4.1. UNDERGROUND MINING--CAPITAL COSTS

4.1.1. EXPLORATION

Exploration costs and data were partly derived from mining and exploration companies and contractors. However, credit is given to Mr. William Salisbury of Salisbury and Dietz, Spokane, WA, for his generous supply of data and overall review.

Exploration can be defined as all the activities and evaluations performed in order to locate and define mineral deposits for the purpose of extraction now or in the future.

Exploration covers a wide range of activities from that of a prospector searching for mineral outcrops to the sophisticated equipment in ground or airborne surveys attempting to detect hidden mineral deposits, followed by extensive sampling and logging of excavations or drilling programs.

An organized exploration program consists of the four following principal stages:

Stage 1. Regional Appraisal
Stage 2. Detailed Reconnaissance of Favorable Areas
Stage 3. Detailed Surface Appraisal of Target Areas
Stage 4. Detailed Three-Dimensional Sampling and Preliminary Evaluation

Costs in this section are directed to those related to exploration activity at the level of "project" status. The point where a company's general exploration program is elevated to "project" status will differ from company to company (or project), but in general this transition is marked by such activity as land purchase or lease, claim staking, geophysical and geological surveys, drilling, etc. In any case, exploration expenditures and efforts increase dramatically over a small unit area. Labor costs are the major cost component and drilling is most often the principal cost item for a project. Exploration costs will range widely depending on methods used, size of project, commodity sought, remoteness, terrain and vegetation conditions, weather, geologic complexity, etc.

Detailed Surface Appraisal of Target Areas

If the results of the detailed reconnaissance are favorable, they may indicate areas ranging in size from 3 to 130 km^2 where more detailed in- vestigation is warranted. This stage of investigation would include all of the ground survey techniques or methods which were used in stage 2, but with more refinement, closer intervals, and greater detail. The methods or techniques used might include additional outcrop examination, geologic mapping, boulder tracking, rock and specialized sampling, and possibly assaying. In addition, the various ground geophysical studies including gravity, magnetic, radiometric, seismic, resistivity, self-potential, and induced polarization would be made. Possibly, this stage would also warrant some trench excavation and drilling, plus field and laboratory tests. Unit costs for the various techniques or methods are given in the exploration tabulation.

Detailed Three-Dimensional Sampling and Preliminary Evaluation

A detailed three-dimensional survey or sampling of a target area ranging in size from 1 to 25 km^2 or more would be made if it appeared that an economical ore body existed. The sampling or survey would be made to determine boundaries or limits and depth, size, shape, mineralization, and grade. This stage of exploration would probably include an extensive drilling program together with borehole logging and geologic mapping. Excavation of test trenches, shafts, and adits might also be included. Samples would be taken, field and laboratory tests would be conducted, and assays would be made to permit econ- omic evaluations to be made. The cost of the stage 4 exploration could vary greatly depending on location, accessibility, ground cover, type of deposit, and the extent of a drilling or excavation program. Unit costs for various techniques or methods are given in the following tabulation.

Description	Manpower	Manhours/unit	Unit Cost	Remarks
Geological Methods:				
Surface geological mapping.....	2 to 4 men	3 to 12/km^2	$75 to $275/km^2	Rate of production and cost depend on terrain, ground cover, complexity of geology, detail required, and scale of mapping.
Geological inference..			$275 to $760/d	A qualified geologist interpret data shown on maps, photographs, or field investigations.
Geophysical Methods:				
Gravitational survey..	1 geophysicist 2- to 3-man survey crew	12 to 50/ profile km	$380 to $1100/ profile km	Production varies from a few to 50 readings per day depending on type of equipment. Production also depends on station spacing and terrain. Surveying is the costly phase of method.
Magnetic Survey:				
Airborne.....	1 to 3 men		$50 to $90/line km plus $2 to $16/line km for interpretation	High sensitivity, helicopter, magnetic, electromagnetic, radioactivity surveys, etc., are usually taken concurrently from aircraft at 400 to 800 line km/d. Production and cost depend on type of aircraft equipment, etc.
Ground.....	2 to 3 men	4 to 6/ profile km ≈	$160 to $180/ line km $2.60 to $2.90/ grid point	Production depends on precision, spacing, of readings and type of readings, type of equipment, weather, terrain, and mode of travel.

