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Hon. Anne Edwards, Minister

MINERAL RESOURCES DIVISION
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OPEN FILE 1993-30

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Canadian Cataloguing in Publication Data
McTaggart, K.C., 1919-
Geochemistry of lode and placer gold of the Cariboo District, B.C.

(Open file, ISSN 0835-3530 ; 1993-30)

Issued by Geological Survey Branch.
Includes bibliographical references: p.
ISBN 0-7726-1975-1
1. Gold ores - Geology - British Columbia - Cariboo Region. 2. Placer deposits - British Columbia - Cariboo Region. 3. Veins (Geology) - British Columbia - Cariboo Region. 4. Prospecting - British Columbia - Cariboo Region. I. Knight, John Bruce. II. British Columbia. Ministry of Energy, Mines and Petroleum Resources. III. British Columbia. Geological Survey Branch. IV. Title. V. Series: Open file (British Columbia. Geological Survey Branch) ; 1993-30.

TN424.C3M47 1993 553.4'1'0971175 C93-092418-5

BRITISH COLUMBIA
CANADA

NOVEMBER 1993

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# INTRODUCTION

This report provides new data on the composition of gold from various lodes and placers in the Cariboo area, southern British Columbia. This material is based on more than 3600 electron microprobe analyses and is complementary to previous research reports (Knight and McTaggart, 1986, 1989, 1990).

The bedrock geology of the district has been discussed by Holland (1954), Sutherland Brown (1957), Struik (1988), Bloodgood (1990) and many others. Stratigraphic studies of the auriferous gravels have been made by Johnson and Uglow (1926), Clague (1987), Eyles and Kocsis (1989), Levson *et al.* (1990), Levson and Giles, (1991) and Rouse *et al.* (1990).

A main objective of this research is to characterize gold by its suite of minor elements. One can then attempt to trace the path of gold from lode to placer by thus fingerprinting different lode sources. In addition, the composition of lode gold is a parameter used in the genetic classification of gold deposits. In general, gold from epithermal lodes has a lower fineness and a wider range than gold from mesothermal lodes (Morrison *et al.* (1991). The study of textures of placer gold yields information on conditions and distance of travel.

Placer and lode gold are rarely pure but are alloyed with other elements such as silver, copper and mercury. Early studies on the composition of gold were made before the electron microprobe was developed and Boyle (1979) provides an exhaustive summary of this research. One of the early studies is that of Warren and Thompson (1944) who analyzed gold from many areas, mainly British Columbia, by spectrographic techniques. Holland (1950) lists fineness values for many placers in British Columbia. Microprobe studies include those of Desborough (1970) who has studied placer gold from many localities in the United States, Giusti (1983) who reported on the compositions of placer gold from Alberta, and Guindon and Nichol, (1982) who studied gold from Ontario.

This report presents new compositional data on lode and placer deposits from the Cariboo area and the reader may find it useful to compare these results with those in earlier reports of Knight and McTaggart, (1986, 1989, 1990).

## ACKNOWLEDGMENTS

This work has been supported by grants from Placer Dome Corporation, Westmin Resources Ltd., the British Columbia Ministry of Energy, Mines and Petroleum Resources, Chuck Fipke and The University of British Columbia. Gold samples were provided by those listed in Table 1 and without these donations this work would have been impossible.

We are pleased to acknowledge the assistance of Yvonne Douma in solving the problem of mercury contamination during polishing. We would like also to thank Ed Montgomery for using his skills in producing a photographic record of placer gold.

Victor Levson read an early version of this paper and made many useful suggestions.

We are particularly grateful to Kathy Wilkie and Margaret McTaggart for their assistance in collecting several of the gold samples described in this report.

# METHODS

## SAMPLE PREPARATION

Gold samples (for locations *see* Figures 1 to 4, in pocket) were either donated or collected in the field by the authors (Table 1). Vein quartz was crushed and ground to sand size and the gold recovered by panning. The sample numbers (Table 1) are the permanent numbers of a collection of gold samples housed at The University of British Columbia.

All placer and some lode particles were photographed so that textural features could be related to composition. Gold particles which are to be photographed, numbered, analyzed and subsequently identified must be large enough to be manipulated by needle or tweezers; the practical lower size limit is about 0.2 millimetre although particles as small as 60 microns have been mounted.

Particles are embedded in plastic cylinders, ground and polished (Douma and Knight, 1992, in press). The gold is examined with a reflecting microscope for contamination, inclusions and heterogeneities before being carbon-coated.

## ANALYTICAL TECHNIQUES

Analyses were made using a SX-50 Cameca microprobe at 100 na (minimum spot size 2 microns), 20 KV using gold M alpha, silver L alpha, copper K alpha, mercury M beta lines, and counting time of 30 seconds on peak. The detection limit for gold is 0.019 weight percent, silver 0.013 weight percent, mercury 0.06 weight percent and copper, 0.025 weight percent at 99 percent confidence (3X sigma of background counts). All analyses are reported in weight percent. Precision in analyses is 0.270 weight percent (1 sigma). Accuracy on pure gold is 99.85 weight percent (1 sigma=.33), and for gold of 800 fine, 1 sigma=1.46 fine.

Preliminary testing of gold from British Columbia indicates that only three elements, silver, copper, and mercury occur at greater than detection limits. This conclusion is in agreement with Holland (1954) who found that in gold from the Yanks Peak area only copper and mercury were consistently present as trace elements. For these reasons testing for other elements is not done routinely. Pre-microprobe studies suggested that gold commonly contains a large variety of elements in easily measureable amounts but that early work, mainly spectroscopic, was by necessity done on large specimens that contained mineral inclusions. In current studies with a microprobe, investigators can examine gold samples under high magnification and thus avoid mineral inclusions.

The analytical results are displayed in two ways: firstly, on scatter plots (Figures 1 and 3) in which weight percent of mercury is plotted against fineness; each cross represents the composition of a single gold particle. Secondly, as histograms (Figures 2 and 4), which show the frequencies of various finenesses in each sample.

TABLE 1
LIST OF SAMPLES

| SAMPLE NAME | NUMBER | SOURCE | NO. OF PARTICLES |
|---|---|---|---|
| LODE SAMPLES ANALYZED | | | |
| B.C. Vein | 594 | panned from dump | 24 |
| *Burns Mountain | 502 | Mike Poshnor | 50 |
| Burns Mountain | 523 | Doug Radies | 1 |
| Cariboo Gold Quartz Mine | | U.B.C. | 10 |
| Cow Mountain | 547 to 551 | Peter Bradshaw | 81 |
| Cow Mountain veins | 589 | panned at outcrop | 35 |
| Forrest claim | 587 | panned at workings | 31 |
| Foster's Ledge | 493 | quartz from dump | 5 |
| Midas | 124 | Jim Logan | 54 |
| Mosquito Ck. Mine | 497, 499 | Richard Hall | 8 |
| **Mount Calvery | 136 | Brendan Gordon | 2 |
| Myrtle | 595 | panned at workings | 65 |
| Spanish Creek | 611 | Gerhard von Rosen | 21 |
| Spanish Mountain (CPM) | 365 | Rick Honsinger | 6 |
| Spanish Mountain (CPM) | 400 | M.A.Bloodgood | 8 |
| Spanish Mountain (CPM) | 401 | M.A.Bloodgood | 32 |
| Wells Adit | 588, 590 | panned from dump | 16 |
| Warspite | 586 | panned from dump | 44 |
| PLACER SAMPLES ANALYZED | | | |
| *Ballarat-St.George's | 500 | Bert Ball | 81 |
| Bassford Creek | 18 | Harry Warren | 19 |
| Beaver Pass | 251 | W.R.Danner | 50 |
| Beggs Gulch | 472 | Bud Wilkinson | 98 |
| Bullion Pit | 406 | A.Panteleyev | 9 |
| Burns Creek | 494 | Guy Carter | 80 |
| California Gulch | 501 | Mike Poshnor | 101 |
| Cariboo River | 462 | John Clague | 37 |
| Cariboo River | 529 | Paul Richardson | 93 |
| Cariboo River Bench | 531 | Paul Richardson | 98 |
| Cariboo River Bench | 605 | Lloyd Tattersall | 28 |
| Cariboo River Bench | 607 | Lloyd Tattersall | 104 |
| Cottonwood | 374 | Gerhard von Rosen | 74 |
| Coulter Creek | 599 | Vic Levson | 94 |
| Cunningham Creek | 496 | Ralph McPerson | 98 |
| Cunningham Creek | 536 | Paul Richardson | 91 |
| Devlin Bench | 598 | Sam Taylor | 28 |
| Dragon Creek | 107 | David Caulfield | 89 |
| Drygulch | 522 | Guy Carter | 103 |
| Eight-Mile Lake | 123 | Bruce Tuff | 105 |
| Fraser River | 135 | Len Knudson | 46 |
| Frye Creek | 187 | Gordon Lund | 105 |
| Gold Creek | 612 | Vic Levson | 107 |
| Hixon Creek | 495 | Bud Helekson | 94 |
| Jerry Creek | 439 | Ron Schafer | 80 |
| Keithley Creek | 603 | John Nap | 9 |
| **Lightning Creek | 19 | H.V.Warren | 43 |
| Lightning Creek | 470 | Oswald Weist | 88 |
| Little Swift | 78 | Karl Sandor | 28 |
| Lowhee Gulch | 596 | panned at gulch | 67 |
| Mary Creek (Toop) | 146 | T.Toop | 160 |
| Maude Creek | 593 | Ed Darvill | 100 |
| Montgomery Creek | 597 | Bob Mars | 43 |
| Morehead Creek | 614 | D.Schindelhauer | 96 |
| *Mosquito Creek | 518, 519 | Anita Brock | 86 |
| Nelson Creek | 59 | Dave Caulfield | 20 |
| Oregon Gulch | 471 | Max Lysakowski | 73 |
| Quesnel River | 530 | Paul Richardson | 88 |
| Quesnel Canyon | 461 | Anita Brock | 104 |
| Slough Bench | 228 | David Caulfield | 97 |
| Sovereign Creek | 60 | David Caulfield | 20 |
| Spanish Creek | 553 | Paul Richardson | 28 |
| Spanish Creek | 604 | Byron Knelson | 2 |
| Spanish Mountain | 554 | Paul Richardson | 75 |
| Sugar Creek | 108 | David Caulfield | 171 |
| Summit | 364 | Raymond Morris | 49 |
| Tertiary Mine | 133 | Len Knudson | 70 |

** Contaminated with mercury*
*** Exact location unknown*

'Fineness', a term commonly used to represent the proportion of gold to silver in alloys of those metals, is calculated by the formula:

fineness =1000 X %Au / (%Au + %Ag).

Thus a nugget that is 90 percent gold and 10 percent silver has a fineness of 900, or is said to be 900 fine.

# TEXTURAL FEATURES OF GOLD PARTICLES

Gold grains show much variety in shape (Knight and Morrison, in preparation). Gold freed from lodes is extremely irregular and consists of aggregates of blebs, intersecting flakes, crystals and wires.

Placer grains also exhibit a wide range of textures. Many placer gold particles from the Cariboo District are relatively thick and possess rough rather than smooth surfaces; many are irregular in outline. Some particles are crystals showing slight deformation or abrasion; others are thin flakes with intermediate dimension up to 10 times the least dimension, commonly of elliptical outline, and many have smooth surfaces. Some particles have been wrinkled, folded or torn. Some placer samples contain examples of most of these textural types.

These modifications to particles derived from lodes are the result of river and glacial transport and are useful in estimating the relative distance of transport, as Knight and Morrison (in preparation) have demonstrated for the Klondike.

