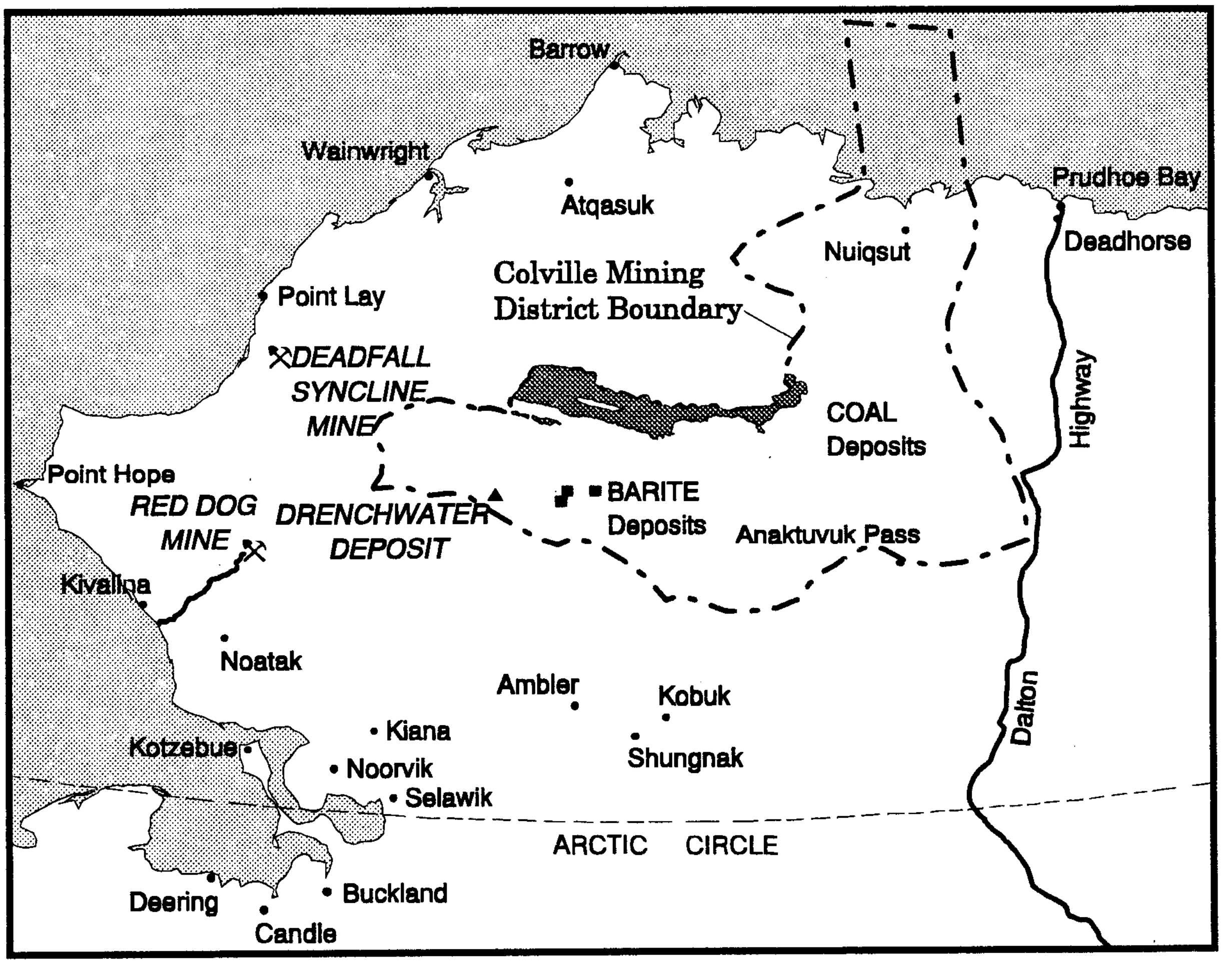
ECONOMIC FEASIBILITY OF MINING IN THE COLVILLE MINING DISTRICT, ALASKA



U. S. DEPARTMENT of the INTERIOR

OFR 49-95

Bureau of Mines

ECONOMIC FEASIBILITY OF MINING IN THE COLVILLE MINING DISTRICT, ALASKA

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July 1995

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

dpy	days per year
g	gram(s)
g/mt	gram(s) per metric ton
kg	kilogram(s)
km	kilometer(s)
km/hr	kilometer(s)/hr
kW	kilowatt(s)
kW·h	kilowatt hour(s)
lb	pound(s)
Mmt	million metric ton(s)
mt	metric ton(s)
mtpd	metric ton(s) per day
mtpy	metric ton(s) per year
ppm	parts per million
st	short ton(s)
tr oz	troy ounce(s)
yrs	year(s)

METRIC TO ENGLISH CONVERSIONS

From	Multiply by	To
g/mt (= ppm)	0.02917	ounces/short ton
kg	2.2046	pounds
mt	1.1023	short tons
m	3.2808	feet
km	0.6214	miles
m^3	1.3080	cubic yards

Temperature conversion centigrade to fahrenheit:

(°C X 9/5) + 32 = °F

ECONOMIC FEASIBILITY OF MINING IN THE COLVILLE MINING DISTRICT, ALASKA

by James R. Coldwell[1] and Edward C. Gensler[2]

ABSTRACT

Mining and processing cost analyses were conducted by the U.S. Bureau of Mines on stratiform zinc-lead-silver, coal, and stratiform barite deposit types that are found in the Colville Mining District. Reserves and gross revenues which would allow these deposits to be minable were modeled. A 15% Discounted cash-flow rate-of-return economic threshold was selected as the minimum acceptable return on investment for the three deposit types.

The economic modeling indicated combinations of grades and tonnages for stratiform sulfide deposits that could be economically viable for orebodies ranging in size from 25 to 130 million metric tons. The gross revenues for a surface mine range from \$200/mt for a 5,000 mtpd operation using the proposed South corridor to \$140/mt for a 17,000 mtpd mine using the proposed North corridor.

The economic modeling indicated underground coal mining was subeconomic for deposits ranging in size from 42 to 250 million metric tons. The required gross revenues ranged from \$300/mt for a 2,200 mtpd mine to \$210/mt for a 13,000 mtpd mine. The economic modeling indicated supplying projected in-state barite demand was subeconomic for the three seasonal surface mines modeled. The required gross revenues ranged from \$600/mt for a 90,000 mtpy mine to \$840/mt for a 6,000 mtpy mine.

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INTRODUCTION

This report is one of a series produced in conjunction with the U.S. Bureau of Mines (USBM) ongoing statewide mining-district evaluation-program. Preliminary economic prefeasibility studies were conducted on three deposit types that occur in the Colville Mining District (CMD) to determine reserves and gross revenues which would allow these mineral deposits to be minable. Two factors were addressed in this study: (1) the magnitude of reserve which would have to exist, and (2) the gross revenues required to earn a 15% Discounted cash-flow rate-of return (DCFROR), which would be necessary to make a deposit economically feasible to mine. The interrelation between these factors is shown in graphical and tabular form in this report.

In order to make these economic assessments for the stratiform sulfide zinc-lead-silver, coal, and barite deposit types, existing mineral deposit information was used whenever possible. Mineral deposit grades and supporting background information were furnished by USBM Mineral Land Assessment (MLA) personnel. Results of field work and sample analytical results from the 1990-94 USBM investigations of the CMD were published in five open-file reports, and an executive summary final report will be published as a special publication (25,35-39)[3].

In the case of coal, deposit and supporting background information were furnished by the Alaska Division of Geological and Geophysical Surveys (ADGGS) personnel. Because detailed deposit characteristics such as depth, thickness, attitude, and volume have not been determined for the partially explored deposits used as examples in this study, assumptions were made on some deposit characteristics. These assumptions are discussed at the beginning of each deposit characteristics section.

