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By Gary E. Sherman

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

pct	percent	tr oz	troy ounce
st	short ton	tr oz/st	troy ounce per short ton
st/d	short ton per day	yr	year

ESTIMATION OF REMAINING LODE GOLD ENDOWMENT IN SELECTED MINING DISTRICTS OF ALASKA

By Gary E. Sherman[1]

ABSTRACT

The Bureau of Mines estimated the remaining lode gold endowment of eight mining districts in Alaska using historic production data. A logarithmic model of cumulative tonnage of ore processed versus cumulative grade was applied to the following districts: Chichagof, Fairbanks, Homer, Hope-Seward, Juneau, Ketchikan, Prince William Sound, and Willow Creek.

To assess the remaining endowment, a computerized production data base was compiled from Bureau records. These data were aggregated in 5-yr intervals for each district. Data were sorted in order of declining grade, and log cumulative grade was plotted against log cumulative tonnage. Linear regression was performed on the data for each district. The linear equation for each curve was used to predict remaining endowment at a limiting mining grade.

Based on conservative extrapolation of the grade-tonnage curves, a substantial total endowment of 8,415,100 tr oz of gold remains in the eight districts. The districts with the greatest remaining endowment are the Juneau, Chichagof, Fairbanks, and Willow Creek Districts.

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INTRODUCTION

The Bureau of Mines Minerals Availability Program (MAP) was established in 1974 to systematically assess mineral supplies from domestic and foreign sources. In the context of MAP goals, an assessment of the remaining lode gold endowment for eight mining districts in Alaska was undertaken.

Exploration activity in Alaska has declined dramatically in recent years, owing primarily to metal price declines; however, there has been a renewed interest in the potential of past lode gold producers. Many past producing lode gold mines in Alaska were unable to resume production owing to economic conditions following World War II. Others discontinued production owing to declining grade or the lack of adequate reserves. Many of the past producers in Alaska may contain significant remaining resources of gold.

Several studies have used grade-tonnage relationships in examining the characteristics of ore deposit types and metal contents (1-3).[2] Lasky (4) established what has become known as Lasky's law, in which cumulative log tonnage plotted against cumulative grade exhibits a linear relationship for many deposit types. This is a negative exponential relationship of the form $g = C_1 - C_2 \log t$, where g is average grade, t is tons, and C_1 and C_2 are constants. Lasky suggested that the tonnage-grade distribution for porphyry copper deposits could be used to estimate unknown copper resources by extrapolating the curve to some limiting cutoff grade (5).

Cargill (6) used historic production data to predict remaining usable resources in a log grade-log tonnage model. Use of historic production data inherently includes geologic, economic, and political conditions that have influenced production. The preferred method would be to measure cumulative return per unit effort, where effort includes such factors as exploration, extraction, processing, and transportation (6). Since data on effort are generally lacking in the mineral industry, cumulative average grade is used in its place. Cargill explained the method as follows:

> The underlying premise of this production-grade method of estimating usable resources is that the sum of industry experiences is reflected in its production and discovery statistics. This premise is true because the mineral and petroleum industries continuously adjust to economic and technologic pressures (each industry is forced by free market economics toward the lowest cost product), as well as to increasing geologic knowledge....The suggestion that the future course of a mining industry can be estimated from its production history dates back at least to 1929 (D.F. Hewett).

Production data were grouped in 5-yr intervals by Cargill to minimize yearly variations in the data, and a least-squares fit to the line was made using the equation

$$\log y = b_0 + [b_1 \log x], \qquad (1)$$

where y = cumulative average grade,

x = cumulative ore,

b_0 = a constant,

and b_1 = slope of the line.

Regression was performed to minimize the expression

$$\sum_{i=1}^{n} (\log y_i - b_0 - [b_1 \log x_i])^2, \qquad (2)$$

where n = number of data points,

y_i = cumulative grade, ith period,

and x_i = cumulative ore, ith period.

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[2]Underlined numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

Cargill (7) proved that, for any point on the curve,

$$y = L_0/(1+b_1), \quad (3)$$

where L_0 = limiting grade.

By selecting an average mining grade and using equation 3 to determine cumulative grade, the initial tonnage of ore at the mining grade can be estimated. Subtraction of past production yields the usable resources available at the mining grade chosen.

Harris (8) expressed concern about the method used by Cargill. He suggested that a reordering of the data by declining grade may be appropriate in certain cases. Such a reordering can produce a curve that is more linear than one based on a time series. Harris argued that by equating cumulative grade with cumulative effort, bias can be introduced when, for example, economic conditions force high grading of an ore body. This upsets the orderly decline of cumulative grade with time. However, Harris stated that reordering of production data may not be strongly indicated when there has been a significant decrease in grades over the life of a mine and when a grade-tonnage relation is fitted only to the low-grade portion of the data. Under these circumstances, the influence of grade variations in early years at relatively high grades is of little consequence. This is true because the cumulative average for the low-grade portion of the data may be unaffected by reordering production data at the earlier high grades (8).

Historically, grade-tonnage relationships provide an estimate of the physical stock or endowment (8). Use of the reordered production data results in modeling of the physical stock, not a quantity-effort relationship as used by