# CHEMICAL CHANGES IN THE SURFICIAL ENVIRONMENT

## GOLD RIMS

Nearly all placer samples studied included gold grains with complete or partial rims (Plate 1). These rims consist of zones of nearly pure gold forming an outer coat to the placer grain. They range in thickness from a few microns to 20 microns or more, are invariably of high fineness (970-999) and are devoid of copper and mercury. Placer particles of high fineness have, in general, thinner rims than gold of low fineness.

There has been much discussion of the origin of placer gold rims. Two main hypotheses are: they are formed by accretion as a coat or outer zone of new gold on the original

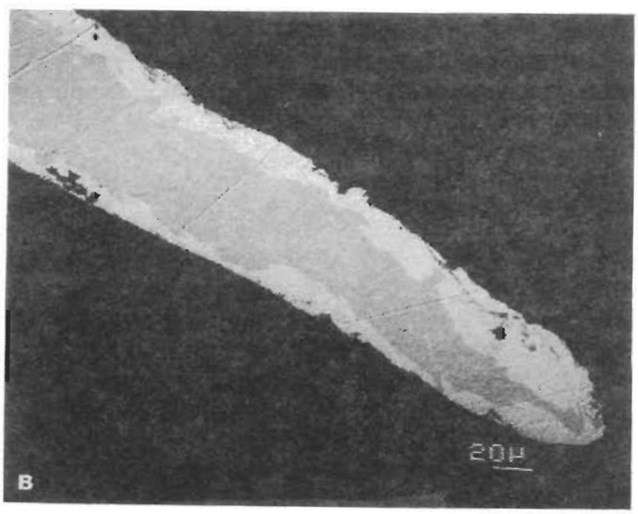



Plate 1. Polished cross-section of a flat placer gold particle showing rimming, from Fraser River.

gold grains; or secondly, they are formed by removal of silver from the outer part of the gold-silver alloy grains by solution or by a complex replacement process. Knight and McTaggart, (1990) concluded from observation and experiment, that rims on gold in the Cariboo are the result of removal of silver and other metals from the margins of the placer grains.

In general, rimmed gold will yield a higher smelter return than unrimmed gold simply because the rims are of nearly pure gold. This fact may explain, in part, why placer gold has been found in some areas to be finer in composition in downstream placers than in placers of the headwaters; the downstream gold has been longer in the surficial environment and its rims are relatively thick.

## 'NEW' GOLD

Gold found in certain gravel deposits, interpreted to be not of detrital origin but rather formed by precipitation from groundwater or low temperature hydrothermal solutions at that site, is referred to as 'new' gold.

Gold particles deposited from solutions within a limited space where environmental factors such as pressure and temperature are uniform should, in theory, all have the same composition. The authors consider that only gold in equilibrium with surface, low temperature, and low pressure conditions, forms the rims described previously, the compositions of which approach pure gold. It is significant that 'new' gold from other areas (*e.g.* Mann, 1984; Lawrence, 1988) has also been determined to be almost without exception, nearly pure gold.

There has been no placer deposit sampled during this research in which all of the gold is of high fineness or of uniform composition. In addition, most of the gold has the form of clastic grains which have been more or less abraded, flattened or otherwise modified during water transport. Furthermore, placer gold inclusions identified in this research are mainly angular quartz and pyrite and fluvially rounded inclusions were not found. Many placer samples are compositionally similar to gold in nearby lodes, strongly suggesting that they were derived from them and did not form as reprecipitated, 'new' gold. For example, in the Coquihalla district copper-rich placer gold can be related to nearby lodes that carry copper-rich gold (Knight and McTaggart, 1990). In the Cariboo placer gold samples from Lowhee Gulch (596), Coulter Creek (599), Mosquito Creek (518, 519) are similar to lode gold from Cow Mountain.

For these reasons it is believed that the placer gold described in this research is not 'new' gold, but has been derived ultimately from lodes and has, in the surficial environment, undergone natural leaching or replacement to produce rims.

Although 'new' gold does not appear to be important in the formation of the placers so far sampled, it has been found in a lode at Blackdome Mine (Knight and McTaggart, 1989) where spongy gold of high fineness is apparently formed by the breakdown of a rare gold-silver sulphide. Almost all examples of 'new' gold described from other parts of the world occur as spongy gold or as plates or films less than 0.1 millimetre across and associated with strongly oxidized zones (Lawrence, 1988; Vasconcelos and Kyle, 1989). Gold contaminated with mercury may also have a spongy texture and may be mistaken for 'new' gold. Eyles (1989), for example, interpreted 'filamentous' gold to be 'new' gold welding placer gold particles together but he did not consider the possibility of mercury contamination.

The authors have not recognized 'new' gold in placer samples from British Columbia.

## THE SOLUTION AND REDEPOSITION HYPOTHESIS

Johnson and Uglow (1926, p. 215), whose memoir on the Barkerville area was written while lode mining there was in its infancy, were struck by the scarcity of free gold in unweathered vein material. For this and other reasons, they concluded that, "Deep decomposition of the veins permitted oxidation of the sulfides and removal of the soluble constituents. Part of the fine gold thus set free from the sulfides formed enrichments in the oxidized parts of the quartz veins. Gold enrichment also took place by a process of alternate solution and deposition of the free gold in the form of crystals, crystal groups, plates or veinlets, and irregular masses, in cracks and cavities in the veins and adjacent country rock near the base of the zone of oxidation. The crystal groups, plates, and irregular masses thus formed, and subsequently modified by the action of the streams, are the main source of the nuggets in the gravels"

The following, more recent data, do not support the conclusion that lode gold has been dissolved and reprecipitated.

- Hanson (1934, page 48A), who studied the area after the veins were developed at depth, pointed out that coarse free gold was abundant in the veins and that "unoxidized veins could also supply gold to the placers." Plates and crystals of free gold, up to several millimetres across, have been found in the Cariboo Gold Quartz mine well below the zone of oxidation. He implied that the solution-redeposition hypothesis was unnecessary.
- In other parts of the world where recrystallization has taken place under surface conditions, the resulting new gold almost invariably has a fineness close to 1000 and is mostly less than 0.1 millimetre across. This is in agreement with the composition of rims on placer gold from the Cariboo which, it is argued, formed subaerially by the removal of silver and is the stable composition in the surficial environment. Very few particles or crystals of this purity have been found in the present study except for a few in the Eight Mile (123) and Dragon Creek (107) placers (Figure 4).
- This research shows that gold samples from underground and surface workings are similar, (compare underground samples from Cariboo Gold Quartz mine with surface samples from lodes on Cow Mountain) and, furthermore, similar gold is found in nearby placers.

These observations cast serious doubt on Johnson and Uglow's hypothesis.

The authors have made no compositional studies of nuggets larger than about 2 millimetres across. The composition of a Cariboo nugget described by Uglow and Johnson (1923) is about 820 fine suggesting that it is not 'new' gold. Indeed, if small particles are not 'new' gold, it is unlikely that nuggets are.

# QUALITY AND NATURE OF SAMPLES

It is probable that donated placer samples have undergone some selection, certainly regarding particle size but also with respect to colour, staining or shape. A great problem in a study which depends largely on statistical devices such as histograms is that samples may not represent the deposits.

The authors were fortunate in having two samples (496 and 536; 98 and 91 particles respectively) from Cunningham Creek, and probably from workings less than one kilometre apart. These were provided by different donors. Comparison (Figures 1 and 2) of these samples show that although they are similar they differ in detail and have identical fineness maxima at 910. The average finenesses of the two samples are 865 and 835. Holland's (1950) average fineness for Cunningham Creek gold is 861.5. The averages are of less significance than the maxima since the former are probably controlled by additions in different proportions from several sources whereas the latter show the compositions of the lodes supplying much or most of the gold. Mercury values are also very similar, except for two high values in one sample (496) which are probably due to low-fineness high-mercury inhomogeneities as described below.

## HOMOGENEITY OF SAMPLE GRAINS

More than 80 percent of the analyses reported here were single spot analyses in which a volume of gold less than 5 microns (.005 millimetre) across, in the middle of a polished surface, was analyzed. Such an analysis will be representative only if the gold particle is reasonably homogeneous, so it is vital to test the homogeneity of the sample grains.

Rims form the main kind of inhomogeneity. These are easily seen under the reflecting microscope because, being of nearly pure gold, they are a brighter yellow than the interior parts of grains. These were routinely analyzed, as well as the interior parts, mainly because they provide a reliable criterion for mercury contamination (*see* below).

Exsolution textures are found in high-copper gold samples and have been described from the Coquihalla district (Knight and McTaggart, 1990). Copper-rich gold has not been found in the Cariboo.

Apart from rims, the most common visible inhomogeneities are patches, veinlets, and irregular complete and partial peripheral zones. Most of these have gradational contacts but some are sharp. The greater the difference in fineness between an inhomogeneity and the body of the particle, the more visible it is. Table 2 lists representative examples showing the number of particles in the sample with inhomogeneities visible under the reflecting microscope, their nature, fineness, and mercury percentages. In general, outer zones, veins and patches have a lower fineness and a higher mercury content than the main part of the particles.

Slight differences in composition cannot be distinguished by colour. For this reason, when time and expense permitted, about every fifth gold particle was analyzed at two sites, one in the middle of the polished grain and one near the edge but inside the rim. Differences in fineness for 189 pairs of determinations from placer particles, core and edge, are plotted in Figure 5. The plot is nearly symmetrical thus indicating no consistent increase or decrease towards the edges. Finenesses of 45 edges for the combined Cunningham Creek samples (496 and 536) and 19 edges from the Cariboo River (607), are plotted as histograms (Figure 6). Comparison of the latter with the histograms of core analyses for these two placer localities indicates that such inhomogeneities are not abundant enough to affect the usefulness of the histograms of Figures 2 and 4, particularly since the Cunningham Creek samples have the highest frequency of inhomogeneities, as shown by core-edge comparisons, of any placer sample studied. In the Cunningham sample, edges have a slightly lower fineness than the cores. Sixty-four of the 195 pairs have a measureable but slight change in mercury content between core and edge. Of these, 40 exhibit an increase in mercury towards the edge and 24 a decrease. Two edge samples, with finenesses of 1000 are probably rims.

Only 45 paired fineness values are available for lode gold particles. Twenty-three core-edge pairs from Cow Mountain (546-551) exhibit no significant change in fineness between core and edge (average difference = 2 fineness points). Mercury, on average, increases slightly towards the edges. Six paired analyses from the B.C. vein (594) have differences similar to those of the Cow Mountain sample.

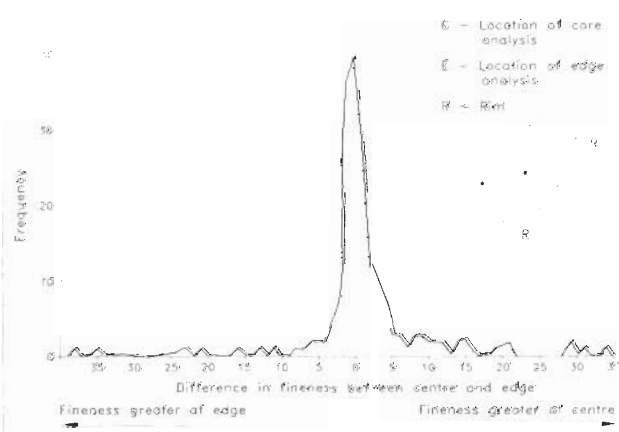



Figure 5. Differences between pairs of analyses for cores and edges of 189 placer particles.