Exploration—Continued

Description	Manpower	Manhours/unit	Unit Cost	Remarks
Seismic survey:				
0- 150-m depth.....	2 to 7 men	1 to 4/depth determination	$35 to $110/depth determination	Portable equipment with 5 to 15 determinations per day.
150-m depth.....	15 to 20 men	5 to 10/depth determination	$180 to $270/depth determination	Vibroseis equipment with 3 to 15 depth determinations per day.
Very low frequency.....	2 men		$315 to $385/line km.	Includes about $40/line km for interpretation.
Resistivity Survey.....	1 geophysicist 1 to 4 asst.	2 to 3/depth determination	$57 to $114/depth determination	None.
Electromagnetic Survey:				
Airborne.....				Usually taken concurrently with magnetic and radioactivity surveys from 1 aircraft at 400 line km or 80 km^2/d.
Ground.....	1 to 4 men	1 to 6/line km	$163 to $390/ line km	Readings taken at 25- 50-m intervals covering 5 to 10 km/d; dependent on on type of equipment, terrain, and mode of travel.
EMP.....	3 men		$4000/loop $1290/line km $2900/$km^2$	Parameters: Approximately 60-m by 120-m grid spacing; 430-m by 850-m loop; 10 lines, 15 stations/line; 10.3 km^2 costs include interpretation.

Exploration—Continued

Description	Manpower	Manhours/unit	Unit Cost	Remarks
Geochemical methods:				
Stream sediment sampling.....	1 man		$19 to $38/km^2	Depends on sampling interval terrain, access, and mode of travel.
Reconnaissance soil sampling.....	1 man	0.05 to 0.20/ sample	$11 to $24/sample	50 to 200 samples/d depending on access, terrain, ground cover, and geologic complexity.
Humus sampling.....			$28 to $55/sample	None.
Biological sampling.			$28 to $55/sample	Do.
Water samples.....			$50 to $95/sample	Do.
Test pit:				
Trenching.....				Depends on whether hand or equipment excavated.
Earth..... Do.	1 to 3 men	0.1 to 2.0/m^3		$2 to $55/m^3
Rock..... Do.	3 men	0.2 to 3.5/m^3		$11 to $100/m^3

Helicopter cost and comparison

Manufacturer and model	Approx cost/h[1]	Passenger capacity[2]	Effective payload (h.o.g.e.[3]), kg		Cruise	
			Sea level	2700m	Speed, mph	Range, km
Hiller-Soloy 12-J...	$ 300	2	450	360	145	240
Bell-Soloy 47G3.....	305	2	500	360	145	350
Bell 206B.....	380	4	450	320	195	550
Hughes 500C.....	360	4	570	360	240	560
Hughes 500D.....	410	4	610	550	255	480
SUD Allouette Lama..	575	4	1,000	900	175	480
Bell 205.....	1,040	14[4]	2,100	1,100	195	210
Bell 214.....	1,855	15[4]	3,600	2,500	280	560

[1]Charter rate, includes fuel.
[2]Without pilot.
[3]Hovering out of ground effect.
[4]Varies, maximum capacity given.

Source: Modified and updated from William G. Salisbury.

Analytic costs

	Assay	Geochemical		Assay	Geochemical
Aluminum.....	$8.74	NAp	Lead.....	$4.96	$2.15
Antimony.....	8.98	$4.12	Lithium.....	7.42	NAp
Arsenic.....	10.36	4.32	Magnesium.....	9.11	3.30
Barium.....	10.12	4.78	Manganese.....	6.60	3.12
Beryllium.....	12.10	NAp	Mercury.....	9.75	4.22
Bismuth.....	7.59	3.50	Molybdenum.....	5.98	2.43
Cadmium.....	5.04	2.46	Nickel.....	4.96	2.15
Chromium.....	7.75	4.28	Platinum.....	27.72	NAp
Cobalt.....	5.46	2.15	Potassium.....	8.41	NAp
Copper.....	4.96	2.15	Silica.....	10.36	NAp
Copper oxide.....	4.29	NAp	Silver.....	8.45	2.81
Fluorine.....	NAp	5.73	Tungsten.....	11.02	5.72
Gold and silver...	9.07	NAp	Zinc.....	4.55	2.15
Iron.....	5.94	2.90			

NAp Not applicable.

NOTE--Sample preparation costs are assay--$1.85 and geochemical--$1.15. Semi-quantitative spectrographic analysis for 30 to 40 elements is $23.32.

Drill capacities (maximum, under ideal conditions)

