FEASIBILITY OF ECONOMIC GOLD MINING IN THE JUNEAU GOLD BELT AREA OF THE JUNEAU MINING DISTRICT, ALASKA

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter
g	gram
kg	kilogram
km	kilometer
lb	pound
m	meter
mt	metric ton
mtpd	metric ton per day
pct	percent
tr oz	troy ounce
yr	year

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ABSTRACT

Preliminary economic mining feasibility studies were conducted by the Bureau of Mines to estimate mining costs in the Juneau gold belt area of the Juneau Mining District, southeastern Alaska. Investigations were conducted on the economics of two mineral deposit types: (1.) Berners Bay vein gold deposits, and (2.) stockwork gold deposits containing gold, silver, and lead.

Cost estimates were developed using the Bureau of Mines Cost Estimating System (CES). Discounted cash flow return on investment (DCFROI) was calculated using the Bureau's MINSIM computer program. Underground mining of a Berners Bay vein gold deposit was found to be economic (15 pct DCFROI) at a recoverable metal value of \$353.67/mt for a 100 mtpd shrinkage stoping mine with a 10 yr mine life, \$324.76/mt for a 20 yr mine life, \$138.63/mt for a 500 mtpd longhole stoping mine with a 10 yr mine life, and \$127.50/mt for a 20 yr mine life. Block caving mining of a large stockwork gold deposit was found to be economic at a recoverable metal value of \$15.28/mt for a 18,000 mtpd mine with a 20 yr mine life.

INTRODUCTION

This report is one of a series produced in conjunction with the Juneau Mining District project being conducted by the Bureau. A mining feasibility report on the Porcupine Mining Area was previously released as open file report 15-87 (1)[3].

Order of magnitude economic feasibility studies were conducted on typical deposit types that occur in the Juneau gold belt area of the Juneau Mining District. These studies determined recoverable metal values required to make a mineral deposit economically mineable. In order to make these economic assessments for two mineral deposit types, existing mineral deposit information was used wherever possible. Mineral deposit grades and supporting background information were furnished by project personnel. Because detailed deposit characteristics such as depth, thickness, attitude, and volume are either unknown or proprietary, assumptions were made on some deposit

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

characteristics. Those assumptions are discussed at the beginning of each deposit section.

The Juneau gold belt is located near Juneau in Southeastern Alaska. The Juneau gold belt has been mined for placer and lode gold since the 1880's. It is an elongate area approximately 160 km long and 20 km wide paralleling the coastline of the mainland. Figure 1 shows the boundaries used in the Juneau Mining District project. Access to the area is provided by ocean-going vessels that ply the waters of the inside passage. The nearest highway is at Haines, approximately 130 km north of Juneau. The port at Juneau is suitable for landing medium to large quantities of seaborne freight. In addition, Juneau International Airport is capable of handling medium to large jet aircraft. The road system in the Juneau gold belt consists of roads from Juneau to Douglas Island on the west, to Berners Bay on the north, and to Thane on the south.

The climate of the Juneau gold belt is typical of much of Southeastern Alaska, which is influenced by maritime weather systems that drop substantial precipitation. The climate at Juneau is cool, with winter temperatures averaging -4° to 2° C. Average summer temperatures are 8° to 17° C. Annual temperature extremes range from -23° to 31° C. Annual precipitation is 230 cm including approximately 240 cm snow (2, p. 16).

ECONOMIC MINE FEASIBILITY STUDIES

Economic feasibility studies for two mineral deposit types were conducted to establish the discounted cash flow return on investment (DCFROI). For the purposes of this report, a DCFROI of 15 pct is considered to be economic. In actual practice, factors considered in determining the minimum acceptable DCFROI for a project include company policy, perceived risk, political and economic climate, and geographic location.