Location and Access

The following descriptions of location and access, land status, and climate are modified from Meyer, Kurtak, and Hicks (37). The geographic location of the Colville Mining District is in northern Alaska and comprises most of the west-central part of the northern slope of the Brooks Range (Figure 1). The area is bounded by the southern divide of the Colville, Kokolik, Kugra, Kukpowruk, Meade, Titaluk, and Utukok Rivers, and the Arctic Ocean. Three physiographic provinces cover the area which include the Arctic Coastal Plain, the Arctic Foothills, and the Central and Eastern Brooks Range (60).

The Arctic Coastal Plain physiographic division is characterized by a low lying plain rising from the Arctic Ocean in the north and extending southward to an elevation of 183 m. Numerous shallow lakes occur in the low lying areas. An occasional abrupt scarp up to 61 m high separates the coastal plain from the foothills (60).

The Arctic Foothills physiographic division consists of rolling plateaus and low linear ridges. The northern foothills, rising in elevation from 183 to 1,068 m, have broad east-west trending ridges dominated by mesa-like mountains. The southern foothills are characterized by irregular buttes, knobs, mesas, east-west trending ridges ranging from 366 to 1,068 m and intervening gently undulating tundra plains (60).

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

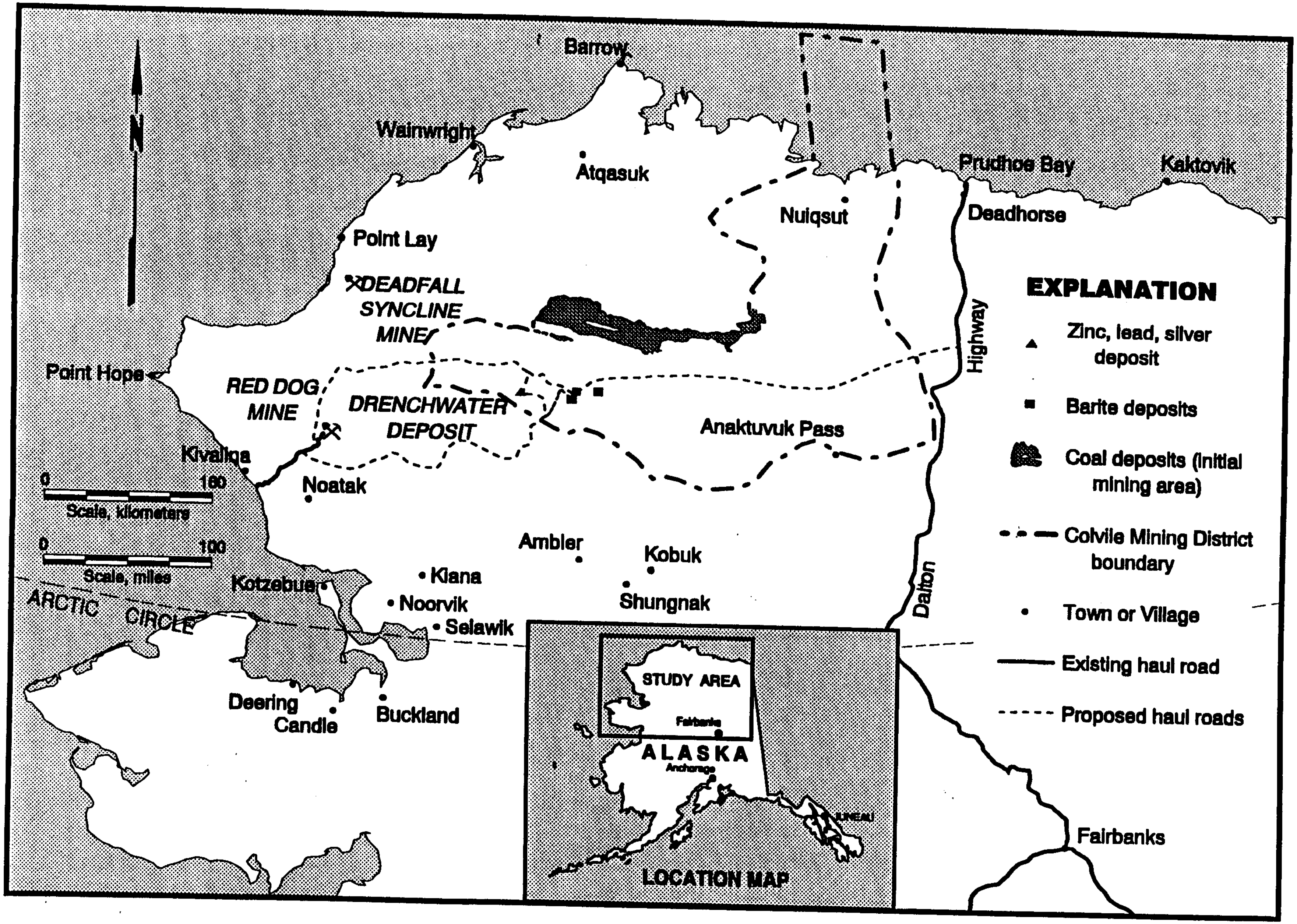

Figure 1. - Location Map Colville Mining District.

The Central and Eastern Brooks Range physiographic division is composed of rugged, glaciated, east-west trending ridges with elevations ranging from 915 to 2,135 m. The higher elevations in the Brooks Range are devoid of trees and have lichens covering the rocky slopes. At the lower elevations the vegetation grades into typical tundra species with stunted alder and willow along river gravel bars (60).

There are no roads, highways, or railroads within the CMD, however a few useable gravel airstrips are at Umiat, Ivotuk, Kikiktat Mountain, and Anaktuvuk Pass. An airstrip, located 32 km west of the CMD, along Eagle Creek, is useful for access to the western part of the CMD. Access to the villages and base camps within the CMD is by aircraft from either Barrow, Bettles, Deadhorse, Fairbanks, or Kotzebue. The Dalton Highway and the Galbraith Lake airstrip, just outside of the eastern boundary of the CMD, can be used for access to the eastern part of the CMD.

Regional population centers include the 22 cities and villages listed in Table 1 and located on Figure 1. Figures shown are 1991 estimates by the Alaska Department of Labor (3).

Table 1. Regional Population Centers

Place	Population	Place	Population
Ambler	301	Kobuk	79
Anaktuvuk	246	Kotzebue	2,886
Atqasuk	217	Noatak	344
Barrow	3,702	Noorvik	520
Buckland	340	Nuiqsut	391
Candle	([4])	Point Hope	680
Deadhorse	33	Point Lay	138
Deering	158	Prudhoe Bay	46
Kaktovik	224	Selawik	597
Kiana	401	Shungnak	224
Kivalina	327	Wainwright	501

Land Status

Land status in the CMD includes those lands managed by the Bureau of Land Management (BLM), National Park Service (NPS), State of Alaska, and Native regional and village corporations. The BLM manages the National Petroleum Reserve in Alaska (NPRA) which is open for oil and gas exploration but unavailable for mineral location and development. The NPS manages the Gates of the Arctic National Park, Preserve, and Wilderness, which is closed to oil, gas, and mineral exploration and development. The State of Alaska has selected land in the area which includes those lands that are and are not available for mineral exploration and development. Native regional and village corporations also have selected lands in the

[4] Candle has a small seasonal population of indeterminate size during the summer months.

area. Small parcels of private inholdings are located within the study area. Some of this land may be available for mineral exploration and development subject to the management policies of the state and private land owners.

Climate

The CMD lies within a zone of continuous permafrost (60). Average summer temperatures range between -2° and 7° C and winter temperatures average between -32° and -21° C in Barrow (19). Mid-day temperatures as high as 29° C have been experienced at both the Ivotuk and Eagle Creek airstrips. Strong winds blow persistently throughout the year, generally from either the southwest or northeast at Ivotuk and from the southwest or southeast at Eagle Creek. Summer afternoon rainstorms and thunderstorms arrive from the south and southwest while morning fog banks move in from the Arctic Ocean either from the northeast or the northwest.