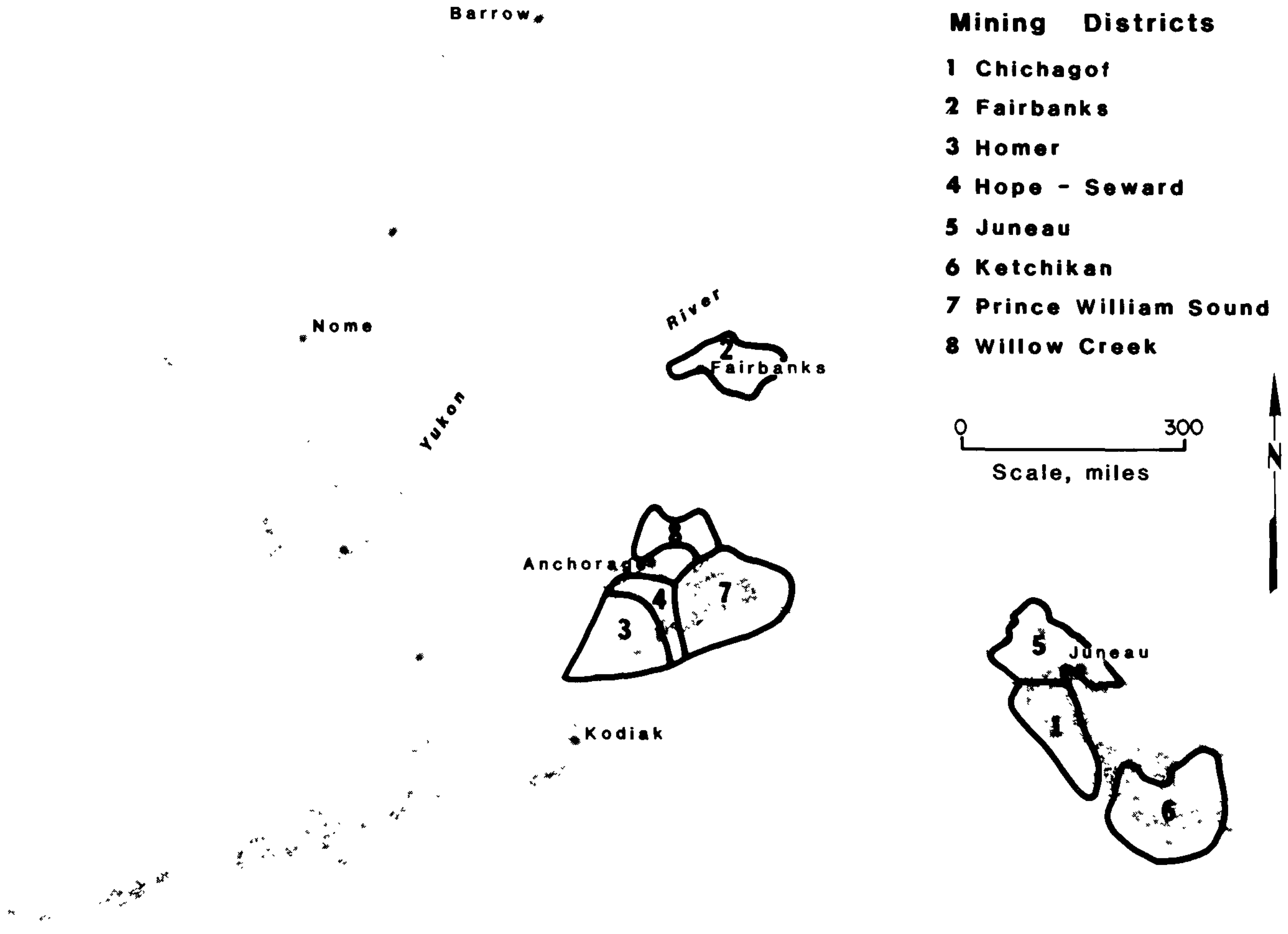

FIGURE 1.—Location of Alaska mining districts. (Modified from Ransome and Kerns (9).)

Cargill (6), since production is ordered by declining grade and not by year.

Based on Harris' arguments, it was decided that reordering of the data by declining grade was the best approach for this study. Cumulative log grade-log tonnage curves were constructed for each district to provide an estimate of the nonproduced portion of the lode gold endowment. Production data from the Chichagof, Fairbanks, Homer, Hope-Seward, Juneau, Ketchikan, Prince William Sound, and Willow Creek Districts were analyzed. Locations of the districts examined are shown in figure 1. Mining district names and boundaries follow the convention of Ransome (9).

PAST AND PRESENT GOLD PRODUCTION

TABLE 1. - Lode gold production, by district[1]

(Ranked in descending order)

District	Gold, tr oz
Juneau	5,652,776.00
Chichagof	826,739.00
Willow Creek	611,833.20
Fairbanks	233,347.10
Prince William Sound	137,889.60
Chistochina	56,843.55
Alaska Peninsula	51,692.54
Ketchikan	51,305.35
McGrath	38,592.88
Unclassified[2]	17,213.60
Homer	16,026.58
Hope	15,113.53
Kantishna	7,643.59
Nome	6,189.17
Petersburg	5,913.23
Admiralty	4,997.13
Anchorage	4,478.78
Seward	3,020.15
Iditarod	2,892.06
Bonnifield	2,301.27
Hyder	2,240.57
Valdez Creek	1,700.80
Nizina	1,363.26
Innoko	478.91
Chisana	172.00
Kodiak	71.24
Fairhaven	70.19
Chandalar	70.00
Aniak	49.70
Yentna	1.65
Redoubt	.24
Total	7,753,026.87

[1]Districts with Bureau production records.

[2]Production for which no district could be assigned owing to lack of information.

Total gold production from Alaska (1880-1984) has been estimated at 31 million tr oz (10). Available Bureau data for the period 1891 to 1965 indicate a total lode production of 7,753,027 tr oz. Table 1 summarizes actual lode gold production by district, sorted in descending order. The majority of lode gold production in Alaska came from the Alaska Juneau Mine and the Treadwell group (the Treadwell, Mexican, Ready Bullion, and 700 Foot Mines), both in the Juneau District. As seen in figure 2, lode gold production dropped sharply after 1917 owing to the cave-in and subsequent closure of the Treadwell group, and again in 1942 following the issuance of War Production Board order L-208, which declared gold mining a nonessential wartime industry. Economic conditions following World War II prevented the resurgence of major lode mining activity, even though attempts were made to open mines with known

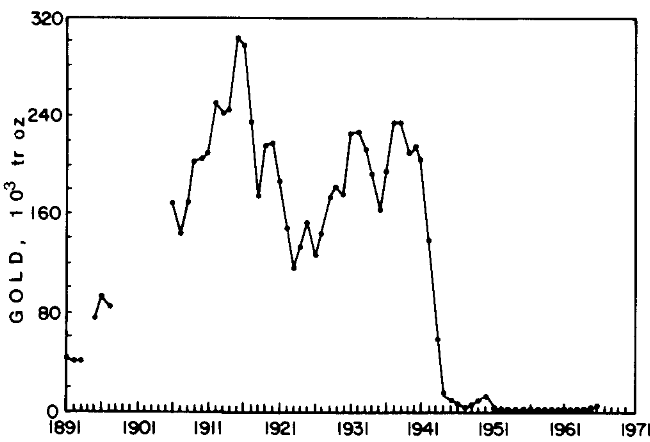

FIGURE 2.—Alaska lode gold production (1891-1965). Missing portions of the curve indicate lack of data. Based on Bureau of Mines production data.

reserves. Lode gold production in recent years has been limited to small-scale (less than 200-st/d) operations such as the Little Squaw Mine in the Chandalar District, the Independence Mine in the Willow Creek District, and the Grant Mine in the Fairbanks District.

Gold production in Alaska in 1984 exceeded 175,000 tr oz, virtually all of it from placer deposits (10).

METHODOLOGY

Alaskan lode gold production records compiled by the Bureau from 1891 through 1965 were entered into a computerized data base to allow retrieval and manipulation. The production records are a combination of mint, smelter, and Bureau canvass records. These data are often lacking in terms of total production for a given mine, but were considered complete enough to attempt an estimation of remaining gold endowment.

The eight districts for analysis were chosen based first on the quantity of information available and secondly on the completeness of the historic production data. Many of the individual mine records lack key information such as tons of ore processed per year and mine name. In some cases only yearly district or regional totals were available.

Where information allowed, missing annual tonnages were estimated. This was accomplished by using an average grade of production for a block of years surrounding the year with no tonnage data. Only years with comparable production levels (troy ounces) were used to compute the average grade. The tonnage was then estimated by dividing the troy ounces produced in the missing year by the average grade for the block of surrounding years.

When no annual tonnage figures were available for most of the district, the data could not be used in the model. Other districts are dominated by mines that produced gold from primary copper deposits. These deposits have lower gold grades than epithermal gold deposits and cannot be aggregated without changing the nature of the grade-tonnage relationship. Aggregating data across deposit types may introduce a high degree of variability in the grade-tonnage curve; therefore data were restricted to production from primary lode gold (quartz vein) deposits. An exception to this is the treatment of the Juneau District, in which production was dominated by large low-grade deposits (Alaska Juneau and Treadwell Mines). Data for the quartz vein deposits were aggregated with those for the low-grade deposits. Since the "high-grade" quartz vein deposits accounted for less than 10 pct of the production from the district, these data exert little influence on the cumulative curve.

