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A SHORT COURSE OFFERED BY
BRITISH COLUMBIA AND YUKON
CHAMBER OF MINES
Vancouver, B.C.

EXPLORATION AND MINING
SEMINAR JANUARY 1986

TABLE OF CONTENTS

MINERAL DEPOSITS

Dr. N.C. Carter

COMMERCIALLY IMPORTANT ORES.

In the following table, the figures after each name of an ore indicate the percentage of the element specified which the pure mineral contains. When this is variable or is merely mechanically included, an interrogation mark takes the place of the above-mentioned figure.

Important ores are in **heavy face type**, less common species are in lighter type, and minerals which are only occasionally mined are treated for the element specified are in *italics*.

Each group is arranged in the order of decreasing importance.

ALUMINUM.
Bauxite (30.2), Cryolite (12.8).

ANTIMONY.
Stibnite (71.8).

ARSENIC.
Arsenopyrite (46), **Smaltite** (71.8), **Cobaltite** (45.2), Niccolite (?), Enargite (19.1).

BARIUM.
Witherite (65).

BISMUTH.
Bismuthinite (40.6).

CHROMIUM.
Chromite (46.2).

COBALT.
Smaltite (?), Cobaltite (35.5), *Arsenopyrite* (?).

COPPER.
Native copper (95), **Chalcopyrite** (34.5), **Bornite** (55.5), **Cuprite** (88.8), **Malachite** (57.6), **Chalcocite** (79.8), Enargite (48.3), Tetrahedrite (?), **Azurite** (55.4), *Covellite* (60.4), *Chrysocolla* (45.2), *Atacamite* (62.4), *Tenorite* (79.8).

GOLD.
Native Gold (99.8), **Pyrite** (?), **Sylvanite** (24.5), **Calaverite** (39.5), Chalcopyrite (?), Hessite (?), Petzite (25.5), Galenite (?), *Arsenopyrite* (?), *Stibnite* (?).

IRON.
Hematite (70), **Limonite** (59.8), **Magnetite** (72.4), Siderite (48.4), Goethite (62.9), *Pyrite* (46.7).

LEAD.
Galenite (86.6), **Cerussite** (77.7), **Anglesite** (73.6), **Pyromorphite** (76.4). Mimetite (69.7), Vanadinite (73.2), Wulfenite (56.5), *Tetrahedrite* (?).

LITHIUM.
Amblygonite (4.7), Spodumene (3.7).

MAGNESIUM.
Magnesite (28.6).

MANGANESE.
Pyrolusite (63.2), **Psilomelane** (?), Manganite (62.4).

MERCURY.
Cinnabar (86.2), *Native Mercury* (99).

MOLYBDENUM.
Molybdenite (60).

NICKEL.
Garnierite (?), **Pyrrhotite** (?), Millerite (64.4), Niccolite (43.9), *Chalcopyrite* (?), *Arsenopyrite* (?).

PLATINUM.
Native Platinum (56.5).

SILVER.
Galenite (?), **Cerargyrite** (75.3), **Pyrargyrite** (50.9), **Proustite** (65.4), **Argentite** (87.1), **Tetrahedrite** (?), Native Silver (95), Native Gold (?). Native Copper (?), Hessite (63), Petzite (43), Stephanite (68.5). *Pyrite* (?), *Chalcopyrite* (?), *Jamesonite* (?), *Stibnite* (?), *Cerussite* (?), *Polybasite* (75.6).

STRONTIUM.
Strontianite (56.8), Celestite (45.7).

SULPHUR.
Pyrite (53.3), **Native Sulphur** (100), **Pyrrhotite** (?).

THORIUM.
Monazite (?).

TIN.
Cassiterite (78.6).

TITANIUM.
Rutile (59.9).

TUNGSTEN.
Wolframite (60.7), Huebnerite (60.7), *Scheelite* (63.9).

URANIUM.
Uraninite (?), **Carnotite** (?), Autunite (51.9), Torbernite (50.8), *Samarskite* (?).

VANADIUM.
Vanadinite (10.6), **Carnotite** (?).

ZINC.
Sphalerite (67). **Smithsonite** (52), **Calamine** (54.1), **Zincite** (80.3), *Franklinite* (?), *Willemite* (58.4).

Note: In the foregoing table, Marcasite is included under Pyrite, and Tennantite under Tetrahedrite.

MINERAL DEPOSITS

1.0 INTRODUCTION

The search for mineral deposits is the principal business activity of most of the 1800 junior resource companies listed on the Vancouver Stock Exchange.

Prospecting and preliminary exploration are conducted to locate prospects which are mineral deposits having at least some potential for being of commercial size and grade.

To improve the odds of finding such a deposit, preliminary exploration is often concentrated in a known mineralized district. If a good prospect is located,"it is further assessed by detailed property exploration and sampling to evaluate its commercial viability.

This section is an overview of the types of mineral deposits with particular emphasis on those that are of current interest to junior (and major) resource companies. Not included are fuels - oil, natural gas, coal and uranium, and industrial minerals.

Commercially important ores and their minerals are shown in the following table. Common ore minerals are rare. The Earth's crust is composed principally of eight elements and metals such as copper, lead, zinc etc. make up less than 1/3 of 1% of the crust. These are generally dispersed rather than concentrated in economic

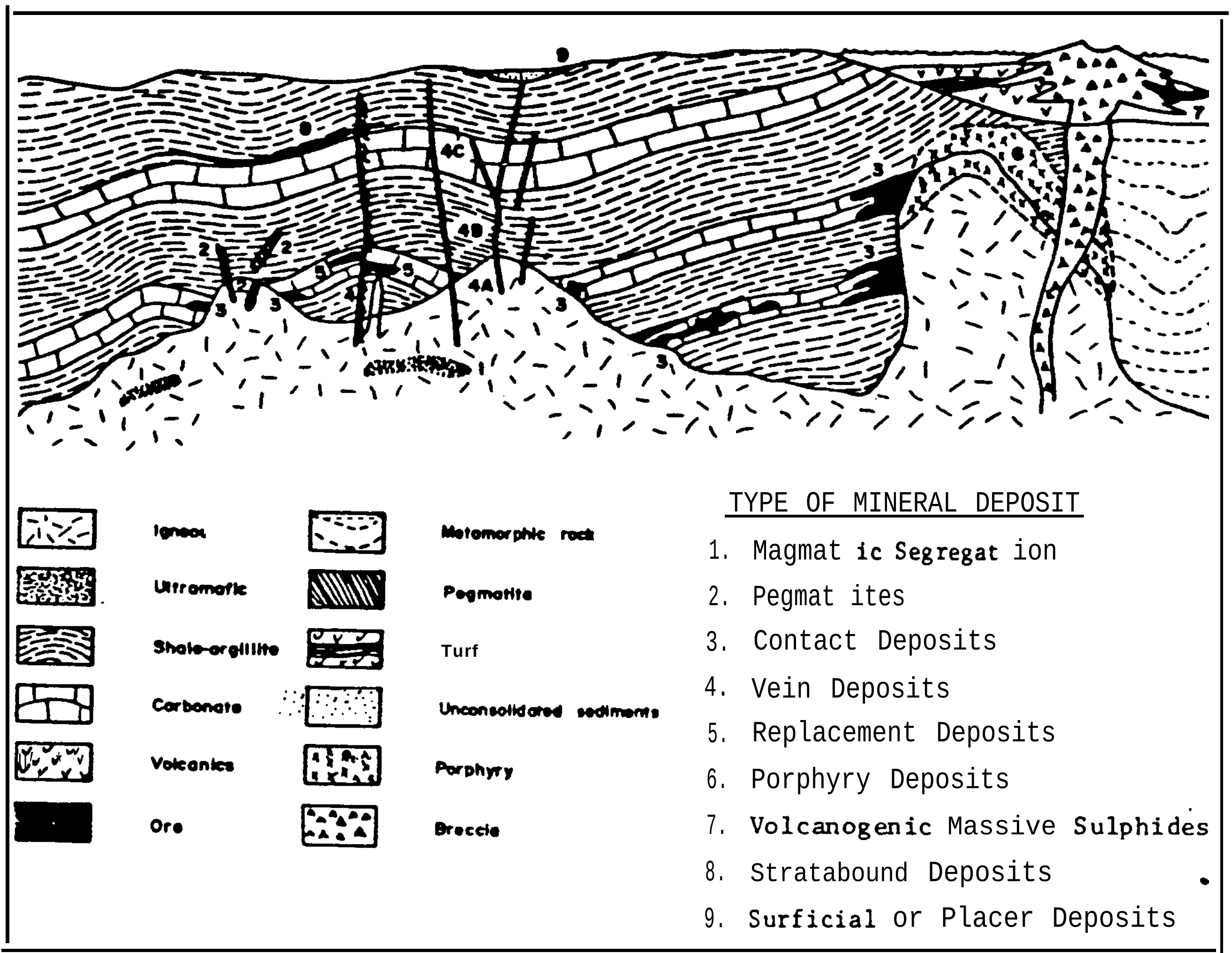


FIGURE 1 - Section through Earth's Crust - Distribution of Mineral Deposit Types relative to Host Rocks

A Mineral Showing is an occurrence of minerals of economic interest. Mineral Deposits are those containing a significant concentration of minerals of economic interest and Ore Deposits are mineral deposits that can be mined and processed at a profit.

Figure 1 is an idealized cross-section through the Earth's Crust showing the disposition of nine metallic mineral deposit types relative to enclosing or host rocks of which there are four major geological units - plutonic, volcanic, sedimentary and metamorphic rocks. Mineral deposit types are described in succeeding sections according to their principal host rock.

2.0 DEPOSITS RELATED TO PLUTONIC ROCKS

Deposits of this type include those within and adjacent to plutonic or intrusive rocks of varying compositions. The most common type in Western North America, developed mainly within granitic rocks, are porphyry deposits. Magmatic segregation deposits are contained in more dense, dark, basic rocks, in which the ore minerals are an original constituent of the rock. Contact metasomatic deposits or skarns are developed in favorable volcanic or sedimentary rocks adjacent to intrusive rocks.

2.1 Porphyry Deposits

The term "porphyry" deposit refers to relatively low grade copper (0.5%) and/or molbdenum (0.15%) mineralization which occurs as disseminations and quartz vein stockworks within and adjacent to porphyritic granitic rocks. These deposits are generally large (50 million tons) and are near surface, rendering them amenable to relatively inexpensive bulk mining by open pit.

Porphyry deposits are significant sources of copper and molybdenum - Figure 2 illustrates the great importance of porphyry deposits as a world wide source of copper metal. They also produce significant gold and silver as by-products.

Current British Columbia reserves of 18 million tons of copper are contained mainly in porphyry deposits. Average grades of copper and molybdenum at two producing mines are as follows:

Lornex	-	0.40%	Copper
		0.014%	Molybdenum
Gibraltar	-	0.30%	Copper
		0.01%	Molybdenum

British Columbia porphyry deposits also produce by-product gold and silver - for example, 48,559 ounces gold was recovered from the Afton mine near Kamloops in 1985.

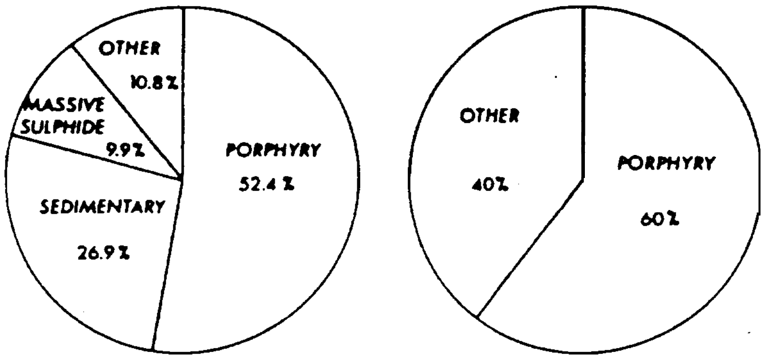
Porphyry deposits feature distinct ore and alteration mineral zoning patterns which are illustrated on Figure 3. These serve as useful exploration guides in the search for this type of deposit.

2.2 Magmatic Segregation Deposits

This deposit type refers to accumulations of heavier minerals within a magma which cools to form an igneous rock. Best examples are those associated with basic and ultrabasic igneous rocks such as gabbros and peridotites composed of dark, heavier silicate rock - forming minerals. Common metals include nickel, copper, chromite and platinum.

CANADA		USA			SOUTH AMERICA	AFRICA	REMAINDER OF WORLD
B.C.	REST OF CANADA	WESTERN	EASTERN	MESO AMERICA			
5.5	2.5	18.6	2.8	5.4	25.8	13.7	25.7

A TOTAL IDENTIFIED RESOURCE = 351x10⁶ TONNES



B PRODUCTION & RESERVES WORLD (Pelissonnier) RESOURCE CANADA (Kirkham) RESERVES BRITISH COLUMBIA

FIGURE 2 - **Porphyry Deposits as a Source** of Copper

PORPHYRY COPPER-MOLYBDENUM DEPOSITS

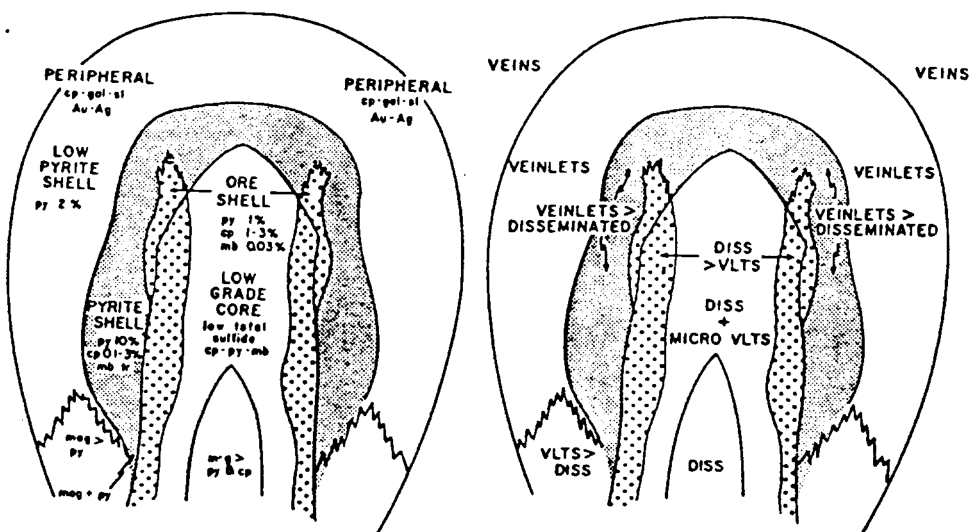


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FIG. 3. Concentric alteration-mineralization zones at San Manuel-Kalamazoo. (a) schematic drawing of alteration zones. Broken lines on Kalamazoo side indicate uncertain continuity or location and on San Manuel side extrapolation from Kalamazoo. (b) schematic drawing of mineralization zones. (c) schematic drawing of the occurrence of sulfides. After Lowell & Guilbert 1970

FIGURE 3 - **Porphyry Deposits - Alteration** and Ore Mineral **Zoning**

The best Canadian example of this deposit type is Sudbury, Ontario which produces 70% of the country's nickel and is the biggest single source of Canada's copper production. Significant quantities of gold, silver, platinum and palladium are recovered as by-products.

Some ultrabasic complexes, including those in South Africa and Stillwater, Montana, are distinctly layered, with bands of chromite containing important platinum and gold values.

2.3 Pegmatites

Pegmatites are coarse grained plutonic rocks consisting of quartz, feldspar and mica which occur as irregular lenses and masses formed as late differentiates" during cooling of a granitic magma.

They may contain significant quantities of tin and uranium and relatively exotic metals such as niobium, beryllium, lithium, tantalum, cesium etc. Gem quality topaz, garnet, tourmaline and beryl are also associated with plegmatites.

2.4 Contact Metasomatic Deposits (Skarns)

These are high temperature deposits commonly formed in chemically receptive rocks (limestone, dolomite) adjacent to plutonic or intrusive rocks. Metals were contained in hydrothermal fluids emanating from a granitic intrusive body. These fluids have converted the limestone-dolomite host rocks to a mixture of diagnostic lime - silicate minerals (epidote, garnet, pyroxene) referred to as skarns.

Metallic minerals common to this type of deposit include copper, zinc, iron, tungsten, tin and gold. The iron (copper) deposits of Vancouver Island and the Queen Charlotte Islands are examples, as is the Canada Tungsten mine in the Northwest Territories.

Gold deposits of the Hedley camp, being developed by Mascot Gold, are further examples of skarn type mineralization.

Figure 4 is a generalized sectional view of the distribution of the Hedley ore bodies - note that no ore was found below the "Marble Line" or limits of skarn development.

3.0 DEPOSITS IN SEDIMENTARY ROCKS

Sedimentary rocks are hosts for stratabound and replacement deposits which are commonly far removed from obvious intrusive or volcanic centres. "Red-bed" copper deposits in sandstones and shales are classic sedimentary ore deposit types and are important producers in parts of Europe and Africa. The Elliot Lake, Ontario uranium deposits are another example of sedimentary deposits as are the Precambrian iron ore deposits in Minnesota and Ungava.

The most important deposits in sedimentary rocks in Western North America are those containing lead-zinc-(silver) and gold.

3.1 Replacement Deposits

Replacement deposits are those in which mineral-bearing solutions have partially dissolved pre-existing rocks (limestones, dolomites) to deposit ore minerals of lead, zinc and silver. They are similar to contact metasomatic deposits

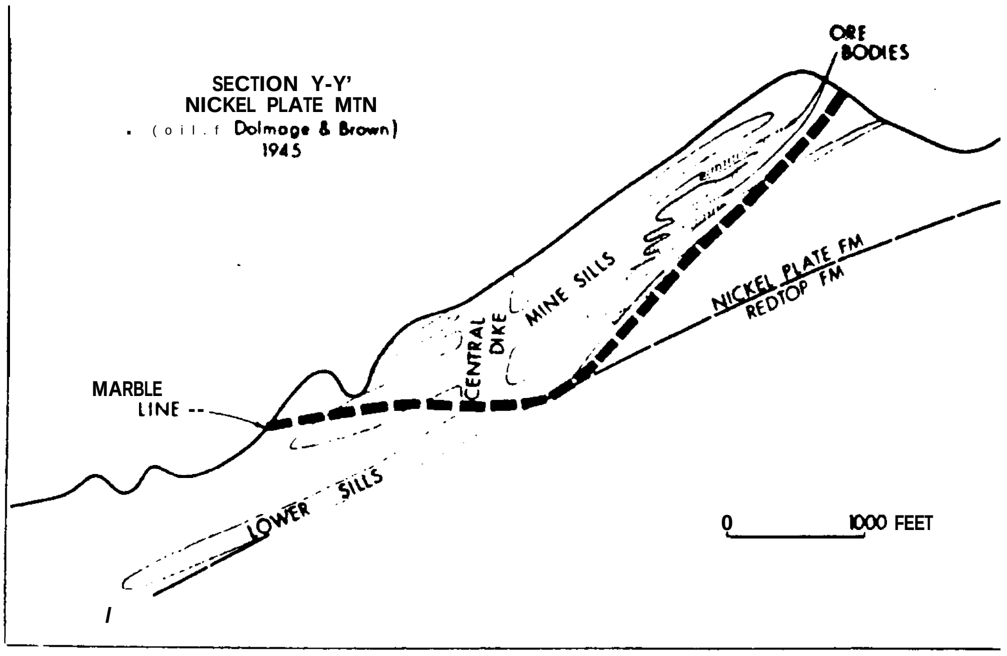
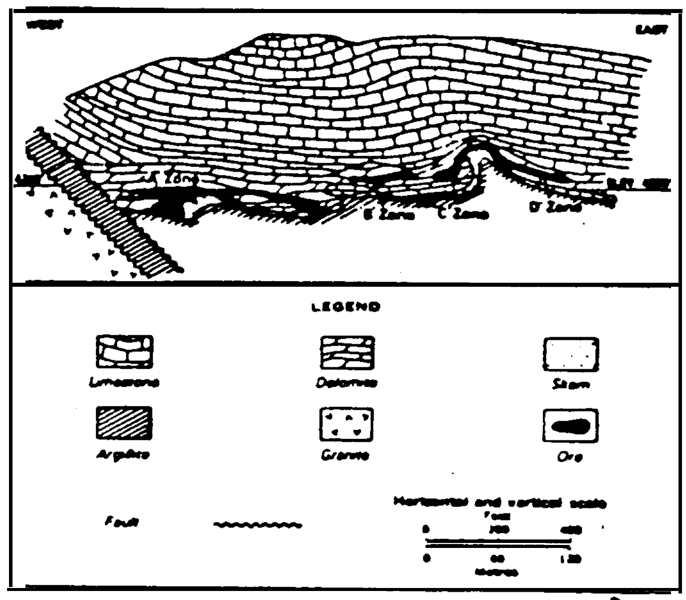


FIGURE 4 - Hedley Gold Deposits, British Columbia (after Bacon,1978,

FIGURE 5 - Jersey Lead-Zinc mine, British Columbia



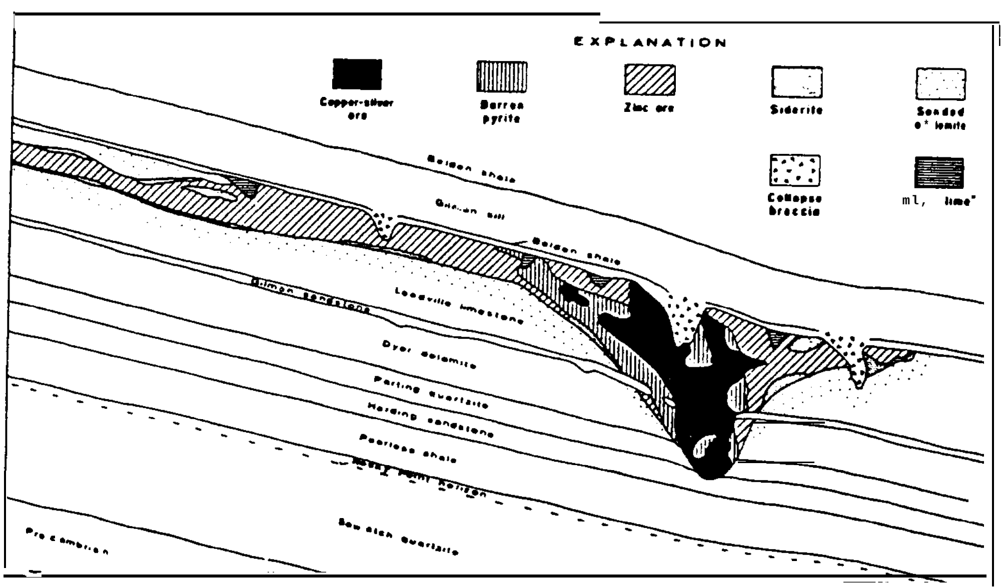


FIGURE 6 - Chimney and Manto Ore Bodies,Gilman,Colorado (after Radabaugh et al, 1968)

but there is no development of skarns and no close or direct relationship to plutonic or volcanic rocks which may have generated the mineralizing solutions.

Deposits of this type include the lead-zinc deposits in the Salmo area of Southeast British Columbia in which ore minerals replace limestone and dolomite above their contact with relatively impervious shale (Figure 5). The Pine Point, N.W.T. lead-zinc deposits are similar.

In some cases, deposits of lead-zinc-silver will occupy pre-existing channelways developed in limestone sequences (Karst topography) to form "chimney and manto" ore bodies, examples of which include Gilman, Colorado, (Figure 6) and Regional Resources' Midway deposit near the B.C.-Yukon border.

Significant Nevada gold deposits - Carlin and Cortez, are also examples of replacement deposits.

- 3.2 Stratabound Deposits

The most common type are "shale hosted" lead-zinc-silver (barite) deposits which are strati form or parallel to their enclosing host rocks. These deposits were formed in a submarine environment on a sea floor contemporaneously with deposition of the host rocks (usually shale). Metals were derived from volcanic exhalative brines, emanating from fault zones as shown on Figure 7.

Examples of this deposit type include those in Yukon (Howard's Pass), Red Dog in Alaska, McArthur in Australia, and Meggan and Rammelsberg in Germany. Figures 8 and 9 are cross-sections of the Sullivan and Cirque deposits in British Columbia. Note that in both cases, the ore bodies are comfortable with the trend of the host rocks.

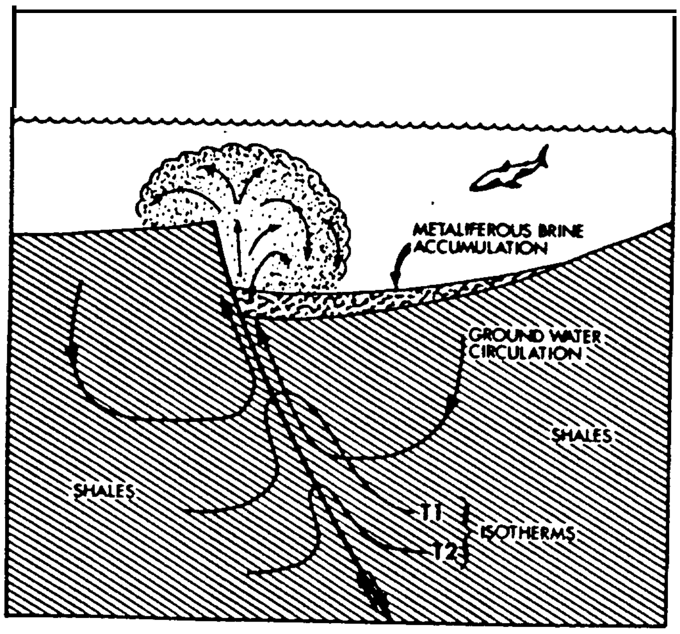


FIGURE 7 - Model for Formation of Lead-Zinc Deposits, Northern British Columbia (after Mac Intyre, 1983)

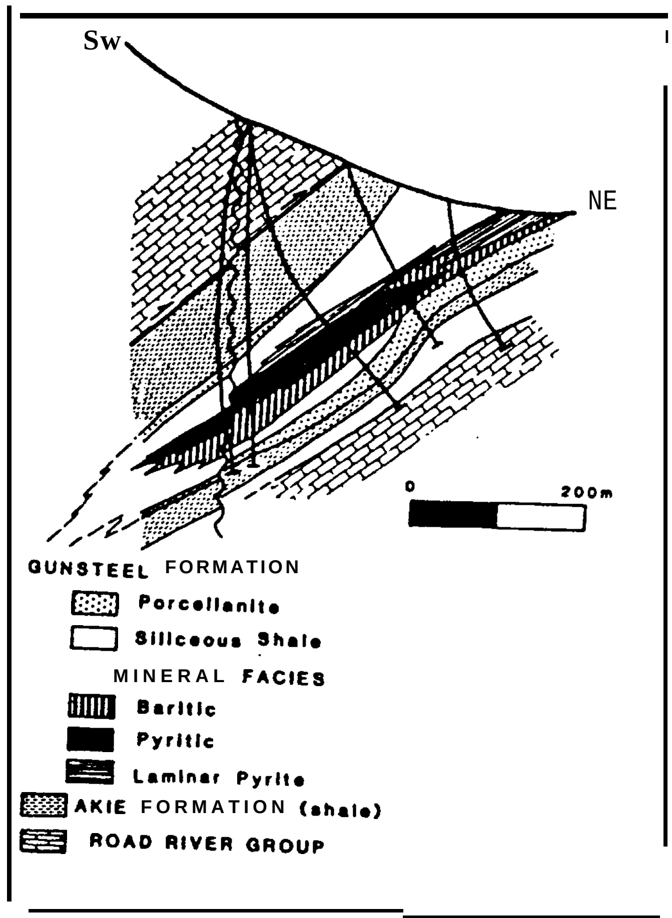


FIGURE 9 - Cirque lead-zinc deposit (after MacIntyre, 1983)

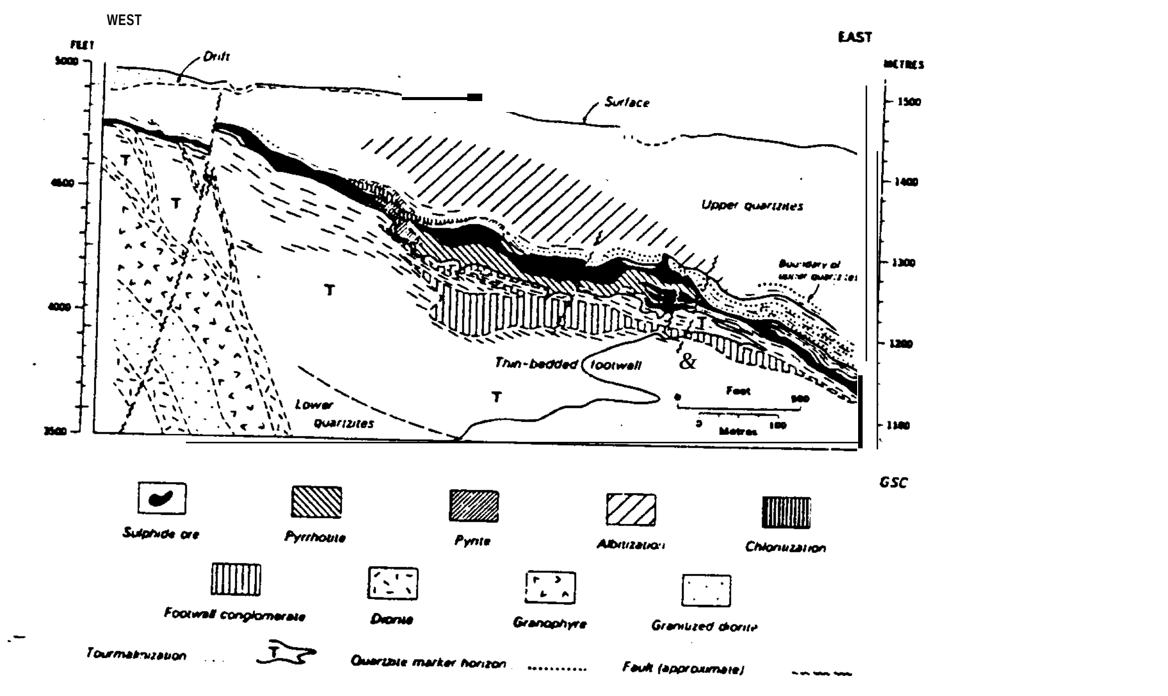


FIGURE 8 - Sullivan Mine, British Columbia (after Freeze, 1966)

Stratabound deposits are large - for example Sullivan mine in Southeast B.C. has produced 115 million tons to date, grading 6% lead, 6% zinc and 2.5 oz/ton silver. Reserves are 45 million tons of similar grade.

4.0 DEPOSITS IN VOLCANIC ROCKS

Volcanic hosted deposits include a great diversity of styles, content and grades of metallic mineralization. Most important types are volcanogenic massive sulfide deposits and vein and vein stockworks.

4.1 Volcanogenic Massive Sulfide Deposits

Massive sulfide deposits are those in which sulfide minerals are concentrated sufficiently, as the name implies, so as to form beds or lenses within and comfortable to enclosing volcanic rocks. They were formed as an integral part of the volcanic processes resulting in the deposition of their volcanic host rocks.

These deposits are polymetallic or multi-element and are of sufficient grade to have a high unit value as contrasted with porphyry deposits. Common metals include copper, lead, zinc, silver and gold.

Deposits of this type occur throughout the geological time scale, from earliest Precambrian to Tertiary, and in fact, are forming at present on oceanic ridges on the sea floor southwest of Vancouver Island.

There are two principal types of volcanogenic massive sulfide deposits. The

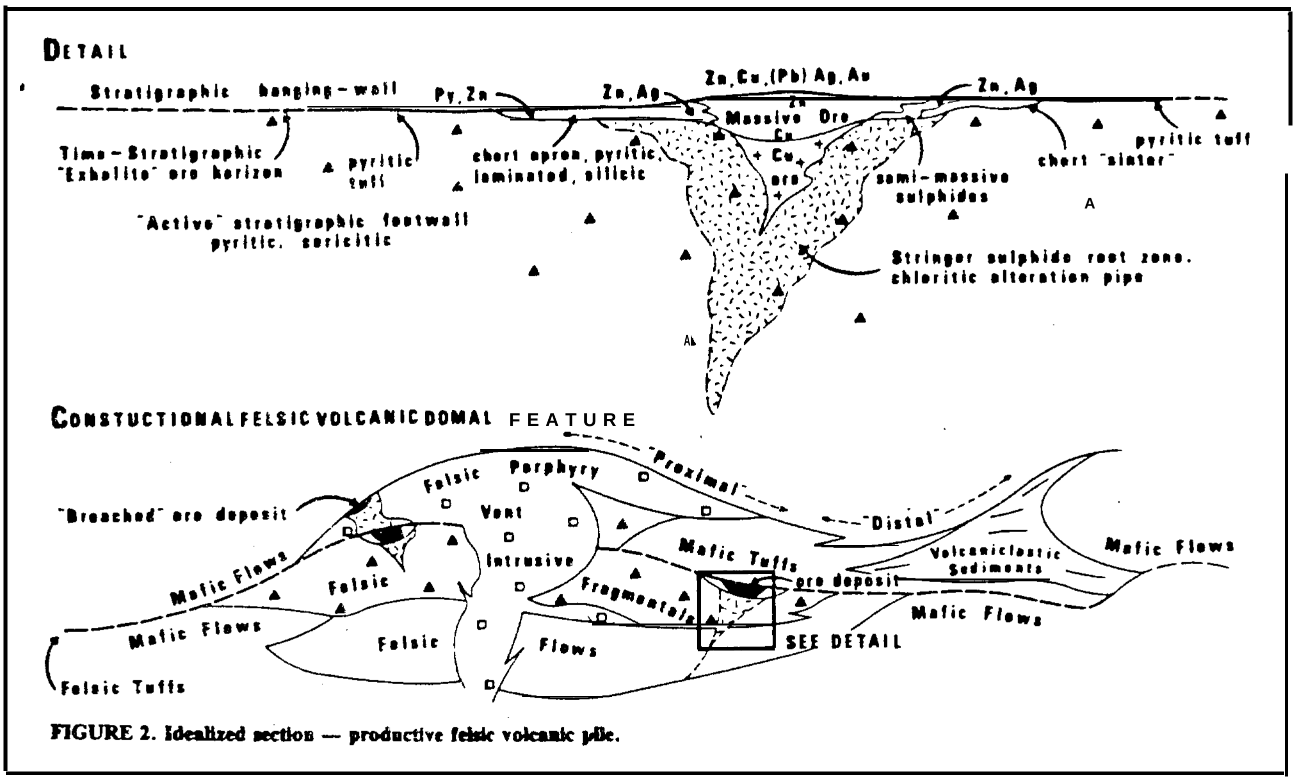


FIGURE 2. Idealized section — productive felsic volcanic pile.

FIGURE 11 - Massive Sulfide Deposits in Felsic Volcanic Rocks (Boldy,1981)

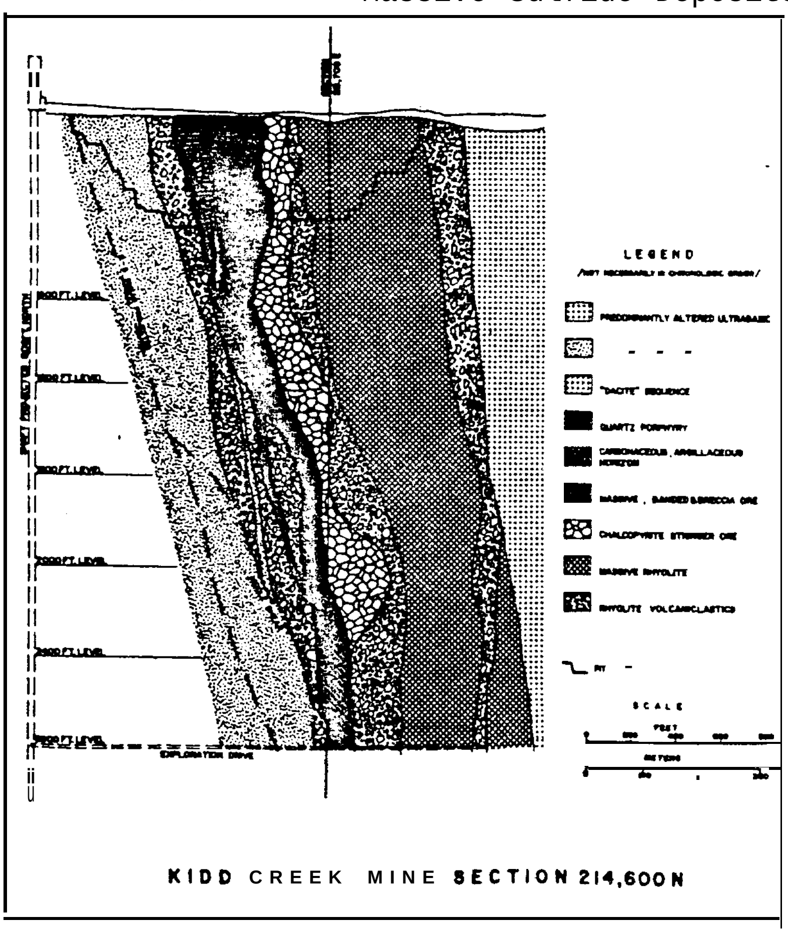


FIGURE 12 - (Walker and Mannard,1974)

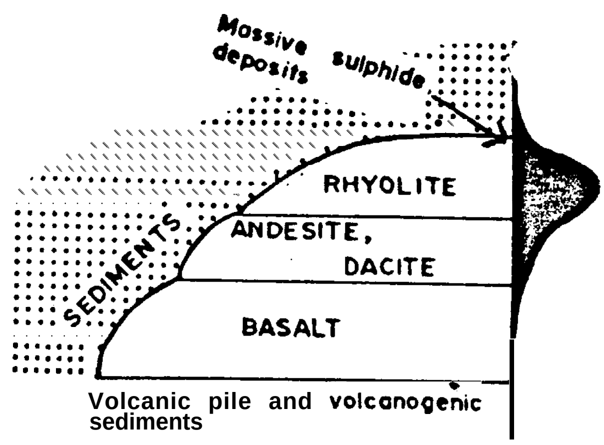


FIGURE 10 - Relative Abundance of Massive Sulfide Deposits in Precambrian Volcanics (after Sangster,1972)

Kuroko (Japan) or Noranda (Quebec) type are hosted by felsic or rhyolitic volcanic rocks close to a volcanic vent. Figure 10 shows that the majority of the Archean (Precambrian) massive sulfide deposits in eastern Canada are related to rhyolites, and Figure 11 illustrates their distribution relative to volcanic vents and volcanic stratigraphy. Examples include the Kidd Creek deposit near Timmins (Figure 12 - note that the ore body is conformable with host rocks) which is exceptionally "large and of good grade - 145 million tons grading 2.4% copper 6% zinc and 2.5 oz/ton silver. The H-W deposit of Westmin Resources on Vancouver Island (15 million tons grading 0.07 oz/ton gold, 1.1 oz/ton silver, 2.2% copper, 0.3% lead and 5.3% zinc) is another example of a rhyolite-hosted massive sulfide deposit.

Mafic volcanic hosted massive sulfide deposits (examples (Anyox, B.C.; Windy Craggy, B.C.; Cyprus) are more copper rich with variable gold and cobalt and" contain only low zinc, silver and lead values as compared to those hosted by rhyolitic volcanic rocks.

4.2 Vein and Vein Stockwork Deposits

While many productive vein deposits are hosted by volcanic rocks, it is important to point out that they also occur in plutonic, sedimentary and metamorphic rocks as well.

Vein deposits are generally tabular bodies consisting of gangue minerals (quartz, calcite) and base and precious metals minerals which occupy cracks, fractures, faults and shear zones in previously formed rocks. They are products of hydrothermal solutions emanating from a magna or heat source.

Many vein deposits, particularly those in Precambrian greenstone terranes, are persistent along strike and to depth, but they pinch and well and may be faulted off or cut off by later intrusive dykes. An example where a vein continues on both sides of a dyke is shown on Figure 13. Ore grade mineralization is not necessarily continuous throughout a vein but may be restricted to ore shoots within the plane of the vein.

Good examples of vein deposits include the gold camps of the Precambrian Shield of eastern Canada, such as Timmins and Kirkland Lake. Vein and vein stockworks of the contiguous McIntyre and Hollinger mines at Timmins produced 100 million tons grading 0.30 oz/ton gold, (equivalent tonnage but higher grade than currently defined Hemlo reserves). Figure 14 shows quartz veining underground at Dome Mine, Timmins.

4.31 Epithermal Gold-Silver Deposits

Epithermal deposits are a type of vein stockwork deposit common to western North America which were deposited at shallow depths by solutions commonly resulting in hot springs at surface. They feature an ordered suite of alteration and ore minerals but are characterized 'by erratic, locally high grade ("bonanza lodes") gold and silver mineralization.

Examples include the Comstock Lode, (Figure 15) and other deposits in Nevada and the Toodoggone area of northern British Columbia. An idealized section showing zoning of alteration and ore minerals in epithermal systems is illustrated in Figure 16.

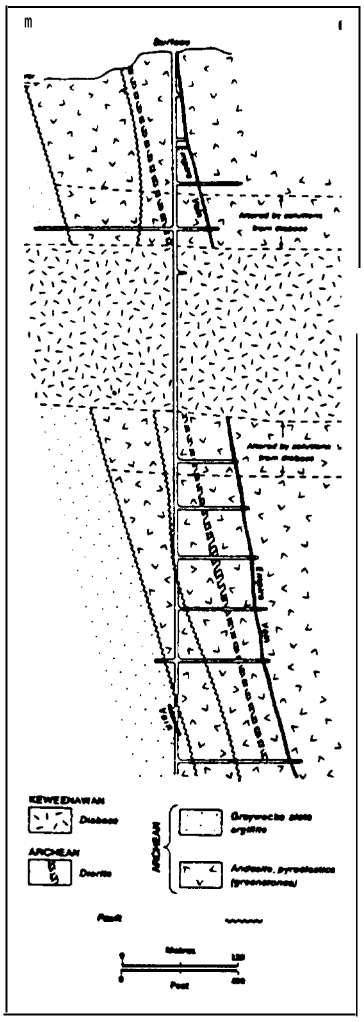


FIGURE 13 -
Section of Gold-
Quartz Vein,
Beardmore,Ontario
(after Boyle,1979)

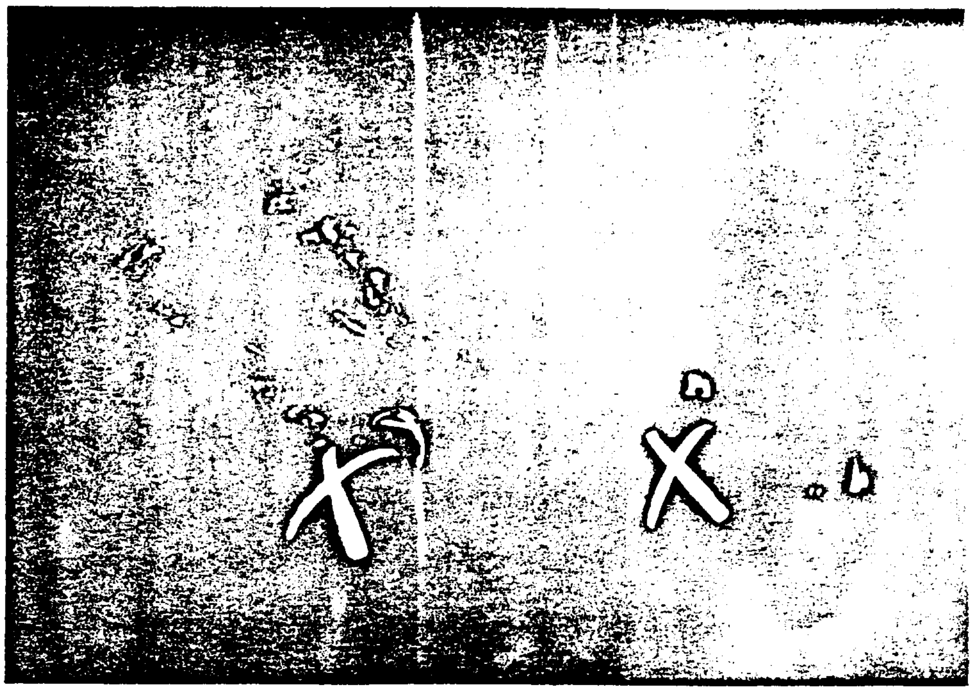


FIGURE 14 - Quartz Veining underground
at Dome mine, Timmins

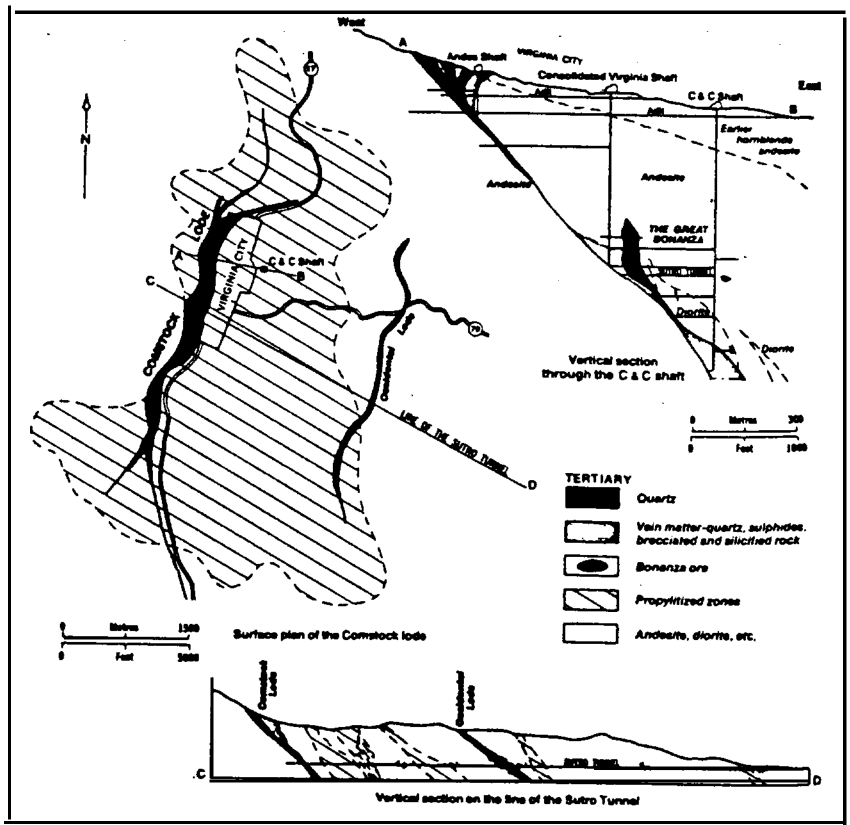
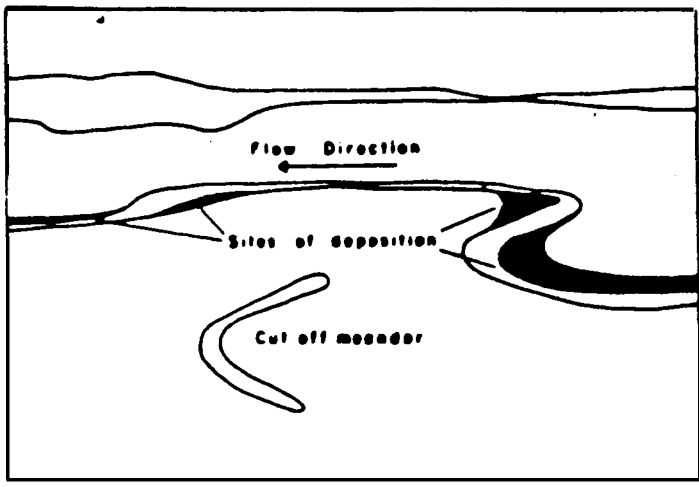


FIGURE 15 - Plan and Section of
Comstock Lode,Nevada
(after Boyle, 1979)

5.0 PLACER DEPOSITS

Placer deposits are masses of sand, gravel or similar unconsolidated material resulting from the erosion of solid rock or veins containing particles or nuggets of gold, silver, platinum or other valuable minerals. Gold is one of several minerals and metals concentrated because of density and resistant physical properties in stream, beach or river sediments. Platinum and silver are other native metals that concentrate because of density and malleable nature. Rubies, dianonds and some other gems concentrate because of hardness while minerals like cassiterite (tin ore), ilmenite (titanium ore), chromite (chromium ore) and magnetite (iron ore) concentrate mainly because of density. Three conditions are generally necessary to form commercial placers: 1.) occurence of a nearby source of minerals; 2.) release of minerals from bedrock by weathering; and 3.) concentration by streams or wave action during the process of erosion. The source area must have sufficient relief for the erosion of a large volume of lighter minerals with the accumulation of the heavier, resistant economic minerals. Figures 17 and 18, show sites of gold accumulation along a stream course.

The accumulation of placer deposits does not necessarily indicate the presence of lode or bedrock deposits in the area and lode gold deposits are often found in areas without significant placer accumulation. The Canadian Shield has many lode gold camps but possible placers were destroyed by glacial activity. The Klondike area does not contain lode deposits capable of supplying gold to the placers but placers are associated with deeply weathered areas of Klondike Schists that were not subjected to recent glaciation. The Atlin area of northern British Columbia has placers with only small associated lodes. Both lode and placer deposits are found in the Cassiar, Cariboo (Figure 19) and Fraser River areas of British Columbia.



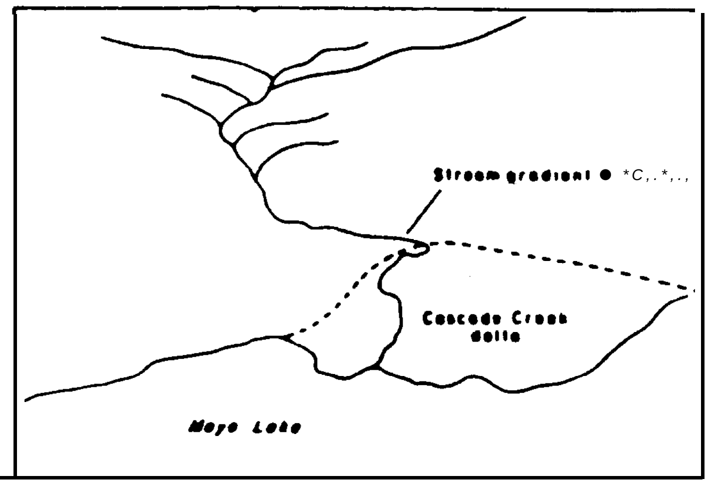


Figure 17 Sites of gold deposition along the inside of meander curves. Cold is also deposited on the ends of sand and gravel hors in braided streams.

Figure 18 Site of gold deposition 0? the apex of the Cascade Creek delta, where the stream gradient decreases.

Sites of Placer Gold Accumulation

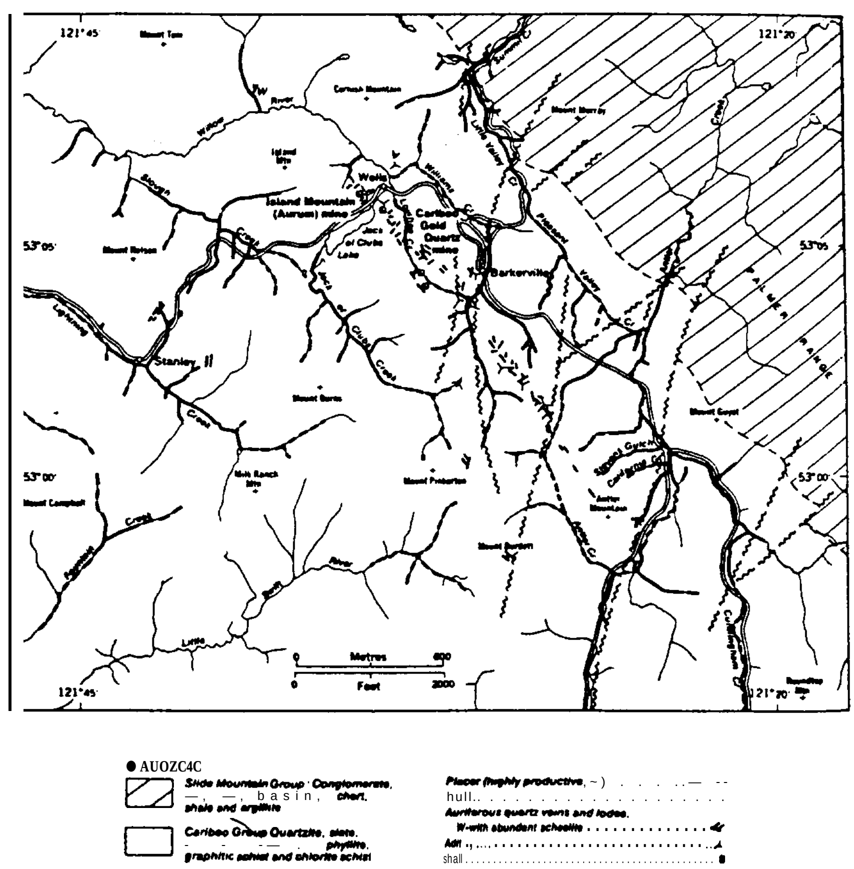


FIGURE 19 - **Cariboo Placer and Lode Gold Area, British Columbia (after Boyle, 1979)**

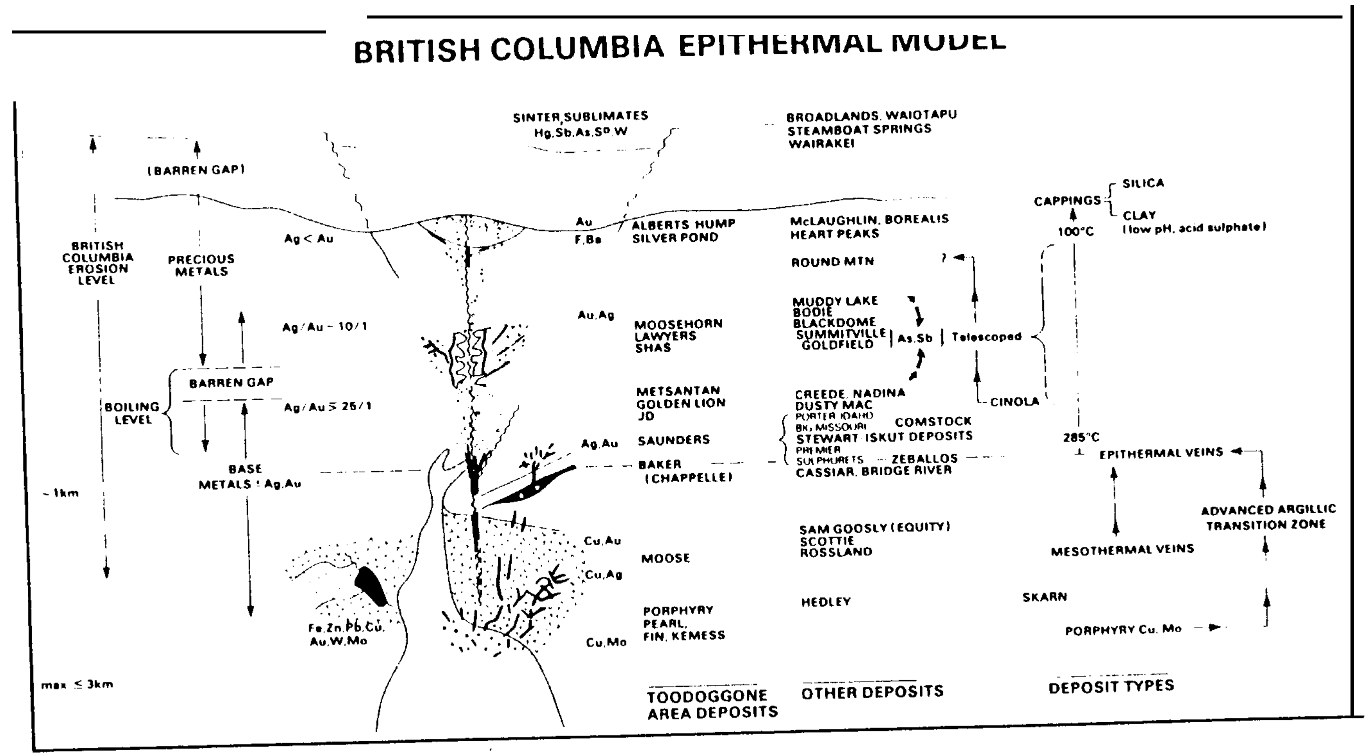

BRITISH COLUMBIA EPITHERMAL MODEL
SINTER,SUBLIMATES
Hg,Sb,As,S°,W
BROADLANDS, WAIOTAPU
STEAMBOAT SPRINGS
WAIRAKEI
(BARREN GAP)
BRITISH COLUMBIA EROSION LEVEL
PRECIOUS METALS
Ag < Au
Au
F,Ba
ALBERTS HUMP
SILVER POND
McLAUGHLIN, BOREALIS
HEART PEAKS
ROUND MTN
CAPPINGS
SILICA
CLAY
(low pH, acid sulphate)
100°C
Ag/Au ~ 10/1
Au,Ag
MOOSEHORN
LAWYERS
SHAS
MUDDY LAKE
BODIE
BLACKDOME
SUMMITVILLE
GOLDFIELD
As,Sb
Telescoped
CINOLA
BARREN GAP
BOILING LEVEL
Ag/Au ≥ 25/1
METSANTAN
GOLDEN LION
JD
CREEDE, NADINA
DUSTY MAC
COMSTOCK
STEWART ISKUT DEPOSITS
ZEBALLOS
CASSIAR, BRIDGE RIVER
285°C
EPITHERMAL VEINS
Ag,Au
SAUNDERS
BAKER
(CHAPPELLE)
BASE METALS ± Ag,Au
~1km
ADVANCED ARGILLIC TRANSITION ZONE
Cu,Au
Cu,Ag
MOOSE
SAM GOOSLY (EQUITY)
SCOTTIE
ROSSLAND
MESOTHERMAL VEINS
HEDLEY
SKARN
Fe,Zn,Pb,Cu,
Au,W,Mo
Cu,Mo
PORPHYRY
PEARL,
FIN, KEMESS
PORPHYRY Cu, Mo
max ≤ 3km
TOODOGGONE AREA DEPOSITS
OTHER DEPOSITS
DEPOSIT TYPES

FIGURE 16

Mineralized Districts

and Regional Exploration

by

D. H. Watkins

for the

B. C. & Yukon Chamber of Mines

January, 1986

MINING CAMPS AND REGIONAL EXPLORATION

D. H. Watkins

1.0 INTRODUCTION

The distinction between mining camps, mining districts, and mining regions is not rigourous but tends to hinge on the number of significant metal occurrences in an area and on a question of scale. Working definitions are provided as follows:

Mining Camp: an area of land, usually on the order of several. tens to several. hundreds of square miles, that is defined by geological, topographic, and/or geographic boundaries within the limits of which ore deposits are being or have been commercially exploited.

Mining District: a mining district implies a larger, more geologically diverse area that a mining camp, and will. have a number of mineral. occurrences within its boundaries. It may include a mining camp within its limits, or an isolated producing deposit, or a number of prospective metal. occurrences.

Mining Region: this term is equivalent to the terms "*metallogenic ' province or region" and refers to large areas with specific types of metal occurrences. It tends to reflect the association of certain metals and metal. deposits with fundamental. geological. processes that occur on a global. scale.

Knowledge of the empirical characteristics of mining camps, districts, and regions and an understanding of the underlying geological. processes is essential. to the formulation of an intelligent investment strategy for exploration and to the efficient and cost effective execution of an exploration program.

2.0 FORMULATION OF EXPLORATION/INVESTMENT STRATEGY

Whether investing directly in exploration or indirectly through a company involved in exploration, a strategy is required to focus the purpose of the program tightly enough to yield a good chance of success. Empirical knowledge of mining camps provides useful information and insight on the following aspects that contribute to the development of a strategy:

cluster effect
target size
economic characteristics of the target
metallurgy
risk level.

An examination of the above characteristics based on observation of known mining camps is the first step in assessing strategy for exploration.

2.1 Cluster Effect

Concentrations of metals into commercially extractable deposits (or mines) do not form random or evenly distributed populations throughout the country; rather, they tend to group into clusters. It is these clusters of deposits that we refer to as mining camps. This clustering effect is important to understand at 2 levels, because:

1) most of the metal production in Canada (and elsewhere) comes from relatively few districts and,

2) the clusters tend to have common characteristics that reflect similarities in the geological environment and common ore forming processes and systems.

More than half of Canada's base metal production comes from polymetallic massive sulphide deposits and most of that production comes from the 11 massive sulphide districts shown in Table 1. The number of economic deposits in these camps range from 4 to 21 with an average of 9 per camp as illustrated In Table l(a).

Table 1: Canadian Massive Sulphide Districts

District	Age	Number of Deposits	Millions Tonnes "Ore"	Millions Tonnes Metal.	Average Grade	Average Gross Value per Tonne
1. Buchans, Nfld.	Ordovician	5	16	3.8	23.6	239
2. Bathurst, N.B.	Ordovician	12	180	15.1	8.4	120
3. Newcastle,N.B.	Ordovician	15	98	5.8	5.9	84
4. Buttle Lk,B. C.	Jurassic	4	22	1.9	8.5	125
5. Matagami, Que.	Archean	9	38	3.8	10.0	107
6. Noranda, Que.	Archean	21	106	3.8	3.6	91
7. Manitouwadge, Ont.	Archean	4	56	3.0	5.4	75
8. Sturgeon Lake Ont.	Archean	6	18	1.8	9.8	125
9. Timmins, Ont.	Archean	5	152	12.5	8.2	109
10. Flin Flon, Man.	Proterozoic	14	72	4.6	6.4	92
11.Snow Lake, Man.	Proterozoic	13	25	1.7	6.8	95

Table l(a): Canadian Massive Sulphide Districts Summary

	Shield	Appalachian/ Cordilleran
Age	Precambrian	Phanerozoic
Number of Major Districts	7	4
In Above Districts (Table 1.)		
Number of Deposits	72	36
Tonnes of Ore (Millions)	477	316
Tomes of Base-Metal (Millions)	32	27
Total Gross VALUE (Billions)	U.S. $47	U.S. $36

Table 2: Canadian Massive Sulphide District Averages

Averages	Shield	Appalachian/ Cordilleran
Gross Value/Tonne	U.S.$98	U.S.$115
Tonnes Ore/ District	68 million	79 million
Tonnes Metal/ District	4.6 million	6.8 million
Number of Deposits/District	10	9
Area of District - Range	50-1500 km^2	200-1200 km^2

On examining these tables it becomes apparent that deposits cluster in important camps and that the frequency of occurrence of camps is similar in the 2 main geological subgroups based on metallogenic regions: 1) Shield and 2) Appalachian/Cordilleran. Other crucial. data on deposit size, tonnes of metal, number of deposits per district can have a major input for strategy for mulation. The tables provide in effect a statistical. list of options.

A review of major gold camps in Canada (Table 3) affirms the tendency of metal. deposits to cluster. More than 30% of Canada's total. Au production comes from just 1 camp (Porcupine) which has 24 different producing mines. A summary comparison of Au producing metallogenic regions (Table 4) illustrates that the Superior province (the major portion of "the Canadian Shield) is by far the most prolific producer of Au camps and Au metal. With this type of data we can formulate specific questions, the answera to which will provide the skeleton of an exploration/investment strategy (see section 2.3).

Table 3: Major Canadian Gold Camps

Camp	Production (x 10^6)	No. of Deposits	Age
1. Porcupine	54.0	24	Archean
2. Kirkland Lake	22.9	8	Archean

3. Red Lake	12.6	14	Archean
4. Vsl. d'or	12.1	12	Archean
S. Larder Lake	12.1	9	Archean
6. M alartic	7.9	6	Archean
7. Long Lac	5.5	11	Archean
8. Pickle Crow	2.1	2	Archean
9. Bralorne	4.2	2	post Triassic
10. Hedley	1.7	4	post Triassic
11. Silbak Premier	1.8	1	Tertiary
12. R ossland	2.7	5	Tertiary

Table 4: C omparison of Selected Au Metallogenic Regions

	Metallogenic R egion			
	Superior Province	Canadian C ordillera	C alifornia	Nevada
Total. Production (oz X 10^6)	1.37.8	14.0	37.9	5.9
No. of Camps >1X$10^6$0Z	10	6	8	1
No. of Mines >1X106OZ	33	5	5 (approx)	2
Average Mine Size (02 x 10^6)	3.8	2	3.2	2
Average No. of Mines/Camp	11.	3	N.A.	10

The foregoing should establish basically, that:

1. m etal deposits cluster in groups called camps or districts
2. these clusters are important in terms of production
3. a review of these camps can provide important strategic information.

2.2 Target Size and Grade

Certain characteristics on the size of potential expiration targets can be ascertained from a review of existing mining ca reps. Figure 1 shows the size distribution of Au deposits in the Superior Province and illustrates that in most mining camps there is one giant deposit, some middle range sizes and a number of smaller deposits, any one of which may provide an acceptable rate of return.

Gold is not unique in this respect. Table 5 shows a break down of the size and grade of massive sulphide deposits in the Pre-Cambrian shield. Again it is apparent that there is often a giant deposit and a distribution of other deposits that decrease in size as they increase in frequency.

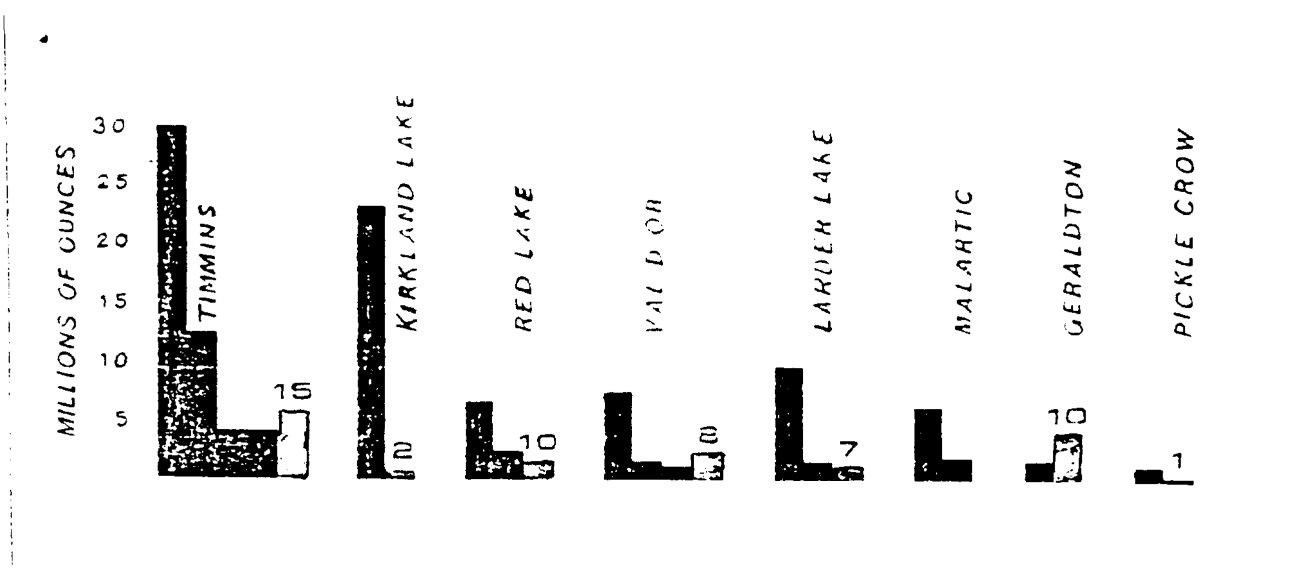
Table 5: Canadian Pre-Cambrian Massive Sulphide Deposits

Tonnage - Grade - Values Characteristics

Croup	Tonnage Range (Millions)	Number Deposits	%	Av. Size (Million T)	Grosa Value/Tonne U.S. $
A	60-115	1	0.9	113.0	122
B	30-60	4	3.5	52.0	79
c	15-30	4	3.5	18.0	90 "
D	7-15	8	7.0	11.0	76
E	4-7	10	8.7	6.0	99
F	2-4	22	19.1	2.6	84
G	1-2	17	14.8	1.3	75
H	o-1	49	42.6	0.4	90
Totals/Average		115*	100.0	5.6	90

% Cu	% Zn	g/t Ag	g/t Au
1.9	4.2	46	1.1

*70 % Producers 30% Non-economic (After Boldy 1977)



SIZE DISTRIBUTION of DEPOSITS in CAMPS of the SUPERIOR PROVINCE

FIGURE 1

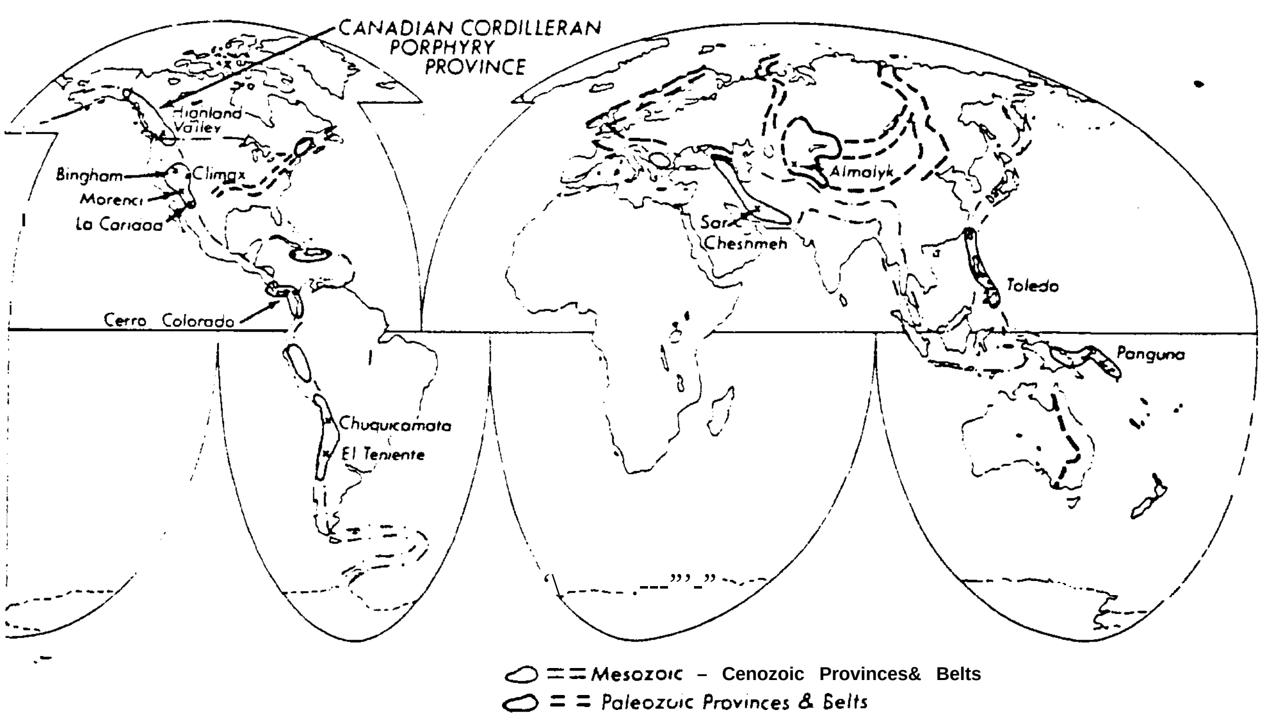


FIGURE 2 — Porphyry provinces of the world and related mountain belts

2.3 Application of Cluster, Size, and Grade Data

After reviewing the kind of inform ation available from co m piling data from mining camps a large number of questions are raised. The answers to these questions will. form the essence of an exploration strategy but can only be provided by the organization or individual who must assess the risks in the questions in order to formulate the strategy. However, the f ollo wing provides some exam pies of questions and considerations.