Annual precipitation in the area is low. Climatological data collected during 1953-87 indicates mean annual precipitation of 26 cm of rain and 145 cm of snow at Anaktuvuk, and mean annual precipitation of 14 cm of rain and 86 cm of snow at Umiat (5,6). Data from Anaktuvuk is probably most typical of the area. Precipitation occurs mostly as snow, but scattered light rain is common during the summer months, along with occasional afternoon thunderstorms (19).

ECONOMIC MINE PREFEASIBILITY STUDIES

Economic prefeasibility studies for stratiform sulfide zinc-lead-silver, coal, and barite deposit types were conducted to establish the DCFROR. For the purposes of this report, a DCFROR of 15 percent is considered to be economically viable. A number of factors control the feasibility of mineral development including physical attributes and geographic location of the deposit, perceived risk, metallurgical attributes of the minerals, metal markets, infrastructure availability, political and economic climate, environmental constraints, and corporate policy. Any forecast of the development potential should weigh all of the factors.

It is important to emphasize that the mine models described in this report are based on hypothetical mining and milling scenarios. The models are not meant to represent a feasibility analysis of specific deposits. This would be inappropriate since such an analysis requires a data base greater in size than that which currently exists for this report. The models can be considered a preliminary estimate at a prefeasibility level.

Bureau policy prohibits issuing any report as to the value of any mine or other private mineral property. The models are arbitrarily assigned descriptive labels to disguise their actual identity. The models are based on MLA resource and grade estimates or assumptions. When applicable, cost information from developing or producing mines in Alaska was used in constructing the models.

Capital and operating costs for the models were determined using the USBM's Cost Estimation System (CES 2.3) and COALVAL (43,56). Cost estimates were escalated using the USBM's Alaska Mineral Industry Cost Escalation Factors (AMICEF) which reflect the higher cost of labor, transportation, and electricity in Alaska (7). Published cost information drawn from permitting documents, environmental impact statements, and private reports was also used (58,59). All cost estimates were expressed in August 1993 dollars.

Using the estimated capital and operating costs, economic models were compiled using cash flow analysis techniques. Discounted Cash-Flow Rate-of-Return (DCFROR), and breakeven prices (gross revenues/mt) were computed. The breakeven prices were compared with long-term average commodity prices. See Appendix A for the economic models and Appendix B for the inflation adjusted twenty and thirty year commodity price averages.

The arctic environment necessitates storing the concentrates for almost a year prior to transporting all of the commodity during a 100 day window when the Chukchi Sea isn't frozen. After ocean shipping, it was assumed the concentrates were also stockpiled at the smelter, located in Japan, prior to treatment. Due to the considerable lag time between mining the ore and receiving revenue from its sale due to these conditions, working capital for the stratiform sulfide and coal models was estimated at 426 days of operating costs less smelting costs and was recovered in the last year of the project.

Large fuel storage facilities capable of supplying the operation year-round are located at the port-site and/or mine/mill/wash plant areas due to the 100 day shipping constraint. Buildings for the operation are oversized compared to their counterparts in the lower 48. The remote location necessitates carrying larger inventories of supplies, materials, and parts to minimize reliance on remote suppliers that may not be able to supply the operation during extreme weather events.

Due to the remote location, it was assumed employees would work a 4-weeks-on, 2-weeks-off schedule for the stratiform sulfide and coal models. One-third of the employees would be on their scheduled days off at anytime. Two-thirds would be on-site for their scheduled work assignments. Employees would be transported to the mine site via charter and commercial aircraft. Approximately 70% of the work force would commute from the 22 local villages and cities located 160 to 440 km from the project sites, with the remaining 30% commuting from Anchorage. The stratiform sulfide and coal projects would produce their own electric power using diesel powered generators. Employees would be housed at a permanent complex built on site.

Stratiform Sulfide Model

The stratiform zinc-lead-silver sulfide deposit model is based on the geology of a mineralized occurrence in the CMD such as the Drenchwater deposit (Figure 1). The Drenchwater deposit, the only one of its type in the CMD has moderate potential for a large shallow-lying near surface, stratiform body. A 150 m x 975 m area anomalous in zinc and lead may represent the surface expression of this possible body. Shallow vertical drill holes would be needed to further define the deposit, as the surface exposures of the mineralized rocks are too poorly exposed and scattered for a resource estimate to be made (26).

The mine models designed for application to the stratiform sulfide deposit model assume that the deposit is located near surface and the structural characteristics of the orebody are such that open pit mining methods are applicable. Minable resource sizes from 25 to 130 million metric tons were modeled to represent the possible size range for this deposit type (15).

Two transportation scenarios were modeled, based on the proposed North and South transportation corridors shown on figure 1. The two conceptual road alignments are based on a preliminary examination of the area topography from appropriate maps.

A total of six open pit mine models using the North Road Corridor were developed for application to this deposit model. Six models using the South Road Corridor were also evaluated, however the difference in gross revenues under this scenario was minimal. Average gross revenues required for the South Corridor models were 1.3% higher (ranging from 0.7% to 2.3%) than the equivalent North Corridor model.

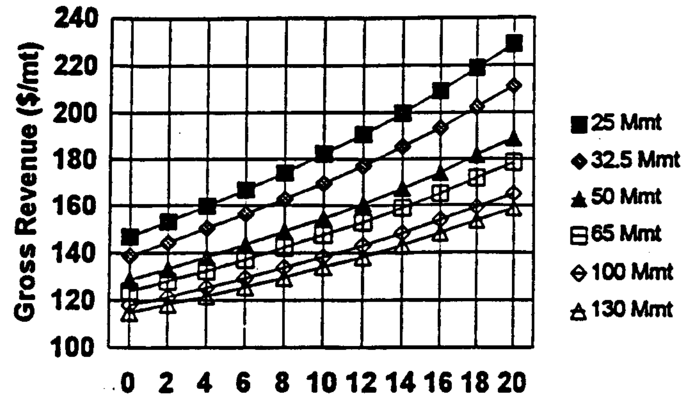

Figure 2. - Gross Revenue vs. Discounted Cash Flow Rate of Return Massive Sulfide Models

The North Corridor requires building 278 km of road, trucking concentrates 350 km, and maintaining 314 km of road year round. The South Corridor requires building 309 km of road, trucking concentrates 367 km, and maintaining 338 km year round. Alaska Industrial Development and Export Authority (AIDEA) lease payments on the existing Red Dog road and port facilities were prorated between Cominco Alaska Inc. and the hypothetical mining firm that would develop the stratiform sulfide deposit.

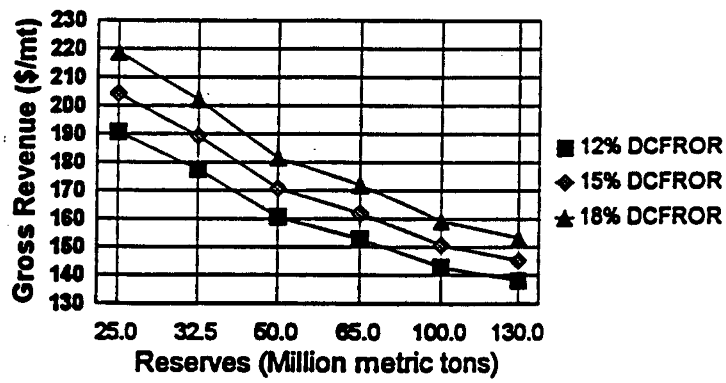

Figure 3. - Gross Revenue vs. Reserve Size Massive Sulfide Models

The proposed gravel mine roads that would connect to the Red Dog road would be 10 m wide and composed of granular fill averaging 1.6 m in thickness and designed to prevent degradation of permafrost. The road, bridges, and culverts would be designed to accommodate large modules brought in during the short construction season. Modular construction techniques similar to those used by Cominco Alaska Inc. at the Red Dog Mine would be used. The average size of thirteen Red Dog modules, constructed off-site and assembled on-site was 39 m length, 18 m width, 18 m height, and 1,045 mt weight (1).