TABLE 2
FREQUENCY AND NATURE OF INHOMOGENEITIES VISIBLE UNDER THE OPTICAL MICROSCOPE

| Name<br>Placers | Sample No. | Number of Particles in sample | Number Showing Inhomo-geneities | Description of Typical example | Value or range of fineness value and (%Hg) for inhomogeneity | Fineness and (% Hg) for host grain |
|---|---|---|---|---|---|---|
| Jerry Creek | 439 | 80 | 1 | Outer zone | 834 (1.5) | 759 (.15) |
| Beggs Gulch | 472 | 98 | 4 | Patches near edge | 469 (.19) to 615 (.2) | 801 (0) |
| Burns Creek | 494 | 80 | 1 | Vein-like | 483 (.24) to 518 (.18) | 754 (.03) |
| Hixon Creek | 495 | 94 | 3 | Vein-like | 970 (0) | 842 (0) |
| Cunningham | 496 | 98 | 2 | Irregular outer zone | 700 (.09) | 738 (.08) |
| California Gulch | 501 | 101 | 9 | Bleb | 422 (.3) | 717 (0) |
| Dry Gulch | 522 | 103 | 3 | Vein-like | 650 (.08) | 817 (0) |
| Cariboo River | 531 | 98 | 1 | Composite outer rim | 470 (.97) to 763 (.11) | 842 (0) |
| Cunningham Creek | 536 | 91 | 5 | Vein-like | 783 (.12) | 890 (0) |
| Maude | 593 | 100 | 7 | Vein-like | 623 (0) | 739 (0) |
| Gold Creek | 612 | 107 | 2 | Patches | 613 (.6) | 723 (0) |
| Morehead Creek | 614 | 96 | 1 | Patches | 669 (1.03) | 752 (.87) |
| Lodes | | | | | | |
| Forrest | 587 | 31 | 6 | Vein-like | 722 (1.3) | 905 (0) |
| Myrtle | 595 | 65 | 1 | Irregular outer zone | 830 (0) | 879 (0) |

Particles of the Forrest sample (587) are inhomogeneous. In 16 paired analyses, 10 have a significant decrease in fineness between core and edge, averaging 25 points in fineness. There is no change in mercury content between core and edge in these pairs. Three paired analyses from the Myrtle lode (595) exhibit an average decrease of 11 fineness points. Gold from lode samples Myrtle, Forrest, and from nearby placers (Maude (593), Beggs, (472) and California (501) from the eastern part of the area, are unusually inhomogeneous and rich in second phases.

## VARIATION OF GOLD COMPOSITION WITHIN MINING CAMPS

Some vein systems have little variation in gold composition within veins or from vein to vein. Examples include the lodes of the Coquihalla area (Knight and McTaggart, 1990) and the Blackdome Mine (Knight and McTaggart, 1989). At the Bralorne Mine preliminary results suggest considerable variation from vein to vein. At the Erickson Mine, for which many samples have been analyzed, veins have considerable variation both within and between veins (Nelson *et al.*, 1990).

The gold of Cow Mountain, including that of Cariboo Gold Quartz mine, ranges between 900 and 950 fine. The gold of nearby Island Mountain is about 870 fine. Holland (1954) reported significant variation in gold composition from the Yanks Peak - Roundtop Area.

## MERCURY IN GOLD

Many of the placer gold particles contain mercury up to a maximum of about 10 percent. It is believed that the mercury in these placer gold samples (with the exceptions noted) is primary and not due to contamination. Lode gold containing primary mercury has been reported in many areas (Knight and McTaggart, 1986).

Samples from certain placers are obviously contaminated with mercury. These particles show thin white mercury-rich rims or fractures and some are agglomerated into silvery, heterogeneous spongy pellets. When the mercury is driven off by heat or other agency, the surface of the gold particle or agglomerate acquires a spongy microcrystalline coat which, though containing trace amounts of mercury, is not silver-coloured. Mercury-contaminated samples were not ordinarily analyzed but laboratory tests confirm that mercury penetrates to the interior of gold particles only rarely and that the compositions of the cores of mercury coated grains are little contaminated except during polishing. Contaminated samples that were analyzed are marked by asterisks in Table 1.

During the preparation of polished sections of gold that contain more than small amounts of mercury, polishing laps

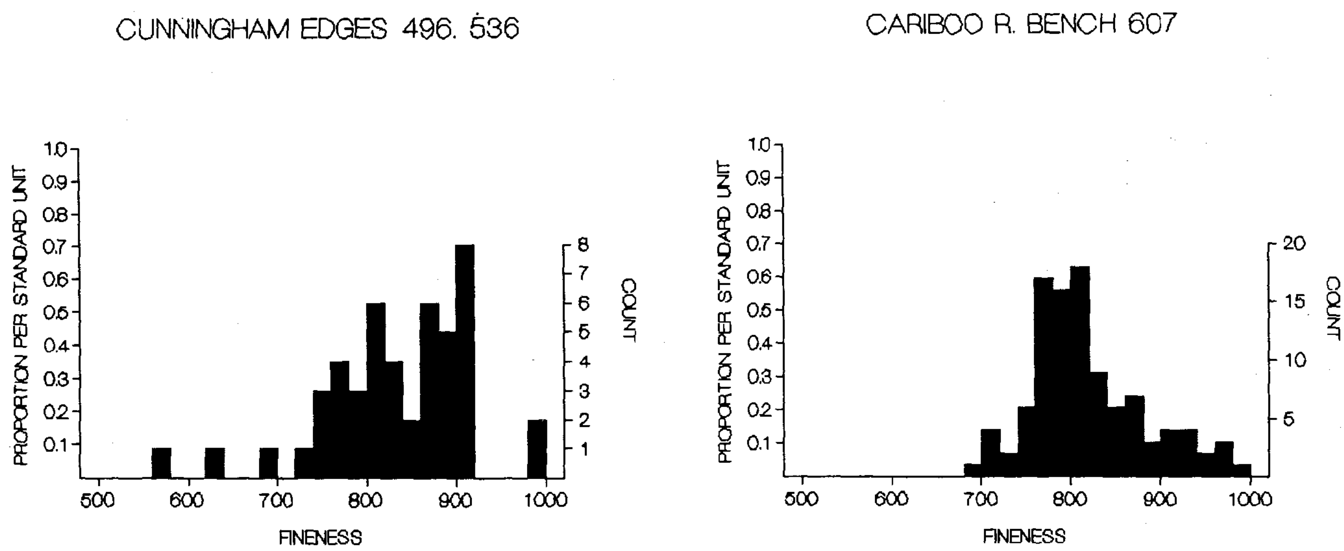



Figure 6a. Histograms of analyses for Cunningham Creek (496 and 536 combined) and for Cariboo River Bench (607).

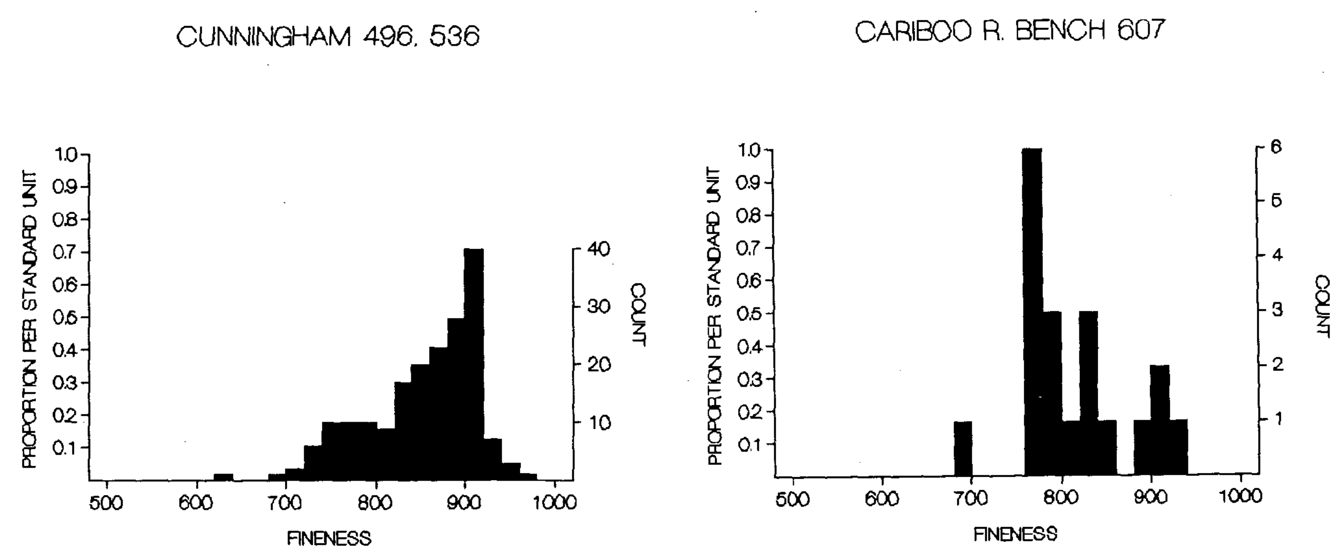



Figure 6b. Histograms showing Cunningham (496 and 536) and Cariboo River (607) edge analyses.

became contaminated with mercury. If mercury-free gold is polished on such a contaminated lap, it may also become contaminated with up to 1 percent mercury. A useful test for such contamination is provided by the observation, made on hundreds of grains, that gold rims described earlier are free from mercury and copper. If rims on polished placer grains contain mercury, repolishing on clean laps and re-analysis have invariably shown that the grains had been contaminated.

Certain of the mercury-fineness plots (Figures 1 and 3) show one or two-high mercury values in an otherwise mercury-free sample. These erratic values may result where the analytical spot chosen was on an invisible inhomogeneity as these are generally relatively high in mercury.

It was stated (Knight and McTaggart 1990, p. 115) that "it appears that an irregular northeast-trending line, passing between Dragon Creek and Slough Bench, separates areas of mercury-rich gold to the northwest, from mercury-poor gold to the southeast." (The definition of mercury-rich gold used here is gold for which the sample shows a notable number of particles with mercury ranging up to about 0.5 percent mercury or higher). For the present report, the number of samples is approximately double that of the earlier one and a larger area is covered. The list of high-mercury gold placers west and northwest of Wells now includes: Dragon Creek (107), Sugar Creek (108), Jerry Creek (439), Gold Creek (612), Mary Creek (Toop) (146), Quesnel Canyon (461) and Frye Creek (187). The only lode found so far to contain high-mercury gold is Warspite (586).

This generalization must be modified as mercury-rich placer gold is found also to the south in the Likely area. Although the mercury is believed to be primary (rims are mercury-free), none of the lode samples from the area contains similar high-mercury gold.

Within the study area, it appears that placer gold is richer in mercury than is lode gold. The authors maintain, on the basis of mercury-free rims, that this mercury is primary. Examination of fineness-mercury plots in Figures 1 and 3 reveals that samples from Slough Bench (228), Cariboo River Bench (531), Beaver Pass (251), Eight-Mile (123) and Jerry Creek (439) (described in detail later) have certain ranges of composition that are mercury-free, and others that are relatively mercury-rich, confirming that the mercury is primary and not due to contamination.

The question remains: why is placer gold richer in mercury than gold from the lodes from which it is believed to have been derived? The data may reflect the relatively small number of lode samples analyzed. Alternatively the lodes may be zoned vertically, the gold containing higher mercury near the surface and lower mercury at depth. Since placers represent gold largely derived from higher levels, they would have higher mercury values.

## COPPER IN GOLD

Several thousand analyses of placer gold indicate that the amount of copper which can alloy with gold to form a single phase increases with fineness to a maximum of about 0.025 percent at a fineness of 700 and of about 0.15 percent at a fineness of 900. High-copper gold, such as is found in the Coquihalla area and in Relay Creek, Bridge River and Fraser River (Knight and McTaggart, 1986, 1990), and in the Wheaton Creek area contains up to about 25 percent copper and, in some specimens, has regular two-phase patterns that resemble exsolution textures. Such gold has not yet been found in the Cariboo district.