1) what commodity to look for
   - different commodities occur in cliff erent areas
2) where to look for the deposit - Shield? Cordillera?
   - Au d eposits are clearly more prolific in the Shield but are there other curcumsances?
     m assive sulphides tend to be larger in the Appalachian/ C ordillera (Table 1) - other factors?
3) what scale to look at
   - do we wish to find a new district, camp, or deposit?
     to find a new camp
       - odds are longer (Le. risk of failure is greater)
       - time commitment is longer
       - overall cost in higher
         BUT
       - entry cost is lower
       - pay off is potentially much higher
     looking within an existing camp
       - odds of discovery are improved
       - time to return of investment decreases
       - entry fee is higher
       - payoff may be profitable but not spectacular
4) what is the significance of particular discoveries and areas
     e.g. Hemlo - a major Au discovery:

is this a giant In a new camp that enhances the probability of other occurrences? or is it an isolated, stand alone anomaly?

e.g. Geraldton - note in Figure 1 that there Is no giant in this camp. Should we look for one here?

A review of mining camps and technical. data can start providing answ era to these basic, strategic questions.

3.0 ECONOMIC CHAR AC TERISTICS OF MINING CAMPS

The ultimate success of an expiration program is not just to find a deposit, but to fLnd a deposit that can be exploited for a profit with minim al. risk. We can look at mining camps and analyze in detail. many of the economic factors that affect risk and rate of return and which therefore should be considered in our exploration strategy. Economic characteristics that require evaluation in each area in which we propose to invest include:

1) C apitalization require ments
   - these can vary as a function of deposit type (e.g. underground vs open pit) or as a function of location (e.g. a much higher capital. cost can be anticipated in central Africa or the Arctic islands than several. kilo m eters outaide Ka mloops)
2) Labour cost and productivity - miners, electricians, etc. are paid substantially Less on average in a Q uebec mining camp than in B. C. Can your project support the extra cost?
3) Transportation - access to roads, rail, seaports etc can have a major impact on capital and operating costs
4) Power - availability and cost has a major impact on capital. and operating costs
5) Taxation - the effects of fast capital write offs, royalties etc vary greatly fro m place to place and can make or break projects
6) Environm ental issues - modem technology can handle most things - at a cost.

Exploring in an existing mining camp enables a precise estimate of the above costs, thereby reducing risks substantially. These factors must be considered against the potential target no matter where you choose to explore.

4.0 METALLURGY

The ability to extract metals from ore is crucial to the economic success of a program. Little can be done to control. this factor outside established mining districts. In known districts, it is reasonable to generalize m etallurgical characteristics of existing operations and attribute them to your potential discovery.

5.0 INTRODUCTION TO THE GEOLOGY OF MINING CAMPS

Having carefully considered the foregoing characteristics of mining camps and districts and decided on where we are prepared to take how much risk for what potential return, it is time to execute our exploration program. The first step is to undersand the geological. controls on the distribution of mining districts and camps and to understand how deposits are distributed within camps.

Exploration for new districts, ca reps, and deposits relies on' the extrapolation fro m the known to the unknown. Any parameters with a sound economic and geological. basis that are a relatively consistent feature in "the nature and distribution of an ore deposit can be used to help find others and attribute quanititative characteristics to the target. Knowledge of economic, geological, and statistical parameters from mining camps enables us to evaluate the possibility of the occurrence of the target being sought and enables us to make some basic assumptions concerning size, grade, risk and profitability of a deposit in the event of exploration success.

5.1 M etallogeny and the Distribution of Mining Districts

Metallogeny is the study of the genesis of mineral deposits with e mphasis on their relation in space and tim e to regional. petrographic (rock) and tectonic (structural) features of the Earthts crust. In other w orals, certain mineral deposits occur in certain broad regions that are characterized by large scale geologic features that affect the Earth on a continental. or intercontinental scale. () re forming events occur associated with particular geologic events at particular geologic times. Examples might be the clustering of tin and tungsten deposit in northwestern Europe (England, France, Spain, Portugal and Austria) associated with the intrusion of a particular type of granitic rock related to a particular mountain building event (orogeny).

Porphyry copper deposits provide another excellent exam pie. N early all. porphyries occur near continental margins (present or past) where one continent is colliding with another and subducting it (Fig. 2). M assive sulphide deposits are known to form in areas of rapid crustal subsidence related among other things to the rifting or breaking apart of continents and to sea floor spreading.

Identification of the large scale environments preserved in the rock record can direct the focus of regional. exploration attention to general. areas of potential. A number of factors that are related to m etallogenesis are discussed in the following:

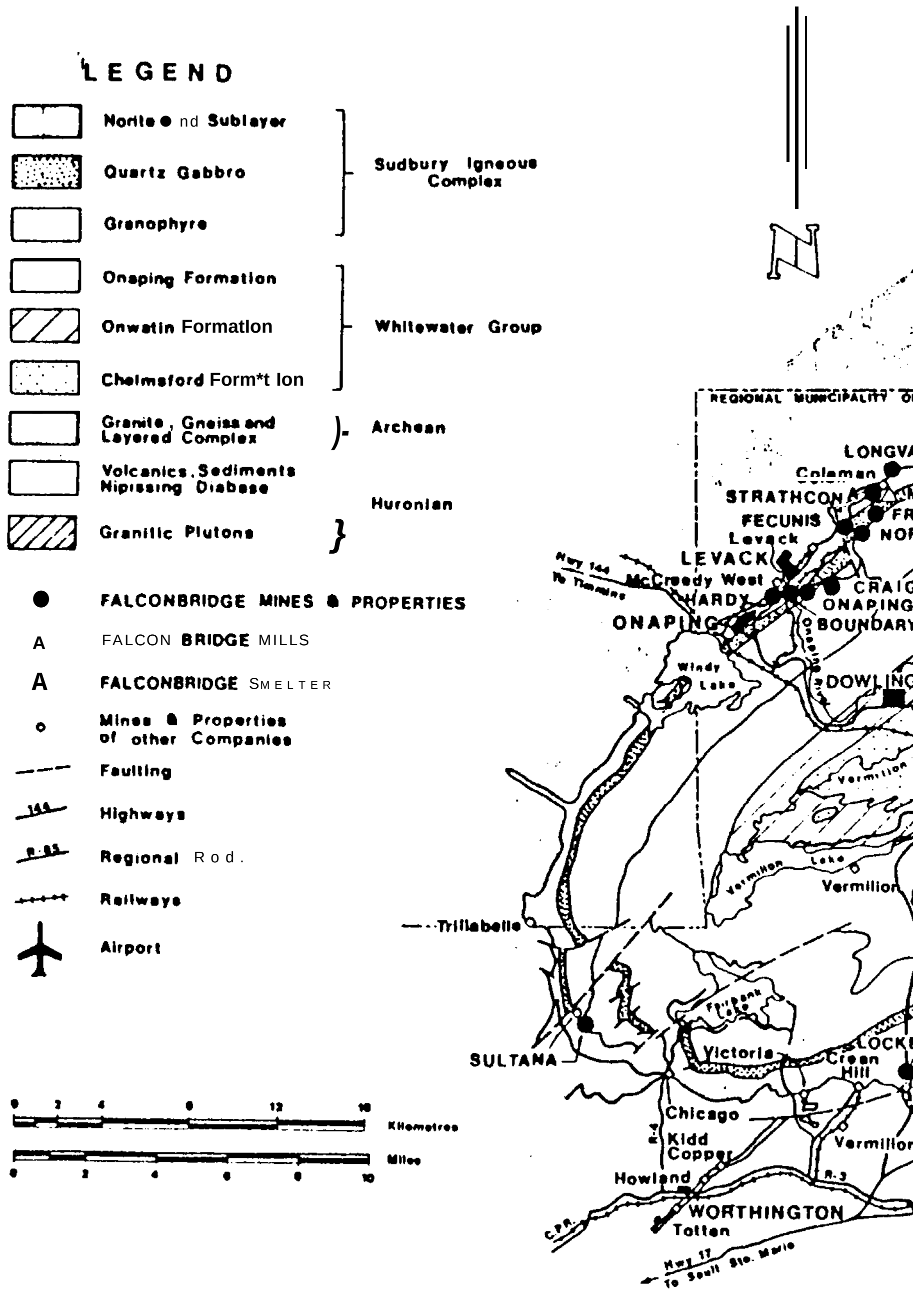
5.2 Lithologic Associations

C ertain ore deposits occur preferentlall.y with certain rock types. Nickel, for example occurs only with ultra mafic rocks. All. the reties in Sudbury (Fig. 3) are located near the margins of the Sudbury Igneous Complex. Nickel. deposits in the Thorn pson belt in Manitoba and the Ungava belt in northern Q uebec are all. associated with ultra m afics. Even the nickel. bearing laterites that form by a completely different process, all. require an ultra m afic association.

G old deposits in the British C olum bian C ordillera show an affinity to specific rock types (Fig. 4). All. are associated with m afic volcanic rocks near major sedimentary contacts. M ost deposit types, certainly within m etallogenic provinces tend to have preferred rock associations.

5.3 Age

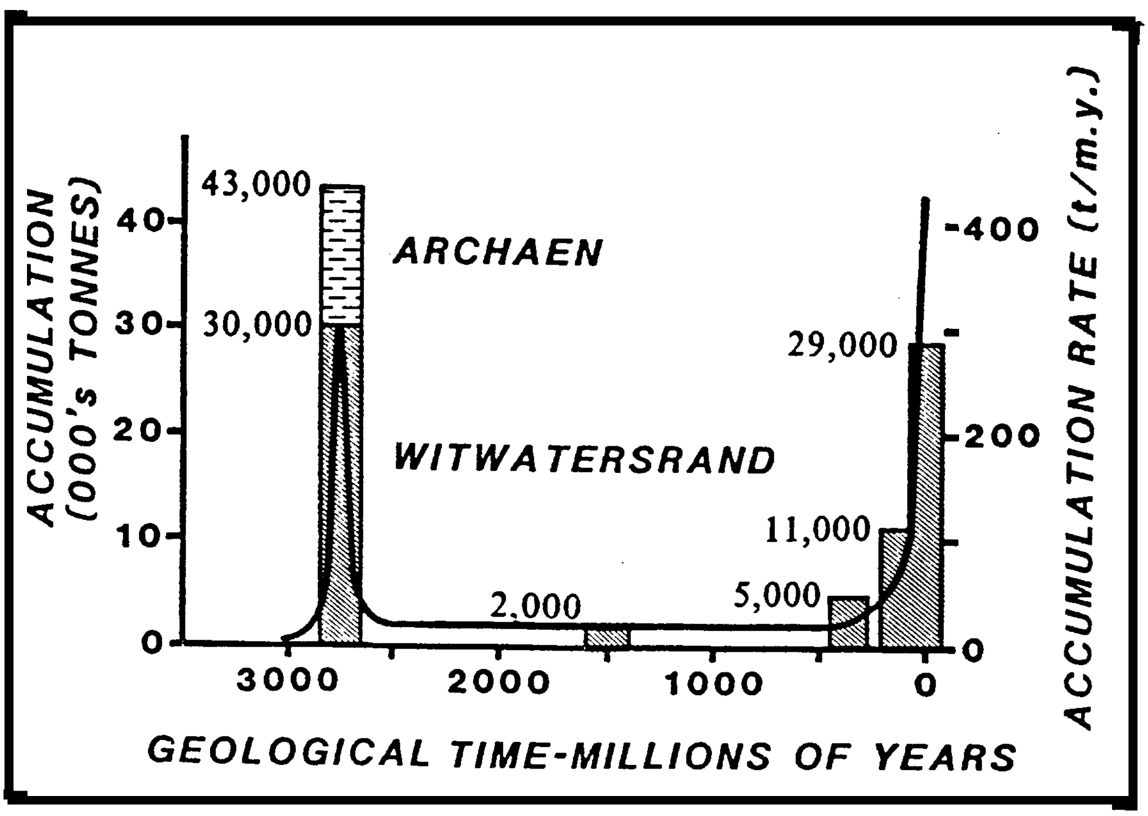
Certain deposits tend to occur at certain tim es during geologic history. These conditions may not be exclusive, but it clearly improves exploration odds


LEGEND
Norite and Sublayer
Quartz Gabbro
Granophyre
Sudbury Igneous Complex
Onaping Formation
Onwatin Formation
Chelmsford Formation
Whitewater Group
Granite, Gneiss and Layered Complex
Archean
Volcanics, Sediments Nipissing Diabase
Huronian
Granitic Plutons
FALCONBRIDGE MINES & PROPERTIES
FALCONBRIDGE MILLS
FALCONBRIDGE SMELTER
Mines & Properties of other Companies
Faulting
Highways
Regional Road
Railways
Airport
Kilometres
Miles
REGIONAL MUNICIPALITY
LONGVA
Coleman
STRATHCONA
FECUNIS
Levack
LEVACK
McCreedy West
HARDY
ONAPING
CRAIG
ONAPING
BOUNDARY
Windy Lake
DOWLING
Vermilion Lake
Vermilion
Trillabelle
SULTANA
Fairbank Lake
Victoria
LOCKE
Crean Hill
Chicago
Kidd Copper
Vermilion
Howland
WORTHINGTON
Totten
C.P.R.
Hwy 144 To Timmins
Hwy 17 To Sault Ste. Marie

MINING CAMP	(Mines > 3,000 oz)	INTRUSIONS		VOLCANIC ROCKS			SEDIMENTARY ROCKS			SED.-VOLC.
		FELS-INT	ULTRAM.	MAFIC	FELSIC	AGE	CLASTIC	CHEM.	AGE	CONTACT
BRIDGE RIVER	2	●	○	●	○	Tr	●	●[d]	Tr	●
ROSSLAND	1'	●	○	●	○	Jr	●	●[e]	Carb.	●
PORTLAND C.	1[a]	●	○	●	●	Jr	●	○[e]	Jr	●
HEDLEY	2	●	○[b]	●	○	[illegible]	○	○	[illegible]	○
ZEBALLOS	4	●	○	●	●	Tr	○	●[e]	Jr	●
CARIBOO	2	○	○	●	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	●
SHEEP CREEK-YMIR	4 / 2 (6)	○	○	●	[illegible]	[illegible]	●	○	Є, Jr	●
INCIDENCE of FEATURE %	~70	~30	100	~30		~85	~70		100

LITHOLOGIC ASSOCIATIONS AND AGE OF CORDILLERAN AU DEPOSITS
(after Hodgson et al)
Fig. 4

● ASSOCIATION PRESENT   ○ ASSOCIATION ABSENT



GOLD IN GEOLOGICAL TIME
Fig. 5 (after Woodall)

to search in the preferred time frame work. Figure 4 shows that most Cordilleran Au deposits In B. C. occur within a narrow time range during the Triassic/Jurassic periods. On a world wide basis, Au is observed to occur mainly in 2 discrete times: the Archean and more recent periods (Fig. 5). Although we don't understand the cause of this time distribution, the empirical observation clearly mitigates against spending a lot of time and money exploring outs-hle its limits.

Another example of age control. is seen at certain major unconformities. Unconformities are major tLme discontinuities in a rock seqûence - a time break In stratigraphy. Most of the major uranium deposits of the world are associated with unconformities or time breaks - the Elliot Lake U deposits, the northern Saskatchewan U deposits, most of the Australian U deposits and the gigantic Olympic Dam Cu-U deposit in Southern Australia all. fall. into this class.

5.4 Linear Features

Districts often show a well defined spatial relationship to major regional structures and cross structures. Gold deposits in Nevada line up along several major fault zones that continue for many miles. The Kirkland Lake - Cadillac "break" is a zone of structural. discontinuity that corresponds to a change from volcanic rocks in the north to sedimentary rocks in the south and is traceable for over 200 miles, hosting 7 major Au camps in that distance (Fig. 6).

These linear features often represent long-lived zones of tectonism that tap deeply into the Earth's crust and control. rock and fluid movements. Areas where 2 major sets of structures intersect are particularly favourable as a possible locus for mining camps and districts.

5.5 Climate/Environmental Associations

Modem day climate causes rocks to break down or weather in different ways depending on temperature, rainfall, and rock chemistry. Many of the Au deposits of Nevada, for example, would not be economic without this weathering process. Weathering causes oxidation of the near surface, 10 w grade rock rendering it amenable to low cost mining and treatment by heap

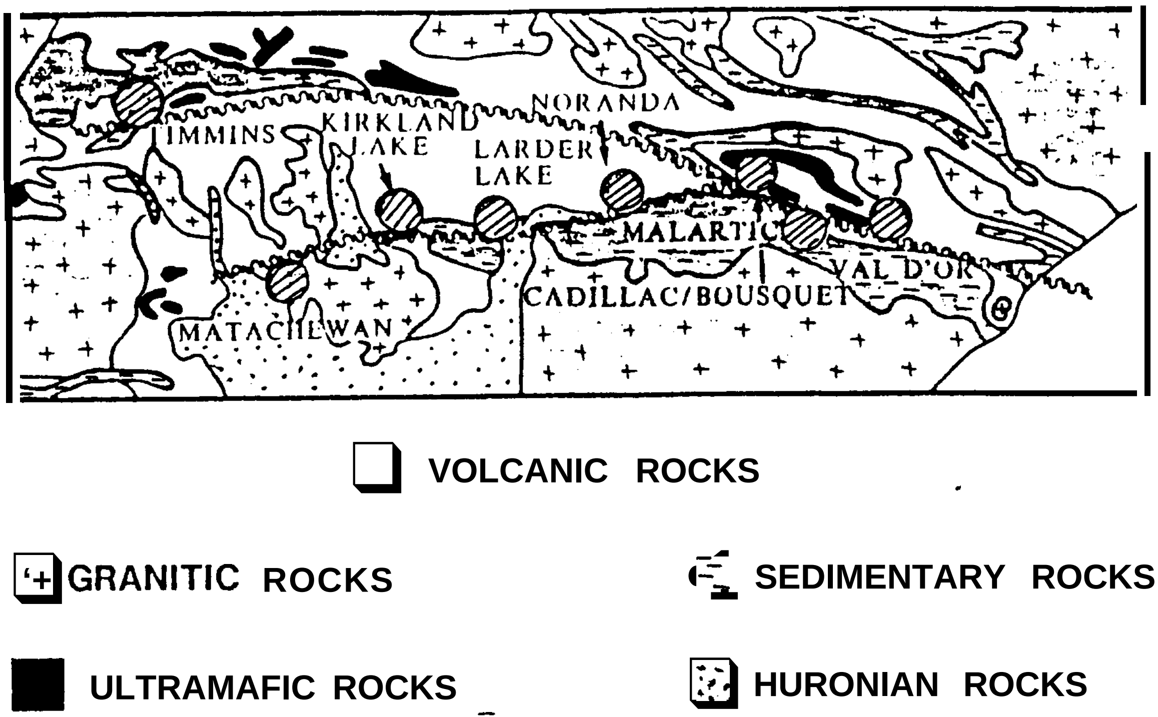


Fig. 6

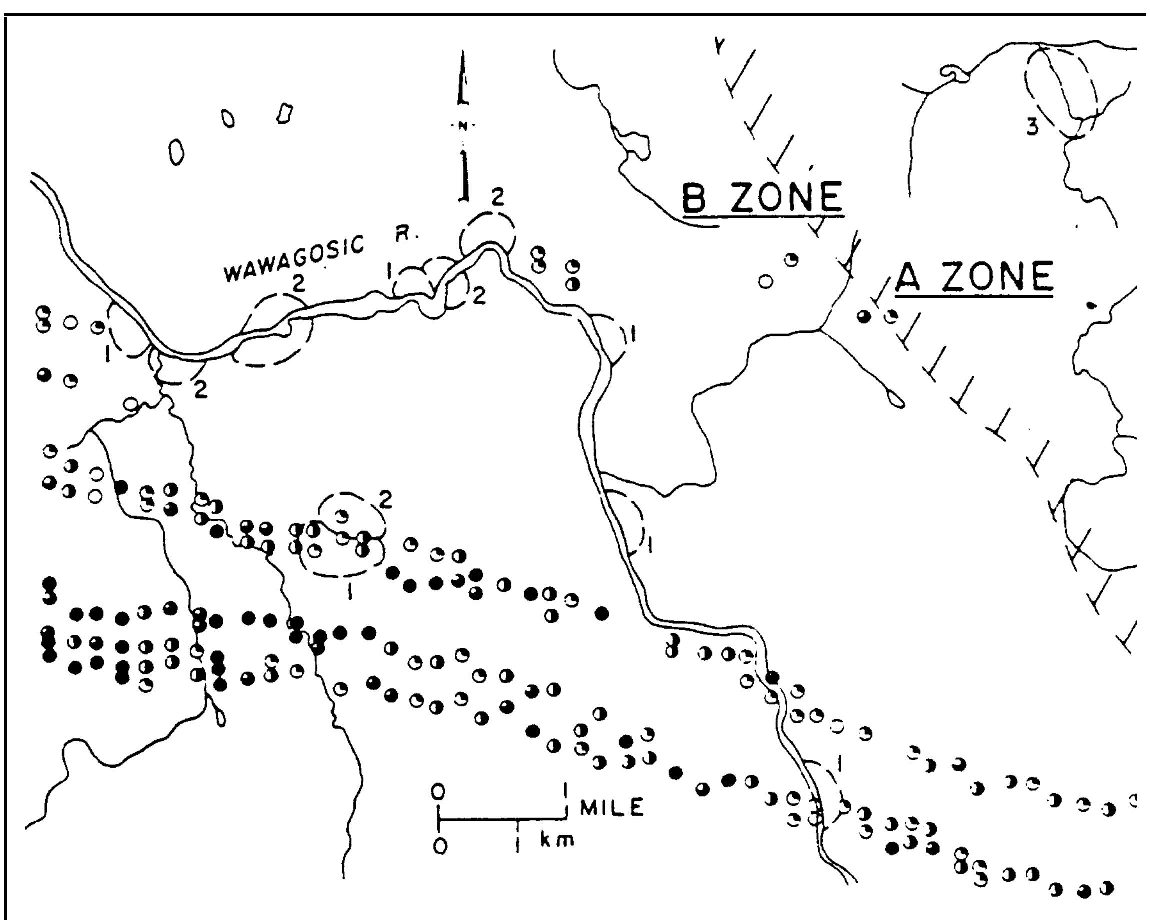


FIG. 7. Discovery Input with geology (after Remick, 1969): 1-mafic volcanics, 2-acidic volcanics, 3-granite

16

leaching. The prim ary (unweathered) rock is not usually economic because it requires crushing and Its rock constituents are highly consum ptive of reagenta like cyanide.

Nickel laterite deposits form when w eathering leaches Ni out of the host untra m afic rock and re -deposits it further down the developing soil profile. The appropriate conditions of formation are only met at a convergence of the right ele m ents of climate, slope, and rock type.

M assive sulphide deposits may only form and be preserved in a sub m arine environm ent. We can therefore narrow the number of districts in which to explore simply by looking for evidence of this sub marine environm ent in the rock record.

5.6 Process Association

Many deposits are formed as a result of specific geological. processes, one of the most common being volcanism. Epithermal Au veins form in association with subaerial. volcanism and are related to collapse structures, calderas, and hydrothermal activity. New mining districts of this type may therefore be found by restricting search to this type of environment.

Similarly, massive sulphides are often associated with volcanic calderas and collapse, but always in a sub m arine environm ent.

6.0 DISTRIBUTION OF DEPOSITS WITHIN CAMPS

Distribution of deposits within camps is controlled by a number of factors similar to those that control the distribution of the camp itself, but on a more finely tuned scale. E mpirical knowledge within a camp can be quite detailed and substantially enhances the potential and probability of making a discovery if that knowledge is properly and persistently applled. The general features that affect deposit distribution in a camp are sum marized with exam ples in the f ollo wing chart:

Control	Remarks	Example
Lithology	camp specific rock associations	- Kirkland Lake syenite - Opemiska Cu-Au deposits with Ventures Gabbro - association of B. C. porphyries with Guichon batholith
Structure	faults, fold, any structures that create open space/permeability for ore fluids - deeper and longer lived structures often best orthogonal. intersecting structures	Lupin Au in fold nose numerous Au veins in fault zones explosive breccias followed by hydrothermal activity
Stratigraphy	- particular time horizons that mark periods of ore deposition	Noranda - main contact deposits
Form	- tabular sheets - conformable	Howard's Pass Zn-Pb
	- tabular sheets - vertical.	Bralorne Au veins
	rod-like	massive sulphides at Snow Lake, Manitoba
	ellipsoidal. or conical.	breccia pipes
Alteration	- differing patterns of zonation and mineralogies associated with ore formation	qtz-carbonate in the Timmins camp chlorite, feldspar destruction in many massive sulphide camps
Metal Zoning	- may occur on deposit and district scales	Noranda Cu, Zn ratios and Au distribution
Paleotopography	- localization of deposits by basins or other topographic features	Noranda association with quartz porphyry domes - McArthur River fault boundary basin
Permeability	- distribution of paleo-acquifers, particularly permeable units or structures and impermeable caps or barriers.	- Hishikari Au mine in Japan

The above listing is not necessarily exhaustive because of the incredible variety In mineral districts and deposit types. However, the point is that each camp has its particular characteristics, empirical knowledge of which can be reasonably used to attribute characteristics to other deposits yet to be found, thereby facilitating exploration and discovery.

7.0 REGIONAL EXPLORATION

Regional exploration is the first stage of field work carried out in a large prospective area once the exploration targets and strategy have been decided upon. It is the first stage of screening a fairly large area with the objective of finding specific targets to follow up with more detailed work. There are 4 broad categories of techniques that are applied to this task:

1. Prospecting
2. Geology
3. Geophysics
4. Geochemistry.

7.1 Prospecting and Geology

The preceding section of this presentation deals with geological. concepts and needs not be repeated. The geologist excercises his talent through field mapping and investigation supported by laboratory work and is generally responsible for integrating all aspects of a program to come up with working models, interpretation, hypotheses, and hard targets. Geologists have many talents and may specialize in a variety of useful categories but if he is an exploration geologist his single minded purpose must to be use every available resource to find ore. And that makes him a trained, professional prospector. Any regional or detailed exploration program requires this individual. to bring all. the clues together to fLnd ore.

f'

7.2 G eophysics

Geophysics Is the art of applying physics to geology and breaks down into 4 m sin categories:

1. Electrical
2. Magnetics
3. G ravity
4. Seismic.

The geophysical techniques most com monly applied to regional. exploration for minerals are electrical and m agnetic. Gravity and seismic are used for regional work in petroleum exploration but tend to be used only for more detailed work in mineral exploration.

7.2(i) Electrical Methods

Electrical. methods break into 2 important categories:

1. electromagnets (EM)
2. direct current methods (most com monly IP)

IP or induced polarization is occasionally used for regional. scale programs when the target is very large (such as porphyry C u deposits). The method introduces electrical current into the ground and measures changes in potential between pairs of electrodes. It is most effective for picking up disse minated mineralization that m ay be associated with alteration related to a deposit and most commonly is used for more detailed work.

Electromagnetic systems (called EM) come in a vast array of packages and are used at all. scales of work from regional to local. E M is best suited to looking for electrically conductive bodies - m assive sulphide deposits are a m ong the most noteable target types. It is also an effective tool for mapping conductive stratigraphy such as graphite bearing sedimentary horizons.]? or regional work, EM systems are mounted in aircraft and flown over the prospective area. This approach can provide a large amount of relevant exploration data in a rapid, cost effective manner.

EM systems all work on the same principal: A strong electrom agnetic field 5s generated by a transmitting loop. This primary field induces electrical.

currents to flow in any conductive body cut by the primary field. The current in the conductive body consequently generates its own secondary electro m agnetic field. A sensitive receiver may then detect this as a distortion in the primary field or may directly detect and measure characteristic of the secondary field.

The net result is that an ano m aly is defined and can be plotted on a map (Fig. 7). The actual. ground location can then be checked and evaluated for potential. f ollo w -up work.

EM is an eff ective system for finding ore deposits that are conductive - but not all. ore deposits are conductive.

7.2(ii) Magnetics

M agnetic surveys Involve the measurement of variations in the Earth's m agnetic field and the magnetic properties of rocks. M agnetic sensors may be used for detailed work but also provide useful inform ation when mounted in an aircraft. M agnetic surveys are often flown in conjunction with EM. Very few minerals are m agnetic, the most com m on ones being m agnetite and pyrrhotite. How ever, these are common minerals in rocks and ore deposits and the inform ation they provide can be useful.

Magnetite may be more common in some rock types and some stratigraphic horizons then in others. This contrast is detected in a magnetic survey and is a useful adjunct to geological mapping. Some alteration processes cause either the form ation or destruction of m agnetite or pyrrhotite, so this technique can also be useful. in locating or m apping alteration zones and structures. And magnetics may directly detect ore deposits if m agnetic minerals are associated with the deposit - a not unusual. circumstance.

M agnetics may directly detect ore deposits, provide an inexpensive and often effective aid to geological interpretation and used in conjunction with EM may help prioritize conductive targets.

7.3 <u>(; eochemistrv</u>

G eoche mistry in exploration is the sampling of rocks, soils, sediments, vegetation and water to detect abnorm al or ano m alous quantities of elements that may constitute part of the ore deposit or be related to the mineralizing process. Analysis of the sampled medium is carded out for 2 classes of elements:

1. ore elements e.g. Au, Cu, Ag, Zn etc
2. pathfinder elements - those elements known to be associated with ore in particular districts such as As, Sb, Bi, Hg.

Statistics are usually used in a given area to ascertain the normal, or background level. of the elements being measured. Anomalous populations can then be identified and a field examination may be carried out in the. area of an anomaly to ascertain the cause.

The primary and secondary mechanisms of dispersion of elements in a geological. environment are quite complex (Figs. 8 & 9) and subject to a wide range of variables requiring a high degree of care in both sampling and interpretation of data. The following table outlines some of the main geochemical survey types with some comments on each.

Maior Classes of Geochemical Surveys

1. Soil surveys
   a) Transported soils
      - mechanical disperion forming dispersion trains of ore or pathfinder elements associated with deposit
      - transport mechanism may be glacial, fluvial etc.
      - good example: Au anomalies in glacial till at Casa Berardi. discovery

   b) Residual soils
      - anomalies may derive from the direct weathering of deposits
      - good example: Cu, Zn anomalies in soils above Brunswick deposit, Bathurst camp

2. Rock surveys
   - detection of geochemical anomalies associated with the passage of ore mineralizing fluids through fractures, fissures, pores or other openings in rock
   - particularly effective to ascertain alteration patterns and may provide a vector pointing towards ore

Genetic classification			Origin	Emplacement	Matrix	Form of dispersion pattern
Syngenetic patterns		Geochemical provinces	Compositional variations affecting large segments of the earth's crust	Igneous intrusion, granitization, or sedimentation	Rocks of diverse types and ages occurring over wide area	Varied
		Local syngenetic patterns	Local processes of petrogenesis, differentiation, metamorphism, or sedimentation		Local plutonic bodies or sedimentary rocks	
Epigenetic patterns	Hydrothermal dispersion patterns	Wall-rock anomalies	Precipitation from solutions related to ore-forming fluids	Movement of solutions; diffusion of solutes	Rocks adjoining ore deposits	Aureoles
		Leakage anomalies	Precipitation from spent ore-forming fluids	Movement of solutions	Rocks in and adjoining solution channelways leading upward from ore	. Halos
		Compositional zoning	Differential depletion of certain constituents of ore fluids with distance from source		Minerals deposited from hydrothermal solutions	Systematic variation with distance from Source
	Pressure temperature effects in epigenetic minerals	Mineral reconstitution	Pressure-temperature control of stability of mineral species	Bulk of reacting components already present	Alteration halos	Generally concentric isotherms indicating higher temperatures toward ore channels
		Chemical geothermometers	Pressure-temperature control of fractionation of elements between coexisting mineral species		Mineralized rock	
		Isotopic geothermometers	Pressure-temperature control of fractionation of stable isotopes between minerals and hydrothermal fluids			

Fig. 8 Classification and general characteristics of the principal types of primary dispersion patterns.

Genetic classification		Dispersion process	Principal transporting agent	Matrix	Mode of occurrence of dispersed elements	Form of dispersion pattern
Syngenetic patterns	Clastic	Weathering in *situ*		Weathered rock Residual overburden Gossan	Resistant primary and secondary minerals; minor constituents of clay minerals and secondary hydrous oxides	Superjacent patterns
		Movement of solid particles by:	Gravity	Residual overburden Gossan Colluvium		Fans and asymmetrical superjacent patterns
			Ice	Moraine		Fans
			Ice	Glaciofluvial deposits		Trains and Irregular patterns
			Water	Sheetwash deposits		Fans
			Water	Stream sediment		Trains
			Water	Lake sediment		Delta fans
			Wind	Aeolian deposits		Fans
	Hydro-morphic	Movement of solutions	Ground water	Ground-water solution	Soluble salt complexes and sols	Fans
			Surface water	Surface-water solution		Trams
				Precipitates and evaporite deposits	Precipitated salts	Lateral patterns
	Biogenic	Plant metabolism	Uptake by living plants	Living-plant tissue	Metallo-organic compounds	Superjacent and lateral patterns
				Organic debris		
Epigenetic patterns	Hydro-morphic	Movement of solutions followed by precipitation	Ground water	Any clastic overburden	Ions sorbed On clay minerals; hydrous oxides and organic matter; ions coprecipitated and occluded in hydrous oxides; metallo-organic compounds; precipitated salts	Superjacent patterns; fans
				Soils of seepage areas		Lateral patterns
			Surface water	Stream sediments		Trains
	Biogenic	Plant metabolism followed by redistribution of organic decomposition products	Nutrient solutions; soil moisture	Any elastic overburden		Superjacent and lateral patterns

Fig. 9 Classification and general characteristics of the principal types of secondary dispersion patterns.

- common example: Na depletion in footw all. of massive sulphide deposits

3. Drainage surveys

   streams act as collectors and therefore sample large drainage areas

   very effective reconnaissance scale coverage

   example: Falconbridge Copper discovery on R ea Au property in Ada ms-Barriere region was initially identified by a prospector sampling streams

4. Vegetation surveys
   - uptake of ele m enta by organic root systems
   - particularly effective in areas of deep rooted plants such as arrid, semi desert and areas of thin soil but heavy vegetation
   - example: British C olum Ma rain forest

The underlying principal to all. geoche mical surveys is the detection of prim ary or secondary anomalies that are dispersed by m echanical, che mical, biogenic or hydromorphic m echanisms and therefore much larger in areal extent than the actual. deposit being sought. Location of geoche mical anomalies may be near or distant from the exploration target depending on the mechanism of dispersion. P ainstaking work is often required to track down the source of an anom sly.

EXPLORATION METHODS LOCAL

Dr. Harlan Meade
Westmin Resources Limited

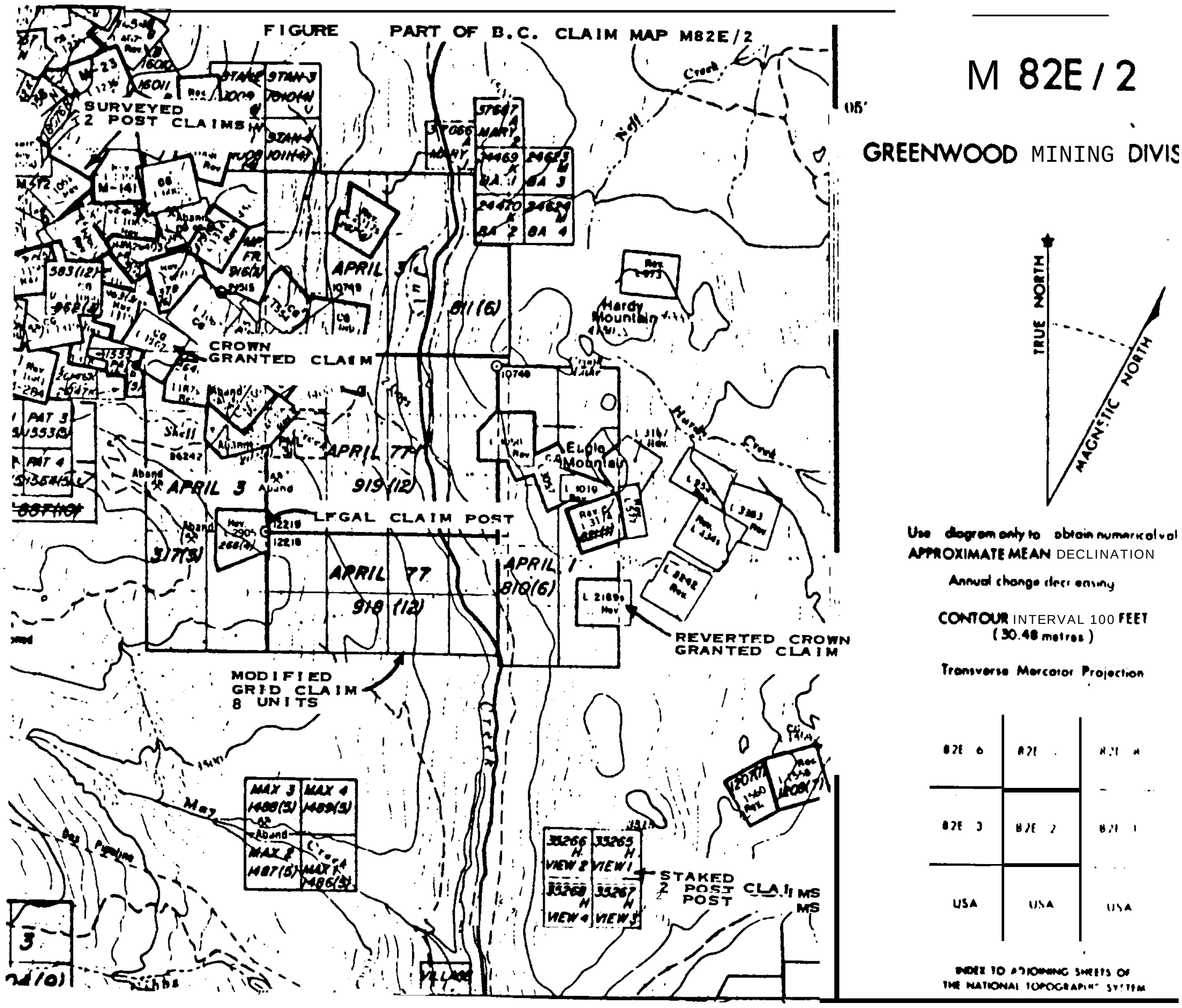


Figure 1. Part of British Columbia Mineral Claim Map 82 E/2 illustrating several types of mineral claims as staked in British Columbia. Separate maps are used to show location of placer claims.

EXPLORATION METHODS

This section will summarize some of the basic exploration techniques from property acquisition through to selection of drill targets and ore definition. Discussion will include some of the pitfalls as well as the positive features of exploration as they affect the investor. In general, considerable caution is required in evaluating exploration results.

1.0 LAND ACQUISITION

Mineral rights may be acquired by an individual or company by either staking mineral claims, acquiring exploration leases, or acquiring mineral rights already held by others through purchase, lease or option, and joint venture. There are three basic types of mineral lands with various degrees of title and maintenance requirements.

i) Staked Mineral Claim (Unpatented Mineral Claims in the U.S.-BLM Land)
- requires exploration assessment work to be filed annually
- surface or other rights may be acquired by taking the claims to mineral or mining lease

ii) Crown-granted or Patented Claims
- granted during 1800s and early 1900s to prospectors and companies
- includes mineral and surface rights subject to small annual land tax
- no assessment work requirement

iii) Deeded Surface Rights with Mineral Rights
- granted pre-1900s to early homesteaders and subject to annual land tax to crown or state
- complex ownership problems are common (subdivided surface, mineral and water rights)

iv)- Government Exploration Lease or Permit

Acquisition of mineral land through lease, option and joint venture requires careful negotiation by all concerned and is one of the major problem areas of getting good properties properly explored and developed with a fair distribution of profits to all parties. Any mineral property is only as good as the underlying agreement.

There are two basic types of carried or royalty positions on the option of metallic mining properties; the Net Smelter Return (NSR) or Gross Value Royalty and Net Profits or Net Proceeds Of Production Royalty. Simply the Net Smelter Return means a share of the amount paid by the smelter after charges and penalties for treatment and refining are deducted and less transportation and other charges after the ore has left the property. A Net Profits Royalty results in a percentage share of Gross Income less all operating expenses, including recovery of capital and preproduction expenditures and interest on these expenditures, and hence Net Profits or Net Proceeds of Production.

A Net Smelter Return agreement requires payment of the royalty regardless of whether the property produces at a profit. This puts a tremendous burden on the parties that provided capital and expertise and deters development of properties, particularity those that are large tonnage-low grade types or have a marginal return. Alternatively, the Net Profits agreements are based on the concept that all parties will share in the profits after the initial investment and operating expenses are " recovered. Some royalties have a "cap" in that after a predetermined amount of royalty has been paid all further rights to a royalty end. This may be attractive particularity if there is a period during the early stage of production wherein the operator has access to 100% of the cash flow or Gross Income to recover capital investment costs.

A third type of agreement is the joint venture wherein exploration and development costs are shared by two or more participants. Various earn-in arrangements are possible with respect to establishment of a joint venture that is initiated by an option agreement. Once all parties are vested, share of profits is usually proportional to share of expenditures. In some instances one or more of the joint venture partners may also have a carried interest on all or part of the joint venture properties. Joint ventures are attractive in that the risk involved in exploration and development is reduced in that projection and allows diversification of risk by participation in many projects.

For a general guide to mining exploration agreements consult "Mining Exploration Agreements", W. B. Gordon Walker, (1984), Special Volumne 28, The Canadian Institute of Mining and Metallurgy, Montreal, Quebec (82 p.).

The following are some sample definitions.

1.1 NET PROCEEDS OF PRODUCTION

"Net Proceeds of Production" means the gross receipts from the sale of each Participant's proportionate share of the Minerals minus deductions therefrom, to the extent of but not exceeding the amount of those receipts, of the then unrecovered amounts of the following classes of Costs made in the following itemized order:-

(a) Marketing costs;
(b) Distribution costs;
(c) Operating costs;
(d) Taxes and Royalties;
(e) Interest costs;
(f) Capital costs;
(g) Exploration costs; and
(h) Prior exploration costs;

it being understood that the deductions in respect of the Costs referred to in paragraphs 1.1 (a), (b), (d), and (e) above shall be based on those Costs as recorded by that Participant and the deductions in respect of the Costs referred to in paragraphs 1.1 (c), (f), (g), and (h) and shall be based on that Participant's proportionate share of those Costs as recorded by the Operator.

1.2 NET PROFITS DEFINITION #1

(b) "Net Profits" means, for any period, the excess, if any, of Gross Proceeds for the period over the aggregate **of:**

(i) operating costs for the period;

(ii) operating costs for all previous periods to the extent they have exceeded Gross proceeds from such periods and not previously been deducted in computing (ie. prior losses); and

(iii) such amount of working capital as, in reasonable opinion, is required for the operation of the Claim as a mine; provided that this amount shall be added to the Gross proceeds in calculating the Net profits for the next period.

(iv) all **Preproduction** expenses to the extent that such **Preproduction** Expenses have not been previously deducted in computing Net Profits hereunder;

(d) "Operating Costs" means, for any period, all costs, expenses obligations, liabilities and charges of whatsoever kind or nature incurred or chargeable, directly or indirectly, by the operator, after commencement of production, in connection with the operation of the Claims as a mine during the period,

(e) **"Pre-production** Expenses" shall mean all exploration and development expenditures, and all other costs, **expenses,** obligations and liabilities of whatsoever nature or kind, including those of a capital nature, incurred or chargeable, directly or indirectly by the operator with respect to the exploration and development of the Claims and equipping them for production up to and including the date of commencement of production.

1.3 NET SMELTER RETURNS

(b) "Net Smelter Returns" shall mean the actual proceeds received from any mint, smelter or other purchaser for the sale of bullion, concentrates or ores produced from the leases and sold, after deducting from such proceeds the following charges to the extent that they are not deducted by the purchaser in computing payment:

(i) in the case of the sale of **bullion,** refining charges only,

(ii) in the case of the sale of concentrates, smelting and refining charges, **penalties,** and the cost of transportation of such concentrates from the Leases to any smelter or other purchaser, and

(iii) in the case of ores shipped to a purchaser net smelter return interest could be **5%** of the market value of the metal content of the ores less refining charges for bullion and less charges for smelting, refining and the cost of transportation (from the mill to any smelter or other purchaser) for concentrates:

The impact of a Net Smelter Return clause in a property purchase or option agreement may be better appreciated after examination of the tables provided in the section titled "Mineral Recovery and Economics" which is the subject of lecture #7 in this series.

EXPIRATION TECHNIOUES

2.0 GEOLOGY

Despite being one of the most definitive exploration techniques, involving minimal expenditure, quality geologic mapping commonly is neglected. Quality geologic mapping requires adequate time and skilled geologists. Since geology is an inexact science subject to varied interpretation based on various personal experience and training, different geologists may arrive on quite different interpretations based on what they see. Therefore, remapping is commonly very worthwhile.

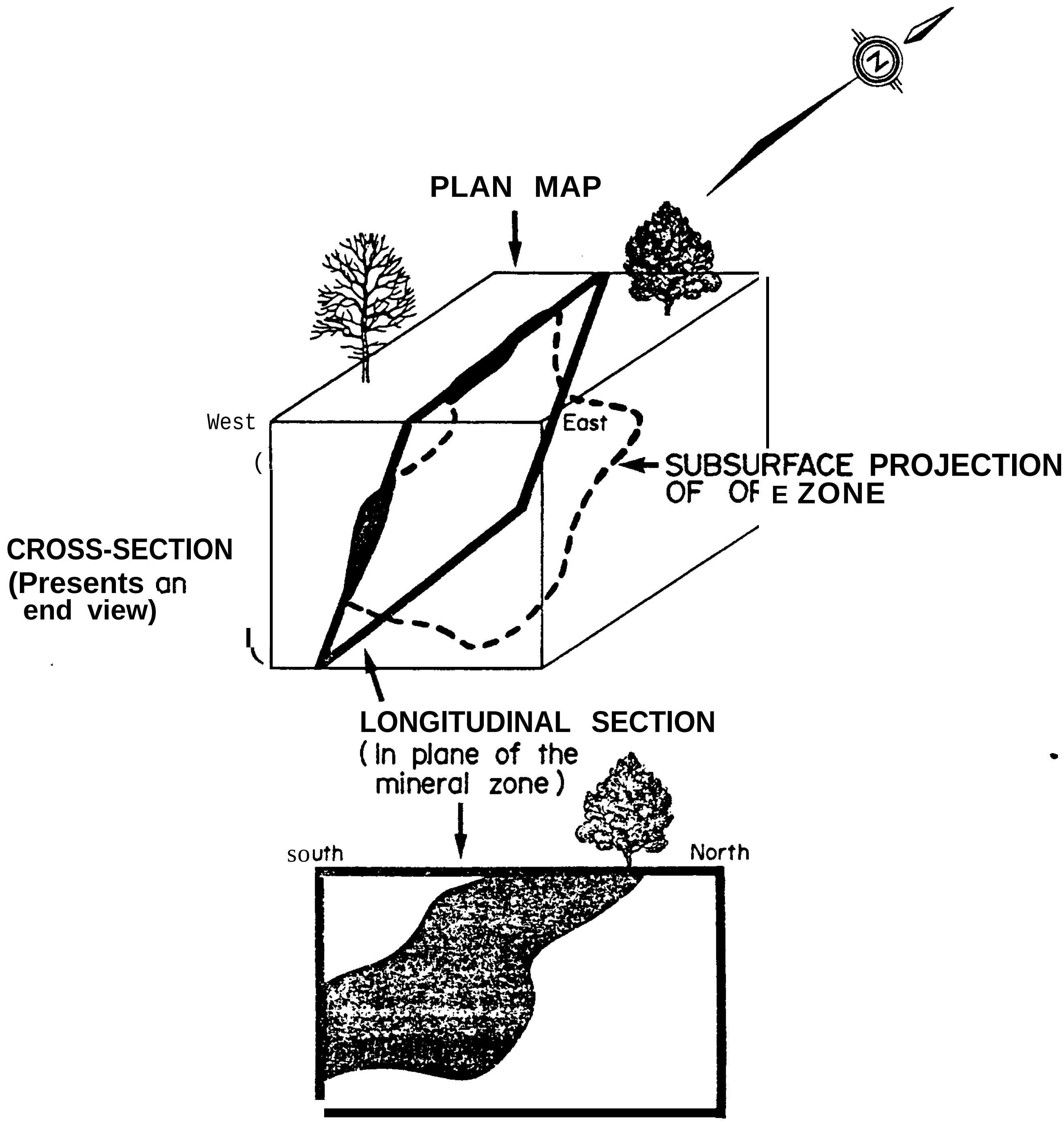
Geologic mapping has two basic components: the recording of basic geologic data such as rock types, alteration, mineralization and structures; and secondly, the compilation and interpretation of this data. Failure in either area may lead to an incomplete geologic evaluation and as more data becomes available a more precise interpretation is possible. As ideas on ore control and ore genesis change; previously evaluated properties may warrant re-evaluation.

2.1 PRESENTATION OF GEOLOGICAL DATA

Presentation of geologic data is commonly done in two forms, plan maps and sections. A key factor in these is the scale and degree of detail being recorded. Maps at a smaller scale (i.e. 1:10,000 is smaller than 1:1,000) tend to be more general and therefore subject to error. When comparisons are being made between mineral properties, it is important to note scale and understand the potential for continuity of the deposit type in question.

Geologic sections are slices through the rocks similar to slices through a loaf of bread. There are two general types; cross-sections which are commonly perpendicular to strike or plunge of the rocks or mineral zone; and longitudinal sections drawn in the plane of the mineral zone or vertically along the long axis of the mineral zone. Figure 2 illustrates the relationship between the various sections. Cross sections and

Figure .2. Schematic block diagram showing plan, cross-section and longitudinal section.



longitudinal sections are extremely important in showing the relationship of drill hole intercepts with underground or surface areas and are commonly used to show projections or continuations of mineral zones, Structures, favorable rock types, etc. Clearly such projections can involve considerable extrapolation of data and therefore are subject to misuse and error.

202 COMPILATION AND INTERPRETATION OF GEOLOGIC DATA

Evaluation of continuity of mineralization is a very difficult task for the professional geologist and therefore investors must use extreme caution and seek professional assistance when faced with making such decisions. Each mineral deposit has its own features as to size, grade, structural or stratigraphic control, favorable host rocks, sharp versus gradational boundary to mineralization, etc.

Using the mineral deposit model presented by Carter, and numerous examples, we can make some general statements as to size, probable continuity of mineral deposits, and potential for multiple deposits in the three main rock environments; sedimentary, volcanic and plutonic rocks. Furthermore, the effects of geological features such as stratigraphy, structure and lithologic association can be observed controlling ore distribution. Table 1 is a gross generalization of these features and additional guidelines can be obtained by comparison with the local mineral district or similar districts elsewhere.

2.3 DEPOSITS IN SEDIMENTARY ROCKS

Stratabound Deposits -

These deposits are formed on the seafloor (Figure 3) and therefore are conformable with stratigraphy and generally have good lateral continuity and large size. The Sullivan Pb-Zn mine in southeast B.C. is a good example (Figure 4) with lateral dimensions of 2000 m x 1600 m. Vertical continuity is limited to thickness of the lense within the strata and is dependent upon

TABLE 1.

GENERAL DEPOSIT TYPES AND PROBABLE CONTINUITY OF MINERALIZATION

DEPOSIT TYPE	LATERAL CONTINUITY	VERTICAL CONTINUITY	MULTIPLE DEPOSITS
Deposits in sedimentary rocks			
- **vein/replacement**	low-mod	**low-mod**	mod-high
- **stratabound**	mod-high*	**low***	low-mod
Deposits in volcanic rocks			
vein/replacement	mod-high	**mod-high**	mod-high
- **stratabound**	moderate*	low-mod*	moderate
Deposits in **plutonic** rock			
vein/replacement	moderate	mod-high	mod-high

*dependent on dip **of** the rock layers - continuity is better within the strata than above or **below** strata

Figure 3. Schematic model for exhalative massive **sulphide** deposits in sedimentary rocks.

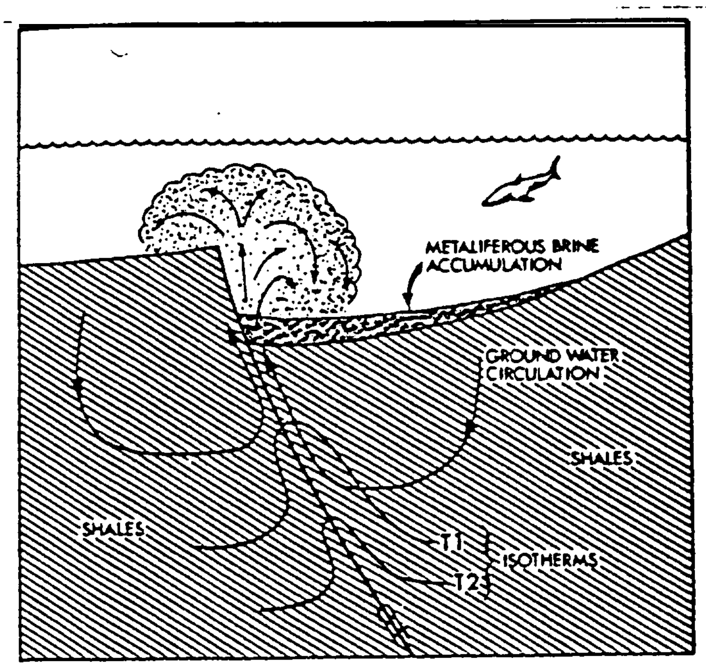
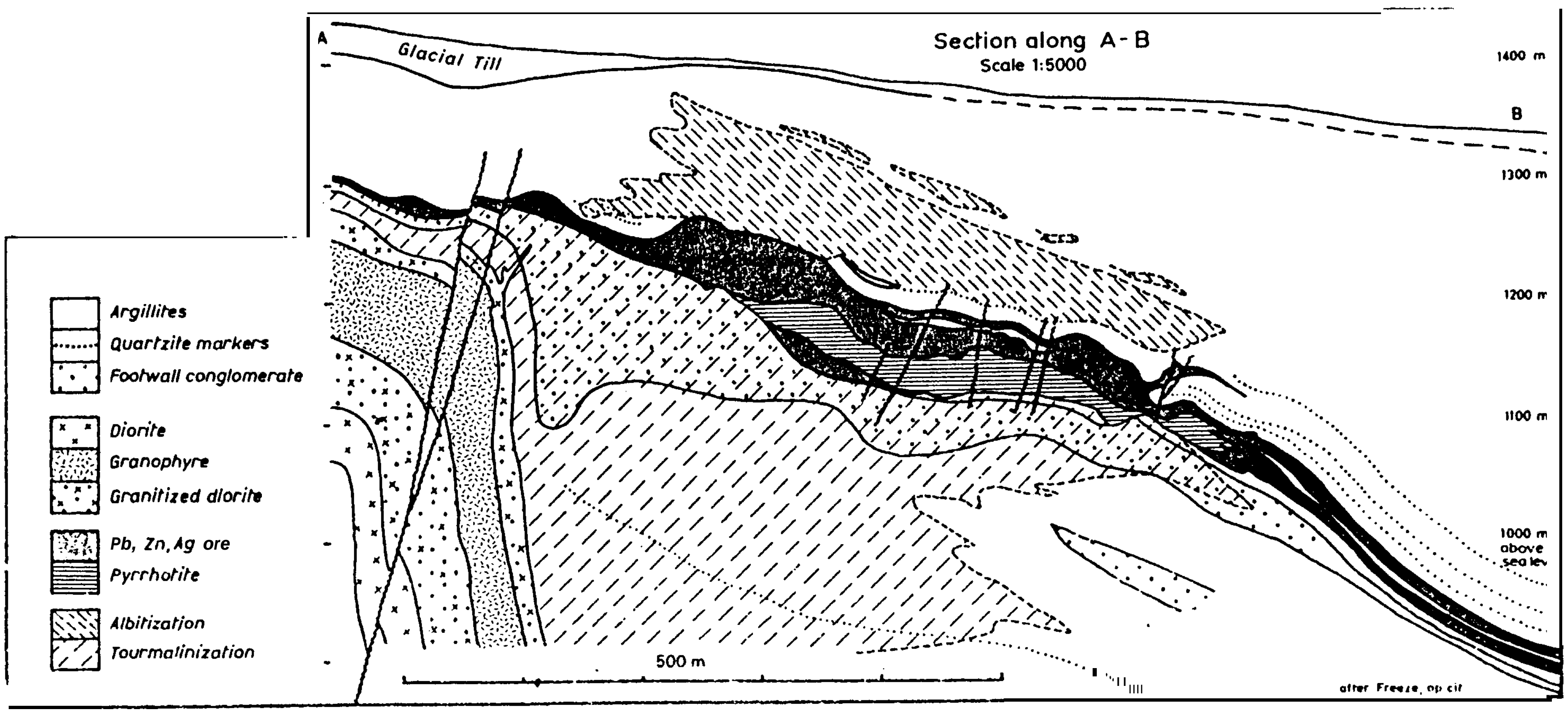


Figure 3.8. **Genetic model for formation of barite-sulphide deposits of the Gataga district.**

Figure 4. Cross-section through the Sullivan sedimentary exhalative massive sulphide deposit, southeast B.C.



dip. Multiple lenses are possible such as in the Anvil District, Yukon Territory.

Vein-Replacement Deposits -

A review of the Carlin District, Nevada, shows continuity of mineralization and multiplicity of deposits at both the regional and deposit scale. Figure 5 shows at least 11 deposits in the district that range from small to very large with total production and reserves of in excess of 21 million ounces of gold. This type of deposit and geologic environment is therefore very significant and of interest to the explorationist and investor. Figure 6 shows that the Carlin deposit has good lateral continuity within the strata, whereas the Cortez deposit is more equidimensional and less conformable to the strata; note the different scales.

2.4 DEPOSITS IN VOLCANIC ROCKS

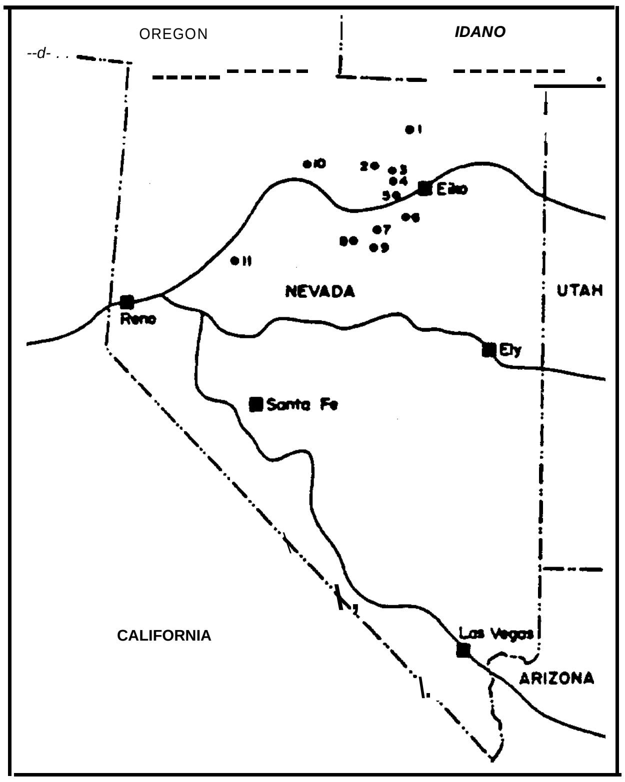
Stratabound Deposits -

These deposits are formed on the seafloor and are conformable with the volcanic and sedimentary host strata. Two major deposit types occur within this group reflecting different lithologic or host rock environments (Figure 7). Kuroko or Noranda type deposits associated with increased abundance of rhyolitic volcanic rocks are characterized by moderate to high Pb, Zn, Au and Ag contents in comparison to the Cyprus type deposits that are within predominantly mafic volcanic sequences and are copper-rich with variable Au and Co, and low Zn, Pb and Ag contents. The Kuroko deposits of Japan, Western Mines, Flin Flon, Noranda and Buchans districts are examples of the former where as the deposits of Cyprus, the Turner-Albright, Granduc and Windy-Craggy deposits are examples of the latter.

The Kuroko type deposit are characterized by a multiplicity of deposits as exhibited in Figure 8 that range from a few hundred thousand tons to several tens of million tons. They are high

FIGURE 5

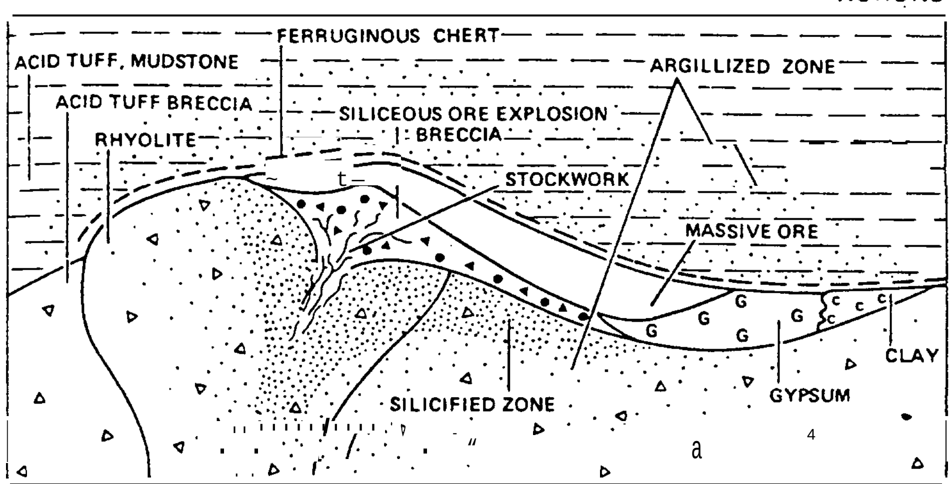
GOLD PRODUCTION AND RESERVES IN THE CARLIN DISTRICT , NEVADA



		Au 000's of oz.	
		PRODUCTION	RESERVES
1)	JERRITT CANYON	7 3 4	1,706
2)	DEE	6	330
3)	GENESIS		5,000
4)	CARLIN	3,577	658
5)	MAGGIE-GOLD OUARRY	184	7,295
6)	RAIN		686
7)	HORSE CANYON		
8)	GOLD ACRES	1,116	201
9)	CORTEZ		
10)	PINSON (PREBLE)	242	484
11)	RELIEF CANYON	1	272
	TOTAL	5,860	16,712

PRODUCTION ANO RESERVES TO DECEMBER 1984

KUROKO



CYPRUS

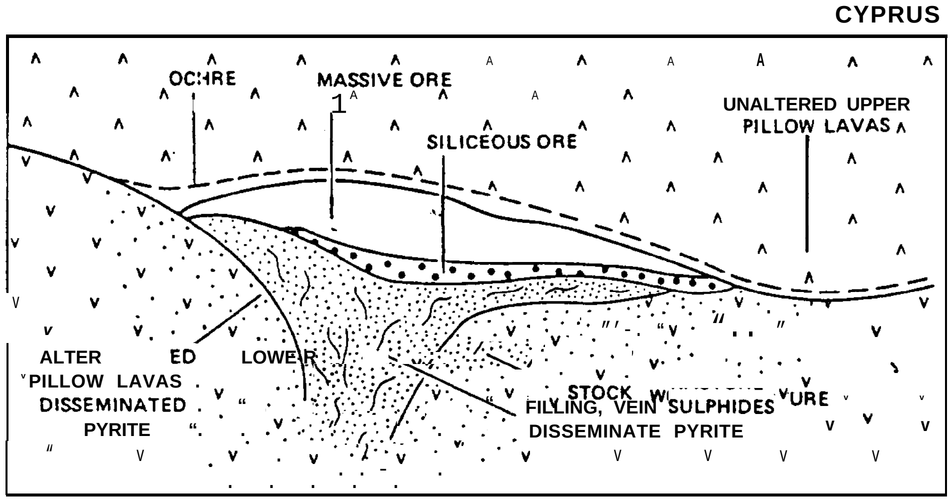


Fig. 7 Schematic diagram showing geological relations of major types of massive sulphides.

Figure *6.* Carlin and Cortez bulk-tonnage replacement gold deposits showing differing geometry of vertical and lateral continuity. (Boyle 1979).

