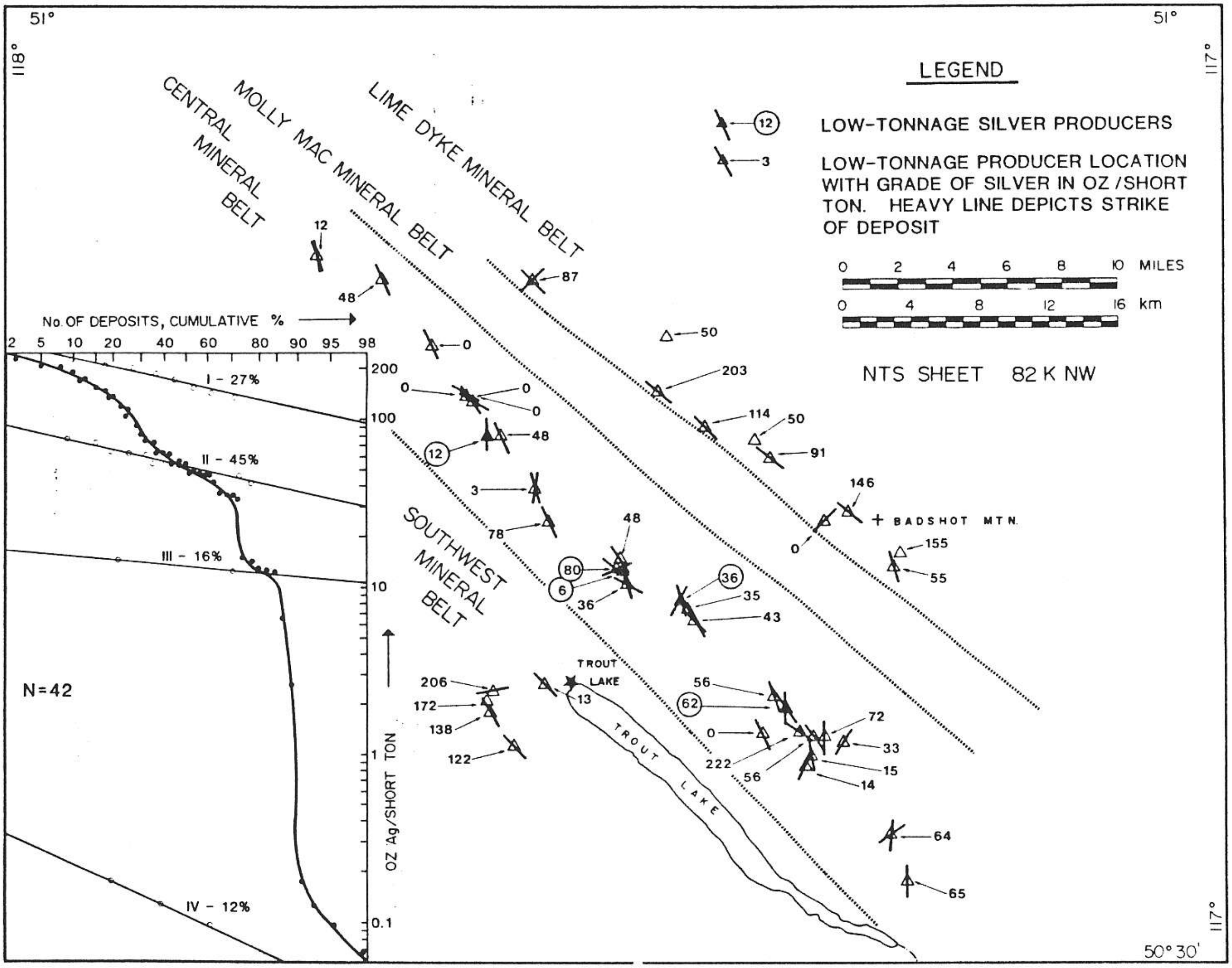


FIG. 4. Locations of high-tonnage and low-tonnage silver producers in the Trout Lake camp with average grades of silver (ounces per short ton) and strike of vein. Inset is a probability graph of mean silver grades interpreted as a combination of four lognormal grade populations (straight lines). Percentages by each population (straight line) are percentages of total deposits in each of the four categories.