The Fifteen Mile Creek lode of the serpentine belt of the Coquihalla area (Cairnes, 1930), discussed in earlier reports (Knight and McTaggart, 1989, 1990), is the only British Columbia copper-gold lode known to the authors. Oen and Kieft (1974) describe copper-gold associated nickel and chromium minerals from the Beni Bousera ultramafite of northern Morocco. Copper-gold occurs in a hortonolite-dunite pipe in the Bushveld Complex (Ramdohr, 1969). Several lode occurrences are known from the Urals and the best known of these is the Zolotaya Gora deposit in rodingite in ultramafic rocks (Murzin *et al.*, 1987) of which some details are given by Knight and McTaggart (1990).

Raicevic and Cabri (1976) describe placer copper-gold and platinum from the Tulameen river downstream from the Tulameen ultramafic complex. Stumpfl and Clark (1966) found placer copper-gold associated with platinum in the Riam Kanan river in Borneo that has its source in a peridotite terrane.

In summary, most copper-gold has been found in ultramafic rocks or in rocks associated with them, such as rodingites or placers derived from them.

Copper, though present in minute amounts in some samples of gold from the Cariboo, has so far been of no value in characterizing the gold.

# LODE GOLD OF THE CARIBOO REGION

## WELLS AREA

Eighteen lode samples from the Cariboo region (Table 1) have been analyzed (Figures 1 to 4). For most of the lode samples, finenesses fall closely around a maximum; examples include Cariboo Gold Quartz and Cow Mountain lodes and the Spanish Mountain lodes. A few, however, show variation in fineness values, and Myrtle (595) and Burns Mountain (502) show two maxima.

The principal lode gold producers were the Cariboo Gold Quartz mine, southeast of Wells and the Island Mountain Mine, southwest of Wells. The workings of these mines almost connect. The Mosquito Creek Mine was developed in the western upper levels of the original Island Mountain mine. These mines are now inactive.

Samples from Cariboo Gold Quartz mine were concentrated from four unoxidized gold-quartz specimens collected from unknown locations within the mine. The fineness averages 947 and mercury is below the detection limit.

The Cow Mountain lode sample (547-551), collected from exploration trenches, consists of 82 particles. Most of the gold in this sample lies close to the maximum fineness of 940, but extremely small particles range down to 900.

Samples from the Wells adit (588, 590) and from nearby outcrops of intersecting quartz veins (589) have a slightly lower fineness maxima (905). The dump from the B.C. vein yielded a fineness maximum of about 925.

All of the above samples characterize a group of quartz veins from the area of the Cariboo Gold Quartz mine workings in Cow Mountain and in Barkerville Mountain. The veins contain gold of fineness 900-950 but the majority of the particles are between 925 and 950 fine. Such gold, fineness 900-950, will be referred to below as *Cow Mountain type* gold.

Two samples of massive pyritic ore from the Mosquito Creek Mine (Alldrick, 1983), one (497) from the Jukes adit and one (499) from the 2184 stope on the second level, contain minute blebs and films of gold between and within pyrite crystals. The first has a fineness of 850 and the second, 869 with mercury below the detection limit. This massive pyrite ore, which has been described as 'replacement' ore, provided much of the mine output.

Our analyses show that the gold of the 'replacement' ore differs from the gold of the quartz veins of the Cariboo Gold Quartz mine. This difference is confirmed by considering the data in Table 3 which shows gold finenesses calculated from the annually reported production of gold and silver from the Cariboo Gold Quartz mine and the Island Mountain mine taken from British Columbia Ministry of Energy, Mines and Petroleum Resources reports.

The Cariboo Gold Quartz production included a small amount of 'replacement' ore and the Island Mountain mine produced a substantial proportion of gold-quartz ore. This mixing could account for the slight differences between the fineness calculated from mine production figures and our own analyses. It is concluded that gold compositions from the two types of ore are different and the analyzed samples are reasonably representative of the lodes.

Grain sizes of lode gold particles from the Cariboo Gold Quartz and the Island Mountain-Mosquito Creek mines are of interest because it is presumed that the lodes of these mines supplied the surrounding placers. The Cariboo Gold Quartz veins contained abundant free gold, and nuggets up to one-quarter ounce were common (Hanson, 1934, p. 46A, 48A). Significantly, nearby placers contain abundant gold of fineness 900-950.

Free gold was rarely seen in the "replacement" ore of the Island Mountain mine. Skerl (1948, p. 590) states "So far as is known neither free gold nor the lead and bismuth minerals have been recognized in the replacement type of ore." In a study of Island Mountain ore, Bacon (1939) illustrates blebs of gold 33 and 37 microns across in massive pyritic ore. In another study, Runkle (1940) shows blebs and films of gold 28 and 55 microns in longest dimension. Samples analyzed for this report were films 5 to 10 microns thick and up to 50 microns long. Gold particles from the Island Mountain and Mosquito Creek mines were therefore extremely small and this property probably accounts for the scarcity of placer gold of fineness 850-875 recovered from nearby placers. An exception is the placer of Red Gulch Creek which has a source in the area of the Mosquito Creek mine, about 1 kilometre distant. Holland's (1950) range of fineness for the placer is 850-887. An 870 maximum, along with two others, is discernable in the Ballarat (500) placer sample (Figure 2).

Lode occurrences from Proserpine Mountain, southeast of Wells, include the Forrest (587) and Warspite (586) show-

TABLE 3
FINENESS OF GOLD, CALCULATED FROM SMELTER RETURNS

| Year | Cariboo Gold Quartz | Island Mountain |
|---|---|---|
| 1938 | 929 | |
| 1943 | 924 | 866 |
| 1944 | 928 | 854 |
| 1945 | 923 | 893 |
| 1946 | 923 | 882 |
| 1947 | 922 | 887 |
| 1948 | 907 | 872 |
| 1951 | 911 | 876 |
| 1952 | 917 | 878 |
| 1954 | 921 | 893 |
| 1955 | 912 | |
| | average 920 | average 878 |

Range based on samples analyzed by the authors:

| | Cariboo Gold Quartz | Island Mountain |
|---|---|---|
| | 925-950 | 850-869 |

ings (Figures 1 and 2). The Forrest sample has a fineness maximum at 890, and the Warspite 830. Comparison of centre and edge composition in the Forrest sample suggests that nearly half the particles in the sample show a slightly lower fineness (up to 50 fineness units) in edge composition, suggesting that even the optically homogeneous particles are zoned. There are no accompanying changes in mercury content.

The authors recovered 5 particles of gold from a mine dump above the forks in Oregon Creek on Mount Nelson at the Foster's Ledge (493) workings. Most of the gold particles resemble that from the Cariboo Gold Quartz and have a fineness near 945.

Holland (1948) provides a single fineness determination of 927 from the Acme vein which lies one-half mile north of Stanley (Figure 2).

A sample from the Perkins vein on Mount Burns (502), from exploration trenches, was partly contaminated with mercury during recovery and polishing. It yielded fineness compositions resembling those from from the Cariboo Gold Quartz mine and Mosquito Creek mine. It has a maximum at 930 and possibly a minor one at 870. Holland (1948) describes this showing and reports that the gold has a range of fineness from about 840 to 915.

A single, relatively large grain from a lode in the western part of Mount Burns (523) has a fineness of 790 and thus is quite different from most of the lode gold described above (Knight and McTaggart, 1990).

## YANKS PEAK - ROUNDTOP MOUNTAIN AREA

A sample from an adit at the Midas group (124) in the Yanks Peak district yielded a fineness of 870 (Figure 3). Holland (1954) made 20 determinations of fineness from veins of the Midas Group and 16 from veins of the Snowshoe Group. These have been plotted as histograms (Figure 4) which show maxima at 890 and 910 and these are more representative than the 870 maximum. Gold samples from the nearby Jim vein fall closely around an average of 867. All of these are from the Yanks Peak area. The only information Holland provides from the Roundtop area is the fineness, 901, of placer gold calculated from mint returns for Harvey Creek which has its source near the Cariboo Hudson mine which produced 5000 ounces of gold before closing in 1939.

## SPANISH LAKE DISTRICT

The authors analyzed five lode samples from the Spanish Lake district (Figures 3 and 4). Most of these are small samples with mercury below 0.15 percent. The samples have a limited and distinctive range of fineness between 750 and 810, averaging 780, and these do not resemble the maxima for other lodes except for a one-particle Mount Burns (523) sample.

## SUMMARY

Certain points stand out in connection with the analyses of lode gold:

- Lode gold from quartz veins south and east of Wells, on Cow Mountain, ranges in fineness between 900 and 950, and is referred to as *Cow Mountain type* gold.
- Lode gold from Island Mountain and Mosquito Creek mines, from ore referred to generally as 'replacement' ore, is of fineness near 870 and is distinct from the Cow Mountain type. It appears that gold particles from these lodes are very small and therefore are not recovered from most of the local placers.
- Lode gold of the Cow Mountain composition occurs on Mount Burns and Mount Nelson.
- Two lode gold samples from Proserpine Mountain at the Warspite and Forrest showings, with fineness at 830 and 890, differ from those analyzed from Cow Mountain, Mount Burns and Mount Nelson.
- Gold from the Yanks peak camp have fineness maxima at 890 and 910. A single sample yields a fineness of 870.
- Gold from lodes in the Spanish Lake area have a fineness averaging 780, notably lower than the finenesses noted above.

# PLACER GOLD OF THE CARIBOO REGION

## INTRODUCTION

Forty-seven samples, each consisting of many particles of placer gold, were analyzed from the Cariboo region (Table 1). It is not feasible to comment on each of these samples but many will be referred to in connection with particular areas and problems. In the northern part of the area around Wells, two broad types of placer gold can be distinguished: gold of the Cow Mountain type (fineness 900-950); and gold of fineness 800-900. This report describes placers characterized by each of these types and also a third type, containing both types of gold. There follows a discussion of the Yanks Peak-Roundtop area and finally of the Likely area.

Interpretation of fineness histograms of placer deposits (Figures 2 and 4) is based on two simple assumptions:

- Samples yielding histograms with a single maximum (*e.g.* Coulter Creek, 599, and Beggs Gulch, 472) are presumed to be derived from veins in a restricted area.
- Two or more widely separated maxima,( *e.g.* Jerry Creek 439, and Eight-mile, 123) are interpreted to indicate mixing of gold from two or more sources.

It should be noted that the fineness maxima for placers are more significant than fineness averages in indicating source composition. In some samples, (*see* Oregon Gulch, 471 and Dry Gulch, 522; Figure 2) the fineness maxima values are higher than the fineness average values indicating mixing of lower fineness gold with gold of the Cow Mountain type. In other samples the maximum value is of lower fineness than the average (Cariboo River Bench, 531 and 607; Figure 4).

A particularly illustrative example is a sample from Sugar Creek (108) showing three maxima. Two strongly contrasting textural types could be identified during sample preparation. One type is chunky, angular and irregular; the other is thin, flattish and discoid. The two types are illustrated in Plates 2 and 3; analyses are presented as histograms in Figure 7. The first histogram shows all three maxima at about 710, 790 and 910 while analyses of the two textural types are shown in the second and third histograms. Comparison shows that nearly all of the particles with fineness around 900 fine are flat particles. It is concluded that the thick, irregular grains, mainly of fineness 790 and to a lesser extent, 710, are of local derivation, perhaps from the numerous quartz veins of Sugar Creek (British Columbia Ministry of Energy, Mines and Petroleum Resources, Report 1947, page A117) and that the strongly flattened, apparently far travelled particles, about 900 fine, may be from the Cow Mountain area.