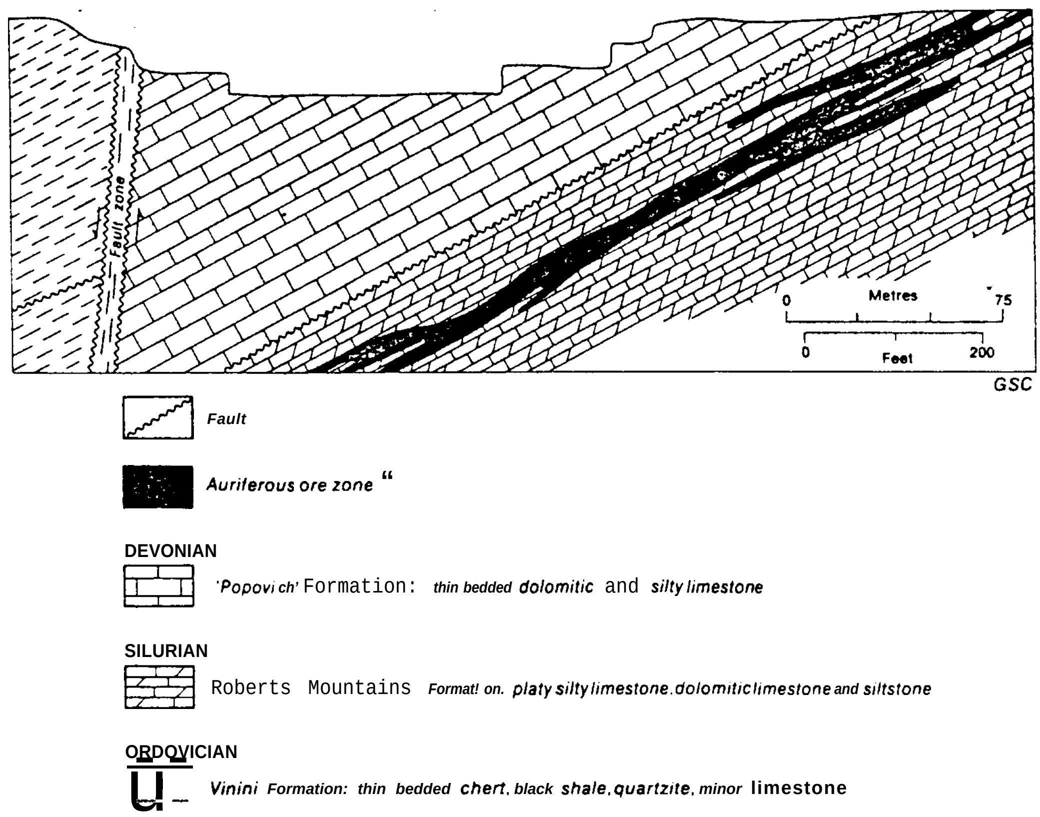


Figure 59. Cross-section of Carlin orebody. Marlin. Nevada (after Hausen and Kerr, 1968)

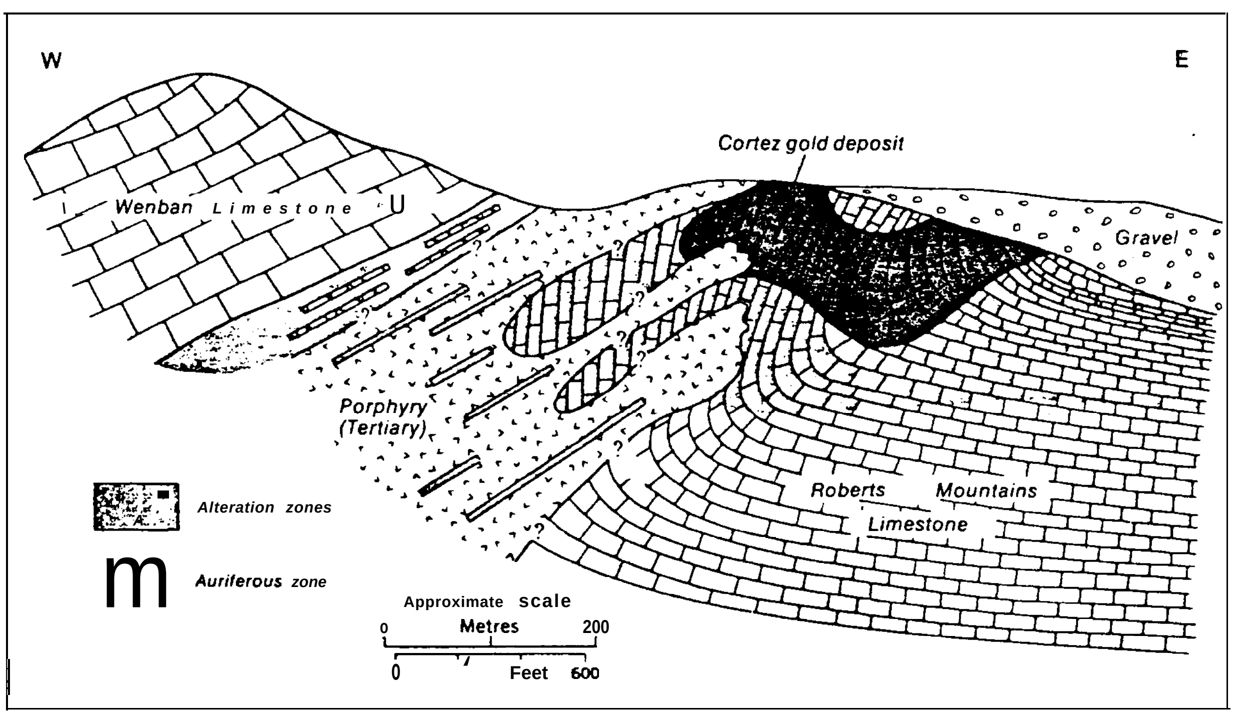
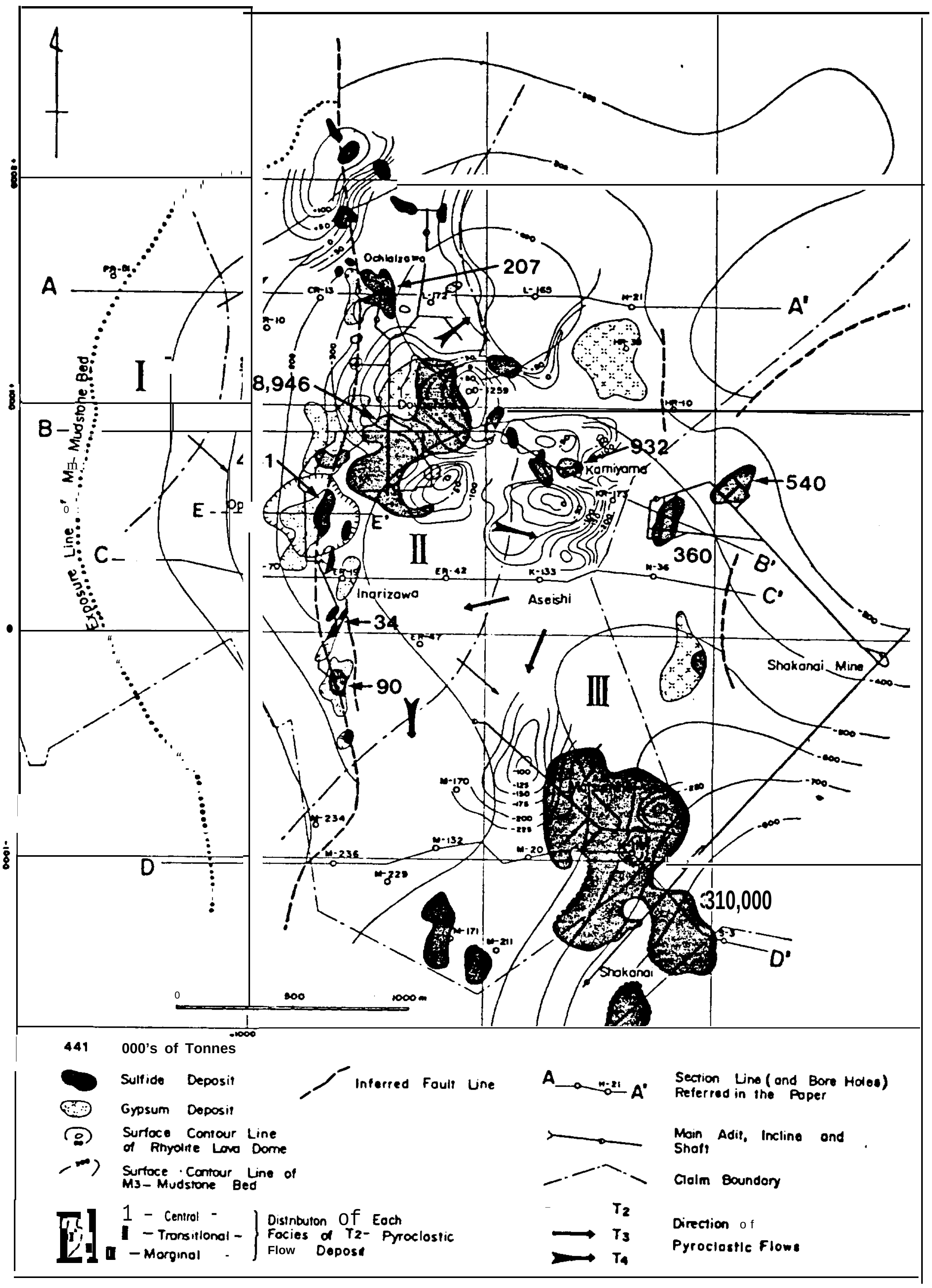


Figure 58. **Idealized cross-section through the Cortez gold deposit from west to east showing rock units, gold deposit, alteration zones (the lower extent of which is *unknown)* and overlying gravels (after Wells *et al.,* 1969).**

Figure 8. Hanaoka Kuroko Belt Japan with distribution of volcanogenic massive sulphide deposits.



grade and attractive exploration targets. Lateral continuity within the strata, for individual ore lenses, can be small to moderate. The Cyprus type deposits tend to have better lateral continuity and form large deposits; however they have lower unit value and are generally less attractive.

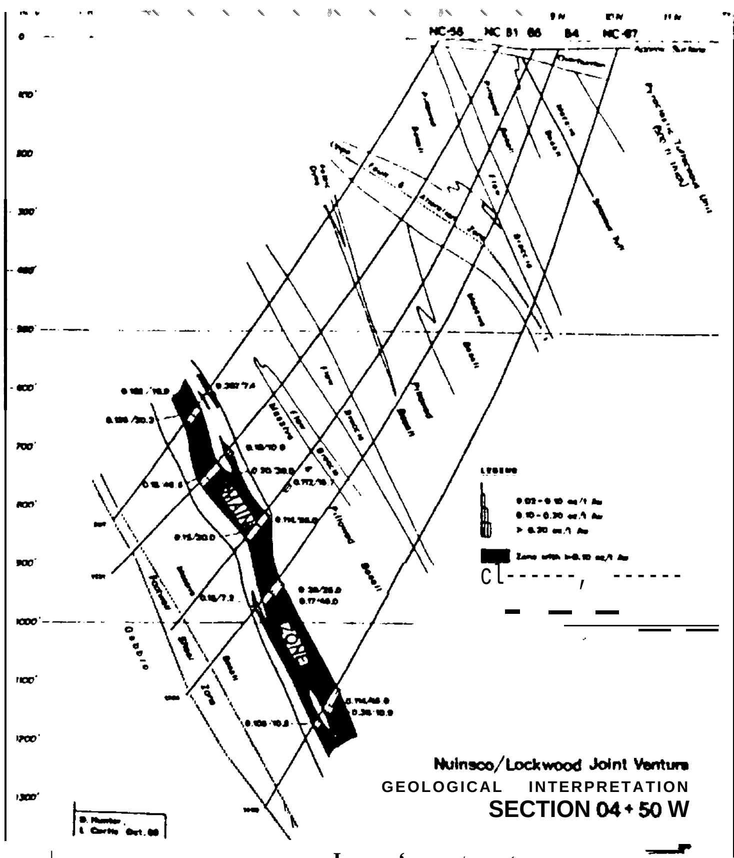
Another example of a stratabound deposit in volcanic rocks is the Cameron Lake deposit, northwestern Ontario. Figure 9 shows a cross-section and longitudinal section of the stratabound gold deposit. The longitudinal section constructed in the plane of the mineralized horizon is particularly instructive in illustrating the distribution of grade of mineralization by using a grade x thickness factor. For example 2 feet at 1 oz/T Au gives a factor of 2.0; similarity 10 feet at 0.20 oz/T Au gives a factor of 2.0. This factor is useful since a general rule of thumb for evaluating whether mineralization is mineable underground is a factor of 2 to 3. The contours of the grade x thickness factor illustrates the pod-like distribution and plunge of the higher grade mineralization. Reserves shown are 900,000 tons grading 0.20 oz/T Au to the 1100 foot level.

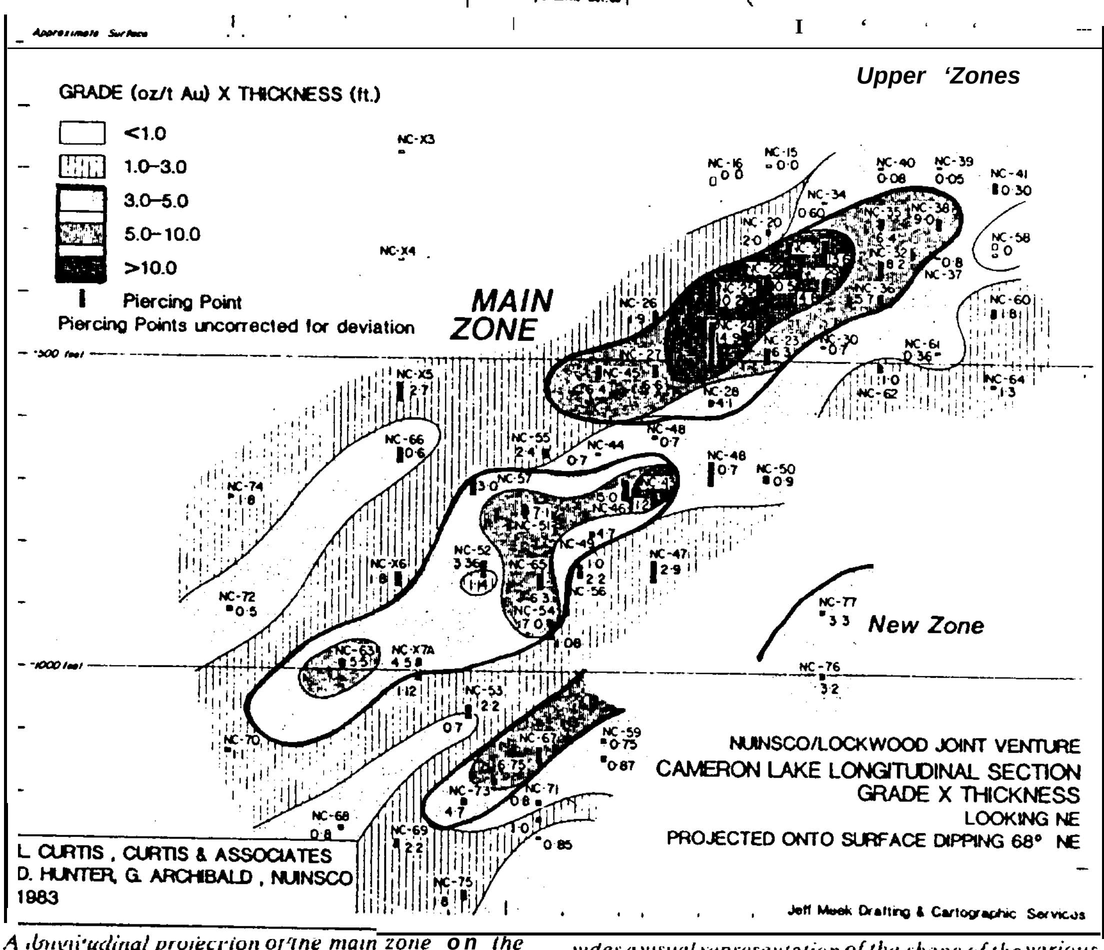
Vein-Stockwork Deposits -

Lateral and vertical continuity of these deposits varies considerably within volcanic rocks. Figure 10 showing the 425 Level in the Hollinger Mine, Timmins District, Ontario is typical of the large Archean greenstone gold deposits. There are many veins that give the deposit large lateral and vertical continuity? however individual veins have lesser continuity. This is typical of many other large greenstone-hosted gold deposits such as Bralorne (B.C.) and Motherlode (California) districts in younger rocks.

Another example is the Madsen Red Lake mine in northwestern Ontario. The plan and cross-section (Figure 11) shows the en-echelon distribution of the mineralized shoots with a short horizontal length and large vertical range of ore shoots. The

Figure 9. Cross-section and longitudinal section of the Cameron Lake Deposit, northwestern Ontario.





A longitudinal projection of the main zone on the Lockwood Petroleum and Nuinsco Resources project near Cameron Lake. The section is contoured with respect to grade (oz./ton) multiplied by thickness (ft.), giving it a "grade-thickness value." For example, hole 76 cut 16 ft. grading 0.2 oz., giving it a grade-thickness value of 3.2. This method of illustrating a deposit provides a visual representation of the shape of the various mineralized shoots within the plane of projection. An industry rule of thumb is that under normal conditions, a grade-thickness of at least 3.0 is needed for an ore shoot to be economic. The entire Shoal Lake deposit under development nearby (Cons. Professor and Union Carbide) has an average grade thickness of 2.92.

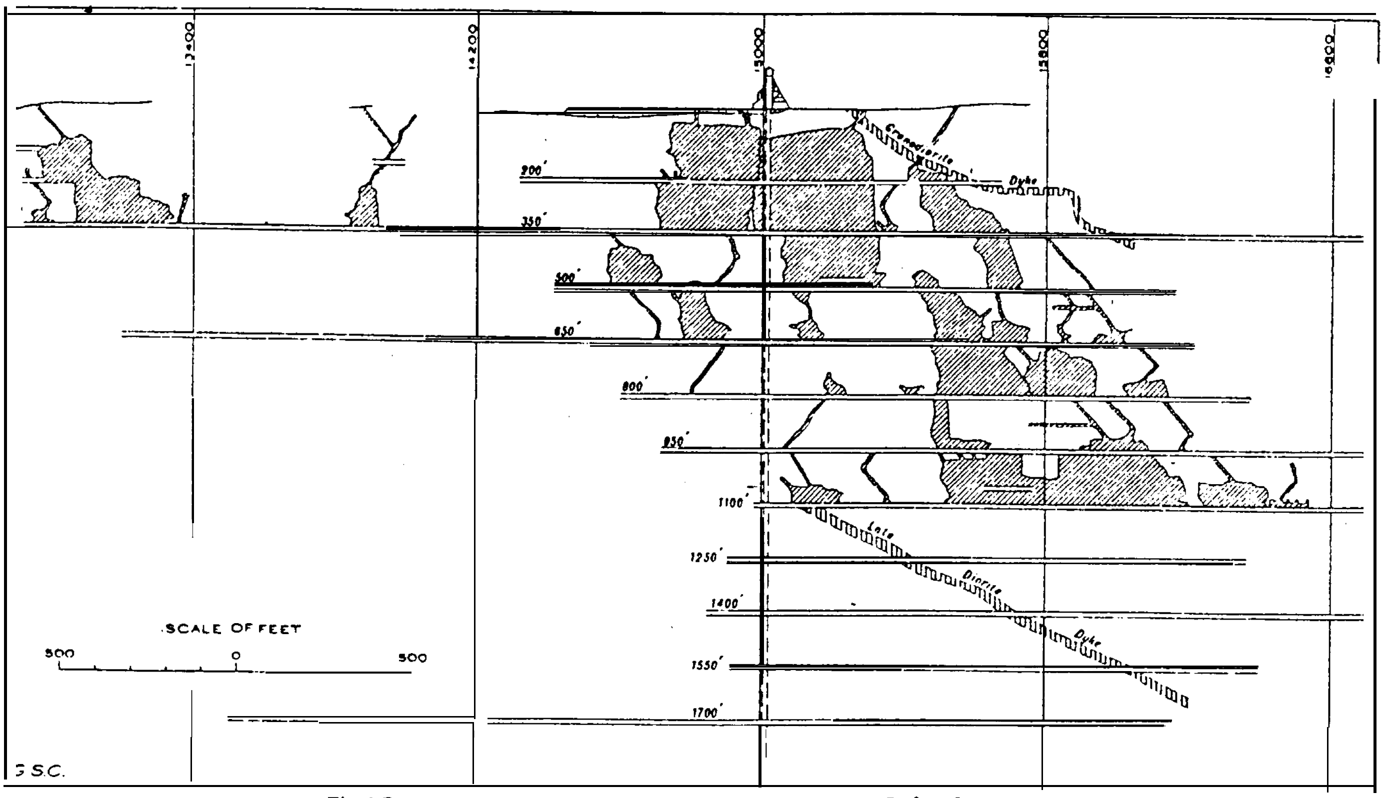


Fig. 12 Longitudinal section in plane of ore zone, Madsen Red Lake mine.

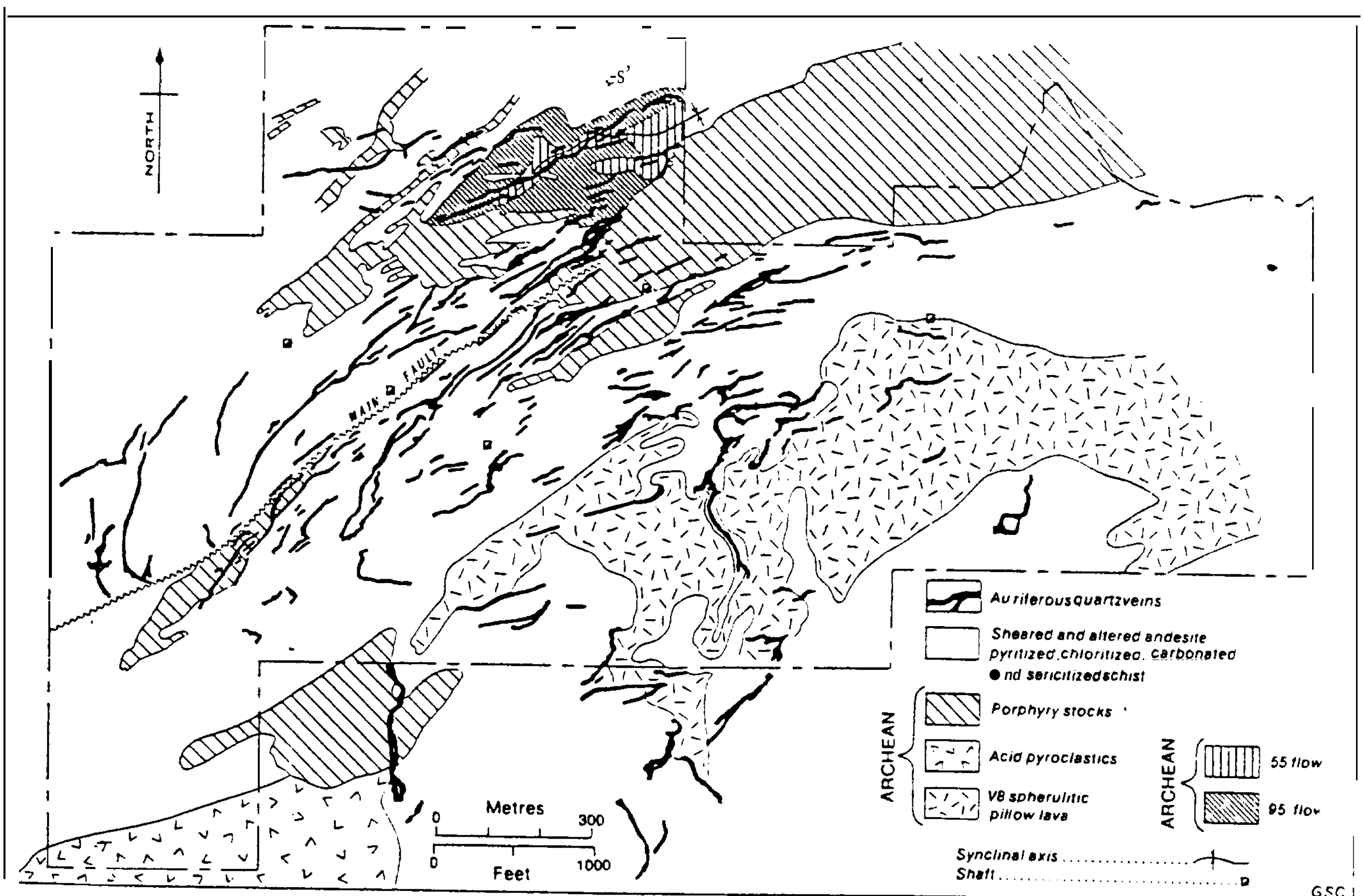


Figure 10 Plan of 425-foot level, Hollinger Mine, Timmins, Ontario, showing complex vein systems (after Jones, 1948a).

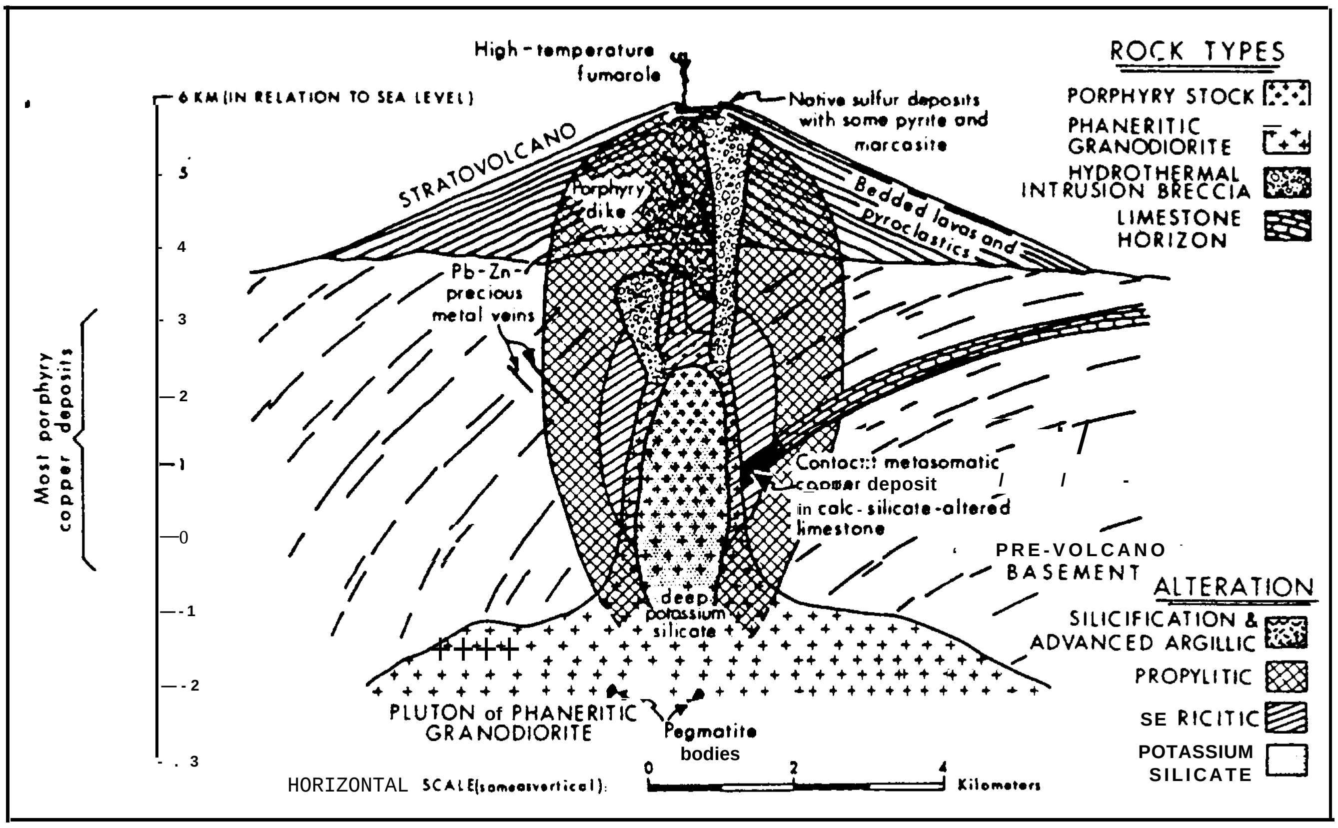
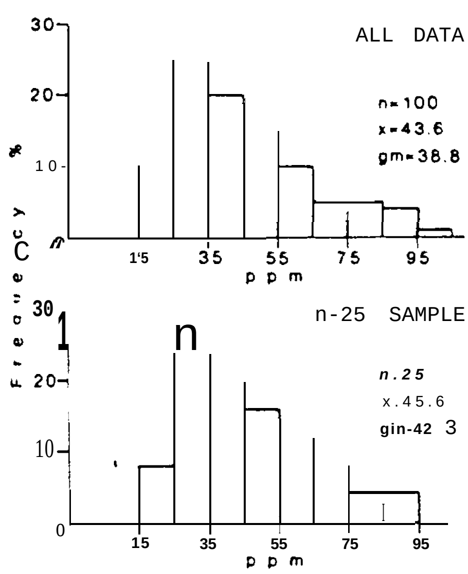


FIGURE 13 - Idealized cross section of a typical, simple Andean porphyry copper deposit showing its position at the boundary between plutonic and volcanic environments. Vertical and horizontal dimensions are meant to be only approximate {modified after Sillitoe (1973], p. 800].

Figure 14. Histogram of geochemical population with arithmetic (x) and geometrical mean (gin) .



mineralized areas/districts or for selection of specific drill targets. A variety of techniques may be used and results commonly are relative rather than absolute and may not correspond well to values obtained by other techniques.

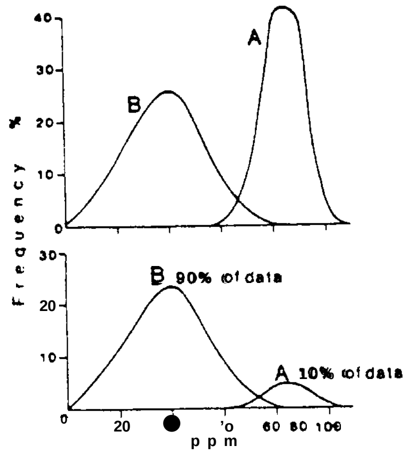
Due to metal zoning during the ore forming process; pathfinder elements, may form a primary dispersion halo around the mineral deposits. For example Hg, As, Sb, Te, F, Se, Cd, Co, Mn, Ba and B may be associated with Cu, Pb, Zn, Au, Ag, W, Mo, U, Ni or other mineralization.

3.1 DEFINITIONS OF ANOMALIES

Concentrations of metals both above and below the background for an area are referred to as anomalies and are the targets for further work. However, not all anomalies are directly related to mineral deposits or their primary dispersion haloes, as some are transported by a variety of processes or result from abnormal accumulations of metal resulting from weathering, etc. There are also no definitive guidelines as to what absolute numbers constitute an anomaly because it is statistically defined and is dependent on variable factors. Figures 14 and 15 illustrate histograms that could reflect possible metal distribution. Figure 14 shows a single population for which an arithmetic mean value (x) can be determined and a standard deviation. Commonly anomalous values are determined as those values that are greater than the mean plus 1 or 2 standard deviations. Figure 15 shows a more realistic histogram of two overlapping populations. Population B may reflect metal abundance in the host rock and population A may reflect a rock type with a higher metal abundance, or mineralization. The overlap can produce a third hybrid population. Cumulative frequency distribution plots can be used to discriminate populations and identify the threshold for anomalous samples related to mineralization.

A general guide to threshold of anomalous values is given in Table 2. Geochemical concentrations generally are given in ppm (parts per million) or ppb (parts per billion).

Figure 15. Histogram of two overlapping populations and cumulative frequency distribution plot for determination of threshold values for the two populations A and B.



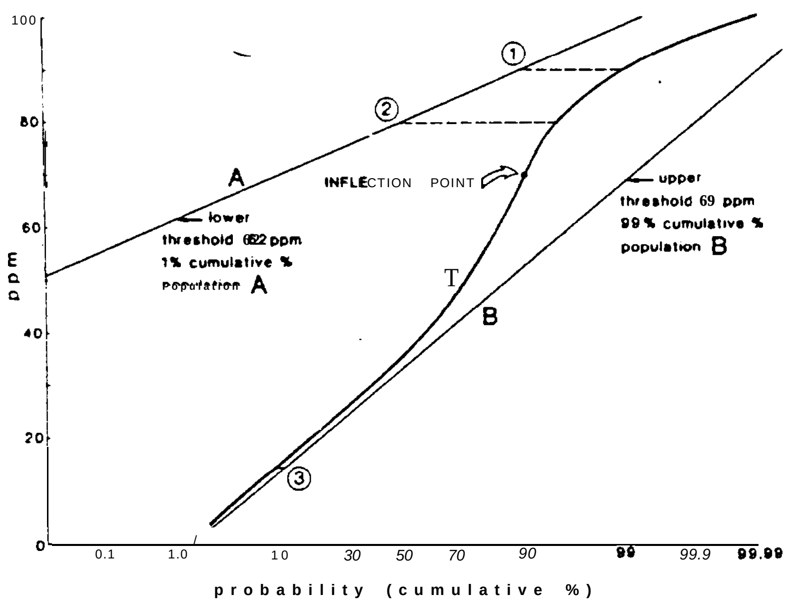


Fig. Cumulative frequency distribution of the 100-sample data set (from Fig. 3-l), and its partition into two component populations AandB.

TABLE 2. RANGE OF THRESHOLD FOR ANOMALOUS VALUES

ELEMENTS	ROCKS in ppm	SOILS in ppm	SILTS in ppm
Au	50 - 100 ppb	40 - 100 ppb	20 - 50
Ag	0.5 - 1.0	0.2 - 0.5	0.2 - 2.5
Cu	100 - 200	50 - 200	100 - 200
Pb	40 - 100	40 - 100	40 - 100
Zn	100 - 500	100 - 300	100 - 300
Mo	5 - 20	2 - 5	2 - 5
W	10 - 50	2 - 10	2 - 10
Ni	100 - 200	100 - 200	100 - 200
As	5 - 10	5 - 20	2 - 5
Sb	5 - 10	5 - 20	2 - 5
Co	10 - 40	5 - 20	
Hg	100 - 500 ppb		50 - 200
Te	2 - 5		
Pt	50 - 100 ppb		
Ba	500 - 10,000	500 - 10,000	500 - 10,000

NOTE : - threshold values for soil assumes sampling of B horizon and will be lower where overburden is thick and extensive and higher in alpine areas or areas with extensive outcrop and little soil development.

values of rocks may be very erratic if intense surface weathering and leaching and reprecipitation of metals has occurred.

values for stream silts are dependent on size fraction analyzed.

Useful conversion factors are:

10,000 ppm = 1%

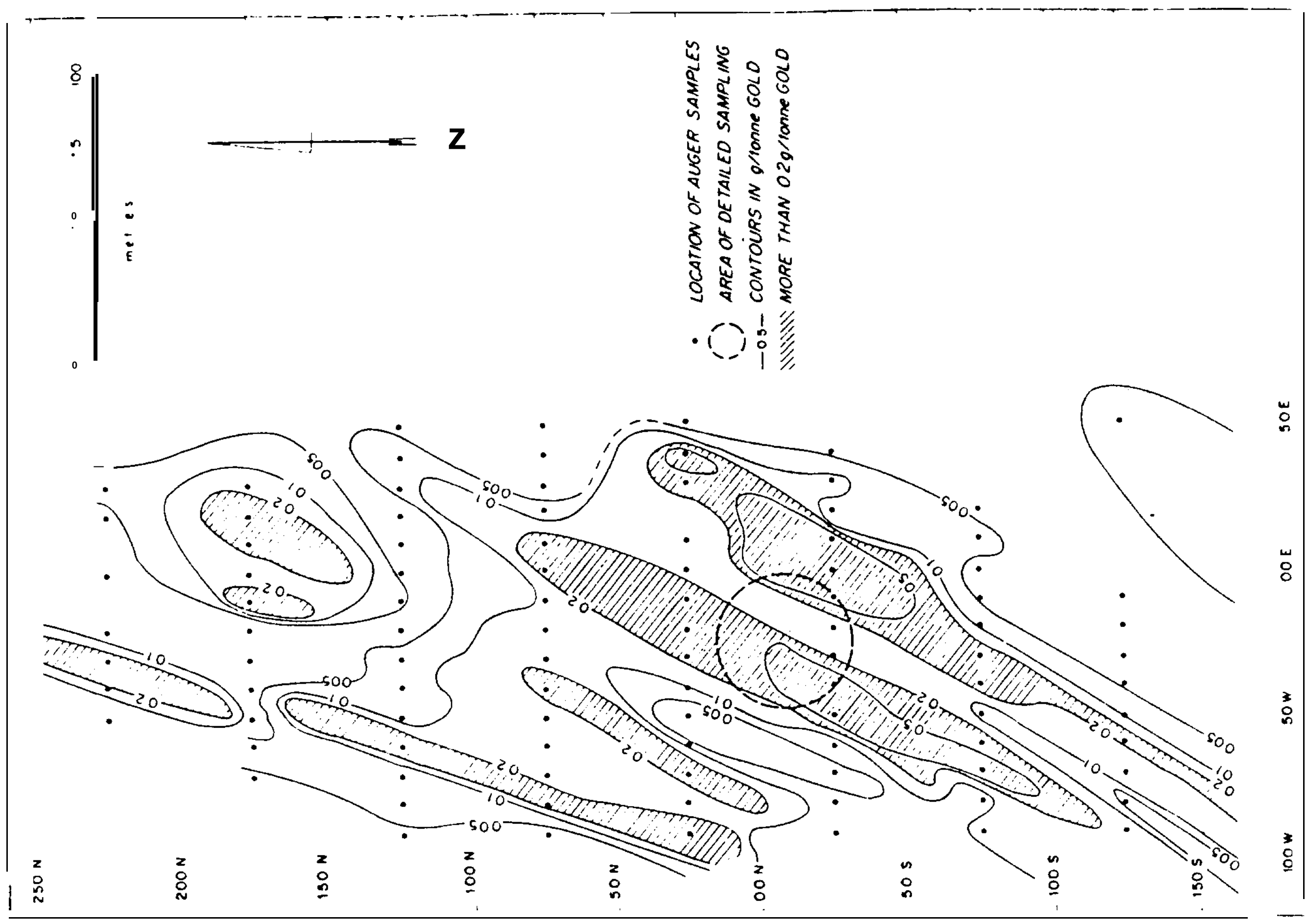
1 ppm = 1,000 ppb = 0.03 oz/short ton = 1 gram/metric tonne

3.2 PRESENTATION OF GEOCHEMICAL DATA

Geochemical data may be presented in plan showing sample sites and metal distribution. Figure 16 shows the results Of sampling of weathered bedrock for Au in g/tonne for a prospect in Fiji. In this environment. the weathering of bedrock may extend 100's of feet deep. Values are contoured 0.05, 0.1, 0.2 and 0.5 g/tonne Au with values greater than 0.20 g/tonne considered anomalous. Note the scale and sample spacing of 10 meters on lines spaced 50 m apart. Soil geochemical results can be shown in the same manner.

Geochemical results can also be shown in *profile section* such as in Figures 17 and 18. The metal content is shown on the ordinate (y-axis) and the distance is on the abscissa (x-axis). The figure showing Pb and Zn distribution in soils shows samples spaced at 25 m intervals and a readily apparent Pb high over the mineralized zone, whereas Zn shows a low directly over the mineralization flanked by higher Zn values. The distribution of Zn and Pb reflect different nobilities of these elements in the geochemical environment with Pb generally being relatively immobile, and Zn being more mobile and therefore transported from the source.

The second figure shows the distribution of numerous elements in rock samples from a porphyry copper deposit. The scale reflects the size of these deposits and the distribution of values shows depletion and enrichment of the elements as a function of the primary metal distribution related to the alteration and mineralization.



g. 16 Distribution of Au in weathered bedrock (auger samples), D‹ ısomo, Vuda. Fiji (from Govett et al., 1980).

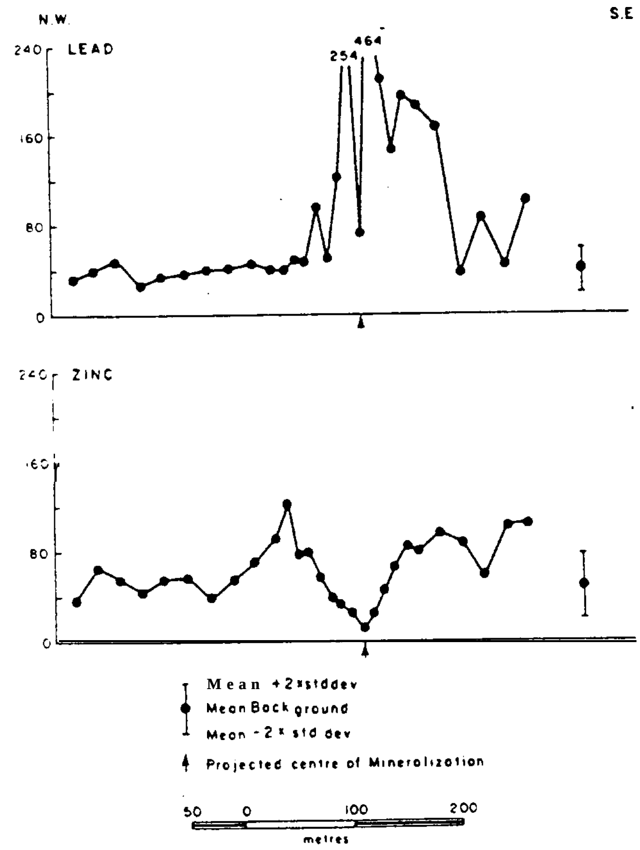


Fig. 17 Distribution of Pb and Zn in B-horizon soils over lead-zinc mineralization

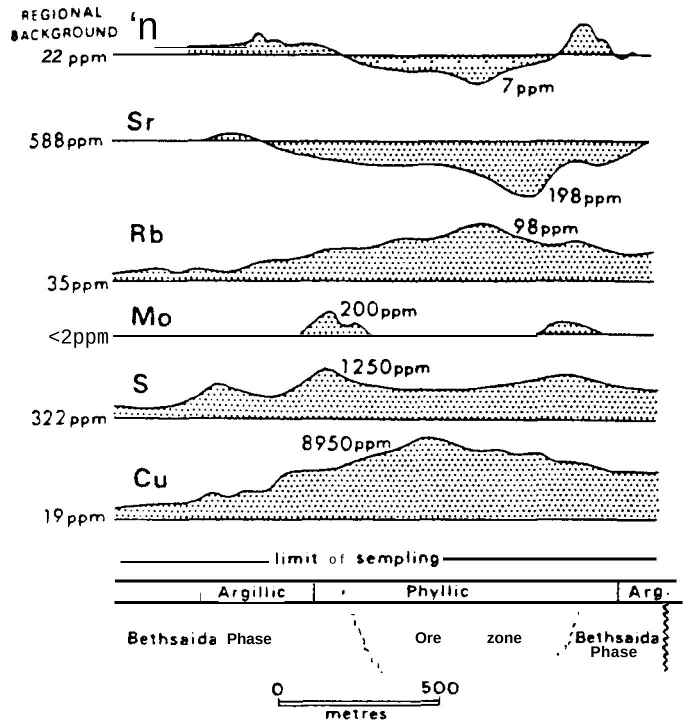


Fig. 18. Schematic illustration of element distribution across the Valley Copper porphyry deposit, British Columbia, Canada. (Redrawn with permission from Olade and, Fletcher, 1976a, Economic Geology, vol. 71, 1976, fig. 9, p. 742.)

3.3 SAMPLING PROCEDURE

i) Stream Sediment Sampling

Sample the fine silt fraction and in some instances the coarser fractions, and analyze for trace elements. Useful for defining larger target areas and is commonly a preliminary exploration survey technique.

Panning of stream sediments to produce a heavy mineral concentrate is also an effective way to explore for W, Au, Ag, Pt and other deposits.

ii) Soil Sampling

Sample the soils for an indication of metal content of underlying rocks. Useful in defining specific targets for trenching or drilling. Concentration of metals in soils is dependent on a variety of interrelated factors:

- Metal concentration in adjacent bedrock (± mineralization).
- Overburden thickness, soil type and distribution.
- Soil horizon sampled.
- Climate, elevation and local vegetation.
- Hydrological factors.

Soil sampling commonly is done on grids with samples at regular intervals. Generally the values are plotted on plan maps for comparison with the geology, geophysics, etc.; however, a graphical presentation for a line or traverse is also useful.

iii) Rock Sampling

It is the most specific of the geochemical methods and is particularly useful in defining small concentrations of metals such as Au, Ag, As, Sb, etc. and recognizing dispersion haloes around mineral deposits. High values may be tested and quantified by normal assay techniques.

4.0 GEOPHYSICS

There are three basic types of geophysical surveys: airborne, ground and down-the-hole surveys. Airborne surveys are best suited for regional exploration and were discussed earlier. Ground surveys are useful as initial or follow-up surveys to define targets on the ground for drill testing. Down-the-hole surveys utilize probes inserted into the hole to test for various geophysical parameters. Use of the latter is relatively new in the mineral exploration industry but has been used extensively in oil and gas exploration. The basic geophysical methods are:

Magnetic: Measuring the magnetic susceptibility of the rocks and utilizing this data for mapping of the subsurface distribution of rock types, alteration zones or mineralization containing the magnetic minerals magnetite and pyrrhotite.

Electromagnetic: Measuring the electrical conductivity of rocks by applying a current to the ground and measuring the response from the rocks. If a highly conductive body (mineral zone) is present in the rocks, it will set up its own current which can be measured. There are numerous different techniques available designed to detect various types of conductors, each with different levels of penetration. In general there are few instruments capable of successfully penetrating below a 400 to 500 foot depth. The method responds to conductive materials such as massive sulphide mineralization, graphite and in some instances fault zones and overburden.

Induced Polarization: These surveys are somewhat similar to the electromagnetic surveys in that they apply an electrical current to the ground and measure the current response in the ground. However, they are designed to test for conductive materials such as sulphide minerals or graphite that are more dispersed or disseminated and therefore not conductive. Two factors are measured, conductivity or chargeability and resistivity.

Resistivity is a measure of the resistance to the flow of an electrical current in a rock and is a function of fracturing, alteration and porosity in the rocks. When these features are intense, resistivity is low and current is easily transported; when the rocks are unaltered and poorly fractured, resistivity is relatively high (measured in ohm-meters). Chargeability is a measure of the electrical surface polarization of metallic minerals which is induced by the electrical currents applied to the ground. It may be measured by time-domain or frequency effect methods.

Self Potential: Is similar to induced polarization surveys in that it measures the inherent electrical conductivity that occurs naturally in the rocks.

Gravity: Measures changes in gravity in the earth and is a less commonly used method to define areas where rocks are more dense due to a large sulphide orebody. Gravity surveys are mainly surface ground surveys.

Radiometric: Measures radioactivity due to radioactive decay of elements such as U, K and Th. Used primarily in the search for uranium ores.

4.1 DEFINITION OF ANOMALIES

Geophysical anomalies require careful interpretation by a geophysicist to determine their magnitude, orientation and cause. Most geophysical anomalies are not directly related to ore deposits; however, combined with geological data and geochemical studies, geophysics can be a useful tool to define areas favorable for mineralization. It is therefore an inexact science, the results of which must be interpreted carefully by professionals. Occasionally, anomalies are found wherein there is no satisfactory explanation of their cause.

An anomalous area is an area that varies considerably, either positive or--negative, from the mean or background level. Mean levels of geophysical response will vary for different rock types and therefore is perhaps most useful in mapping sub-surface geology. Geophysical anomalies have little investment value until the anomalous zone is shown to have significant metal content.

4.2 PRESENTATION OF GEOPHYSICAL DATA

The data may be presented in plan maps or more commonly in sections. The sections correspond to individual survey lines and for electromagnetic and induced polarization provide a profile of the response with depth that allows interpretation of depth features of the anomalies. For electromagnetic surveys several different frequencies are commonly used to provide more information about the conductors. Strong conductors should have a response at both lower and higher frequencies, whereas weaker conductors produce anomalies at higher frequencies due to electromagnetic coupling.

Figure 19 is an example of an airborne electromagnetic (INPUT) survey from the area of the Selbaie Mine in northwestern Quebec. Each circle represents an EM conductor on north-south flight lines spaced approximately 900 feet apart. Weaker conductors are open circles whereas stronger conductors are solid circles. The string of conductors are called formational conductors that probably represent graphitic sedimentary beds that may not be of interest. Of greater significance are the isolated conductors that are the A & B zones of the Selbaie deposit. Figure 20 shows the horizontal loop ground EM survey over the A zone conductor and anomalous EM response on lines 4w, O and 4E that are spaced 400 feet apart. The conductor was tested by drill holes B-1 and B-2 that led to the discovery of the Cu-Zn-Ag massive sulphide deposit.

FIG. 19 Discovery Input with geology (after Remick, 1969); 1-mafic volcanics, 2-acidic volcanics, 3-granite

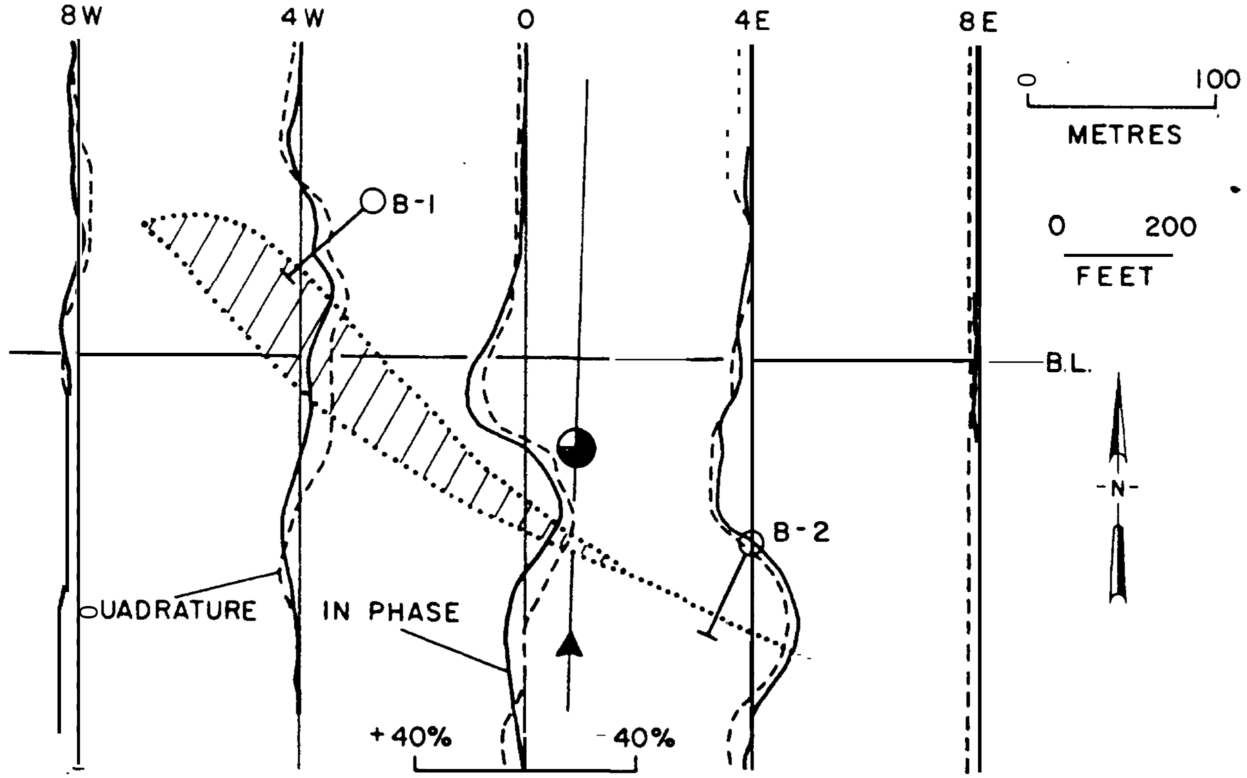


FIG. 20 A zone; HLEM profiles, coil separation 300 ft, frequency 2400 Hz; with discovery Input anomaly and drillholes.

Figure 21 shows both a plan map and profile section of the ground EM and magnetic response of the Thompson nickel deposit in Manitoba. The iron-sulphide mineral pyrrhotite results in a strong EM and magnetic response.

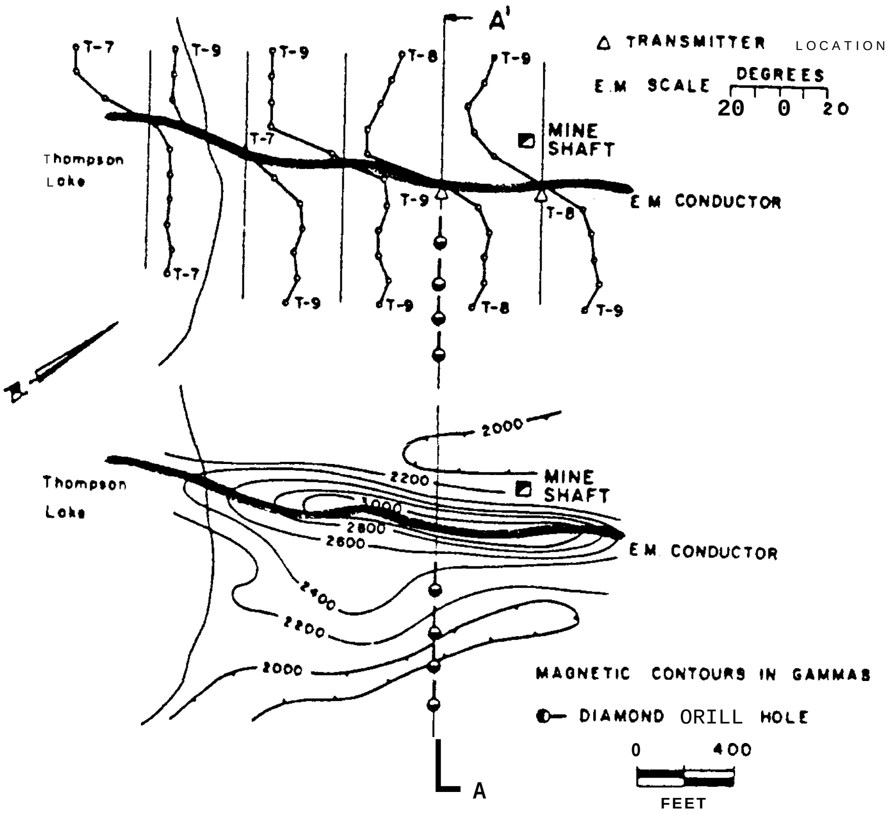


Figure . Section A-A', Thompson mine.

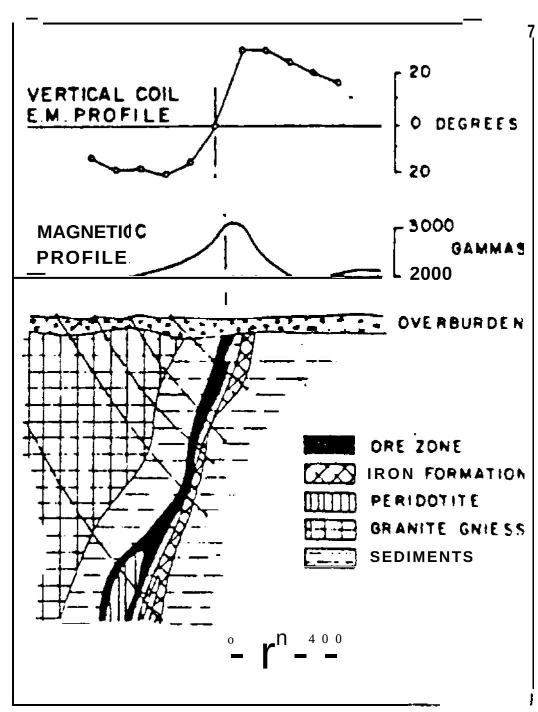
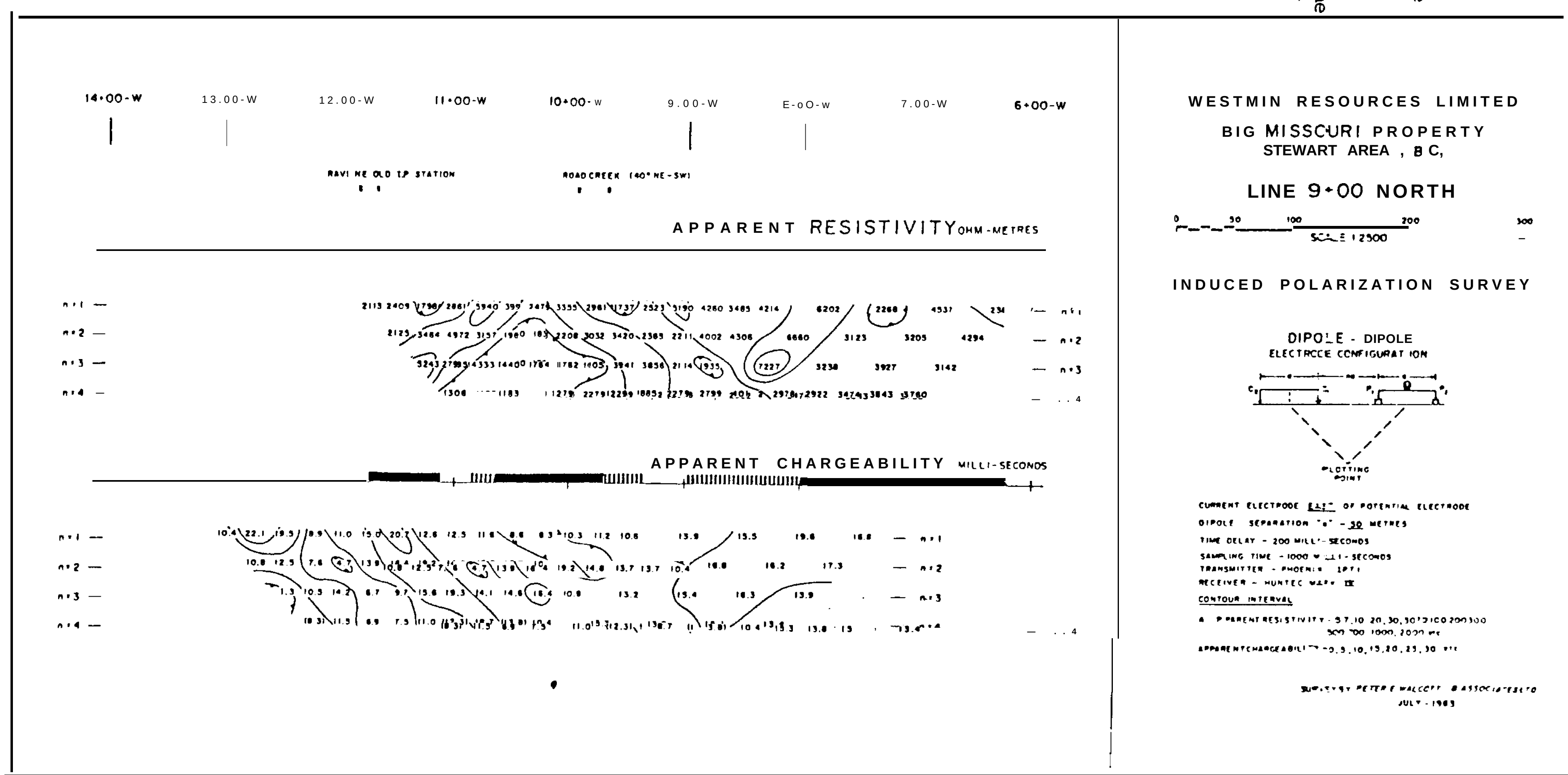


Figure . Ground electromagnetic and magnetic surveys in detail area, Thompson mine.

Figure 21 . shows a section through the Thompson orebody with corresponding ground geophysical profiles. The electromagnetic conductor coincides with the position of the ore zone and is caused by the conductive sulphides of the ore. Pyrrhotite, which is the major constituent of the ore, is both conductive and magnetic, and is also the major cause of the magnetic anomaly,

Figure 22 is a profile section of an induced polarization survey on a line crossing a mineralized zone on the Big Missouri gold-silver property near Stewart, B.C. The chargeability and resistivity response are plotted in profile section with data from increasing depth plotted as the electrode spacing increases from N=l to N=4 (ie. 50 m to 200 m); N=l data is at approximately 25 meters depth whereas N=4 is at approximately 100 meter depth. Modeling of geophysical response assists in the interpretation of the anomalies with the strong chargeability anomaly

Figure 22. Induced polarization pseudosection or profile section showing chargeability and resistivity response of a mineralized zone on the Big Missouri gold-silver property, Stewart, B.C.



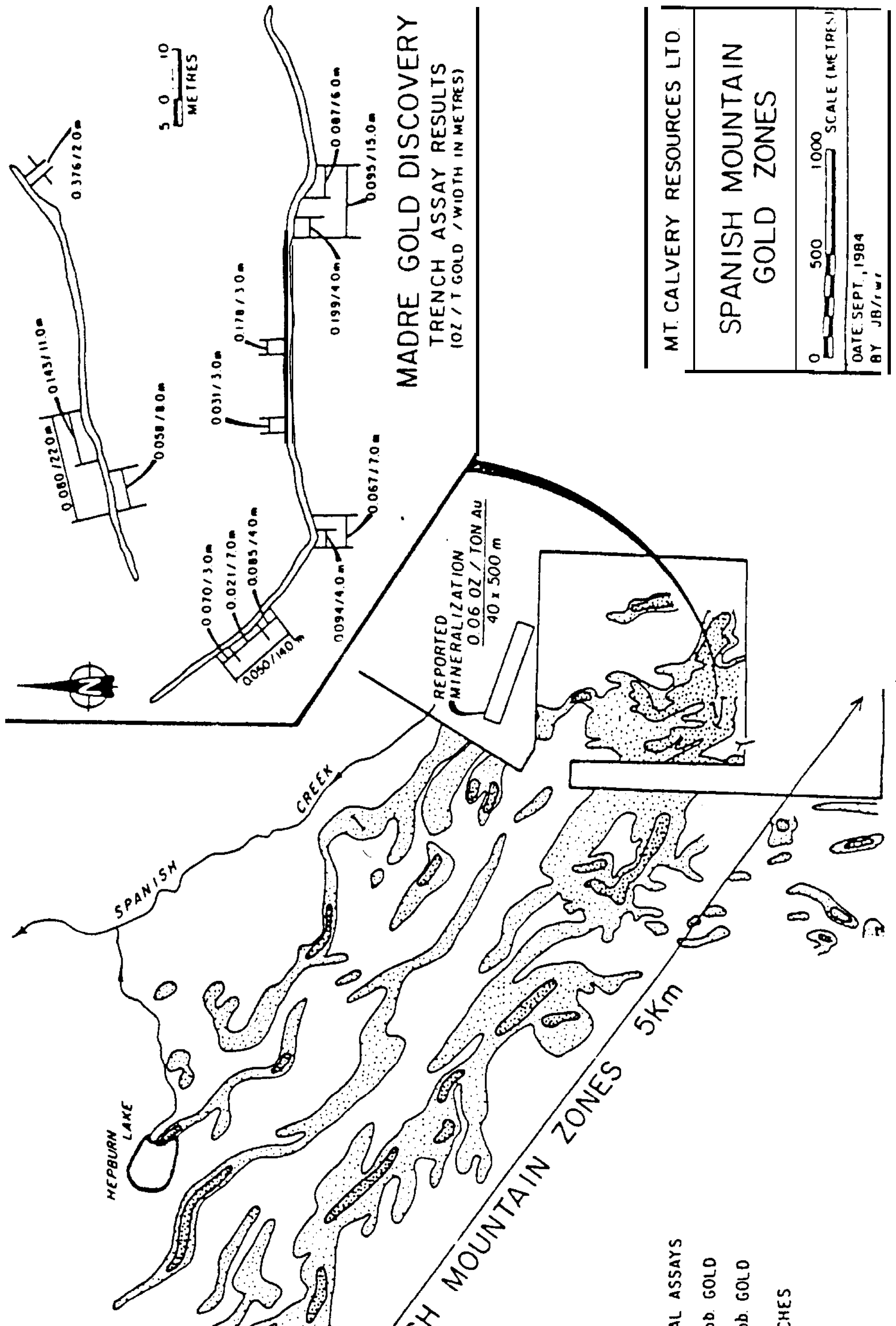
associated with the disseminated sulphide mineralization shown in the solid bar and the weaker anomaly in the broken bar. Using the profile section the 1P data may be compared to geology, geochemistry or other geophysical results and position of drill holes shown. Geophysics is a tool to assist these other techniques and therefore should be presented together.

5.0 PHYSICAL WORK

With todays tractors and backhoes, trenching and stripping is much more easily accomplished than hand work done by early prospectors. It remains a very cost effective method of exploration but is subject to increasing environmental concern. When selectively done, it can provide good information to focus drilling programs into more favorable areas. Combined with drilling and blasting, trenching can provide fresher rock for sampling and thereby avoid the effects of weathering.

Figure 23 from a press release in the George Cross Newsletter is a good example of the effectiveness of trenching and the relationship of mineralization in the trenches to gold soil geochemical anomalies. The map also shows property boundaries and relationship of the mineralized zones trenched relative to mineralization on an adjacent property. In this example, the trenching probably provided geological information as to the

Figure 23. Trenching of gold soil geochemical anomalies in Hepburn Lake area, Cariboo Gold District, B.C.



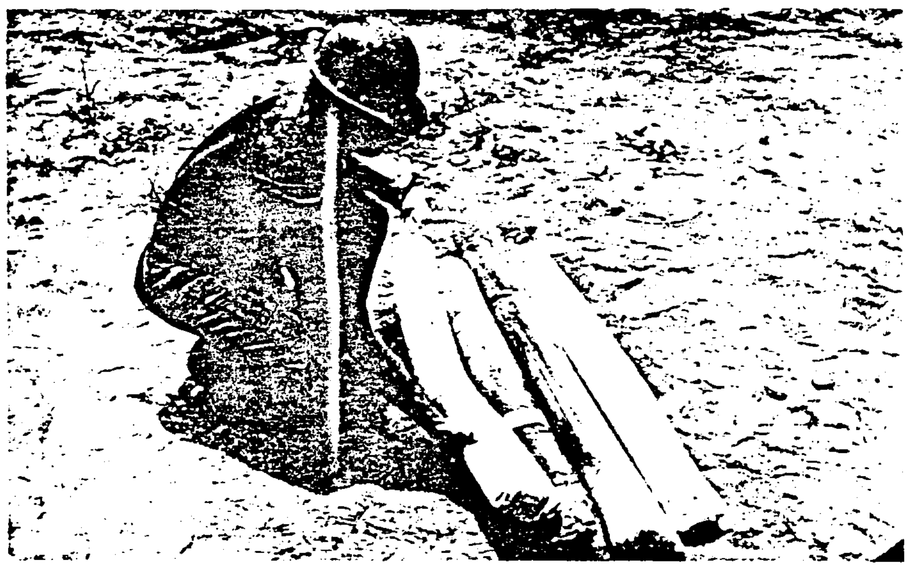
6.0 DRILLING

Two basic types of drills commonly are used in mineral exploration: diamond drills that produce drill core (generally 1" to 4" in diameter) and rotary *or* percussion drills wherein only chips of the rock are recovered. The latter is faster and more economical than diamond drilling but provides less geological information.

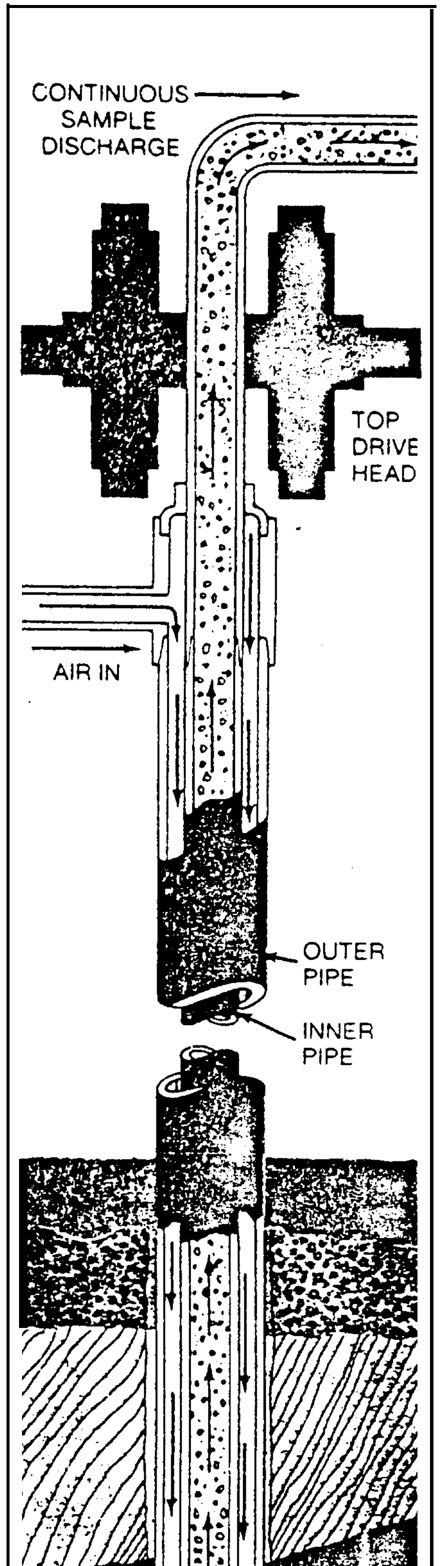
Diamond drilling generally costs from $15 to $30 per foot depending on location, core size, drilling conditions and hole depth. The core is very useful for determining rock types, structure and controls on mineralization and alteration. Analytical testing of core is done by either assay or geochemical analysis. Core is usually halved with one half sent for assay and the other half kept for reference. Core drilling offers the advantage of being able to accurately define the limits of mineralization for sampling. Generally core recovery is good. In faulted ground, however, only broken core or sand may be recovered. Sand and fine material washed up the hole and recovered is referred to as sludge. Assays of sludge material in areas of poor core recovery should be interpreted with caution since the sample is not representative of the rocks -- this is particularity true for precious metal deposits.

Percussion drilling makes use of compressed air to drive a bit through rock and produces sand and rock chips. There are two basic types of percussion drilling; normal and reverse circulation. In normal circulation the drill bit is larger than the drill steel to which it is attached and the drill cuttings return outside the drill steel and therefore are in contact with the wall of the hole. A simple air-track drill used in road construction uses this principle. Figure 24 shows an example of *reverse* circulation wherein dual wall drill rods are used with air forced down the

Figure 24. Reverse Circulation Percussion Drilling Method.



Chips are collected and stored in plastic bags approximately the size of the drill hole diameter, so that samples are arranged in relation to depth formation.



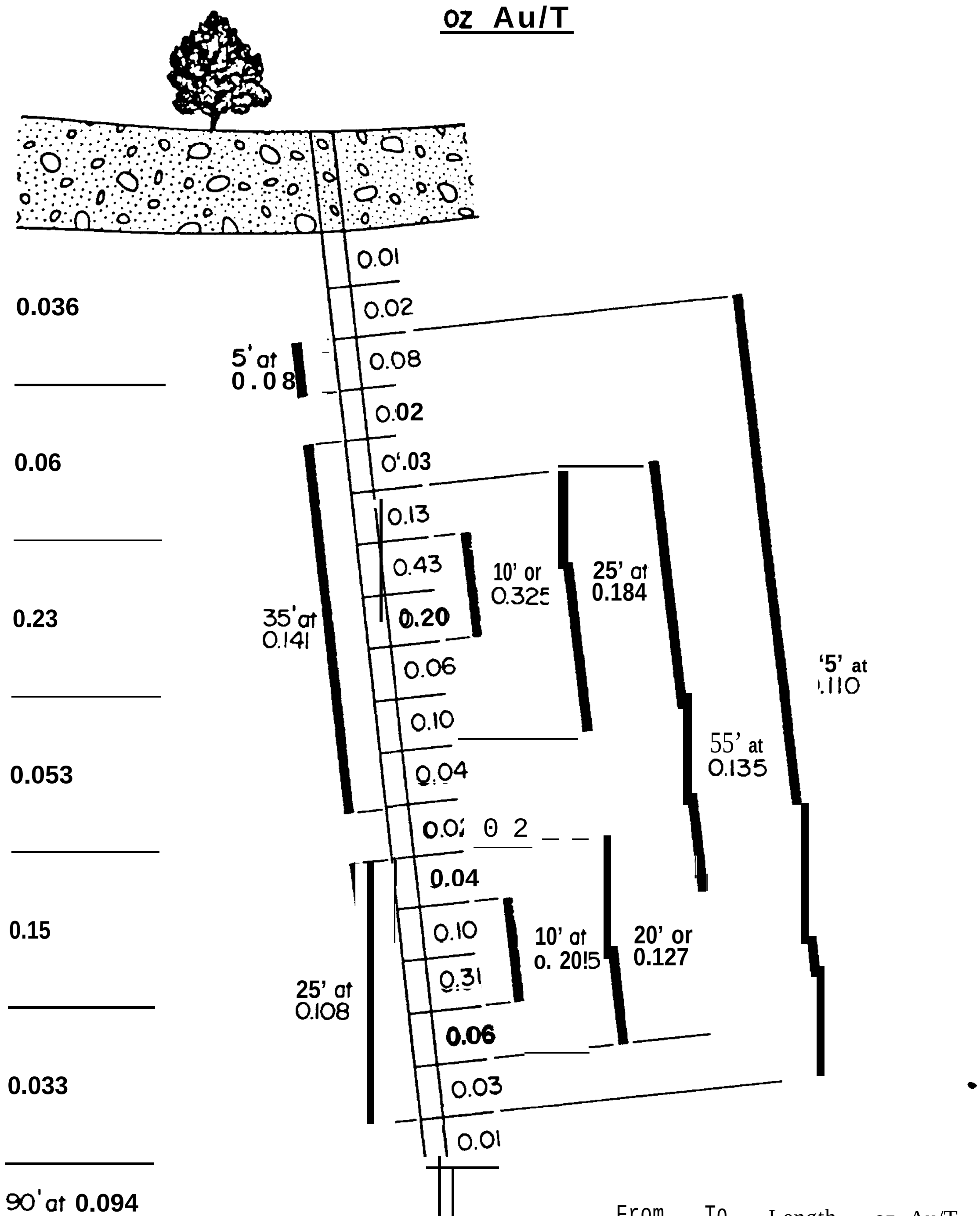
may be sampled, however without the selectivity of core drilling. The coarser fragments may be examined under a microscope and the rock types, ore minerals and alteration recorded as a log. Little structural information is possible. This method is used because of its low cost ($5 to $15/foot), speed of drilling and ability to drill larger diameter holes. It is particularity suited to deposits having disseminated widespread mineralization and works well in semi-arid areas where the water table is low and only air is required to flush the holes.