High-grade gold deposits have only 2% of their mean grades below 0.250 oz/ton, a value above the upper grade of the high-tonnage gold ore producers. The low-grade gold population may contain two or more additional populations. An inverse relationship between gold grade and tonnage is indicated.

Lead and zinc

Figure 7 combines probability plots of lead and zinc. Two populations seem to be represented in each curve, possibly one normal and one lognormal. In both cases, the data base is too small to permit meaningful partitioning of the populations.

Metal content vs. production tonnage

Metal content is calculated as grade times tonnage, yielding total metal produced (ounces for precious metals, short tons for lead and zinc). Figure 8 is divided at 670 tons to focus attention upon the high-tonnage and medium- + low-tonnage groups.

Near-linear subparallel dispersions of metal contents versus production tonnage show that high-tonnage and medium- + low-tonnage deposits have produced on the average similar proportions of each commodity. Because total content of metals is a measure of the value of a deposit, the production tonnage can be used as a single measure of the relative worth of a deposit, obviating the need to sum several metal contents of a polymetallic deposit through the medium of fluctuating dollar values and metal prices (cf. Sinclair 1979). Consideration of total metal content rather than grades may also smooth some of the bias introduced by hand sorting of ore, particularly common for production from deposits of less than 1000 tons.

Variations in metal contents combine variabilities arising from both size and grade. Consequently, metal content can be a complex variable to interpret. Nevertheless, metal content appears to be extremely useful as a classification scheme for Lardeau vein deposits. Figure 8 is also of interest with respect to silver, which plots in two separate linear groupings of data that can be approximated by two subparallel lines. The lower group represents low-grade silver deposits; the upper group represents high-grade deposits. The two groups overlap substantially in terms of tonnage, but their separation is facilitated because of the second dimension (metal content) present in the classification scheme.

These data also support the suggestion by Sinclair (1979)