Capital and operating costs were calculated using the Bureau of Mines Cost Estimating System (CES) (3,4,5). Power generation was assumed to be by diesel-electric generators at the mine site. Capital costs of generation equipment were included in the mine and mill capital costs, and scaled to the mining rates. Alaska wage rates and cost adjustment factors were used to escalate costs from "lower 48" to Alaska costs. All costs used in this report are in March 1987 U.S. dollars.

Cash flows were calculated using the Bureau of Mines MINSIM mine simulation computer program using Alaska tax parameters, including the mining license tax. Both 10 and 20 yr mine lifes were assumed, with a 5 yr preproduction period. Results of MINSIM program runs are reported in the text as graphs and tables which relate recoverable metal value (RMV) to DCFROI. RMV is the combined dollar value of all salable

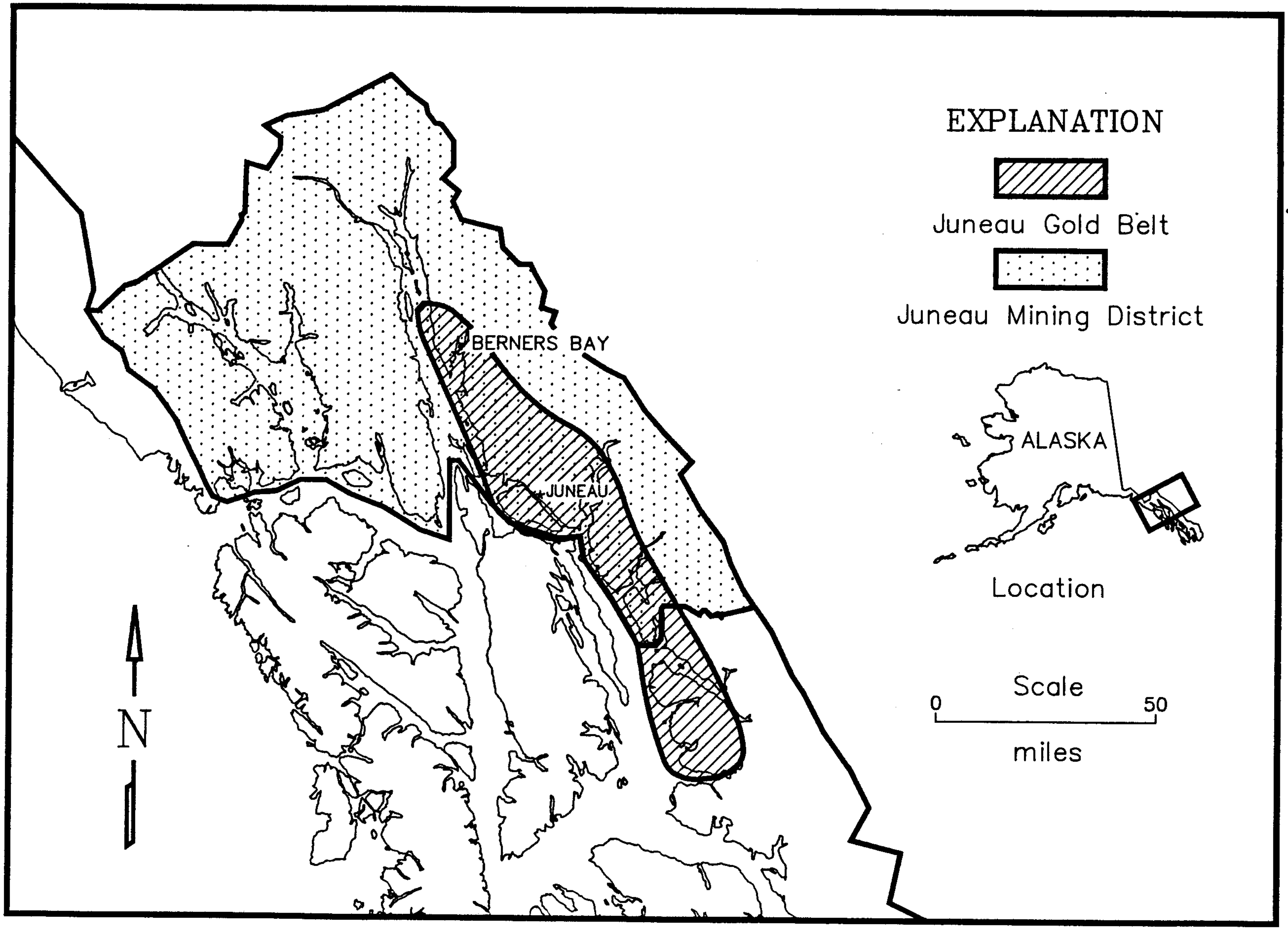

Figure 1. - Location of the Juneau Gold Belt.

products from a given mineral deposit expressed in \$/mt. RMV was used to reduce the individual effects of commodity grades, recoveries, and metal prices to a common base so that a single curve relating ore value of the deposit to DCFROI could be created. The equation used in calculating RMV for a deposit is:

$$\sum_{i=1}^{n} G_i R_i S_i V_i, \qquad (1)$$

where G_i = mill feed grade of commodity i,
R_i = mill recovery of commodity i,
S_i = smelter recovery of commodity i,
V_i = \$/unit of commodity i,
and n = total number of commodities.

For example, using equation 1 the RMV for a gold ore with a grade of 15.55 g/mt, 80 pct mill recovery, 99 pct smelter recovery, and a gold price of \$430/tr oz (\$13.83/g) is:

(15.55 g/mt)(0.8)(0.99)(\$13.83/g) = \$170.32/mt.

By calculating the RMV for a deposit type and using the graph (figures 2 and 3) for the appropriate mining method and mine life, the expected DCFROI can be estimated.

Berners Bay Vein Gold Deposits

Berners Bay is located at the extreme northern tip of the Juneau gold belt (figure 1). A total of 27 mines and prospects are located in the area. Lode gold deposits in this area are centered in and around the Jualin diorite which hosts fissure, stockwork, and stringer veins. The majority of the mines in the past have worked fissure and stockwork veins, the stringer veins being of inadequate tenor to support mining. Past producing mines in the Berners Bay area include the Comet, Jualin, Kensington, Bear, and Northern Belle. Information on the mines and prospects of the Berners Bay region was presented in a preliminary summary as a part of the Juneau Mining District Study (6).