Recovery in percussion drilling is commonly 100% (or more) providing ample flushing capacity is used. Care is required in sampling to make sure all material is recovered and representatively sampled. Larger diameter holes should provide more representative samples. Percussion drilling provides a variety of means for contamination of samples and it is argued, commonly without reason, that it produces lower assays than diamond drilling, particularity for Au and Ag. Reverse circulation drilling is less susceptible to contamination than normal circulation drilling and generally gives results similar to diamond drilling. Discrepancies between percussion and diamond drilling may be due to fact that higher, but more erratic values, may be obtained for smaller diameter drill core wherein the nugget effect is greater.

6.1 INTERPRETATION OF RESULTS

Interpretation of drill results requires consideration of several factors:

i) Assay interval: It is general practice to average high assays, particularly for Au or Ag, in with lower assays to make longer intervals. Figure 26 shows assay results for a drill hole and a



BENCH GRADE (15 ft)

USING A 0.03 oz Au/T CUT 'OFF

	From	To	Length	oz Au/T
	20	95	75	0.110
incl.	20	25	5	0.08
"	25	35	10	0.025
"	35	60	25	0.184
"	40	50	10	0.325
"	60	70	10	0.030
"	70	90	20	0.127
"	75	85	10	0.205
"	90	95	5	0.03

Figure 26. Various alternatives for compositing assay data and tabulation of drill hole assay data.

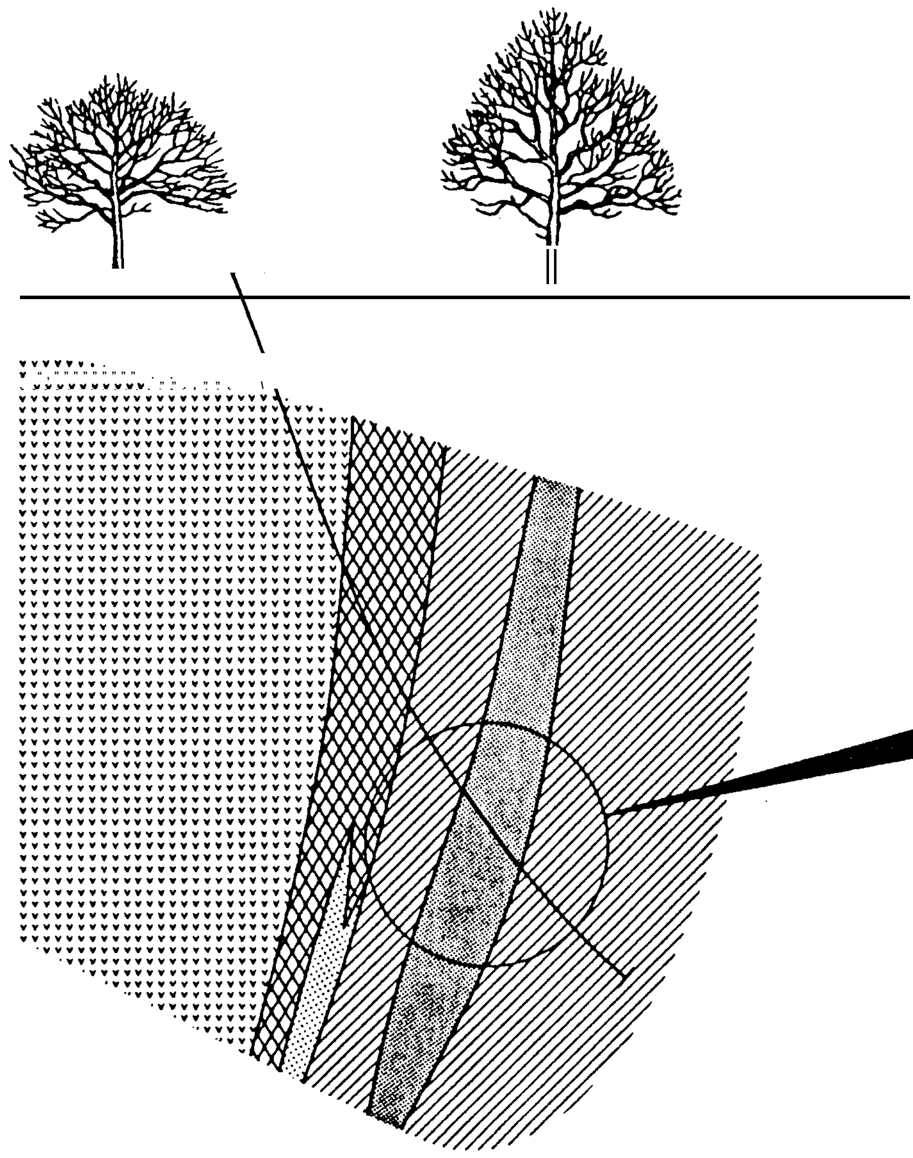
on the left side of the drill hole are those derived if an 0.03 oz/T Au cutoff is used as is common in open pit gold deposits. The column on the far left represents the data composite to 1S foot benches and is how the mining engineer would view the mining grade. Hence there are numerous ways to interpret drill hole data.

High assays are by nature erratic and therefore care should be taken in their use. Commonly assays over 1 oz/T Au are cut to 1 oz/T Au, etc. giving a Cut Grade versus an Uncut Grade. When a single high assay is included in a long interval it is good practise to check and see what portion it adds to the complete interval. Specifics on assay techniques will be described elsewhere.

ii) True thickness versus length of interval: It is good practice to collar drill holes such that they intersect the proposed mineralized zone at a high angle. This is not always possible and therefore the true thickness must be determined in Figure 25.

Some unscrupulous operators have been known to drill down a mineralized structure. It is misleading to drill vertical holes where mineralized structures are vertical; hence, considerable drilling is done with angle holes. Drilling angle holes and . particularity holes at less than -60 degrees, is easier with diamond drilling than percussion drilling.

iii) Recognition of mineable widths: Certain grades and widths are required for each metal to make mineable orebodies. These factors also vary with respect to metallurgy, ground conditions and location or proximity to infrastructure such as towns, power and roads. Minimum mine widths for vein deposits generally are accepted at four feet and therefore values for narrow veins should be diluted to at least a four-foot width. Due to the cost of mining narrow widths, minimum widths for base metal deposits is commonly more than 10 feet. Other factors such as those using



TRUE THICKNESS

(grade) X (width) are commonly used to determine economic mineralization.

iv) Geological Interpretation: The significance of mineralized intercepts during the early stages of drilling is dependent on the type of mineralization encountered and the geologist's interpretation of probable continuity. The estimate of continuity usually is based on local experience in the district or by comparison to similar deposit types elsewhere. This - ability to judge is what exploration is all about -- we as geologists have all been wrong at least once. It is wrong to be too pessimistic or too optimistic; to try and be correct on the basis of one or two drill holes is folly.

7.0 EVALUATION OF THE EXPLORATION PROGRAM AND RESULTS

i) Evaluation of Effectiveness of the Exploration Program

- were all the right exploration tools used?
- was all the data integrated into a common picture or model?
- did the exploration program explore and test all the property? If not, what expense would be required to significantly improve testing of the potential?
- was the exploration program cost-effective?

ii) Evaluation of the Results (assuming significant mineralization was located)

- is the mineralization similar to the deposit type being sought? If not, then the model for control of mineralization must be redefined to assist further exploration.
- does the grade and thickness indicated coincide with that require for mining? - a difficult but necessary question to try to answer.
- is there potential for expansion of the mineralized zone(s), increased grade or thickness?
- in an open pit deposit, is the waste to ore ratio acceptable?

- are ground conditions amenable to low cost mining?
- are the ores amenable to simple beneficiation or processing?

iii) Successful Exploration Programs

An effective exploration program should identify targets that are economically attractive and then utilize techniques that minimize the risk of missing an ore deposit or spending too much money on a target that will not be viable. This begins with selection of favorable deposit types and acquiring properties under favorable terms in geologically and geographically attractive areas. The planned exploration program should be thorough, utilizing a variety of techniques, and should identify drill targets as quickly as possible. Geological evaluation is critical to the selection of targets and effective exploration of them. Results of the initial phase of drilling and subsequent drill programs will constitute major decision stages wherein the viability of the potential mineral deposit must be reviewed. There is an inherent danger in judging exploration success at too early a stage. Unfortunately many deposits are such that further work results in further encouragement, however, whether a viable deposit will be found is questionable. Such projects may be continued, put on hold and kept as inventory, or farmed out to others for further work. There are also those prospects that through hard work, persistence and good market timing turn out to be good mines; for example Endako, Equity Silver, and Golden Sunlight. The risk that can be taken is then a function of the financial strength of the explorer and the size of the reward if a viable mineral deposit is developed. It should be emphasized that mines are not so much found as made through hard work and determination through both the exploration and development stages.

Successful exploration programs therefore have several common features:

i) they search for well defined economic targets
ii) they have reasonable acquisition costs including fair agreements
iii) they have favorable location and infrastructure

iv) they utilize quality geological evaluation techniques with well executed exploration programs by dedicated personnel

v) there is commonly a favorable political and economic climate

vi) adequate exploration and capital funding

vii) good management

viii) Good Luck

June 12, 1984

SELECTING A JUNIOR PRECIOUS METALS STOCK
A MINING GEOLOGIST'S POINT OF VIEW

BY

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INTRODUCTION

While attending the November 1985 National Committee for Monetary Reform convention in New Orleans, 1 had the opportunity to meet American investors with a keen interest in Canadian junior resource - precious metals stocks. A recurring topic in my discussions with these investors was their concern over the large number of Canadian - listed stocks and their subsequent inability to identify attractive investment targets. "We can't see the trees for the forest. Everyone is telling the same story . . . my company is a certain double or triple . . . we will be in production in twelve months . . Who does the investor believe?"

The investor and the mining geologist have a common goal; that is, to participate in the discovery and development of a revenue producing asset - a mine. As a result, the mining geologist shares some of the investor's dilemma. Which company should he approach when searching for precious metals option or joint venture opportunities? Which proper ty has the best potential to develop into a mine? Are the reported exploration results significant.?

This article reviews some of these fundamental considerations from a mining geologist's point of view. These factors may assist the investor in developing a junior company - precious metals investment strategy.

Junior Companies and the Vancouver Stock Exchange

Today, junior mining companies are the engine of the precious metals exploration business in North America. While many major mining companies continue to cut exploration expenditures or withdraw completely from the mining business, junior exploration - development companies push ahead. Most of these companies excel at risk taking and decision making. When these attributes are meshed with business and technical skills, a junior company can become a major player in the precious metals exploration business.

There are some 2000 stocks listed on the four Canadian exchanges; some 60 percent of these stocks are listed on the Vancouver Stock Exchange (VSE). The VSE can be best described as a junior company exchange. Many of the VSE-listed stocks are actively involved in precious metals exploration - development programs in Canada and the United States. Most lack cash flow and depend upon public financing to fund work programs. In 1985, VSE-listed companies raised $ Cdn. 321 million on 700 transactions; 62 percent of these were through private placement. Approximately two-thirds of the funds go into mining exploration.

The VSE has been described by some observers as a parking lot. A significant number of investors and promoters are there for a quick-flip and large capital gain. This strategy is not always successful. Disgruntled players have commented that the easiest way to make a small fortune on the VSE is to start off with a large fortune. In spite of this high-profile, gunslinger image, there is good potential for significant capital gain, over the longer term, on the VSE. The key to a successful longer term strategy is sound advice and timing. Most investors rely on their broker for advice. Unfortunately many brokers are not well enough informed about rudimentary technical aspects of the precious metals exploration business. Hence, the “herd mentality” and quick-flip approach is used in many brokerage houses. Success in the longer term may require a contrary or against-the-grain approach, or recognition that the people and/or property in a company have some fundamental value that the market has not yet appreciated.

The investor wants capital gains and dividends; the broker wants a commission and a satisfied client; the mining geologist wants to discover and develop a mine. It is in their common interest to identify special investment or option situations.

There are three key factors that determine the longer term growth and market potential of a junior resource company: people, property, promotion. Question your broker about these factors when he recommends a stock.

People

The key to success is people; luck only helps.

Management shapes and controls the junior company. Management's incentive to perform is the stock option and capital gain. Knowledgeable mining people will not waste time trying to turn a "sow's ear into a silk purse." Credible people will find and explore credible properties.

In-house business and technical skills are essential. Most companies excel at raising money; however, many fall short of the mark when applying funds to exploration programs. A strong technical (mining) officer can solve this problem. The investor or broker should target those companies whose officers are well up on the learning curve. Someone else has paid for their mistakes. They know of what they speak. The investor may obtain corporate profile information from the Canadian Mines Handbook printed by Northern Miner Press, Toronto, Ontario.

If success means finding a mine, most junior companies have not been successful. However, numerous companies have had technical success. A technical success is a promising discovery that has insufficient tonnage and/or grade to warrant a production decision. Fortunately the market does not discriminate between technical and economic success during the euphoria of discovery. The investor or broker should' target those companies whose officers have a track record with some technical . success. Their time will come.

Property

The best place to look for blueberries is in a blueberry patch.

Canada has enormous precious metals wealth. She is the non-communist world's second biggest gold producer and ranks number four in silver production. Canadian gold production is largely primary, that is from gold mines, whereas over half the silver production is a by-product from base metals mines.

Canada's precious metals-bearing deposits commonly occur in camps - "blueberry patches." Camps consist of clusters of separate mines - "blueberries" - within a geographically and geologically distinct area. Individual mines in a camp may show a wide variation in tonnage and grade but commonly share similar geological features. Noteworthy Canadian operating camps include: Val d'Or, Kirkland Lake, Timmins, Noranda, Red Lake, Cobalt and Keno Hill. Some camps lack operating mines but contain favorable geology and interesting occurrences of mineralization. These are called exploration camps - these mines have yet to be discovered. Active Canadian exploration camps include: Casa-Berardi, La Ronge and Toodoggone. Nevada an-d parts of California could be considered as large precious metals camps or districts. VSE-listed junior companies are hard at work in all of these areas.

Holding mineral claims in an emerging or established mining camp offers several advantages to a risk capital - financed junior company:

1. The company does not have to re-invent the wheel. Precious metals are known to occur in the area. The question is: Are they present in economic concentrations on the company's ground? A company working outside of a camp is essentially looking for a new camp (or wheel). This is at best, a high-risk business. A camp approach is a conservative approach.

2. Infrastructure, services and access are often in place. Local communities are familiar with mining; skilled workers are available; local anxieties over environmental issues are diminished. These factors mean lower exploration, development and operating costs. Custom milling facilities may be nearby resulting in lower capital costs.

3. Your neighbour's news is your news. Camp exploration discoveries generate considerable market activity. Not unlike the real estate business, three factors exert significant control over the market value and profile of a mining property: location, location, location.

4. Structurally-controlled or vein-type precious metals deposits are notoriously fickle. Distribution of gold and/or silver values can be erratic; mining and metallurgy difficult. A staged exploration-development

program can span several years and cost millions of dollars. Operating experience from other mines in the camp can be of enormous value. The junior company can learn from the mistakes of others.

5. Major companies are attracted to mining camps for similar reasons. When much of the favorable ground is held by juniors, major companies commonly enter into joint venture or option agreements. These agreements can provide an opportunity for the junior company to participate in the development of the property at minimal risk.

In summary, a junior company, with limited financial resources, has a better shot at success in a "blueberry patch." Let others do the wildcatting. Many companies maintain a mixed or balanced approach, that is they hold properties both inside and outside of established camps. The investor may obtain corporate property information from the Canadian Mines Handbook.

Promotion

The story must be told and sold.

Most junior companies excel at promotion, that is persuading an investor to buy stock. These investments ultimately finance the company's work programs.

The story is usually a brief progress report and is commonly "told" through a news release. These releases keep the market informed about the company's activities. Most releases are published in the George Cross Newsletter, Today's Market Line, and Stockwatch. All are based in Vancouver. Unknown to many investors, all VSE news releases carry the following disclaimer: "This news release has been prepared by (company officer), who accepts responsibility for its content. The Vancouver Stock Exchange has neither approved nor disapproved the information contained herein." In some cases the longer term investor has to look through the "smoke and mirrors" to separate promotional hype from reality.

The sales approach varies from company to company. Some companies report all the facts; others don't. A mining geologist becomes skeptical when certain information appears, or fails to appear, in a news release. The longer term investor should share some of this skepticism. Some examples follows:

1.	Release	. . . the company has acquired a gold property in the Hemlo district.
	Interpretation	The property is within a 100 mile radius of Hemlo. "
	Comment	When locating a property relative to a camp the reporting company should be specific. For the statement to be a positive one, there should be some similarity between the geology of the subject property and the camp geology. If this is not stated, assume the worst.
2.	Release	. . . the property contains a total of 500,000 ounces of gold with a value of $160 million.
	Interpretation	The company has no idea what it will cost to produce an ounce of gold.
	Comment	A meaningless statement. It may well cost $300 million in capital and operating costs to recover $160 million (500,000 ounces) in gold. The anticipated or projected costs required to produce an ounce of gold should be included in such a release. Table 1 shows some typical gold mine operating data. A rule of thumb: for a property to be placed into successful commerical production the recoverable ore value ($/ton - Column A) should be approximately twice the operating cost ($/ton - Column B). Funds generated in excess of operating costs are used to recover capital and interest expenses and to pay taxes and dividends. In spite of its

relatively high grade, Example 2 should not be placed into commercial production at present gold prices. In contrast, Example 4 has the lowest grade and recovery, yet on an operating cost per ounce basis (Column C) it is a profitable operation. Low grade mines with low operating costs can generate "high grade" profits. High grade mines with high operating costs can lose money with the best of them.

3. Release

. . . a recent rock chip sampling program returned the following results:

Sample	oz gold/ton
1	0.74
2	1.65
3	0.24
4	0.63
5	0.55

Interpretation

Gold is present on the property but probably not in economic concentrations.

Comment

Rock chip assay results are meaningless unless the width, across which the sample was taken, and the position of the sample are stated. For example, 0.24 ounces gold per ton over a width of 25 feet is an impressive assay result; 1.65 ounces gold per ton over 0.1 feet may not be of particular interest. If the words "grab sample" appear in the release, the investor should read "selected high grade sample." The sample is probably not representative.

4. Release

. . . diamond drill hole X-14 returned a 42 foot section grading 0.8 ounces gold per ton from 204 - 246 feet including a 2 foot section grading 15.6 ounces gold per ton. Assay results are listed in Table 2.

TABL

Typical Gold Min

Example	Mine Type	1 Ore Grade (Ounces Gold Per Ton)	2 Gold Recovery (%)	(Tons Re Ou
1	Underground	0.25	93	
2	Underground	0.15	95	
3	Open Pit Milling	0.10	80	
4	Open Pit Heap Leach	0.06	65	

Note: Column 3. $\frac{1}{\text{Column 1} \times \text{Column 2}}$

Column A = Column 1 x Column 2 x $325

Column C = Column 3 x Column B

TABLE 2

Hole X-14 Assay Results

Interval (ft)	Width (ft)	Ounes Gold/Ton
204 - 214	10	0.05
214 - 224	10	0.06
224 - 226	2	15.6
226 - 236	10	0.05
236 - 246	10	0.08

Interpretation

For the section to average 0.8 ounces gold per ton over 42 feet, the remaining 40 feet of the section had to average 0.06 ounces gold per ton. The narrow, high grade value (15.6) is 260 times greater than the wide low grade value (0.06). The release is highly promotional.

Comment

Mineralization in structurally-controlled precious metals deposits is often erratic. The continuity and significance of narrow, high grade values can only be determined after considerable exploration and development work. Because spectacular or bonanza values often lack continuity it is standard practice to discount or “cut” high values in the early stages of an exploration program. In the case of gold, all values greater than 1 ounce per ton are commonly reduced to 1 ounce per ton. Accordingly, the narrow 15.6 ounces gold per ton assay should not have been stretched out” over 42 feet. With the narrow value cut to 1 ounce per ton, the section would grade O. 1 ounces gold per ton over 42 feet as compared to an uncut value of 0.8 ounces per ton over 42 feet. A major difference! Average results can be misleading.

The 0.1 value is a respectable and significant section. It may well be economic (ore) and able to stand on its own merits (see Table 1). Its value should not be exaggerated.

When reviewing a drill hole or rock sample release, the investor should remember that the more regular the distribution of assay values the more reliable and predictable the average grade. Generally, individual values - cut as required - roughly within an order of magnitude (10 times) of each other will give a reliable average grade for a section. More extreme variations in individual values should be treated with caution.

The release should also state or show the position of hole X-14 relative to other zones of mineralization or drill holes on the property. This would give the investor some feeling for the possible dimensions (tonnage) of the mineralized zone. One good hole does not make a mine.

5. Release

. . . the Stage 1 diamond drilling program cent inues to return favorable results. Management is negotiating the purchase of a mill for the property.

Interpretation

Management is several steps ahead of itself and may be tour ting disaster.

Comment

A production decision is based upon favorable results from a staged work program that can span several years and cost millions of dollars. Many proper ties do not "pass" all the stages. The purchase of a mill, while exploration work is still in progress is not only premature but it may deplete the company of necessary funds to complete the exploration program.

There are many other examples. Look for all the facts when reviewing exploration results in a junior company news release.

conclusions

Neither the broker nor the investor should be expected to have a detailed understanding of the mining business. However the broker is placing the investor's money and is being paid to do so. I would think it reasonable to expect that the broker have some fundamental understanding of the mining business. Some brokers and investment advisors do this by maintaining close contact with mining industry professionals. When necessary they make it their business to have a technical opinion on a property or company. Two newsletter writers that use this approach are Jerry Pogue: North American Mining Stock Report, National Securities Corp., Seattle and Robert Bishop: Penny Mining Stock Report, Lafayette, California. There are probably others.

For the investor who wants to learn more about the mining business, a set of lecture notes Exploration and Mining for Brokers is available from the British Columbia and Yukon Chamber of Mines, Vancouver, Canada.

In summary there are three questions to ask when considering a junior mining stock: People - do they have a track record? Property - where is it and does it have potential? Promotion - are the results significant? Ask your broker for the facts.

J.P. Franzen, P.Eng. is a mining consultant at 4990 Cedar crest Avenue, North Vancouver, British Columbia, Canada, V7R 3R8. His background is in precious metals exploration, development and production. He is a director of two VSE-listed companies.

SAMPLING AND ASSAYING

Dr. W.G. Bacon
Bacon, Donaldson and Associates Ltd.

Chemex La

Analytical Chemists • Geochem

CERTIFICATE C

TO : STEPHEN, J.C. EXPLORATION LIMITED

1458 RUPERT STREET
NORTH VANCOUVER, B.C.
V7J 1E9

CC: A. HEAGY

Sample description	Prep code	Pb %	Zn %
07586 E	207	8.38	1.16
07587 E	207	12.20	1.51
07590 E	207	--	--
07591 E	207	--	3.01

CTA

-Registered

SAMPLING AND ASSAYING

SAMPLING

1.0 INTRODUCTION

Sampling is the method used to determine the chemical and physical characteristics of the *ore* from a property or any large mass of material. The product of sampling is a sample. The intent of sampling is to produce a small portion of the whole that is representative of the whole with respect to those values one wants to determine.

The representative portion, called the sample, is usually subjected to chemical analysis and in some cases to physical property determinations.

Usually, but not always, the analytical techniques are accurate. However, the original sampling step and the secondary sampling techniques used to obtain the small portion used for the analysis are frequently poor and in many cases inadequate for the property evaluation calculations . This is often true for any sample procedure even in metallurgical process plants.

2.0 SAMPLING TECHNIQUES

2.1 INTRODUCTION

The sampling techniques used depend upon the type of deposit and degree to which it is developed, i.e., the property maybe a prospect, in the exploration stage or in the development phase.

Sampling should be a method used to accurately determine what is in the ground. It should never be a hit or miss haphazard method - it should be carefully planned to provide the information desired.

Because engineers/geologists require different information at different stages of property development the correct sample procedures will vary throughout the development of the property.

Different types of deposits require different sampling procedures as well. Well disseminated low grade base metal deposits, precious metal, hard rock deposits, precious metal placer deposits and non-metallic mineral deposits all present different sampling problems.

In general deposits with highly erratic contents of high value, high density minerals, cause major sampling problems.

2.2 SAMPLING METHODS

2.2.1 INTRODUCTION

Various types of samples are taken regularly and reported as:

i) grab,
ii) chip,
iii) channel,
iv) drill,
v) bulk, composite and test pits.

These designations for the type of sample are often reported incorrectly and very often misunderstood by those people the report is used by for investment purposes.

2.2.2 SAMPLE DESIGNATIONS AND USEFULNESS

i) GRAB SAMPLE

Grab samples are exactly what the word implies - the geologist or prospector simply removes a portion of rock or material without any regard to what tonnage or volume the sample may represent. In general grab samples are not samples as they do not represent any portion of the whole (except their own weight and volume).

Grab samples are used to prospect a property - they are used to determine rock types, mineralization and in some cases are analyzed chemically. The only honest purpose of subjecting a grab sample to chemi-cal analysis is to determine the presence of minerals or metals. It is a very valid technique for the determination of rock types and mineralization by microscopy or simple hand lense observation.

There are certain circumstances where a grab sample has true meaning. In operating mines With 1 Ow grade highly disseminated ore it has been shown to be possible to perform grab samples that can be analyzed and then a known factor can be applied to provide valuable information for internal use within the company.

ii) **CHIP SAMPLE**

Chip samples are applied to exposed rock surfaces. The method is usually used for hard uniform rock that fractures independently of the values. The method consists of chipping small pieces of rock along a line or over an area, the-pieces must be uniform in size and be uniformly spaced.

The chip sample is often used instead of a channel sample because it is less difficult to take and thus much cheaper to perform. It has more meaning than a grab sample and less than a channel sample.

The inherent problem with chip sampling is the problem of getting uniform chip sizes across a width or over an area. The chip size varies with the ease of breaking the rock. Outcrops, underground faces or backs often contain cracks, fissures, contacts between different rock types or other features that cause the chip size to vary. Varying chip sizes cause the analysis to be weighted in favour of the larger chips.

iii) **CHANNEL SAMPLE**

A channel sample is also applied to exposed rock surfaces. The method is used to sample across formations. The sample is taken by cutting a groove across the exposed rock usually at right angles to the formation. The groove is usually rectangular in cross-section. The cross-section is 2 to 5[9] inches wide and 1 to 2 inches deep. The cross-sectional area is decided upon by nature of the rock type(s) and the weight or volume necessary to get an acceptable sample.

The sample must be taken using a hammer and a moil and not a rock hammer because of varying harnesses. With the hammer and moil a straight line can be made of uniform depth.

It is important to note that most outcrops or underground surfaces are not flat but are curved or irregular in shape. Even when the surface is flat it may not be at right angles to the formation. It is necessary to take the channel sample so that each unit of length represents the same volume of material or a known volume of material. (See Figure, 1).

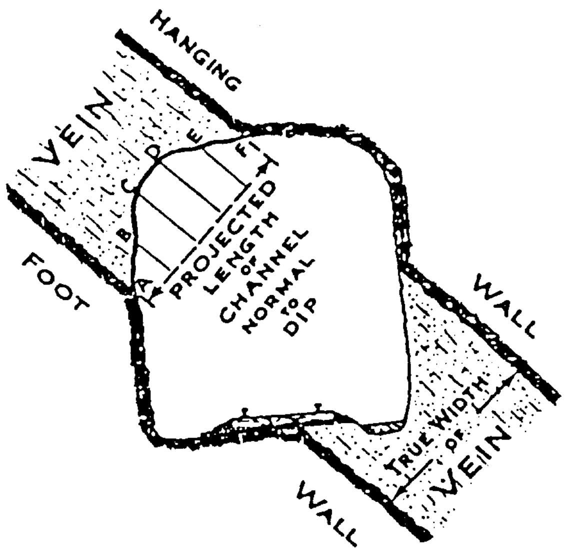


fig. 1. Sampling curved surfaces.

In the case where it is impossible to cut even depths then lengths of nearly straight sections are taken as individual channel samples and the results are weighted by the volume they actually represent. The overall channel sample value is thus calculated from the individual samples.

iv) DRILL SAMPLE

Drill samples, either diamond drill cores and sludge or rotary churn or percussion samples are very common exploration or development methods.

The core, sludge or cuttings must be sampled carefully and in full regard to the theory of sampling. While sampling is most important within the ore zones it is also practised in waste sections to provide for dilution calculations and characteristics of waste rock that must be stripped or removed to get at the ore.

The sample interval is usually defined by geological changes such as a change in rock types or physical problems such as break in the core. Each length of core is split in half using a core splitter. One half the core is retained for rock type determinations, mineralogical studies and specific gravity measurements. The other half is sent for chemical analysis.

As well as the core there is the sludge to be recovered as a secondary sampling procedure. The sludge is collected in various settling devices by passing the return drill water through the settling device.

There are many sample errors that arise in drill hole sampling. These errors can lead to erroneously high or low values. Soft rock usually drills to slightly smaller diameter whereas hard material may grind well or fracture brittly and become ground up. Sludge may be lost to fractures or faults or under certain circumstances material can be washed out of faults, fractures and unconsolidated rock formations into the sludge. Casing of holes is often used in these circumstances. Due to settling problems sludge samples are often useless.

Churn drill and reverse circulation rotary percussion and other types of rotary drilling that produce cuttings only are also subject to many types of sample error. In these types of drilling all the material is conveyed to the surface either pneumatically or hydraulically - in both cases the cuttings are separated by gravity leading to the loss of fines. This type of drilling is subject to sluffing in and loss of sample to unconsolidated formations. The best samples are obtained when the hole is completely cased.

The cuttings are often split down in the field by use of a Jones riffle splitter - this is better done in an on-site laboratory or at an indepedent laboratory. The splitting of samples of the drill site often leads to contamination and consequent misinformation.

v) **BULK, COMPOSITE AND TEST PIT SAMPLES**

These sampling methods are usually used to obtain large samples. They can be obtained by trenching or pitting. The composite sample can be made by combining various smaller samples from multiple trenches, pits or large diameter drill holes . Bulk, composite and test pit samples are usually used for samples that are sent to smelters and/or pilot plants for evaluation.

3.0 SAMPLE REQUIREMENTS AND PREPARATION PROCEDURES FOR USEFUL ANALYSES

3.1 INTRODUCTION

Dr. Pierre Gy has developed a general equation to calculate sample requirements for particulate materials based upon the physical and mineralogical characteristics of the ore to be sampled.

The samples described above are taken in the field. These samples must be prepared for analysis in such a way that a small portion can be analyzed physically or chemically. Thus there is a second sampling problem - how does one obtain a small portion of the sample (i.e., sample the sample) so that the analytical values determined are representative of the values in the original sample with a known and reasonable accuracy.

3.2 LABORATORY PREPARATION PROCEDURES

3.2.1 INTRODUCTION

In general the analytical techniques used are much more accurate than the sampling or sample preparation techniques. The important physical and mineralogical characteristics of each ore type must be known and considered in the design of a good sample preparation procedure.

A typical procedure for chip, channel, drill core or drill cuttings from a porphory copper deposit is:

i) Firstly, the sample is stage crushed to approximately -1/8 inch.

ii) Secondly, the -1/8 inch material is reduced in weight by riffling. A riffle is the only acceptable method of reducing this weight - cone and quartering is not.

iii) The sample is then dried. It may be necessary to dry the sample prior to the first step if it is excessively wet.

iv) The sample is then pulverized to at least minus 150 mesh.

v) The sample is then riffled with a microsplitter. Common practise is roll and quarter but this is not as accurate as microsplitting with a riffle.

vi) The microsplit samples can be retained as various fractions for analysis and reference or check analysis.

It is stressed that this procedure is only an example of one type of *ore* preparation and is not applicable to all or even many ore types. This procedure is simply presented to provide a basis for the following discussions.

3.2.2 STATISTICAL ASPECTS OF SAMPLE PREPARATION

There are errors in all aspects of sampling and analysis. These errors are of two types - random and non-random.

Non-random errors are serious and usually avoidable; examples of non-random errors are:

i) salting - deliberate addition to the sample

ii) contamination - non-deliberate addition to the sample.

iii) dust losses

iv) poor riffling or cone and quartering procedure.

v) errors in weighing.

Random errors are statistical in nature and cannot be avoided. They can be kept within acceptable limits by the sampling and preparation techniques used.

The preparation procedure presented indicates various steps, each of which introduces a random statistical error.

If we use S_n to designate the error in the nth step, then the total error S_T is:

$$S_T^2 = S_1^2 + S_1^2 + \cdots + S_n^2$$

S_T^2 is the variance and S_T is the variance of the overall statistical preparation error. The purpose of careful sampling and sample preparation is to reduce S_T to an acceptable level for the desired results.

The basic concept that must be understood is that analytical results are not the true measure of the original sample but the analytical result will fall within limits of the actual value. Figure 2 graphically demonstrates this fact. Curve A shows a much narrower distribution than curve B and thus represents a better sample preparation procedure than that used for sample B.

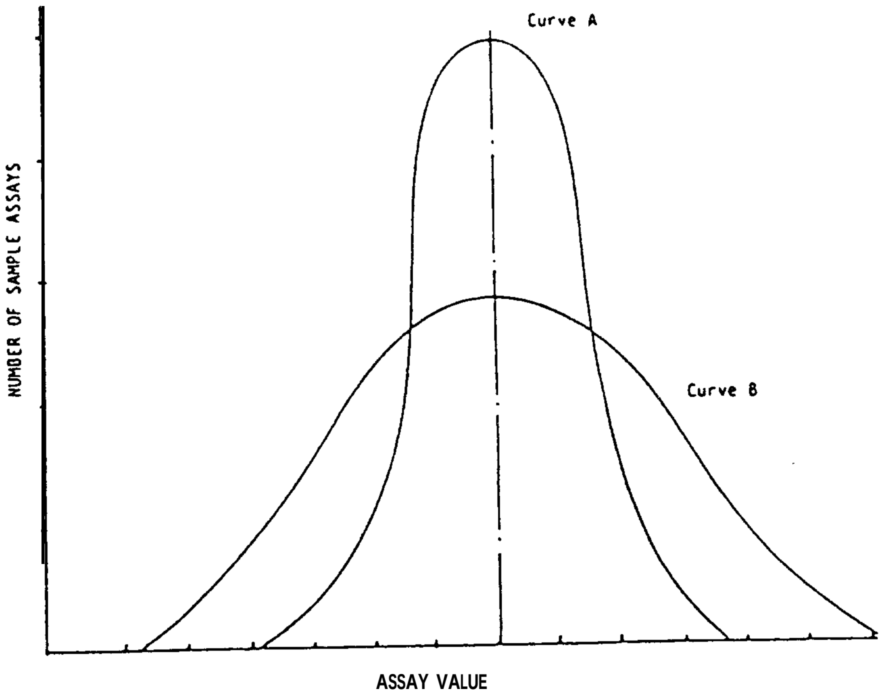


Figure 2.

Distribution Curves
for Two Sample Preparation Procedures

With the development of a distribution curve, such as that shown in Figure 2, it is possible to refine a sample preparation technique and analytical technique combination that will produce results with the desired accuracy.

3.2.3 GY'S SAMPLING EQUATION

Gy's equation is:

$$M = \frac{Cd^3}{S^2}$$

where

M = weight of sample required in grams
C = a constant for the material being sampled. It is composed of four parameters which are characteristic for the material being sampled - f, g, 1 and m.

C= f x g x 1 xm

f = a shape factor which is 0.5 for all practical purposes - except for typical placer gold where it is 0.2.

9 = a particle size distribution factor which usually has a value of 0.25 (except for close size distributions where it is 0.5).

1 = is a liberation factor with values between 0 and 1. "1" = 1 for completely heterogeneous and "1" = 0 for completely homogeneous materials. "l" is determined from the table given in Table I. In Table I "d" is the 95% passing size and "L" is the practical liberation size.

TABLE I

Liberation factor 'l'	0.8	0.4	0.2	0.1	0.05	0.02
Feed and Middlings d/L values	1	4	10	40	100	
Concentrates	hetero-geneous			homo-geneous		
Tailings	hetero-geneous			homogeneous		

Table I

m = is a mineralogical composition factor and:

$$m = \frac{1-a}{a} [(1-a) r + a t]$$

r = specific gravity of the valuable mineral
t = specific gravity of the gangue.
a = average mineral content expressed as a decimal fraction (i.e., 0-1.0).

d = 95% passing size of the sample in centimeters.

s = the standard deviation from the random sampling, usually using the **95%** level for a normal distribution.

3.2.4 APPLICATIONS OF GY'S EQUATION

Gy's equation can be used to determining the following:

1) determination of the required sample size

M from

$$M = Cd^3/s^2$$

if one knows:
d = the 95% passing size
s = the desired accuracy
and c = the sampling constant

2) determination of the sampling error from

$$s^2 = Cd^3/M$$

if one knows:
M = the sample weight
d = the 95% passing size
1 = the liberation factor
the approximate assay and mineral characteristics

3) the size to which a particular sample should be crushed from

$$d3 = M\, s^2/C$$

3.2.5 PRACTICAL EXAMPLE OF GY'S EQUATION

What is the weight of sample to be taken from an ore containing 1% Cu approximately (chalcopyrite copper = 34.5% Cu) that has been crushed to 95% -2 cm. The practical liberation size L is 150 mesh (.01 cm) and the accuracy required is ±10%.

1) % mineral = a = 1.0/.345 = 0.029
decimal fraction
2) d/L = 2.0/.01 = 200, from Figure 4 1 = 0.04
3) chalcopyrite specific gravity = 4.2 gangue
specific gravity = 2.8
4) f = 0.5 and g = 0.25, average values

then C = 0.5 x 0.25 x 0.04 x m = .005 x m

$$m = \frac{1-.029}{.029} [(1-.029)\ 4.2 + .029\ (2.8)]$$

$= 139.2$

C = **0.69_ 0.7**

and for 10% assay error (0.10) gives an "s" value of 0.05 (5.0×10^{-2}), $s^2 = 2.5 \times 10^{-3}$

and $M = 0.7 \times (2.0)^3/(2.5 \times 10^{-3}) = 2240$ g

A table can be made for other conditions:

Table II

	Top Size	"l" liberation factor	C sampling constant	s^2 Variance	M Sample weight
1	2 cm	0.04	0.07	2.5×10^{-3}	2240 g
2	15 cm	0.01	0.17	2.5×10^{-3}	574 kg
3	48 mesh	0.50	8.7	2.5×10^{-3}	94 mg
4	2 cm*	0.04	0.07	6.25×10^{-4}	8960 g

* for 5% accuracy

Conclusions drawn from the above samples

1) Large particle size (15 cm, 6 in) require very large samples, small particle sizes (48 mesh) require small samples.

2) To reduce the accuracy from 10% to 5% requires a quadrupling of the sample size.

3 .2.6 SAMPLE PREPARATION FOR GOLD ORES

For ores containing free gold (placer or lode) ground to the liberation size Gy recommends "f" of 0.2 and "g" of 0.2 with a liberation factor of 1.0. For "m" he recommends 20/a where "a" is the gold assay in gins/metric ton.

These values along with the facts: low assays of 1-2 g/tonne for Au are not uncommon in ores, high accuracy is required because of the high value and extremely variable distribution and particle sizes leads to erroneous results using Gy's equation.

Where +200 mesh free gold particles occur, the sample preparation procedure must be modified to include a screen to remove coarse metallics at one or more preparation stages . These metallics are weighed and assayed separately. A portion of this gold content is added to the assay value of the pulverized sample to obtain the total assay value.

For placer ores containing coarse gold particles it is common practise to take large bulk samples. These samples are wet screened to remove the large gangue portions. The screened product is treated by gravity concentration to remove the coarse gold (and other high specific gravity minerals). The gravity tailings maybe further processed by riffle splitting and amalgamating or cyaniding the remaining portion.

Table III presents the problem of sampling gold ores with coarse (7,200 mesh) gold particles. For this purpose the gold particles were assumed to be spherical and of the same size.

TABLE III Weights and distributions of gold particles for an ore containing one gram per ton of gold as metallics

Gold Particle Size-mash Tyler (mm)	Weight Per Particle Gold (spheres}	No. Particles Per Gram Gold	No. Gold Particles in 30g Assay Sample
8 (2.3621	0.13	6	o?
10 (1.651)	0.045	22	0?
65 (0.208)	0.0006	1,250	07
15O(O.1O4I	0.00001	100.000	3
200(0.074}	0.000005	200.000	6
400(0.037)	0.0000006	1.667.000	50

12

At 8 mesh the particles would weigh 0.13 g each and in an ore assaying 2 gin/ton there would only be 15 particles of gold . At 65 mesh there would be 1250 gold particles/ton and at 400 mesh there would be 1,700,000 particles/ton.

If a normal gold assay were performed the sample size would be approximately 30 g of ore. If the assay was 1 g/ton the number of gold particles in the assay would be:

Mesh Size	Number of Particles	Assay Expected	Actual Assay oz/ton
8	0	0	1.0
200	6	0.83-1.17*	1.0

* 5, 6 or 7 particles, ± 17% accuracy

There are two well used rules of thumb for gold assaying:

1) There should be at least 20 particles of gold in the sample used for assay.

2) No particle should represent more than 1/20,000 of the weight of the assay sample (for gold no particle should weigh more than 30/20,000 = .0015 g).

This is why many gold assays are conducted by processing by flotation, cyanidation and/or amalgamation where a 2000 g. sample or larger can be used. This is the only practical solution to coarse gold placer deposits.

Figure 3 presents a. sample preparation procedure for a copper-gold-silver ore and Figure 4 presents a sample preparation procedure for a coarse gold only ore. Each sample preparation technique must be tailored for the ore before successful assaying will be achieved.

4.0 ASSAYING

4.1 -INTRODUCTION

It is impossible in a simple overview presentation to detail any particular assay procedure or the possible pit falls that maybe encountered during assaying. Suffice it to say that assaying for the base metals is relatively easy once a proper sample has been taken and properly prepared for assay.

It is possible to make generalizations about various analytical procedures as described below. Due to the increasing importance of assaying with respect to precious metals and the preponderance of myths with respect to gold assaying a more detailed account is made herein.

4.2 GENERAL ANALYTICAL PROCEDURES

4.2.1 ATOMIC ABSORPTION SPECTROSCOPY

The concentration of an element in a sample can be determined by measuring the absorption of radiation in the atomic vapour produced from the sample, at a wavelength specific for the element required.

In normal commercial procedures the sample is dissolved (digested) thereby putting the constituent elements into solution. The solution is vaporized in a flame. The radiation is produced by a hollow cathode lamp. The flame is produced by various fuels and oxidants.

The precision of the atomic absorption method is of the order of 1 - 2%, and this degree of precision with good sensitivity makes the method particularly suitable for the determination of trace impurities. It is also considered to be suitable for accurate analysis up to 5%.

There are several possible sources of interference in atomic absorption methods. It is impossible to discuss these in this simple write-up.

4.2.2 OPTICAL EMISSION SPECTROSCOPY

Spectrochemical analysis has been USed in the mining industry for many years. Trace analysis is the principal use of emission spectroscopy.

This remains the most useful technique for the screening of samples for a large number of unknown elements of varying concentration.

In general this technique is not used for quantitative. results for base metals or precious metals.

4.2.3 X-RAY METHODS

These methods include various techniques such as:

1) X-ray Fluorescence (XRF)
2) X-ray Wave Length Dispersive Spectroscopy
3) X-ray Energy Dispersive Spectroscopy
4) X-ray Diffraction Analysis (XRD).

In general these methods are not used on a routine basis for assaying. However they all have applications in the mining industry.

XRF is sometimes used to give quantitative results for specific elements. X-ray Wave Length Dispersive Spectorscopy and Energy Dispersive Spectroscopy are usually used in conjunction with electron microprobe or scanning electron microscopes. XRD is used for mineral identification and not assaying.

4.2.4 WET CHEMICAL PROCEDURES

These methods include gravimetric, volumetric, colormetric and polarographic methods. They are not usually used at the exploration or in the mine development stages in the mining industry.

4.2.5 INDUCTIVELY COUPLED PLASMA-ATOMIC EMISSION SPECTROSCOPY (ICP - AES)

In atomic emission spectroscopy (AES) elements are quantified by the quantity of characteristic optical radiation they emit when heated. The technique of heating is to put the sample into solution and feed it into a plasma which is at 8000°C. The plasma is produced by inducing charged particles to move using an external electrical field and so inductively coupled plasma ICP. The instruments used vary greatly in sophistication and accuracy.

4.2.6 NEUTRON ACTIVATION

In neutron activation, the sample is bombarded with neutrons in a reactor. This makes many of the elements present radioactive and these are quantified by the characteristic gamma radiation they emit. The technique is commonly applied to five assay beads for platinum group metals (PGM's).

It can also be applied to large samples for gold. It is very accurate and very expensive.

4.2.7 FIRE ASSAYING

Fire assaying is still the most widely used procedure for ores of gold and precious metals. It now however is often a combination of fire assay and a secondary method that produces the final result.

5.0 PRECIOUS METALS ASSAYING

5.1 INTRODUCTION

The assaying for gold, silver and precious metals can be accomplished using many procedures. Among these procedures are fire assay, atomic absorption spectroscopy and neutron activation. Inductively coupled plasma (ICP) is also occasionally employed . These methods can all achieve accurate results when employed by properly trained and careful technicians.

The field of assaying for precious metals is one full of intrigue, misinformation, old-wives-tales, ignorance and out right fraud. The problem with the entire field of gold, silver and precious metals assaying is the persistent stories of deposits in which these metals are present in "unassayable" forms. This will be discussed in more detail later in this discussion.

Let it be said at this stage that: ALL THEORIES OF UNASSAYABLE GOLD, SILVER OR **PLATINUM GROUP METALS ARE FALLACIOUS!**

5.2 FIRE ASSAYING FOR GOLD, SILVER AND PLATINUM GROUP METALS .

Fire assaying is still the most widely employed procedure for gold, silver and PGM containing ores. It is relatively inexpensive when carried out in volume by a well organized laboratory and can be very accurate when performed 'by well trained personnel with adequate controls.

It must be pointed out that fire assaying is capable of determining a gold level of 0.002 oz/ton for a 1 assay ton sample. This is a very low amount of gold -consider:

.002 oz/ton is 0.002 mg/assay ton

and one assay ton weighs 29.166 gm.

∴ the .002 oz/ton assay is the equivalent of

$$\frac{.002\ \text{mg}}{29.166\ \text{g}} = \frac{.000002\ \text{g}}{29.166\ \text{g}}$$

$$= .0685\ \text{ppm.}$$

This is a very low quantity of gold and means the assayer has to weigh 0.000002 g (2 micrograms) . The advances in modern electronic balances has allowed this degree of accuracy to be obtainable.

5.2.1 STANDARD FIRE ASSAY

The standard fire assay determination is a batch fusion or smelting of the original sample with the proper fluxes and reagents to decompose the matrix and incorporate it in the slag and to reduce a quantity of metallic lead which will dissolve and *collect* practically all of the precious metals in the slag. This first step, or the fusion step, is completed by separating the lead from the solidified slag.

The second stage is called cupellation, in this stage the lead is oxidized in a cupel dish to lead oxide which simply melts then is absorbed into the cupel dish (some volatilizes) . At the completion of this stage the gold, silver and PGM are left as a Dore bead in the center of the cupel . This stage is completed when the Dore bead is weighed.

The third stage is called parting and is the process of placing the Dore bead in a nitric acid solution to dissolve the silver (or in ancient terms to part the silver from the gold). This stage is complete when the remaining gold is weighed - the difference in weight between the Dore bead and the gold is the silver assay.

The above procedures appear to be very simple but actually involve science and art requiring proper training and years of experience. In B.C. the assurance one has of obtaining good fire assay results is to send samples to an assay lab that has a “Certified ‘Provincial Assayer”.

5.2.2 HYBRID FIRE ASSAY PROCEDURES

All these procedures start with the fusion assay and produce a lead button. Fusion assays from all types of ores, that maybe very different in nature, produce beads that are quite similar in nature and thus maybe processed in a more standard manner.

Thus cupellation can be eliminated by wet chemistry and instrumental methods. This is still not a common method but is used and does produce accurate results.

The most common hybrid method involves the elimination of the.parting procedure. Instead of parting the bead the bead is completely dissolved and analyzed using atomic absorption spectroscopy to determine the bead contents. This allows the determination of all the precious metals.

A second common hybrid method is to take the bead and analyze it using neutron activation for its contents. This is an accurate method of determining the platinum group metals.

5.3 ATOMIC ABSORPTION SPECTROSCOPY (AAS) FOR PRECIOUS METALS

Two methods of AAS are used for gold determinations: direct AAS of dissolved ore and AAS of the concentrate from preconcentrated samples.

AAS has been successfully applied using both methods for the determinations of gold. However AAS is not the panacea it has been stated to be in many circumstances and imprecision or loss of accuracy can result if adequate precautions are not taken to prevent losses and eliminate interferences.

The basic driving force behind the use of AAS for gold analyses is less time and less money. AAS is an acceptable method for the determination of gold and silver on very low grade ores. It, however, is not as precise as fire assaying for high grade ores or concentrate.

The procedure involves the digestion of the sample first and then the extraction of the gold in solution into an organic solvent (of which many are used). Standards must be produced that have the same matrix or as close a matrix as possible to the sample(s) being analyzed. Reliable background. correction is essential for quantitative work unless the standards and sample matrices are nearly identical. This is difficult to accomplish inasmuch as different samples contain different and unknown levels of base metals.

Interferences are common and lead to erroneous results in many cases: for gold ferric iron, NaCN, KCN, Zn, Se, Te, Ti, Ni and Co all interfere, for silver ferric iron, NaCN and KCN interfere. Many of these interferences are eliminated by back ground correction accessories on all modern instruments.

In any event, for low levels of gold or silver and good laboratory practise, accurate results can be obtained using AAS .

5.4 UNASSAYABLE GOLD

5.4.1 UNASSAYABLE GOLD

Many ignorant people have proposed there are compounds of gold that can not be fire assayed:

i) gold chlorides
ii) gold double thiosulphates
iii) hydrocarbons compounded with gold
iv) micron sized gold that evaporates
v) tellurides and selenides cause gold to evaporate
iv) compound "X" that prevents fire assaying

These are ignorant statements and are either made by incompetent people or those trying to perpetrate a fraud. Quoting Beamish, "After 40 years of research in the field I have not experienced an example of failure of the classical assays to find a paying ore!"

5.4.2 NEW ASSAY METHODS TO IMPROVE GOLD AND SILVER RESULTS

Over the last 15 years we have been asked to check out a multitude of new assay procedures including the following changes to the standard fire assay:

1) using large inquarts of silver as a collector
2) using silver chloride as a collector
3) using copper as a collector
4) increasing or lowering the fusion or cupellation temperatures
5) different parting acids.

Not once has the procedure produced the correct assay for gold or silver.

Also the use of wet chemistry to dissolve the ore followed by electrolytic recovery has been used in various scams.

The best way to check out any "new" assay procedure is to have it checked by a competent lab against an acceptable assay procedure.

5.5 ASSAY PROCEDURES FOR COARSE GOLD AND/OR ERRATIC GOLD VALUES

The problem of dealing with coarse erratic gold values is common and, as we have seen, involves the necessity of large samples. The following methods are used to help alleviate this problem:

5.5.1 PRECONCENTRATION

A concentration of the gold values into smaller fraction of sample is called preconcentration . This method is used in many cases where the sample that must be analyzed is too large for multiple assays.

The sample is subjected to gravity or flotation processing to produce a concentrate containing a large percentage of the gold. The concentrate weight is small enough to be completely assayed. Because the tailing from the processing is much *lower* in value it can be reduced in weight and a small fraction assayed.

5.5.2 TOTAL SAMPLE ASSAYING

Large samples can be totally treated by cyanidation, thiourea treatment or amalgamation to recover gold and silver. The gold and silver assays for cyanidation and thiourea are evaluated by assaying the solution and the tailings. In the amalgamation procedure the amalgam is recovered by elutrition and amalgam is dissolved in nitric acid as retorted to recover gold and silver. The amalgamation tailings are assayed normally.

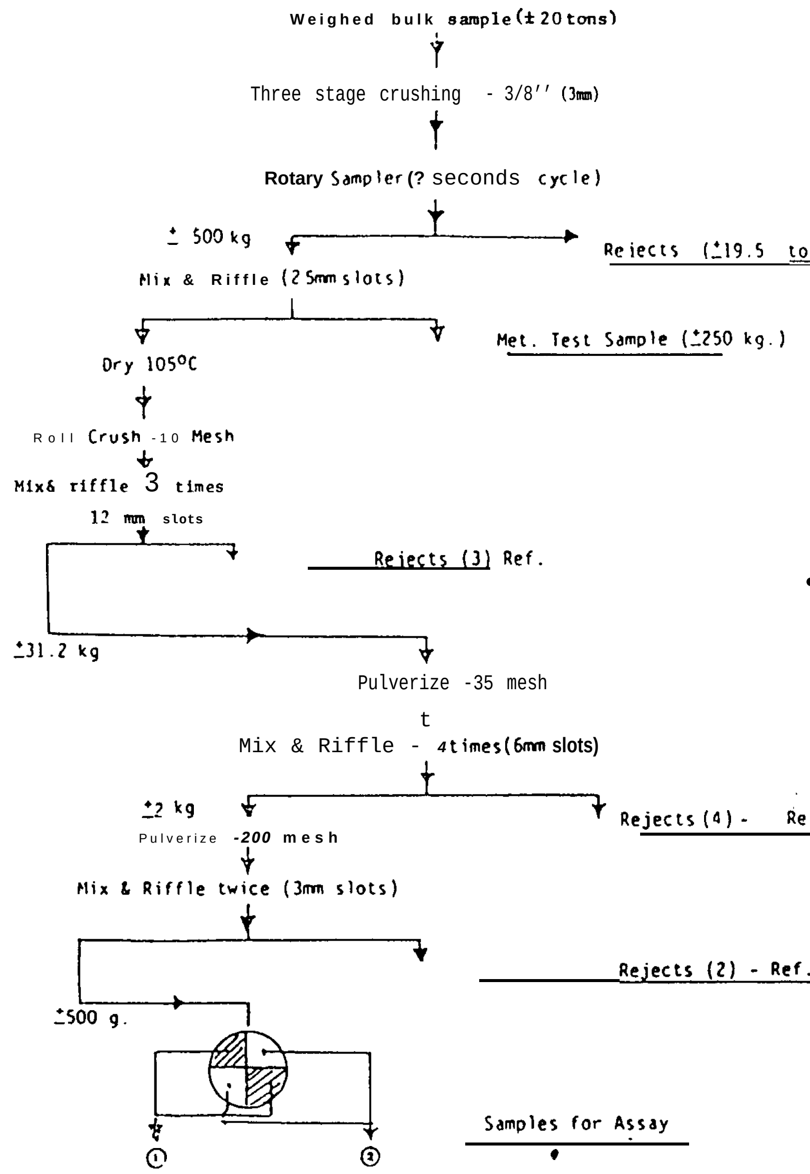


Figure 3. Bulk sample preparation procedure for copper- gold-silver ore.

ORE RESERVES, MINE EVALUATION,

IMPORTANT INVESTMENT CRITERIA

J.W. MUSTARD, P.ENG., CANADA TUNGSTEN MINING CORPORATION LIMITED

INTRODUCTION

This paper is an overall attempt at highlighting those factors which are crucial to the success or failure of an exploration program or mining venture. Discovery of significant mineralization is only one step (perhaps large) towards production, and much is required before the first gold bar is poured. A remark attributed to Mark Twain is apropos: "A mine is a hole in the ground owned by a liar lolling in the nearest cheap saloon". However, in modern times he may be lolling on some exotic resort ! Investors and companies are continually challenged by holes of all sorts and must confront them armed with as much knowledge as possible for fear of turning down a **real money machine.**

No one ever "found" a mine unless it existed at some previous time and was subsequently lost. Mineralization is found or discovered, ore bodies are defined and mines are made. While it seems obvious that the above statement is a basic tenet of the business of mining, many geologists, promoters, presidents, investors and others overlook it. Unbridled enthusiasm is a major source of fuel that drives exploration and mining activity - however the element of realism can sometimes be lost in the process. Decisions are often based on intuitive, subconscious considerations that may be referred to as "gut" feelings or hunches. This ill-defined and somewhat old fashioned method continues to be an important tool at certain stages. However, the factors involved are extremely complex and varied so a thorough understanding of the process is necessary.

In this section, we will look at some of the ways mines are made and in the process we will discover some ways are better than others. Emphasis will be placed on the calculation of ore reserves, and many examples will be used to illustrate the concepts involved.

THE BUSINESS OF EXPLORATION

Structure

Exploration and mining organizations span a very diverse range of all types, shapes and sizes. They range from one man companies to large multi-national, mega-mining organizations. Large mining companies too often excuse smaller deposits as being unattractive because the generated cash flow would be too small to support the large overhead costs. The smaller company can and continues to make significant contributions to discovery by re-examination of prospects and by exploration and production from deposits considered too small by larger companies.

The exploration process evolves from a generative stage followed up by target acquisition, testing, evaluation, definition, delineation, predevelopment and production. It is the generative stage where smaller companies can and do have a decided advantage over their bigger cousins. Unencumbered by a bureaucratic process, they develop ideas and immediately test them as well as react to immediate outside forces. The smaller the company (organization) the stronger is their strength based on survival considerations.

Any successful exploration group must:

1. place strong emphasis on technical competence
2. have excellent communication networks
3. give consideration to long range focus
4. let upper and lower management influence size and allocation of budget.

Successful companies are characterized by:

1. Can do attitude
2. Creative and highly productive atmosphere
3. High quality staff
4. High standards
5. Decentralized
6. Responsive and accommodating

Criteria"for Success

The exploration process is dependent upon people who must be mentally and physically prepared to work as independents. Since people are involved, successful exploration means strong support for those that are driven to succeed. Every person within the chain from the Board of Directors to the field crew must believe that his efforts will make a difference. Each person must not only have confidence in himself, but must have confidence in all who participate in the exploration process. The Board of Directors must be sure that the "right" people are in place and all people involved must feel the support of management. Confidence is the critical factor.

VALUE OF ORE AND OREBODY CONCEPTS

Introduction

All ore deposits have fixed dimensions and unalterable characteristics that do not change with time. Any changes imposed are a resultof differing levels of knowledge, understanding and expectation. While it is not the intent to give a definition to the word "ore" - it must be clear that use of the word does imply that the contained metal is amenable to profitable extraction and beneficiation. Reserve estimates are the "best" judgments and assumptions about geological, operational and metallurgical factors for a particular deposit, and should always be viewed with a certain degree of caution at all stages. Despite the appearance of a high degree of accuracy, reserve statements are estimates and not precise calculations.

The basic data used to calculate reserves is not measurement in total, but is based on selective sampling. Thus a new factor must be considered which is an assessment of quality. Quantity (volume) is usually simpler to estimate because of geometric limitations and the relatively narrow range of density values. On the other hand, grade can vary from 1 ppm to 600,000 ppm (60%). It is still not widely appreciated that the mean value is merely one point on a range of statistical probabilities. The spread or range of grades is affected by the following 3 non-statistical factors:

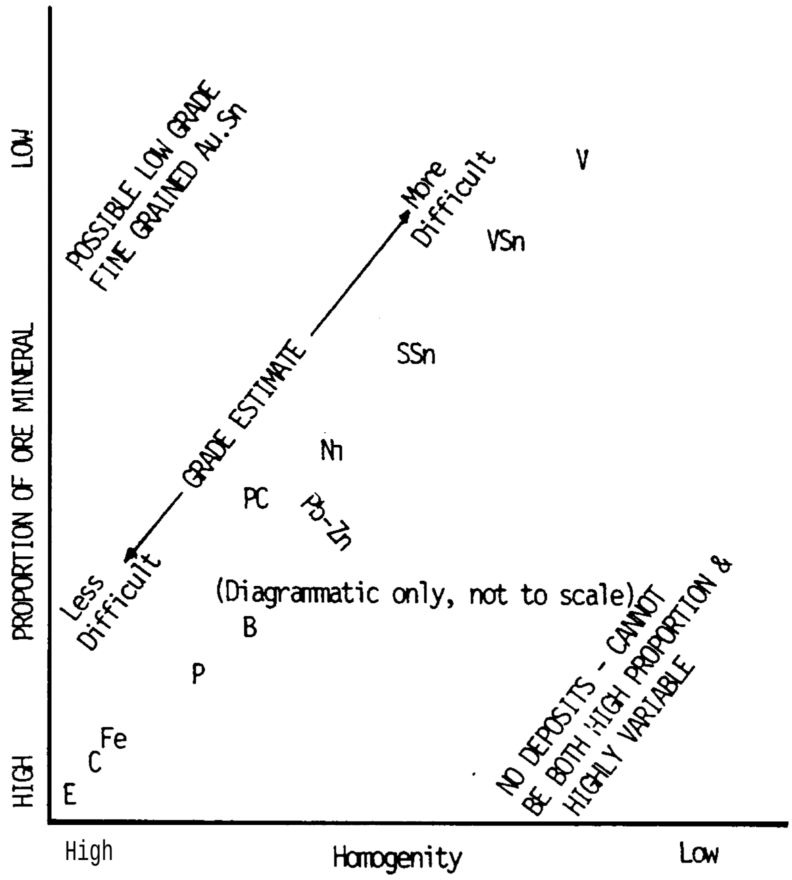
1. Density of drilling
2. The proportion of valuable mineral
3. Homogeneity

Figure 1 illustrates a schematic relationship between homogeneity and proportion of mineral. Bedded type deposits (evaporite, coal, iron) are in the low risk category while discordant type (veins, faults) occupy-the high risk end.

Representativeness and Reliability

Data used for estimations is derived from sampling of various means (see lecture notes by Dr. W. G. Bacon). For most detailed evaluations, some type of drilling results usually form the bulk of the data base (diamond drilling, percussion drilling, rotary drilling). Results of any estimation are based on analysis and interpretation of samples, which in aggregate may represent only 1/10,000,000 of the orebody being evaluated. A bias tendency in both sampling and interpretation must always be considered possible.

Geological continuity is a major factor in representativeness, and must be assessed. Deposits of excellent continuity would include coal, bauxite and some porphyry deposits - all with differing proportions of the ore mineral. At the extreme end of the continuity axis are deposits that are



E	- EVAPORITE
C	- COAL
Fe	- BEDDED IRON ORE
P	- **Phosphate**
B	- **Bauxite**
Pb Zn	-STRATIFORM LEN) - ZINC
Ni	- STRATIFORM NICKEL
SSn	- STRATIFORM TIN
PC	- PORPHYRY COPPERS
Vsn	- TIN VEINS
V	- GOLD, SILVER VEINS

Figure 1 - Proportion of mineral versus homogenity

discontinuous and have little continuity within relatively short distances. This concept is illustrated schematically in Figure 2. Obviously one needs more data points from discontinuous deposits.

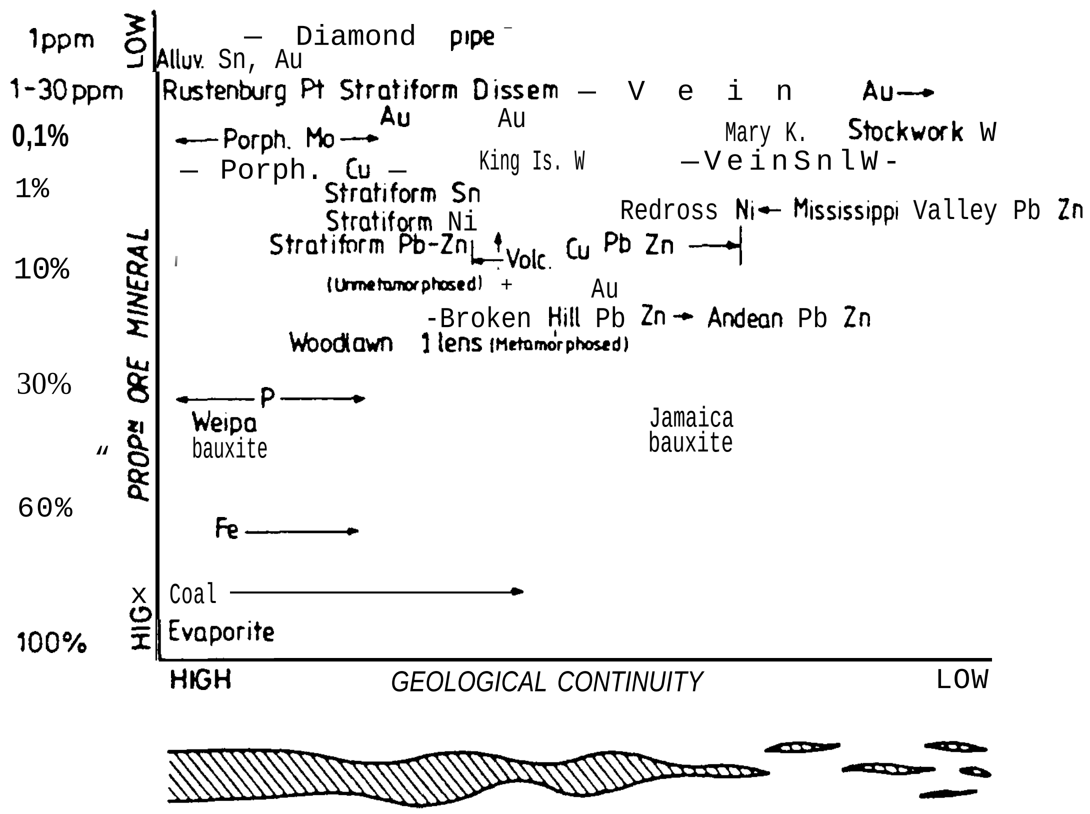


Figure 2 - Ore mineral versus continuity plot

The nature of the sampling programme is often a major factor in the reliability and represent ativeness. The number of sample points relative to the continuity and geometric relationship between sample points and the deposit shape is extremely critical.

Numbers of samples or numbers of drill holes are too often limited by a successful discovery: a "mine" has been found - why do you want to do more drilling? Numerous examples exist where production has commenced before exploration and evaluation have finished. The idea of 30 or 60 m drill hole spacing based on analogy or some other reason should be tested on each unique deposit. Statistical analysis provides an indication of sample requirement based on the characteristics of the sample population.

Since drilling forms the bulk of the sampling methods, let us examine in more detail the attitudinal relationship of drill holes to deposits. Assuming an inclined deposit, drill holes should be oriented such that they cut the ore structure at or near 90 degrees. This gives a more accurate representation of mineable widths at a very early stage of exploration. Up to 45 degrees the intersection indicates true width within a range of say, 2:1, below 30 degrees, the sample no longer represents anything like what would be actually mined in stoping.

Figures 3 and 4 represent these geometric concepts.

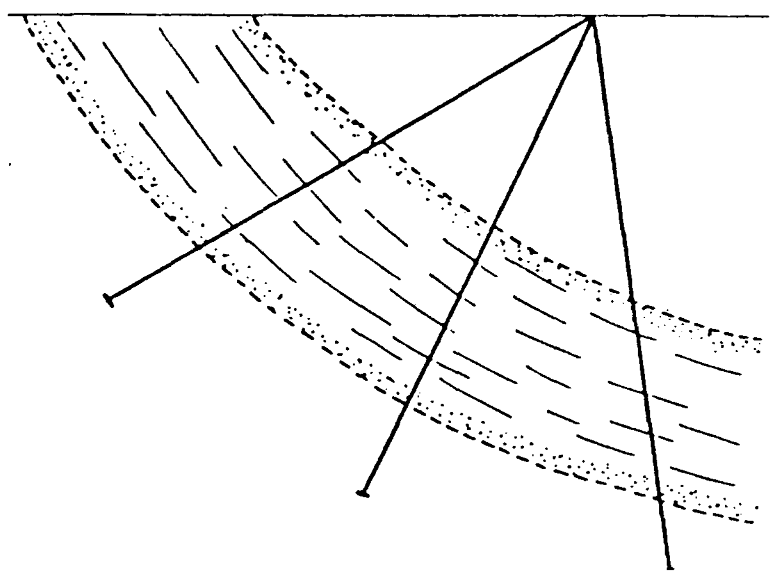


Figure 3 - Large angle of intersection yielding samples representative of what may lie between drill holes

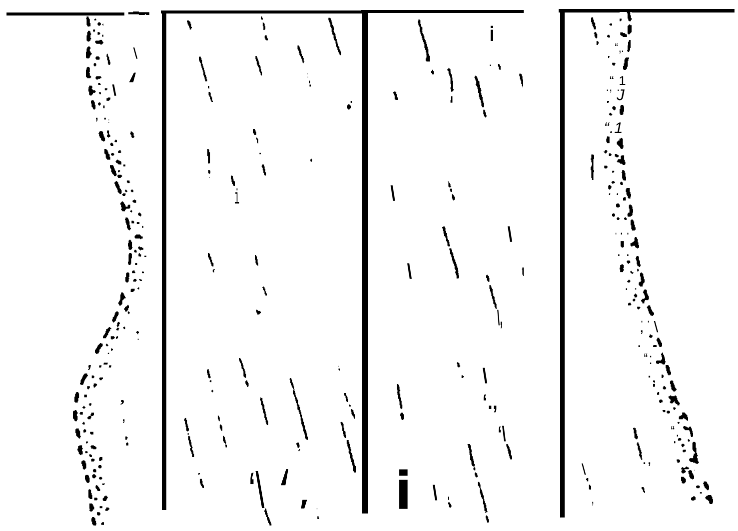


Figure 4 - Small angles of intersection yielding samples not representative of material lying between dril holes

In Situ and Recoverable Reserves

In situ or geological reserves depend largely on the geological interpretation 'of sampling and assaying. It often relies on inference based on established criteria at other, like deposits. Recoverable reserves are what is actually expected to be mined and should involve judgments about mining methods, recovery (in milling), dilution and presence or absence of contaminants. In any estimation, the distinction between in situ and recoverable reserves should be pursued to the point where an estimate is convertible into a schedule of production and where possible, short term variations within the overall estimate can be foreseen. In a like manner but in a different field, insurance companies are very sensitive to short term departures from an overall estimate, of say mortality tables.

The following list provides the principal factors involved in estimating recoverable reserves. These points will be discussed more fully later, and examples given:

1. Cut-off grade: At an early stage of evaluation this is usually combined with minimum mining width. It also makes certain assumptions about costs and metal prices. Conceptually, a cut-off grade is that grade below which all related costs are higher than the revenve generated. A single cut-off may be equivalent grades of several metals, combined to reflect current prices.