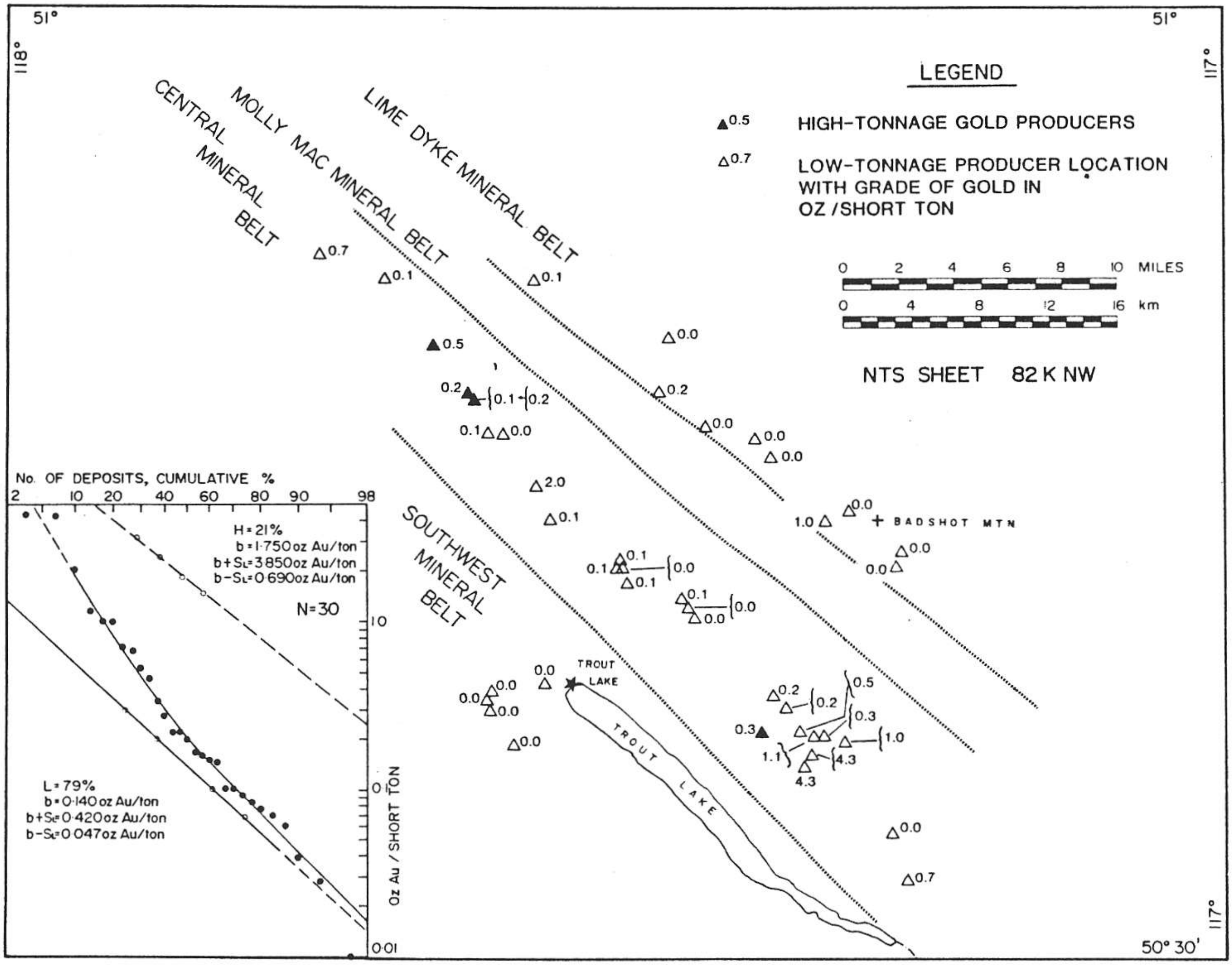


FIG. 5. Locations of high-tonnage gold producers (closed triangles) relative to other types of producers (open triangles) in the Trout Lake camp. Gold grades (ounces per short ton) are shown for each deposit. Inset is a probability graph of 30 available average gold grades. Filled circles are cumulated individual values whose distribution is approximated by a smooth curve. The curve is interpreted as a mixture of two populations estimated by the condition (lower) and dashed (upper) straight lines. Parameters of the lognormal distributions are determined graphically as the geometric mean b and the central 68% data range ($b + S_L$ to $b - S_L$). The percentage of each population is indicated.

that tonnage is a reasonable relative value measure for vein deposits, although in this case an added complication exists in the form of two linear trends of tonnage versus silver content.

Triangular graphs

Triangular plots show clustering of deposits in terms of three elements. However, it is important to realize that absolute abundances are lost for data plotted on such diagrams where three elements that form a small percentage of the whole are being considered, as is the case with average ore grades from the Trout Lake camp. For purposes of clarity, silver and gold are maintained as oz/ton and lead and zinc as percent metal in constructing the triangular plots shown in Fig. 9. The advantage of this procedure is that lines from a vertex to the opposite side of the triangle can be labelled directly in terms of commonly used metal ratios such as Ag (oz)/Pb (%), Au (oz)/Zn (%), Pb/Zn, and Ag/Au.

Distinctive symbols are used for high-tonnage silver ore producers, high-tonnage gold ore producers, and low-tonnage producers. Fig. 9*a*, the silver–lead–zinc plot, shows (1) that zinc is generally subordinate to lead, and (2) that the silver/lead ratio (oz/%) is highly variable but only rarely is less than one. Note that in Fig. 9*a* a line drawn from the zinc vertex to the opposite side of the triangle defines a constant Ag/Pb ratio, in this case, in ounces of silver per percent of lead. For example, the line from the zinc vertex of the Au–Pb–Zn plot to the midway position on the opposing triangle face represents a ratio of 1 oz Ag for each percent of lead. Both high- and low-tonnage silver deposits plot in comparable fields: both are relatively high in silver. The two low-zinc deposits with lowest proportions of silver to lead are contained in the Broadview formation (grits), whereas the other deposits with higher proportions of silver to lead are largely in the Sharon Creek – Ajax and Triune–Index formations (slate–phyllite). Only one high-tonnage gold ore deposit has recorded lead and zinc values for production, and average lead and especially zinc grades are extremely low. The remainder of the deposits where gold is the primary metal product have a comparable low base-