Some samples show a wide range of compositions without clear maxima and these are probably from placers having several sources. Most of these are distant from known lodes. Examples are Quesnel Canyon (461) and Fraser River (135).

## WELLS AREA

### *PLACER GOLD OF THE COW MOUNTAIN TYPE*

The compositional data indicate that the placers of Lowhee Gulch (596), fineness maximum 930, were derived from the nearby Cow Mountain lodes. Haggen (1925, page 28) states that in Lowhee Gulch "the lower 6 to 10 feet of bedrock gravel was rich in coarse gold, much of it having rugged pieces of quartz attached, showing that it was derived from neighboring auriferous veins, and had not travelled." The gold accumulated mainly by colluvial, mass-wasting processes and probably moved only a few hundred metres from its lode sources.

The placer samples from Coulter Creek (599), Slough Bench (228) and Mosquito Creek (518, 519) show strong fineness maxima in the Cow Mountain range of lode gold compositions (900 to 950) (Figure 2). Burns Creek (494) placer, Oregon Gulch (471) and Drygulch (522) show similar maxima but may have been derived partly or wholly from lodes on Mount Burns.

Placer gold of fineness 900 to 950 is found in a tract (A in Figure 8, in pocket) up to 10 kilometres wide that extends from Williams Creek to the west, to Wingdam. The well defined head of the tract lies at Williams Creek. East of Williams Creek there appears to be little placer gold of fineness greater than 900, except far to the south at Cunningham Creek. The outline of this tract is based mainly on Holland's (1950) data*. Holland's values are averages, and gold of several different compositions that made up most of his samples cannot be distinguished. Consequently, his data, al-

FOOTNOTE:
* Holland's fineness values, calculated as the number of parts of gold in 1000 parts of alloy, are probably slightly lower than those presented in this report; he points out (Holland, 1948, page 39), "Mint figures of gold and silver fineness add up to about 970 to 990. The remaining 10 to 30 parts represent base metals that in part may have been original constituents of the natural gold or may have become combined during fusion at the mint." The fineness determinations made by the authors follow the current practice of basing fineness on the ratio of gold to combined gold and silver. Holland refers to fineness based on this ratio as the "true fineness".

Plate 2. Irregular, chunky gold particles from Sugar Creek (108). Scale at bottom of photograph in tenths of millimetres.

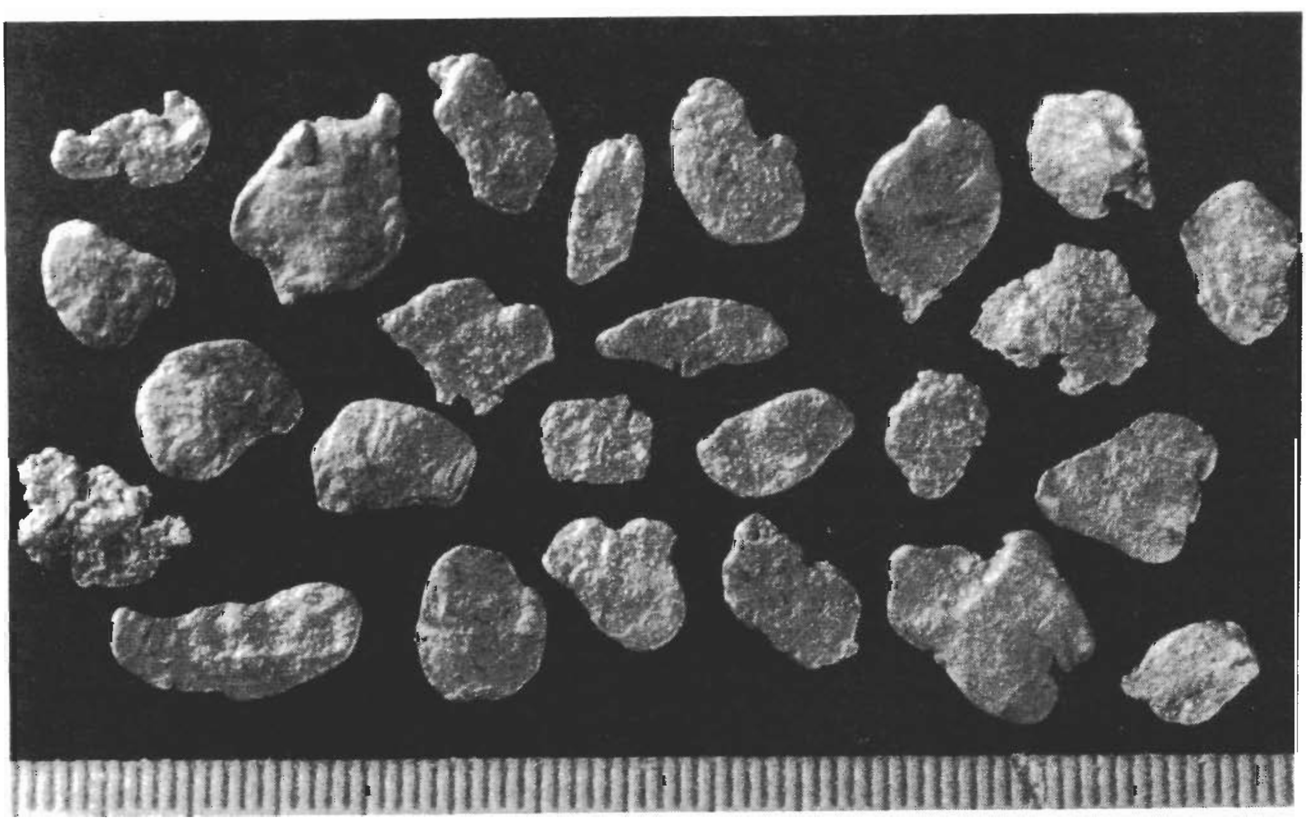
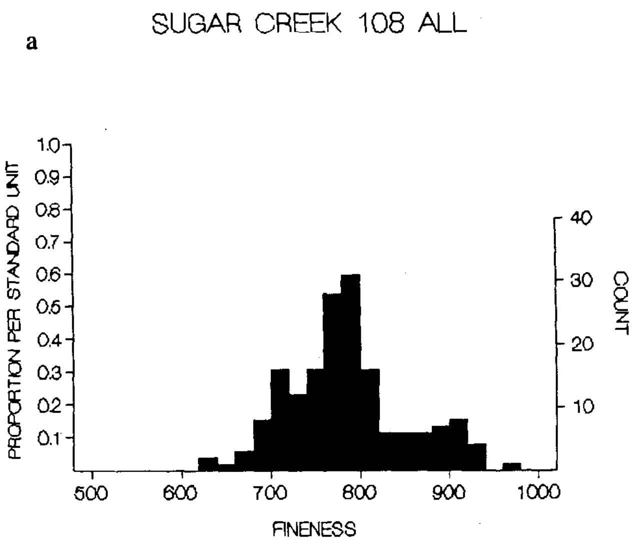
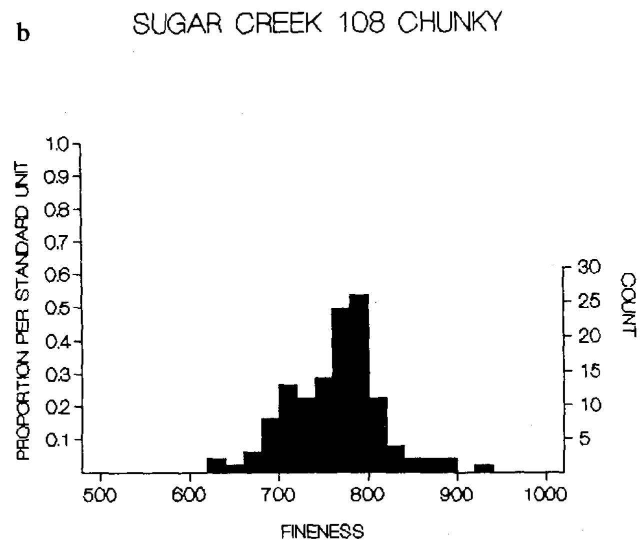


Plate 3. Flat, thin gold particles from Sugar Creek (108). Scale at bottom of photograph in tenths of millimetres.

a




b




c

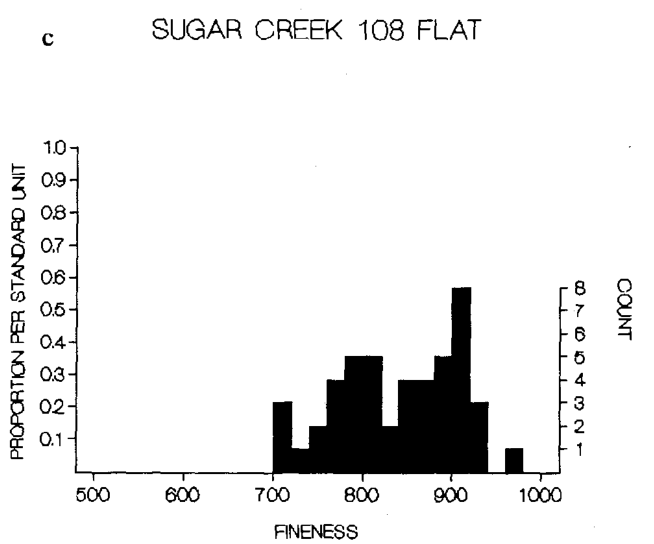



Figure 7. Histograms of fineness of placer gold particles from Sugar Creek (10B). a. All analyzed particles. b. One hundred and twenty-three mostly chunky particles. c. Forty-seven, mostly thin flat particles.

though based on very large samples, are of somewhat limited value in relating placers to lodes.

The southern edge of this tract crosses the upper part of Lightning Creek (Figure 8) but cannot be located accurately. The gradual change from fineness less than 900, that predominate in the headwaters, to fineness greater than 900 found nearer to Stanley, marks a zone of mixing of gold in the 800 fineness range with Cow Mountain Type gold. This change of fineness in the upper part of Lightning Creek was recognized by the placer miners in the early days (Holland, 1948).

It could be argued that the extremely rich placers of Lightning Creek, in the section extending one and one-half miles east of Stanley, with gold mostly of fineness 900 to 950, was derived from Cow Mountain lodes but there are serious problems with this hypothesis. There is no obvious fluvial path. Clague (1989), and Eyles and Kocsis, (1989) agree that some gold was excavated by glaciers from ancient placers, carried up to scores of kilometres by the ice, and dumped in morainal material. Much of this auriferous till was reworked by glacial meltwater streams and post glacial streams and the gold redeposited. It seems unlikely, however, that the ice sheet would have carried gold southwest down into the valley of Jack of Clubs Creek, up over a mountain barrier and into the headwaters of Lightning Creek. The lode gold of the Burns Mountain (502), Foster's Ledge (493) and Acme prospect samples are of Cow Mountain composition. Although Holland (1948, page 41) points out that the Lightning Creek placer gold was not derived solely from the veins at these three showings, he suggests that the rich placers east of Stanley were derived from veins "very close to the position of the worked out deposits."

It seems likely that glaciers carried Cow Mountain-Type gold northwest to Sugar Creek (F in Figure 8, in pocket) where it became mixed with gold of the nearby lodes. Cow Mountain gold was also carried northerly to Eight Mile Lake (123) and Summit (364) placers (C in Figure 8) but it was mixed with gold of lower fineness, much of it of fineness 830.