2. Percentage extraction: Principally depends on the type of mining method vs the geometry and ground conditions of the orebody. Extraction rates vary from 100% (open pit) to 50% (room and pillar). See Mining Methods and Costs notes by J. P. Franzen.

3. Dilution: Inevitably, actual mining cannot follow a specific contact between ore and waste. This implies that a certain amount of material below the cut-off will be mined as ore. Also, internal dilution results from the unavoidable inclusion of low grade material during mining of a particular block. These two factors decrease the available grade and too often increase the tonnage. An estimation, or calculation of the dilution is very important in deposits of high unit value.

Metallurgical Recoverability

A tacit assumption so far has been that the minerals of economic importance are technicaly recoverable at reasonable costs. I will not attempt to provide any detailed discussion of the various factors, but will merely list the important criteria which should be considered (for a more detailed discussion see the paper by Pendreigh).

1. Grade of ore to be treated i.e. feed grades (estimated from recoverable reserves).

2. Liberation size of valuable minerals (80% passing size of liberated. mineral or minerals).

3. Work index of ore (determines power requirements).

4. Impurities in ore that will determine reagent schemes.

5. Ecological constraints of tailings disposal and hence reagent combinations to be used in the process of concentration.

6. Final concentrate grades that can be produced. What, if any are the smelter charges?

7. Impurities in concentrate (Antimony, Arsenic, Mercury) that may limit where the concentrates can be further treated or sold.

8. Recovery of co-products.

9. Determine whether flotation, leaching or a combination of both is the best method of mineral beneficiation.

10. What is the most economical grinding circuit i.e. conventional rod/ball milling, single stage ball, autogenous or semi-autogenous.

ECONOMIC MINERAL ASSOCIATIONS

Table 1 lists economic mineral associations for several commodities and deposit types. "Average" mining grade and tonnage is given to provide a guide as to what ranges of values are important. However, many commodities are recovered at a much lower grade as co-products and by-products. And, of course, there are higher grade "bonanzas", but generally of limited tonnage.

It is important to know the range of mineable grades and tonnages of current mine operations. Many companies are promoted on what appears to them to be economic grades, but based on analogy, one can infer that a substantial increase in either grade or tonnage (or both) is needed before a mine can be possible. One method commonly used to increase a particular grade is to combine all metals present to arrive at an equivalent grade. This is done based on current prices for each commodity, such that the resulting grade reflects the ratio of price differences. Silver is commonly expressed as a gold equivalent grade. Combining grades in this manner gives the illusion that the deposit is of a higher unit value and does not necessarily mean the other commodities are recoverable.

RESERVE CALCULATION METHODS

General-Concepts

All ore reserve calculations are based on only two basic types of data - volume and grade. Grade of mineralization or tenor has been discussed previously and will be elaborated on more fully. Tonnage is derived from the volume of mineralized material by calculation, involving an estimate of the tons per unit volume. This section will discuss the various methods used to calculate volume, and assign grade since these are the two most important factors that are the subject of much misunderstanding.

Volume is commonly calculated by determining the area of a particular deposit, then multiplying by the third dimension (thickness). While this may sound simple, it is often very complex, involving numerous different approaches, with differing results.

TABLE 1

ECONOMIC MINERAL ASSOC1ATIONS

Commodity Ore minerals	Associations Examples	Ore Assemblages	Mining Grade	Average Tonnage
CHROMIUM Chromite - 33-58% Cr203 (Fe, Mg) Cr_2O_4	LAYEREO ULTRAMAFICS - STRATIFORM Bushveld Complex, S.A. Great Dyke, Zimbabwe Stillwater Complex, Montana	Chromite	25-50% Cr203 Cr/Fe ratio critical	25-1000 m tonnes
	PODIFORM (ALPINE ULTRAMAFICS) Kazakh, USSR			
GOLD Native gold Au Calaverite 39% $AuTe_2$ Sylvanite 24% $(Au,Ag)Te_2$ Petzlte 25% Ag_3AuTe_2	CHEMICAL SEDIMENT HOSTED Central Pat, Lupin Homestake, Detour Lake	Native Au, tellurides chalcopyrite	6-17g/tonne	1-5 m tonnes (Detour - 25 m tonnes)
	PALEO-PLACER Witwatersrand, S.A.	Base metal sulfides U-Th minerals	10 ppm Au 280 ppm U 30 ppm Ag	10-400 m tonnes
	CLASTIC SEDIMENT HOSTED ("Bulk" deposits) Carlin, Jerritt Canyon Golden Sunlight, Nevada	Native gold pyrite, aresenopyrite	1-10 g/tonne	1-40 m tonnes
	VOLCANIC ASSOCIATE VEIN AND SHEAR ZONE Con and Giant, Yellowknife Dome, Campbell Red Lake	Native gold tellurides	5-7g/tonne	1-30 m tonnes
	INTRUSION ASSOCIATE Lamaque, Belmoral Hollinger; Kalgoorlie, Australia	Native gold Au-Ag	7-15g/tonne	1-50 m tonnes

Commodity Ore minerals	Associations - Examples	Ore Assemblages	Mining Grade	Average Tonnage
LEAO ZINC Galena - 86% Pb PbS	STRATIFORM VOLCANIC ASSOCIATE Western Mines, Buchans, Kuroka, Japan	Sphlalerite, chalcopyrite galena	Pb 1-5X ZN 5-6% Cu 0.5-2% Ag 10-60g/t	1-8 m tonnes
Sphalerite - 60-67% Zn ZnS	SEDIMENT HOSTED Sullivan, Crique, Faro	Sphalerite, galena, barite	Pb 1-13% ZN 1-14% Ag tr-180 g/t	4-500 m tonnes
PLATINUM METALS Sperrylite 56% Pt $PtAs_2$ Ferroplatinum 75% - 85% Pt Braggite 59% Pt (Pt, Pd, Ni)S	LAYEREO INTRUSIVE - GABBRO Stillwater Complex, Montana Merensky Reef, S.A. Bushveld Complex, S.A.	Pentlandite, chalcopyrite, cubanite, millerite	1-20 g/tonnes PGE	1-100 m tonnes
TUNGSTEN Wolframite 60% - 70% W03 $(Fe, Mn)WO_3$	VEIN Cornwall, England (Hemerdon)	Wolframite	0.2% W03	80 - 150 m tonnes
Scheelite 80% W03 $CaWO_3$	SKARN Cantung, Mactung Sandong, S. Korea King Island, Australia	Scheelite	0.5-2.0% W03	5-40 m tonnes

Figure ‘5 illustrates the basic principles involved. This figure shows a vertical section through two drill holes and we want to define the area created by the trapezium shape and assign on average grade.

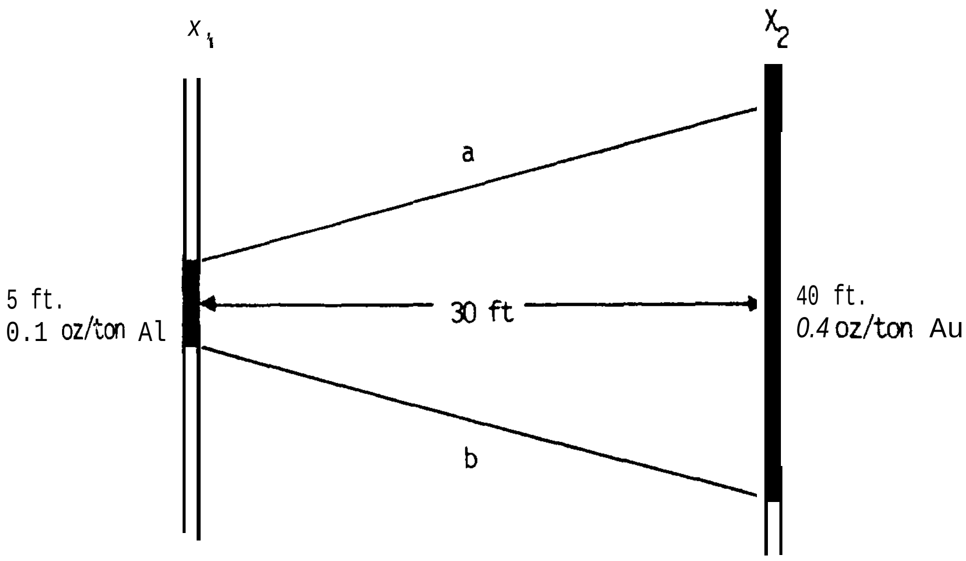


Figure 5 - Section through two adjacent boreholes intersecting a gold bearing structure

The area in the figure is easily determined by the trapezium shape:

$$
\begin{aligned}
A &= 1/2\ h\ (a + b) \\
&= 30/2\ (5 + 40) \\
&= 45 \times 15 \\
&= 675 \text{ sq. ft}
\end{aligned}
$$

Grade can be assigned by taking the average of the two assay intervals which would give a value of 0.25 oz/ton. However, this simple average fails to account for the much thicker intercept in X2, which certainly contains more metal. A common way of accounting for the difference is called the length weighted average, where the grade is given by

$$g = \frac{\Sigma l \times a}{\Sigma l}$$

"1" is the length of the interval, and "a" is the assay value. The above formula is read "the sum of length times assays divided by total lengths used". In the above example this would give a grade of:

$$\frac{(5 \times 0.1) + (40 \times 0.4)}{5 +}$$

$$= 0.36 \text{ Oz/ton AU}$$

In this example, there is a positive correlation between grade and thickness - the longer intersection has the higher grade. If the grades are swapped i.e. the longer intersection has the *lower* grade, then the length weighted grade would be 0.13 oz/ton. The simple average would still be 0.25, no matter which interval has the higher grade. The ordinary mean should never be used because it gives the same answer whether there is a negative or positive correlation.

In normal reserve calculations, we have a large number of drill holes to be used. Generally, reserve calculations can be divided into two groups: plan and sectional. The following two sections will describe these methods in more detail. The decision on which method to use depends on many elements but the overall geometry is a critical factor. A high level of geological understanding of the orebody is necessary before a reliable tonnage and grade estimate can be determined.

Plan Methods

Plan methods which are based on assigning areas of influence around drill holes are shown in Figure 6.

The first method (a) is based on dividing the ore body into rectangular blocks. If the holes are regularly spaced, the lines separating the blocks are drawn halfway between the holes. If the holes are irregularly spaced, the size of the blocks will be arbitrary. Methods (b) and (c) are two variations of the polygonal method. In the first (b) the sides of the polygons around each hole are located by joining the points at the intersections of the bisectors of the angles between the lines joining the holes. In the second (c) the sides of the polygons are the perpendicular bisectors of the lines between holes. In the "area of influence" methods each block or polygon is assigned the grade and thickness of the hole at its centre. The area of each block or polygon is determined and then multiplied by its thickness to determine the volume. The sum of the individual volumes gives the total volume of the ore body. The average grade is determined by summing the products of each block volume and its grade and dividing this sum by the total volume.

These "area of influence" methods over-evaluate when there is a positive correlation between thickness and grade and under-evaluate when there is a negative correlation. This problem is overcome by the triangular method. With this method, the area is divided into triangles by drawing lines

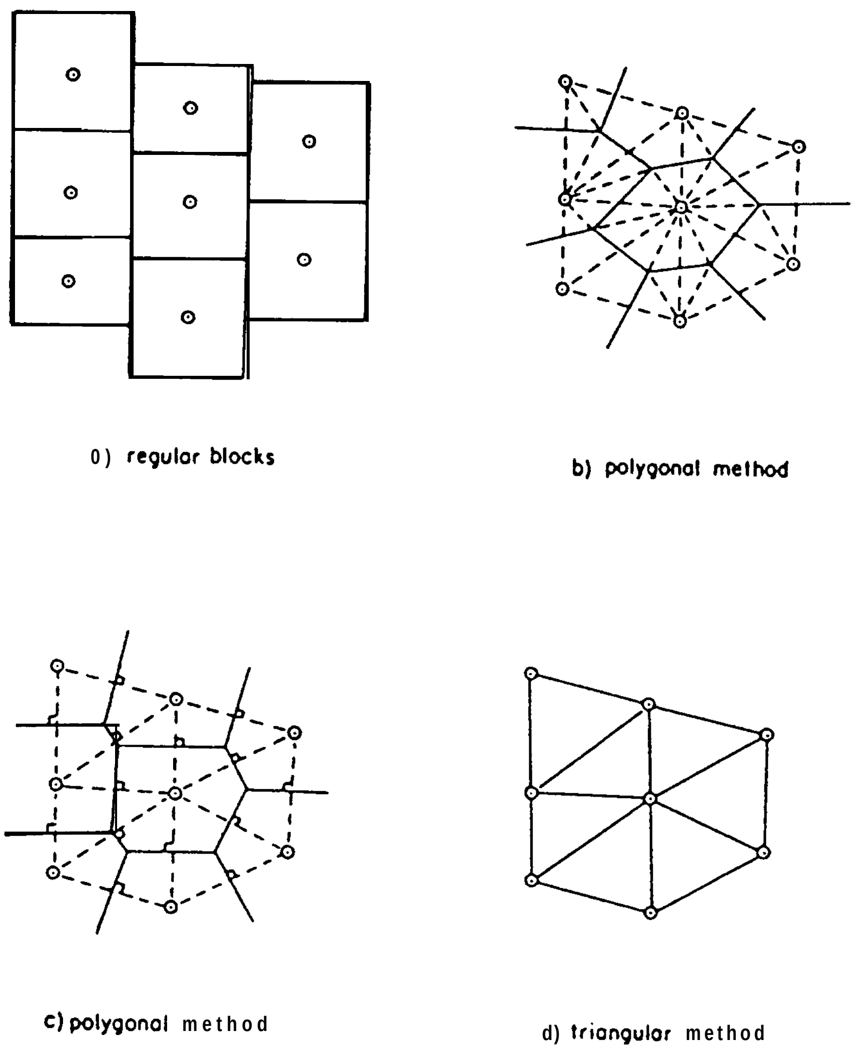


Figure 6 - Some different methods for calculating ore reserves of low dipping ore bodies in plan

between the holes. The thickness and grade for each triangle is determined as a weighted average of the values in the holes at the corners of the triangle. The grade can be determined by either the meter-% or percentage method. In the case of the percentage method the formula for the three dimensional case becomes:

$$g = \left(\frac{\Sigma PT}{\Sigma T} + \Sigma P\right)/4$$

Another plan method, known as contouring, is simple to use and gives reasonable results. Following is a summary of the method:

1. Two contoured maps of the tabular deposit are prepared. One shows lines of equal "thickness (isopachs); the other has lines of the product of thickness or width and grade giving a product called Ft% or M%.

2. The areas between all contours on the isopach map are measured separately, and multiplied by the mean thickness between the appropriate contours. The sum of these represents the volume of the ore body. The total volume is then divided" by the total area gives a mean thickness, as required in step 3. Tonnage can be calculated from the volume by using the appropriate tonnage factor.

3. The contoured map of Ft% is used to find the mean Ft% by a process analogous to that used to find the mean thickness. The mean Ft% value is divided by the mean thickness or width and gives the mean percentage or average grade.

An example of a M% contour map for a copper deposit is given in Figure 7. In plan methods, there must be assurances that distinct horizons are not overlapped. If discontinuous lenses and separate horizons are overlapped dramatic overpredictions in tonnage willl result. The actual ore intercepts must be used rather than the assumed intercepts from the collar location. This will involve several downhole surveys for deep holes and mathematical calculation of actual co-ordinates. Plan methods do not generally allow as precise a control on the geological factors as do sectional methods.

Cross SectionalMethods

These are based on drawing sections across the ore body, determining the areas of ore in each section and computing the final volume by using the distance between sections. In addition to being an alternative method to plan methods, cross-sectional methods are useful for determining reserves of irregular bodies or bodies of variable dip which cannot be calcualted by ordinary plan methods. Figure 8 shows an example of a drill section. First the ore body section is divided into compartments at the mid-points between holes and the grade in each hole is assigned to its respective compartment. Next the area of each compartment is calculated and

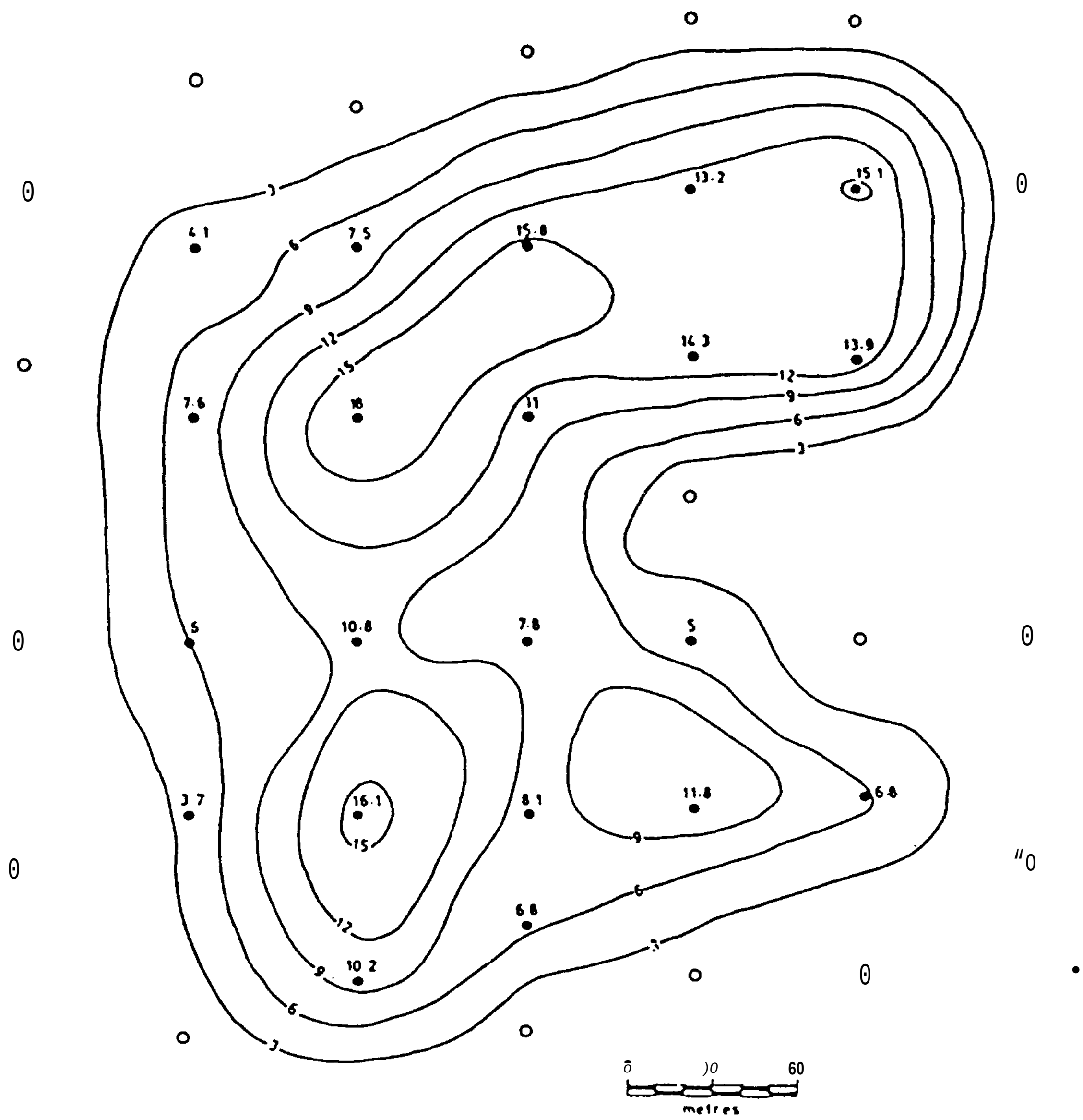


Figure 7 - Meter-% map of a copper deposit

multiplied by its grade. These are summed and divided by the total area to give the average grade for the section. In the example given the average grade becomes:

$$\frac{425 \times 5 + 418 \times 3.5 + 216 \times 3.2}{425 + 418 + 216} = 4.04\%$$

over a total area of 1059 m^2.

Much more complex orebodies can be evaluated in a similar manner.

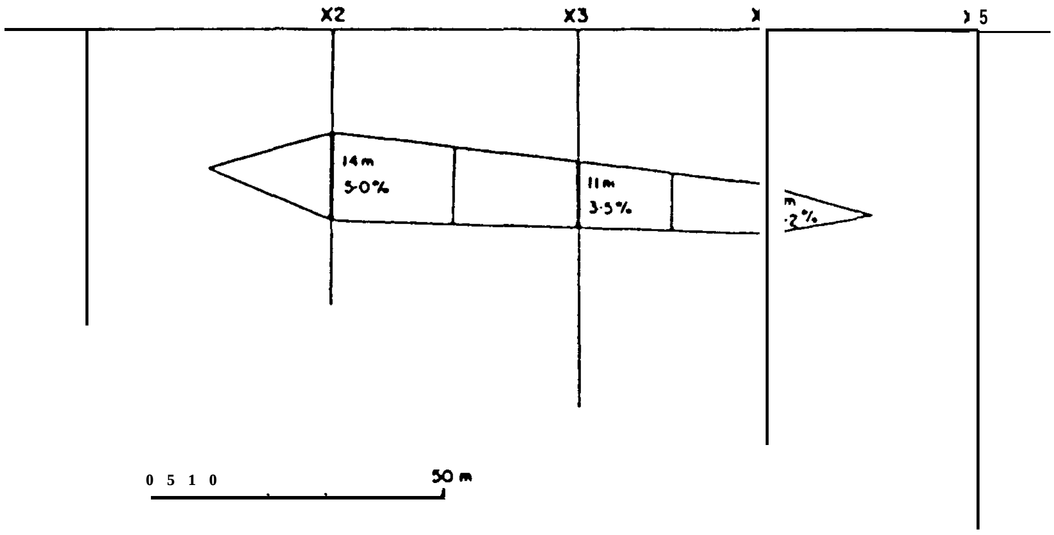
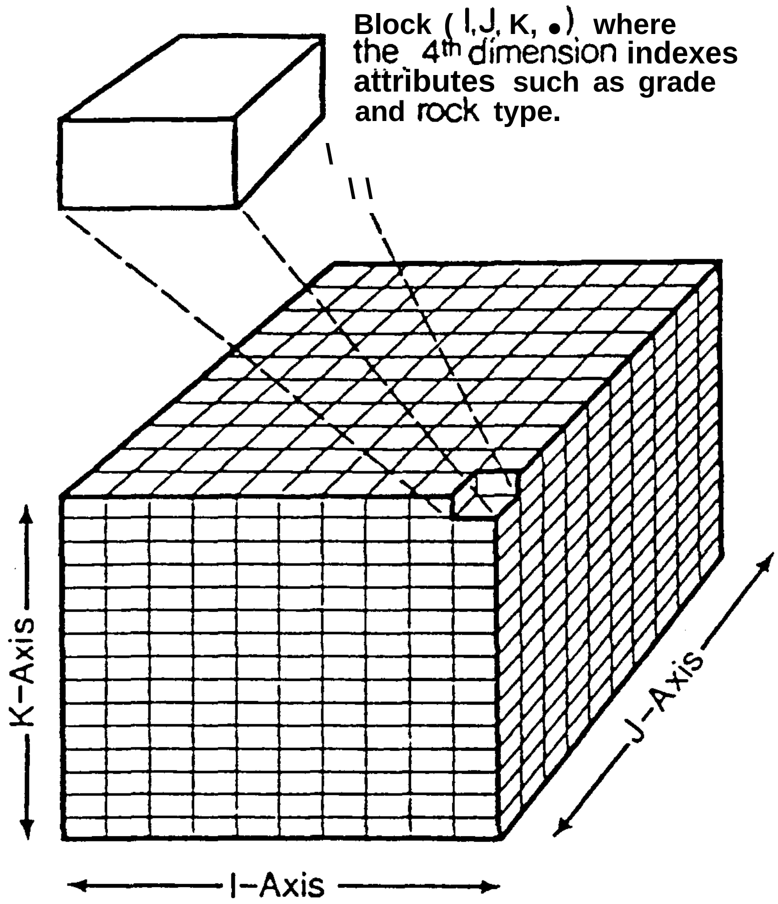


Figure 8 - Example of a drill section through a copper ore body to illustrate ore reserve calculations by the cross-sectional method

When dealing with orebodies dipping at more than 20 degrees, it is no longer satisfactory to 'use ordinary plan methods as they tend to underestimate the total reserves. At a dip of 20 degrees this underestimation is 6%, at 25 degrees it is 9%, at 40 degrees it is 23%. To avoid this it is best to use cross sectional methods.

Estimation by Blocks

This method is commonly used for very large open pit deposits and consists of dividing the orebody into a series of blocks, the size of which depends on the bench height, mining method and drill hole spacing. Grade and tonnage values are assigned to each block based on geological interpretation, and interpolating between data points. This method generally involves a high number of mathematical computations which are made with use of computers. Geostatistics or the theory of regionalized variables is becoming more and more common in reserve estimation. Figure 9 is an example of the basic design of a block model.



4-Dimensional data structure to represent block model
The first three dimensions locate a block in space and the 4th dimension indexes the block "s attributes.

Figure 9 - Schematic block model

Cut-off Grades

8efore determining ore intersections for reserve calculations, it is important to define the minimum grade which should be included. This is known as the cut-off grade. The value chosen is usually somewhat below the actual minimum economic grade as it is generally found that the higher grades in the deposit will raise the overall average to the economic grade required. For example, if the economic grade in a particular copper deposit is 3%, the cut-off grade used in the ore reserve calculations might be 1%. Smal 1 changes in the cut-off grade used might make big differences in the overall tonnage and this could affect the economic viability of the deposit. For example, the ore reserves of a nickel deposit might be 3 million tonnes at 2.4% using a 1% cut-off and 10 million tonnes at 1.3% using a 0.5% cut-off. The larger tonnage of lower grade ore might be a more attractive economic proposition than the smaller higher grade tonnage. For this reason, it is normal practice to carry out calculations using various cut-off grades for comparative purposes.

Tonnage Factors

In converting volumes to tonnages it is necessary to multiply by a tonnage factor. In Imperial measure this is usually quoted in cubic feet per ton (either short or long, though in North America the short ton of 2000 lb. is generally used). In metric units the tonnage factor is simply the specific gravity or density which converts cubic metres to metric tons or tonnes (1000 kg). Tonnage factors need to be determined experimentally from density measurements in the field or lab. Density measurements on drill core or rock samples are easily carried out using the standard procedure of weighing the specimen in air and then weighing it immersed in water where the density is given by:

$$\frac{\text{Weight in air}}{\text{Weight in air - Weight in water}}$$

In Imperial measure, the tonnage factor is calculated by the following formula:

$$\frac{2000}{\text{Sp.gr} \times 62.5} = \text{cubic ft/ton}$$

RESERVE CALCULATION EXAMPLE

As an illustration of the calculation of reserves in a small vein the following example is given:

A drift within a gold bearing quartz vein has been sampled after each 5 ft round. Assay values and vein widths and their products are given in Table 2.

Required

1. Estimate the average assay value

2. Estimate the reserve for the block assuming:
   (a) mineralized vein extends 50 ft above and 50 ft below the sampling level.
   (b) expected linear decline to 80% of level grade on both lower and upper blocks.

TABLE 2

SAMPLES TAKEN AT 5 FT. INTERVALS ALONG DRIFT

Sample No.	True Width W	Assay Oz/ton Au A	Product W X A	Zone
72	4.2	1.53	6.43	HIGH GRADE ZONE
73	5.7	3.21	18.30	
74	5.7	2.53	14.42	
75	8.4	0.93	7.81	
76	8.1	1.92	15.55	
77	12.9	1.28	16.51	
78	10.5	3.01	31.60	
79	9.3	1.02	9.49	
	64.8		120.11	
80	8.7	0.63	5.48	GRADE ZONE
81	10.8	0.31	3.35	
82	6.3	0.32	2.02	
83	4.8	0.38	1.82	
84	6.0	0.38	2.28	
85	6.6	0.23	1.52	
86	6.0	0.51	3.06	
87	6.6	2.18	14.39	
88	3.3	0.32	1.06	
89	6.0	0.31	1.86	
90	4.2	0.15	0.63	
91	4.2	0.13	0.55	
92	5.4	0.41	2.21	
93	6.6	0.36	2.38	
94	7.5	0.38	2.85	
95	8.4	0.08	0.67	
96	7.8	0.37	2.89	
97	6.9	0.37	2.55	
98	10.2	0.67	6.83	
99	12.6	0.23	2.90	
100	10.5	0.31	3.25	
101	9.3	0.84	7.72	
102	6.3	0.21	1.32	
103	4.5	0.43	1.94	
	169.50		75.53	
Grand Total	234.3		195.64	

(c) 20% mine dilution by barren wallrock.
(d) tonnage factor - 12.5 cu.ft.

3. If the reserves in the vein are comprised of the block whose reserve has been estimated in part two plus three other blocks whose reserves are listed below, calculate the total reserve.

No. 2 block	16,000 tons, 0.62 oz/ton Au
No. 3 block	24,000 tons, 0.47 oz/ton Au
No. 4 block	5,000 tons, 1.02 oz/ton Au

Example

1. Estimate of Average Assay Value

A. High Grade Section

Samples 72-79 Assay $= \frac{\Sigma WA}{\Sigma W}$

Uncut average assay $= \frac{120.11}{64.8} = 1.85$

If samples 73 and 78 are cut to 1.85
then cut average $= \frac{100.18}{64.8}$

$= 1.55$ Oz/ton Au

B. Low Grade Section

Samples 80-103 Assay $= \frac{\Sigma WA}{\Sigma W}$

Uncut average assay $= \frac{75.53}{169.50} = 0.44$ oz/ton

If sample 87 is cut to 0.44
then cut average $= \frac{64.04}{169.50}$

$= 0.38$ Oz/ton Au

Example

2. Estimated Ore Reserves

- 80% Linear Decline to Hanging and Footwall limits
- 20% Mining Dilution
- Tonnage Factor 12.5 cu.ft/ton

A. High Grade Section

i) Average grade $= \frac{1.55 + 0.8\ (1.55)}{2}$

$= 1.39$ oz/ton

ii) Average width $= \frac{64.8}{8}$ 8.10 ft.

iii) Height = 100 ft.

iv) Length = 8 x 5 = 40 ft.

v) Volume = 8.1 x 40 x 100 = 32,400 cu.ft.

vi) Tonnage $= \frac{32,400}{12.5} =$ 2,592 tons

With 20% mining dilution

Tonnage = 1.20 x 2,592 = 3,110 tons

Grade $= \frac{2,592 \times 1.39}{3,110} = 1.16$ oz/ton

B. Low Grade Section

i) Average grade $= \frac{0.38 + 0.8\ (0.38)}{2} = 0.34$ oz/ton

ii) Average width $= \frac{169.5}{24}$ 7.06 ft.

iii) Length = 24 X 5 = 120 ft.

iv) Height = 100 ft.

v) Volume = 100 x 120 x 7.06 = 84,720 cu.ft.

vi) Tonnage $= \frac{84,720}{12.5} =$ 6,777 tons

With 20% dilution

Tonnage $= 1.20 \times 6,777 = 8,132$ tons

Grade $= \frac{6,777}{8,132} \times 0.34 = 0.28$ oz/ton

Example

3. CombinedTonnage

A. High grade block

Combine high grade part of block 1 and block 4

$$\frac{3,100\ (1.16) + 5,000\ (1.02)}{8,1\ 0} = 1.07$$

Thus: 8,110 tons grading 1.07 oz/ton Au.

B. Low grade block

$$\frac{8,132\ (0.28) + 16,000(0.62) + 24,000\ (0.47)}{8,132 + 16,000 + 24,000} = 0.49$$

Thus: 48,132 tons grading 0.49 oz/ton Au

C. Total vein tonnage

$$\frac{48,132\ (0.49) + 8,110\ (1.07)}{48,132 + 8,110} = 0.57$$

Thus: 56,242 tons grading 0.57 oz/ton Au.

CYCLE OF MINE OPERATIONS

The life cycle of a mine is essentially a function of depletion once an orebody has been outlined. The scale of time is almost indefinite - no cycle is ever really complete as long as the possibility of discovery remains. Some mines may have short, colourful lives based on high grade surface showings, while others may continue for decades and even centuries. As so often happens, one mine development leads to others as more and more knowledge is gained from a particular environment.

The beginning of a representative cycle may be preceded by spurts and false hopes, rapid depletion of small orebodies while data and understanding is acquired. This phase may precede main orebody discovery and development by several years (Mt Isa was mined sporadically for 30 years before discovery of the rich Ag-Pb-Zn-Cu mineralization).

The far end of the cycle is completed by abandonment. The decision to abandon an operation is often made after several years of barely profitable operations (or unprofitable). The operation is run on a continuous decreasing cost basis in the hope that the geologist (by this time expected to show signs of genius) can find some ore near the mine. The final phase of abandonment is not necessarily associated with complete exhaustion of ore. Mines are often abandoned because costs increase beyond revenue. This can be brought about by high taxes, higher operating costs, low metal prices, strikes, change in ore types, etc; ore ceases to be ore.

The life cycle of a mine is illustrated in Figure 10.

Between the beginning and end of the cycle, the overall characteristics are illustrated by the following pattern:

A. Discovery in the district - prospects and small mines opened and abandoned without significant production.

B. Repeated examination of the district by geologists and engineers.

C. Recognition of a potential major orebody.

D. The production interval
   1. Preliminary estimates of geologic, technologic, and economic conditions.
   2. Preliminary financing on the basis of high risk.
   3. Delineation and testing of the orebody.
   4. Further financing on the basis of reduced risk.
   5. Development of the mine, supporting plants, and townsite.
   6. Employment and training of labour and technicians.

E. Expanding (youthful) production
   1. Beginning of dividends to investors.
   2. Addition-of new tunnels, shafts, pits, and processing plants.
   3. Vertical growth toward higher value, finished products through smelting, refining, and fabrication.
   4. Horizontal growth toward control of additional materials and facilities, such as
      a. Limestone and coal for smelter.
      b. Phosphate rock for use with smelter acid in manufacturing fertilizer.
      c. Power plants, cement plants, railroad system, explosives and machinery plants within the immediate economic area.
      d. Adjacent mines for access as the mine grows larger.

F. Mature production
   1. Innovations in mining and processing to offset lowering grade and rising costs.
   2. Verification of the limits of the orebody.
   3. Innovations to extend the life of the orebody.
   4. Increased local exploration for possible extensions and increased "outside" exploration.
   5. Cost reduction and extension of machinery life.

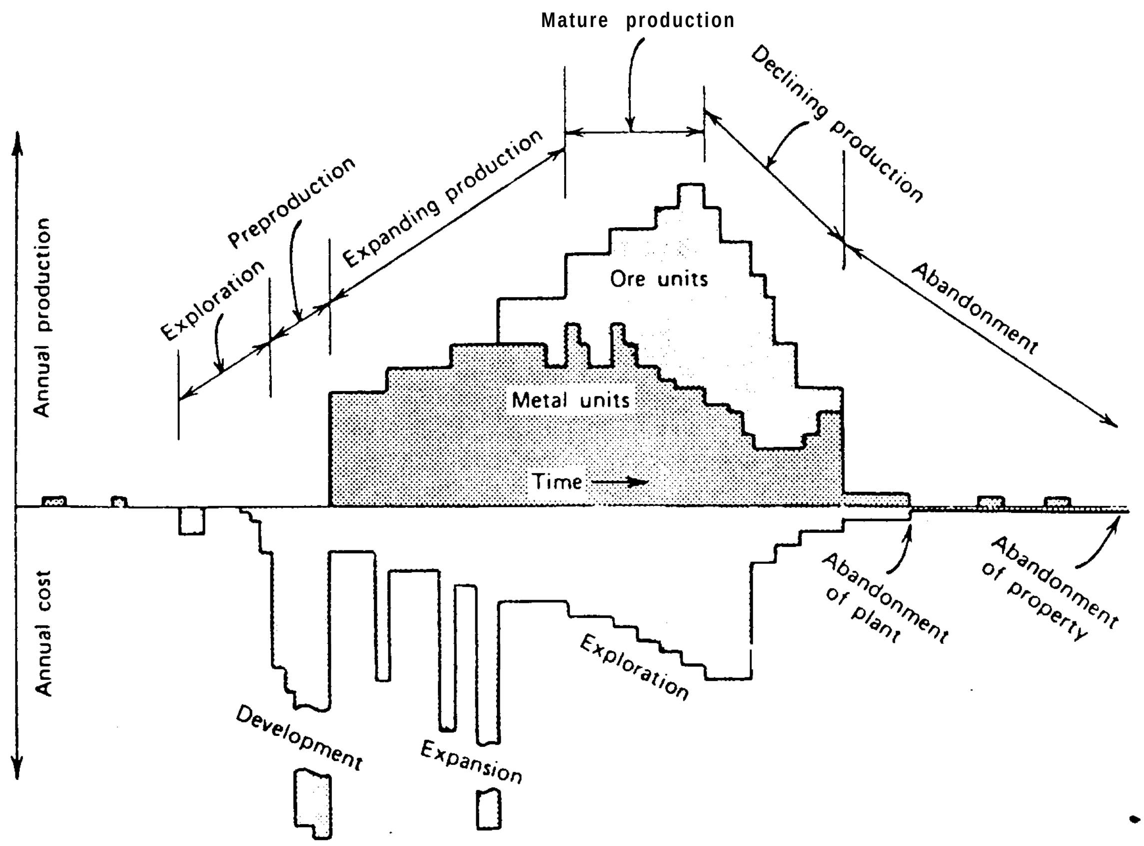


Figure 10 - The life cycle of a mine

G. Declining (old-age) production

1. Sale or lease of assets to a neighboring mine.
2. Cutbacks in local exploration and development with continuing or increased "outside" exploration.
3. Blending of ore from pillars with lower grade ore.
4. Custom processing of ore from other mines.
5. Cost reduction by concentrating on fewer stopes and working benches.
6. Mining of shaft pillars.

H. Mine abandonment, with
1. Salvage of machinery.
2. Departure of most of labour force.
3. Milling or leaching of mine dumps.
4. Custom milling and smelting of ore from other mines.
5. Lessee operations - sporadic as economic conditions change.

ECONOMIC EVALUATION AND FEASIBILITY STUDIES

All evaluation studies have, as a common goal, the assessment of profitability of a proposed project. Studies differ only in the level and accuracy of information utilized at the time of study. All potential investors in a project require these and similar studies.

Stages

1. Preliminary - An approximate estimate made without detailed engineering data. It is needed as a guide to expenditures of further small amounts of money. Its real purpose being to guide further data collection and indicate where future efforts should be concentrated. It is normally expected that an estimate of this type would be accurate within plus or minus 30%.

2. Intermediate - Accuracy of data is somewhat of a mixed bag. The reserve tonnage, grade and general geometry are usually well known. Metallurgical testing results, while not absolute, giveagood indication of recovery rates and concentrate quality. Marketing and sales data is seldon firm. Most of the work required for infrastructure and to meet environmental standards has been qualified but not quantified. Mining methods best suited to the ore zone are now apparent, but operating details are not yet final. Data which is used to develop gross revenue, capital and operating costs and subsequently a return on investment - all these are dependent on numbers which have an accuracy of plus/minus 15-20%. This stage is the jumping off point into big bucks country, so every effort must be made to be as objective and realistic as possible in the creation of this important stage of the study.

3. Advanced - Scope follows the same general outline as previous studies and is based on detailed design criteria. Accuracy is expected in plus/minus 10% range.

The major subjects which must be covered are:

1. Design of operation
2. Ore reserves
3. Mining and processing production schedule

4. Estimates of capital and operating costs
5. Estimates of reserves and taxes
6. Financing arrangements
7. Cash flow analysis

The final feasibility must be "bankable" - that is acceptable by a major finance house. It must set the final stage for detailed construction schedule, design, procurement, etc.

Estimation of schedules, costs and reserves during preliminary and intermediate studies is usually accomplished through a combination of experience, analogy and deductive reasoning. The final feasibility study continues to use these methods but has the added strength of detailed design criteria.

Analogy, or comparison applies available information from projects with similar characteristics or uses "rule of thumb" such as capital costs for a standard flotation plant at $X/ton per day. When making the preliminary evaluation study, this method is usually all that is available. By the time the intermediate study begins, however analogy, while still useful must be tempered with large doses of experience and awareness of the unique characteristics of each individual project.

Following is an outline of what aspects should be addressed in any evaluation study. Depending on the stage of study, items such as cash flow analysis, legal aspects and marketing studies may not be included.

Ore Reserves

Reports covering style and type of mineralization, with full description of all geological data. Geologic data should cover not only the property in question, but all aspects of regional geology, which might provide knowledge to the origin, nature and extent of mineral deposits in the area.

Maps showing properties, topography, principal geological features, existing mine workings, structures, outcrops, exploration shafts and adits, drill holes, etc.

Review of sampling method.
Review of bulk samples and results.
Grade checking to confirm original estimates.
Extent of leached or oxidized zone.
Close spaced sampling for short term production.
Sufficient exploration to define limits of mineralization.
Review of all elements in tonnage and grade calculations.
Independent audit of tonnage and grade by third party.

W

For underground mining, describe mining method, mine plant and equipment required, the general surface plant, plans for pre-production development, and planned daily productive capacity.
For open-pit operations, describe operating procedure and equipment requirements, illustrated by plans; also describe and justify the overall stripping ratio, the contemplated cut-off grade of ore and planned productive capacity.
Estimation of dilution, losses and overall recovery waste disposal schedules and plans.

Milling

Initial testwork on drill core and bulk samples. Scale pilot plant testwork over time.
Effect of changing ore types and grade in overall recovery.
Description of extraction process including any untested technology, patents or special licenses.
Detailed flowsheet and metallurgical balance.
Product specification and recovery.
Resume of alternate processing means and justification of rejection.
Planned arrangements for ore and product transportation.
Estimated overall output of each product as percentage of design capacity for each of first five years upon startup.

Utilities, Services, Labour

Requirements, source, availability, cost and reliability of all utilities and reasons for selection of source in each case, includig comparison of advantages of purchasing against in-plant production.
Power requirements in peak kilowatt demand and annual consumption.
Fuel requirements for heat, steam and plant process.
Water supply.
Transportation and communications.
Surface support requirements - offices, laborator es, warehouse.
Housing and recreational.
Manpower requirements and availability, includ ng skilled ad unskilled labour, technical and supervisory staff.

General

Specifications for equipment and construction.
Types of construction equipment required for the work, indicate what is available locally and what must be imported.
Special construction problems: climatic conditions, topography, environmental, procurement.
Construction plan.
Proposed methods of contracting, and breakdown of work into separate contracts.

Test of installed equipment and equipment guarantees.
Operating organization and quality of management - including recruiting and training.

Technical Soundness

Justification of location of project.
Proven reliability of plant processes and equipment.
Demonstrate superiority of adopted processes.
Compatibility of adopted processes with Potential capabilities of available management, operating and maintenance personnel.
Analysis of any adverse factors and resources to overcome them.
Assurance that mine and plant will produce the quantity and quality of products specified on a continuing and dependable basis.

Market Situation

Local, regional and worldwide market trends during past five years, as applicable for each major product and any competing products showing:
Domestic production, quantity and value, fob mine or plant.
Imports and exports, quantity and value, cif or fob.
Net local consumption, quantity and value.
Present consumption in country and comparison with other countries.
Any local laws, regulations or customs affecting marketing of proposed products, including import and export duties, tariffs, quotas, restrictions, price controls, subsidies and tax exemptions.

Market for Proposed Products

Future market trend for each product showing estimated quantity and value of imports, exports, domestic production, and domestic consumption for the next five years.
Trends in use of present or prospective competitive products.
Analysis of market for each product, including cif and domestic price studies, foreign markets, and distribution costs and methods.
Survey and analysis of all existing or potential users of the several products.
Evidence of salability of the product, in the form of sales contracts or intentions to purchase.
If part of proposed production is intended for export show for each major product:

Number of units to be exported.
Proposed markets and cost of transport.

Competitors

Names, location, present and future output, production costs and selling prices of present local competitors in the same field of production. Information as to any anticipated changes in competition, such as expansions, modernization, new plants, new competing products, etc. Information as to foreign competition and any anticipated changes in laws or regulations which might affect volume of imports.

Competitive Position

Selling prices which must be met in domestic and export markets.
Estimated transportation costs and export expenses.
Maximum competitive selling prices fob mine or plant.
Competitive advantages of proposed project:
Relative availability and cost of labour
Modern production equipment and processes
Transportation costs
Dependability of supply

Legal

Ownership of mineral rights
Rents and royalties
Property payments to third parties
Licensing and permitting to all levels of government
Employment laws
Corporation obligations to optionee or joint venture partners
Environmental and native land claims

Environmental

Impact statement
Baseline studies
Public hearings
Staged permitting process
Reclamation plans

Capital Cost

Detailed cost estimates for land, engineering, and construction
Estimate of pre-production interest
Financing arrangements for pre-production cost

Working Capital Requirements

Amount required at startup and at the end of the first, second and third years of operation, to cover supplies, repair parts, auxiliary materials, products in process, finished products, accounts receivable and cash on hand.

Sources and availability of local and foreign currency funds required.
Anticipated occurrence of seasonal peaks in working capital requirements and method contemplated to meet such peak financial requirements.

Production Cost (broken down into local currency and dollar costs)

Production estimates showing tonnage and grade of run-of-mine ore produced and milled, tonnage and grade of mill products and percentage of mill recovery.
Estimate of the direct cost of producing each of the major products and any intermediate products for mining and milling operations separately, supported by detailed calculations.
Estimate of pre-operating cost prorated to production cost.
Adopted wage rates and production factors used in production cost analysis, taking into account legal wage and salary scales, including all fringe benefits such as social security, vacation pay, medical allowances, displacement allowances and travel pay.
Provisions included for personnel facilities such as transportation, housing, subsistence, recreation, medical care, etc.
Number of shifts and days of operation per year used in calculations, and basis for determination.
Government preferences or allowances taken into account such as (1) exemption from or deferment of any general or specific taxes on products, (2) exemption from or deferment of corporate or local taxation, and (3) any special depreciation allowance for tax purposes.
Estimated effect of possible wide fluctuation of any cost factors entering into computations.
If producing the same or equivalent products in an existing plant, show present production costs in same general form.
Breakdown of production costs into local costs and dollar costs.
Availability of foreign exchange to permit necessary imports of materials and supplies.

Costs of Distributing and Selling

Description of methods of distributing and selling products and estimate of costs thereof.
Costs of advertising.
Administrative expense.

Selling Prices

Proposed selling prices in domestic and export market and relationship to current prices.
Deduction for cost of selling, distributing and transportation.
Net selling prices at the plant and adjustments that might be made in case of wide fluctuation of any of the cost factors.

Cash Flow Analysis

Production schedules year by year.
Net revenue at minesite after transportation and treatment charges.
Unit operating costs.
Cash flow schedules incorporating depreciation, taxes, royalties, etc.
Rate of return, payback, present value, etc.
Sensitivity analysis on prices and operating costs.

FINANCIAL ANALYSIS

The following section is taken from a publication and information provided by Wright Engineers Ltd.

Financial Analysis is the process whereby the merits of an investment proposal are evaluated. The understanding of financial analysis is an important consideration from an investor viewpoint. The evaluation process is very complex because it is based on estimates, projections, and trends which are subject to varying degrees of uncertainty.
A major investment decision is probably the most important decision a corporation can make because such expenditures are usually irreversible. The viability of an investment is determined by its ability to generate sufficient cash flow. Such cash flow is the residual after paying all capital costs, operating and maintenance costs, financing costs, income taxes and royalties. Major projects are characterized by an initial capital outlay over a few years, with a positive cash flow starting as production commences.

Requirements to Analyse a Project

An investment decision should be based on the following:

1. Estimates of cash outflows (investment capital, loan repayments, debt service, operating costs) and cash inflows (return from investment and external financing).

2. Estimates of availability and cost of capital.

3. A set of investment standards or criteria to utilize in selecting or evaluating investments.

The estimates of cash flows in (1) above are usually determined in considerable detail and are outlined under Feasibility Studies. Estimates in (2) come from a variety of sources including bankers, investment dealers, consultants, public data, and industry contacts. Investment standards in (3) are typically the internal rate of return and the net present value. The payback period is often used to show “exposure” to outside forces such as taxation charges, interest rates, etc. The net present value requires the determination of an appropriate discount rate to equate cash flows to present value.

Sensitivity Analysis

sensitivity analysis shows the impact of changes to a variety of parameters such as metal prices, inflation rate, operating costs, exchange rate, capital costs, metal recovery or any combination. In this manner factors critical to the succes of a project can be isolated, and highlighted.

An approach to determine the important parameters on which to perform sensitivity analysis follows. In summary, an attempt is made to place the variables in an economic analysis in a grid or matrix. The impact of a change in each parameter is analyzed to determine its importance to the valuation and also to its degree of control by the company preparing to make the investment. A typical grid for a mining project would probably look something like that shown in Figure 11.

In general terms, items in different quadrants require different levels of attention. For items in the quadrant of "low company control" and "low importance to valuation" an assumption is made as to the appropriate inputs. In the quadrant of "high company control" but "low importance to valuation" the decision authority as to the appropriate inputs is usually delegated to a more junior level. Detailed analysis should focus on the quadrant of "high company control" and "high importance to valuation".

This area should be tightly controlled and re-evalated periodically as prices or other important factors change. In the area of "high importance to valuation" and "low company control", contingency plans should be set up and the factors in this quadrant should be consistently monitored. It is in this area where a significant amount of sensitivity analysis should be performed in order to properly assess the risks of changes in parameters which are largely external to a particular project. It should be noted that the placement of the variables on the grid will vary from project to project.

Financing

Various financing considerations are listed below:

1. Debt to equity ratio
2. Protective covenants (test to see if they are met)
3. Interest rate (fluctuating with prime rate, or a fixed rate)
4. Security for loan
5. Interest coverage
6. Multiple loan structures (including loans denominated in foreign currencies)

SENSITIVITY GRID

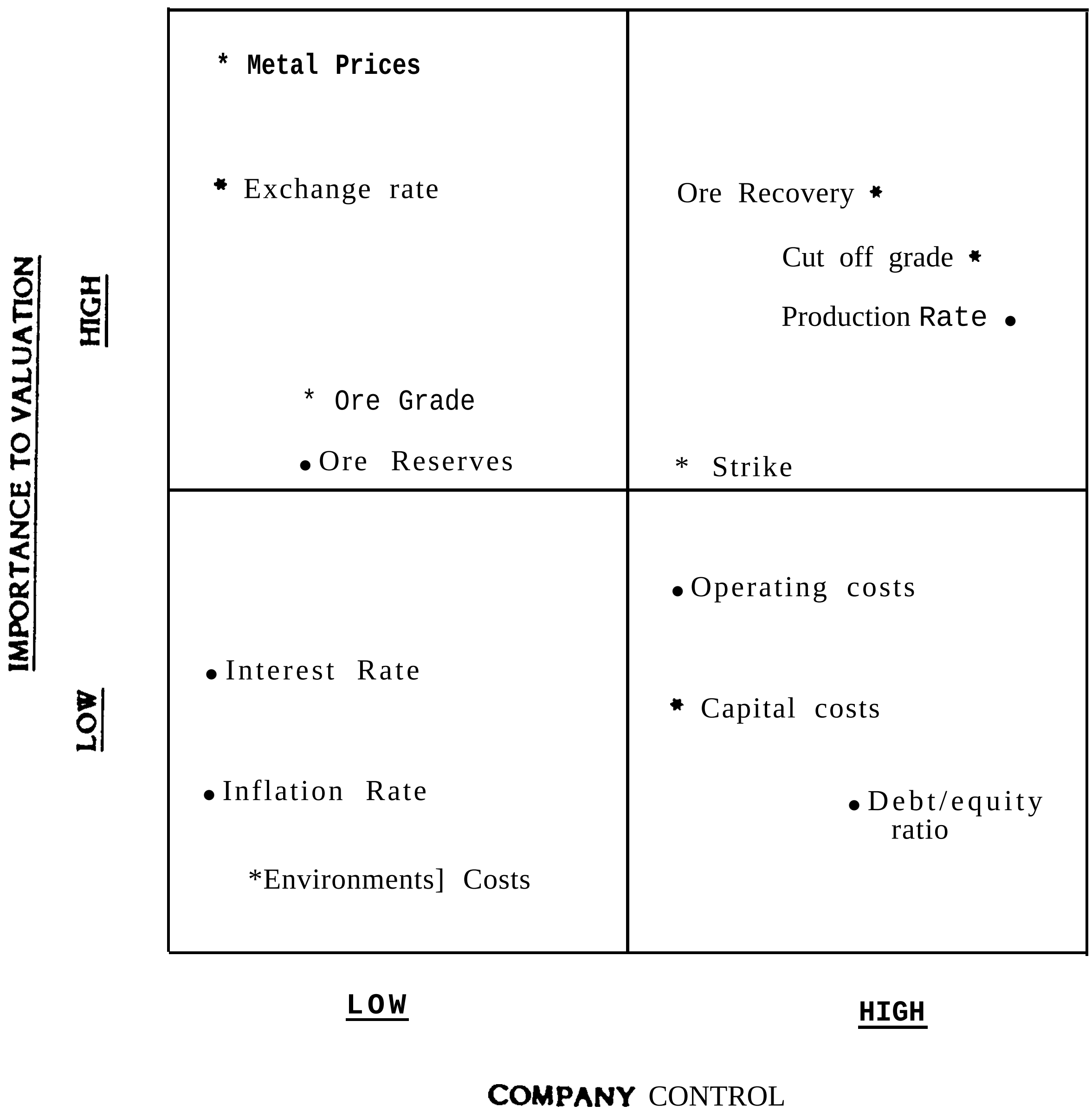


Figure 11 - Sensitivity Grid

7. Debt interest and principal repayment terms, such as:

   a. pay back as quickly as cash flow permits
   b. pay back as percentage of cash flow
   c. amortization of loan
   d. equal principal payments per year
   f. combinations of the above for different loans

8. Preferred dividends
9. Taking mine product as settlement for loan
10. Equipment financing or leasing.

Example

Valuing a project using a discounted cash flow approach requires projecting yearly cash inflows (revenue) and subtracting yearly cash outflows (operating costs, capital costs, taxes, interest, etc.). Table 3 shows a simplified version of cash flow analysis. The results show a 25.2% rate of return and a net present value of 1.9 million at a 15% discount rate. The analysis is very sensitive to changes in many of its components, two of the most critical are shown in Figures 12 and 13.

TABLE 3

CASHFLOW SUMMARY

$ MILLIONS CAN.

	1984	1985	1986	1987	1988	Total
REVENUE		10.0	10.0	10.0	10.0	40.0
- Operating Costs		5.0	5.0	5.0	5.0	20.0
- Total Capital Costs	10.0					10.0
- Total Taxes Paid				2.2	1.6	3.8
= Net Equity Cash flow	-10.0	5.0	5.0	2.8	3.4	6.2
Discounted at 15%	-10.0	4.3	3.8	1.9	1.9	1.9
Rate of Return (%)						25.2

NET PRESENT VALUE vs GOLD PRICE

AT VARIOUS DISCOUNT RATES

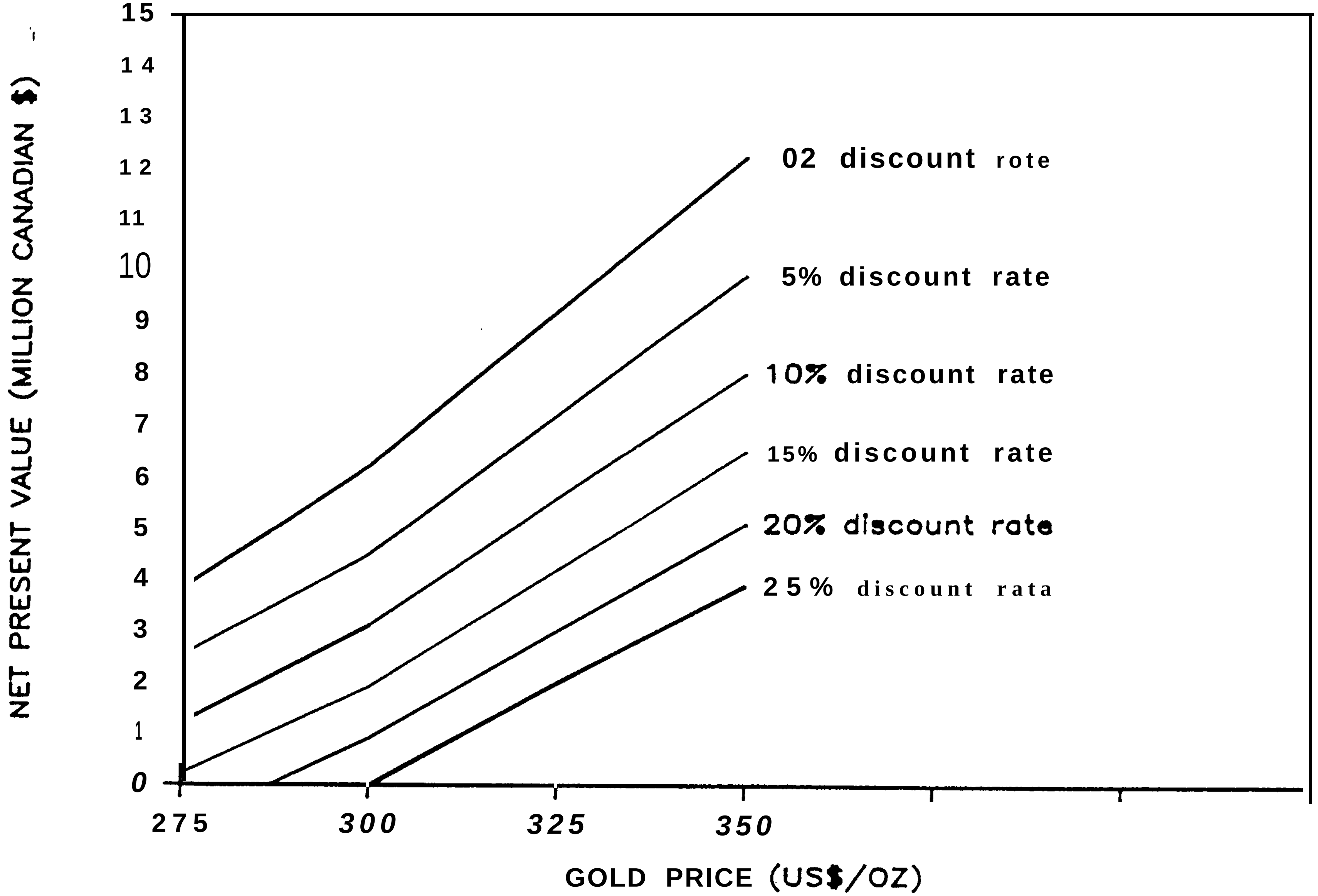


Figure 12

SENSITIVITY ANALYSIS

AT A 15% DISCOUNT RATE

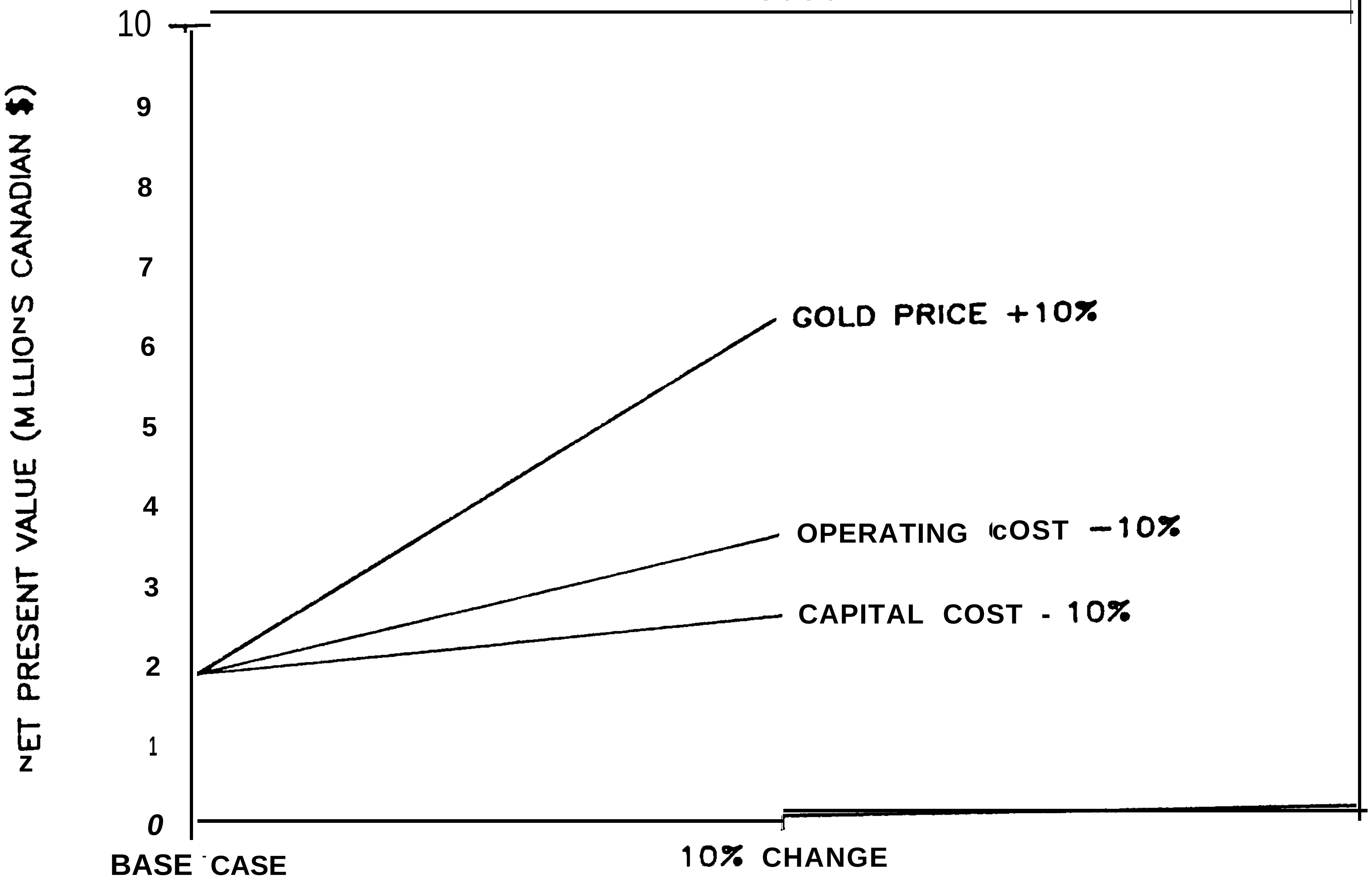
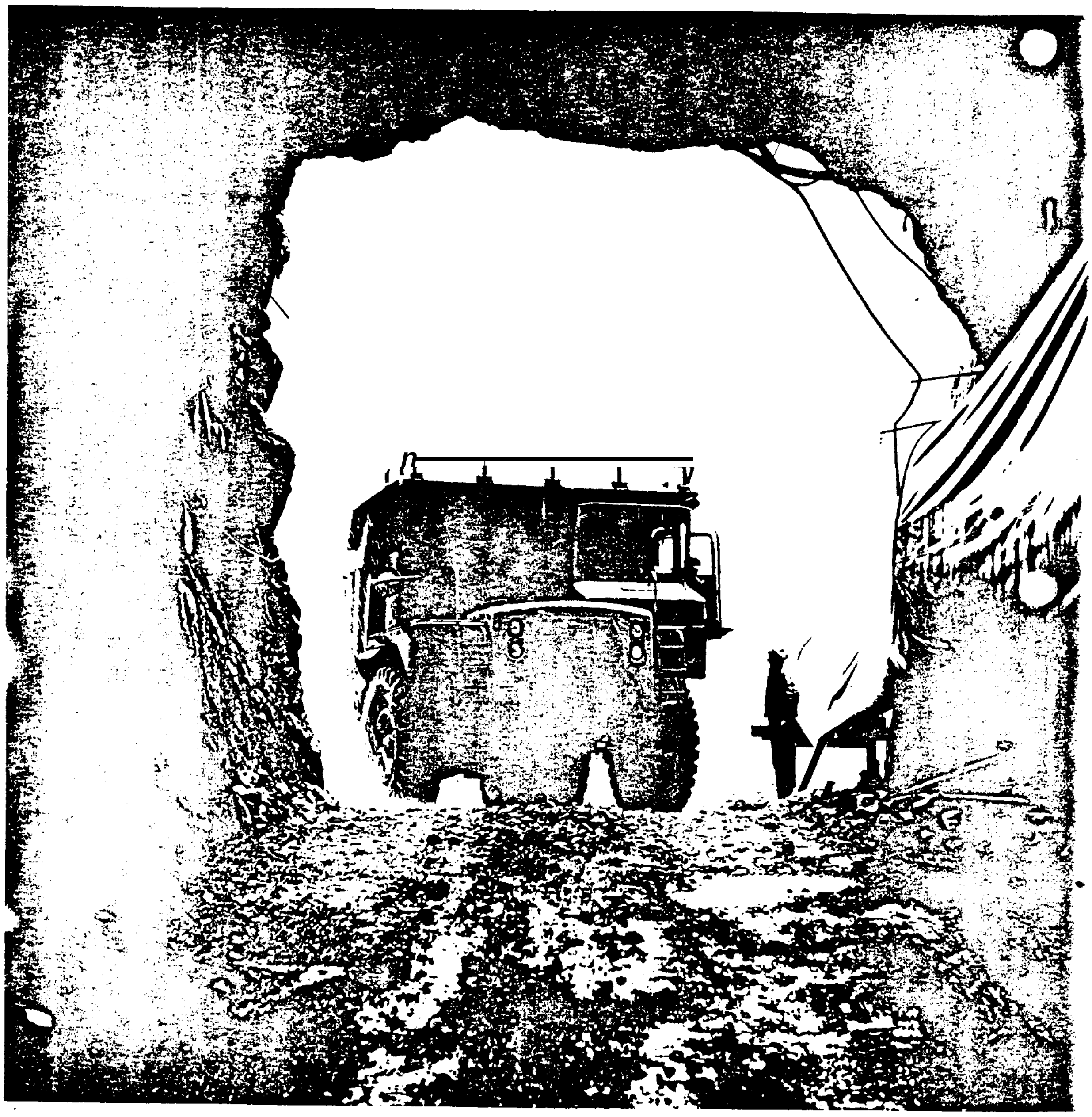


Figure 13

MINING METHODS

J.P. Franzen, P.Eng.



I. INTRODUCTION

The decision to develop a prospect into an Operating mine follows the discovery, delineation and evaluation stages of a successful mineral exploration program. In making a production decision, several factors will have been considered:

1. Ore reserves and grade.

2. Mining method(s) and rate(s).

3. Capital and operating costs.

4. Present and future metal prices.

5. corporate objectives and policy.

The purpose of this paper is to describe some of the principal metal-mining methods, their associated costs and when they should, or could be used.

Much of the material in this presentation has been excerpted from the SME Mining Engineering Handbook (1973) and the SME Underground Mining Methods Handbook (1982).

WRIGHT ENGINEERS LTD. kindly supplied mining cost data. The manuscript benefited from review by Bill Gilmore and Jim Leader, WRIGHT ENGINEERS LTD.

11. SELECTING A MINING METHOD

The criteria that enter into the choice of a mining method are derived from the following group of factors:

1. SHAPE, SIZE AND SPATIAL POSITION OF THE ORE DEPOSIT

The thickness, areal extent and attitude of ore deposits varies widely. A different method for extraction will prevail in the case of large, massive deposits in comparison to narrow vein deposits.

The location of the deposit in relation to the ground surface is another factor, generally defined by increased need for support of mine workings with increasing depth. Depth is, of course, a major factor in choosing an underground method over a surface-mining method.

2. SPATIAL DISTRIBUTION OF METAL VALUES

The grade of the ore has an important bearing on the selection of a mining method. A low-grade ore requires the adoption of a low-cost method, even though this may result in great ore losses. Conversely, if the ore is rich, a method resulting in maximum recovery at a higher cost of extraction, may be indicated.

If the ore minerals and their values are distributed uniformly throughout the major part of the deposit, the need for selectivity in mining vanishes.

Erratic mineralization, in the form of lenses and stringers in barren rock, may call for a selective method of mining, where stoping may be confined to the extraction of the lenses and stringers, to keep dilution at a minimum.

Deposits whose boundaries are not well defined, with values grading downward gradually into the country rock, require selective stoping methods, coupled with close sampling control, to define assay boundaries.

3. MECHANICAL PROPERTIES OF ORE AND COUNTRY ROCK

The applicability of the various mining methods depends fundamentally upon the degree to which the ore and wall rocks will stand unsupported, and how well the methods meet the requirements for ultimate support of the backs and the walls of the excavations.

In most mines, especially those operated over an extended period of time, mining methods and practices evolve gradually, to meet the local conditions.

4. ECONOMIC FACTORS

A mine cannot exist unless the value of the ore produced covers the cost of; mining, benefication, transportation, overhead expenses, capital amortization and interest, and leaves a reasonable profit after all expenses are met. Economic factors embrace all items of cost and product price, which may be broadly grouped into the following major categories: the direct cost of mining the ore, the cost of procuring and recovering the initial capital investment, the ability to generate cash flow to ensure self-perpetuation of the operation, and the character of the market in which the product will be sold.

The cost of producing a ton of ore is one of the largest, if not the largest single item in total mining and milling costs. It does not necessarily follow that low-cost stoping methods result in low-cost final products. A low-cost-per-ton mining method may so dilute the ore with waste that the combined cost of mining, milling and handling may be greater than the cost of using a more expensive stoping method. The choice of a "selective" vs. "non-selective" mining method is an important primary step in the decision process.

Capital requirements and rate of production are closely related. A large productive capacity necessitates a large capital expenditure. Low-grade orebodies usually require mining at high levels of production, to ensure low costs and profitable mining. This, in turn, requires a large capital expenditure.

While numerous variations of particular mining techniques have been developed to take advantage of local mining conditions , all share a common fundamental cycle: that is, drilling, blasting, loading and transporting.

The following sections describe the basic metal-mining methods.

III. UNDERGROUND MINING

1. INTRODUCTION

If the depth of an ore deposit is such that removal of overburden or waste rock makes surface mining unprofitable, underground methods should be considered. The problem of recovering the mineral from such a deposit is reduced to selecting or developing a mining system that is both safe and profitable. Figure 1 shows a simple layout of an underground mine.