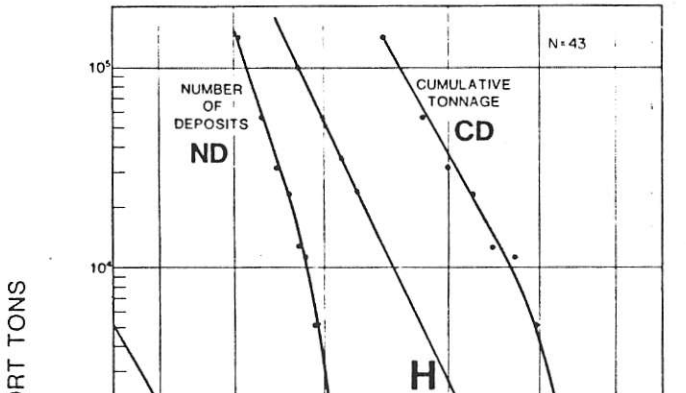


FIG. 6. Probability graphs of production tonnages, Trout Lake camp. In curve ND number of deposits are cumulated, whereas in curve CT total production tonnage is cumulated; in both cases cumulation is from high values to low. Curve ND is interpreted as a mixture of two lognormal size (production tonnage) populations shown as two straight lines (Sinclair 1976, 1974). Percentages and parameters of these populations as determined graphically are shown as geometric mean b and the central 68% range of data from $b - S_L$ to $b + S_L$ where these latter two expressions are the 84th and 16th percentiles of the lognormal populations.

metal content; consequently, they would cluster on the silver–lead line near the silver vertex.

Figure 9*b*, silver–gold–lead, depicts the relationship of silver and lead more forcefully. There are no gold–lead deposits without appreciable silver content. High-tonnage silver ore deposits lie near the silver–lead line. Gold is invariably present, but its share of the total metal content is small. The pair of large-tonnage silver ore deposits with ratios that plot midway between silver, gold, and lead occurs in the Broadview Formation, as noted previously, whereas deposits with higher proportions of silver to lead are contained in older formations. High-tonnage gold ore deposits plot on the silver–gold line where the proportions of silver/gold are approximately 25:75.

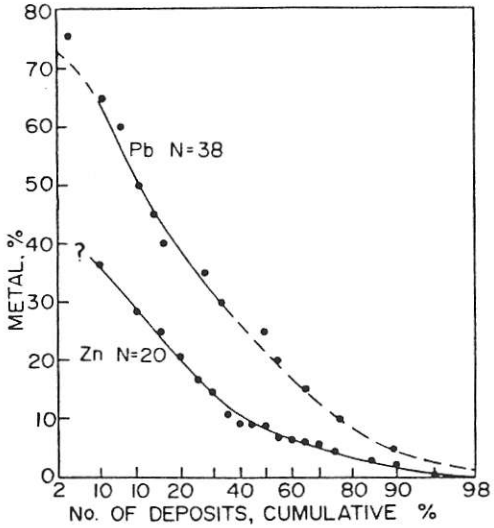


FIG. 7. Probability graphs for mean Pb grades and mean Zn grades of all past producer veins at Trout Lake mining camp.

Figure 9*c*, silver–gold–zinc, shows a pattern similar to that of the silver–gold–lead graph with the exception that one of the large-tonnage silver deposits in rocks older than the Broadview Formation has a slightly lower silver/zinc ratio than do the Broadview-hosted deposits. Besides the group of high-tonnage gold ore producers that cluster near silver/gold proportions of 25:75, there appears to be a group of low-tonnage silver ore deposits that have a very low gold content. Two populations of silver–gold deposits therefore may be indicated: one with low quantities (less than 0.500 oz/ton) of both silver and gold, and the other with high quantities of silver (greater than 15 oz/ton) and low quantities of gold (less than 0.500 oz/ton). An overprinting of one population upon the other could explain the several deposits where either silver or gold grades could have made the property economic. There are no gold–zinc deposits without recorded silver content.