In each mine model, the associated mill uses three product flotation to process the ore. It was assumed that fine grinding of ore similar to that at the Red Dog Mine would be required. Appendix A, Table A-1 lists the basic mine model descriptions. Table A-2 lists all costs generated for each mine model.

Open-pit mine-models assume the use of rubber-tired front-end loaders, trucks, and percussion drills. The stripping ratio was assumed to be 1:1. Two concentrate storage buildings are included in the model, one at the mill-site capable of storing six weeks of production, and another at the port-site capable of storing nine months of production.

Table 2. - Summary of cash flow analysis for mine models applied to stratiform sulfide deposits

Deposit Type	Deposit Size (Mmt)	Mine type (extraction method)	Mining rate (mtpd)	Gross Revenues ($/mt) North 15% ROR	Gross Revenues ($/mt) South 15% ROR
Stratiform sulfide	25.0	Open pit	5,000	$200	$204
Stratiform sulfide	32.5	Open pit	6,100	185	189
Stratiform sulfide	50.0	Open pit	8,500	168	171
Stratiform sulfide	65.0	Open pit	10,000	160	162
Stratiform sulfide	100.0	OpenPit	14,000	149	151
Stratiform sulfide	130.0	Open Pit	17,000	$144	$146

Figures 2, and 3, shown on the previous page, graphically present the results for the stratiform sulfide deposit mine-models. Table 2, shown on the top of this page, summarizes the results of the Gross Revenue vs. DCFROR cash flow analysis for the mine models. The gross revenues required to achieve a 15% DCFROR range from a high of $200/mt for a 5,000 mtpd mine using the South transportation corridor, to a low of $140/mt for a 17,000 mtpd mine using the North transportation corridor.

Coal Model

The coal deposit model is based on the geology of coal deposits in the CMD (Figure 4). According to ADGGS, the CMD contains an estimated hypothetical resource of 300 billion metric tons of subbituminous and bituminous coal estimated using the U.S. Geological Survey coal resource classification system (63). Over 84% of the coal is bituminous, 95% of the coal is in located in the foothill province where dips may exceed 15%, with 92% of the coal under less than 152 m of overburden (14).

The coal area shown on Figure 5 depicts the location of a small portion of the total coal resources in the district. The area shown was estimated to contain 8.3 billion metric tons of hypothetical coal resources. It was selected for modeling because it was identified by the ADGGS as the best location for initial mining in the CMD (13).

It should be noted that coal mining is underway approximately 200 km west of the CMD at Deadfall Syncline. Since 1984, Arctic Slope Regional Corp. (ASRC) has had a pilot scale project testing the feasibility of reducing demand for expensive petroleum-based products in remote areas by substituting coal mined at the Deadfall Syncline area of northwest Alaska. In 1991, the Alaska Legislature awarded $2 million to the company to continue the project's exploration and feasibility studies. Coal from the project near Point Lay is transported in 2-kg bags to the villages by barge and sled. About 270 mt of coal per year is used in this manner. The company mined a 11,000 mt sample for a test burn in Japan during 1994. Underground mining at the Kuchiak Research Mine is replacing surface mining at the Mormon Mine.

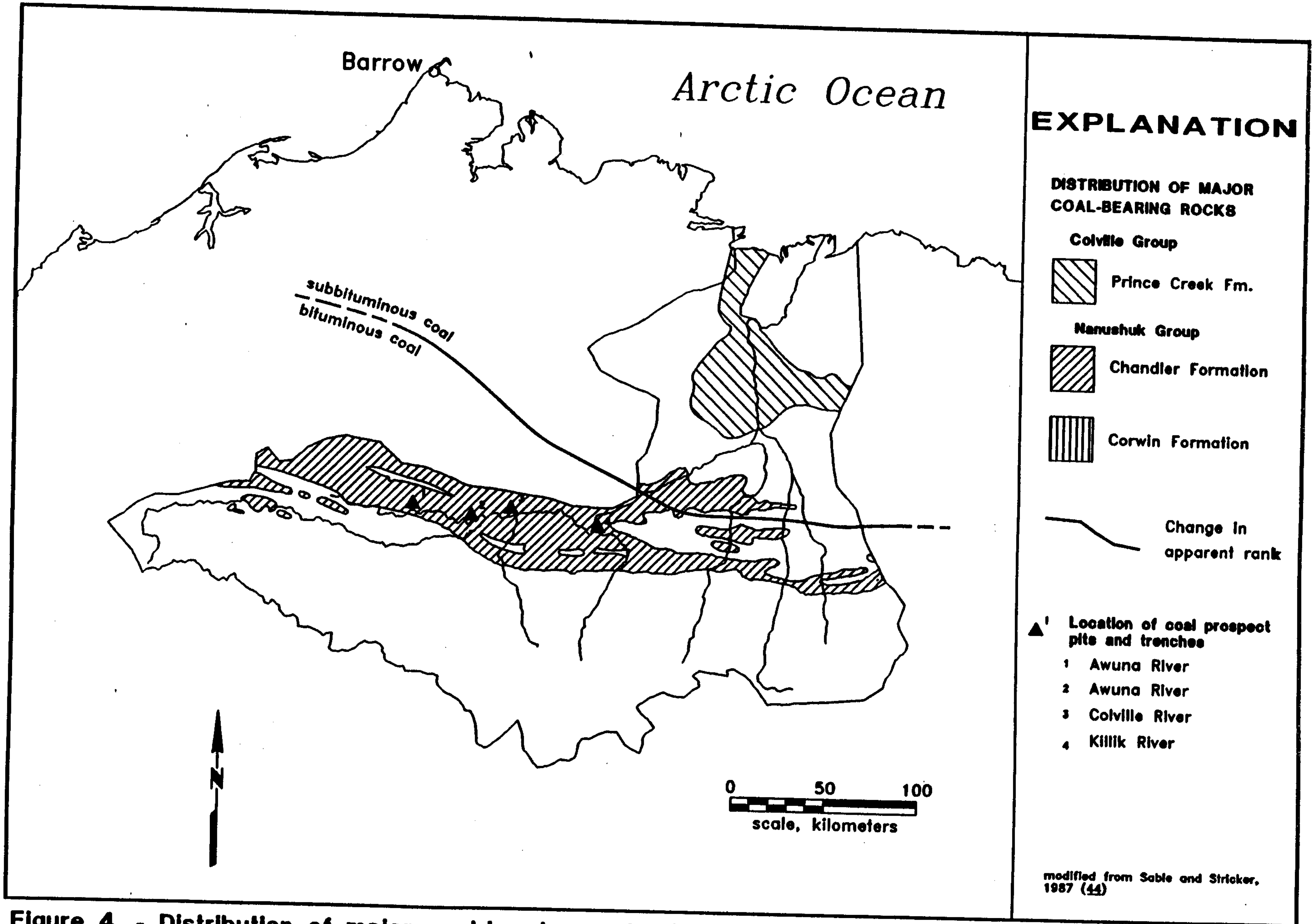

Figure 4. - Distribution of major coal-bearing rocks (Nanushuk Group and Colville Group) in surface and subsurface within the Colville Mining District.