2. ACCESS AND DEVELOPMENT

The access and development of an underground orebody has two purposes:

1) To obtain further and more detailed information as to the size and character of the deposit.

2) To provide access for stoping and transporting mineral.

Two problems are presented:

1) Mode of entry - which involves a decision between vertical shafts, inclined shafts, horizontal adits-

ramps, or any combination of these, as means of reaching the orebody from the surface.

2) Lateral or subsidiary development - which deals chiefly with the arrangement and location of workings within the orebody. This will be described later in this section.

The first underground openings in an orebody are often made during the advanced stages of a successful exploration program. These openings provide access to the deposit and allow the operator to establish vertical and horizontal headings from which detailed diamond drill (tonnage, grade), bulk sample (metallurgy, grade control) and rock mechanics (stability, mining method) information may be obtained. An experienced operator will attempt to size and position the openings so that they may be effectively used if and when the deposit is placed into production.

There are three principal methods of access to an underground orebody:

1) Shafts - vertical and inclined.

2) Adits - track and trackless.

3) Ramps - trackless and conveyor.

Any one or combination of these methods may be used at a particular property (Figures 1 and 2). Operators usually attempt to locate methods of access outside the ore zone. In this way, large blocks of ore are not tied up by the access excavations and unavailable for mining.

It is beyond the scope of this presentation to review all methods and factors in detail; however, some fundamental points are worth mentioning.

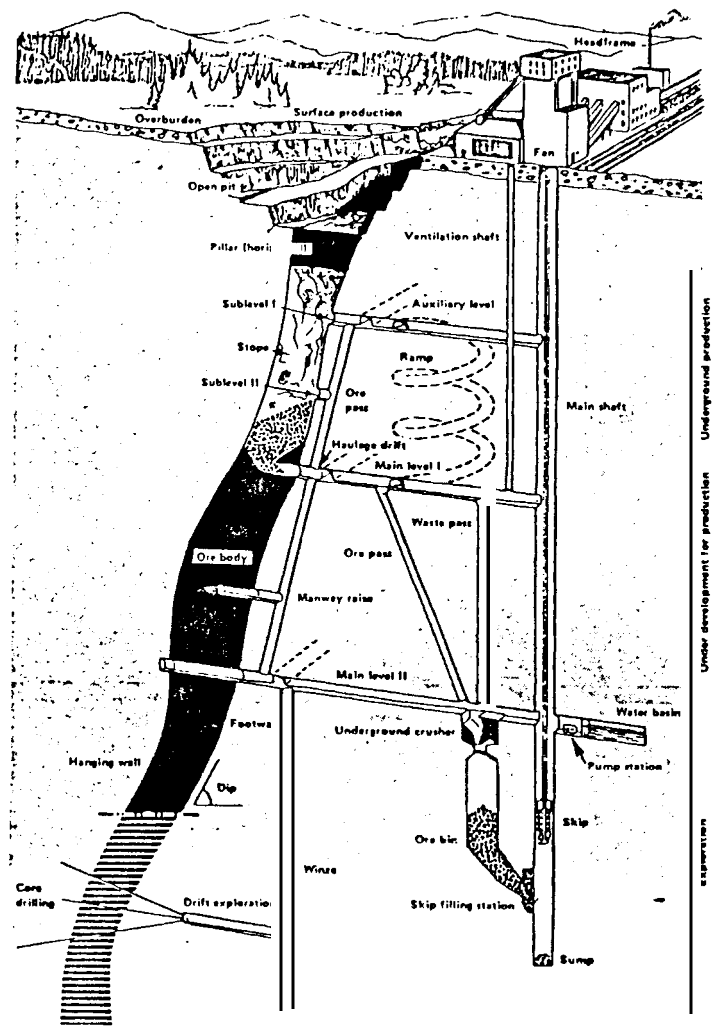


FIGURE 1

Sample layout of an underground mine, identifyi
various mining operations and terms.

A. Shafts

Shaft sinking is the most difficult type of underground excavation (Figure 3); it is also the most expensive - $6,000/metre for a major vertical production shaft. Shafts may be circular or rectangular in outline. As the shaft advances, the ground is supported by any one or a combination of timber, steel and concrete. Average advance in a major shaft is in the order of 100 metres per month.

The sizing of a shaft is a key factor since its capacity will limit the tonnage of ore and waste that can be hoisted to the surface each day. Some operators will sink a production size shaft to provide access for further exploration of the deposit; others may favor a cheaper, exploration shaft that could be slashed out or enlarged, should the property go into production.

Once underground excavations have been established on the property, additional shafts for ventilation, escapeway or production may be raise-bored (Figure 4A) or drilled (Figures 4B and 4C) to surface. In some instances, both methods are employed (Figure 5); raise-boring establishes a narrow pilot hole to surface, which is then enlarged by drilling and blasting. These "upside-down" shafts are called raises. Raising is the second most difficult type of underground excavation; it may also be used to provide exploration and development headings inside the orebody.

A shaft method of entry should be considered where the orebody shows strong continuity with depth, or where the orebody is deeply buried beneath cover rocks (Figures 1, 2 and 6). Shallow orebodies may also require shaft access if deep, wet overburden and/or bad ground conditions preclude the use of a ramp.

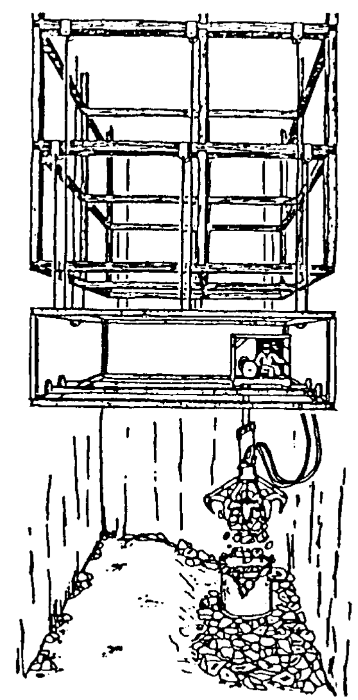


FIGURE 3

Cactus-grab mucker in a square shaft.

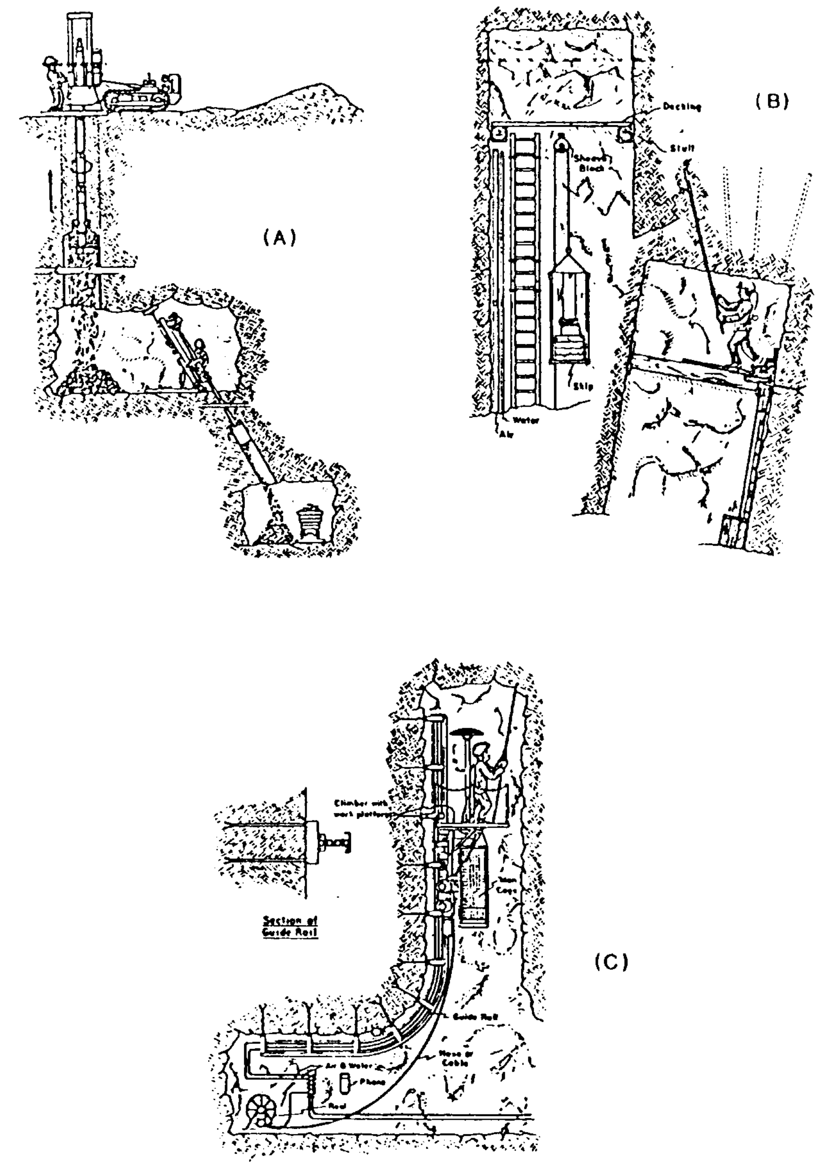
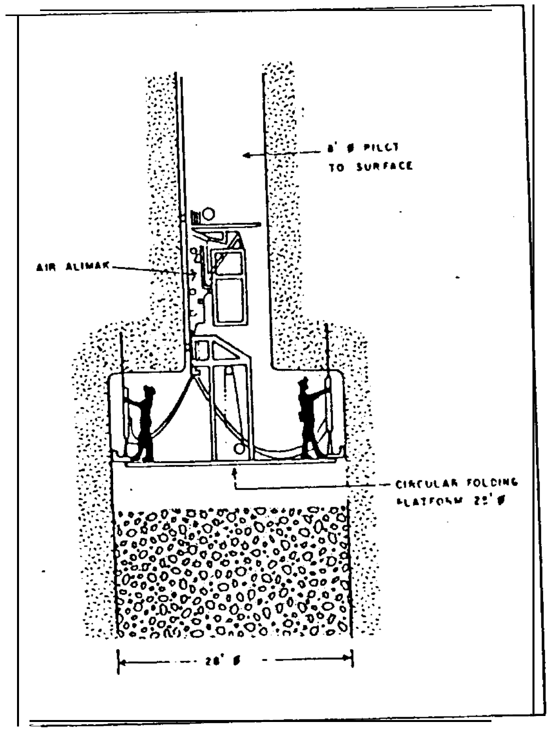


FIGURE 4

A. Inclined and vertical raise-boring

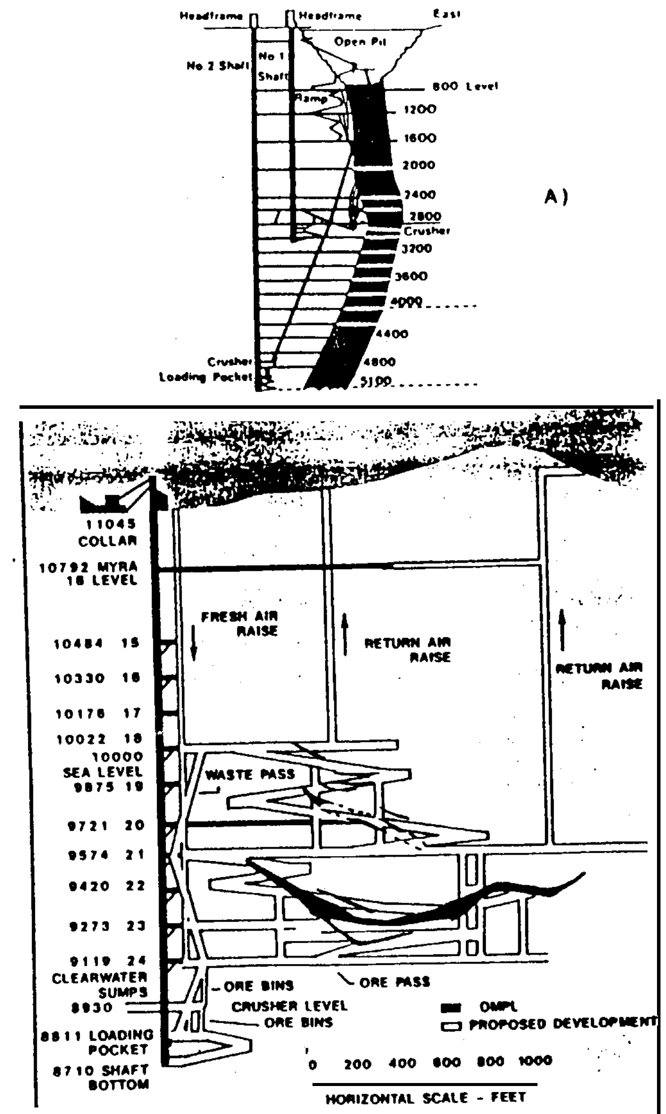
B. A raw or untimbered raise.

C. Raise development with an alimak raise climber.



Enlargement of a raise-bored shaft by drilling and blasting.

F GURE 5



A. CROSS-SECTION OF THE KIDD CREEK MINE.
B. CROSS-SECTION OF THE HW MINE - WESTMIN

FIGURE 6

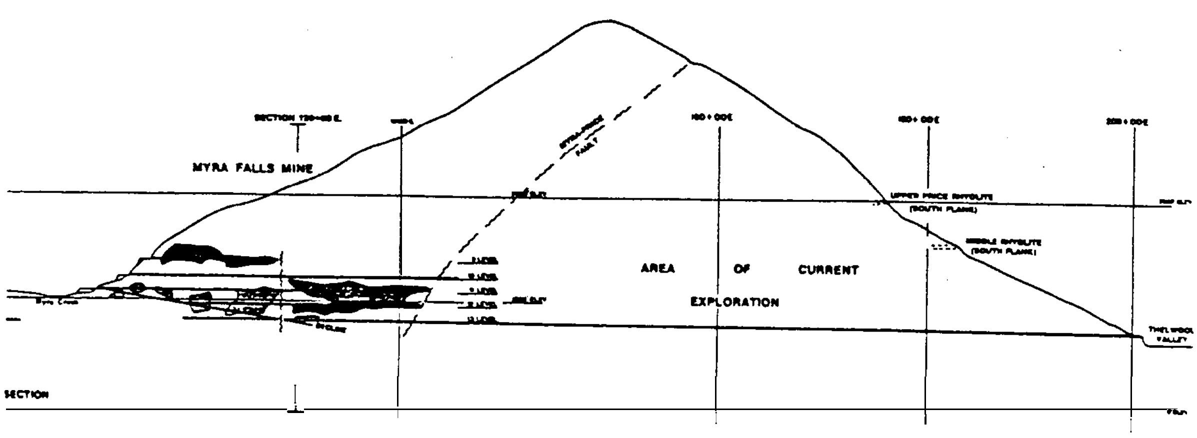
B. Adits, Crosscuts and Drifts

Horizontal tunnels can be driven faster and cheaper than shafts and ramps. Typical costs for a 4 metre by 4.5 metre, horizontal opening are in the order of $1500 per metre. The excavation may be free standing, but in difficult ground conditions, it will require support, such as; roof bolt mats, timber, steel or concrete-shotcrete. The amount of support required and the length of the tunnel are two factors to be considered when examining other methods of entry.

Tunnel entry is at its best in mountainous regions (Figure 7). A series of adits in rough topography can quickly open up sufficient areas of the orebody for production; natural ventilation is possible; and pumping of water is eliminated as the tunnel drains by gravity.

To secure economical handling of the broken ore, haulage drifts and crosscuts should be relatively straight or change direction by easy curves, and should be driven on a regular grade. Haulage may be by tracked equipment, conveyor belts or rubber-tired haulage equipment.

Typical tunnel advance in a mechanized mine is in the order of 7 metres per day on a three-shift basis.



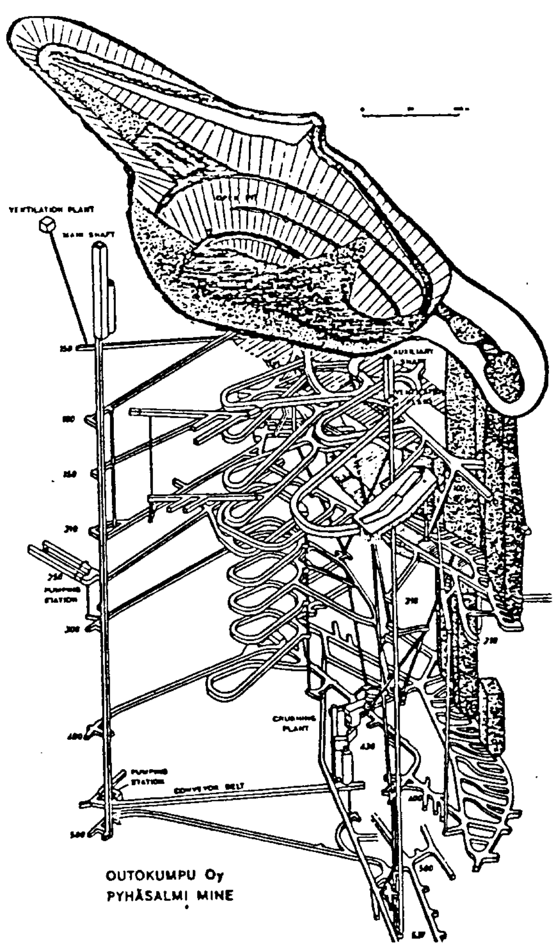
LONGITUDINAL SECTION OF THE MYRA FALLS MINE - WESTMIN .

FIGuRE 7

c. Ramps

Many recently discovered deposits near to the surface have been accessed, explored and developed by a framework of ramps (Figure 8) . These excavations allow the use of large, mobile, rubber-tired drills, loaders and trucks, with their attendant high productivity and lower maintenance and labor costs. In short, these openings allow open pit equipment to work underground.

To reach a common vertical distance, a ramp must be



Isometric View of the Pyhasalmi mine (Outokumpu) showing ramp development.

FIGURE 8

considerably longer than a vertical shaft (Figure 8). In spite of this difference in length, a ramp is often the most cost effective method for initial access to an orebody. Advance is in the order of 7 metres per day on a three-shift basis. Ramp excavations commonly measure 3 metres high by 5 metres wide and may attain grades of 15%. Ground conditions must be good, as the most cost effective excavations are-free-standing, or require little support. Equipment selection is governed by an economic haulage distance, which depends upon size of payload, speed at which the vehicle operates and grade of the haulageway.

Ramp mining methods allow rubber-tired equipment to move from level to level under their own power without being disassembled for moving. It is common practice to service and maintain the equipment underground.

3. STOPING-SELF-SUPPORTING METHODS

Self-supported openings are openings in which the loads are carried on the sidewalls or pillars of unexcavated rock. The size of the opening that can be excavated will depend on the type of rock materials that comprise the sidewalls and pillars. The unsupported span may range from a few metres to tens of metres.

A. Sub-level Open Stoping

Sub-level stoping is a large production open stoping method that normally is confined to fairly regular orebodies, where both the ore and country rock require little support during mining activities. The method is characterized by a comparatively high development to stoping ratio, which is compensated for somewhat by the fact that the majority of the development is in ore.

On a production cost-per-ton basis, sub-level stoping is one of the lowest cost methods available.

The two basic requisites of an orebody using sub-level stoping are size and strength. Since the sub-level system creates large openings that remain unfilled without support during the life of the stope and are subject to repeated seismic shocks from large blasts, the rock must be structurally stable. Wall failure in a stope may not only jeopardize the stope itself, but also cause serious dilution of the ore being drawn from it.

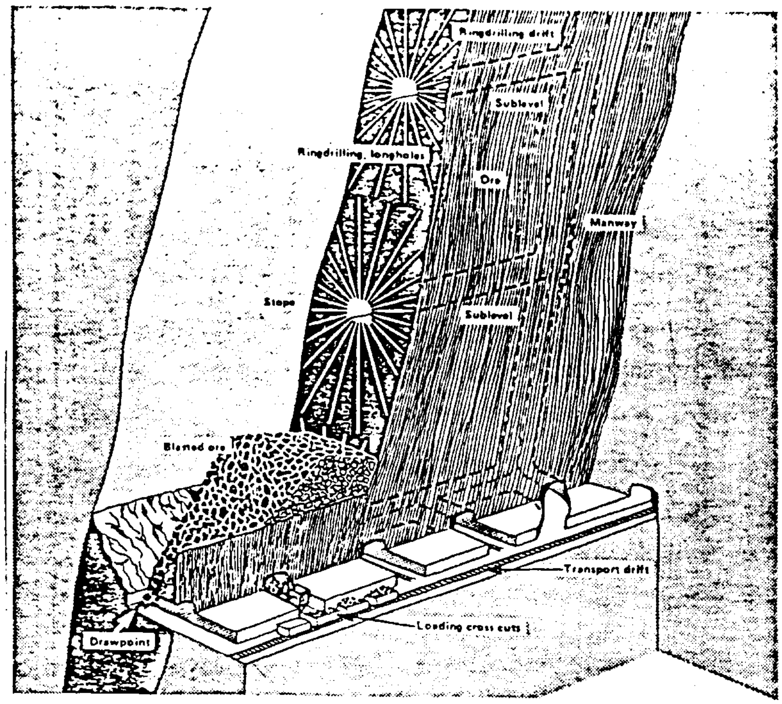
Long-hole (5 cm) fan drilling (Figure 9) or large diameter blast-hole drilling (15 cm diameter) from sub-levels (Figure 10) are the most common sub-level stoping techniques in use today. Stope drilling is commenced at the lowermost sub-level and if more than one sub-level exists, they all will be drilled prior to blasting. To enable the blasted ore to fall free, the lowermost sub-levels are blasted first. The ore is pulled from the drawpoints by slusher or LHD equipment, for transport to the mill.

The large amount of stope development (requiring a high capital outlay) is offset by the fact that most of it is in ore and the actual stoping operation is very efficient, particularly in wide stopes. Recovery may be as high as 90% where pillar recovery is practiced, often with little dilution.

Operating examples of sub-level open stope mining include: Into and Falconbridge mines in Sudbury.

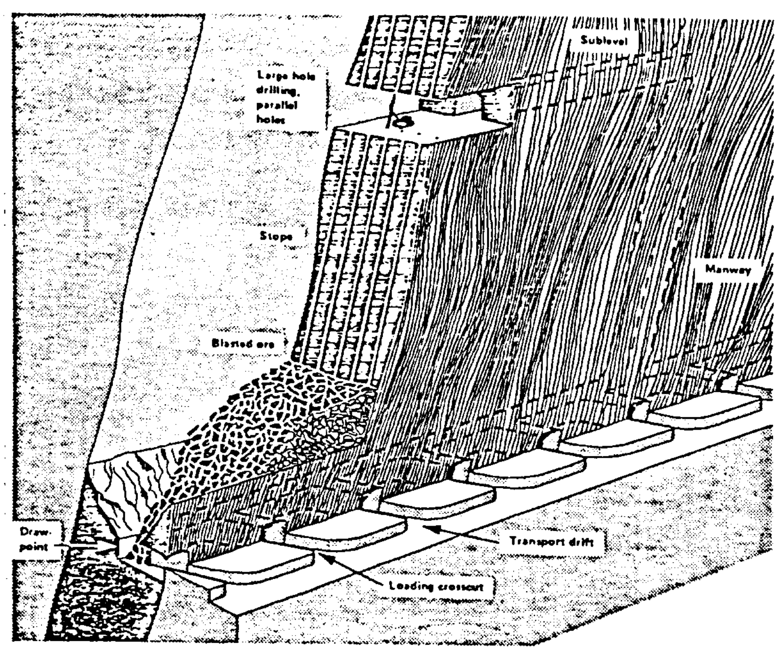
An average mining cost for the sub-level open-stoping method is $8.50/ton.

Production rates range from 1000-5000 tons/day.



Sub-level stoping with ring drilling as a primary means of breaking ore.

FIGURE 9



Sub- level stoping with large - hole drilling and blasting.

FIGURE 10

B. Vertical Crater Retreat Mining (VCR)

VCR is a large-production, cost-effective stoping method that uses large diameter (16 cm) blast holes. The basic principles behind VCR and sub-level open stoping using large diameter blast holes are similar. These include:

1. Develop a stope by excavating a regularly spaced series of sub-levels along its strike length.
2. Drill a series of large diameter longholes from. the sub-levels downwards to the limits of the orebody (Figure 11) and
3. Load the holes and blast.

There are, however, several significant differences:

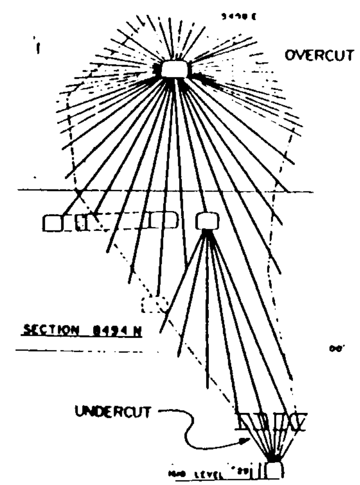
1. In an ideal situation, drill levels in a VCR stope may be up to 100 metres vertically apart. Comparable drill levels in a sub-level stope are in the order of 20 metres vertically apart. Precision drilling of large diameter VCR holes allows the longer holes to be successfully completed and loaded.
2. The VCR stope is brought up blast by blast with the back kept level at all times (Figure 11B). A sub-level stope normally has a stepped back.

The major advantage of VCR over sub-level stoping is one of cost. VCR results in an appreciable saving in development work - few drilling sub-levels are needed - and there is an overall reduction in the consumption of powder for secondary blasting of oversize and at draw-point hang-ups.

Broken ore falls into a void created by previous blasts; the broken material is extracted from numerous draw-points at the haulage level (Figure 11B).

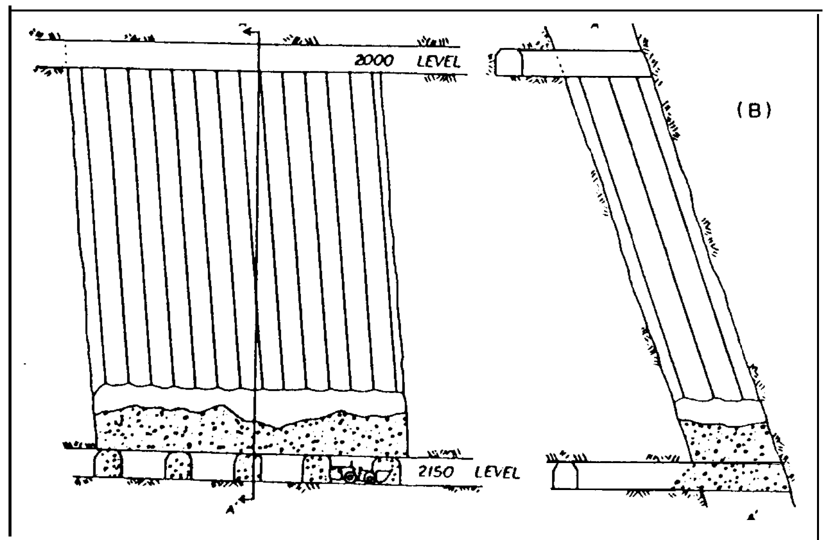
Operating examples of VCR mines include: Strathcona Mine, Falconbridge, Ontario.

The average mining cost for the vertical crater retreat method is $6.50/ton.



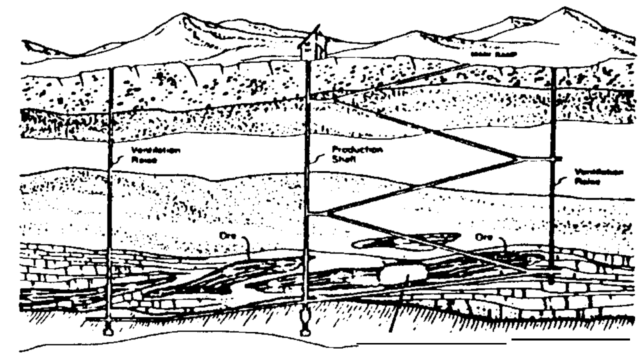
a

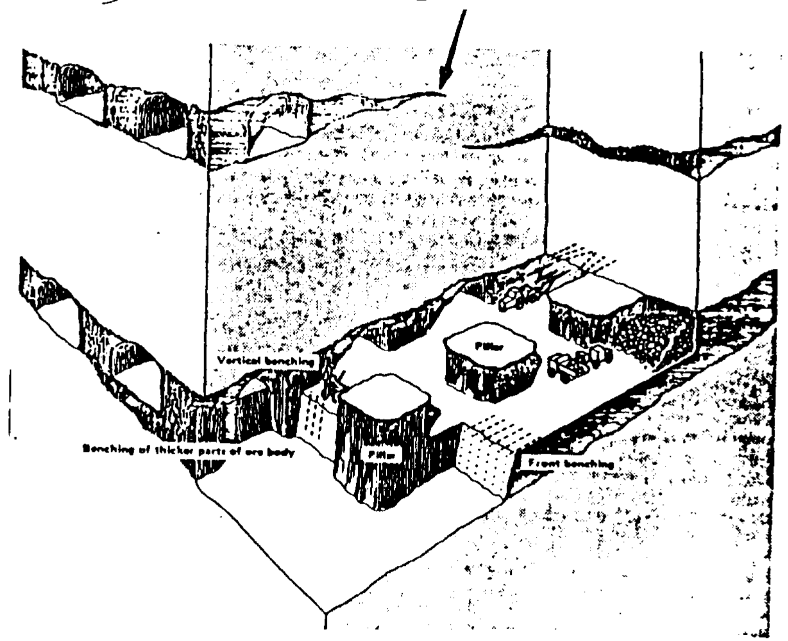
A. TYPICAL VCR STOPE CROSS-SECTION SHOWING DRILL HOLE LAYOUT AT COPPER MINE (HBMS).



B. TYPICAL VCR STOPE LONGITUDINAL SECTION SHOWING DRILL HOLES, FLAT STOPE BACK AND BROKEN ORE AT DRAW POINTS.

FIGURE





MECHANIZED ROOM AND PILLAR OPEN STOPING N A FLAT-LYING OREBODY

F GURE 2

Production rates range from 500-5000 tons/day.

C. Room and Pillar

Generally, a mineral deposit of considerable areal extent cannot be mined as a single unsupported open stope or excavation. To maintain stability, support is required within the limits of the deposit. 'If this method of support is attained by leaving areas of un-excavated ore or waste, the system of mining is referred to as room and pillar open stoping. The flat-lying zinc mines in eastern Tennessee, the lead-zinc mines in the Tri-State district and the Troy Mine in Montana all employ pillared open stopes.

Regular pillar systems are employed in deposits of considerable areal extent, in which the ore grade and ore thickness are relatively uniform. Pillars have a uniform size, cross-sectional shape and spacing (Figure 12). The span will depend upon the quality of the roof rock. If it is massive, openings with spans up to 30 metres may be mined. In fractured rock, spans from 15 to 30 metres are not uncommon. In bedded rock, in which the roof has formed as a parting, the roof span will depend upon the thickness of immediate overlying beds.. The average extraction of available ore is in the 60-80% range.

Open stoping with pillars that are randomly spaced and/or random in size is used in mining larger pockets or lenses of ore, especially if the ore grade and/or thickness of the deposit is variable. Wherever possible, the pillars are left in leaner ore or waste. If ore is high-grade, pillars are usually extracted in final mining.

Room and pillar mines are generally highly mechanized. Self-propelled, twin-boom jumbos and large capacity rubber-tired haulage equipment are standard equipment. The load-haul portion of these operations is typically most expensive, with the costs gradually increasing as mining advances and the haulage distances become longer. When haulage distances exceed the economic limit of the LHD units, the muck is transferred to large trucks.

The average mining cost for the room and pillar open stope method is $9.12/ton.

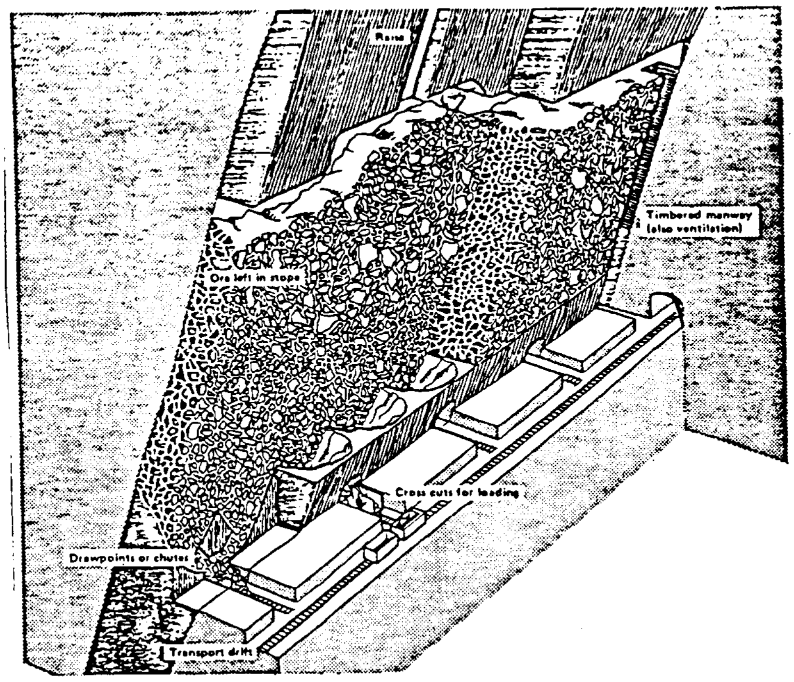
Production rates range from 1500-11,000 tons/day.

D. Shrinkage Stoping

Shrinkage stopes are stopes in which broken ore is used for a working platform and to support the walls of the stope (Figure 13). As broken rock requires a larger volume than solid, some muck must be drawn off as the stope advances. Hence the name "shrinkage".

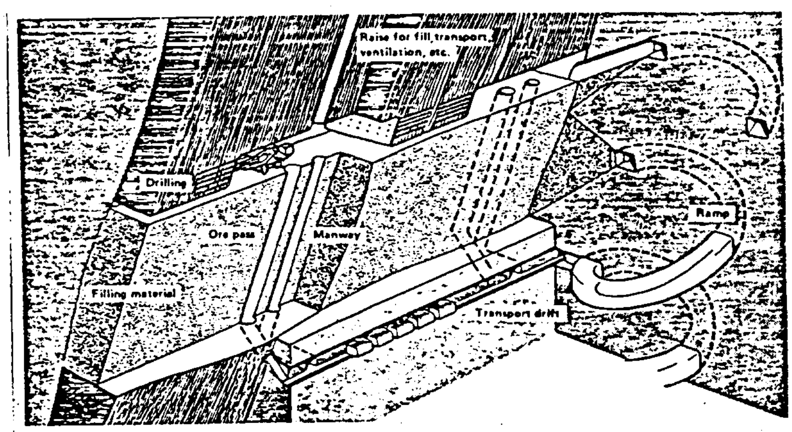
Shrinkage stopes are most used in steeply dipping vein-type deposits where the ore is strong enough to stand with no support, and the walls with very little. Slabbing and minor weakness in the country rock can be tolerated as long as resulting dilution is not a serious problem, but severe slabbing will plug the drawpoints and squeezing will bind the broken ore in place. Ore must be strong because it is uneconomical to support the back.

Once the stope has been prepared, stoping is relatively straightforward. Almost without exception, stopes are mined overhand with a relatively flat back. In small stopes, the back may have a stepped profile. The value of waste pillars is questionable, but they may be used in holding a weak hanging wall. Pillars should be placed between pockets so as to hinder draw as little as possible. When excess muck is drawn, care must be taken not to draw off too much, or staging must be erected to drill the back.



Shrinkage stoping in a large vertical orebody.

FIGURE 13



Cut and fill mining in a large vertical orebody.

FIGURE 14

Shrinkage stopes represent a large broken reserve and can be used to smooth feed tons and grade to the mill and quickly increase production, to take advantage of markets.

Operating examples of shrinkage stope mines include: gold mines in West Australia, tin mines in England and parts of the Creighton Mine, Ontario.

The average mining cost for the shrinkage stoping method is $35.00/ton.

Production rates range from 500-1100 tons/day.

4. STOPING SUPPORTED METHODS

A supported opening is one in which a significant part of the incumbent load is carried on artificial support systems, such as timber and backfill.

A. Cut and Fill Stoping

A filled stope is one in which ground support is provided by some form of waste material. Filling, therefore, is an integral part of the stoping process.

The orebody is extracted in small sections, which are partially or completely filled before adjacent ore is extracted (Figure 14) . The waste material is called fill or backfill. The most common forms of fill are waste rock, sand or gravel, and tailings. Timber, when used, is for temporary support of the walls or back and is not necessarily systematic.

In most filled stopes, progress is upward (Figure 14) . Supported openings are extended through the fill for access , ventilation and ore removal. Stope characteristics, however, are variable. The size of the section mined before filling depends on the strength of the ore and wall rock. The ore-removal system varies with the properties of the fill, equipment available and overall economics.

The most common applications for filled stopes are in steeply dipping orebodies with restrictive dimensions and weak walls, where complete extraction or selective mining is desirable.

Traditional filled-stope methods have been considered relatively expensive methods, with low output. However, post-filling of open stopes have made filled stopes considerably cheaper. Productivity in mechanized operations approaches. that of room-and-pillar mining.

Advantages of filled stoping methods include:

1. Ground stability is maintained.
2. Low dilution with good recoveries of ore is possible, and waste that must be mined frequently can be left in a stope.
3. Ore can be removed as it is broken, which minimizes adverse chemical reactions and provides early return on the expenditure required in mining the stope.

Inherent disadvantages to the method include:

1. Stope production is not easily varied and stope output is irregular because of the intermittent breaking of ore as a result of the fill cycle.
2. Backfill must be provided as required.
3. Mining costs are increased by filling.

Operating examples of cut and fill mines include: Myra Mine (Westmin); various Inco mines, Sudbury, Ontario.

The average mining cost for the cut and fill stoping method is $27.00/ton.

Production rates range from 500-1100 tons/day.

B. Square Set and Fill Stoping

In square set stoping, small blocks of ore - a 2 metre by 2-metre square set is approximately 20 tonnes - are blasted, extracted and timbered before the next set or section is taken (Figure 15). A set of timber consists of a vertical post and two horizontal members mutually at right angles and known as a cap and a girt. The timber is sawed to fit interlocking ends of adjoining timbers (Figure 15). Successive sets 'are installed to form a complete cellular timber support structure. Adjoining timber sets are framed to support the ground and form a continuous structure of horizontal floors composed of rectangular frames supported at their corners by posts. The stope is generally filled with waste rock.

Square-setting is applicable to many situations and is commonly used under the following conditions:

1. Recovering highgrade pillars between cut and fill stopes and above and below access drifts.
2. Mining orebodies in incompetent or heavy ground which is too narrow, too flat or too irregular for caving.
3. Mining highgrade orebodies where ore losses and dilution in caving are not acceptable.

This method of stoping has declined due to increasing cost of labour and materials, declining reserves of ore at a high enough grade to support these costs and the development of hydraulic sand-fill methods which provide better support and VCR pillar recovery methods.

Operating examples of square set and fill mines include: United Keno Hill Mines, Yukon.

The average mining cost for the square set and fill stoping method is $70.00/ton.

Production rates vary from 2OO-11OO tons/day.

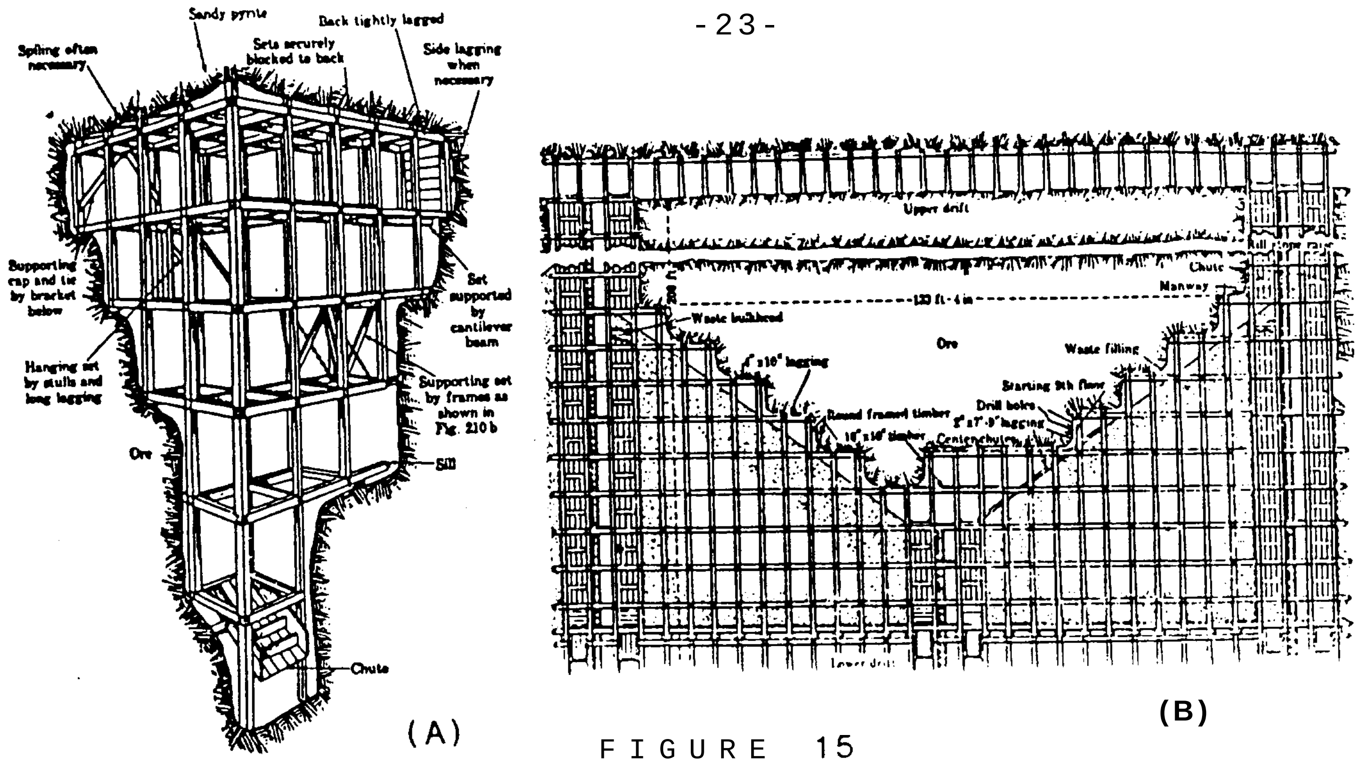


FIGURE 15

A. A square set stope.

B. The square set system.

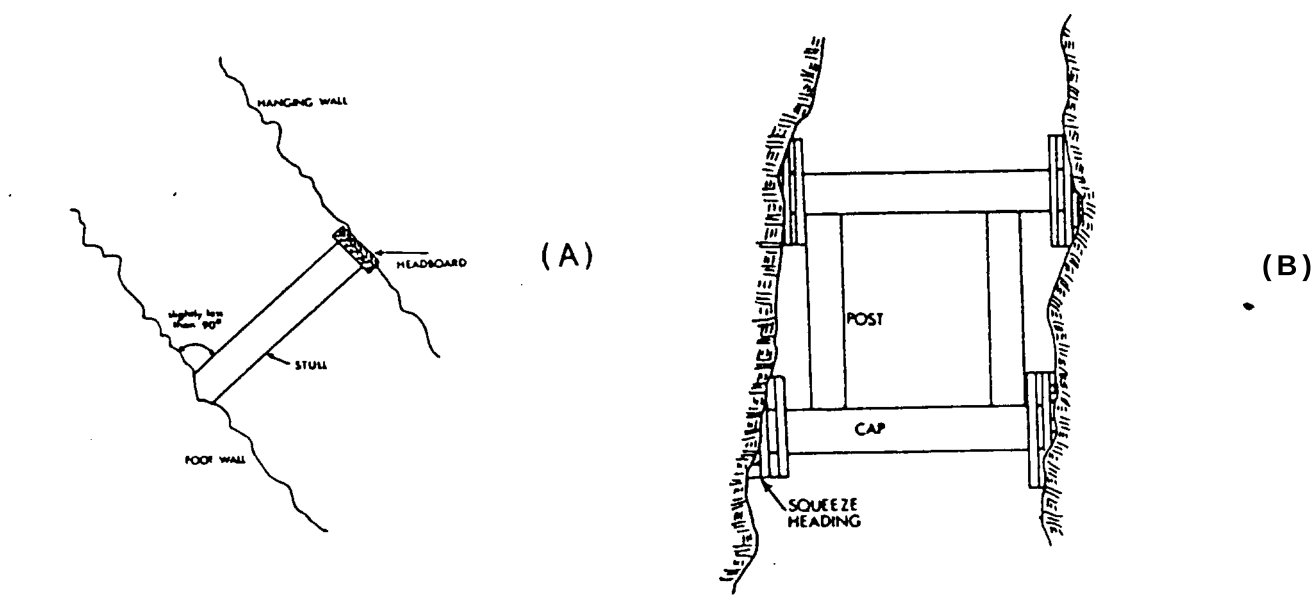


FIGURE 16

A. Single stun without post - cross section.

B. Stun and fill - supported stope - cross section.

C. Stull Stoping

Setting timbers from the hanging to footwall of the vein is the approach in stun stoping (Figure 16) . It is employed only in narrow veins where the span can be covered by a single timber of reasonable size and may be used with or without fill. In some cases, pillars are left to help in support of the hanging wall.

The objective of the stun method is to transfer sufficient load from the hanging wall to the footwall, to prevent collapse of the hanging wall during the mining operation. A secondary consideration is providing a foundation for the miners to work from and support floors needed to prevent spilled or loose rock from falling where the men may be working.

Where steady and continuous closure exists, squeeze blocks are installed in conjunction with the stuns, to prevent breakage of the stuns before mining is complete. These blocks will crush slowly, allowing the walls to move without damaging the stuns, while still providing support.

Stun stoping permits broken ore to be removed by gravity or, under certain conditions, slushers or scrapers may be used.

The stun stoping method is best used where:

1. Ore bodies are small and it is not practical or economical to provide a method of filling.
2. Ore is irregularly distributed in the vein and permits removal of highgrade sections, leaving the lowgrade and barren areas behind for support.

Operating examples of mines using stun stoping include: United Keno Hill, Yukon; tin mines in England.

The average mining cost from stun stoping method is $30.00/ton.

Production rate ranges from 100-1000 tons/day.

5. CAVING METHODS

Two caving methods are generally recognized: Sub-level Caving and Block Caving. In all cases, the general requirements for use of the method are massive-type mineral deposits of large horizontal area, such as thick beds, massive or wide veins.

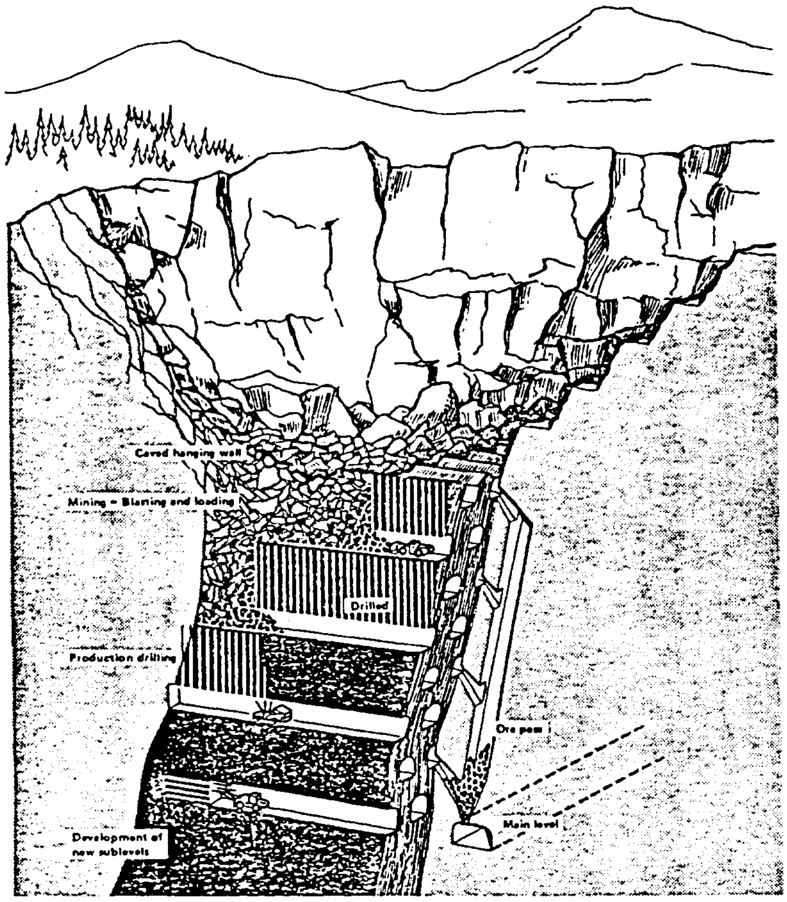
The rock materials, due to the fracture pattern, should cave when support is removed from a sufficient area. Overburden must cave and follow the ore down as it is removed. The method is most applicable to large, lowgrade deposits.

A. Sub-level Caving

Sub-level caving is a high-production method combining a minimum of labour and a high degree of mechanization. The method is most suitable for massive and steeply inclined medium width orebodies.

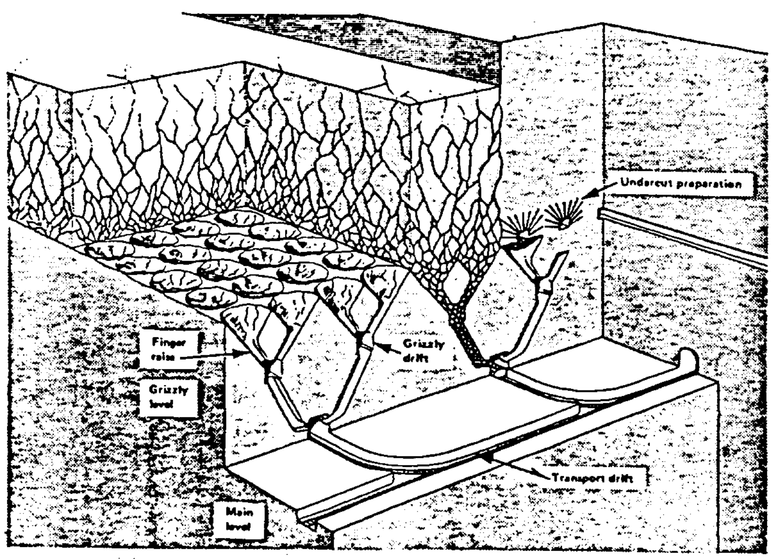
Basically, the stoping procedure consists of driving , a series of sub-levels commencing at the top of the orebody (Figure 17) . A starting vertical slot is cut " and then a series of ring patterns drilled and blasted, the broken ore being drawn off after each blast. The capping must cave and follow the ore down during the drawing off procedure, to localize the broken ore and to avoid serious weight problems and the possibility of dangerous collapse airblasts. Some dilution of the ore is inevitable with the method, and careful draw control must be exercised if a portion of the ore is not to be lost. Ore recovery and dilution under controlled conditions compares with that obtained from block and panel caving.

Some major advantages over open stoping methods in strong orebodies are the reduced labor requirements and no



Sub-level caving in a large and steeply dipping
orebody.

FIGURE 17



Block caving in a massive orebody, showing the
conventional mining layout.

FIGURE 18

pillars to be recovered or stopes to be filled. practice dictates that where high ore recoveries are required, these will, of necessity, produce high dilution. Optimum operations at present show from 15 to 20% dilution with an 85 to 90% ore recovery.

Examples of mines using sub-level caving include: . Craigmont (Placer) and Granduc (Esso) .

The average mining cost for the sub-level caving method is $15.00/ton.

Production rate ranges from 5000-15,000 tons/day.

B. Block Caving

Block caving gives a lower mining cost per ton than any other underground method. It requires a relatively large capital expenditure for preliminary development, and basically is for large-scale work.

Requirements, besides those common to all caving methods, are suitable orebodies. They must have enough horizontal area to cave freely and without excessive dilution by waste rock from sidewalls. Large, massive deposits meet these conditions. Veinlike deposits must be wide and dip rather steeply. Ideal conditions are strong walls, from which ore parts easily. Capping must cave when underlying ore is dropped. Weight of overburden is beneficial as an aid in crushing the ore.

Block caving is not a selective method, as underground sorting is not feasible. Therefore, a fairly uniform distribution of values in the orebody is necessary. Outlines of the orebody should be fairly regular. Small extensions of ore into walls are not recovered and low-grade inclusions in the ore cannot be left unmined. Some dilution and loss of ore are inevitable in block caving. Their amounts effect the economic minimum and maximum grades of ore, to which the method is applicable.

Main haulageways and draw points are constructed below the block to be caved (Figure 18). The block is undercut and permitted to collapse. The material "caves" from the bottom of the block. Broken material is drawn off and the caving of the mass progresses upward through the ore. If rock is drawn faster than the ore caves, a void will be created that could result in a dangerous situation. The uncaved portion, or a large part of the uncaved portion, might drop as a block, causing a destructive airblast through the extraction opening.

Ore recovery is generally in the 80-100% range; dilution varies between 10 and 20%. Ore caves and crushes by its own weight and that of the overlying capping into pieces of suitable size for handling. Oversize pieces must be blasted to pass through drawpoints. Caving usually extends through the overburden to the surface, with the overburden subsiding as the underlying ore is removed. Draw continues until the ore values of the material from the drawpoints decrease to a predetermined limit. Cutoff points can be determined by assay and visual inspection.

The average mining cost for the block caving method is $6.00/ton.

Production rates range upward to 40,000+ tons/day.

6. PRODUCTION AND COST SUMMARY

The following tables are intended to show the range of both capital expenditures and operating costs that might apply to underground mines. These costs are very general and intended only as a guide. They are based on costs for base metal mines located in areas with good access and infrastructure and no adverse climatic, or geologic conditions. Examples of such mines are the Westmin operation on Vancouver

Island and the now defunct Craigmont mine in central B.C.

The sizes of operation shown in the examples range from a very small mine producing less than 500 tonnes of ore a day, to an extremely large underground caving operation capable of producing 15,000 tonnes every day. The grade of ore will vary tremendously from mine to mine and for each stoping method.

A. Capital Expenditures

Table A shows how the capital expenditures vary for some different sizes of mine, and different methods of stoping. The costs have been broken down into different parts of an operation. These figures represent average capital expenditures for a mine located in a favorable area. Mines in remote or hostile areas will require larger expenditures of capital.

In each case, mine CAPEX costs are approximately 30% of the total CAPEX cost.

B. Operating Costs

Table B lists some typical operating costs, including the sizes of operation shown in Table A. The total operating costs in the right hand column include: mining, milling, administration and general overheads.

The mining costs are divided into the major activities of Development, Stoping, Haulage and Hoisting. The General category includes pumping, ventilation, general administration, surface costs and administration.

Costs vary widely for mines using the same type of stoping method. The table is based on an average of many operations and assumes that the stoping method is the major one used.

TABLE A

EXAMPLES OF TYPICAL CAPITAL EXPENDITURES FOR UNDERGROUND MINING

1984 DOLLARS CDN X 10^6

T.P.D. Ore	Site, Access & Buildings	Mine	Mill	Power, Water & Tailings Disposal	Work Capital	Admin & Eng.	Int. 10%	Total
500	3.85	13.22	11.08	3.71	2.87	5.26	5.00	44.99
1000	4.26	17.15	13.36	4.25	3.51	6.24	6.10	54.88
1500	4.67	19.94	13.82	4.78	3.69	6.91	6.75	60.76
5000	7.17	33.33	26.58	8.11	6.77	11.19	11.65	104.82

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TABLE B

TYPICAL UNDERGROUND OPERATING COSTS - BASE METAL

Mining Method	T. PD.	Tons Per Manshift	Cost Per Ton of Milled Ore: Development	Stoping	Tramming Hoisting	General	Total Mining	Total cost
Square Set	<500-1,100	10	7.0	50.0	4.0	14.0	70.00	126.00
Shrinkage	<300-1,100	16-24	3.2	18.5	6.3	7.0	35.00	65.00
Cut & Fill	1,000	12-30 conventional 33-30 mechanized	3.0	11.3	4.0	8.7	27.00	50.00
Room & Pillar	1,500-11,000	32-64	0.9	4.3	1.19	2.70	9.12	25.00
Blast-Hole	5,000		1.3	2.0	.70	4.50	8.5	18.5
Block Caving	15,000	130-300	1.8	1.0	1.26	1.92	6.00	12.6

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Most mines employ a number of stoping techniques to suit the shape and ground conditions of various parts of their orebodies. The range of production for each stoping method varies widely, and the table indicates some ranges. In general, Table B is ordered in decreasing cost for each type of stoping, and this 'somewhat aligns with an increase in production rate.

Total mining costs are approximately 50% of the total operating cost. An increase in tons per manshift (productivity) is reflected in a substantial decrease in comparable total mining costs.

Table C shows the relative percentages of mining costs broken down into the various activities for each stoping method. It must be stressed that these are average values only. In highly mechanized operations (cases 7,8 and 9), stoping costs are generally lower than in labour intensive operations (cases 1 to 6). Deve lo-pment costs tend to be higher in the mechanized operations.

TABLE C

TYPICAL % VALUES OF uNDERGROUND MINE OPERATING COSTS

RATE (TPD) ACTIVITY	200-1000+ 1	2	220-1000+ 3	4	90-1200 5	200-1500 6	1s00-10000 7	1s00-10000 8	10000+ 9
Development	13	12	11	11	9	9	10	15	30
Stoping	58	64	42	66	53	60	47	24	17
Tramming and Hoisting	9	a	15	7	18	13	13	7	21
General	20	16	32	16	20	18	30	53	32
TOTAL	100		100		100	100	100	100	100

1) Square set open stopes
2) Square set filled stopes
3) Cut and filled stopes
4) Under hand cut and filled stopes
5) Shrinkage stopes
6) Top sliced stopes
7) Room and pillar stopes
8) Sub-level open stopes (Blasthole and VCR)
9) Block caving stopes

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IV. OPEN PIT MINING

1. INTRODUCTION

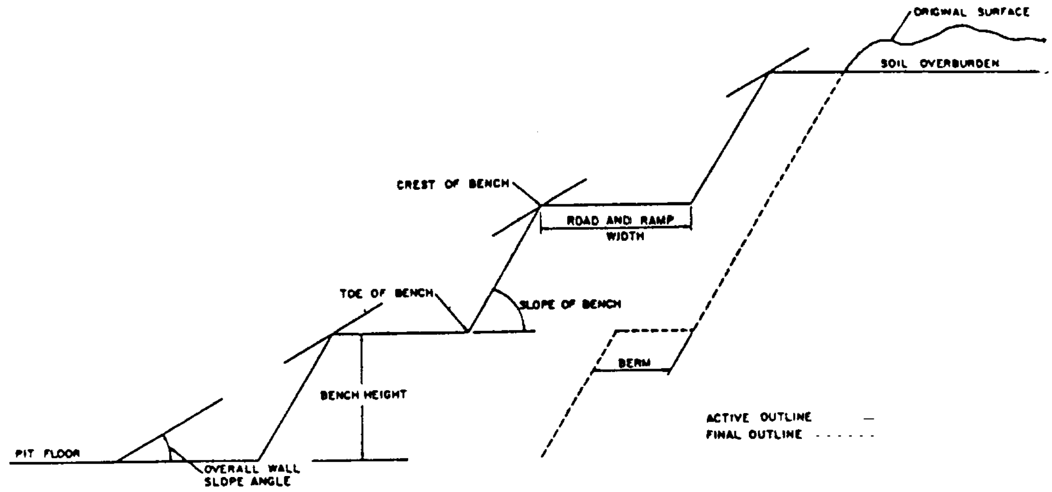
Open pit mining can be employed in any mineral deposit in any rock type lying near or on the surface. The excavation is open to the sky and weather. Some predominant advantages are inherent in open pit mining; first, it is flexible, allowing for large fluctuations in production schedules at short notice, without undue deterioration of workings; second, the method is safe. Loose material can be seen and removed or avoided, and crews can be readily observed at work by supervisors. The relatively small number of men employed contributes to safety because small crews are more easily trained in safe work practices; third, selective mining is possible without difficulty. Grade control can be easily accomplished by leaving lean sections temporarily unmined, or by removing waste; fourth, the method permits high rates of production that results in low unit costs. These costs are often a fraction of the cost of underground mining.

The method is best suited to orebodies with substantial horizontal dimensions and little or no overburden cover. Open pit nomenclature is shown on Figure 19.

The mine is developed by excavating rock along a series of regularly spaced, horizontal lifts or benches. Access roads and ramps connect the benches and allow haulage trucks to remove material from the deepening pit.

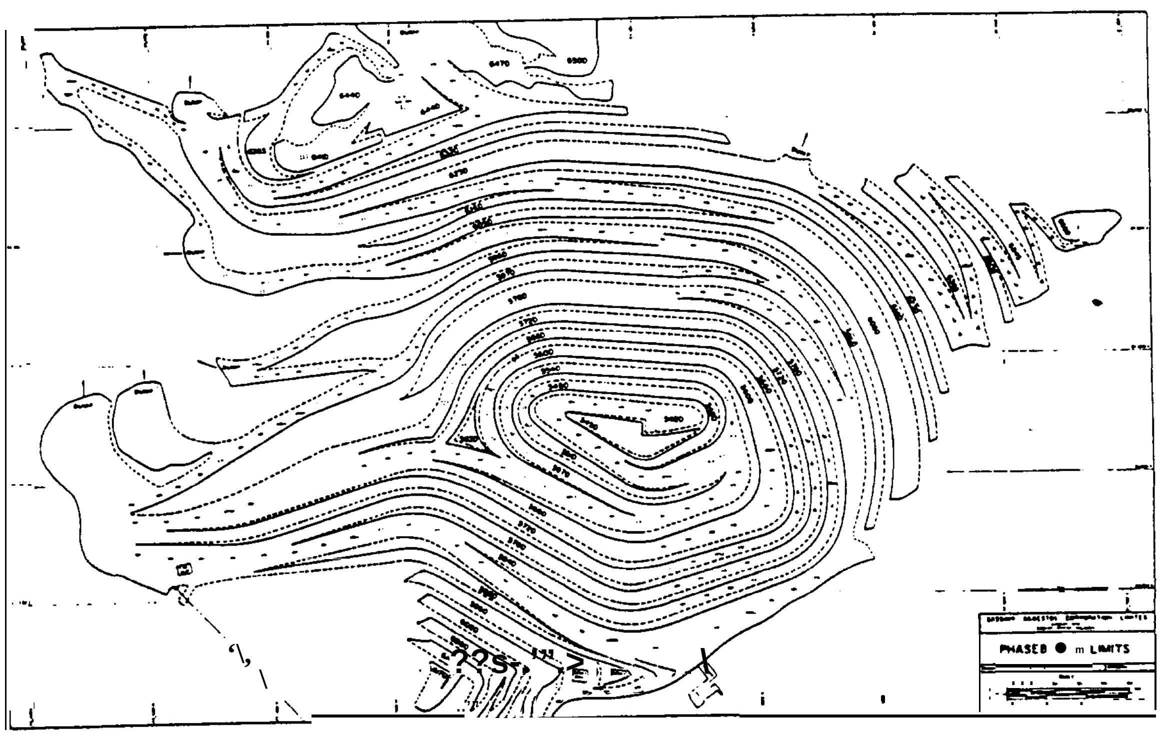
2. PLANNING AND PIT DESIGN

One of the first steps in the development of an open pit mine design is building a computer-based mineralization inventory. Such an inventory is, in effect, a complete model of an orebody which describes the topography, geology, mineralization of the orebody.



Typical open-pit profile with nomenclature.

FIGURE 19



TYPICAL PIT PLAN SHOWING BENCH ELEVATIONS AND ROAD LAYOUT.

FIGURE 20

The orebody is subdivided into a set of blocks or small regularly shaped unit volumes (Figure 21A) . Each block is assigned an X,Y,Z co-ordinate. Physical characteristics pertinent to the analyses are assigned to each block. These characteristics may include grade, rock type, metallurgical characteristics (i.e. oxide or sulphide) and rock mechanics information. A pit optimization computer programme exam-ines all these data and determines the shape of an economic open pit (Figure 20). The results of this pit outline are printed out bench by bench, giving bench tonnages and grade of ore, tons of waste and overburden, and the cumulative stripping ratio (Table D) . A range of anticipated metal prices can be used in determining cutoff grades and the pit optimized for each.

Once a long-range open pit mining plan has been established, it is essential to develop a series of short-range mining plans. These plans will define the intermediate steps required to reach the final pit limits under physical, operating and legal constraints (Figures 21A,B,C) . They also provide the pit geometry, ore grade, stripping ratio and expected profit, information necessary for future produ-ction forecasts and equipment needs.

The mining sequence of the orebody should be analyzed, to take into consideration, not only the varying metallurgical characteristics, but also the varying ore grade, availability of ore, haulage routes, mining capacity, grade, etc. For example, an orebody may average 0.70% copper, but it may be practical to mine at 1% for a few years, then at 0.70%, leaving 0.50% copper for the last year. On the other hand, the operation probably could be planned to mine close to the **average 0.70% copper for the entire life of the mine.**

Another important element of short-range open pit planning is to provide ample operating room to permit more economical mining practices. Tight bench room effects a minimum

MININGMODEL: INTERIM PIT #1 (DEMO) DATA FILE NAME: PIT1

OREBODYMODEL: DEMONSTRATION 3-D MODEL

DATAFILE NAMES: BLOCK1 AND: BLOCK2

RESULTS FOR ORE :

TABLE D

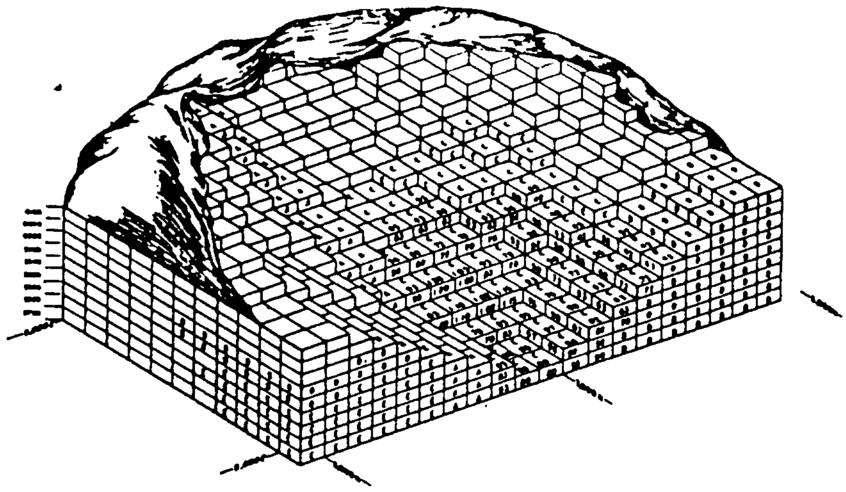
ORE								
.EV	NAME	CUT-OFF % Cu	VOLUME	DENSITY Tn/m3	TONNAGE	Cu GRADE % Cu	Pb GRADE % Pb	Zn GRADE % Zn
1	1015m	2.50	395.60	2.54	1004.84	4.47	2.06	0.00
2	1010m	2.50	459.50	2.54	1167.13	4.56	2.29	0.00
3	1005m	2.50	397.00	2.54	1008.38	4.07	2.19	0.00
4	1000m	2.50	389.50	2.54	989.33	4.64	2.28	0.00
5	995m	2.50	375.00	2.54	952.50	4.60	2.18	0.00
6	990m	2.50	307.00	2.54	779.78	4.15	2.29	0.00
7	985m	2.50	262.50	2.54	666.75	4.64	2.20	0.00
8	970m	2.50	251.50	2.54	638.81	4.81	2.31	0.00
9	975m	2.50	206.00	2.54	523.24	4.17	2.27	0.00
10	970m	2.50	172.50	2.54	438.15	4.12	2.36	0.00
11	965m	2.50	150.00	2.54	381.00	4.47	2.33	0.00
12	960m	2.50	126.50	2.54	321.31	4.91	2.42	0.00
13	955m	2.50	94.00	2.54	238.76	4.09	2.40	0.00
14	950m	2.50	85.00	2.54	215.90	4.33	2.47	0.00
15.	945m	2.50	63.50	2.54	161.29	4.66	2.44	0.00
TOTAL		2.50	3735.10	2.54	9487.17	4.45	2.26	0.00

N.B. VOLUMES AND TONNAGES ARE SHOWN IN THOUSANDS

RESULTS FOR WASTE AND TOTALS :

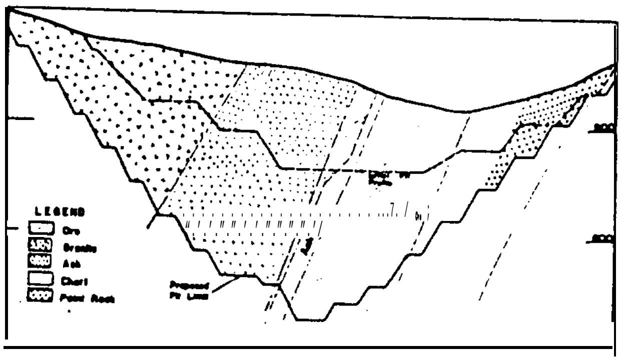
		WASTE			TOTAL		
.EV	NAME	VOLUME	DENSITY Tn/m3	TONNAGE	VOLUME	DENSITY Tn/m3	TONNAGE
1	1015m	75.20	2.54	191.01	513.60	2.54	1304.56
2	1010m	62.00	2.54	157.48	549.50	2.54	1395.73
3	1005m	35.00	2.54	88.90	494.00	2.54	1254.76
4	1000m	24.00	2.54	60.96	446.00	2.54	1132.84
5	995m	14.00	2.54	35.56	395.00	2.54	1003.30
6	990m	6.50	2.54	16.51	348.50	2.54	885.19
7	985m	1.50	2.54	3.81	285.00	2.54	723.90
8	970m	0.00	0.00	0.00	251.50	2.54	638.81
9	975m	0.00	0.00	0.00	218.50	2.54	554.99
10	970m	0.00	0.00	0.00	184.00	2.54	467.36
11	965m	0.00	0.00	0.00	153.50	2.54	389.89
12	960m	0.00	0.00	0.00	126.50	2.54	321.31
13	955m	0.00	0.00	0.00	99.50	2.54	252.73
14	950m	0.00	0.00	0.00	85.00	2.54	215.90
15	945m	0.00	0.00	0.00	63.50	2.54	161.29
TOTAL		218.20	2.54	554.23	4213.60	2.54	10702.50

N.B. VOLUMES AND TONNAGES ARE SHOWN IN THOUSANDS



(A)

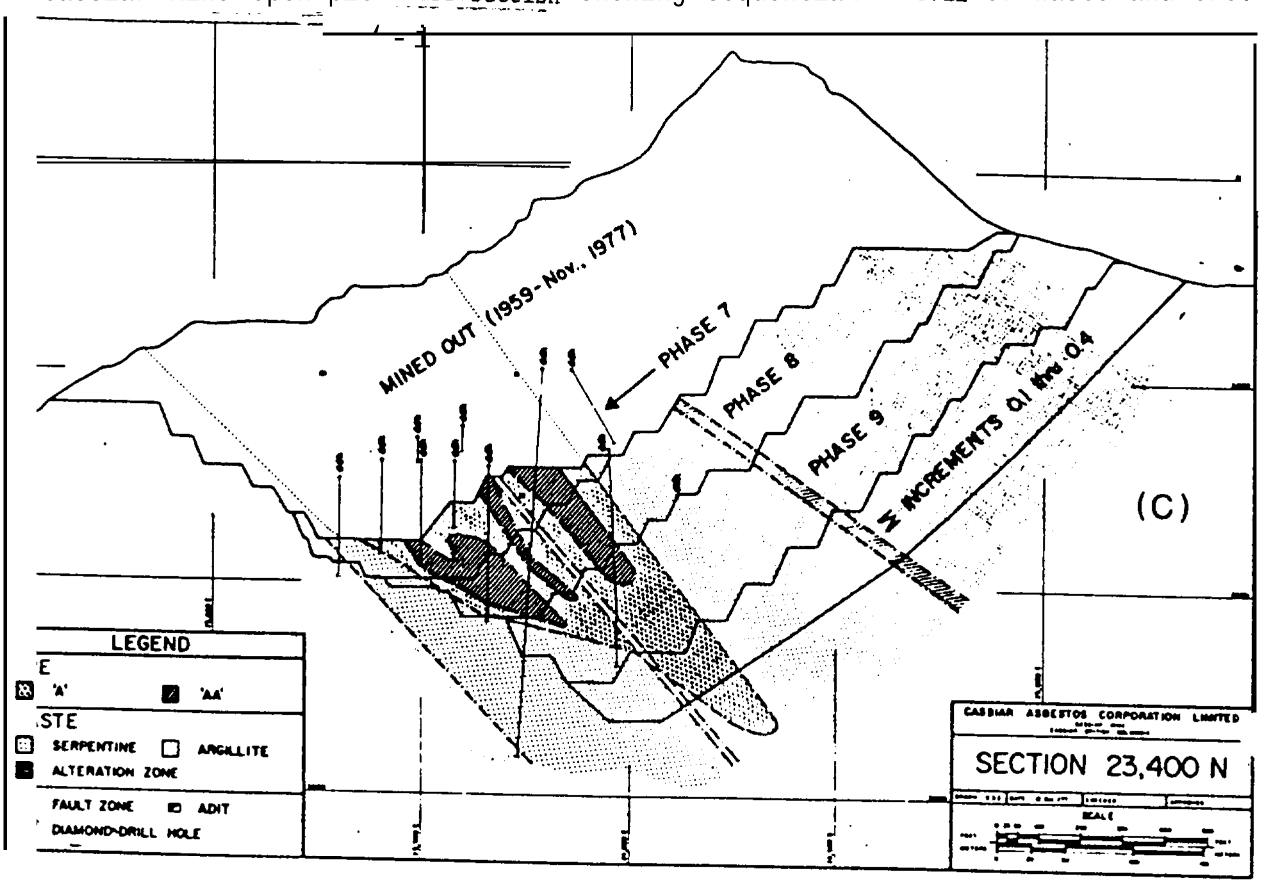
Typical three- dimensional mineralization inventory.