In summary, triangular diagrams provide a useful means of examining groupings or classifications of deposits in Trout Lake mining camp on the basis of metal ratios. High-tonnage gold deposits stand out as a distinctive cluster based exclusively on the Au/Ag ratio (~ 75:25). High- and low- tonnage Ag deposits are all relatively rich in Ag (Ag/Pb = 1 oz/1%) and plot in more or less coincident fields. The two size groupings thus appear to be entirely due to structural controls. Note that low-silver lead–zinc replacements in limestone have not been considered in discussion of these diagrams because of the scarcity of multielement production data.

Simple correlation of metal grades and production tonnage

Probability graphs presented in Figs. 4–7 show that grade and tonnage variables for Trout Lake camp have complex frequency distributions that can be interpreted as mixtures of two or more lognormal populations. Consequently, simple correlation coefficients can be viewed only in a semiquantitative manner when interpreting their statistical significance. Nevertheless, these coefficients can be used as an indication of the relative goodness to which two variables are related in linear fashion. Simple linear correlation coefficients for Trout Lake mean grades and production tonnages are provided in Table 5 for log-transformed data.

These data are shown in a correlation diagram in Fig. 10 where deposit relative value (as depicted by production tons) is seen to be inversely correlated with precious metals and uncorrelated with average base-metal grades. From these data, the

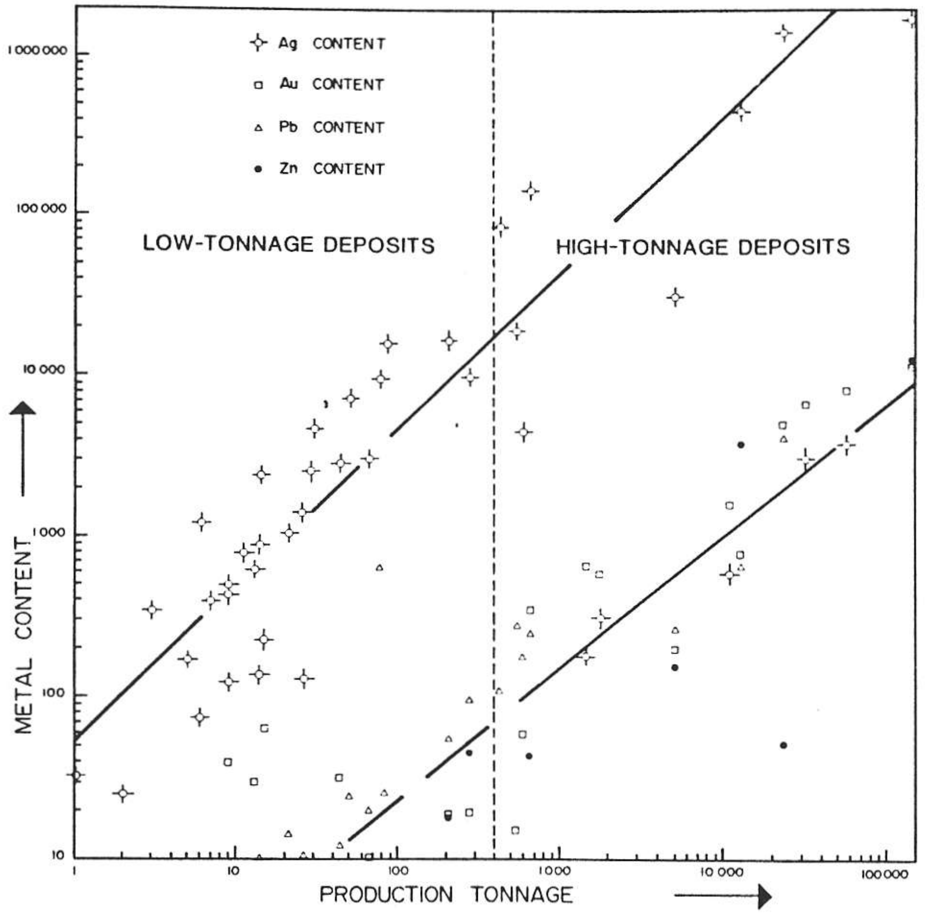


FIG. 8. Metal contents versus production tonnages, Trout Lake mining camp. Diagonal lines accentuate two groups of silver deposits based on size and silver content.

best single estimator of potential size is log (Ag grade), although it is apparent that silver grade does not provide a particularly good estimator of potential deposit size.