Four lode gold mine models were evaluated for this region. Table 1 lists the attributes of each model used in the study. All mines have a preproduction period of 5 yr, during which exploration, environmental studies, permitting, development, equipment and plant purchases, and construction are completed.

TABLE 1. - Berners Bay gold mine models.

Rate, mtpd	Life, yr	Ore Reserve	Operating days/yr	Stoping method
100	10	330,000	330	Shrinkage
100	20	660,000	330	Shrinkage
500	10	1,650,000	330	Longhole
500	20	3,300,000	330	Longhole

Potential exists in the Berners Bay region for deposits with reserves similar to those listed above. Ore grades used to generate the curves in figures 1 and 2 were based on average grades from past producing properties in the region. Use of RMV produces curves which are grade/recovery independent, therefore the grade used in the discounted cash flow analysis need not be exactly representative of the actual grades which may exist in a given deposit or region.

Shrinkage Stoping, 100 mtpd

The operating and capital costs for the 100 mtpd shrinkage stope gold mine were based on mining a 2 m wide vein using rail haulage to ore passes and hoisting ore via a 122 m deep shaft. The steeply dipping vein system would be developed along the footwall. Beneficiation would consist of gravity concentration and amalgamation. Infrastructure costs were included to account for the cost of a marine terminal facility and a 6 km road to the mine site. Total capital costs for the 10 yr mine are $17,233,800. The 20 yr operation requires a capital outlay of $17,276,900. The primary difference between the costs of the operations is the additional production development required to mine twice as much ore. This is reflected in the higher mine operating cost and increased working capital requirement of the 20 yr mine. Mine and mill reinvestment costs were not used in this study. Costs for the 10 and 20 yr operations are presented in the appendix (tables A-1 and A-2).