Drill Model	- HOLE LENGTH, METERS (feet) -					Approx av weight lb (kg)
	EW	AW	BW	NW (Nc)	HW	
Truck mounted -hauled:						
Joy 22.....	NAp	NAp	900 (3000)	600 (2000)	NAp	4000 (1800)
Longyear 24.....	270 (890)	220 (720)	NAp	NAp	NAp	1075 (490)
Longyear 34.....	NAp	520 (1700)[1]	430 (1400)[1]	340 (1100)[1]	200 (700)[1]	3300 (1500)
Longyear 38.....	NAp	940 (3100)[1]	700 (2400)[1]	580 (1900)[1]	370 (1200)[1]	3300 (1500)
Longyear 44.....	NAp	1500 (5000)[1]	1200 (3940)[1]	936 (3070)[1]	716 (2350)[1]	5100 (2300)
Diamond Drill DDC	NAp	550 (1800)	500 (1650)	300 (1000)	NAp	1900 (860)
CP 670 Rotary....	NAp	NAp	NAp	NAp	+300[2] (+1000)[2]	
Helicopter transportable:						
Hydraulic Winkie..	NAp	300[3] (1000)[3]	240[4] (800)[4]	44-30[5] (100)[5]	NAp	550 (250)
Diameck 251.....	NAp	370 (1200)	NAp	NAp	NAp	2500 (1100)
Acker Mark III....	NAp	520 (1700)[1]	430 (1400)[1]	340 (1100)[1]	NAp	2600 (1200)
Acker Mark II.....	NAp	550 (1800)	495 (1625)	380 (1250)	340 (1100)	2860 (1300)
Ingersol Rand T4W.	NAp	NAp	NAp	NAp	760[2] (2500)[2]	

NAp Not applicable.
[1]Q Series wire line.
[2]Rated capacity.
[3]IEX.
[4]IAX.
[5]BW.

NOTE: Figures are maximum capacities under ideal conditions.
Source: Data from William G. Salisbury, Salisbury & Dietz Inc., as collected from literature and as provided by contractors, May 1980.

DRILLING

CORE DRILLING

Core drilling varies from nonexistent to extensive, depending on many unknown factors. Core drilling is performed on centers varying from 30- to 245 m and to varying depths. The following tabulation gives the average range of costs for core dia- meter and depth of hole for drilling medium hard rocks. Costs could be higher or lower depending on hardness, location, access, and weather conditions.

Drilling cost, dollars per meter

Core		Drilling depth range, m			
Size	Diam, cm	0-150	150-300	300-450	450-600
PQ.....	8.49	$100-$115	$125-$138	NAp	NAp
NC[1].....	6.10	62- 79	69- 85	$90	$100
NX[1].....	5.40	59- 71	62- 75	80	90
BX.....	4.13	49- 64	52- 69	75	85
AX.....	2.86	43- 57	49- 62	70	80
EX.....	2.22	36- 52	43- 59	NAp	NAp

NAp Not applicable.
[1]Primarily surface exploration core sizes.

Subcontractor Factor If drilling is accomplished by a drilling subcontractor, multiply cost by 1.10 to compensate for subcontractor's markup.

ROTARY DRILLING

Conventional.....	$125-$185/h; $7-$36/m.
Reverse circulation.....	$125-$185/h; $11-$39/m.
Mobilization-demobilization...	$1,500-$2,500 and $1.90-$2.20/km.

PERCUSSION DRILLING

Downhole hammer.....	$40-$59/m.
Mobilization-demobilization...	$1,500-$2,500 and $1.90-$2.20/km.

CAUTION: Drilling costs are impacted significantly by demand. Costs correlate poorly with industrial inflation factors. Base costs here are representative of January 1984 costs, a time of low drilling demand and very depressed prices for drilling contractors.

Contract downhole logging costs--survey changes

	Cost per--			Plus cost per meter
	Day	Week	Month	
Portable gamma ray rental.....	NAp	NAp	[1]$2,600	NAp
Truck gamma ray surface profile resistivity:				
Daily.....	$420	NAp	NAp	$0.69
Weekly.....	NAp	$1,588	NAp	0.36
Monthly.....	NAp	NAp	4,646	0.36
Directional survey.....	NAp	NAp	735	0.15

[1]Month minimum.

Loss of equipment charge--Contractee is charged for replacement value of equipment lost. Probes may cost $3,200 and cable may cost $2.30/m.

Mobilization-demobilization charge - $50/d/person; $0.90/mile over 100 mile/d mobilization.

GAS--MILEAGE:

Assume on average, 80 mi/d for 18 days going to field project.
Total miles = 1,440 miles.
Assume 300 miles are driven each way going to and from project.
Total miles = 600 miles.

1,440 miles + 600 miles = 2,040 miles
(2,040)($0.10/mi) = $204/month

Assume: 20 working d/month, 10 days off/month (8 days rest and 2 days off, holiday, weather, project supervisor discussions).

LABOR:

	Annual salary equivalent (overhead)	Sampling program work schedule
Supervisor.....	$36,000 (35%)	4 d/month (includes travel, supervisory, and interpretation.)
Full-time geologist.....	26,000 (35%)	Full-time (20 d/month).
Part-time sampler.....	18,000 (15%)	Full-time (20 d/month).