Production records were cross referenced with the Bureau of Mines Minerals Availability System (MAS) sequence number for each deposit to verify that each mine was assigned to the proper district. Following elimination of duplicate and/or secondary records, the data were aggregated in 5-yr intervals for each district. Cumulating the data over a 5-yr period smooths the cumulative grade-tonnage curve by lessening the yearly variation. Curves were plotted, and a least-squares regression analysis was performed to fit a linear equation to each line. Extrapolation of the curve to a limiting grade provided an estimate of remaining gold endowment. Remaining endowment is defined for the purpose of this study as the nonproduced portion of the mineralized rock (at a limiting grade) associated with lode gold deposits that have produced in the past. Limiting grade is chosen to be less than the lowest production grade in the district, but greater than a technologic cutoff grade. Vein gold deposits in Alaska generally had a production grade greater than 0.2 tr oz/st. The Juneau District deposits produced at grades of less than 0.15 tr oz/st. Based on these historical values, the limiting grade (grade at which remaining endowment was calculated) was taken to be 0.1 to 0.2 tr oz/st less than the historic production grades. Care should be taken not to extrapolate the curves beyond reasonable limit. Taking a very low limiting grade can result in estimates that are astronomically high and probably invalid.

Most of the cumulative grade-tonnage curves for the districts examined illustrate an upper high-grade portion with a flatter slope than the rest of the curve. This is because many of the mines in Alaska were short-lived, high-grading operations. For a mine (and therefore aggregated district data) to exhibit an orderly decline in grade over time, the mining operation must operate over a sufficient time span to allow a representative sampling of the ore body. Because of this, the upper data points were dropped in the regression analyses for all of the districts except Chichagof, Juneau, and Willow Creek.

The estimate of remaining endowment is based on an average limiting grade. Limiting grade is converted to a cumulative grade using equation 3. This cumulative grade is used in the equation

$$x = 10^{((\log y - b_0)/b_1)}. \qquad (4)$$

The tonnage x represents the total amount of ore originally present at cumulative grade y. Total gold present is equal to the product of x and y. Subtracting the previous production from the original amount of gold present yields an estimate of remaining endowment in troy ounces of gold.

ESTIMATION OF REMAINING ENDOWMENT

Table 2 shows the eight districts chosen for analysis along with the number of mines in the data set, documented production, total tons of ore produced, and average grade. Documented production is defined as gold production for which annual tons of ore produced are known. Tonnage of ore per year is essential in forming the cumulative grade-tonnage curve; mines lacking this information are not included in the analysis. For this reason, the production figures for each district in table 2 are less than those in table 1.

Individual estimates by district are discussed in the following sections. For each district a table lists the remaining gold endowment estimates for a range of limiting grades. The range of estimates is given for each district to illustrate the dependency of the estimate on the limiting grade chosen. As stated previously, at some point the limiting grade becomes meaningless in terms of mining, and the endowment estimate can approach astronomical proportions.

A total remaining gold endowment of 8,415,100 tr oz was estimated for the eight districts. Appendix A presents raw production data for the eight districts, and appendix B gives regression analysis results by district.

TABLE 2. - Summary of districts analyzed

District	Number of mines[1]	Documented production, tr oz gold	Total ore, st	Average grade tr oz/st
Chichagof............	8	787,347	827,313	0.95
Fairbanks............	56	230,499	195,071	1.18
Homer................	8	10,391	9,020	1.15
Hope-Seward..........	20	17,587	18,271	.96
Juneau...............	28	5,583,121	116,089,758	.05
Ketchikan............	37	16,042	38,175	.42
Prince William Sound.	27	82,777	74,818	1.11
Willow Creek.........	28	607,726	539,624	1.13

[1]Number of mines included in the analysis.

TABLE 3. - Remaining endowment estimates, Chichagof District

Limiting grade, tr oz/st	Cumulative grade, tr oz/st	Original ore available, st	Remaining gold endowment, tr oz
0.1............	0.183	32,386,600	5,139,400
.2............	.366	7,019,100	1,781,600
.3............	.549	2,869,600	788,100
.4............	.732	1,521,200	[1]326,200
.5............	.915	929,800	63,400
.6............	1.097	623,200	0
.7............	1.280	443,400	0
.8............	1.463	330,200	0

[1]Estimate of remaining endowment based on historic grades.

CHICHAGOF DISTRICT

Production from the Chichagof District (table 3) came primarily from the Hirst-Chichagof and the Chichagoff Mines. These two mines accounted for over 98 pct of the gold produced in the district. Figure 3 is a plot of the cumulative grade-tonnage data. Linear regression of the data in figure 3 yields values of 2.67 for b_0 and -0.453 for b_1. The lowest grade material produced in the Chichagof District was ore with a grade of 0.49 oz/ton. Using 0.4 oz/ton as a limiting grade in equation 4, the estimated remaining endowment of gold in the district is 326,200 tr oz. Since the majority of the production data came from two mines and continued over a significant time span, the grade-tonnage curve fits the model well. Table 3 shows estimates of remaining endowment for the Chichagof District over a range of limiting grades.

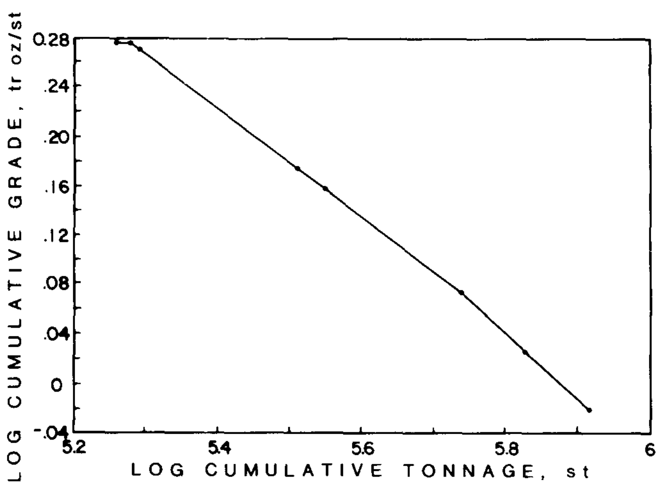

FIGURE 3.—Grade-tonnage curve, Chichagof District.

TABLE 4. - Remaining endowment estimates, Fairbanks District

Limiting grade, tr oz/st	Cumulative grade, tr oz/st	Original ore available, st	Remaining gold endowment, tr oz
0.1...........	0.123	42,718,665,800	5,254,165,400
.2...........	.246	1,028,435,000	252,764,500
.3...........	.369	116,265,200	42,671,400
.4...........	.491	25,031,500	12,060,000
.5...........	.614	7,525,100	4,389,900
.6...........	.737	2,819,500	1,847,500
.7...........	.860	1,229,700	[1]827,000
.8...........	.983	599,300	358,600

[1]Estimate of remaining endowment based on historic grades.

FAIRBANKS DISTRICT

Gold production in the Fairbanks District came from a number of mines, many with a short production span. The Clearly Hill, Free Gold, Hi Yu, and McCarty Mines accounted for 65 pct of the district production.

Figure 4 shows the cumulative grade-tonnage curve for the district. The upper data point was eliminated from the data set for the purposes of the regression since it represents a small high-grade portion of the total district production. Regression yielded an equation with values of 1.07 for b_0 and -0.186 for b_1. Based on the aggregated data, a grade of 0.895 tr oz/st was the lowest average grade mined in the district. Using a limiting grade of 0.7 tr oz/st, a total remaining endowment of 827,000 tr oz gold was estimated for the Fairbanks District. Table 4 shows the estimates for the district over a range of limiting grades.