The strongest linear relationship indicated in the correlation matrix is Pb vs. Ag ($r = 0.72$) for which a linear relationship explains 52% of the variability. This linear relationship quantifies the close association of silver and lead that is characteristic of many deposits throughout the Kootenay Arc.

One of the aspects of production data that we are concerned with is the possibility that grades vary in a regular way as a function of deposit size. It is apparent that the best individual element (Ag) to use as a basis for estimating deposit size by production tonnage will suffer from a very large error. To improve this situation, the interrelation of all elements with tonnage will be examined through the application of multiple regression techniques.

Multiple regression applied to forecasting deposit size

Multiple regression techniques have been used in a few cases (Orr and Sinclair 1971; Sinclair 1972, 1982) to develop quantitative models that determine a value measure of polymetallic vein deposits as a function of known mean grades. The general methodology is based on the empirical relationship suggested by Sinclair (1979):

$$\log_{10} (\text{production tons}) = \beta_0 + \Sigma\, \beta_i \log_{10} (M_i) \pm e$$

where β_0 and β_i are constants and e is a random error. Constants differ from one mining camp to another, but in general e is small relative to the range of production tonnages (about six orders of magnitude) for a given vein camp (Goldsmith and Sinclair 1985). Production tonnages of past producers therefore define a single continuous relative value measure for polymetallic vein deposits. The approximate linear relationship of log (metal contents) to log (production tonnages) is demonstrated clearly in Fig. 8 for Trout Lake camp, leading to the possibility of establishing a quantitative model for "value" of a vein deposit in the camp in terms of known average grades (Goldsmith and Sinclair 1985). The advantages of such a model are at least twofold. (1) Individual deposits that are outliers from the model are "anomalous" and warrant examination in detail. Thus, the model approach results in specific targets being isolated for detailed examination. (2) Average grades based on sampling of newly found deposits can be substituted in a camp model to provide insight into resource potential.

For Trout Lake camp past producers form three groups: (*i*) Ag–Pb–Zn deposits, (*ii*) Au deposits low in Pb and Zn, and (*iii*) a combination of the two foregoing groups where type (*i*) apparently has been superimposed on type (*ii*). In general, the Ag–Pb–Zn deposits have been small producers, whereas Au deposits have been relatively large producers (see Table 2). Average production grades for four metals are available for 14 separate deposits in Trout Lake camp. An additional four deposits have known average Au and Ag grades and extremely low Pb and Zn grades that were not measured. Grades of 0.1% for both Pb and Zn in these deposits have been substituted because it is not possible to take logarithms of zeros. These 18 deposits serve as the basis for a multiple regression analysis