## *PLACER GOLD OF FINENESS 800-900*

The Conklin Gulch placers, with gold fineness averages between 805 and 836, (Holland, 1950), were probably derived locally from lodes of the Warspite-type (586) on Proserpine Mountain and had insignificant, if any, contributions from Cow Mountain. In a similar way, it seems probable that the gold of Red Gulch creek, average fineness 870 (Holland, 1950), was derived by mass wasting of the Mosquito Creek lodes (497,499), at most a few hundred metres distant (E in Figure 8).

Placer gold of fineness 800 to 900 is prominent in the headwaters of Williams Creek (Figure 8), in placers as far east as Antler Creek and as far south as California Creek. This gold is unlikely to be Island Mountain gold, about 870 fine, because Cow Mountain-type gold is not identified in this eastern section, and gold of the two types, originating in sources only a kilometer or two apart, would probably have travelled together. At least one lode (Warspite, 586) carrying gold of this fineness range occurs on Proserpine Mountain. The nearby Forrest sample (587), fineness maximum 890, is finer than placer gold found nearby. Other lodes are reported (Johnson and Uglow, 1926) but there are no compositional data for them.

The abundance of placer gold, mainly of 800 to 860 fineness in the area east of Williams Creek, upper Antler Creek, in Beggs and California Gulches, Maude Creek, Ballarat placer and Devlin Gulch, suggests that lodes yielding abundant gold of this fineness range exist, or existed, in the Antler Mountain - Proserpine Mountain area. This material was carried north, where it mixed with Cow Mountain gold to form the bimodal Ballarat (500), Devlin Bench (598), Eight Mile (123) and Summit (364) placers (in area C, Figure 8).

In view of the difficulty of transporting gold from Antler and Proserpine Mountains to the headwaters of Lightning Creek, perhaps a local source at the southern side of the tract provided gold of this composition.

Cunningham Creek gold, with fineness maximum near 900, does not appear in the Antler drainage and was apparently not carried north.

The placer sample from Dragon Creek (107) is anomalous in that it shows a strong fineness maximum at 805 and an average value of 817. It contains up to 2.5 percent mercury. These fineness values contrast with Holland's (1950) averages, over the years 1916 to 1940, of 889 to 926. Calculation, however, of the fineness for 1941 to 1945 production (Holland's data) yields an average of 820. It seems possible that the latest production differed from the earlier. That the nearby Montgomery Creek (597) and Nelson Creek (59) placers show subsidiary fineness peaks at 810 also suggests that the Dragon Creek sample cannot be rejected. Johnson and Uglow (1926, page 156) state that "the gold on Dragon Creek is noted for its coarse, nuggety character and .... is evidently local in origin . . ." There is no known lode source which could supply this gold.

In an area west and northwest of Wells, 800-fineness gold is dominant: Dragon (107), Nelson (59), Jerry Creek (439), Gold Creek (612) and is present in small proportion in Montgomery Creek (597) and Burns Creek (494). Area D in Figure 8 encloses several of these, many of which contain particles with mercury in excess of 0.25 percent.

## *PLACER GOLD OF MIXED ORIGIN*

The Ballarat (500) sample from just downstream from Barkerville on Williams Creek, shows three maxima, probably the result of mixing of gold of the Cow Mountain type, gold of the Mosquito Creek lodes and gold of 810 fine from Proserpine Mountain. This mixing seems to be confirmed by Holland's average fineness for Williams Creek gold (Figure 8) which is probably a mixture of Stouts Gulch and Conklin Gulch gold. Mixing also occurs also at Devlin Bench (598) and to the north at Eight-Mile (123) and Summit (364).

The Jerry Creek (439) sample contains gold from at least two sources. The histogram (Figure 4) for this placer shows a dominant maximum at about 800 fine and less prominent maxima at 910 and 970. This sample contains 49 flat thin particles and 31 chunky ones. Eighteen of twenty grains that have fineness greater than 900 are thin, and only two are chunky. Furthermore, the maximum mercury content of those flat grains of more than 900 fine is 0.29 percent whereas those of lower fineness reach 1.73 percent. There are obviously two kinds of gold in this sample: a far travelled, high fineness, low mercury type; and, a relatively short travelled, low fineness, high-mercury type.

Such mixing occurred also at Sugar Creek (108) (*see* above).

## PLACER GOLD OF THE YANKS PEAK - ROUNDTOP AREA

The Cariboo Hudson mine and other lodes of the Roundtop Mountain area (Holland, 1954) probably supplied much gold to Cunningham Creek. These lodes lie in a tributary of Cunningham Creek and are less than 10 kilometres upstream from the placers. There were possibly some contributions from the more distant Yanks Peak showings. The composition of gold from the Midas and Snowshoe groups, with maxima at 890 and 910 (Figure 4) are compatible with the 910 maximum for the Cunningham Creek placers (496, 536). Gold of the Cunningham Creek type is not prominent in the rich placers of upper Antler Creek (averages 819-861, Figure 8) and is not identified to the north.

## PLACER GOLD OF THE LIKELY AREA

In placers south of the Quesnel and Cariboo Rivers gold of fineness 790 to 810 is dominant. These placers appear to have been derived from the nearby Spanish Mountain lodes, samples of which (136, 365, 400, 401,and 611) show maxima that range from 750 to 810 fine.

Five samples from the Cariboo River and its benches (462, 529, 531, 605), and from Quesnel River (530), are of mixed origin. They show weak fineness maxima near 800 (Spanish Mountain lode source?) and stronger maxima near 900. The 900 maxima may represent contributions from the Yanks Peak area (fineness maxima 890 to 910). In four of these samples (462, 529, 530 and 531), very flat thin particles can be distinguished from chunky particles, the latter making up one-quarter to one-half of each sample. In each sample most or nearly all of the chunky particles fall around 800 fine. Particles of 900 to 950 fine are nearly all flat and thin and appear to be relatively far travelled.

The small Keithley Creek (603) sample may be a similar mixture of fineness types.

## DISTANCE OF TRAVEL OF PLACER GOLD PARTICLES

The most obvious criteria for distance-of-travel for placer gold are those indicating very short travel: features such as preservation of delicate crystal habit and attached or enclosed fragments of vein quartz. These are easily seen. Distance-of-travel is more difficult to estimate for gold particles that have lost these primary features. The degree of flatness of placer particles is the most useful criterion for distance-of-travel in the fluvial environment. Gold differs from brittle minerals, such as quartz, in being malleable and thus yields to pressure rather than becoming rounded by abrasion. This criterion probably applies only to gold particles a millimeter or less in diameter as large sheet-like nuggets are unknown. Flatness, as used here, is based on measurement of the maximum, minimum and intermediate dimensions of a particle (Knight and Morrison, in preparation).

The application of the flatness criterion is difficult for several reasons. First, account cannot be taken of the original shape of the particle in the lode, whether thin or chunky. Second, flat particles are more easily entrained in turbulent water than equant grains and this difference can lead to a biased sample. Third, most of the samples of the present study are mixtures of gold from several sources (examples are Sugar Creek and Jerry Creek samples placers).

Nevertheless, estimates of distance of travel appear to work reasonably well in an unglaciated area, such as the Klondike. In the Cariboo, which has been heavily glaciated, attempts to estimate distance of travel using the criterion of flatness have had limited success.

An 18 kilometre distance of travel for the Ballarat (500) sample, estimated on the basis of the thinness and flatness of particles, appears anomalous in that it is probably from Cow and Proserpine Mountains less than 5 kilometres distant. The nearby Devlin Bench (598) sample, similar in composition to the Ballarat, by the same criteria, is assigned a travel distance of 4 kilometres, a more reasonable distance. The explanation for this discrepancy may be that the Ballarat sample was scooped from the surface of a container of concentrates and therefore probably contained a high proportion of flat, slow-settling particles.

The Mosquito Creek (518, 519), Burns Creek (494), Dry Gulch (522), and Oregon Gulch (471) placer samples, all of which could reasonably be derived from nearby Cow Mountain or Burns Mountain, show unacceptably large travel distances when judged on the criterion of flatness. It is suggested (V. M. Levson, personal communication) that some of the placer gold was modified by glacial action. The effect of glacial transport on the flatness of small gold grains is unknown.

The distances of travel calculated for each of the Cunningham Creek (496, 536) samples are 1 and 3 kilometres. Estimated distances of travel for Beggs Gulch (472), California Gulch (501), Beaver Pass (251), Hixon Creek (495), Tertiary Mine (133) and Mary Creek (Toop, 146) are short and suggest derivation from nearby lodes.

The Frye Creek (187) sample, which has two distinct textural populations (Knight and McTaggart, 1989), is probably derived from two sources, one near and one distant.

## SUGGESTIONS FOR PROSPECTING

The geochemical data of Figures 1 to 4, the data of Holland (1948, 1950), and information on distance of travel allow speculation on sources of placer gold for which lodes have not been identified. These sources may, of course, have been eroded completely away.

Placer gold from California and Beggs Gulches have fineness maxima near 800. Lodes with gold of this composition have not been identified nearby. Gold in these samples has an unusually low degree of flattening and wear, and appears to have travelled only a short distance, perhaps from a source or sources on Antler Mountain.

The sources of the rich placers of upper Antler Creek, for which there is little information (Holland, 1950, gives a range of average fineness of 819-861) and for which the authors have no textural information, are unknown. The gold appears to differ in fineness from that of the Cunningham Creek placers which it is believed was derived from veins near the Cariboo Hudson mine in the Yanks Peak-Roundtop area.

Several rich placer streams and gulches drain Proserpine Mountain, including Grouse, Maude, Canadian, French, Conklin and Upper Williams Creek. The gold in these placers has fineness averages (Figure 8) ranging from about 800 to 860, with many between 800 and 835. The many gold-quartz veins of Proserpine Mountain are probably the source of this gold. Two of these veins were sampled. The Warspite (586) sample ranges in composition from 790 to 900 fine, and the Forrest (587) has a well defined maximum of 890 fine. The lack of clear correspondence between the compositions of the placer gold and the two lodes suggests that the other veins of Proserpine Mountain should be tested.

The placers of upper Lightning Creek (Figure 8) have two general compositions - those of the headwaters show fineness averages from about 850 to 890 whereas those near and slightly upstream from Stanley, near 900. An explanation for these observations is difficult because only averages of compositions are known. The problem of assessing the significance of such averages is illustrated by the authors' Dry Gulch (522) sample from near Stanley (Figure 2). The average fineness is 892; a prominent maximum occurs, however, at 930 fine and a minor one at 850 fine - the average value is almost meaningless. Lightning Creek averages may, therefore, represent mixtures similar to those at Dry Gulch. It seems probable that much of the gold of Lightning Creek near Stanley was of Cow Mountain composition. In view of the difficulty of transporting the gold from Cow Mountain to Lightning Creek or deriving it from the rather small known lodes nearby, the authors must agree with Holland (1948) who concluded that the rich placers of upper Lightning Creek were derived from veins in the Lightning Creek watershed.

Gold of fineness of 800, some with high mercury, is prominent in Dragon Creek (107) and Nelson Creek (59) samples and is subsidiary to Cow Mountain type gold in the Montgomery (597) and Burns Creek (494) samples. Lode sources for the 800-fine gold may lie in Eaglenest, Nelson and Burns Mountains. Similar gold is conspicuous to the north in the Sugar Creek (108) and Jerry Creek (439) placers.

The lode sources of the gold of many samples from the western part of the area (*see* Figures 3 and 4) remain unknown. Gold of the Cow Mountain type is prominent along Lightning Creek and Cottonwood Creek to Fraser River.