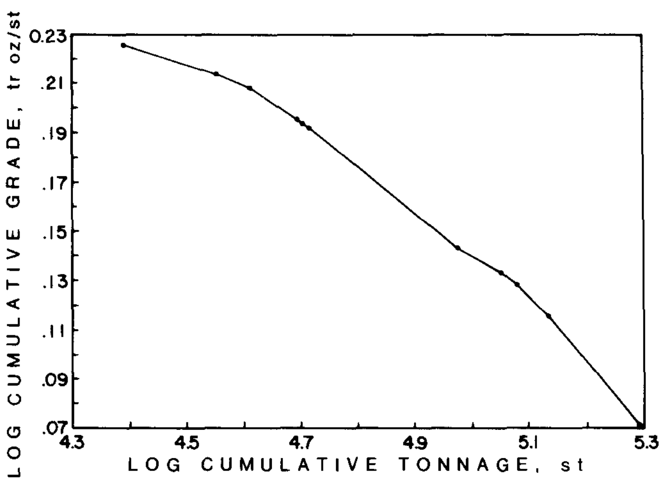

FIGURE 4.—Grade-tonnage curve, Fairbanks District.

TABLE 5. - Remaining endowment estimates, Homer District

Limiting grade, tr oz/st	Cumulative grade, tr oz/st	Original ore available, st	Remaining gold endowment, tr oz
0.1............	0.127	246,486,300	31,293,400
.2............	.255	9,617,500	2,442,100
.3............	.382	1,466,500	549,800
.4............	.509	385,700	185,900
.5............	.637	135,800	76,100
.6............	.764	58,300	34,200
.7............	.892	28,300	14,900
.8............	1.019	15,300	[1]5,200

[1]Estimate of remaining endowment based on historic grades.

HOMER DISTRICT

Gold production in the Homer District came primarily from the Nuka Bay region and is based on data from eight mines which produced high-grade ore over a 20-yr period. Figure 5 is the cumulative grade-tonnage curve for the district. The upper data point was eliminated from the data set in the regression analysis. Regression of the curve yielded coefficients of 0.91 for b_0 and -0.215 for b_1. Past mining reached a lower grade of 0.94 tr oz/st. Using a limiting grade of 0.8 tr oz/st yields an endowment estimate of 5,200 tr oz of gold. Table 5 shows the remaining endowment estimates for the district over a range of limiting grades.

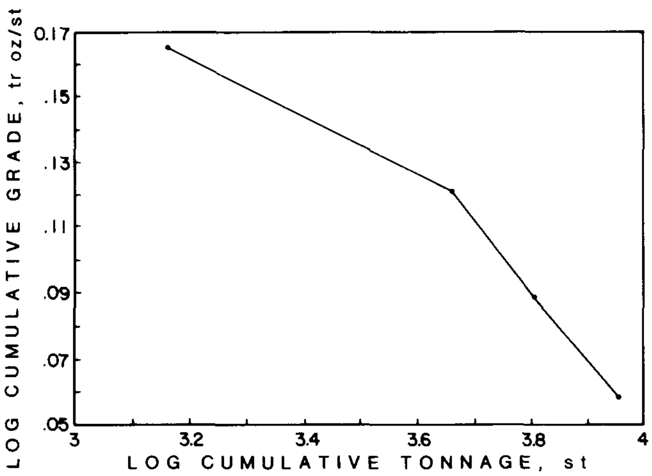

FIGURE 5.—Grade-tonnage curve, Homer District.

TABLE 6. - Remaining endowment estimates, Hope-Seward District

Limiting grade, tr oz/st	Cumulative grade, tr oz/st	Original ore available, st	Remaining gold endowment, tr oz
0.1............	0.131	88,300,700	11,549,800
.2............	.263	4,734,200	1,227,500
.3............	.394	867,600	324,200
.4............	.525	260,000	[1]118,900
.5............	.656	102,000	49,300
.6............	.788	47,300	19,700
.7............	.919	24,800	5,200
.8............	1.050	14,200	0

[1]Estimate of remaining endowment based on historic grades.

HOPE-SEWARD DISTRICT

Data for the Hope and Seward Districts were combined to produce the cumulative grade-tonnage curve in figure 6. All mines in the district occur in the Valdez Group of metasediments and are typically small, high-grade vein deposits (11). Many of the mines produced over a 10-yr period. The most sustained production came from the Lucky Strike Mine, which was active for 26 yrs.

The upper data point on the grade-tonnage curve was eliminated from the data set in the regression analysis. Regression yielded coefficients of 1.01 for b_0 and -0.238 for b_1. The lowest grade mined previously in the district was 0.54 tr oz/st; using a limiting grade of 0.4 tr oz/st, an estimated 118,900 tr oz of gold remain. Table 6 shows remaining endowment estimates over a range of limiting grades.

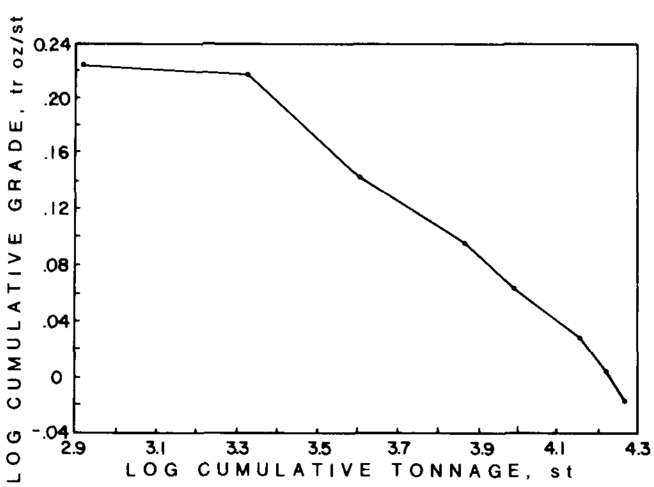

FIGURE 6.—Grade-tonnage curve, Hope-Seward District.

TABLE 7. - Remaining endowment estimates, Juneau District

Limiting grade, tr oz/st	Cumulative grade, tr oz/st	Original ore available, st	Remaining gold endowment, tr oz
0.01...........	0.016	2,572,130,300	35,571,000
.02...........	.032	385,683,100	[1]6,758,700
.03...........	.047	134,652,600	745,600
.04...........	.063	60,379,700	0
.05...........	.0883	32,496,300	0
.06...........	.1060	19,614,200	0
.07...........	.1237	13,130,400	0
.08...........	.1413	9,053,800	0

[1]Estimate of remaining endowment based on historic grades.

JUNEAU DISTRICT

The Alaska Juneau and Treadwell group mines accounted for 91 pct of the gold production in the Juneau District. Figure 7 is a cumulative grade-tonnage plot for the district. The more gently sloping upper part of the curve is due to the large influence of relatively higher grade material from the Treadwell group. According to Bureau records, the grades at the Treadwell and Alaska Juneau mines averaged 0.11 and 0.03 tr oz/st respectively. Based on Bureau data used in the grade-tonnage model, the Treadwell group processed over 19 million tons of ore, thus influencing the grade-tonnage curve to a large extent.