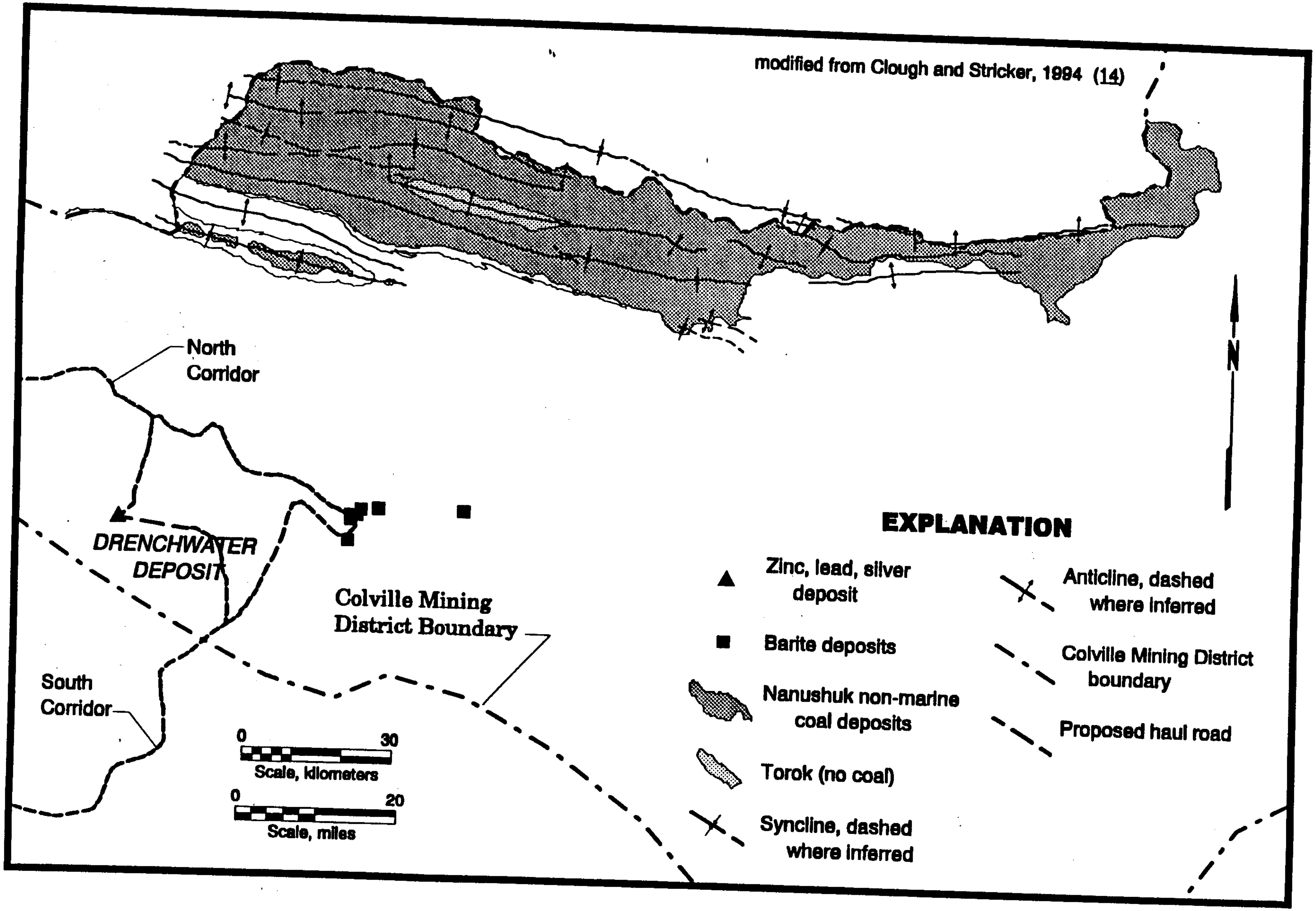

Figure 5. - Coal geology and deposit location map.

Surface mining may be possible, however with steeply dipping seams in flat lying terrain, the stripping ratio increases rapidly downdip and the pit limit is reached in a relatively short distance from the seam outcrop. Longwall mining may be possible, but the available geological, permafrost, and rock mechanics data to make this determination is limited.

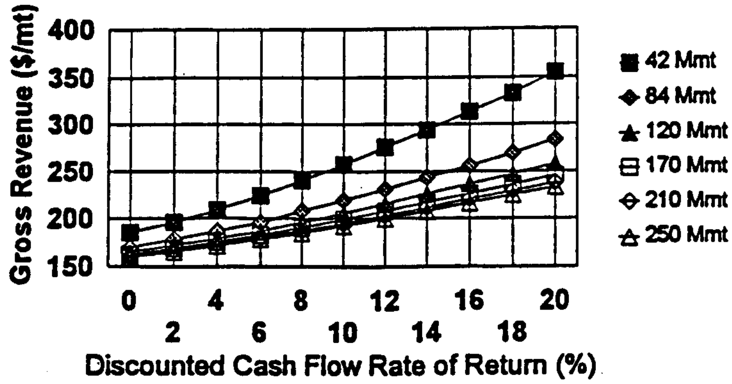

Figure 6. - Gross Revenue vs. DCFROR Coal Models

Longwall and surface mining scenarios were not considered in the economic modeling. Both methods are less costly than continuous mining. The revenues required to cover mine and wash plant capital and operating costs account for approximately 18 to 23% of the total gross revenue. The models indicate that even if mine and wash plant capital and operating costs were reduced to zero, this reduction would be insufficient to make the coal models economically viable. Comparison of figures given in the fifth and sixth columns of Table 3 demonstrates this point.

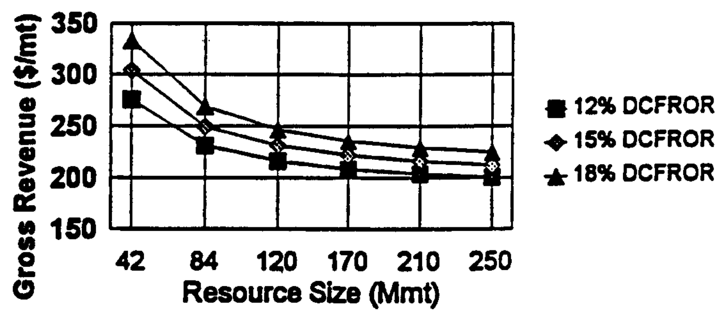

Figure 7. - Gross Revenue vs. Resource Size Coal Models

The mine models were designed for application to a single 1.8 m coal seam, folded into anticlines and synclines (Figure 5), with dips that may exceed 15° utilizing underground continuous methods (13). Careful design of the development entries, crosscuts, and panel layouts may require entries to be driven cross-dip to reduce the dip-angle to that which would accommodate the selected equipment.

Permafrost degradation could present significant mining problems, but may be controlled with special measures, such as the addition of tempering rooms driven off the main entries and crosscuts near the surface of the mine, where the temperature of the intake air entering the mine would adjust to that of the underground workings during operation. New tempering rooms would be driven as necessary as mining proceeded and the old rooms were abandoned. This approach would minimize potential thawing of permafrost by limiting the affected area of the mine (8,16).

On-site coal fired power generation for project use was considered for the coal models. Preliminary capital cost estimates of $1,500/kW of installed capacity and $0.03/kW·h operating costs for coal fired power generation were compared to capital costs of $300/kW of installed capacity and $0.15/kW·h operating costs for diesel power generation over a 30 year life for the six coal models (4,41,57).

Table 3. - Summary of cash flow analysis for mine models applied to coal deposit

Deposit Type	Deposit Size (Mmt)	Mine type (extraction method)	Mining rate (mtpd)	Gross Revenues ($/mt) 15% ROR[5]	Gross Revenues ($/mt) 15% ROR[6]	Gross Revenues ($/mt) 15% ROR[7]
Coal	42	Continuous	2,200	$249	$290	$304
Coal	84	Continuous	4,500	199	240	250
Coal	120	Continuous	6,700	182	223	230
Coal	170	Continuous	8,900	173	215	222
Coal	210	Continuous	11,000	167	210	216
Coal	250	Continuous	13,000	$164	$206	$212

The cost comparison indicated that coal fired power generation would reduce the required gross revenues for diesel powered generation by approximately 3 to 5%. However, this cost reduction is insufficient to make the coal models economically viable. Comparison of the figures given in the sixth and seventh columns of Table 3 demonstrates this point.