Much of this gold, very thin and flat, appears to have travelled some tens of kilometres. A fraction of the Fry Creek (187) sample (Knight and McTaggart, 1989), which is angular with many quartz attachments and inclusions, appears local in origin. The textures of samples from Mary Creek (Toop) (146) and the Tertiary Mine (133) (Knight and McTaggart, 1989) suggest travel of only a few kilometres.

Although the generalization (Struik, 1988) that most of the gold lodes of the Cariboo are in the Downey Succession is valid, it should be pointed out that the Spanish Mountain lodes and the Hixon Creek lodes (Bowman, 1886) lie in a separate group of rocks. It is possible that placer gold at Mary Creek (Toop) (146), Tertiary Mine (133) and Frye Creek (187) (in part) which seems little travelled, was derived from lodes lying far to the west of the Downey Succession.

# SUMMARY

- Lodes of Cow Mountain, characterized by gold of fineness 900-950, supplied much gold to nearby placers.
- Gold of the type found in Island Mountain and Mosquito Creek mines, averaging about 870 in fineness, appears not to have been recovered from most of the nearby placers probably because the gold particles were extremely small.
- Gold of the Cow Mountain type (fineness 900-950) is abundant in placers lying west and northwest of Wells.
- Placers east of Williams Creek are characterized by gold in the 800-900 range of fineness. Gold of the Cow Mountain type is nearly absent.
- A source for the abundant placer gold of composition 800-850 of Antler, Beggs and California Creeks may exist or may have existed in the Antler Mountain area.
- The origin of Lightning Creek placers, which are rich in gold of the Cow Mountain fineness range, is unknown. A mechanism for its transportation from the Cow Mountain area is hard to contrive and the gold is probably local in origin.
- The Ballarat, Devlin Gulch, Eight-Mile, and Summit placers, north of Barkerville, contain mixtures of Cow Mountain type gold and gold in the 800-850 range of fineness.
- Gold of fineness around 800 is abundant in some placers northwest of Wells (Nelson, Dragon, Sugar and Gold Creeks); lode sources for this gold are as yet undiscovered.
- Placer samples from Sugar Creek and Jerry Creek seem, on both textural and compositional grounds to be from two sources, one local and one distant.
- The placers of Cunningham Creek were probably derived from veins in the Roundtop area. The Cunningham Creek gold, dominated by gold of fineness close to 910, is not conspicuous in placers to the north in Antler, Grouse, Maude, Canadian or French Creeks.
- Gold of the Yanks Peak lodes is about 900 fine whereas the lodes of the Spanish Mountain area carry gold of about 800 fine.
- Placers south of Cariboo and Quesnel Rivers are characterized by gold of about 800 fine and are probably derived from lodes of the Spanish Mountain type.
- Some of the placers of Quesnel River are marked by two dominant types of gold, one of the Spanish Mountain type and one of fineness around 900, possibly derived from Yanks Peak.
- The solution and redeposition hypothesis of Uglow and Johnson should be abandoned for the Cariboo region. 'New gold' has not been identified except as rims.
- Further systematic collection and microprobe analysis of lode and placer gold could help identify new placer-gold sources.

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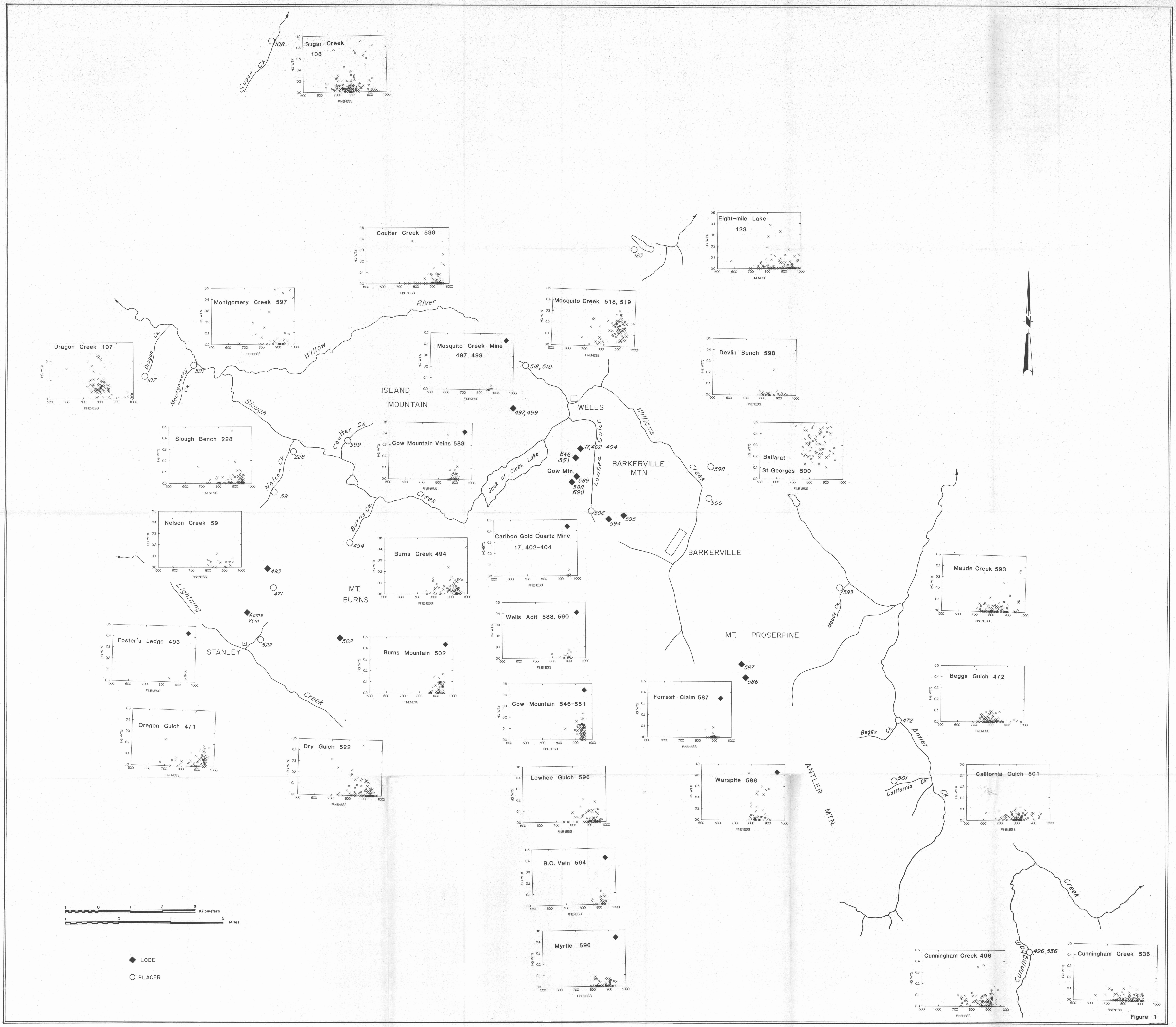
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Sugar Ck.
Coulter Creek 599
Eight-mile Lake 123
Montgomery Creek 597
Mosquito Creek 518, 519
Dragon Creek 107
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Montgomery Ck.
Willow River
Mosquito Creek Mine 497, 499
Devlin Bench 598
ISLAND MOUNTAIN
WELLS
Slough
Slough Bench 228
Cow Mountain Veins 589
Coulter Ck.
Nelson Ck.
Jack of Clubs Lake
Lowhee Gulch
BARKERVILLE MTN.
Williams Creek
Ballarat - St Georges 500
Cow Mtn.
Nelson Creek 59
Burns Ck.
Cariboo Gold Quartz Mine 17, 402-404
Burns Creek 494
BARKERVILLE
MT. BURNS
Lightning Creek
Maude Creek 593
Maude Ck.
Acme Vein
Wells Adit 588, 590
Foster's Ledge 493
STANLEY
Burns Mountain 502
MT. PROSERPINE
Beggs Gulch 472
Beggs Ck.
Antler Ck.
Cow Mountain 546-551
Forrest Claim 587
Oregon Gulch 471
Dry Gulch 522
Lowhee Gulch 596
Warspite 586
ANTLER MTN.
California Gulch 501
California Ck.
B.C. Vein 594
Creek
Kilometers
Miles
Myrtle 596
LODE
PLACER
Cunningham Creek 496
Cunningham
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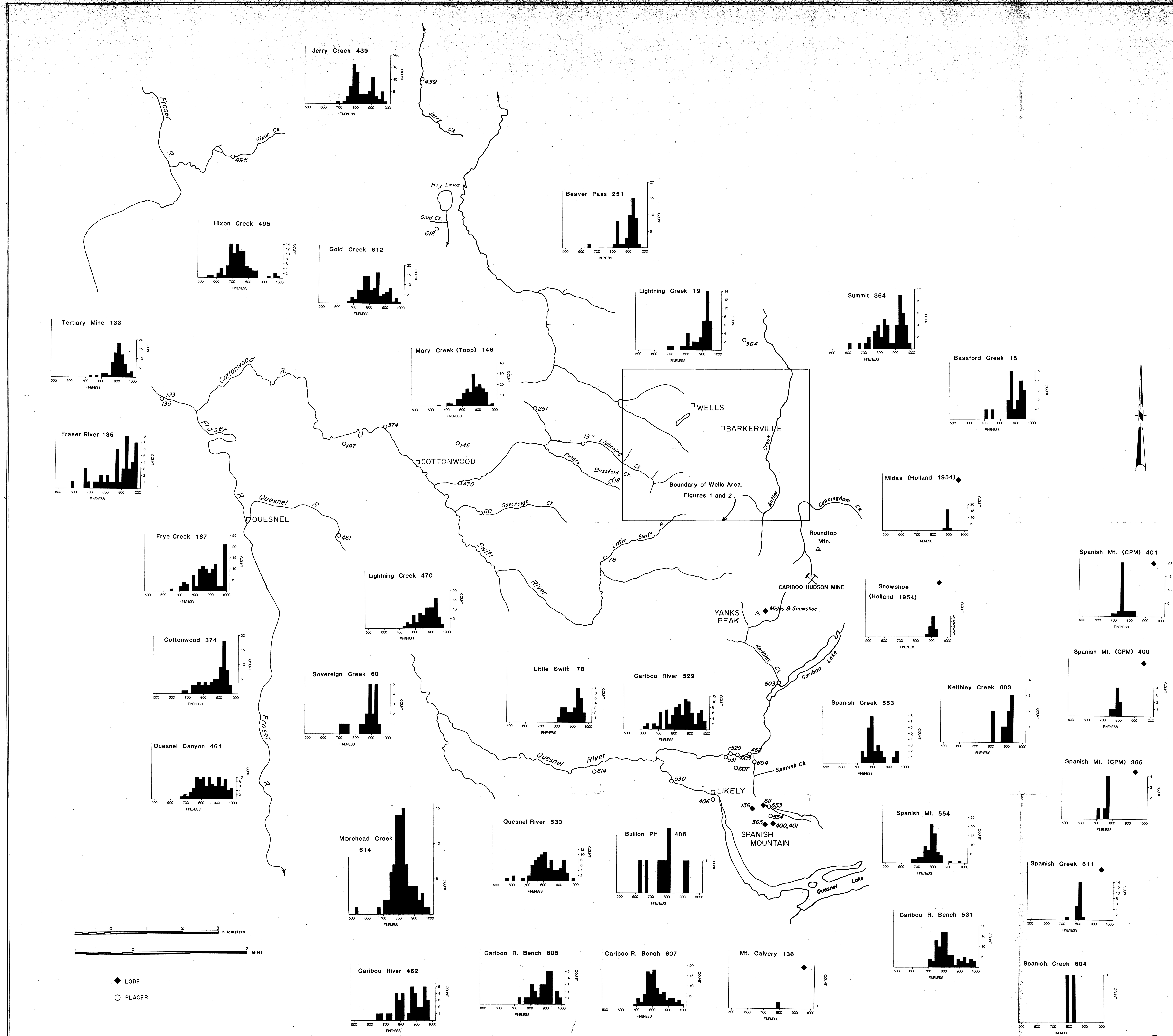
FINENESS