To include the influence of the Treadwell group production in the endowment estimate, all data points were used in the regression analysis. The resulting least-squares fit is not as good as could be obtained by eliminating the upper two points; however, including the Treadwell data yields a more realistic estimate of the remaining gold endowment in the Juneau District.

The resulting regression equation has coefficients of 2.14 for b_0 and -0.428 for b_1. At a limiting mining grade of 0.02 tr oz/st, 6,758,700 tr oz of gold remain as predicted by the grade-tonnage model. Table 7 lists the remaining gold endowment estimates over a range of limiting grades.

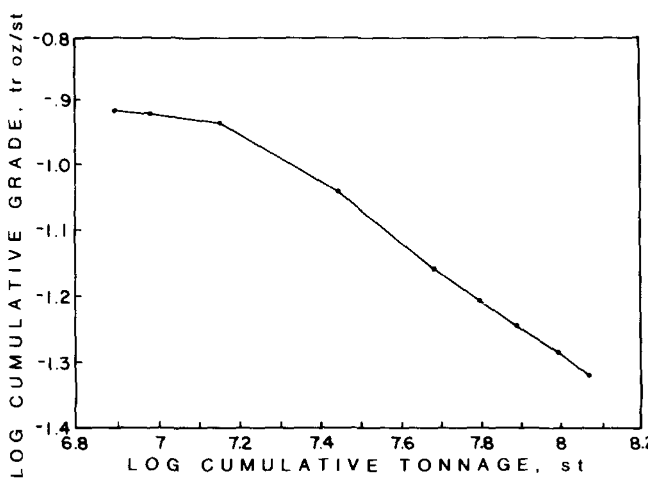

FIGURE 7.—Grade-tonnage curve, Juneau District.

TABLE 8. - Remaining endowment estimates, Ketchikan District

Limiting grade, tr oz/st	Cumulative grade, tr oz/st	Original ore available, st	Remaining gold endowment, tr oz
0.1............	0.158	527,900	67,400
.2............	.317	79,800	[1]9,300
.3............	.475	26,600	0
.4............	.634	12,200	0
.5............	.792	6,700	0
.6............	.950	4,100	0
.7............	1.109	2,700	0
.8............	1.267	1,900	0

[1]Estimate of remaining endowment based on historic grades.

KETCHIKAN DISTRICT

Gold produced from the Ketchikan District came from deposits with markedly lower grades than the other districts, except for the Juneau District. Most of the gold in the district was produced as a byproduct from primary copper mines. Only production data from primary lode gold deposits are included in the estimation of remaining gold endowment. Average grade of the deposits in the data set was 0.42 tr oz/st, compared with grades near or above 1.0 tr oz/st in the other districts (excluding Juneau).

Figure 8 is the cumulative grade-tonnage curve on which the regression was performed. The upper two data points were eliminated from the data set in the regression. Regression yielded coefficients of 1.31 for b_0 and -0.369 for b_1. Based on the lowest mined grade of 0.28 tr oz/st, a limiting grade of 0.2 tr oz/st was used to estimate the remaining gold endowment. This yielded a total of 9,300 tr oz of gold. Table 8 shows the remaining endowment over a range of limiting grades.

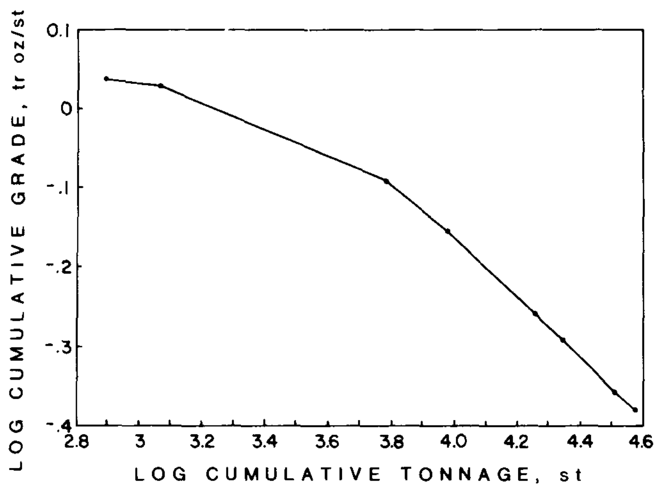

FIGURE 8.—Grade-tonnage curve, Ketchikan District.

TABLE 9. - Remaining endowment estimates, Prince William Sound District

Limiting grade, tr oz/st	Cumulative grade, tr oz/st	Original ore available, st	Remaining gold endowment, tr oz
0.1............	0.183	3,926,000	635,700
.2............	.367	849,200	228,900
.3............	.550	348,700	109,000
.4............	.733	185,300	[1]53,000
.5............	.917	113,200	21,000
.6............	1.100	75,900	700
.7............	1.283	54,100	0
.8............	1.467	40,300	0

[1]Estimate of remaining endowment based on historic grades.

PRINCE WILLIAM SOUND DISTRICT

The Prince William Sound District produced 82,777 tr oz of gold from relatively high-grade quartz vein deposits. The largest producers were the Cliff and Granite Mines. Figure 9 shows the cumulative grade-tonnage curve for the district. The upper data point was eliminated from the data set for purposes of the regression. Regression yielded coefficients of 2.26 for b_0 and -0.455 for b_1. Based on 0.44 tr oz/st as the lowest grade mined, a limiting grade of 0.4 was used in the regression equation to predict remaining endowment. A total of 53,000 tr oz of gold are estimated to remain in the district. Table 9 lists remaining endowment estimates over a range of limiting grades.

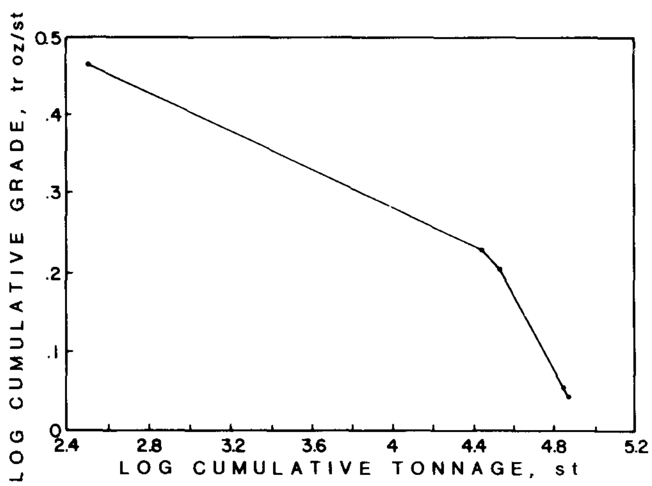

FIGURE 9.—Grade-tonnage curve, Prince William Sound District.

TABLE 10. - Remaining endowment estimates, Willow Creek District

Limiting grade, tr oz/st	Cumulative grade, tr oz/st	Original ore available, st	Remaining gold endowment, tr oz
0.1...........	0.127	15,722,138,900	1,996,103,900
.2...........	.254	608,907,100	154,054,700
.3...........	.381	90,909,000	34,028,600
.4...........	.508	23,582,500	11,372,200
.5...........	.635	8,280,200	4,650,200
.6...........	.763	3,499,200	2,062,200
.7...........	.890	1,699,600	904,900
.8...........	1.017	909,100	[1]316,800

[1]Estimate of remaining endowment based on historic grades.