(B)

Open-pit cross section showing initial pit profile and proposed pit limit.

Cassiar Mine open-pit cross section showing sequential removal of waste and ore.



(C)

FIGURE 21

stripping ratio, but results in a costly operation, as well as hampering drilling and blasting operations. Shovel and haulage operations are also facilitated by ample working room. This means flat pit slopes in contrast to the final pit slope that must be as steep as possible to minimize the overall stripping ratio.

To minimize high stripping ratios during the early years of mine life, operating slopes should be as steep as possible and, at the same time, provide ample bench room for optimum operating efficiency.

Sequential stripping (cutting the wall back) may be used to avoid the early, short period high waste to ore ratios (Figure 21C).

The question as to whether material is mined or left behind ultimately depends upon that block's stripping ratio. It is worth remembering that the difference between a 39 degree and 40 degree slope in a 300-metre deep pit is 3.5 million tons of waste for 300 metres of length. It is, therefore, obvious how a small variation in the slope of the pit walls will affect the economics of a mining operation.

3. PRODUCTION METHODS AND ECONOMICS

Once the geometry and characteristics of the orebody have been established, the next step is to select equipment and determine operating practices for an efficient operation. The equipment combinations and permutations are endless; some generalizations follow:

In the initial equipment selection there are several factors to consider. One of the first items would be the total volume and type of overburden to be removed. If this volume is great enough and it is unconsolidated or soft, scraper-conveyor belt systems or rippers can be justified. If the volume is less, or if the character of the material requires drilling and blasting, then truck and shovel or front-end loader systems ordinarily are the most economical methods. With little stripping, the equipment can be standardized to handle both ore and waste.

Another important factor is the degree of ore control required. An orebody with uniform ore grade is mined more efficiently and with lower operating costs than one with varying ore grades.

Principal factors to be considered in selecting mining equipment, in addition to the above, are:

1. Life of the property.
2. The daily production rate desired.
3. The strip ratio.
4. Capital available.
5. Haul distance.
6. Bench height.
7. The working area available.
8. The" road width available.
9. Climatic conditions.

For maximum truck-shovel efficiency or productivity, it is necessary to match the haulage trucks to the shovels and to the haul distance and haul grade. The various truck sizes and types would be compared for total cycle times and total cost per ton while being loaded by various-size shovels. In obtaining the proper balance between shovel size and truck size, it also is necessary to look at the number of full shovel buckets necessary to fill the truck to its rated capacity.

Rubber-tired front-end loaders should be considered when high-speed mobility, operating flexibility and selective ore mining are controlling factors.

When selecting the blasthole drills, important factors to be considered are: the hardness of ground, which will determine the type of drilling method and drill bit; and the daily mine tonnage, which affects the size of drill and required power source.

The construction and maintenance of good haulage roads will increase the pit's efficiency. It is necessary to have a good road layout, watching the grades and degree of curves.

4. PRODUCTION AND COST SUMMARY

The following tables are intended to show the range of both capital expenditures and operating costs that might apply to open-pit mines. These costs are very general and intended only as a guide. They are based on costs for base metal mines located in areas with good access and infrastructure, and no adverse climatic or geologic conditions. One example of such an area is the Highland Valley of B.C.

The sizes of operation shown in the examples range from a very small mine producing 1500 tonnes of ore a day, to an extremely large open-pit, mining up to 90,000 tonnes every day. The stripping ratio (S.R.) has been kept constant at 2:1 waste:ore (w/o) and the grade of mineral varied to reflect the size of operation.

A. Capital Expenditures

Table E shows how the capital expenditures vary for different sizes of mine. The costs have been broken down into the different parts of an operation. These figures represent average capital expenditures for a mine located in a favorable area. Mines in remote or hostile areas will require larger expenditures of capital.

In each case, mine CAPEX costs are approximately **27%** of the **total CAPEX cost.**

B. Operating Costs

Table F lists some typical operating costs ($ per ton milled) for the sizes of operation shown in - Table E. The total operating costs in the right hand column include: mining, milling, administration and general overheads. The mining costs are also shown separately. In the examples shown, the mining costs are approximately half the total costs. With increasing mine size, productivity increases and mining costs decrease. The mining costs will vary considerably for different stripping ratios.

In an open-pit mine, the mining costs are broken down into activities of drilling, blasting, loading, hauling and general. The last category includes pumping, maintenance and labour supervision. Each of these can be represented as a percentage of the total mining cost, and some examples are shown in Table G. The ratio of these costs varies, depending on many factors, such as: hardness of rock, length of haulage route and type of blasting explosives required. In most cases, haulage is the largest cost factor in the total mining cost.

TABLE E

EXAMPLES OF CAPITAL EXPENDITURES FOR OPEN-PIT MINING

T. P.D. Ore	Site, Access & Buildings	Mine	Mill	Power, Water Tailings Disposal	Work Capital	Admin. & Eng.	Int. 109	Total
1,500	S.03	13.87	13.09	5.19	6.12	5.83	5.25	S4.38
2 ,S00	5.87	17.80	16.67	6.31	4.20	7.48	7.29	65. S0
5,000	7.72	26.50	27.68	8.8S	6.37	10. S1	10.96	98.60
25,000	17.14	71.32	76.93	22.2s	16.89	23.70	28. S3	2S6 .74
So, 000	2s.21	113.02	120. S6	33.90	26.34	35.69	44.34	399.07
90,000	37.38	177.14	18S.96	S1.38	40.67	53.73	68.28	614. S4

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TABLE F

TYPICAL OPEN-PIT OPERATING COSTS -- BASE METAL

T. P.D. Ore	S.R. W/O	Grade %	Tons Per Manshift	Cost Per Ton of Milled Ore: Drilling 8%	Blasting 10%	Leading 178	Hauling 43%	General 22%	Total Mining	Total Operating
1,s00	2:1	2.0	100-1s0	. S0	.62	1.05	2.66	1.3s	6.18	13.19
2,s00	2:1	2.0	100-1S0	.42	.52	.89	2.23	1.15	5.21	11.12
5,000	2:1	1.0	100-1s0	.33	.42	.70	1.76	.91	4.14	8.67
25,000	2:1	.5	200+	.20	.26	.43	1.10	.56	2.55	5.11
So, 000	2:1	.S	200+	.16	.21	.3s	.88	.4s	2.0s	4.08
90,000	2:1	.5	200+	.14	.18	.30	.77	.40	1.79	3.46

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TABLE G

EXAMPLES OF COST BREAKDOWNS FOR OPEN-PIT

MINING

Percentage Cost per ton of material handled

Drilling	8	15	9	5	12	7	12	7
Blasting	10	17	14	20	19	12	17	21
Loading	17	18	13	6	15	14	20	14
Hauling	43	34	24	14	30	44	33	45
General	22	16	40	55	24	23	19	12
	100	100	100	100	100		100	
	(1)	(2)	(3)	(4)	(5)		(6)	

(1) Average for 13 large Cu pits. S.R. Av = 2.8:1
(2) 200 T.P.D. Zn Mine - 3:1
(3) 7000 T. P.D. Ag Mine - 3.3:1
(4) 22,000 T. P.D. Cu, Au, Ag Mine - 1:1
(5) 10,000 T. P.D. Cu Mine = 1.25:1
(6) 3 large coal mines.

MINERAL RECOVERY AND MARKETING

R. Pendreigh, P.Eng.

Vice President, Metallurgy

WRIGHT ENGINEERS LIMITED, VANCOUVER

MINERAL RECOYERY AND MARKETING

1. INTRODUCTION

Most of the stages in the development of a mining property have been discussed by previous speakers in this series. Geological principles, ore deposits and exploration methods, mining methods, the principles of sampling and assaying, and financing considerations have all been reviewed.

The final link in the chain of events is the recovery and marketing of the ore, concentrate or metal. This paper will cover the unit operations and processes involved in producing a saleable product from ore supplied by the mining engineer, marketing the product, and the factors to be considered in the design of the processing plant and ancillaries.

2. THE ROLE OF THE METALLURGIST

To the interested but non-technical participant in the business of mining, the metallurgist and his function may be more mysterious than the geologist and mining engineer. The following definitions should help.

Metallurgy - The art and science of extracting metals (and industrial minerals) economically from their ores, and the subsequent refining, alloying, shaping, treating, and the study of their microstructure, constitution and properties.

This definition covers a wide field from receipt of ore from a mine all the way through to the study of microscopic defects in exotic alloys. While a metallurgist is aware of the basic principles of all aspects of metallurgy, of necessity, he has to specialize in a narrower field to be effective. The following table illustrates the range of metallurgists.

RANGE OF METALLURGISTS

Area	Ore ⟶ Concentrates ⟶ Metal ⟶ Alloys/Products		
Description	⟵ Mineral Processor ⟶		
	⟵ Extractive Metallurgist ⟶		
	⟵ physical Metallurgist ⟶		
Activities	Mineral Dressing	Hydrometallurgy	Heat Treating
	Mineral Processing	Pyro Metallurgy	Shaping
		Electro Metallurgy	Corrosion
			etc.

Within the field of interest - mining - the role of the metallurgist can be defined as follows:

Metallurgical Engineer - Responsible for carrying out projects in the field of mineral processing and extractive metallurgy for base and precious metals. This work includes the areas of research and development, process and plant design, plant operations and management, feasibility studies and consulting, plant performance evaluation, costing and financial analyses.

As indicated above, 'he can be called a mineral processor, hydrometallurgist, mill superintendent, etc. depending on his role.

3* BASIC PRINCIPLES

Generations of students have been taught that extractive metallurgy should conform to the LSD doctrine where

L = liberation
S = separation
D = delivery

Ores contain valuable minerals in sizes ranging from one micron (0.001 mm) to the whole ore body. At one end of the scale, for example, there are minute grains of gold encased in pyrite. At the other end a high grade coal seam or a limestone or pyrite deposit may be mined as a whole. Typically, individual mineral grains will be found disseminated throughout a waste material or associated or intermingled with the other valuable minerals. The first requirement is to liberate these minerals.

Once liberated, each individual mineral or group of minerals must be separated into marketable products which are then delivered for sale. The liberation and separation must be accomplished in a practical and economic manner.

A range of typical ore grades is shown below. This illustrates, for precious metals in particular, that the feed material to a processing plant may contain only minute quantities of the desired mineral.

RANGE OF **ORE GRADES**

	Concentration	Parts per Million (ppm)
Diamonds	10 carats/ 100 tons	0.02
Gold	1 gram/ton	1.0
	0.1 ounce/s. ton	3.43
Copper	0.3 %	3000
Zinc/Lead	5 - 20 %	
Iron Ore	30 - 60 %	
Coal	70 - 80 %	

5 carats = 1 gram
1 troy ounce = **31.103** grams
1 short ton = 1.102 tons (metric)

4. UNIT PROCESSES AND EQUIPMENT IN MINERAL PROCESSING

There are a very large range of processes and equipment which are utilized in mineral processing. In this section, an attempt has been made to categorize and list the better known processes and equipment, in a very concise manner. More detailed descriptions can be obtained from textbooks and relevant technical journals.

4.1 Liberation

Mineralogy - The appropriate liberation size can be gauged from testwork on an empirical basis e.g. correlate the response to subsequent processing with the degree of grinding. Mineralogy is being used much more widely nowadays to complement this approach. Electron microscopes are used to scan samples and determine individual mineral grain sizes and the distribution of individual elements within the grains. In this way, a more precise definition of liberation size is obtained and, perhaps more importantly, some of the reasons for poor recovery can be established on a rational basis.

Crushing - is the term applied to the breaking of rock from as large as a five foot cube down to less than half an inch. Crushing can be accomplished in stages (usually two or three) and equipment can range in size from a unit weighing over 600 tons to the smallest weighing a few kilograms. The main types of crushers in use are: jaw, gyratory (primary, standard, shorthead, gyradisc), rolls and hammer (horizontal and vertical types). In a few cases, coarse breakage of rocks has been achieved by steam shattering or high pressure water jets.

Grinding - is used to reduce material from around a top size of 12 inches down to less than 10 microns. (one micron is 0.001 mm). Grinding, or milling, is carried out in large revolving cylinders in which the feed material is tumbled and broken down to the required size.

Traditionally, milling was conducted in rod and ball mills where the grinding charge was either steel rods or balls. Rod mill size is limited to around 15 foot diameter by 20 feet long and 2000 hp. Ball mills are larger with a behemoth of 21.3 feet diameter by 31.5 feet long (6.5 x 9.6 m) operating at Kirkenes in Norway. This mill is powered by an 8.1 megawatt (10,860 hp) wraparound motor and has a throughput of 1000 tons per hour.

With the trend in recent times to larger and larger mines, there has been increasing emphasis on the use of large autogenous mills where the mill accepts a very coarse feed of up to 12". In some cases, a charge of steel balls is added and the operation is then called semi-autogenous grinding (SAG). SAG mills can be as large as 36 foot diameter by 15 foot and powered by 2, 6000 hp motors per mill.

The advantages of SAG circuits over conventional circuits include lower capital cost, the ability to handle wet and sticky ores, relatively simple flowsheets, large unit size, less labour requirements. However, such circuits consume more grinding energy than conventional crushing followed by rod and/or ball milling. Typically 15 to 35% more grinding power is required and this may have a deciding influence on choice of circuit depending on local power costs and circuit capacity.

Crushing and grinding, collectively labelled comminution, is the most expensive operation in mineral processing, accounting for about 50% of the total power consumed.

Grinding is also undertaken in vibratory, centrifugal and tower mills. The latter were developed in Japan and are very power efficient when used for ultra fine grinding. Cominco will probably "be installing nine 450 hp tower mills at Red Dog for grinding lead and zinc rougher concentrates.

4.2 Separation

This can be accomplished by employing differences in either physical or chemical factors between individual minerals or between minerals and waste rock.

Physical factors include size, shape, density, colour, hardness, magnetism and conductivity.

Chemical factors include surface chemistry and basic chemistry.

The following examples are typical of some of the processes and equipment employed.

4.2.1 Size

Particles can be separated according to size by two methods, screening or hydraulic classification.

Screens separate material into an oversize and undersize fraction, can be either stationary or vibrating and are used very widely, especially in comminution circuits. Variations include grizzlies, trommels, sieve bends, "banana" screens, probability sizers and endless belts.

Classification is the process of separating mixtures of particles into a number of fractions on the basis of their relative velocities in a carrying fluid, either water or air.

Classifiers sort material both according to size and also density, whilst screens rely only on size differences. For example in hydraulic classification it is not unusual to find small dense particles joining with large, lighter particles, both having about the same mass. Particle shape also affects separation.

The commonest classifier is the hydrocyclone, which has displaced to some extent rake and spiral classifiers, previously widely used.

4.2.2 Density

Particles can be separated depending on differences in their density or specific gravity.

Gravity separation (the general term for this process) was the main mineral processing method up to abut 1920 when flotation was developed. It still remains the main method of separation or concentration for tungsten, iron ores, tin and chrome ores and is used as an auxiliary process for gold, copper, lead/zinc ores, and others.

Feed size to gravity separation varies from around 6 inches down to 10 - 50 microns depending on the mineral and equipment used. Feeds should be deslimed and sized, wherever practical, ahead of gravity concentration to improve performance. As noted for classification, gravity separation also depends on particle size, as well as density.

Gravity concentration can be futher categorized into mechanical equipment operated with added water and processes using heavy media.

Mechanical equipment in use includes jigs (Harz, Bendelari, Denver mineral, Baum, Batac), pinched sluices and cones such as the Reichert cone, spirals with single, double or triple starts and capacities up to 6 tph. (Humphreys, Reichert), shaking tables (Wilfley or Deister) with capacities of up to 2 tph, duplex concentrators, multi-deck concentrators, cross-belt separators and pneumatic tables.

Gravity concentration is invariably used in the processing of placer deposits for gold and other precious metals. All of the above machinery is used in various combinations. In addition, certain cheap, simple equipment is also used such as rockers, sluices, pans, etc.

Gravity separation becomes more and more difficult and inefficient as difference in densities of the heavy and light minerals becomes less. In very general terms, when the quotient of:

$$\frac{D_H - D_F}{D_L - D_F}$$

(D_H = heavy mineral density)
(D_L = light mineral density)
(D_F = density of fluid)

is less than 1.25 to 1.5, gravity separation is no longer commercially feasible. However, by employing a liquid denser than water, separation of particles with densities close to each other can be achieved. As can be imagined, particles of specific gravity (S. G.) 1.6 will sink and particles of S.G. 1.4 will float if the fluid S.G. is 1.5.

Commercially, dense fluids are produced by forming a suspension of fine magnet te or ferrosilicon in water. There minerals are used as they can be recovered (and recycled) by magnetic concentration" These dense fluids are called heavy media, and heavy media separation is used for coal preparation, diamond recovery, and for removal of gangue from ores, such as chalk from lead/zinc ores.

4.2.3 Magnetism

Magnetic separation at low intensity is widely used for the separation and recovery of strongly magnetic materials such as magnetite (an iron ore), and- heavy media. Magnets are also used for removal of tramp metal from conveyor belts.

Recent developments in this field include the application of wet high intensity magnetic separation (WHIMS) to difficult separations such as concentration of low grade iron ores containing haematite, to removal of magnetite impurities from scheelite, to purification of talc and to the concentration of low grade gold tailings where the gold is associated with pyrite.

Super conducting alloys have been developed for use in permanent magnets.

4.2.4 Colour

Differences in colour and appearance were used traditionally in manual waste sorting. Nowadays, sophisticated automatic ore sorters can identify differences due to colour, or magnetism, or conductivity, or radioactivity, or fluorescence or simply metal content. Each of the commercial machines has similar operating principles. Ore particles in specific size ranges are spread in a monolayer on a feed belt. An analyser scans the ore, measures the return signal and activates compressed air jets to eject the desired particle out of the stream of falling particles from the belt discharge. The measurement of metal content is particularly useful since many ores do not exhibit marked differences in colour, magnetism etc. from the accompanying waste material. Metal contents of above 0.5% can be detected by gamma ray scattering analysis, and this machine can be used on base metal ores containing iron, cobalt, nickel, copper and zinc or any combination of these.

4.2.5 **Flotation**

Flotation is the main separation method dependent on differences in surface chemistry. Very simply, some particles are hydrophobic (water hating) and others are hydrophilic (or water loving). When a mixture of fine particles in water is agitated with air and certain reagents, separation is effected. These reagents include collectors, which coat the hydrophobic particles. Air or nitrogen bubbles attach to the coated particles which are then floated to the surface as a froth which is skimmed off. The gangue or unwanted particles leave as tailings. Other reagents added to the process include frothers, to stabilize the froth, modifiers to adjust acidity or alkalinity depressants and dispersants. Specific collectors and other reagents are used for specific separations. By adjusting alkalinity, collector and depressant additions copper, lead and zinc minerals can be recovered separately.

Flotation is carried out in cells which are cubical boxes equipped with mechanical agitators. Cell size has been increased and units as large as 1750 cubic feet are being installed now. The benefits of larger cells include smaller floor area, lower operating costs and better control.

A new development, column cells, has been pioneered in Canada and mainly developed in B.C. This is a simpler operation with many benefits when applied to the later, cleaning stages of flotation.

Flotation concentrates are dried and usually sent to smelters for recovery of metals. In some cases, hydrometallurgical techniques are employed.

4.2.6 Other Methods.

Other mineral processing methods relying on differences in surface chemistry include the recovery of diamonds which are hydrophobic and adhere to grease.

5. UNIT PROCESSES AND EQUIPMENT IN EXTRACTIVE METALLURGY

As noted earlier, there is no consistent division between mineral processing and extractive metallurgy. One classification places hydro, pyro and electrometallurgy in the domain of extractive metallurgy.

5.1 Hydrometallurgy

5.1.1 Leaching

Leaching is the most common hydrometallurgical process. The desired metals or minerals are dissolved by a liquid reagent and subsequently separated from the unwanted gangue by some form of liquid-solid separation. Common examples of leaching are the dissolution of gold and silver in dilute cyanide solution, leaching of oxide copper and uranium ores with sulphuric acid, and dissolution of uranium and tungsten by alkalis. Other leaching agents include hydrochloric and nitric acids, and thiourea. Leaching has traditionally been accomplished by agitating a milled slurry of ore in a series of tanks for periods of up to 36 - 48 hours. Recently, other leaching methods have been used increasingly. Heap and vat leaching is a low cost method applied to low grade ores. Pressure leaching is used for refractory ores or where high temperatures and pressures are essential. Bacterial leaching depends on certain strains of bacteria which, typically, accelerate sulphur oxidation and allow subsequent dissolution of the desired metal or mineral. Bacterial oxidation occurs naturally on copper waste dumps and has been tested with success at Equity Silver Mines.

5.1.2 Amalgamation

This is a special sort of "leaching" where mercury selectively absorbs gold to form an amalgam. The amalgam is separated from the residual material and mercury is recovered by retorting.

5.1.3 Solvent Extraction

After leaching, solutions are separated from solids by filtration or countercurrent recantation, after which the dissolved metals are recovered. One recovery method is solvent extraction where the aqueous solution is mixed with an organic reagent which selectively extracts the desired metal. Extraction is conducted in a series of mixers followed by settling tanks where the organic and aqueous phases are separated. Metal can be recovered from the loaded organic by stripping with another reagent followed by precipitation or electrowinning.

Solvent extraction is used widely on uranium and copper mines. Cobalt, nickel, rare earths and tungsten are also separated by solvent extraction.

5*1 .4 Ion Exchange

This process is similar to solvent extraction. Small resin beads are manufactured with specific qualities such that they adsorb certain minerals or metals in preference to others. In this way, uranium or gold can be adsorbed from a stream of solution passing through a bed of resin beads and recovered later by stripping or resorption. Resin beds are contained in columnar vessels.

5.1.5 Carbon Adsorption

Like ion exchange, activated carbon granules have a specific affinity for certain metals, notably gold and silver. Gold and silver are recovered after cyanidation by passing carbon granules counter current to the slurry in a "carbon-in-pulp" (CIP) process; or at the same time as cyanidation in a "carbon-in-leach" (CIL) " process; or from solutions after heap leaching in carbon columns. After loading or adsorption, the loaded carbon is removed, gold is stripped or desorbed by subjecting the carbon to a flow of hot, strong cyanide under pressure, and final recovery achieved by precipitation by zinc, or by electrowinning.

5.1.6 Precipitation

Metals can be precipitated from solution by displacement by other metals. This is called cementation and examples are the precipitation of gold by zinc dust in the Merrill Crowe process, and the cementation of copper by scrap iron. Also, metal salts can be precipitated by altering the solution chemistry such as by increasing the alkalinity.

5.2 Pyrometallurgy

Ores or concentrates can be heated in various ways to achieve metal separation and recovery.

5.2.1 Roasting

Generally, roasting processes are conducted at moderate temperatures below the fusion point of the feed material. Drying or calcining removes excess water, such as from gypsum, and oxidises base metals prior to smelting. Roasting is used to drive off volatile elements and break up minerals to expel gases such as sulphur dioxide. Calcining and roasting can be accomplished in rotary kilns, multiple stationary hearth furnaces or fluid bed roasters.

5.2.2 Smelting

Temperatures as high as 1800° C are used to melt the feed material. Suitable fluxes are added, which combine with unwanted gangue to form slag which is removed and discarded. A matte or liquid metal stream is poured out and cast 'into moulds for subsequent processing and refining.

Blast, reverbatory, convertor, flash, induction and electric furnaces are all widely used. Fuels vary from pulverised coal to oil and gas and use is made of the sulphur content of the feed. When sulphur is oxidized, significant quantities of heat are generated and in some cases, by using pure oxygen as the suspending gas, no extraneous fuel is required for smelting sulphide concentrates.

5.5.3 Electrometallurgy

In this category we find processes such as electrorefining, and electrowinning. In the former impure metals are cast as anodes (after smelting) and placed in a cell through which electrolyte is pumped. A suitable current is passed through conducting bus bars and pure metal is plated out on cathodes which can then be remelted and sold. Most copper and lead refineries operate on this principle.

In electrowinning, the desired metal is plated out on a cathode directly from the electrolyte which is usually derived from leaching. A suitable inert anode is used in the cell to close the electrical circuit. Copper, zinc and manganese are recovered by electrowinning.

6. MISCELLANEOUS PROCESSES

A selection of processes not covered previously follows:

UNIT PROCESSES AND EQUIPMENT - MICELLANEOUS

Aeration, agglomeration, agitation
Blending
Calcining, centrifuging, chlorination, clarification conditioning, conveying, compacting, crystallization
Drying, dust collection
Evaporation
Filtration, flocculation
Granulation
Heat transfer
Membrane separation
Ore storage (stockpiling, materials handling)
Product handling (storage, packaging, loading, blending) pumping
Reagent handling
Sampling
Thickening (conventional, high capacity)

7. PROCESS COMBINATION OR DEVELOPING A FLOWSHEET

Some of the unit processes and equipment used in the recovery of minerals have been described above. Many others exist and many more are being developed to meet the demands of economics and markets. In order to achieve the aims of processing ores from mine to marketable product in the most economic manner, the individual processes must be combined into a flowsheet. To do this requires several stages of development.

7.1 Sampling

This has been described by Dr. Bacon earlier. Every effort should be made to ensure that the samples selected from the property are truly representative of both the average ore qualities and extremes of chemical composition or physical characteristics such as hardness.

7.2 Assaying

Again, it is important to ensure accurate assaying, with sufficient cross checking to instill confidence in the results.

7.3 Testing

Testwork should be conducted on the representative samples to assess "the amenability of the ore to various unit processes and the degree of recovery expected. For best results, testing should be undertaken by knowledgeable laboratory technicians under the guidance of experienced metallurgists. Mineralogical examination plays an important role in the early stages of testwork.

Initially, testwork is done on a bench scale and batch basis in order to establish the liberation and separation requirements such as grind size, flotation time and reagents, suitability of gravity concentration, leach time and reagents, settling and filtering characteristics, etc. For simple ores such as "free milling" gold ores, data developed at this stage may be sufficient to enable plant design to begin.

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For other ores, further testing may be required to investigate the effects of recycling solutions or middlings products and this can be done on a bench scale, continuous method.

Should problems arise with regard to acceptable recoveries or process design criteria, a campaign has to be initiated to resolve these issues by investigating alternative processes or combinations of processes.

In some cases where novel or risky concepts are proposed, or where large scale testing is essential, or where a suitable scale of operation is required to demonstrate the applicability of the proposed process either to the property developer or permitting agencies, then pilot scale continuous testing is undertaken.

All processes have to be environmentally acceptable and gaseous or liquid effluents rendered harmless. For example environmental cyanide levels are now so low that all new gold mines have to include a cyanide destruction step in the process. Acidic slurries or solutions have to be neutralized. Tailings dams have to be designed either for zero discharge or for discharge of excess solution in a very controlled manner.

7.4 Design Criteria

Once the basic flowsheet has been selected, the design criteria should be established by confirmatory testwork. These criteria will be used in the selection and sizing of equipment. Design criteria should include abrasiveness and hardness of different ore types, grinding power requirements, grind size, reagent suite and consumption, water requirements, and many others. Each intermediate and final product should be assayed. Preliminary trade-off studies should be undertaken to ensure economic flowsheets are being selected.

7.5 Flow sheet Development

The selected flowsheet should be developed from the testwork and design criteria and reflect current, state of the art technology and design. in general compact, easily maintained plants incorporating the largest practical unit size of equipment shoul be the aim. However, this is not alwyas easily achieved, especially where more than one mineral or metal is to be recovered and where separation is not easy due to factors such as intimate intermingling of minerals or ultra fine grain size.

Some examples of flowsheets are attached - see Figures 1 -4 and schematic flowsheets for Teck Corona and East Kemptville.

8. MARKETING

8.1 Products

Products for marketing can range from ore through concentrates to pure metal depending upon commodity) size and location of the mine, and marketing factors. Bulk commodities such as coal, limestone, iron ore and some industrial minerals constitute the main component of the ore mined and processing may vary from simple crushing to complex upgrading. Gravity or, more commonly, flotation concentrates are often transported off site to a custom smelter and the metal sold on behalf of the mine owner. Some concentrates are treated with chemicals at site to remove impurities and bring the concentrates within desired specifications, e.g. scheelite and molybdenite, prior to sales as concentrates. Gold and silver are usually processed as far as bullion or dore metal bars at site, and require a minimum of further processing at refineries such as the Royal Mint. Bullion may contain 3- 10% impurities as base metals; gold is sold as 99.9% or 99.999% pure metal.

8.2 Custom Smelting

Concentrates are processed by a custom smelter according to agreed terms and conditions. Each smelter has slightly different conditions and charges due to differences in geographical location, ability to blend various concentrates, capacity, etc. Therefore, sellers of concentrates usually make detailed comparisons before signing a contract.

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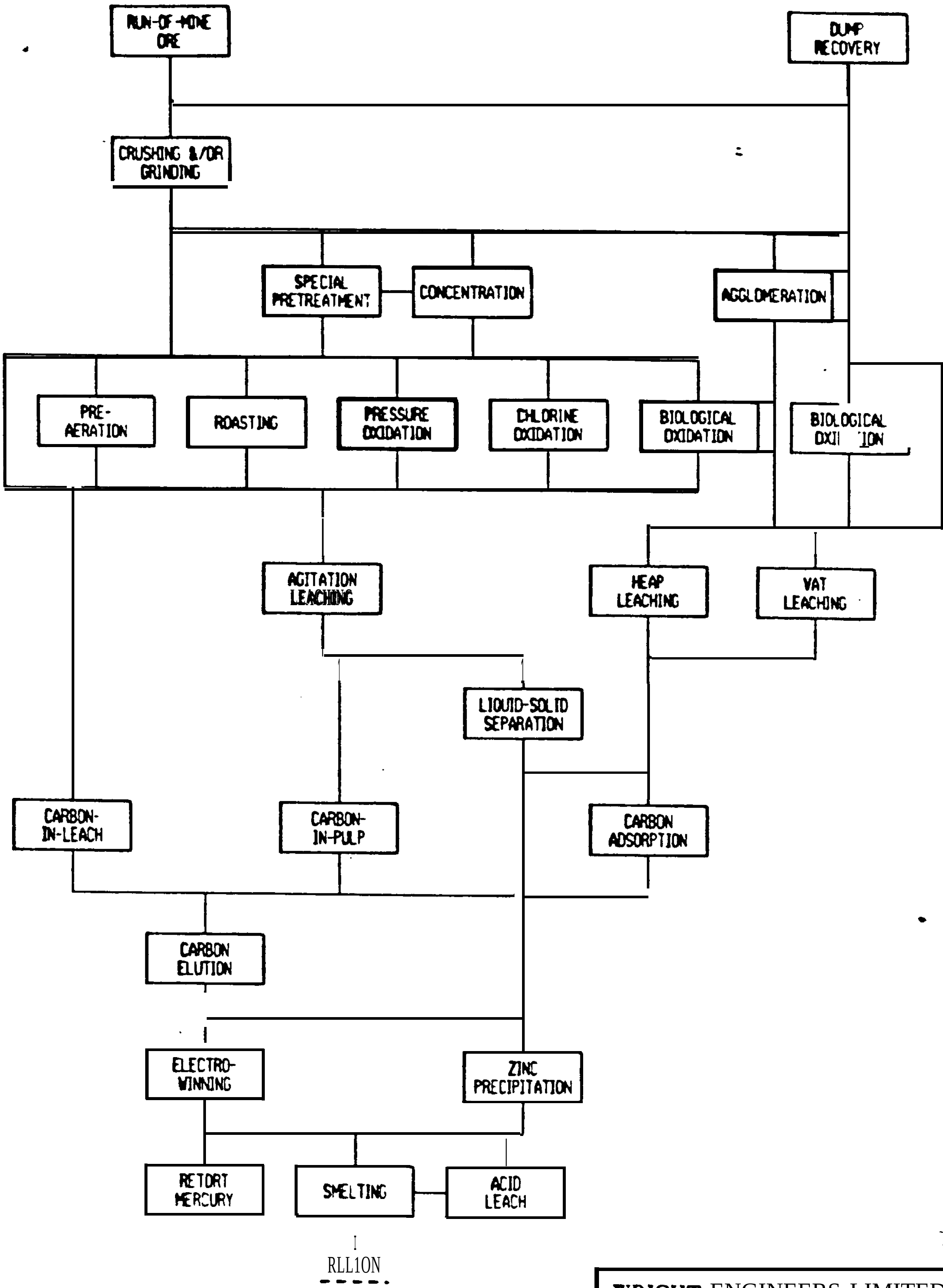


FIGURE 1. PROCESSING **OPTIONS** FOR GOLD ORES [21

WRIGHT ENGINEERS LIMITED

VANCOUVER — CANADA

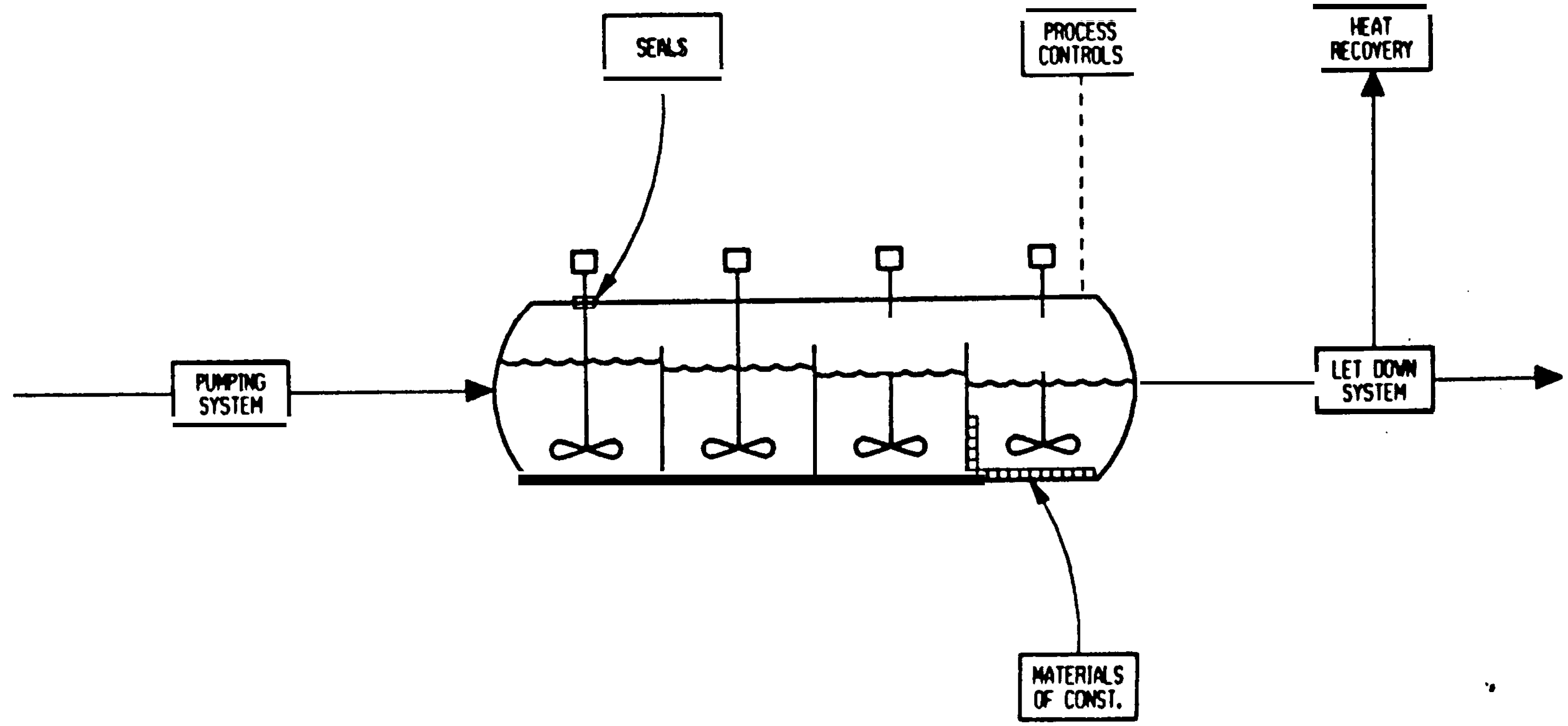


FIGURE 2. PRESSURE LEACH AUTOCLAVE - CRITICAL DESIGN AREAS

WRIGHT ENGINEERS LIMITED

ANCOUVER —— CANADA

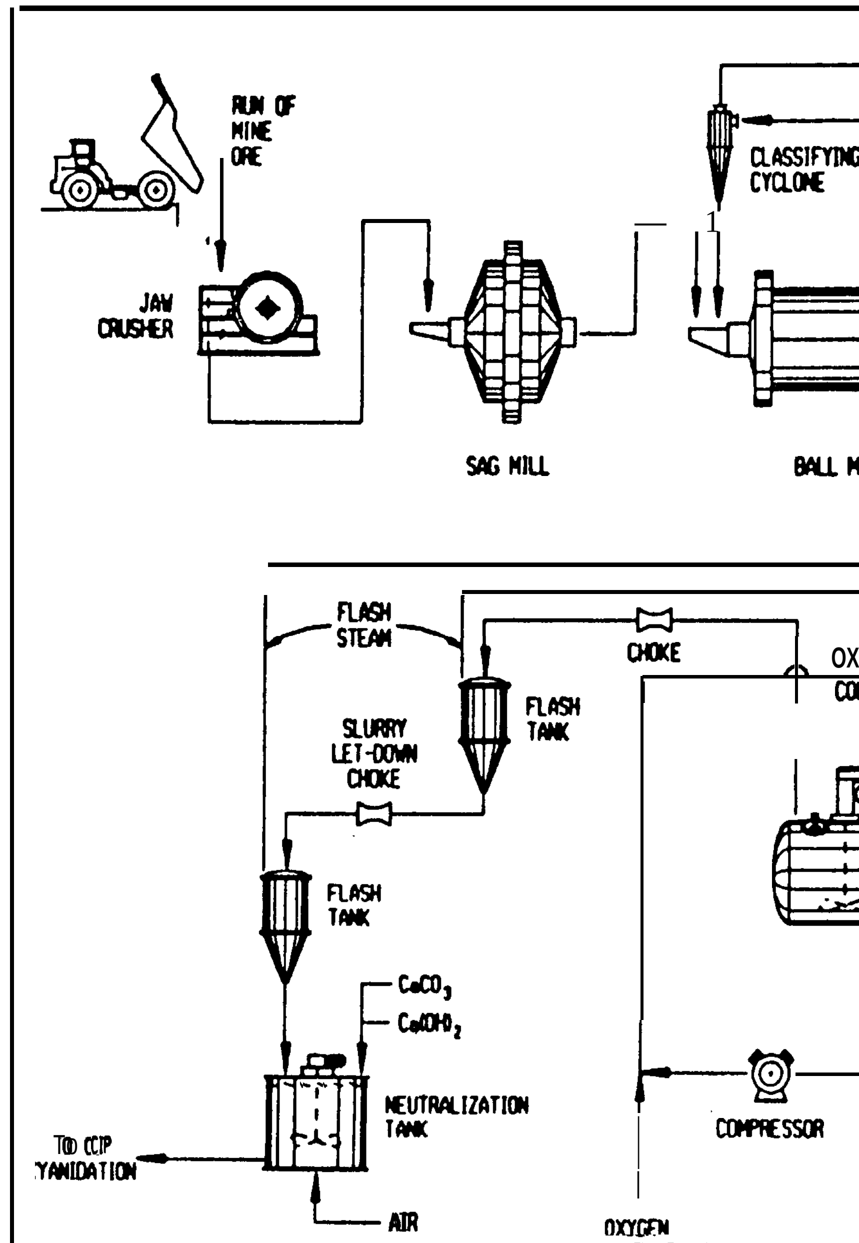


FIGURE 3. FLOWSHEET FOR

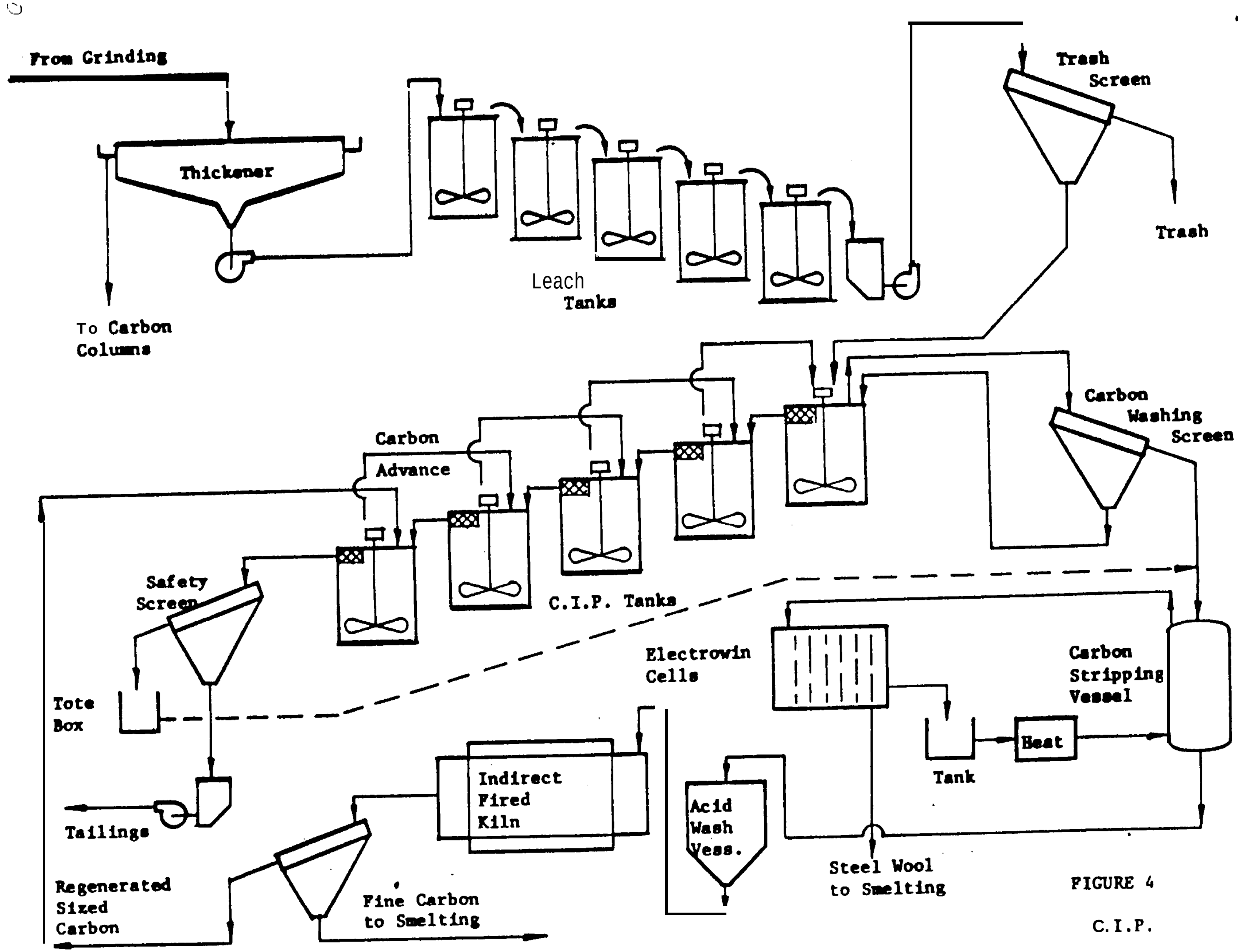
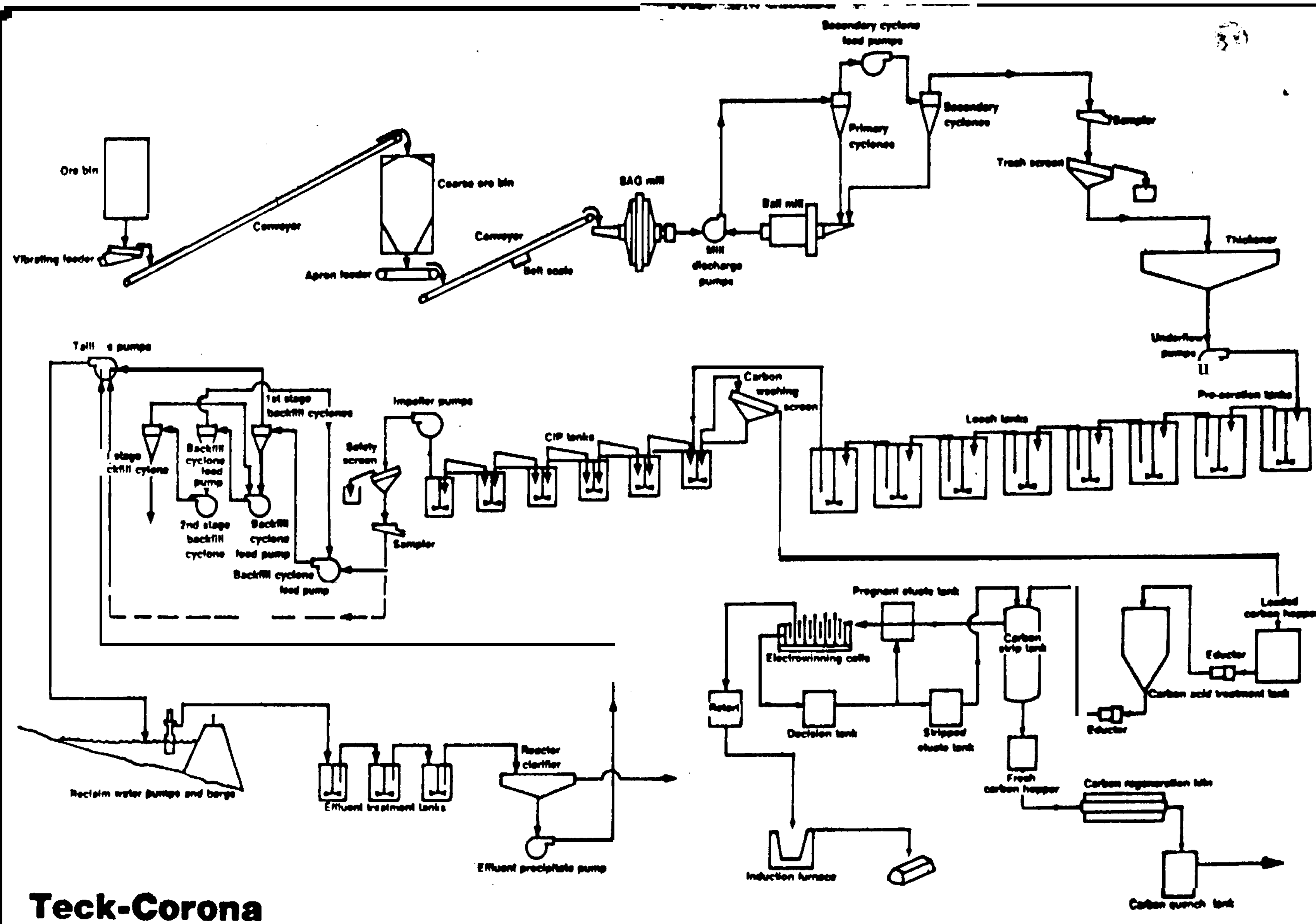

From Grinding
Thickener
To Carbon Columns
Leach Tanks
Trash Screen
Trash
Carbon Advance
Carbon Washing Screen
Safety Screen
C.I.P. Tanks
Tote Box
Electrowin Cells
Carbon Stripping Vessel
Tank
Heat
Tailings
Indirect Fired Kiln
Acid Wash Vess.
Regenerated Sized Carbon
Fine Carbon to Smelting
Steel Wool to Smelting

FIGURE 4

C.I.P.



Teck-Corona
Operating
Corporation

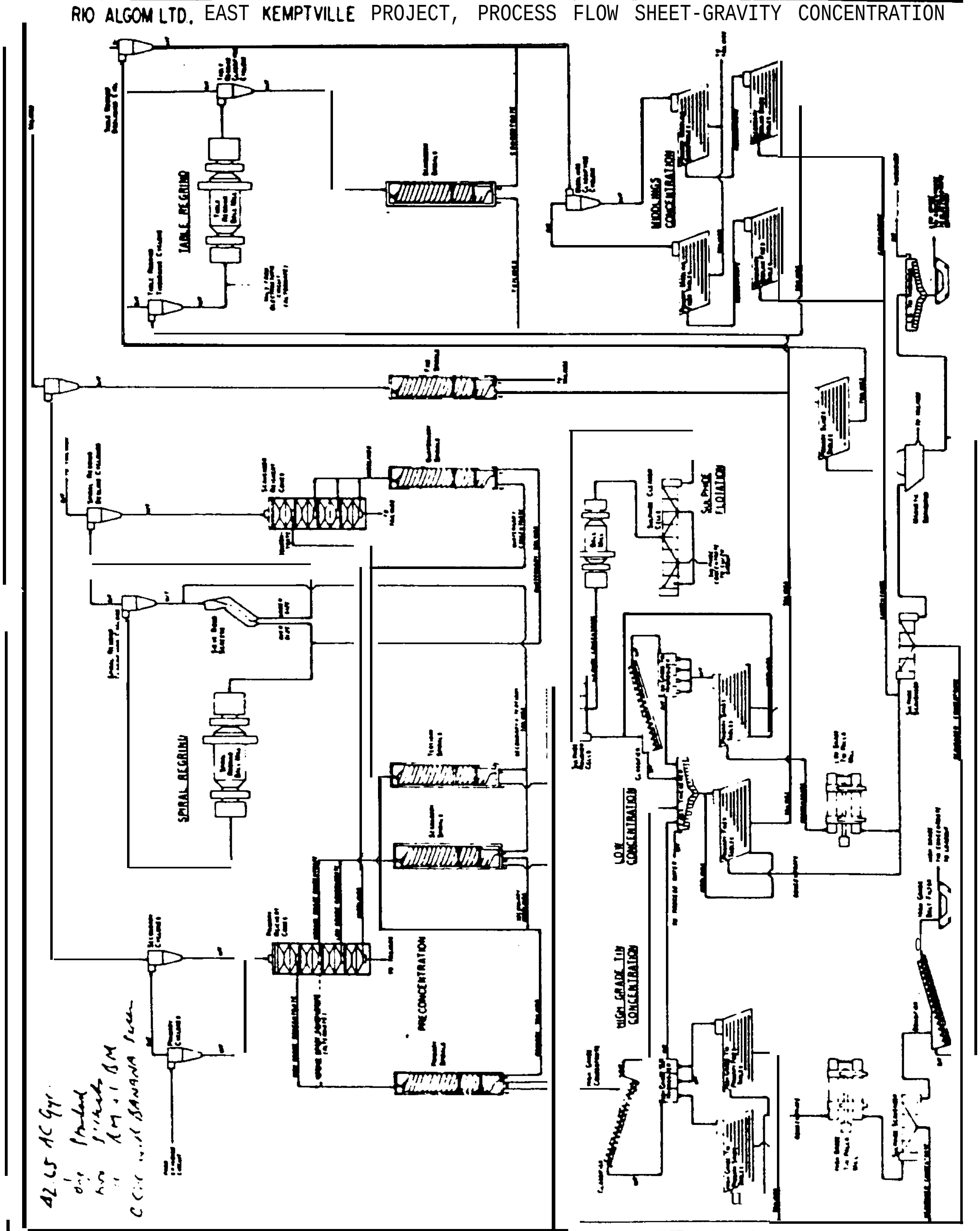
Flowsheet

Hemlo
Project

CMJ 9/85

PTO

RIO ALGOM LTD. EAST KEMPTVILLE PROJECT, PROCESS FLOW SHEET-GRAVITY CONCENTRATION



Typical smelter contracts include clauses such as:

Terminology or definitions - Units of weight and currencies are defined. For example, the term "unit" would be defined as one percent (l%) of a ton of concentrate e.g. one unit of copper means 22.0462 pounds of copper per dry metric tonne (dint) concentrate.

Quality - Broad guidelines are established for concentrate analyses: The seller will not exceed specified limits for impurities and moisture. Buyer can refuse certain shipments.

Duration of Agreement

Quantity - Approximate quanitities to be delivered yearly.

Shipment - Size and frequency of shipments is outlined. Terms of delivery e.g. c.i. f., or f.o.b.

Insurance - Defines ownership and responsibilities.

Weighing, Sampling, Assaying - Procedures, standards and "splitting limits" for assays are defined. A panel of umpire analysts is usually nominated for' assays falling outside splitting limits.

Payment Basis - For those metals to be paid, payment is based on a percentage of the contained metal less a certain number of units per d.m.t. For example, for copper concentrate, payment could be 96% of contained copper less one unit. For silver in a lead concentrate, payment could be for 93% less 0.2 troy ounces for each unit of contained copper with a minimum deduction.

Payments are related to either producer prices or L.M.E. prices as published in Metals Week for the quota tional period. Provisional payments may be made for a percentage of the metals.

Quotational Period - This is usually the month after the month of delivery, but can vary depending on the smelter.

Charges - Charges are levied for both smelting and refining; for smelting, a base charge per d.m.t. concentrate and for refining, a charge per kilogram of accountable metal. These charges are tied to fuel and labour costs.

Penalties - Within the limits agreed (see Quality) penalties are payable for impurities in excess of a minimum. For example for a copper concentrate, arsenic over 0.3 units, antimony over 0.3 units, zinc over 4.0 units and lead over 2.0 units. Excess moisture is also penalized.

Miscellaneous - legalities such as title and risk, force majeure, successors and assigns, notices and governing law are detailed. Taxes and duties are allocated.

Examples of payment terms and a calculation of actual payment are attached as Appendices 1 and 11. Appendix 11 was presented by Dr. Wolfe of Cominco for the 1984 course.

8.3 Net smelter Return (NSR)

For each concentrate, the net smelter return is calculated by deducting transport and insurance charges from the net smelter payment.

During testwork and design, the flowsheet selection will be influenced by the net smelter return deriving from each flowsheet alternative. Also, during operation of the plant, control strategy is based on mximizing the economic recovery, which is defined as:

$$\frac{\text{NSR/ton ore}}{\text{Gross value in ore}}$$

Also, the net dollar value per tonne of ore in place in the mine can be calculated after allowing for mining dilution to arrive at a head grade to the mill. A concentration ratio for each concentrate (if more than one is produced) is calculated from the metal balance or distribution for that particular process. The concentration ratio (C. R.) is the ratio of mass of ore milled to mass of concentrate produced. The net dollar value of ore is then:

$$\frac{1}{C.R.} \times NSR/d.m.t.$$

Depending on ore grade and smelter terms, the net dollar value can be a third to a half of the in situ gross value, for base metal concentrates.

For gold and silver bullion, payment is usually based on 98% of value or refining charges of around $5/ounce, depending on quantities and purity.

9. ENGINEERING

Concurrent with testing, the first of several feasibility studies will probably be undertaken. As work progresses and information is utilized to develop flowsheets and designs, more detailed estimates and studies are prepared to enable a decision to be taken to proceed with the project.

9.1 Probabilities and Accuracy Levels in Capital Cost Estimating

The major factor in determining the accuracy level of any capital cost estimate is the amount of engineering data available to develop the estimate. There are generally five different levels of estimates which may be developed during the life of a project beginning with an order of magnitude estimate based on not much more than a knowledge of the type of process and location of the plant and concluding with a definitive estimate which will probably not be produced until engineering is at least 75% complete. Obviously, as better engineering data becomes available, the confidence level in the estimate will increase, the spread between the upper and lower predicted accuracy limits will narrow and the amount of contingency included will decrease. This relationship between engineering data and estimate accuracy is illustrated on the enclosed chart.

After the completion of any level of base estimate, an assessment of the risk of over or under running should be made. The use of Monte Carlo simulations is an accepted way of developing a range of probable costs associated with any estimate and is helpful in determining an appropriate level of contingency to apply to the base estimate. The accompanying graph illustrates the result of a Monte Carlo analysis performed on a feasibility study estimate. The lower horizontal line indicates the base estimate, the upper line indicates the most likely cost and the difference between them is the contingency which must be applied to the base estimate to attain a 50% confidence level. The curve indicates the probability of over-running any given cost.

9.2 Design Engineering

A general sequence of activities is presented. many of these activities are carried out concurrently, especially for projects which are to be "fast-tracked".

- Flowsheet development
- Material and energy balances
- Equipment specification and selection
- Piping and instrumentation diagrams (P + I. D.'s)
- Control strategies (automation, computer control)
- Trade-off studies
- Plant design - layouts, general arrangements
- Basic, then detailed design
- Operating parameters and costs
- Scheduling men and resources for construction
- Materials of construction
- Hazard analysis
- Environmental concerns including tailings disposal
- Operating philosophy and instructions
- Construction management
- Commissioning, training operators, meeting production guarantees.

9.3 Recent Examples

Three examples of new gold projects are reviewed as they illustrate the concepts mentioned above.

a) **Homestake, McLaughlin Project** - This 3000 tpd plant was commissioned earlier this year. This refractory gold ore is being processed by SAG and ball mills, then pressure oxidation followed by cyanidation and CIP. This is the first large scale pressure oxidation process to be commissioned. The mine is sited 100 miles north of San Francisco in Napa County.

Over 450 drill holes were sunk, 180 permits were obtained and the capital cost was U.S. $200 million, of which $6 million was spent on environmental permitting. Over 36 tons of rock must be mined to produce 1 ounce of gold.

b) **Cannon Mine, Wenatchee** - This plant is rated at 2000 tpd and was commissioned this year. Second hand equipment was used and the circuit includes rod and ball milling. A flotation concentrate is sold to smelters, though this may be processed at site, later, by pressure oxidation. Again environmental costs were disproportionately high. A published breakdown of costs follows:

	$ Millions
Geology	3.0
Environmental	10.0
Mine	17.0
Mill	14.0
Tailings dam	20.0
Others	7.5
	71.5

The tailings dam wall is 350 feet high “and had to be designed for a 10,000 year flood limit.

c) **Teck-Corona, Hemlo** - This high grade, underground mine started milling in May this year. Plant capacity is 1000 tpd, though tonnage at present is limited to 700 tpd due to mining constraints. This mill employs cyanidation and CIP. Direct costs for the plant were C $ 17 million and operating costs are forecast as between $15 - 20 per ton.

d) A summary of recent gold projects is attached for interest.

10. OPERATIONS

During the operation of a plant, the metallurgist in charge must respond to economic conditions. As mentioned earlier, strategies should be implemented to maximize revenue by striving for the best economic recovery. In addition unit costs should be contained as far as possible by reducing manageable operating costs for labour, reagents, etc. by introducing new ideas or by increasing throughput.

As examples, North American producers of copper are now the world's marginal suppliers and account for most of the short run adjustment of supply and price. There have been many mine closures, yet the surviving producers (mills and smelters) have managed to reduce their costs by 15 - 20 US c/lb. over the last 3 years.

10.6 SMELTER TERMS

Zinc and lead concentrate sales were based on June, 1985 smelter contracts from Cominco, the pertinent points of which are listed below. It should be noted that the smelter contracts are Canadian dollar denominated.

10.6.1 zinc concentrates

Payments Per Short Dry Ton:

Lead:	Pay for 80% of the contained lead (minimum deduction 20 pounds) less 12.00¢ per pound.
Zinc	Deduct 0.15 units of zinc per unit of contained iron and 0.125 units of zinc for each unit of SiO_2 in excess of 0.5% Si02 and pay for 85% of the balance.
Silver:	Deduct 0.2 troy ounces of silver for each unit of contained copper and pay for 93% of the balance (minimum deduction from the balance 1.5 troy ounces) at 97% of price.
Gold	Pay for 93% of the contained gold (minimum deduction 0.05 troy ounces) at 98% of price.

Deductions per Short Dry Ton

Treatment Charge:	The base treatment charge shall be $220.00.
Zinc Price:	Increase the treatment charge by $3.50 for each 1.00¢ by which the composite price for zinc exceeds 50.00¢ per pound.

Penalties per Short Dry Ton

Iron Content:	Increase the treatment charge by $1.80 for each unit of contained iron.
Silica Content:	Increase the treatment charge $0.50 for each unit of SiO_2 greater than 0.5% SiO_2.
Moisture Content:	Increase the treatment charge by $0.50 for each unit of moisture greater than 6.0% but less than or equal to 8.0% and by $1.50 for each unit of moisture greater than 8.%.

10.6.2 Lead Concentrates

Payments per Short Dry Ton

Lead:	Deduct 0.1 units of lead for each unit of contained copper over 0.75% and pay for 92% of the balance (minimum deduction from the balance will be 20 pounds). The deduction from the composite price shall be 12.00¢ per pound plus 0.25¢ per pound for each 1.00¢ the composite price exceeds 33.00¢ per pound.
Zinc	Deduct 0.7 units of zinc for each unit of iron by which the iron content is in excess of 1.44 times the zinc units and pay for 60% of the balance (minimum deduction from the balance will be 20 pounds) less 15.00¢ per pound.

Silver: Deduct 0.2 troy ounces of silver for each unit of contained copper and pay for 93% of the balance (minimum deduction from the balance 1.0 troy ounce) at 97% of the price.

Gold: Pay for 93% of the contained gold (minimum deduction 0.03 troy ounces) at 98% of the price.

Copper: Pay for 4 O% of the contained copper (minimum deduction 10 pounds) less 20.00¢ per pound.

Deductions per Short Dry Ton

Treatment Charge: The base treatment charge for lead concentrates will be $150.00.

Penalties per Short Dry Ton

Moisture Content: Increase the treatment charge by $0.40 for each unit of moisture greater than 8.0% but less than or equal to 10.0% and by $1.00 for each unit of misture greater than 10.0%.

Iron Content: Increase the treatment charge $3.55 for each unit of iron in ● xcess of the sum of five units plus 1.44 times the zinc units.

10.6.3 Gold in Bullion **Pay for 98%.**

10.6.4 Silver in Bullion **Pay** for 96%.

10.6.5 Freight $25/SWT for concentrate shipments to Trail, B.C.

APPENDIX II

Table 2

ZINC CONCENTRATE COMINCO LTD. SEPTEMBER 25, 1981
TRAIL, B.C.

PRELIMINARY SETTLEMENT: ABX MINERALS - ZN CN

IN ACCOUNT WITH: ABX MINERALS LTD.