A total of six continuous mine models using the North Road Corridor were developed for application to this deposit model. Cost models from the USBM's COALVAL program were adapted to the CMD (43). Underground continuous-miner models incorporate the use of continuous miners, shuttle cars, roof bolters, and scoops and an associated wash plant would be used to process the coal. It was assumed that underground mining would result in some dilution due to intersection of the roof and floor and the required grading necessary to create reasonable entries and crosscuts for panel layouts on a dipping seam.

The proposed North Corridor scenario was modeled for the coal deposits, as previous modeling had shown no significant advantage to the South Corridor. This scenario requires building 358 km of road, trucking coal 430 km, and maintaining 394 km of road year round. AIDEA lease payments on the existing Red Dog road and port facilities were prorated between Cominco Alaska Inc. and the hypothetical mining firm that would mine the coal deposit.

Table 3 lists the basic mine model descriptions. All costs generated for each mine model are listed in Appendix A, Table A-3. Figures 6, and 7, shown on the previous page, graphically present the results for the coal deposit mine models. Table 3 summarizes the results of the Gross Revenue vs. DCFROR cash flow analysis for the coal mine models.

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[5] Gross revenues required to recover all costs except mine and wash plant.

[6] Gross revenues required to recover all costs using coal fired power generators.

[7] Gross revenues required to recover all costs using diesel powered generators.

The first Gross Revenue column represents recovery of all costs except mine and wash plant capital and operating costs. The second Gross Revenue column represents the use of an on-site coal fired power plant for project power generation. The third Gross Revenue column represents the use of conventional diesel generators for project power generation. The Gross Revenues required to achieve a 15% DCFROR range from a high of $304/mt for a 2,200 mtpd mine to a low of $212/mt for a 13,000 mtpd mine.

The models suggest that mining coal deposits is subeconomic at the present time. Coal is a low value commodity and is readily available on the world market. The Australians are currently producing coal from similar mines using continuous methods for approximately $21-$28/mt. Australia is geographically closer to Japan than all of its competitors and this advantage has helped Australia gain the largest share of Japan's market. Australia's share is almost three times that of the next largest supplier, Canada (50).

Barite models

A number of occurrences of barite have been located in the foothills on the north side of the Brooks Range and DeLong Mountains (Figure 1). During the 1990 field season Kelley discovered the Abby Creek barite deposit while doing geologic mapping (21). This was followed by the discovery of the Bion and Stack deposits, by Kelley and Tailleur, in the area where Bion Kent and Irvin Tailleur had noted the occurrence of "heavy rocks" in 1950. This discovery in 1991 happened by looking for heavy white rocks similar to the Abby Creek barite occurrence. The same search methodology resulted in the discovery of the Tuck barite deposit in 1991 and the Ekakevik, Longview, and Lakeview deposits in 1992 (21).

The CMD has an indicated barite resource of 13 Mmt (specific gravity > 4.2), which could be mined by relatively inexpensive open pit methods. Initial analysis of samples taken from the barite outcrops found in the CMD indicate that the vast majority would meet or exceed all quality specifications without any need for beneficiation before processing other than crushing.

The five largest deposits, which represent 98% of the resource, have steep dips of about 66°. Larger amounts of overburden and waste rock will have to be removed to recover the same amount of ore compared to deposits with shallow or flat dips.

Table 4. - Summary of cash flow analysis for mine models applied to barite deposits

Deposit Type	Deposit Size	Mine type (extraction method)	Mining rate (mtpd)	Gross Revenues ($/mt) 15% ROR
Barite	180,000	Surface	60	$841
Barite	750,000	Surface	250	648
Barite	2,700,000	Surface	900	$600

Three seasonal mines operating 100 dpy during the summer months were modeled based on supplying approximate and projected in-state demand. Approximate 1993 consumption in Alaska was 12,000 mtpy, and was unlikely to increase significantly. Development of a major oil field would increase projected probable maximum consumption in Alaska to approximately 91,000 mtpy (9,18,40).

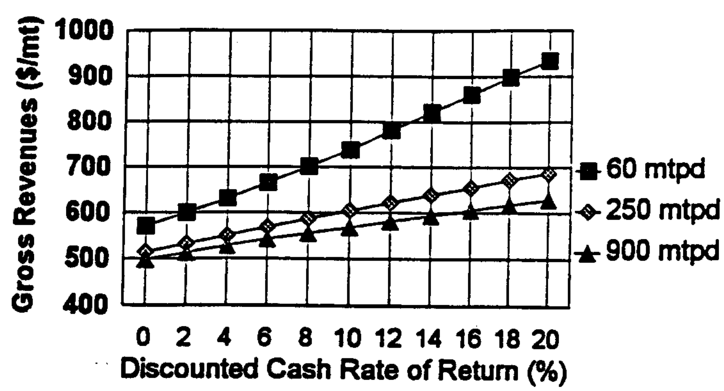

Figure 8. - Gross Revenue vs. Discounted Cash Flow Rate of Return Barite Models

It was assumed the barite was processed into a finely crushed product, 90% passing 325 mesh (44 microns), API specific gravity greater than 4.2, soluble calcium less than 250 ppm, low mercury and cadmium, carbonates less than 3,000 ppm, and soluble sulfur of less than 250 ppm (42).

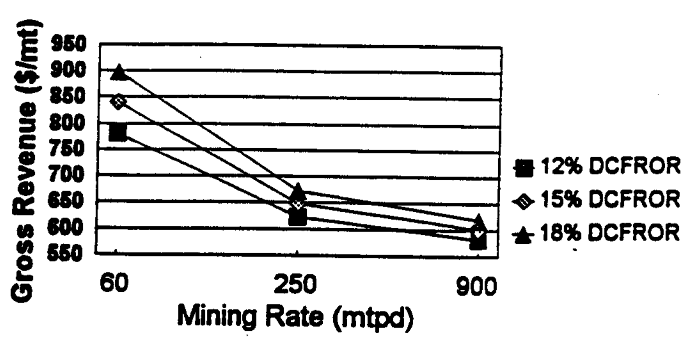

Figure 9. - Gross Revenue vs. Mining Rate Barite Models

All three models assumed L-100 Hercules aircraft (21 mt capacity) were selected for supplying the seasonal mining operations and transporting the barite to Prudhoe Bay (62). Permitting requirements would be simpler, construction costs would be relatively low, speeds are high, and year-round usage is possible. Surface mining techniques using drilling and blasting, and front end loaders would be utilized. A small camp facility with accommodations for 12-15 employees would be built. Raymond Ring Roller Mills equipped with double whizzers would be used to process the barite at Prudhoe Bay on a year round basis. The models include the cost for airstrip construction capable of accommodating a Hercules L-100. Although this choice leads to low capital costs, operating costs are high due to the increased transportation costs.

Transportation scenarios for an all-weather access road connecting the operation to the Red Dog road and port, off-road vehicles operating during the winter, and a winter road similar to the road that is built each year to supply the Lupin Mine were eliminated from consideration due to economic, environmental, and operational difficulties owing to terrain or seasonal operation (23,49).

Figures 8, and 9 graphically present the results for the barite deposit mine models. Table 4, on the previous page, summarizes the results of the Gross Revenue vs. DCFROR cash flow analysis for the barite mine models. The Gross Revenues required to achieve a 15% DCFROR range from a high of $841/mt for a 6,000 mpty mine to a low of $600/mt for a 90,000 mtpy mine. All costs generated for each mine model are listed in Appendix A, Table A-4.