WILLOW CREEK DISTRICT

The Willow Creek District was the third largest producer of gold in Alaska. The majority of production came from the Independence, Fern, Lucky Shot, War Baby, and Gold Cord Mines. Exploration, development, and minor production have taken place in the district in the last 5 yr.

Figure 10 shows the cumulative grade-tonnage curve for the district. Regression of the data yielded coefficients of 1.28 for b_0 and -0.213 for b_1. Based on 0.87 tr oz/st as the lowest grade produced in the district, an estimated 316,800 tr oz of gold remain at a limiting grade of 0.8 tr oz/st. Table 10 shows the remaining endowment estimates over a range of limiting grades.

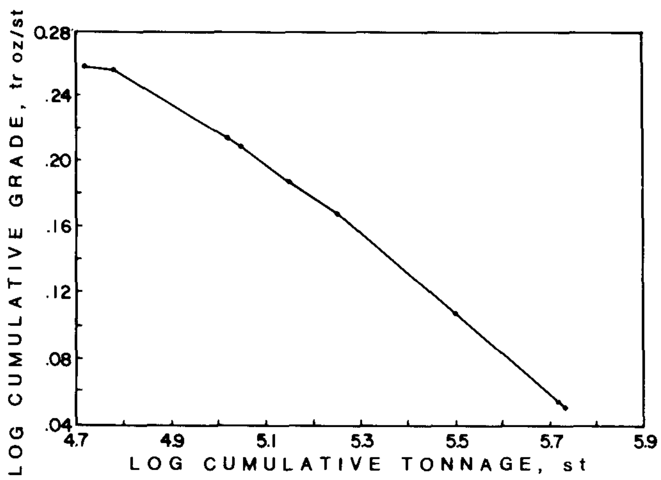

FIGURE 10.—Grade-tonnage curve, Willow Creek District.

DISCUSSION

The remaining gold endowment tables presented for the eight districts indicate the dependence of the estimate on the limiting grade chosen. The conservative approach based on past mining grades was used to determine a likely estimate of the nonproduced portion of the endowment. Based on past production history, the estimates listed in the tables can be considered to be a conservative estimate of remaining gold endowment. Table 11 presents a summary of the remaining endowment by district, ranked according to quantity remaining.

The feasibility of mining a deposit in any of these districts is not addressed. Economic feasibility depends on metal prices, deposit characteristics, and reserves and grade. The estimates presented above are intended to show the possible amount of lode gold remaining.

Clearly other districts with major past producers may have remaining gold resources and future production potential. Not all districts were examined owing to the nature of the production data available. Exclusion of a district from this study does not mean it has limited or no potential remaining gold resource.

The Juneau District has the largest remaining lode gold endowment, at a grade of 0.02 tr oz/st. Recent interest has been shown in the Alaska Juneau Mine and the Treadwell group mines. Barrick Resources Corp. obtained a lease on certain properties in 1984 and has been examining mine records and maps. Some fieldwork has also been conducted, and exploration targets have been defined (10).

The Fairbanks District has been the site of extensive reexamination of past producers in recent years. Underground work and drilling have taken place at a number of properties (10). Presently, Silverado Mines LTD, in a joint venture with two other participants, is preparing to return the Grant Mine to production.

The Chichagof and Willow Creek Districts have also had recent exploration activity, with a focus on reopening past producing mines. Interest has also been expressed in the other districts that were examined.

It is possible that some of the past producing gold mines in Alaska will come into production within the decade. Based on the results of this study, more than 8.4 million tr oz of gold could be produced from the eight districts examined, provided that the political and economic climate is favorable. Other districts such as the Alaska Peninsula, Kantishna, and Bonnifield also have potential for future lode gold production, but lacked sufficient production data to be analyzed in this study.

TABLE 11. - Summary of remaining endowment

District	Limiting grade, tr oz/st	Initial ore, st	Past production, tr oz gold	Remaining endowment, tr oz gold
Juneau	0.02	385,683,100	5,583,121	6,758,700
Fairbanks	.7	1,229,700	230,499	827,000
Chicagof	.4	1,521,200	787,347	326,200
Willow Creek	.8	909,100	607,726	316,800
Hope-Seward	.4	260,000	17,587	118,900
Prince William Sound	.4	185,300	82,777	53,000
Ketchikan	.2	79,800	16,042	9,300
Homer	.8	15,300	10,391	5,200
Total		389,883,500	7,335,490	8,415,100

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APPENDIX A.--RAW PRODUCTION DATA FOR DISTRICTS ANALYZED

TABLE A-1. - Raw production data, Chichagof District

Year	Ore, st	Gold, tr oz	Grade, tr oz/st	Year	Ore, st	Gold, tr oz	Grade, tr oz/st
1906...........	60	351	5.85	1928...........	3,539	4,290	1.21
1907...........	1,353	3,172	2.34	1929...........	4,071	3,818	.94
1908...........	2,071	2,792	1.35	1930...........	1,760	490	.28
1909...........	744	992	1.33	1931...........	12,584	6,249	.50
1910...........	4,282	7,784	1.82	1932...........	34,333	17,897	.52
1911...........	10,577	7,062	.67	1933...........	15,216	10,912	.72
1912...........	22,915	11,447	.50	1934...........	28,370	9,583	.34
1913...........	22,000	11,367	.52	1035...........	24,500	14,744	.60
1915...........	33,850	44,517	1.32	1936...........	21,475	11,866	.55
1916...........	36,822	39,453	1.07	1937...........	21,855	15,172	.69
1917...........	38,794	39,554	1.02	1938...........	25,588	21,811	.85
1918...........	33,978	60,200	1.77	1939...........	23,484	15,267	.65
1919...........	42,187	89,097	2.11	1940...........	38,070	12,945	.34
1920...........	33,243	83,080	2.50	1941...........	45,919	10,167	.22
1921...........	33,855	71,339	2.11	1942...........	4,184	5,081	1.21
1922...........	39,307	48,707	1.24	1943...........	534	776	1.45
1923...........	11,639	26,135	2.25	1944...........	200	22	.11
1924...........	44,283	18,489	.42	1947...........	12	11	.92
1925...........	66,470	22,609	.34	1950...........	537	397	.74
1926...........	33,725	25,779	.76	1951...........	100	151	1.51
1927...........	8,827	11,773	1.33				