Figure 1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Bassford Creek 18
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Midas (Holland 1954)
Frye Creek 187
Lightning Creek 470
Snowshoe (Holland 1954)
Spanish Mt. (CPM) 401
Cottonwood 374
Sovereign Creek 60
Little Swift 78
Cariboo River 529
Spanish Creek 553
Keithley Creek 603
Spanish Mt. (CPM) 400
Quesnel Canyon 461
Spanish Mt. (CPM) 365
Morehead Creek 614
Quesnel River 530
Bullion Pit 406
Spanish Mt. 554
Spanish Creek 611
Cariboo R. Bench 531
Cariboo River 462
Cariboo R. Bench 605
Cariboo R. Bench 607
Mt. Calvery 136
Spanish Creek 604
FINENESS
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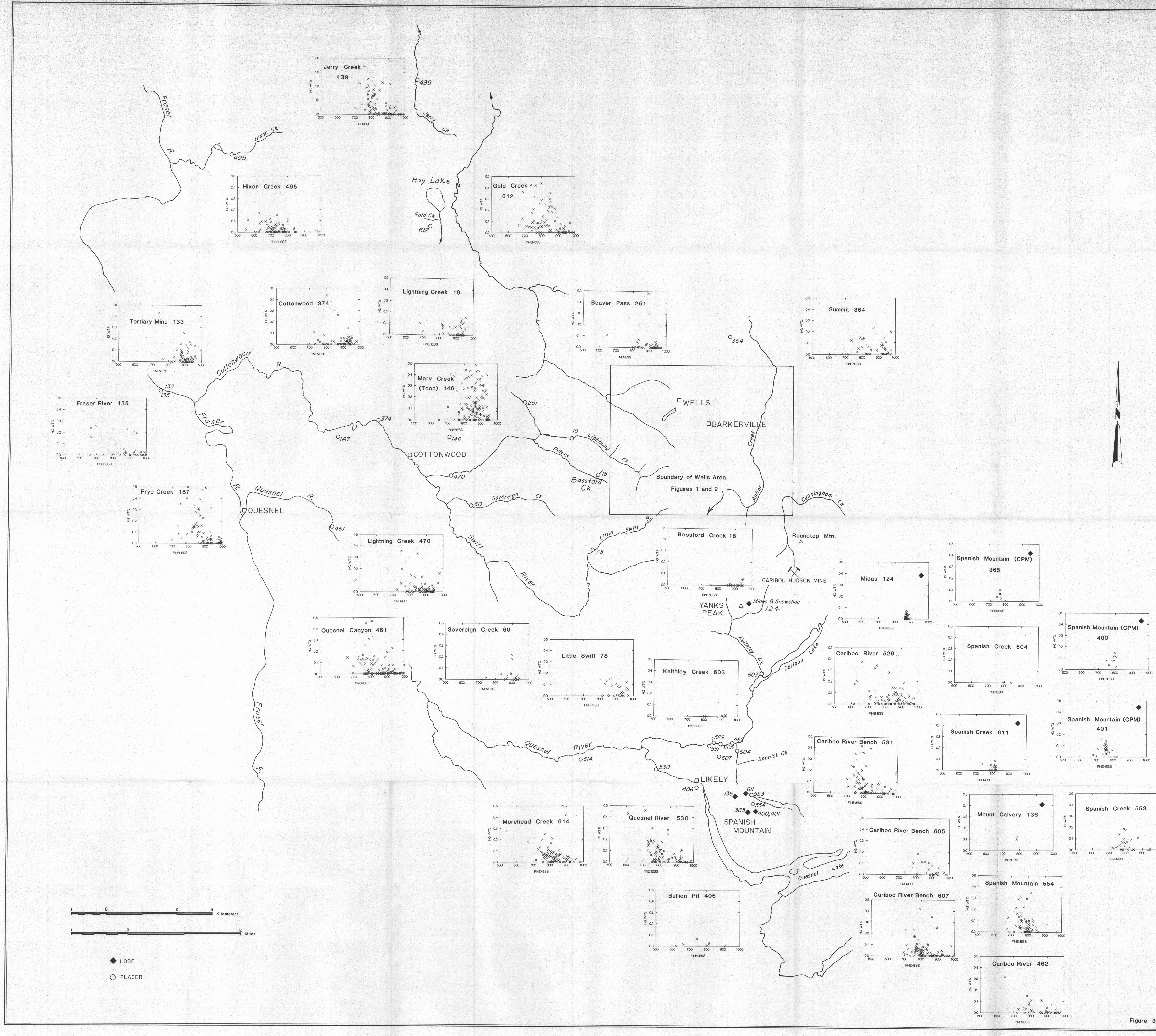
Fraser R.
Hixon Ck.
Jerry Ck.
Hoy Lake
Gold Ck.
Cottonwood R.
Quesnel R.
Swift River
Little Swift R.
Sovereign Ck.
Lightning Ck.
Peters
Bassford Ck.
Antler Creek
Cunningham Ck.
Keithley Ck.
Cariboo Lake
Spanish Ck.
Quesnel River
Quesnel Lake
WELLS
BARKERVILLE
COTTONWOOD
QUESNEL
LIKELY
Boundary of Wells Area, Figures 1 and 2
Roundtop Mtn.
CARIBOO HUDSON MINE
YANKS PEAK
Midas & Snowshoe
SPANISH MOUNTAIN
Kilometers
Miles
LODE
PLACER

Figure 4



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Gold Creek 612
Hay Lake
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Jerry Ck.
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Lightning Ck.
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Bassford Ck.
Boundary of Wells Area, Figures 1 and 2
Antler Creek
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Sovereign Creek 60
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Keithley Creek 603
Cariboo River 529
Spanish Creek 604
Spanish Mountain (CPM) 400
Quesnel River
Spanish Ck.
LIKELY
Cariboo River Bench 531
Spanish Creek 611
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SPANISH MOUNTAIN
Morehead Creek 614
Quesnel River 530
Mount Calvery 136
Spanish Creek 553
Cariboo River Bench 605
Quesnel Lake
Bullion Pit 406
Cariboo River Bench 607
Spanish Mountain 554
Cariboo River 462
HG WTS
FINENESS
Kilometers
Miles
LODE
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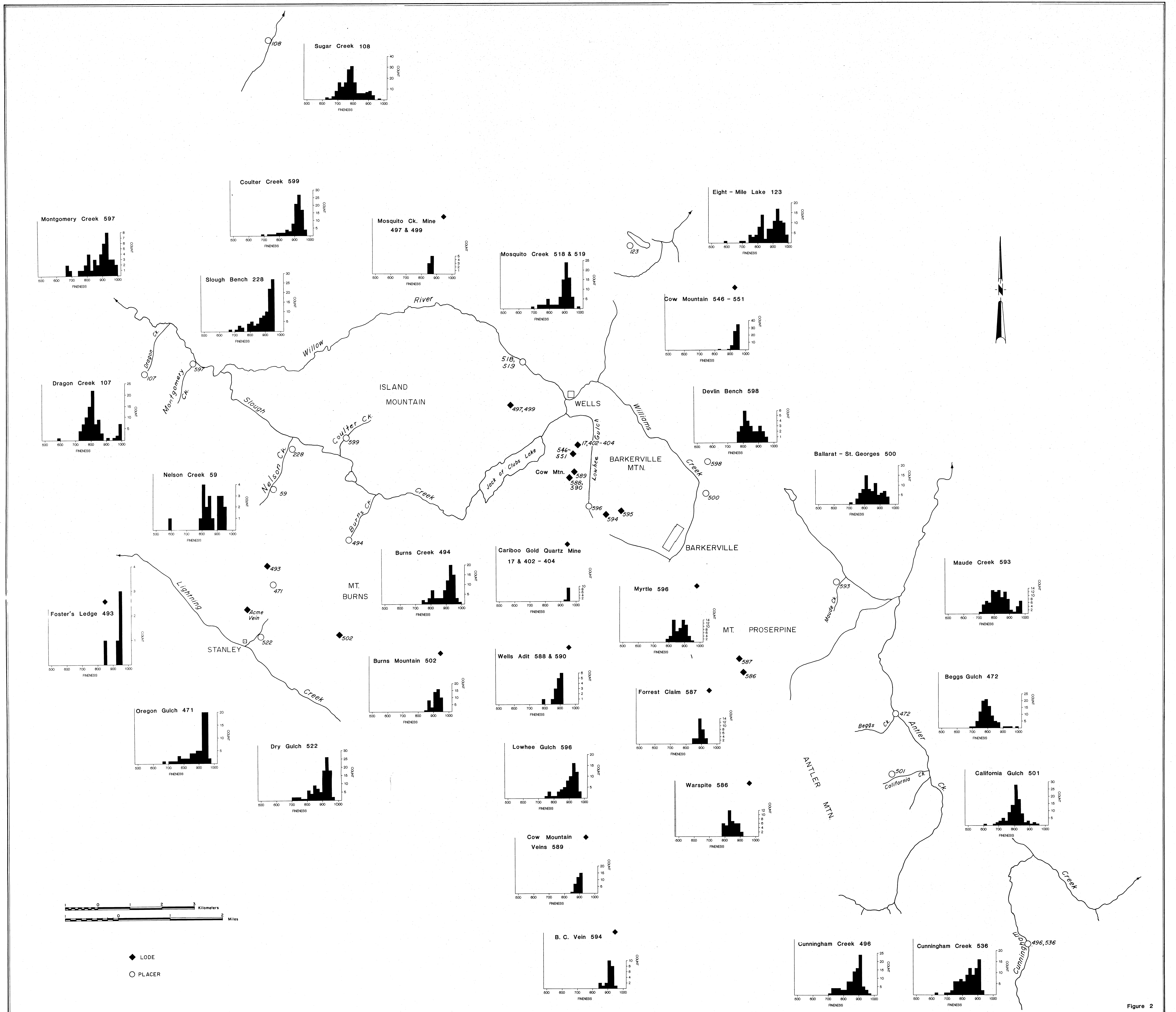
Figure 3


Sugar Creek 108
Coulter Creek 599
Montgomery Creek 597
Mosquito Ck. Mine 497 & 499
Eight - Mile Lake 123
Slough Bench 228
Mosquito Creek 518 & 519
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Dragon Creek 107
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Nelson Creek 59
Ballarat - St. Georges 500
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Cariboo Gold Quartz Mine 17 & 402 - 404
Maude Creek 593
Foster's Ledge 493
Myrtle 596
Burns Mountain 502
Wells Adit 588 & 590
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Beggs Gulch 472
Oregon Gulch 471
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Cow Mountain Veins 589
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Cunningham Creek 496
Cunningham Creek 536
COUNT
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Willow River
Slough Creek
ISLAND MOUNTAIN
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BARKERVILLE MTN.
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Jack of Clubs Lake
Lowhee Gulch
Williams Creek
Coulter Ck.
Nelson Ck.
Burns Ck.
Dragon Ck.
Montgomery Ck.
Cow Mtn.
MT. BURNS
STANLEY
Lightning Creek
Acme Vein
MT. PROSERPINE
ANTLER MTN.
Antler Ck.
Beggs Ck.
California Ck.
Maude Ck.
Cunningham Creek
Kilometers
Miles
LODE
PLACER

Figure 2


FIGURE: 8 GOLD FINENESS - NORTHERN CARIBOU