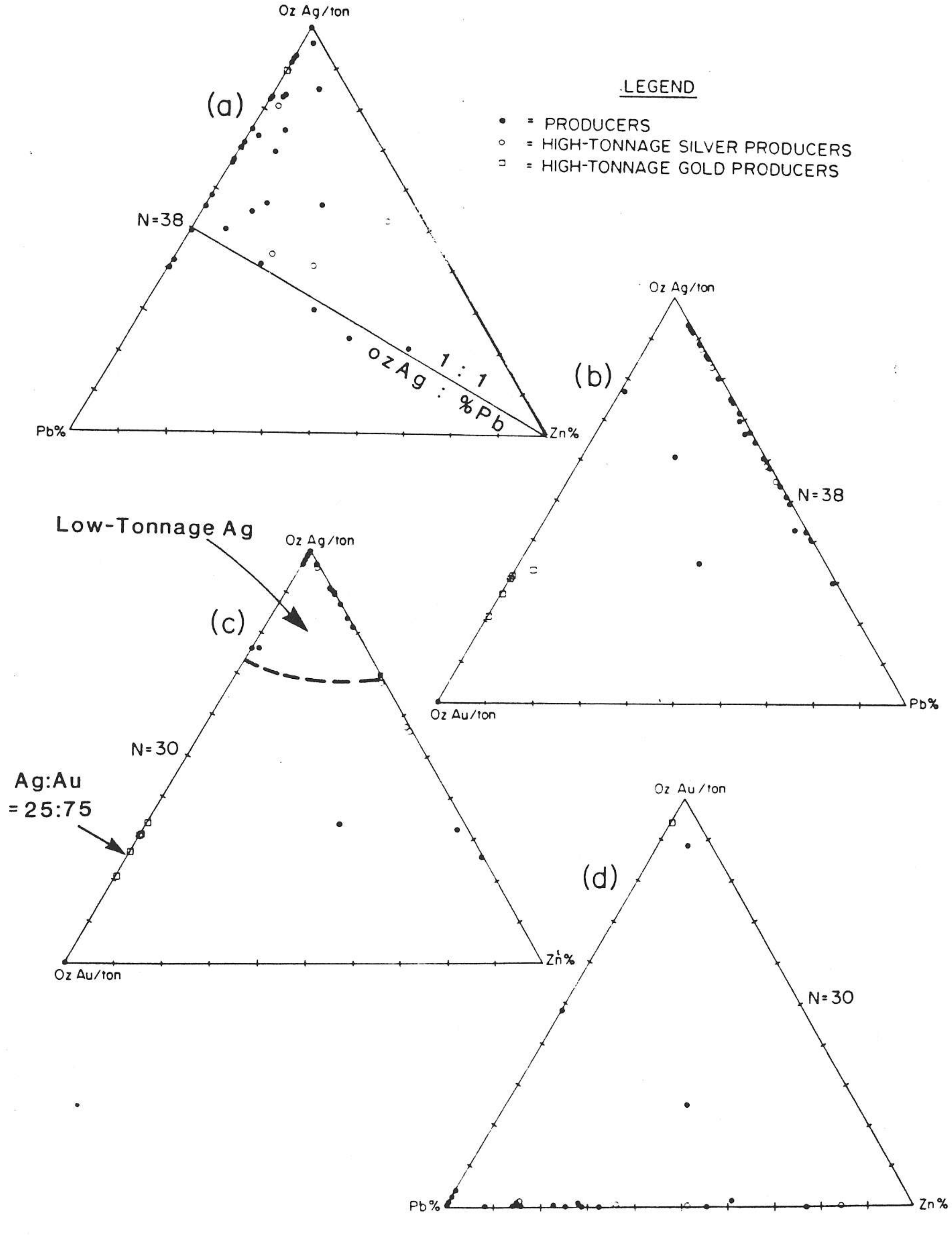


FIG. 9. Triangular graphs for average deposit grades, Trout Lake mining camp (Goldsmith and Sinclair 1984).

TABLE 5. Correlation matrix for logarithmic values of production data from 43 producers, Trout Lake mining camp*

	Tons	Ag	Au	Pb	Zn
Tons	1.00				
Ag	−0.49	1.00			
Au	−0.41	−0.18	1.00		
Pb	−0.20	0.72	−0.33	1.00	
Zn	−0.07	0.13	−0.58	0.56	1.00

*Absolute values above 0.4 are underlined.

with production tons as the dependent variable and average production grades as independent variables. The model obtained is

$$\log(\text{tons}) = 1.917 - 1.995 \log(\text{Au}) - 0.907 \log(\text{Pb}) \pm 1.089$$

with $R^2 = 0.57$. In other words, the potential size of a deposit as measured by log (tons) can be estimated within a standard error of about an order of magnitude using only the average Au and Pb grades. Moreover, low grades of both Au and Pb indicate relatively large tonnages. Of these two variables Au is correlated most highly with tons (for log (Au) and log (tons), $r = -0.50$). Thus, Au grade alone is a relatively good indicator of potential size.

Models of this sort are empirical, and while they can be used to interpolate, it is unwise to extrapolate with a model beyond the limits of data on which it is based. Consequently, the model quoted above would be considered unrealistic if estimated tonnages approached or exceeded one million tons.

An alternative approach to the use of two mineral deposit types assumed to be two extremes of a continuum in the preceding example is to develop a multiple regression model within a single deposit type. This has been attempted for the Ag−Pb−Zn vein category, that being the only group for which sufficient data are available. Data exist for 12 deposits and lead to the following model obtained by backward stepwise regression:

$$\log(\text{tons}) = 1.128 - 1.239 \log(\text{Au}) \pm 0.995$$

with $R^2 = 0.44$. The variables Pb, Zn, and Ag have dropped out of the equation because their coefficients were found to be indistinguishable from zero at the 0.05 level. A striking feature of this result is that Au is the most important "value" estimator in a deposit type in which the Au content is of little economic importance relative to the much more abundant metals (Ag, Pb, and Zn).