TABLE A-2. - Raw production data, Fairbanks District

Year	Ore, st	Gold, tr oz	Grade, tr oz/st	Year	Ore, st	Gold, tr oz	Grade, tr oz/st
1910...........	148	841	5.68	1938...........	12,440	10,315	0.83
1911...........	875	3,103	3.55	1939...........	15,474	18,117	1.17
1912...........	4,708	9,417	2.00	1940...........	17,414	18,195	1.04
1913...........	12,237	16,905	1.38	1941...........	13,571	13,751	1.01
1914...........	6,526	10,905	1.67	1942...........	7,054	13,502	1.91
1915...........	6,545	10,535	1.61	1943...........	3,000	3,561	1.19
1916...........	1,111	1,905	1.71	1944...........	1,250	1,428	1.14
1917...........	1,200	2,142	1.79	1945...........	2,427	4,217	1.74
1918...........	1,035	1,294	1.25	1946...........	1,295	1,676	1.29
1919...........	1,384	1,507	1.09	1947...........	461	1,126	2.44
1920...........	504	967	1.92	1948...........	498	277	.56
1921...........	949	2,104	2.22	1949...........	463	207	.45
1922...........	1,524	2,542	1.67	1950...........	199	309	1.55
1923...........	1,278	1,197	.94	1952...........	152	236	1.55
1924...........	4,528	4,870	1.08	1953...........	275	398	1.45
1925...........	3,663	4,064	1.11	1954...........	194	144	.74
1926...........	1,089	788	.72	1955...........	1	1	1.00
1927...........	1,919	4,064	2.12	1956...........	1	1	1.00
1928...........	4,871	4,004	.82	1957...........	55	28	.51
1929...........	4,657	3,618	.78	1958...........	5	2	.40
1930...........	1,964	2,527	1.29	1959...........	214	538	2.51
1931...........	3,222	6,000	1.86	1960...........	1,075	1,215	1.13
1932...........	12,549	12,590	1.00	1961...........	135	279	2.07
1933...........	214	222	1.04	1962...........	162	293	1.81
1934...........	297	389	1.31	1963...........	861	1,134	1.32
1935...........	4,519	3,665	.81	1964...........	2,447	2,055	.84
1936...........	12,418	5,669	.46	1965...........	3,172	3,556	1.12
1937...........	14,839	15,688	1.06				

TABLE A-3. - Raw production data, Homer District

Year	Ore, st	Gold, tr oz	Grade, tr oz/st	Year	Ore, st	Gold, tr oz	Grade, tr oz/st
1917...........	5	1	0.12	1932...........	21	102	4.84
1918...........	1	0	.32	1933...........	423	429	1.02
1924...........	40	43	1.08	1934...........	326	252	.77
1925...........	637	949	1.49	1935...........	255	147	.58
1926...........	764	1,121	1.47	1936...........	1,550	1,497	.97
1927...........	1,602	2,100	1.31	1937...........	1,141	1,266	1.11
1928...........	165	279	1.69	1938...........	341	306	.90
1929...........	200	311	1.56	1940...........	84	23	.27
1930...........	325	451	1.39	1941...........	160	103	.64
1931...........	847	803	.95	1942...........	60	55	.92

TABLE A-4. - Raw production data, Hope-Seward District

Year	Ore, st	Gold, tr oz	Grade, tr oz/st	Year	Ore, st	Gold, tr oz	Grade, tr oz/st
1911.............	274	478	1.74	1931.............	937	415	0.44
1912.............	534	697	1.30	1935.............	212	29	.14
1913.............	1,133	856	.76	1936.............	208	295	1.42
1914.............	1,831	1,195	.65	1937.............	125	183	1.46
1915.............	815	804	.99	1938.............	922	1,208	1.31
1916.............	711	835	1.17	1939.............	542	707	1.30
1917.............	140	223	1.59	1940.............	1,598	1,718	1.08
1918.............	297	460	1.55	1941.............	722	634	.88
1919.............	96	435	4.53	1942.............	387	438	1.13
1920.............	55	169	3.08	1944.............	40	41	1.03
1921.............	150	345	2.30	1945.............	450	228	.51
1922.............	300	643	2.14	1946.............	399	191	.48
1923.............	250	218	.87	1947.............	655	308	.47
1924.............	800	761	.95	1948.............	224	143	.64
1925.............	392	116	.29	1949.............	120	127	1.06
1926.............	315	231	.73	1950.............	55	34	.62
1927.............	5	7	1.40	1954.............	520	209	.40
1928.............	450	231	.51	1955.............	47	318	6.77
1929.............	751	505	.67	1956.............	194	815	4.20
1930.............	605	329	.54	1958.............	10	9	.90

TABLE A-5. - Raw production data, Juneau District

Year	Ore, st	Gold, tr oz	Grade, tr oz/st	Year	Ore, st	Gold, tr oz	Grade, tr oz/st
1891.......	330,471	37,043	0.11	1925.......	3,485,976	98,985	0.03
1892.......	291,865	32,715	.11	1926.......	3,829,783	93,913	.02
1893.......	336,560	37,725	.11	1927.......	4,267,810	112,646	.26
1895.......	440,342	50,554	.11	1928.......	3,720,087	151,951	.04
1896.......	401,765	47,868	.12	1929.......	3,838,660	164,477	.04
1897.......	562,342	57,774	.10	1930.......	3,924,460	162,800	.04
1905.......	4,125	3,553	.86	1931.......	4,162,350	179,785	.04
1906.......	1,406,746	159,557	.11	1932.......	4,001,630	151,347	.04
1907.......	1,210,486	129,953	.11	1933.......	4,428,564	151,150	.03
1908.......	1,473,345	159,099	.11	1934.......	3,756,206	128,602	.03
1909.......	1,480,871	196,234	.13	1935.......	3,489,492	119,032	.03
1910.......	1,429,072	173,116	.12	1936.......	4,366,801	149,207	.03
1911.......	1,564,741	180,868	.12	1937.......	4,442,765	151,773	.03
1912.......	1,714,336	202,293	.12	1938.......	4,663,950	148,015	.03
1913.......	1,567,746	190,485	.12	1939.......	4,648,154	128,863	.03
1914.......	1,685,696	185,047	.11	1940.......	4,739,792	123,415	.03
1915.......	2,955,339	214,035	.07	1941.......	4,354,857	119,618	.03
1916.......	3,481,259	221,177	.06	1942.......	2,765,885	77,126	.03
1917.......	3,360,614	165,313	.05	1943.......	1,461,905	39,949	.03
1918.......	2,054,676	92,172	.04	1944.......	379,350	10,316	.03
1919.......	3,211,261	112,706	.04	1945.......	888	734	.83
1920.......	3,375,704	127,382	.04	1947.......	10	8	.80
1921.......	2,854,076	104,232	.04	1948.......	72	102	1.42
1922.......	2,463,231	76,088	.03	1949.......	101	391	3.87
1923.......	2,476,242	69,035	.03	1950.......	119	352	2.96
1924.......	3,068,217	92,500	.03	1951.......	15	41	2.73

TABLE A-6. - Raw production data, Kechikan District

Year	Ore, st	Gold, tr oz	Grade, tr oz/st	Year	Ore, st	Gold, tr oz	Grade, tr oz/st
1906.............	1,650	994	0.60	1929.............	35	128	3.66
1907.............	200	97	.48	1930.............	250	55	.22
1908.............	100	83	.83	1931.............	40	45	1.13
1909.............	2,700	155	.06	1932.............	100	82	.82
1910.............	400	77	.19	1933.............	2,648	431	.16
1913.............	4,401	1,501	.34	1934.............	3,012	278	.09
1914.............	2,250	932	.41	1935.............	3,203	337	.11
1915.............	626	412	.66	1936.............	561	517	.92
1916.............	800	278	.35	1937.............	961	1,403	1.46
1917.............	716	272	.38	1938.............	1,374	1,414	1.03
1918.............	1,147	393	.34	1939.............	1,415	914	.65
1919.............	400	130	.33	1940.............	1,569	1,001	.64
1920.............	250	74	.29	1941.............	346	213	.62
1921.............	1,800	576	.32	1942.............	188	133	.71
1922.............	4	1	.13	1945.............	7	16	2.29
1923.............	1,350	176	.13	1946.............	72	57	.79
1924.............	7	46	6.59	1947.............	148	84	.57
1925.............	90	98	1.09	1948.............	153	235	1.54
1926.............	15	40	2.68	1949.............	632	338	.53
1927.............	2,064	1,406	.68	1950.............	130	75	.58
1928.............	359	544	1.52	1954.............	2	2	1.00