The models suggest that mining barite deposits is subeconomic at the present time. Barite as broken ore is a low value commodity and is readily available on the world market. In 1994, China, the major market supplier sold barite for about $13/mt FOB Houston in 36,000 mt lots, equivalent to one freighter load (20).

SUMMARY AND CONCLUSIONS

Mining prefeasibility investigations were conducted for three mineral deposit models. The models were based on real and hypothetical deposits that occur in the CMD. Mine models were developed for application to the mineral deposit models and capital and operating costs were estimated using the USBM's Cost Estimation System (CES 2.3) and COALVAL. Published cost information drawn from industry publications, permitting documents, and environmental impact statements were also used. All costs were escalated by factors which reflect the higher cost of labor, transportation, and electricity in Alaska.

The cost data for each mine model was used to perform a cash flow analysis for each mine model, and the discounted cash flow rate of return (DCFROR) was calculated. The goal of the prefeasibility study was to determine the break-even price per metric ton of minable ore (or per metric ton of clean coal) that would cause the simulated cash flow of each of the mine models to achieve a 15% DCFROR economic threshold. The 15% DCFROR threshold was selected as the minimum return on investment that would be considered acceptable.

Based on the prefeasibility studies, the models suggest that mining coal and barite deposits in the CMD is subeconomic at the present time. Economic development in the district is hampered by the area's remote location and the high costs of developing transportation infrastructure. For a model to successfully amortize all of its capital costs and the continuing expense of transporting the commodity to market requires an exceptional deposit.

The arctic environment necessitates transporting all of the commodity during a 100 day window when the Chukchi Sea isn't frozen. Large tonnage, high grade, stratiform sulfide deposits may be economically feasible if additional work proves the existence of sufficient reserves amenable to open pit mining methods and current milling technology. However, mineralized rocks are too poorly exposed and scattered for a resource estimate to be made of mineral occurrences of this type in the CMD.

The mining prefeasibility study can be used in a preliminary manner to compare the results of the economic analysis of a model to a real mineral prospect that possesses geological and structural attributes similar to the model.

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APPENDIX A. - CAPITAL AND OPERATING COSTS FOR CMD MINE MODELS

The tables in this appendix give the capital and operating costs for the CMD mine models. Capital costs are categorized into six groups which include all acquisition, exploration, infrastructure, mine, mill, and working capital costs for each model. Operating costs are categorized into six groups which include general and administrative, infrastructure, mine, mill, smelting, and transportation operating costs.

Table A-1. - Mineral deposit and mine model descriptions

Deposit type	Deposit size (Mmt)	Mine model	Mining rate (mtpd)	Mine life (years)[8]	Mill type
Stratiform sulfide	25.0	Open pit	5,000	14	Flotation
Stratiform sulfide	32.5	Open pit	6,100	15	Flotation
Stratiform sulfide	50.0	Open pit	8,500	17	Flotation
Stratiform sulfide	65.0	Open pit	10,000	18	Flotation
Stratiform sulfide	100.0	Open pit	14,000	20	Flotation
Stratiform sulfide	130.0	Open pit	17,000	21	Flotation
Coal	42.0	Continuous	2,200	30	Wash Plant
Coal	83.0	Continuous	4,400	30	Wash Plant
Coal	125.0	Continuous	6,700	30	Wash Plant
Coal	166.0	Continuous	8,900	30	Wash Plant
Coal	208.0	Continuous	11,000	30	Wash Plant
Coal	249.0	Continuous	13,000	30	Wash Plant
Barite	0.18	Surface	60	30	Roller Mill
Barite	0.75	Surface	250	30	Roller Mill
Barite	2.70	Surface	900	30	Roller Mill

[8] Mine life estimate is based on 350 days per year for stratiform sulfide and coal models. Barite models are based on 100 days per year.

TABLE A-2. - Capital and Operating costs for stratiform sulfide models

Model Description						
Resource Size (Mmt)	25	32.5	50	65	100	130
Mining Rate (mtpd)	5,000	6,100	8,500	10,000	14,000	17,000
Capital Costs ($ millions)						
Acquisition	$33.7	$35.7	$40.1	$43.5	$50.5	$56.1
Exploration	53.6	53.6	53.6	53.6	53.6	53.6
Infrastructure	322.0	335.0	364.0	388.0	438.0	476.0
Mine	37.7	41.2	48.8	54.8	67.0	77.0
Mill	105.0	122.0	156.0	183.0	238.0	280.0
Working Capital	136.0	155.0	193.0	223.0	285.0	332.0
TOTAL[9]	$688.0	$742.0	$856.0	$945.0	$1,130.0	$1,280.0
Operating costs ($/mt)						
Gen & Admin	$2.70	$2.43	$2.04	$1.83	$1.55	$1.39
Infrastructure	1.79	1.55	1.22	1.06	0.84	0.73
Mine	6.42	6.11	5.69	5.44	5.13	4.99
Mill	16.60	15.80	14.60	14.00	13.00	12.50
Smelting	63.70	63.70	63.70	63.70	63.70	63.70
Transportation	35.90	33.20	29.80	28.00	26.20	25.20
TOTAL[9]	$127.00	$123.00	$117.00	$114.00	$110.00	$109.00

TABLE A-3. - Capital and Operating costs for coal models

Model Description						
Resource Size (Mmt)	42	84	120	170	210	250
Mining Rate (mtpd)	2,200	4,500	6,700	8,900	11,000	13,000
Capital Costs ($ millions)						
Acquisition	$20.7	$22.4	$23.7	$24.9	$26.0	$27.2
Exploration	50.0	50.0	50.0	50.0	50.0	50.0
Infrastructure	313.0	358.0	395.0	429.0	463.0	496.0
Mine	20.8	30.0	39.6	48.9	58.1	67.7
Wash Plant	11.3	12.0	13.1	13.9	14.6	15.5
Working Capital	149.0	289.0	432.0	575.0	719.0	863.0
TOTAL[9]	$565.0	$762.0	$953.0	$1,140.0	$1,130.0	$1,520.0
Operating costs ($/mt)						
Gen & Admin	$3.39	$2.23	$1.87	$1.60	$1.39	$1.28
Infrastructure	3.59	3.34	3.20	3.11	3.04	2.97
Mine & Wash Plant	39.60	38.70	38.40	38.20	38.10	38.10
Transportation	125.00	118.00	116.00	115.00	114.00	114.00
TOTAL[9]	$172.00	$163.00	$160.00	$158.00	$157.00	$156.00

[9] Figures may not sum due to independent rounding.

TABLE A-4. - Capital and Operating costs for barite models

Model Description			
Resource Size (Mmt)	0.18	0.75	2.70
Mining Rate (mtpy)	6,000	25,000	90,000
Capital Costs ($ millions)			
Camp Facilities	$1.10	$1.47	$1.86
Infrastructure	0.33	0.48	0.48
Mine	0.13	0.41	1.39
Mill	1.10	1.65	3.85
Airfield	6.13	6.13	6.13
Working Capital	3.18	12.70	44.60
TOTAL[10]	$12.00	$22.80	$58.30
Operating costs ($/mt)			
Gen & Admin	$5.13	$1.23	$0.37
Infrastructure	15.00	7.01	1.95
Mine	9.30	5.22	3.49
Mill	21.70	11.80	10.40
Transportation	479.00	479.00	479.00
TOTAL[10]	$531.00	$505.00	$495.00

[10] Figures may not sum due to independent rounding.

APPENDIX B. - ECONOMIC ASSUMPTIONS

This appendix includes information regarding the development of the fifteen economic models. It notes most of the major assumptions regarding income tax rates, depletion, depreciation, commodity prices, exploration and permitting costs, working capital, salvage value, and reclamation expense.

Economic Factors

It is important to emphasize that the mine models described in this report are based on hypothetical mining and milling scenarios. The models are not meant to represent a feasibility analysis of specific deposits. This would be inappropriate since such an analysis requires more precise data than that available for this report.