Longhole Stoping, 500 mtpd

Costs for the 500 mtpd longhole stoping mine were based on mining an ore zone (fissure vein and stockwork) with an average width of 18 m. Ore would be hauled by rail to ore passes and then hoisted 450 m to the surface. Development costs include shaft sinking, crosscutting, drifting, raising, and stope preparation. Jigs would be used to produce a concentrate for amalgamation. The hutch product from the jigs would pass to a flotation circuit to recover the gold contained in the sulfides. Infrastructure costs were included to account for the cost of a marine terminal facility and a 3 km road to the mine site. Total capital costs for the 10 yr mine are $38,403,400. The 20 yr operation requires a capital outlay of $38,520,100. As in the 100 mtpd operation, the primary difference between the costs of the 10 and 20 yr mines is the additional production development required to mine twice as much ore. All costs are given in the appendix (tables A-3 and A-4).

Results

The required RMV to obtain a given DCFROI for each mine type in the Berners Bay area is listed in table 2. The data shown in table 2 were used to construct curves relating the RMV to DCFROI. This relationship

TABLE 2. - Required recoverable metal value (RMV) for required DCFROI, Berners Bay vein gold deposit.

DCFROI, pct	RMV, $/mt			
	100 mtpd 10 yr	100 mtpd 20 yr	500 mtpd 10 yr	500 mtpd 20 yr
0.....	225.16	200.85	84.39	75.14
5.....	255.24	228.51	96.94	86.60
10.....	296.12	267.67	114.55	103.27
15.....	353.67	324.76	138.63	127.50
20.....	426.61	401.70	169.74	160.05
25.....	518.88	498.51	209.29	201.44

for the mine models is shown on figure 2. As expected, the RMV for a 20 yr operation is less for a given DCFROI. It is interesting to note that although the required RMV is lower for a 20 yr operation, the difference between it and the 10 yr mine is relatively small. In the case of the 500 mtpd mine, the average RMV difference for a given rate of return is roughly $10/mt.

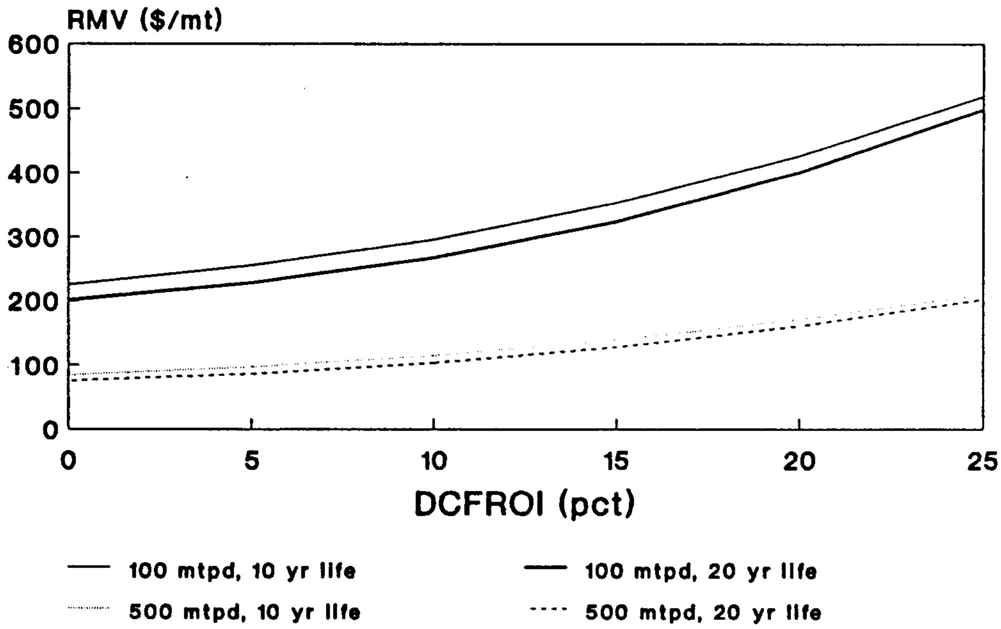

Figure 2. - Effects of recoverable metal value (RMV) on rate of return, Berners Bay vein gold deposits.