Deposits without recorded production

A search of the available literature did not locate grade data for well-sampled mineral deposits from which no production exists. Several channel samples over a length of at least 4 ft were considered a minimum upon which to characterize metal grades for use in multiple regression models. Should this information be available in private files for specific deposits, the multiple regression models derived from production records might be applied as an evaluation procedure. Assay data for all four metals (Ag−Pb−Zn−Au) should be collected during future evaluations in the Trout Lake area for use in the most satisfactory of the multiple regression models.

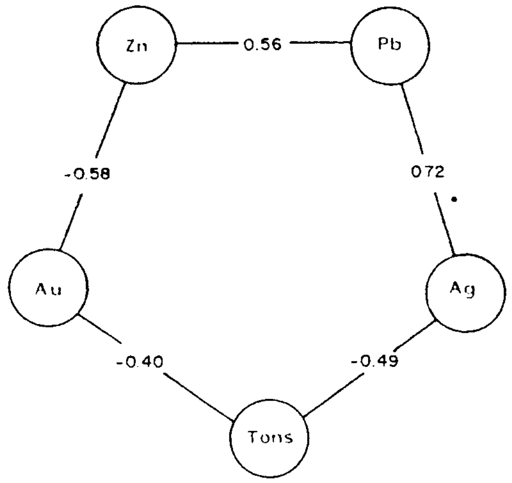


FIG. 10. Correlation diagram for mean metal grades and production tonnages, Trout Lake mining camp. Deposit size (tons) is negatively correlated with both Au and Ag grades.

Conclusions

A rigorous, systematic evaluation of quantitative production and location data for Ag−Au−Zn−Pb veins in the three mineral belts of the Trout Lake mining camp, British Columbia, provides useful insight to a variety of mineral exploration decisions as follows:

(1) Comparative exploration success rates as indicated by past productivity show the Central mineral belt to be the most productive per unit area. Assuming equal intensity of exploration among mineral belts and representative success rates in all cases, highest productivity may imply highest potential for exploration.

(2) High concentrations of small mineral occurrences are favoured sites for the location of relatively large Ag−Au−Zn−Pb vein deposits in Trout Lake camp.

(3) Probability graphs demonstrate that two principal size categories of vein producers exist in Trout Lake camp, where size is indicated by production tonnages of ore and is structurally controlled. Detailed field studies of structural control are required to characterize the two populations.

(4) Probability graphs indicate the likely existence of four fundamentally different categories of average silver grades. These grade categories correspond to (*i*) low-tonnage, high-grade silver ore deposits; (*ii*) large-tonnage, high-grade silver ore deposits; (*iii*) large-tonnage, medium-grade silver−gold ore deposits; and (*iv*) large-tonnage gold deposits with very low silver grade.

(5) Production tonnage is demonstrated to be an adequate single value estimator of relative value of an Ag−Au−Zn−Pb deposit in Trout Lake camp. Consequently, production tonnage will serve as a dependent variable representing deposit value in mathematical modelling.

(6) Triangular graphs emphasize the relationship between silver and lead and the apparent independence of gold from other metals. Large-tonnage silver ore deposits with low silver/lead ratios may occur in the Broadview Formation; deposits with higher proportions of silver to lead are contained in older formations.

(7) A matrix of simple correlation coefficients based on all deposit types as a single group shows that average precious-

metal contents (especially silver) are more closely related (inversely) to deposit size (production tonnage) than are base-metal average grades.

(8) A multiple regression model for production tons in terms of four average production grades (Ag, Au, Zn, Pb) forecasts tonnage with a standard error of about one order of magnitude. Such a model applied to average grades may forecast deposit size early in the exploration of a newly found deposit. Practical applications of the multiple regression model might be based on either or both of diamond drill or channel (surface and underground) samples.

Acknowledgments

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