	Annual cost plus salary overhead	Per month	$/sampling project month
1 supervisor.....	$48,600	$4,050	$ 810
1 full-time geologist....	35,100	2,925	2,925
1 part-time sampler.....	20,700	1,725	1,725
Pay total for month.....			$5,460

TRAVEL:

A. Per diem:

	Per diem rate	Days on per diem	Total per diem
Supervisor.....	$50	2.75	$ 137.50
Full-time geologist.	50	19.0	950.00
Part-time sampler...	50	19.0	950.00
			2,037.50
Per diem total for month.			2,038.00

B. Vehicle Cost:

Assume on average 300 miles to project area and 80 miles driven to and from point of lodging.

1. Geologist and Sampler

Vehicle is 4 x 4 Ford Bronco, lease rate is $1,200 month, mileage free. Assume vehicle uses unleaded gas costing $1.10/gal at a rate averaging 12 mi/gal.

$1.10/12 = 9.2¢/mi + 0.8¢/mi oil and lube = 10¢/mi

a. Gas cost

1. Miles to and from project area:
300 mi/trip x 2 trips/work period x 2 trips/month
= 1,200 mi/month.

2. Miles to and from field lodging to project:
17 one-way trips x 40 miles x 2 work periods
= 1,360 mi/month.

Total cost = (1,200 miles + 1,360 miles)(10¢/mi) =
$256/month.

b. Four-wheel drive rental-lease - $1,200/month, unlimited mileage, Ford Bronco.

2. Supervisor

Assume supervisor makes one trip per month to project area. Day of travel each way.

Assume vehicle cost of supervisor is 25¢/mi.

Monthly gas cost: 300 miles x 2 (one-way trips from main office) = 600
40 miles x 2 (motel to project) = 80
680 miles

680 miles x 25¢/mi = $170/month.

3. Total Monthly Transportation Cost

1.	4 x 4 vehicle gas cost.....	$256
2.	4 x 4 vehicle lease cost.....	1,200
3.	Supervisor vehicle-gas cost....	170
		1,626

SAMPLING SCHEDULE:

20 d/month work schedule

3 d/month travel (1.5 days spent on travel each 10-day work period)
2 d/month laying out "zero" base lines
0.5 d/month sample handling
5.5 days of nonsampling

20 days less 5.5 days of nonsampling = 14.5 days of sampling per month.

Sample rate (from Amselco, Inc., Montana)

1. 30° to 40° slope, average open conditions, 100-ft spacing, 2 persons with Brunton and tape working from previously from Amselco, surveyed base line. Equals 65 samples/d.

   Total samples/month = 65 samples/d x 14.5 days = 942.5 samples/month.

2. Flat and few obstructions, 100-ft sample intervals, esti- mated 100 samples/8-h day.

   Total samples/month = 100 samples/d x 14.5 days = 1,450 samples/d.

3. Thick underbrush, e.g., blackberries, vine maple, possible swamp.

   - add extra 2 d/month for base line.
   - estimate 25 to 50 samples/d, based on sampling interval (100-, 50-, 25-ft).
   - will use 38 samples/d.

   (38 samples/d)(14.5 days - 2 days) = 475 samples/month.

MISCELLANEOUS FIELD EQUIPMENT COSTS:

Sample Cost:

Assume 70¢/sample. Includes sample bag, label, area map, flagging-marking, and postage. Others would include field clothing and equipment.

Sample Preparation and Drying Prior to Assay (from Amselco, going rate):

Preparation..	$0.80
Drying.....	0.25
Total.....	1.05

Total Sample Cost for Miscellaneous Field Equipment and Sample Preparation:

$0.70
1.05
1.75

COST SUMMARY:

Labor (monthly)

Salary.....	$5,386
Per diem.....	2,038
Transportation...	1,626
Total.....	9,050

Initial sampling costs

Condition	Cost per sample[1]	Field equipment and sample preparation	Total cost per sample
Good, 1,450 samples per month.....	$6.24	$1.75	$8.00
Average, 943 samples per month.....	9.59	1.75	11.34
Poor, 475 samples per month.....	19.05	1.75	20.80

[1]Based on a $9,050 labor cost per month.

The above costs assume a relatively large long-term sampling program as opposed to a short 1-, 2-, 3-, or so, day sampling program. Per sample cost for the latter case could be substantially larger.

The initial sampling costs were provided to an exploration contractor who is accustomed to doing this type of work. The contractor felt the initial sampling costs were low by $2.00 to $3.00 across the board. The explanation may be that additional in-office expenses are incurred such as planning, programming, plotting, map drafting, analytic plotting, etc.

As a result, the initial per sample costs are increased to $2.50 and the totals are rounded to the nearest higher dollar.

Sampling costs

Condition	Sample rate	Field equipment and sample preparation	Total cost per sample[1]
Good, 1,450 samples per month.....	**$7.99**	**$2.50**	**$11.00**
Average, 943 samples per month.....	**11.34**	**2.50**	**14.00**
Poor, 475 samples per month.....	**20.80**	**2.50**	**24.00**

[1]**Rounded.**