To use the curves to estimate the DCFROI for a gold deposit with sufficient reserves to mine 10 yr at 500 mtpd with a grade of 9 g/mt and a recovery of 80 pct, the RMV must first be calculated. Assuming a gold price of \$14.47/g (\$450/tr oz) the RMV would be:

$$RMV = (9\ g/mt) \times 0.8 \times (\$14.47/g) = \$104.18/mt$$

Using the curve for 500 mtpd (fig. 2), 10 yr operation in figure 2, an RMV of \$104.18/mt yields a DCFROI of roughly 6 pct. By this method, the expected rate of return on a mine in this region with similar geologic and metallurgic characteristics can be estimated by knowing the grade, recovery, and gold price.

Data points for each of the four models were fitted to a third order polynomial equation to allow calculation of the rate of return given the RMV for a deposit. Correlation coefficients for each of the polynomial regressions exceeded 99.9 pct. Equation coefficients are presented in table 3. For example, a deposit with an RMV of \$280/mt and reserves sufficient to operate for 10 yr at 100 mtpd, the expected rate of return can be calculated using the appropriate equation and coefficients as follows:

$$DCFROI = B0 + (B1 \times RMV) + (B2 \times RMV^2) + (B3 \times RMV^3) \qquad (2)$$

where b0, b1, b2, and b3 = third order polynomial equation coefficients.

In the case of the example,

$$DCFROI = -73.21 + (0.518 \times \$280/mt) + (-1.0236E\text{-}03 \times (\$280/mt)^2)$$

$$+ (7.5189E\text{-}07 \times (\$280/mt)^3)$$

$$= 8.1 \text{ pct.}$$

Use of equation 2 and the coefficients in table 3 rather than the curves provides a quick way to accurately determine the DCFROI for a deposit of interest.

TABLE 3. - Third order polynomial equation coefficients for use in calculating DCFROI from a known RMV, Berners Bay vein gold deposits.

Mine model	Equation coefficients			
	B0	B1	B2	B3
100 mtpd, 10 yr	-73.21	0.5180	-1.0236E-03	7.5189E-07
100 mtpd, 20 yr	-68.42	.5369	-1.1567E-03	9.1427E-07
500 mtpd, 10 yr	-60.23	1.0958	-5.3335E-03	9.7662E-06
500 mtpd, 20 yr	-56.88	1.1540	-6.1680E-03	1.2202E-05

Assuming a minimum acceptable rate of return of 15 pct for a 10 yr operation, the RMV for a 100 mtpd mine would have to be \$353.67/mt. For the 500 mtpd mine an RMV of \$138.63/mt would be required. Operating for 20 yr lowers the required RMV: \$324.76/mt, 100 mtpd, and \$160.05/mt, 500 mtpd. Contributions of annual cash flow to the DCFROI beyond 20 yr have little impact on the final rate of return. Additional capital costs in the form of plant and equipment reinvestment become a factor as the life of the mine exceeds the useful life of the original equipment.

Use of a cheaper stoping method in the 100 mtpd mine model would lower the RMV. Assuming rock stability was not a problem, open stoping would be a lower cost alternative. Costs for open stope mining were not considered in this report.