The models can be applied to get a preliminary estimate at a prefeasibility level. The models were based on published resource and grade data and do not include company proprietary data which, if available, would probably change the outcome of the evaluation. When applicable, cost information from developing or producing mines in Alaska was used in constructing the models. Alaska Mineral Industry Cost Escalation Factors (AMICEF) of 1.66 for operating labor, 1.69 for capital labor, 1.12 for capital costs, and 1.73 for electricity were used to reflect higher CMD costs (7).

A number of factors control the feasibility of mineral development, including physical attributes of the deposit, metallurgical attributes of the minerals, metal markets, infrastructure availability, political climate, environmental constraints, and corporate policy. Any forecast of the development potential should weigh all of the factors. Results and the conclusions presented here should be considered preliminary.

Cash Flow Assumptions

All gross revenue unit prices ($/mt) are equal to the amount of revenues required before ALL expenses including royalties, mine and mill operating costs, off-site transportation costs, smelting costs, and taxes are deducted. The stratiform sulfide model assumes zinc, lead, and bulk zinc-lead concentrates will be sent to Japan. Federal, Alaska corporate income, and mining license tax rates were simulated with a 41% tax rate during the first 3 years of production, 43% in the 4th year, and 45% thereafter. Property taxes were considered as necessary (2).

Federal coal royalties, black lung tax, and Surface Mining Control and Reclamation Act (SMCRA) reclamation taxes were used in the coal models. All projects were assumed to be equity financed by a single corporate producer that could expense tax due against other income. Modified Accelerated Cost Recovery System (ACRS) depreciation and Percentage Depletion were utilized.

Exploration costs were considered for all models. Acquisition capital cost represents the direct cost of permitting and was estimated at 4% of the total project cost (46). It was assumed that salvage value will equal reclamation cost. Mine and mill reinvestment was not considered. Project duration is limited to no more than 30 years.

Calculation of Gross Revenue

Assume mill feed with grades of 11% zinc, 396.5 g/mt silver, 3% lead, and 3.6 g/mt gold was mined from a deposit. Mill recoveries were estimated at 90% for zinc, 85% for silver, 81% for lead, and 71% for gold. Smelter recoveries were estimated at 75% for zinc, 87% for silver, 80% for lead, and 55% for gold. Using the 30 year average prices shown on Table B-2, the Gross Revenue ($/mt) equals $237. The equation used in calculating Gross Revenue for a deposit is:

$$\sum_{i=1}^{n} GiRiSiVi,$$

where

Gi = mill feed grade of commodity i,
Ri = mill recovery of commodity i,
Si = smelter recovery of commodity i,
Vi = $/unit of commodity i,

and n = total number of commodities.

The calculations are shown in the worksheet below.

CALCULATION OF GROSS REVENUE						
Commodity	Grade (decimal)	Mill Recovery (decimal)	Smelter Recovery (decimal)	Unit	Price	RMV
	Gi	Ri	Si		Vi	(GiRiSiVi)
Zinc	0.11	0.90	0.75	mt	$1,420	$107
Silver	396.5	0.85	0.87	g	$0.30	88
Lead	0.03	0.81	0.80	mt	$1,120	25
Gold	3.6	0.71	0.55	g	$12.18	17
TOTAL						$237

How To Use Worksheet

1. Estimate minable resource size, and resource commodity grades to be evaluated.

2. Refer to Figure 2, select appropriate graph line representing nearest estimated minable resource size. Read Gross Revenue ($/mt) from y-axis. This is the minimum value per metric ton of minable resource adjusted for mining recovery, dilution, mill and smelter recovery required to yield a 15% DCFROR using the mining and milling scenario described in the report.

3. To translate this value into a gross in place value (GIPV), back calculate value using assumed mill recoveries or pilot testing results if available, and appropriate smelter recoveries. Suggested commodity prices shown in Table B-2 may be used for other prices as desired.

4. Gross Revenue includes base smelter charges of $209/mt zinc concentrate, and $196/mt lead concentrate. Gross Revenue should be adjusted for smelter recovery as per the formula and all price and assay adjustments which reduce the smelter payment.

Transportation Costs

The potential forms of transportation available to mineral development are aviation, marine, highways, railways, pipeline and off-road transportation. For remote locations with low-tonnage high-value commodities such as precious metals, aviation, marine, and off-road transportation generally prove to be economically viable. For higher production levels and larger deposits, highway or pipeline construction becomes more viable. Very large deposits and production levels warrant railway construction ($3,000,000 per km) (28,30,34).

The cost for an all-weather road over permafrost ranges from $300,000 to $900,000 per km in northern Alaska. Considering the distance to the Dalton highway or a direct route to Prudhoe Bay from the barite deposits would entail capital costs on the order of $200,000,000 would be required for the connecting road alone. Long delays would be expected for permitting and constructing this 340 to 400 km connecting road to the Dalton Highway.

Another possibility is a winter road similar to the road built each year to supply the Lupin Mine. The 600 km road from Yellowknife, Northwest Territories, Canada to the mine is reconstructed each year, beginning in September, at a cost of about $5,000,000 (49). Standard tractor trailer trucks haul in a year's supply of most bulk materials. Trucking begins when the ice on the lakes gets 2 m thick. Between 700 and 900 round trips are required each season from late January to early April. Over 80% of the route is constructed over water on frozen lakes (23). The terrain in the CMD is not conducive to this type of winter road construction and operation, CMD terrain is more rugged, and does not have numerous large lakes.

Table B-1 is a summary of data presented in the Western and Arctic Alaska Transportation Study (27-34). All costs are expressed in 1993 dollars.

Table B-1. - Transportation Costs Summary

Method	Capital Cost	Operating Cost[11]	Comments
All Weather Road	$600,000/km	$.32/mt km	permafrost, 1.5 m thick gravel
Pipeline	$224,000,000	$.35/mt-km	20 cm dia., 130 km long, 907,000 mtpy capacity solids
Off-Road Haul Vehicle	$266,000/unit	$.25/mt-km	Foremost Delta-3, 13.6 mt payload, 40 km/hr cruise
Railway	$3,000,000/km	$.43/mt km	Assume same as Ambler to Cape Nome
Aircraft	$6,130,000 per gravel runway, 1.6 km x 30 m	$.59/mt km	Hercules L-100, 21 mt payload, 435 km/hr cruise

Commodity Prices

Most commodity prices used in the evaluation for comparison purposes were determined by

[11] All operating costs are one way cost except for pipeline.

Commodity Prices

Most commodity prices used in the evaluation for comparison purposes were determined by using an inflation adjusted thirty-year average for the years 1964-1993. Prices for the years 1964-1993 from various Bureau publications were escalated to 1993 dollars using U.S. Department of Commerce, Bureau of Economic Analysis Gross National Product implicit price deflators and then averaged (51-55).

The twenty year average price for silver is recommended for comparison purposes due to the effects of government policies on this metal prior to 1973. Thirty year prices are recommended for comparison purposes for the other commodities because they are more realistic than the ten year average price (1984-1993) which is usually lower. All prices shown in Table B-2 are given in 1993 dollars.

Table B-2. - Ten, Twenty, and Thirty year Average Commodity Prices (1964-1993)

	English Units				Metric Units			
Commodity	30 YR AVG	20 YR AVG	10 YR AVG		30 YR AVG	20 YR AVG	10 YR AVG	
Barite	$48.62	$47.13	$50.68	st	$53.59	$51.95	$55.86	mt
Lead	0.51	0.49	0.38	lb	1.12	1.07	0.83	kg
Silver	9.44	11.06	6.68	tr oz	0.30	0.36	0.21	g
Zinc	$0.64	$0.68	$0.63	lb	$1.42	$1.50	$1.39	kg