TABLE A-7. - Raw production data, Prince William Sound District

Year	Ore, st	Gold, tr oz	Grade, tr oz/st	Year	Ore, st	Gold, tr oz	Grade, tr oz/st
1910...........	4,440	10,745	2.42	1932...........	52	36	0.70
1911...........	3,325	7,981	2.40	1933...........	95	62	.65
1912...........	4,692	11,369	2.42	1934...........	1,641	976	.59
1913...........	7,650	8,229	1.08	1935...........	658	384	.58
1914...........	7,120	7,809	1.10	1936...........	375	624	1.66
1915...........	16,790	11,252	.67	1937...........	1,748	1,014	.58
1916...........	12,513	7,739	.62	1938...........	785	1,038	1.32
1917...........	5,350	4,503	.84	1939...........	72	58	.81
1918...........	444	638	1.44	1940...........	1,204	874	.73
1919...........	15	52	3.45	1941...........	3,253	3,885	1.19
1920...........	20	6	.30	1942...........	1,300	1,775	1.37
1921...........	39	65	1.67	1944...........	40	17	.43
1922...........	170	423	2.49	1946...........	500	282	.56
1923...........	7	14	1.93	1948...........	2	291	4.50
1924...........	78	405	5.20	1949...........	1	4	4.00
1925...........	53	129	2.43	1955...........	25	26	1.04
1929...........	24	20	.84	1963...........	8	3	.38
1930...........	268	250	.93	1964...........	1	1	1.00
1931...........	60	60	.99				

TABLE A-8. - Raw production data, Willow Creek District

Year	Ore, st	Gold, tr oz	Grade, tr oz/st	Year	Ore, st	Gold, tr oz	Grade, tr oz/st
1909...........	912	665	0.73	1935...........	18,332	16,501	0.90
1010...........	144	1,046	7.27	1936...........	27,550	17,815	.65
1911...........	1,048	2,596	2.48	1937...........	50,399	37,467	.74
1912...........	3,000	4,838	1.61	1938...........	22,965	31,804	1.38
1913...........	3,028	4,884	1.61	1939...........	45,302	38,958	.86
1914...........	10,110	14,376	1.42	1940...........	62,740	51,490	.82
1915...........	6,717	11,962	1.78	1941...........	50,240	48,194	.96
1916...........	12,182	14,473	1.19	1942...........	32,389	37,549	1.16
1917...........	7,883	9,466	1.20	1943...........	16,280	13,079	.80
1918...........	7,886	12,874	1.63	1944...........	600	3,839	6.40
1919...........	6,730	7,882	1.17	1945...........	1,967	1,838	.93
1920...........	2,850	3,067	1.08	1946...........	2,698	1,275	.47
1921...........	3,591	5,722	1.59	1947...........	562	358	.64
1922...........	7,242	11,513	1.59	1948...........	355	476	1.34
1923...........	9,132	8,622	.94	1949...........	5,416	5,071	.94
1924...........	8,075	9,766	1.21	1950...........	10,270	8,806	.86
1925...........	15,834	21,990	1.39	1951...........	410	335	.82
1926...........	2,537	2,082	.82	1952...........	205	70	.34
1927...........	7,866	7,084	.90	1953...........	200	46	.23
1928...........	3,443	4,623	1.34	1954...........	240	156	.65
1929...........	39	363	9.31	1955...........	56	39	.70
1930...........	13,975	1,725	.12	1958...........	31	46	1.48
1931...........	7,951	21,282	2.68	1960...........	136	132	.97
1932...........	13,618	34,371	2.52	1961...........	72	97	1.35
1933...........	16,578	36,867	2.22	1963...........	5	3	.60
1934...........	17,833	38,141	2.14				

APPENDIX B.--REGRESSION ANALYSIS RESULTS, BY DISTRICT

CHICHAGOF DISTRICT

Equation coefficients:
b0 = 2.6669   b1 = -0.4533

Partitioned sum of squares

Source of variation	Degrees of freedom	Sum of squares
Due to regression..............	1	0.1101
Deviations from regression.....	7	0.0001
	----	--------
Total.............	8	0.1102

F = 5,529.26

Coefficient of determination (r squared) = 0.9987
Correlation coefficient (r) = 0.9994

FAIRBANKS DISTRICT

Equation coefficients:
b0 = 1.0672   b1 = -0.1860

Partitioned sum of squares

Source of variation	Degrees of freedom	Sum of squares
Due to regression..............	1	0.0200
Deviations from regression.....	8	0.0002
	----	--------
Total.............	9	0.0203

F = 655.84

Coefficient of determination (r squared) = 0.9879
Correlation coefficient (r) = 0.9940

HOMER DISTRICT

Equation coefficients:
b0 = 0.9072 b1 = -0.2149

Partitioned sum of squares

Source of variation	Degrees of freedom	Sum of squares
Due to regression..............	1	0.0019
Deviations from regression.....	1	0.0000
	----	--------
Total.............	2	0.0019

F = 998.16

Coefficient of determination (r squared) = 0.9990
Correlation coefficient (r) = 0.9995

HOPE-SEWARD DISTRICT

Equation coefficients:
b0 = 1.0100 b1 = -0.2382

Partitioned sum of squares

Source of variation	Degrees of freedom	Sum of squares
Due to regression..............	1	0.0408
Deviations from regression.....	5	0.0003
	----	--------
Total.............	6	0.0411

F = 600.84

Coefficient of determination (r squared) = 0.9917
Correlation coefficient (r) = 0.9959

JUNEAU DISTRICT

Equation coefficients:
b0 = 2.1353 b1 = -0.4282

Partitioned sum of squares

Source of variation	Degrees of freedom	Sum of squares
Due to regression..............	1	0.1268
Deviations from regression.....	6	0.0002
	----	--------
Total.............	7	0.1270

F = 3,270.77

Coefficient of determination (r squared) = 0.9982
Correlation coefficient (r) = 0.9991

KETCHIKAN DISTRICT

Equation coefficients:
b0 = 1.3080 b1 = -0.3686

Partitioned sum of squares

Source of variation	Degrees of freedom	Sum of squares
Due to regression..............	1	0.0640
Deviations from regression.....	4	0.0001
	----	--------
Total.............	5	0.0641

F = 5,042.70

Coefficient of determination (r squared) = 0.9992
Correlation coefficient (r) = 0.9996

PRINCE WILLIAM SOUND DISTRICT

Equation coefficients:
b0 = 2.2594 b1 = -0.4545

Partitioned sum of squares

Source of variation	Degrees of freedom	Sum of squares
Due to regression..............	1	0.0476
Deviations from regression.....	5	0.0001
Total.............	6	0.0478

F = 1,611.45

Coefficient of determination (r squared) = 0.9969
Correlation coefficient (r) = 0.9985

WILLOW CREEK DISTRICT

Equation coefficients:
b0 = 1.2777 b1 = -0.2132

Partitioned sum of squares

Source of variation	Degrees of freedom	Sum of squares
Due to regression..............	1	0.0609
Deviations from regression.....	8	0.0004
Total.............	9	0.0613

F = 1,144.77

Coefficient of determination (r squared) = 0.9931
Correlation coefficient (r) = 0.9965

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