Stockwork Gold Deposit

Evaluation of a stockwork gold deposit similar to the Alaska Juneau-Perseverance deposits was undertaken using a block caving mining method. Deposit data used to generate the RMV curve was based on historic production data for the Alaska Juneau Mine. Grades used were: 1.4 g/mt gold, 0.92 g/mt silver, and 0.028 pct lead. For the purpose of this study, mine recoveries were fixed at 100 pct. Two products would be produced: a bullion product containing 84.6 pct gold and 15.4 pct silver; and a lead concentrate containing 18.4 pct lead with 0.009 pct gold and .05 pct silver. The bullion product would be produced by gravity and amalgamation methods. Prices for this product were assumed to be FOB mine. The lead concentrate would be produced by conventional froth flotation methods. Mill recoveries for the bullion product were assumed to be 69.4 pct for gold and 19.2 pct for silver. Mill recoveries for the lead concentrate were assumed to be 7.9 pct for gold, 61.8 pct for silver, and 81 pct for lead. Concentrate transportation was assumed to be by barge and truck to smelters in British Columbia, Canada.

Block Caving

Costs were developed for an underground mine using the parameters above and block caving mining methods at a mining rate of 18,000 mtpd. The mine model assumes operation 330 days per year with a 20 yr mine life. This requires an ore reserve of 118,800,000 mt. Block caving is the lowest-cost underground mining method possible for a gold deposit of this type in the Juneau gold belt. Dilution of mined ore must be taken into account in the grade determination for this deposit type. A 5 km access road would be required. Ore removal would be by grizzlies feeding belt conveyors from large stopes averaging 100 by 70 by 60 m in size. A portion of the ore would have to be hoisted from deeper levels of the mine. Mine-run material would be crushed and then upgraded by optical sorting to approximately double the gold grade. Reject would be conveyed approximately 1.5 km to a waste dump. Remaining material would pass through gravity separation, flotation, and amalgamation circuits to produce two products. Infrastructure costs include a 5 km access road and diesel powered electric generators. Total capital costs for the project are $172,756,000. Mine and mill costs are summarized in the appendix (table A-5).

Results

The required RMV to obtain a given DCFROI for this mine type is listed in table 4. The data shown in table 4 were used to construct the curve relating the RMV to DCFROI in figure 3.

TABLE 4. - Required recoverable metal value (RMV) for required DCFROI, stockwork gold deposit.

DCFROI, pct	RMV, $/mt 18,000 mtpd 20 yr
0.....	8.79
5.....	10.21
10.....	12.29
15.....	15.28
20.....	19.20
25.....	24.11

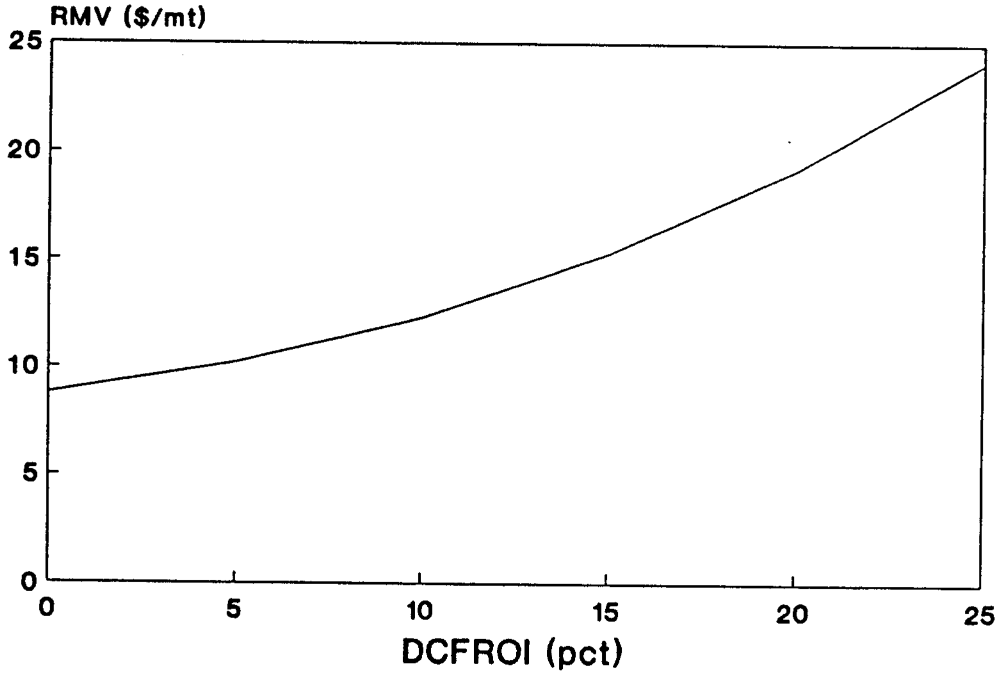

Figure 3. - Effects of recoverable metal value (RMV) on rate of return, stockwork gold deposit, block caving.

To use the curve to estimate the DCFROI for a deposit with sufficient reserves to mine 20 yr at 18,000 mtpd, the RMV must first be calculated. Prices for this example are: gold at $14.47/g ($450/tr oz), silver at $0.19/g ($6/tr oz), and lead at $0.64/kg ($0.29/lb).

The RMV would be:

Gold in bullion:	
(1.4 g/mt) X 69.4 pct rec X ($14.47/g) =	$14.06/mt
Silver in bullion:	
(0.92 g/mt) X 19.2 pct rec X ($0.19/g) =	0.03/mt
Lead in Pb con:	
(0.028 pct) X 81 pct rec X ($0.64/kg) X (1000 kg/mt)=	0.15/mt
Gold in Pb con:	
(1.4 g/mt) X 7.9 pct rec X ($14.47/g) =	1.60/mt
Silver in Pb con:	
(0.92 g/mt) X 61.8 pct rec X ($0.19/g) =	0.11/mt
TOTAL RMV	$15.95/mt

Using the curve in figure 3, an RMV of $15.95/mt yields a DCFROI of roughly 16 pct. The data points in table 4 were used to perform a third order polynomial regression to determine equation coefficients for the curve in figure 3. The correlation coefficient for the regression was greater than 99.9 pct. The DCFROI for this type of deposit can be calculated using equation 2,

where RMV = recoverable metal value for the deposit,

B0 = -52.06,

B1 = 8.9006,

B2 = -0.3937,

and B3 = 6.5189E-03.

Using table 4, the mine is economic (15 pct DCFROI) when the RMV is $15.28/mt. As in the case of the vein gold models, use of the curves requires that the deposit under consideration have similar geologic and metallurgic characteristics and, in this instance, have sufficient reserves to operate for 20 yr.

DISCUSSION

The mine models and results presented in this report can be used as a guide in determining the viability of a lode gold deposit in the Juneau gold belt. While not providing an absolute estimate of feasibility for any given deposit, the curves and equations presented can be used in an order of magnitude fashion to determine what grades, recoveries, and metal prices are required to make a deposit worth considering. Use of the curves requires that a deposit be of similar geologic and metallurgic character as those used in developing the curves presented in this report. Application of the curves to deposits outside the Juneau gold belt will result in erroneous results since the costing was done using regional factors specific to the area.

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APPENDIX--Detailed Cost Information

TABLE A-1. - Capital and operating costs, 100 mtpd Berners Bay vein gold deposit, 10 yr mine life.

Category	Cost	Beginning yr	Ending yr	Total
CAPITAL				
Exploration.....	$ 125,000/yr	1987	1988	$ 250,000
Acquisition.....	250,000/yr	1987	1987	250,000
Development.....	909,000/yr	1988	1991	3,636,000
Mine plant......	1,341,500/yr	1989	1991	4,024,500
Mine equipment..	207,700/yr	1989	1990	415,400
Mill............	1,328,600/yr	1989	1991	3,985,800
Infrastructure..	885,000/yr	1988	1991	3,540,000
Working capital.	1,132,100/yr	1992	1992	1,132,100
Total.....				17,233,800
OPERATING				
Mine operating cost...........	123.48/mt	1992	2001	
Mill operating cost...........	43.48/mt	1992	2001	

TABLE A-2. - Capital and operating costs, 100 mtpd Berners Bay vein gold deposit, 20 yr mine life.

Category	Cost	Beginning yr	Ending yr	Total
CAPITAL				
Exploration.....	$ 125,000/yr	1987	1988	$ 250,000
Acquisition.....	250,000/yr	1987	1987	250,000
Development.....	909,000/yr	1988	1991	3,636,000
Mine plant......	1,341,500/yr	1989	1991	4,024,500
Mine equipment..	207,700/yr	1989	1990	415,400
Mill............	1,328,600/yr	1989	1991	3,985,800
Infrastructure..	885,000/yr	1988	1991	3,540,000
Working capital.	1,175,200/yr	1992	1992	1,175,200
Total.....				17,276,900
OPERATING				
Mine operating cost...........	130.65/mt	1992	2011	
Mill operating cost...........	43.48/mt	1992	2011	

TABLE A-3. - Capital and operating costs, 500 mtpd Berners Bay vein gold deposit, 10 yr mine life.

Category	Cost	Beginning yr	Ending yr	Total
CAPITAL				
Exploration.....	$ 500,000/yr	1987	1988	$ 1,000,000
Acquisition.....	500,000/yr	1987	1987	500,000
Development.....	2,862,200/yr	1988	1991	11,448,800
Mine plant......	1,303,000/yr	1989	1991	3,909,000
Mine equipment..	787,900/yr	1989	1990	1,575,800
Mill............	4,099,100/yr	1989	1991	12,297,300
Infrastructure..	1,442,400/yr	1988	1991	5,769,600
Working capital.	1,902,900/yr	1992	1992	1,902,900
Total.....				38,403,400
OPERATING				
Mine operating cost...........	41.03/mt	1992	2001	
Mill operating cost...........	22.41/mt	1992	2001	

TABLE A-4. - Capital and operating costs, 500 mtpd Berners Bay vein gold deposit, 20 yr mine life.

Category	Cost	Beginning yr	Ending yr	Total
CAPITAL				
Exploration.....	$ 500,000/yr	1987	1988	$ 1,000,000
Acquisition.....	500,000/yr	1987	1987	500,000
Development.....	2,862,200/yr	1988	1991	11,448,800
Mine plant......	1,303,000/yr	1989	1991	3,909,000
Mine equipment..	787,900/yr	1989	1990	1,575,800
Mill............	4,099,100/yr	1989	1991	12,297,300
Infrastructure..	1,442,400/yr	1988	1991	5,769,600
Working capital.	2,019,600/yr	1992	1992	2,019,600
Total.....				38,520,100
OPERATING				
Mine operating cost...........	44.92/mt	1992	2011	
Mill operating cost...........	22.41/mt	1992	2011	

TABLE A-5. - Capital and operating costs, 18,000 mtpd stockwork gold mine.

Category	Cost	Beginning yr	Ending yr	Total
CAPITAL				
Exploration.....	$ 2,000,000/yr	1987	1991	$10,000,000
Acquisition.....	4,800,000/yr	1987	1987	4,800,000
Development.....	2,987,000/yr	1989	1991	8,961,000
Mine plant......	9,219,000/yr	1989	1991	27,657,000
Mine equipment..	9,263,600/yr	1990	1991	18,527,200
Mill............	29,526,000/yr	1989	1991	88,578,000
Infrastructure..	6,500,000/yr	1989	1989	6,500,000
Working capital.	7,732,800/yr	1992	1992	7,732,800
Total.....				172,756,000
OPERATING				
Mine operating cost..........	5.21/mt	1992	2011	
Mill operating cost...........	1.97/mt	1992	2011	

TABLE A-6. - Smelter and transportation costs, 18,000 mtpd stockwork gold mine.

Category	Cost/mt	Beginning yr	Ending yr
Lead Smelter...	225.00	1992	2011
Transportation.	17.50	1992	2011