LOT NUMBER: 19 SERIAL NUMBER: 3495

CAR NUMBERS	DATE RECEIVED
1 TRUCK	0825 81

NET WET WEIGHT	MOISTURE	NET DRY WEIGHT	SHORT DRY TONS
29440 LBS	9.9000 %	26525 LBS	13.2625

ASSAYS:	GOLO	SILVER	COPPER	LEAD	ZINC	SULPHUR	SILICA
	0.0170	13.1500	0.1800	5.7000	38.6000	34.4000	4.4000
	OZ/DRY TON		%	%	%	%	%

ALUMINA	IRON	LIME	ANTIMONY	ARSENI C	BISMUTH	MAGNESIA	CADMI UM
0.0000	13.8000	0.1200	0.0300	0.3500	0.0000	0.1000	0.2800
%	%	%	%	%	Z	%	%

METAL PRICES: " SEPTEMBER 24, 1981

EXCHANGE: $US TO $CDN = 1.19770 STERLING TO $US = 1.83030

LABOUR RATE = 15.880

COMINCO CDN PRICE 59.500 • 0.260	=	15.47000
US PRICE 49.250 • 1.19770 •0.370	=	21.82509
LME PRICE 000.000 / 2204.6 •1.19770 •0.370	=	20.10111
CALCULATED ZINC PRICE	=	57.39620
PB PRICE 421.225 •1.83030 / 2204.6 •1.19770 - 0.100	=	31.88463 #/LB
ZN PRICE 57.39620 - 15.000	=	42.39620 ¢/LB
AG PRICE 9.47000 • .970 •1.19770 - 0.000	=	11.00195 $/02
CD PRICE 2.000 •1.19770 - 0.700	=	1.69540 $/LB

PAYMENTS PER TON

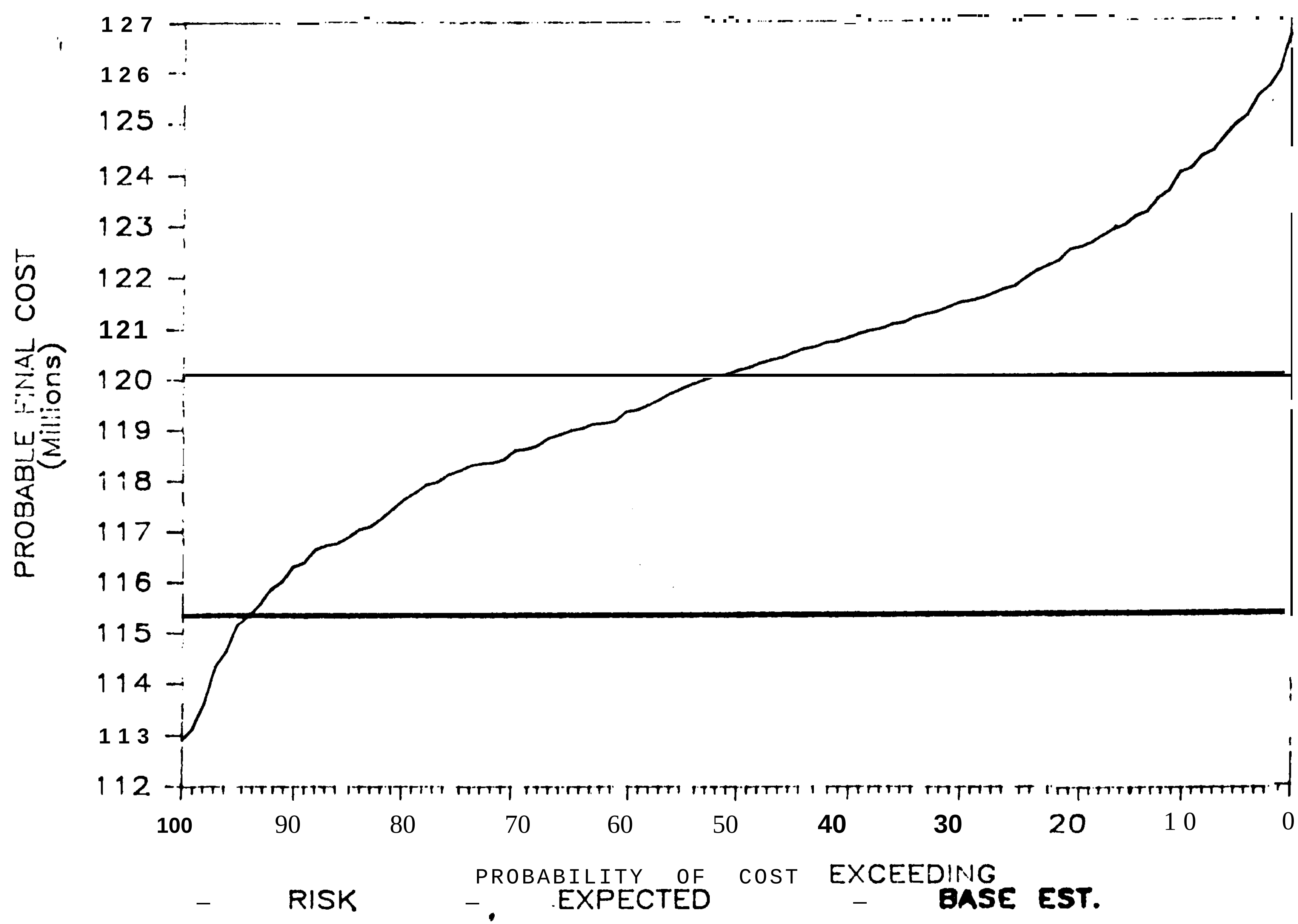
	CONTENT	DEDUCTIONS	PAID FOR		
PB	114.00 LBS	22.80 LBS	91.20 LBS	=$	29.08 LEAD
ZN	772.00 LBS	150.99 LBS	621.01 LBS	=$	263.28 ZINC
AG	13.150002	1.0360 02	12.114002	=$	133.28 SILVER
CD	5.60 LBS	4.04 LBS	1.56 LBS	=$	2.64 CADMIUM
			TOTAL PAYMENT	=$	428.28

DEDUCTIONS

BASIC TREATMENT CHARGE	=$	-51.00
LABOUR : LABOUR RATE = 15.880	=$	-1.68
TRUCKING CHARGE	=$	-6.00
ZINC PRICE - 46.00000 • 3.00	=$	-34.19
IRON = (13.8000 -0.1 %) •1.80	=$	-24.84
MOISTURE	=$	-3.85
NET DEDUCTIONS	=$	-121.56
VALUE/S.D.T. -- F.O.B. TADANAC	=$	306.72
VALUE/S.D.T. * 13.2625 S.D.T.	=$	4067.87
ADVANCE PAYMENT	=$	3050.00

3-L-

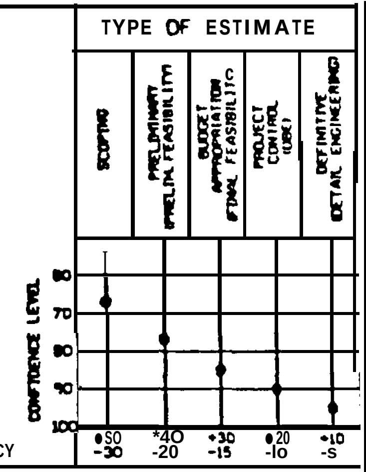
RISK ANALYSIS GRAPHIC



TYPE OF ESTIMATES, ENGINEERING BASIS REQUIRED AND EXPECTED CONTINGENCY

WRIGHT ENGINEERS LIMITED

VANCOUVER — CANADA



S ESTIMATE ACCURACY

	INFOFU'LATION REQUIRED
ROJECT SCOPE ND PROCESSES	PRODUCT AND CAPACITY, SITE LOCATION AND REQUIREMENTS. UTILITIES AND SERVICE REQUIREMENTS, BUILDINGS AND AUXILIARY FACILITIES REQUIREMENTS, RAW MATERIALS AND PRODUCT HANDLING MD STORAGE REQUIREMENTS
ROJECT CHEDULE	PRELIMINARY
	DETAILED
ITE REPARATION	LOCATION OF SITE
	GENERAL DESCRIPTION OF SITE ANO FACILITIES
	SUBSOIL INVESTIGATION
	LDCATIOU AND DIMENSION OF SITE FACILITIES
	TOPO MAPS, GENERAL SITE PREPARATION DRAWINGS (PLOT PLAN)
	PLANT, ROAO, RAILROAD AND OTHER SITE PREPARATION DRAWINGS
ROCESS LOU HEETS	DESCRIPTION AND SKETCHES
	PRELIMINARY
	FINAL
QUIPMENT ,ELECTION AND AYOUT	PRELIMINARY EQUIPMENT LIST
	FINAL EQUIPMENT SPECIFICATIONS
	PRELIMINARY GENERAL ARRANGEMENT DRAWINGS
	FINAL GENERAL ARRANGEMENT DRAWINGS
UILDINGS AND STRUCTURES	PRELIMINARY SIZES AND TYPE OF CONSTRUCTION
	PRELIMINARY STRUCTURAL DESIGNS
	FOUNDATION SKETCHES
	ARCHITECTURAL CRITERIA
	GENERAL ARRANGEMENTS AND ELEVATIONS
	DETAIL DESIGNS, DRAWINGS ANO SPECIFICATIONS
TILITIES	APPROXIMATE QUANTITIES (STEAM, MATER, POWER)
	PRELIMINARY FLOW DIAGRAMS ANO NEAT BALANCES
	FINAL FLOU DIAGRAMS AND HEAT BALANCES
	DETAIL DESIGNS, DRAWINGS AND SPECIFICATIONS
PROCESS PIPING AND INSTRUMENTATION	PRELIMINARY P AND ID'S AND CRITERIA
	FINAL P AND IO'S AND CRITERIA
	DETAIL DESIGNS, DRAWINGS AND LINE LISTS
	PRELIMINARY MOTOR LISTS

Plate No. 4A

Major Gold Projects in the 1980's

Company	Location	Start-up Date	Milling Rate t/d	Published Au Production kg/a	Recovered Gold g/t	Capital cost M$
1. Teck/Corona	Hemlo, Ontario	1985	1000	4 500	12.33	90 Cdn.
2. Noranda (Goliath)	Hemlo, Ontario	1985	3000	9000	8.22	292 Cdn.
3. Homestake	Napa Valley, California	1985	2700	6 220	6.31	200 U.S.
4. Asamera	Wenachee Washington	1985	1 800	3900	5.94	40 U.S.
5. Carlin Gold	CarlIn, Nevada	1986	7 000	5 300	2.07	1-30 Us.
6. Sonora Gold	Jamestown, California	1986	5400	3700	1.88	80 Us.
70 Kidston Gold Mine	Kidston, Queensland	1985	14 Ooo	8900	1.74	137 A
8. Golden Sunlight	Whitehall, Montana	1983	5400	2900	1.47	52 U.S.

VGM/jt
85-11-01

FLOW THROUGH SHARE FINANCING

Randall Yip, CA.

September, 1985

FLOW-THROUGH SHARES - A COMMENTARY

The objective of this commentary is to provide a brief introduction to Flow-Through Shares.

Flow-Through Shares are shares issued in exchange for funds expended on Canadian Exploration Expense.

Canadian Exploration Expense is defined in the income tax act and relates to expenses incurred to explore for a mineral resource in Canada. Certain expenses incurred prior to the start of production to bring a mineral resource in Canada into production also qualify as Canadian Exploration Expense.

The benefits to the investors are that the exploration expenses flow back to them, resulting in a tax write-off equal to 100% of their share of funds expended on Canadian Exploration Expense (basically exploration expenses incurred during the year for exploration in Canada).

A new amendment to the income tax act allows a further 33-1/3% of exploration expenses[1] to be written off by the investor against income from all sources.[2]

The investors acquire the Flow-Through Shares at a zero tax base and will pay tax on the capital gain or income basis on disposal of the shares. The tax treatment depends on how the taxpayer is ordinarily taxed on disposal of these shares.

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1. Only “grass roots” Canadian Exploration Expenses qualify as a basis for deduction as earned depletion at the rate of 33-1/3% of such expenses.

2. Previously, this deduction could only be made against resource income to a maximum of 25% of net income. The 25% limitation still applies under the new rules.

The investors would benefit by a tax deferral and could realize an actual income tax savings. An actual tax savings would occur if the investor is taxed on the capital gains[3] basis on disposal of the Flow-Through Shares. The after tax gain (or 10SS) on disposal of Flow-Through Shares is dependent on income tax considerations and the amount realized on disposition of the shares.

A possible disadvantage of investing in Flow-Through Shares is that the investors may be liable for damages caused by the exploration activities carried out on his - behalf. This liability could be covered by liability insurance carried by the company.

The benefit to the company is the ability to attract funds for financing at possibly a higher than usual price for its shares.

For Flow-Through Shares issues to be successful, the company should:

1) Have a well defined exploration program planned well in advance.
2) Contact professional advisors, such as lawyers and accountants well in advance for planning and documentation requirements.
3) Package the offering in an attractive and professional manner.
4) Provide relevant information to brokers or other sellers of Flow-Through Shares.

The disadvantages to the companies involved in Flow-Through Shares offerings are:

1) The company would not be able to use the "transferred" exploration expenses to shield future resource income from taxation.
2) The exploration must be in Canada.
3) The exploration must be carried out in the calendar year for the investors to receive tax deductions on the purchase of Flow-Through Shares.

---

3 The May 23, 1985 budget proposes to allow a capital gains tax exemption for individuals up to a lifetime limit of $500,000. This exemption is to be phased in over six years starting at the budget date. Flow-through shares are not specifically excluded in the budget from qualifying for the capital gains exemption.

4) The agreements should be signed and the money advanced before the funds are spent on exploration expenses, otherwise, the exploration expenses may not be deductible by the investors.

5) Tax shelter offerings of this type are most attractive in the latter part of the year, whereas this may not be the best time for exploration.

6) The company should carry liability insurance to protect the inves· ors from liability arising from exploration carried out on their behalf.[5]

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4. Agreements bet ween the company and investors concerning the issue of Flow-Through Shares.

5. Exploration financed by the issue of Flow-through Shares.

RANDALL W. YIP, BSc. CA
Chartered Accountant

Rogers Building,
Suite 222-470 Granville Street,
Vancouver, B.C. V6C 1V5
(604) 685-8769

INDEX

A. OBJECTIVES OF PRESENTATION

The objective of this presentation is to:

(1) give an introduction to tax and other implications of investing in and offering flow through shares;

(2) outline of the steps involved in a flow-through hare financing.

B. PRESENT TRENDS AFFECTING THE MINING INDUSTRY

(a) Low metal prices

(b) Increased competition

(c) Decrease in demand for metals

EFFECTS

Mine closures
Decreased exploration
Decreased general economic activity
Difficulty in raising funds through equity issues

WHAT THE FEDERAL GOVERNMENT IS DOING

increase tax write-offs available for mineral exploration

WHAT OTHER PROVINCES ARE DOING

Quebec - Bonus deduction of 66-2/390, from Quebec Provincial Tax for qualifying Quebec exploration incurred by the individual.

Other programs to provide grants and geoscientific information.

At $ risk for flow-through shares can be as little as 9% of $'s invested.

Ontario - Has Ontario Mineral Exploration Program (OMEP).

Provides cash grants or credits of up to 25% of qualified exploration costs to persons who do not have mineral income.

EFFECTS OF PROVINCIAL INCENTIVES ON FINANCING MINERAL EXPLORATION

Increase exploration expenditures in Ontario & Quebec.

IMPACT OF FLOW-THROUGH SHARES

Across Canada in 1984

Over 130 million in total was raised through flow-through share financing on Canadian stock exchanges.

Flow-through share financing may:

(a) Increase the general level of mining and related business activity;

(b) Require the services of stockbrokers, lawyers, accountants, prospectors and other service people and companies;

(c) Help provide the necessary funds for mineral exploration activities;

(d) Lessen the risk for investors by lowering the after tax cost of investing in exploration companies.

C. WHAT A FLOW-THROUGH SHARE IS

In a flow-through share issue, investors enter into an agreement with a company in which investors incur Canadian Exploration Expense (CEE) soley as consideration for shares of the company.

THE AGREEMENT MUST BE MADE AND FUNDS ADVANCED BEFORE THE CEE IS INCURRED

CEE IS DEFINED IN THE TAX ACT

- Expenses to explore for a mineral resource in Canada
- Can include placer mining
- CEE expenses such as:
  - Trenching
  - Prospecting
  - Geological & Geochemical Surveys
  - Diamond or percussion drilling

SHARES

- Only issued after related CEE incurred
- May be other restrictions i.e. 1 yr holding period on private placements.

D. **COMPANIES ABLE** TO ISSUE FLOW-THROUGH SHARES

Public & Private companies are able to finance with flow-through shares.

TYPE OF FINANCING ALLOWED

For Private Co.'s Restriction Due To Securities Act

Private Co.'s can sell shares only to persons who are not members of the public.

For Public Companies

Public issues via prospectus or SMF
Private placements.

Types of Shares Which Can Be Issued

Common or preferred shares
Can be issued with rights attached but actual issue to the shareholder must be tied to qualifying CEE expended
Companies often issue a combination of common and flow-through shares.

E. EFFECTS ON THE INVESTOR

Receive shares based on CEE expended during the year.

100% of investment on flow-through shares can be deducted as CEE, any CEE not deducted can be carried forward to future years.

Bonus deduction of $1 for 3 of grassroots CEE as earned depletion, can be deducted during the year; any not deducted can be carried forward. (Limited to 25% of net income after the deduction of CEE.)

Deducted on the tax return as "other deductions" (see Schedules A and B).

Will be usually taxed as capital gains on disposition of the shares unless (A CB=0) the taxpayer is a dealer or trader in securities. *

DISADVANTAGES

1. Liability
2. Liquidity

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* May qualify for the capital gains exemption as proposed in the May, 1985 budget.

SCHEDULEA

MR. INVESTOR

OTHER DEDUCTIONS

1985

Flow-Through Shares	
Sample Resources Ltd.	
Canadian Exploration Expense	$1,800.00
Related Earned Depletion	600.00
Total Deduction	$2,400.00
Carrying Charges	
Safety Deposit Box	18.00
	$2,418.00

SCHEDULEB

SAMPLE EXPLORATIONS LTD.

STATEMENT OF CANADIAN EXPLORATION EXPENSES- 1985

CANADIAN EXPLORATION EXPENSE

Number of units issued - 14 at $1,800 each
(entitling each unit subscribed to 3,000 shares on completion of the program)

Expenditures:

Prospecting and sampling	$ 10,000
Vehicle expense	1,000
Field supplies	500
Assay and geo-chemical analysis	2,400
Helicopter	4,000
Trenching	2,000
Blasting	1,000
Maps	500
Geological consulting	2,000
Camp costs	1,800
CANADIAN EXPLORATION EXPENSE	$ 25,200
Canadian Exploration Expense - per unit	$ 1,800

Depletion:

(b) Mining Exploration Depletion base - increase per unit	$ 600

The following has subscribed and paid for 1 unit(s):

Mr. Investor
1234 Main Street
Vancouver, B.C.

President

One copy to be filed with your 1985 Income Tax Return

F. EFFECTS ON THE CORPORATION

CEE & Related on such issues are not available to corporations to offset against future taxable income.

Flow-through shares are usually issed at a premium, less shares needed to be issued.

ACCOUNTING FOR FLOW-THROUGH SHARES

Increased in deferred exploration expenses
Increase in share capital
Effect on Canadian Exploration Expense pool should be disclosed in notes to financial statements.

G. DOCUMENTATION REQUIREMENTS

1. Trust Agreement with transfer agent (optional).
2. Subscriber Agreement.
3. Accountants''opinion" letter
4. Offering information about the company and the proposed exploration program.
5. Statement of Canadian Exploration Expense incurred on behalf of the investor.
6. Approval from the V.S.E. and Superintendent of Brokers.

FLOW THROUGH SHARE FLOW CHART

1. FORMATION OF A COMPANY[1]
2. ACQUISITION OF A RESOURCE PROPERTY
3. EXPLORATION PLANNING
4. PREPARATION OF
   1. TRUST AGREEMENT
   2. SUBSCRIBER AGREEMENT
   3. OPINION LETTER AND/ OR OFFERING DOCUMENT[2]
5. TRUST AGREEMENT SIGNED
6. OPINION LETTER AND/ OR OFFERING DOCUMENT TO THE INVESTOR
7. SUBSCRIBER AGREEMENT SIGNED $'s COLLECTED & FORWARDED TO THE TRUSTEE
8. COMPANY CARRIES OUT CEE[3]
9. COMPANY ISSUES AUTHORIZED REQUEST FOR FUNDS FROM THE TRUSTEE TO COVER THE COSTS OF CEE[3] CARRIED OUT

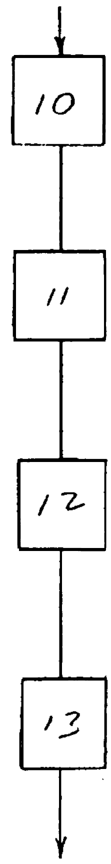
1. Company may already exist and may be public or private
2. If needed
3. Canadian Exploration Expense

TRUSTEE ISSUES FUNDS TO THE CORPORATION AND THEN ISSUES SHARES TO THE INVESTORS BASED ON THE AMOUNT OF CEE EXPENDED

COMPANY MAILS TO THE INVESTORS STATEMENTS OF CEE & RELATED EARNED DEPLETION

INVESTORS FILES PERSONAL INCOME TAX RETURN WITH STATEMENT OF CEE & EARNED DEPLETION

INVESTOR SELLS SHARE & REPORT'S DISPOSALON PERSONAL INCOME TAX RETURN



4. FOR GRASSROOTS CEE INCURRED AFTER APRIL 19, 1983 (REGULATION 1203 DATED FEB 14,1985)

TAX EFFECT OF INVESTMENT IN FLOW THROUGH SHARES

Tax saving		Common Shares	(367. Marginal Tax Rate) Flow through Shares	(43% Marginal Tax Rate) Flow through Shares
(1)	Investment.	100.00	100.00	100.00
(2)	Tax deduction			
	Canadian exploration expense		100.00	100.00
	Earned depletion allowance		33.33	33.33
		Nil	133.33	133.33
(3)	Tax savings	Nil	48.00	57.33
(4)	After tax cost of investment (1)-(3)	$ 100.00	52.00	42.67
Gain on after tax cost of investment				
(5)	Proceeds	100.00	100.00	100.00
(6)	Adjusted Cost Base	100.00	ØØ	ØØ
(7)	Capital Gain	ØØ	100.00	100.00
(8)	Taxable Capital Gain	ØØ	50.00	50.00
(9)	Tax	00	18.00	21.50
	Net after tax proceeds (5) (9)	100.00	82.00	78.50
	Less after tax cost (4)	100.00	52.00	42.67
	Gain	ØØ	30.00	35.83
	Percentage gain on after tax cost	00%	57.7%	84.0%

Assumptions :

1. Funds are expended on CEE (Canadian Exploration Expense) and all CEE earn depletion and together are deductible from all sources of income.

2. Shares are acquired for $100.00 and later sold for $100.00 and the investor pays tax on a capital gain basis.

FORMULATING A PHILOSOPHY FOR JUNIOR COMPANY EXPLORATION INVESTMENT

by

T.G. Hawkins
Vice President, Director
MPH Consulting Limited

Vancouver, British Columbia

Prepared for Presentation
Exploration and Mining
for Junior Company Executives
and Investors Seminar
The Engineers Club, Vancouver
January 27-28, 1986

Introduction

The following presentation has been prepared to provide some insight into the problems of unsuccessful junior company investment. I will not address the problem of the regulation of junior companies.

We are all familiar, I believe, with numerous drastic investment and technical failures at all levels of development and by all types of exploration firms. Such failures by junior companies are reflected in disastrous market results and, in general, a bad name for junior exploration companies, promoting and for our most renowned junior company haven, the Vancouver Stock Exchange. Examples include multi-million dollar investments on plant and mine preparation where no ore exists. Other examples, both within Canada and abroad, include projects that have undergone fifteen years of "feasibility studies" that clearly demonstrate, with "back-of-the-envelope" calculation that a project is uneconomic. Inappropriate arguments are continually made as to why the project should be prepared for production. A junior company that gets involved in either of these situations becomes a disaster in itself.

There are three main points that I would like to make; they form the basis for the formulation of what I perceive to be a philosophy for successful junior company exploration and are supported by evidence which I hope to present today.

1) The" philosophy of the junior company, rightly or wrongly, reflects the biases and training of the chief executive.

2) The role of junior companies in the process of discovering economic reserves is invariably inaccurately documented. As such, the philosophies and expectations of the uninformed are equally inaccurate due to their perceptions of:

   a) the time, and
   b) the money that is required to take an exploration concept to a production decision;

3) The successful junior investment company is not, or should not, be involved in discovering mines , but rather should be involved in acting as a short listing agent for a mineral property real estate market.

Philosophy - What is it?

By definition, the philosophy of the junior company must reflect the rationale or practical wisdom which defines and explains the general laws of successful mineral exploration investment.

Paul Bailly of Occidental Minerals tabled a number of philosophical approaches to mineral exploration investment. I have added interpretive comments to reflect common misconceptions related to these philosophies.

1) The elephant country approach - Looking for elephants where other elephants have been found or where elephants are projected to exist.

2) Grass roots exploration - Reconnaissance coverage of previously unexplored or previously explored areas.

3) Scientific ore finding - Based on multi-phased discriminating procedures at the expense of simple techniques.

4) The prospector and his burro technique - Cheap is beautiful.

5) The fortuneteller method - Bring your samples to us and we will tell you your fortune.

6) The grasshopper approach - Review every prospect that has ever been generated but never really make a decision or understand that which is being assessed.

7) Throw the book at it technique - By completing more and more surveys, the attractiveness of the mineralization will improve?

8) Saturation exploration - Applying every technique to every situation, as in the pure statistics approach.

9) The bulldog approach - Being one method applied to every situation.

10) The black box approach - Applying new and magical chemical and/or physical exploration techniques to deposits or properties that have not previously been demonstrated to be feasible.

There are examples of failure in all of these types of exploration "philosophies" but the failure is generally related not to the approach but to its misuse and to its singular dependence as a rationale for mineral exploration investment.

It is also possible to determine from an organization's modus operandi, who it is that is calling the shots, particularly when lopsided objectives are being practised, as in a number of the examples given above. The philosophy of the chief executive body is very much biased by the training of that chief executive, which in most cases for the junior company is an individual. The philosophy of the junior exploration company, then, is very much formulated on the biases, the training and the experience of the decision maker.

Peter Joralemon documented a number of interpretations of "ore" as seen through the eyes of the different professions that are involved in the mineral exploration process. I have borrowed some of his categories, and embellished some of the definitions:

1) The geologist's ore - which is found in perfect lineaments or perfect structures with classic alteration, classic textures, fitting previously defined models.

2) The geophysicist's ore - is characterized by classic chargeabilities, or perfect modelling curves, good resistivities, high conductivities, or magnetic susceptibility contrasts.

3) The metallurgist's ore - is certainly a category of more and more interest, particularly given projects where leaching is to be applied: heap leaching, vat leaching, tank leaching, pipe leaching--of gold or any other type of economic mineral.

4) The engineer's ore - is defined by operating costs, physical shape, character, the accessibility of the reserves.

5) Miner's ore - is ore in which production rates can be high, bonuses can be made, and ground conditions are good.

6) Assayer's ore - which "ore" can be and has been the subject of a number of disasters that have been born in the test tube. With the increase in gold and silver prices, the acceptable limits of accuracy have changed and now with the change in the emphasis on new and previously unexplored "for minerals , such as rare earths, platinum group metals etc., new standards are continually being tabled.

7) Lawyer's ore - is based upon certain rights, agreements and land status that otherwise make a project impossible, never mind uneconomic.

8) Politician's ore - is that which will increase votes by providing assistance programs in road construction, community development, job creation etc.

9) prospector's ore - for the most part is defined by the irresistible urge and an overall and general understanding of what is attractive.

10) The promoter's ore - or should I say, venture capitalist's ore, is that which will sell stock.

We are in an age of what has been called over-specialization, which can result in a lack of respect by some trained individuals for the knowledge that is held by individuals of other disciplines. A team effort is required in the exploration development venture if success expected.

Some Facts and Figures

To quote Louis Slichter of UCLA, "Vital statistics in prospecting are just as vital to prospectors as are the corresponding vital statistics in the insurance business." Exploration statistics are becoming more and more plentiful. Most studies concentrate on appraising the expectations of finding ore. I expect that, in the process of formulating an exploration philosophy, it is more important to look at the statistics of survival of the junior exploration company.

Knowing as we do that the process of "discovering" an economic deposit is made up of many sub-elements which are more or less synergistically related and that the whole is not simply the sum of the parts, let us assume three stages within the continuum of discovery:

1) ground acquisition or mineral rights acquisition, claim staking;
2) initial discovery by sampling which demonstrates economic grades over economic widths; and
3) delineation and feasibility.

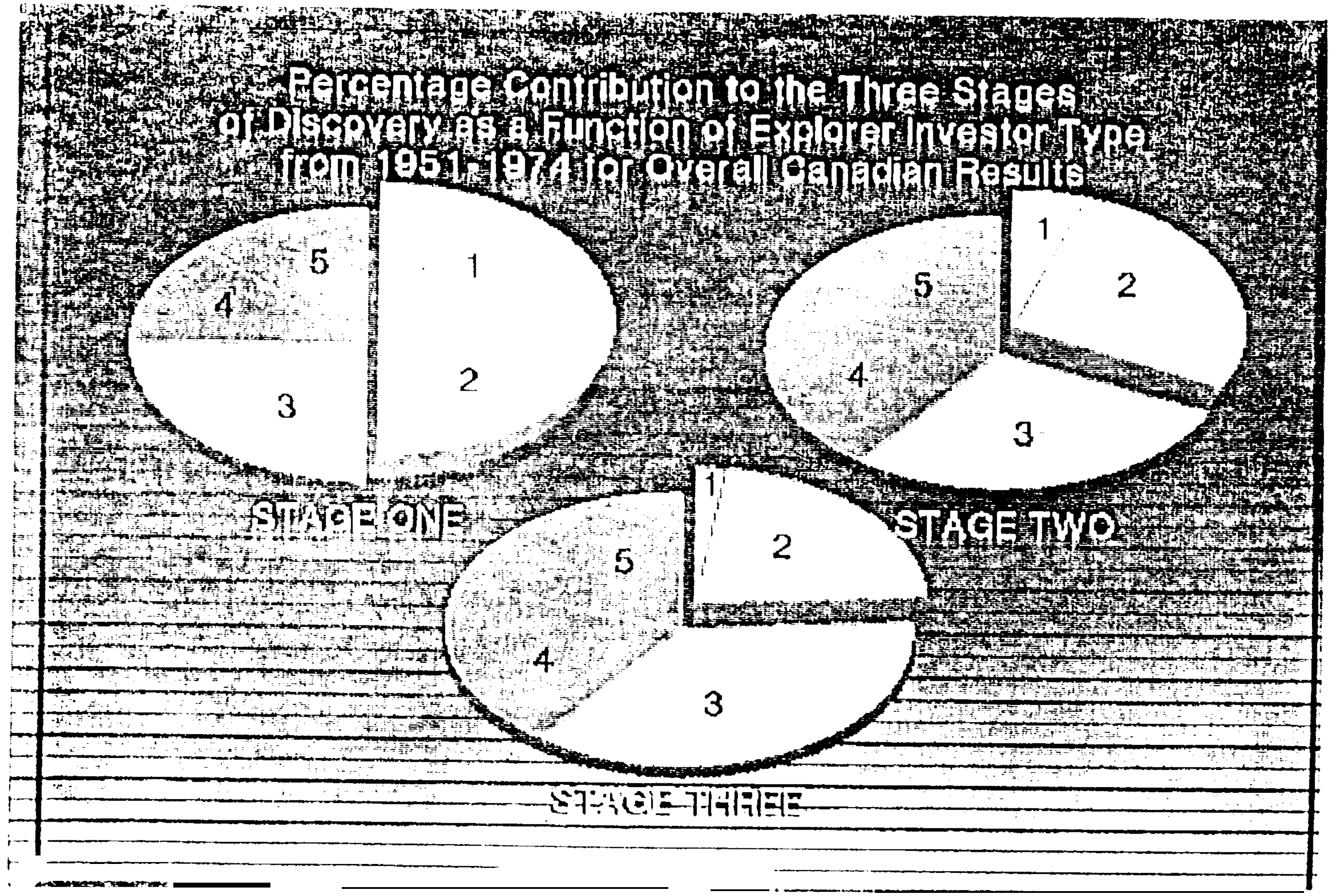
Remember, the economic discovery has not been made until the production decision is taken.

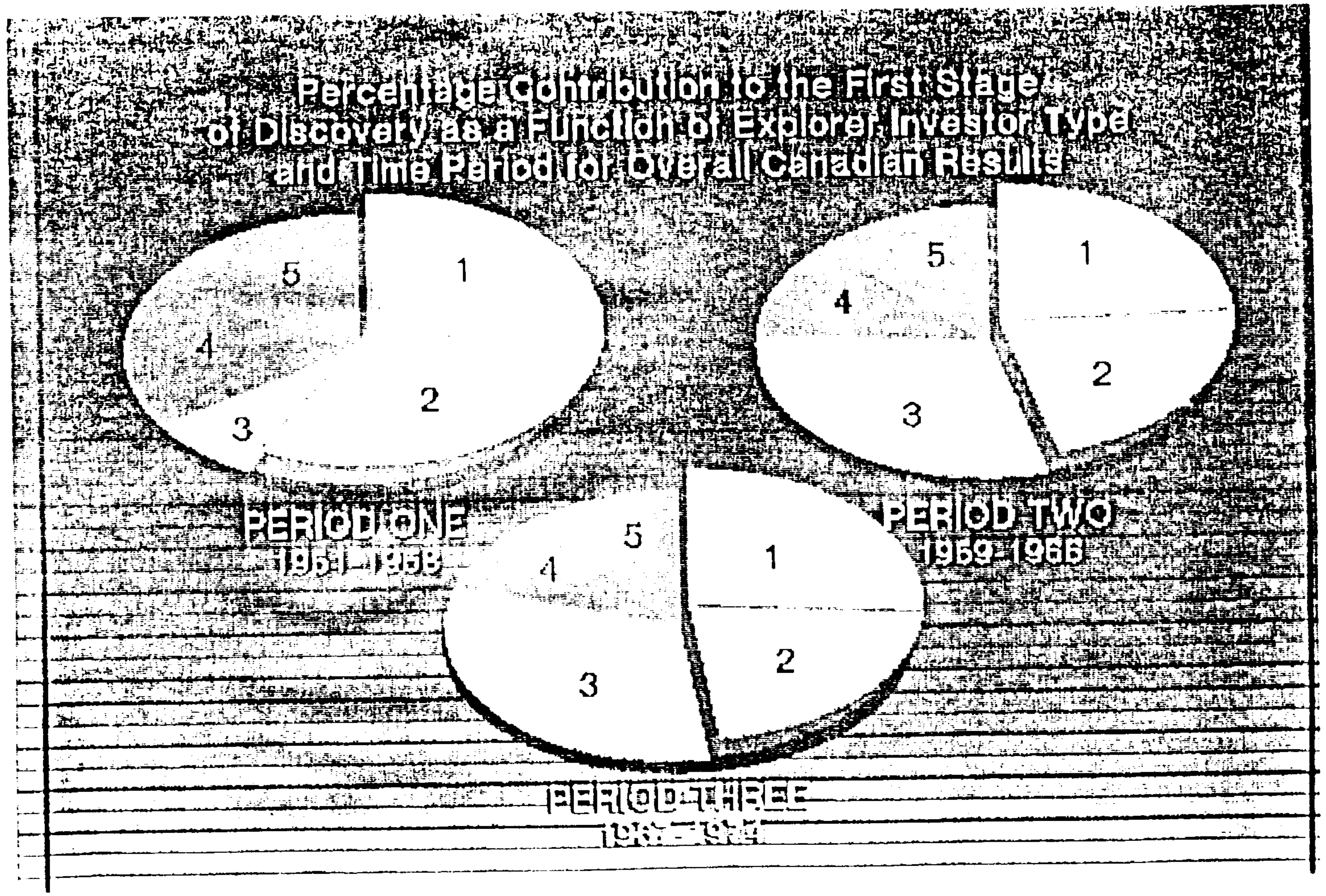
There are a number of different types of explorationists in the industry, all of which are competing for funds while complementing one another in the process of discovery. They are:

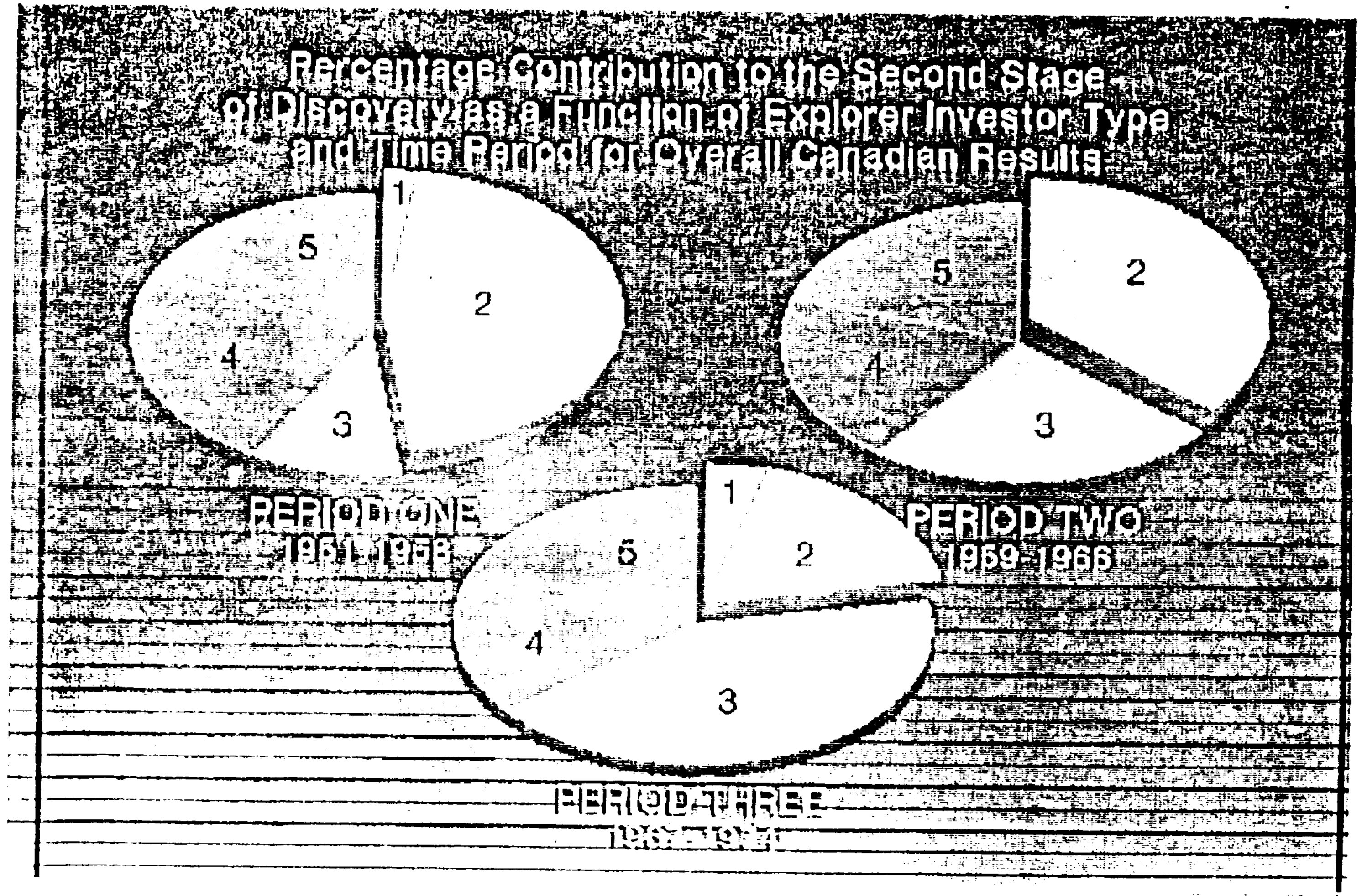
1) the individual prospector;
2) the junior exploration company;
3) the mining company;
4) the integrated mining company;
5) the external investor, being new entrants to the field of exploration that are well funded and can commit extensive resources .

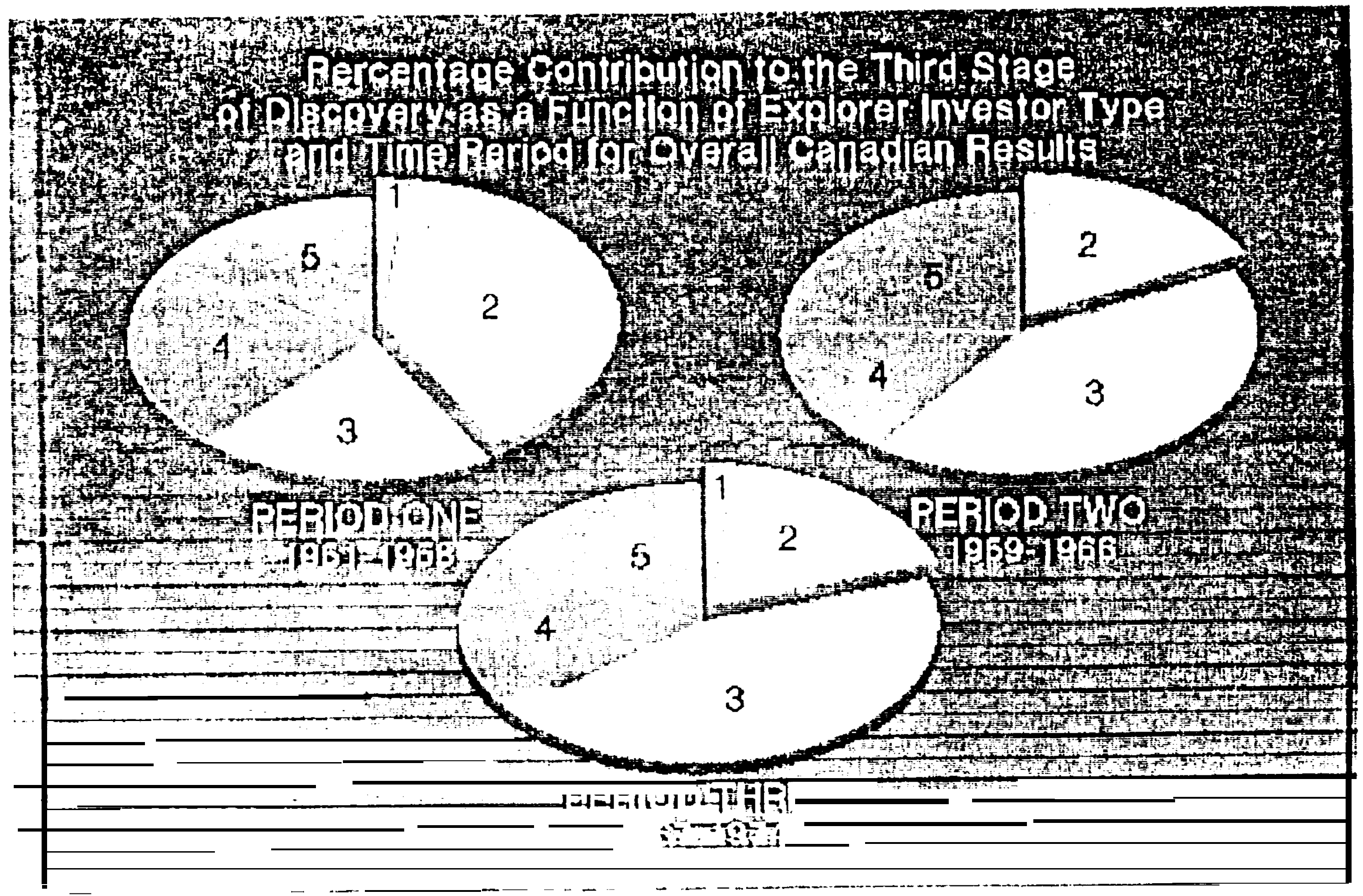
The following statistics cover a time period from 1951 to 1974, the period of rapid development of base metal exploration sciences and techniques in North America. They also cover the case histories of 86 Canadian deposits.

The junior company and prospector, with whom the junior company is inexorably linked, especially in modern times, have consistently


Percentage Contribution to the Three Stages
of Discovery as a Function of Explorer Investor Type
from 1951-1974 for Overall Canadian Results
1
2
3
4
5
STAGE ONE
1
2
3
4
5
STAGE TWO
1
2
3
4
5
STAGE THREE


Percentage Contribution to the First Stage of Discovery as a Function of Explorer Investor Type and Time Period for Overall Canadian Results
PERIOD ONE
1951-1958
PERIOD TWO
1959-1966
PERIOD THREE
1
2
3
4
5


Percentage Contribution to the Second Stage
of Discovery as a Function of Explorer Investor Type
and Time Period for Overall Canadian Results
1
2
3
4
5
PERIOD ONE
1951-1958
PERIOD TWO
1959-1966
PERIOD THREE


Percentage Contribution to the Third Stage
of Discovery as a Function of Explorer Investor Type
and Time Period for Overall Canadian Results
1
2
3
4
5
PERIOD ONE
1951-1958
PERIOD TWO
1959-1966
1
2
3
4
5

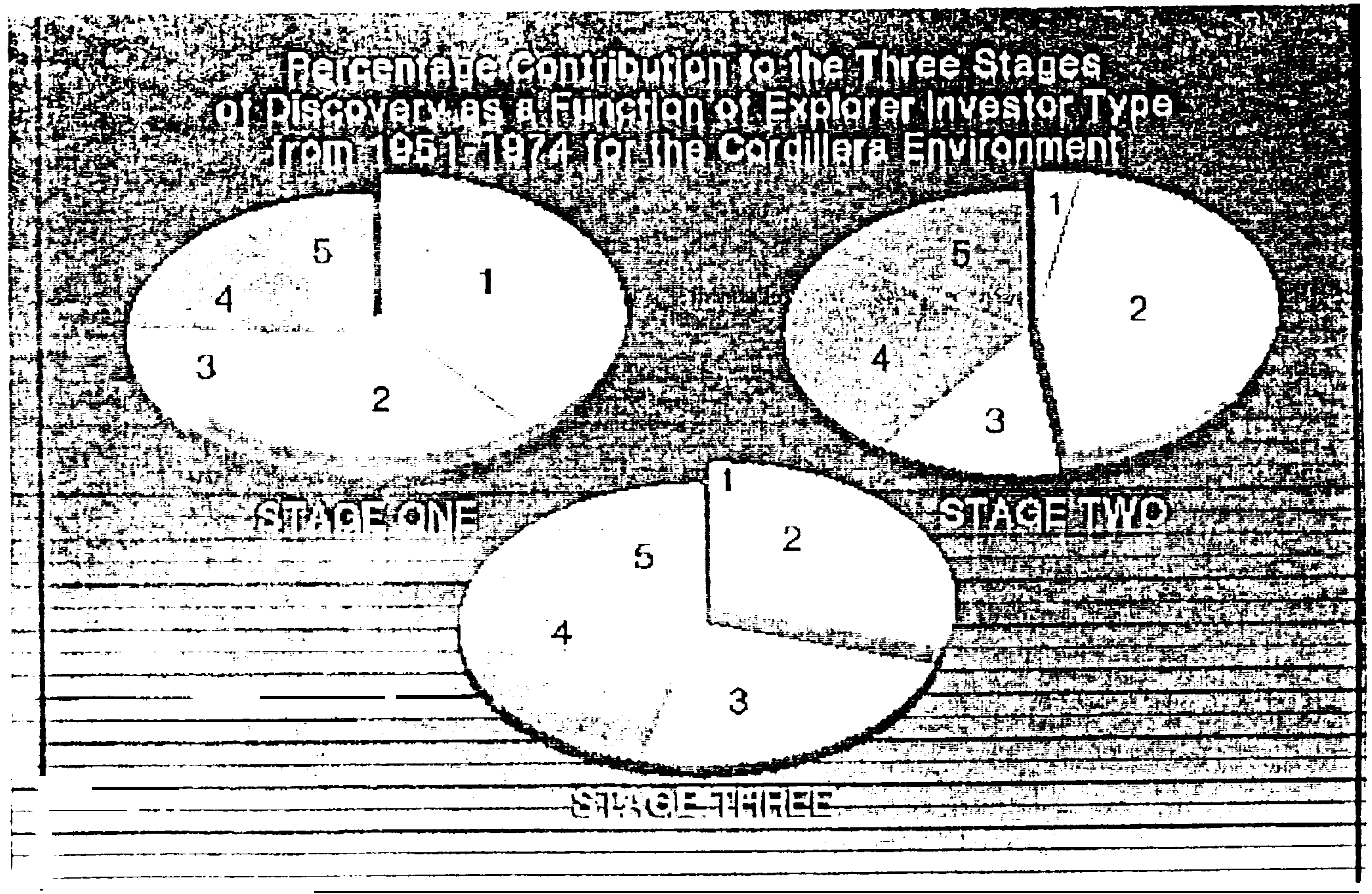
accounted for 50% of the first-stage discoveries in Canada. A 30% contribution is made at the second stage and 28% at the third stage.

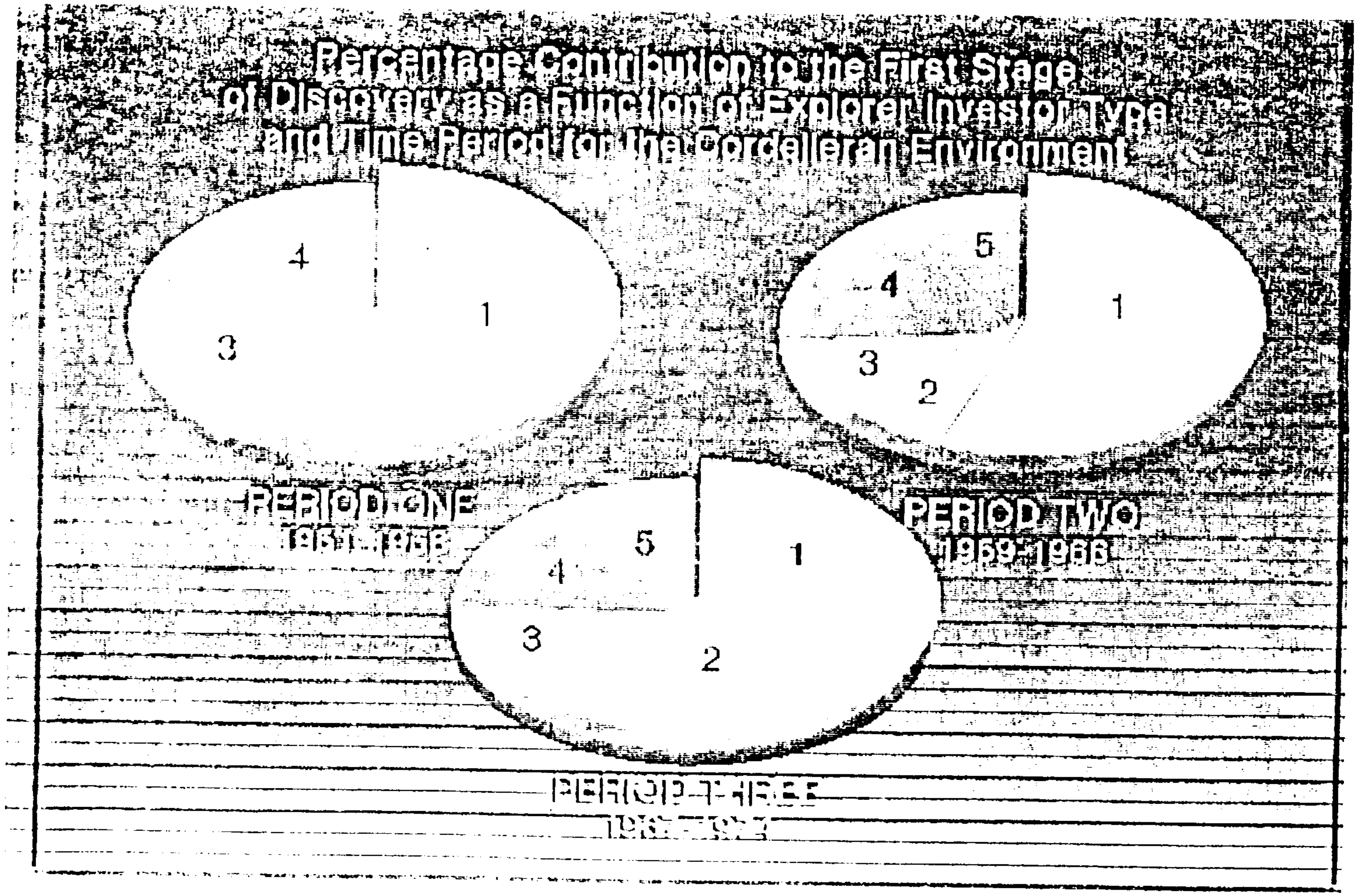
We can also see that this first-stage contribution by the junior companies is relatively consistent, and has been maintained over time. It is evident from recent publshed activities, although the detailed statistics that provided these numbers are not available to me now that I have joined industry, that the historic role the junior companies have played in the discovery of economic deposits is being maintained.

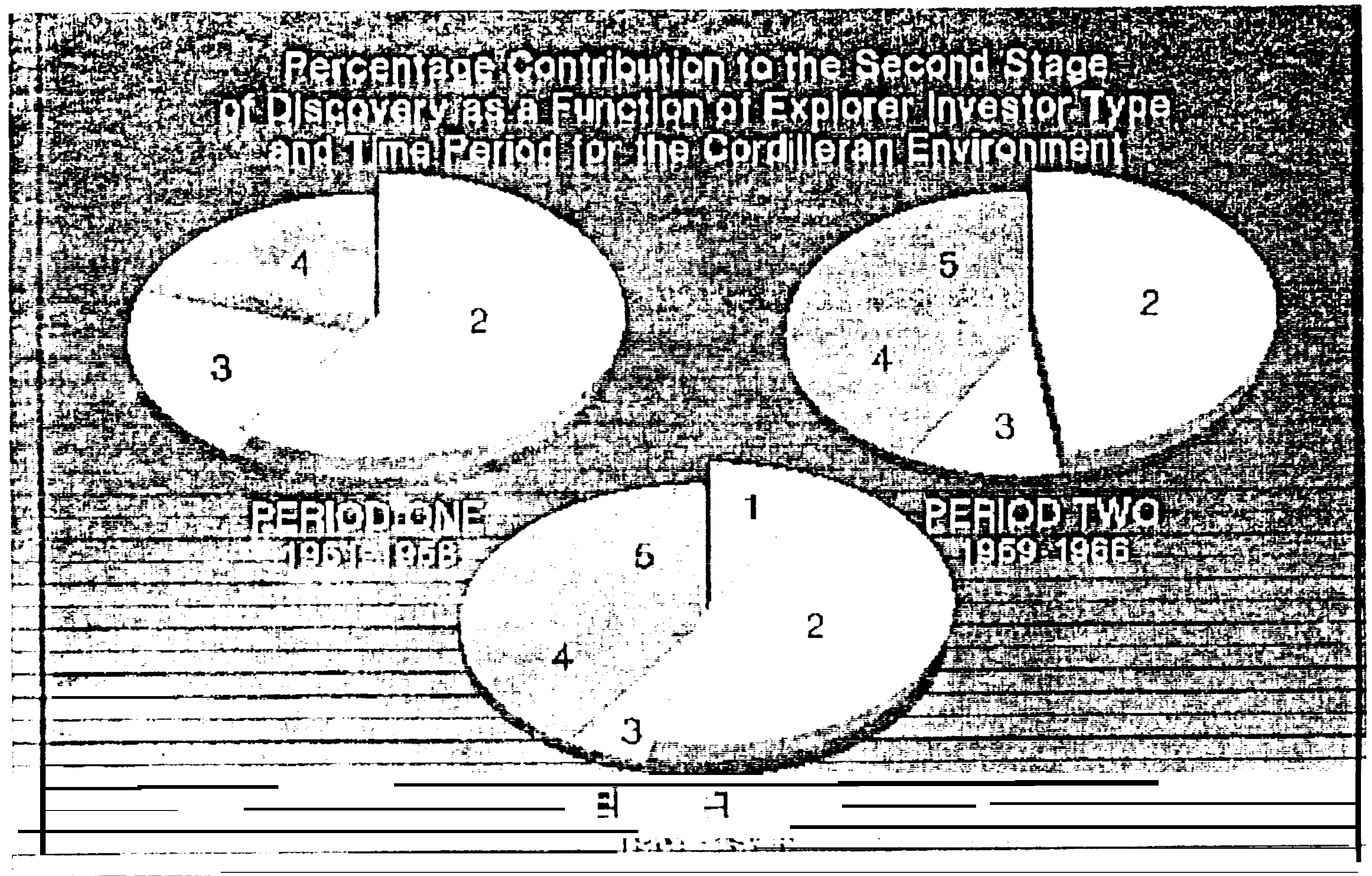
In the Cordilleran environment , i.e. the environment with which this conference is closely linked, British Columbia and the Yukon Territory, we can see that the percentage contribution by the junior exploration company and individual is nearly 65% for the stage one discovery, 50% for stage two, and a little more than 30% at stage three.

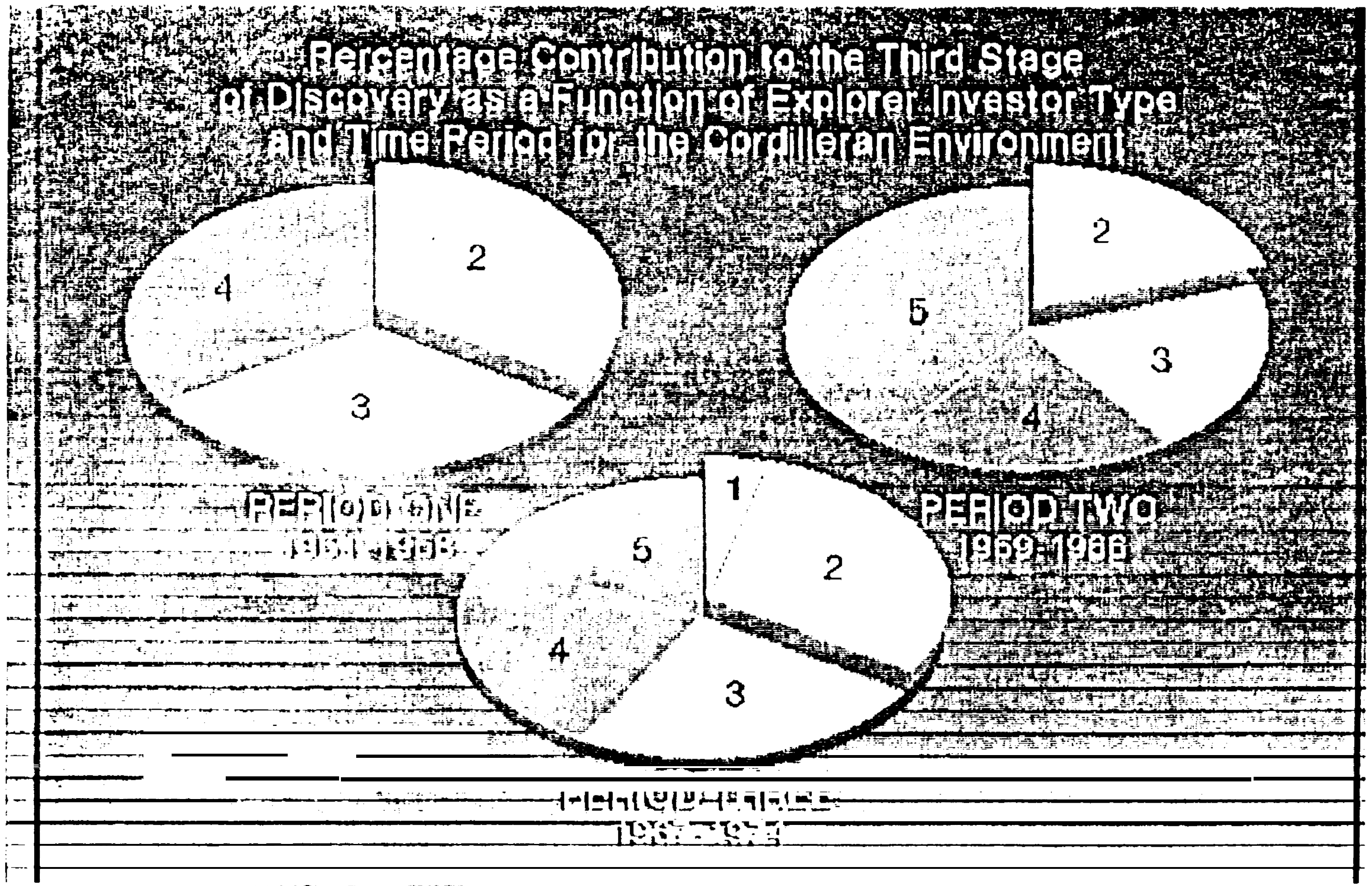
Again, over time this percentage contribution has not changed at the stage one and stage two discovery.

The average investment characteristics for the various investor types and for the various environments are demonstrated here with annual budgets in 1974 dollars. The individual and exploration company that is vying for success through discovery at stage one and/or stage two levels, should be looking at a minimum of eight to nine years of investment of $270,000 per annum, remembering again, 1974 dollars. In 1985 dollars this amount would equal about 2.5 times that amount. If these numbers seem rather


Percentage Contribution to the Three Stages
of Discovery as a Function of Explorer Investor Type
from 1951-1974 for the Cordillera Environment
5
1
4
3
2
STAGE ONE
1
5
2
4
3
STAGE TWO
1
2
5
4
3
STAGE THREE


Percentage Contribution to the First Stage
of Discovery as a Function of Explorer Investor Type
and Time Period for the Cordelleran Environment
4
3
1
5
4
1
3
2
PERIOD ONE
PERIOD TWO
1959-1966
5
4
1
3
2
PERIOD THREE


Percentage Contribution to the Second Stage
of Discovery as a Function of Explorer Investor Type
and Time Period for the Cordilleran Environment
4
2
3
PERIOD ONE
5
2
4
3
PERIOD TWO
1959-1966
1
5
2
4
3


Percentage Contribution to the Third Stage
of Discovery as a Function of Explorer Investor Type
and Time Period for the Cordilleran Environment
1
2
3
4
5
PERIOD TWO

disturbing at this level, you should attempt to explain to the larger, fully integrated oil companies and governments that they should be looking at at least fifteen years of spending one million dollars a year.

One of the classic incorrect responses to these statistics, however, is to postulate that if it takes fifteen years at a million dollars a year, then it takes five years at three million dollars a year. It is a false and dangerous assumption that these expenditures can be turned off and on like a tap and still produce successful results.

We as consultants are continually confronted with clients who believe their expertise is better than average. Unfortunately, these figures include only those companies that have succeeded, and they include all the better than average people as well.

However, what is glaringly obvious from this particular set of statistics is that the junior exploration company and/or individual is not in the business of finding mines. It simply cannot afford to. What the junior company is very good at, what is the supreme area of expertise even when stacked against major companies, is the ability to define and short-list good targets for venture or sale to the major investor.

The company that sees the favorable opportunity early and acts promptly will achieve a major advantage over others that delay too long in improving their analysis of a situation. For the junior company, this is the only true advantage but it is a major

Average Exploration Characteristics as a Function of Explorer-Investor Type & Environment (1961 - 1974) Hawkins 1979

Explorer-Investor Type	Average Budget		Average # of Discoveries at One or More Stages		Average # of Years of Expenditure to Realize Above	
	Cordilleran	Canada	Cordilleran	Canada	Cordilleran	Canada
1	17,557	15,654	1.2	1.3	9	8
2	270,538	247,484	1.0	1.0	6	6
3	1,136,315	1,010,660	1.8	1.5	13	10
4	756,160	2,782,184	1.7	5.0	22	20
5	[illegible]010,942	1,227,[illegible]	[illegible]	1.2	17	10

advantage. Decisions can always be made more quickly in the junior mining company. Unfortunately, that includes both good and bad decisions.

There are exceptions to the rule. Under conditions that are exceptional , one might make a different decision. But too many decisions now are based on unreal expectations , supported by terribly limited resources .

Where then should the junior company invest? how should it invest? when should it stop investing? what should it invest in? what is it that makes the junior company successful? It must first be accepted that the junior company management is graded on the increase or decrease in value of their stock in the market place. The senior company is graded on the increase in value of their dividend and the longevity of value of their stock. The junior company is successful only if it can apply limited funds to high-risk situations at the initial stages and then allow major investors to carry them in the high technical risk phases of a project. A junior company is only as good as its last deal, which in turn will determine the company's ability and the abilities of the individuals involved to raise financing for the next deal. The finding of the mine, however, must be at the risk of the major company.

A Rationale or Philosophy for
<u>Corporate Survival for the Junior Exploration Company</u>

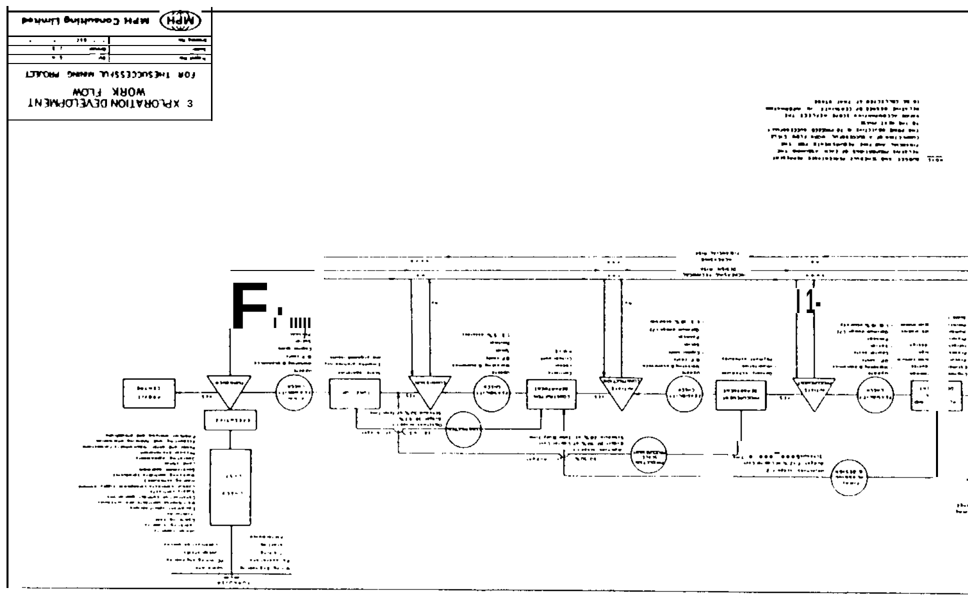
We are in an age of the market. Many agree that a marketing approach to many problems will aid in survival. The junior company is marketing properties to major companies and marketing investments to people on the street.

Let us return to some of the questions raised a short time ago: "Where should the junior company and individual invest? How should it invest? When should it stop investing? What should it invest in?

The following work flow diagram is a simplification of what the exploration development process looks like. It is divided into two separate sides for the purpose of demonstrating to engineers and geologists at which point the work flow is the responsibility of the exploration geologist and at which point the work flow is the responsibility of the development engineer.

Given our previous comments, let us say that the time represented on the following work fiow chart is twelve years and if a completed production facility is assumed at the point of profit centre turnover, anywhere from 50 million to 300 million dollars has been spent for a reasonably sized, revenue-generating mine.

We go to the front end of the chart and refer to some of our previous comments and different descriptions of ore. At the "think tank" level, all definitions of ore should be pooled in order to identify opportunities whether they be metallurgical, operations, financial, marketing, geological, legal, political. From this point, and following the identification of an opportunity or a number of opportunities, regional resource appraisal, regional exploration, mineral rights acquisition, target appraisal, delineation, feasibility studies and plant


EXPLORATION DEVELOPMENT
WORK FLOW
FOR THE SUCCESSFUL MINING PROJECT
MPH Consulting Limited

construction are successively carried out. Also, given our previous comments, phase 1 of a discovery is at property acquisition: phase 2, is at target appraisal: and phase 3 begins at delineation, which phase is carried on throughout a good part of the final feasibility.

In order to help define the risk element at various stages of this work flow process, I like to use scales of the drawings that will be constructed at each stage as a representation of the degree of accuracy of information and, therefore, the risk that is evident at each stage. Let us say, for instance, at the regional resource appraisal stage the scale of a drawing would be 1 :250,000, at the next stage 1:50,000, and the next 1:2500, and 1:500, and 1:100, and 1 :2 and finally, 1 :1 or full scale and 100% accuracy. It costs a lot of money and it takes a tremendous amount of time to zero in on a target of the size of 1 in a field of 250,000.

In terms of budget at stage one, and at 1:250,000 scale we are spending 1% of the total budget; at the 1 :50,000 scale we 'are spending 5% of the total budget; at 1 :2500 we are spending 10% of the total budget; at 1 :500 10% of the total budget, and at scale 1 :100 we are using up 15% of the total budget and in the final design and construction stage, we are using 60% of the total budget. These figures are presented only as an indication. In total costs would be incurred at the final design and construction stage than at the exploration stages.

At the target appraisal stage, when the first drill holes are put down, the opportunity for speculative increases in stock is at its greatest. There is no real, immediate value or advantage to the junior company in terms of increasing credibility or increasing stock value during the delineation and preproduction stages. Maximum value is generally created by a good promoter at the target appraisal stage. This, then, must make the most logical cut-off point to which the junior company should take a project. The junior company takes responsibility for investing when exploration risk is highest, but where financial risk is lowest. As a group, they are the most effective and efficient investors of that high risk capital.

At the point where a legal agreement is made, the junior company should be able to retain sufficient free ride to profit, should a major deposit be developed.

Another point that is often forgotten is that the price that the major company pays the junior company for highly advanced, or high potential projects is minimal compared to the cost of buying those reserves from scratch, i.e. exploring and expending funds required to discover those reserves in-house. In this way, the major company does not have to finance all the failures which it would fund through a total program as part of its own exploration effort. The junior exploration group must determine deposit types, commodities, locations, market potential, financing packages and legal agreements that are attractive to the major company.

In order for the work flow to be continuous, those that start the exercise must be completing a project that is in agreement with those that will finish it. In other words, those to whom you will market the project, must be in the market to purchase that particular project. As such, the junior exploration company must be aware of where, for what, and with whom the major company is exploring.

In appreciation of the survival requirements of the junior company and the philosophy that it has adopted, it is paramount that major partners be selected at least partially on the basis of their sympathy for the junior companies' survival requirements.

Design and Implementation of
Programs Consistent with the Chosen Philosophy

We have now determined that the junior exploration company is in the business of short-listing mineral properties for option to the major companies. We have also determined that the development of a mine is a process that costs many tens of millions of dollars and takes ten to fifteen years to complete. We accept that within that time span and for the duration of that expenditure, the junior exploration company is involved up to the point of initial economic indications, although the sooner the property can be vended for a carried interest, the lower are the financial risk and probably the exploration risk for the junior company. We also must remember, however, that the only true advantage the junior company has over the major company is the ability to effectively and efficiently invest high-risk front end capital and to make corporate decisions quickly. They must, therefore, maintain flexibility. Any decision to proceed with an exploration project must be justified and rationalized by the economics, the budget and schedule and the scope in order to market attractive projects to potential senior investors.

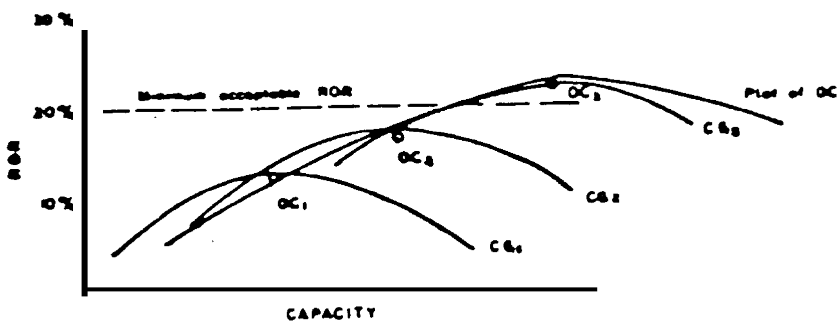
Preliminary economics must be monitored from day 1 . There are innumerable examples of programs and projects being carried out by junior exploration companies, mining companies , senior mining companies, that cannot possibly be justified on an economic basis. The'projects don't make any sense in the present and they will not make any sense in the foreseeable future and yet company after company, program after program is designed to expend high-risk capital and commit resources to those projects. In some cases, however, redefining the project or 'orebody' can demonstrate economic feasibility. Orebodies are not finite but represent a whole range of tonnages and grades. What might not be an economic" 900 ton per day project at an average grade of 0.1 oz gold/ton, . might be economic at 100 tons/day at 0.5 oz gold/con.

The scope of any new project must define;

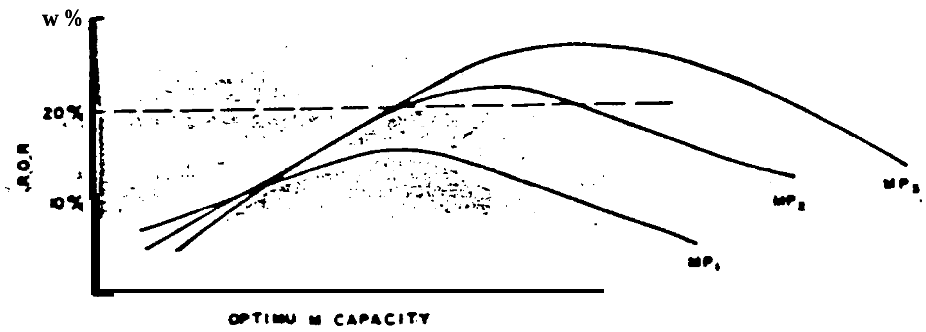
1) the certainty or accuracy of information to be collected and
2) the decisions to be made at the end of the project.

Again, we can refer to numerous examples of property exploration programs that are being carried out which will result in the purchase of a mill, or the completion of a first phase drilling program that will result in the determination of proven tonnage and grade figures. There are two things wrong with these plans, given that we have accepted short listing of mineral properties as

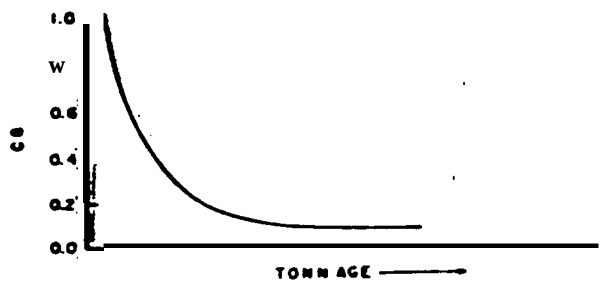
ECONOMIC CHARACTERISTICS

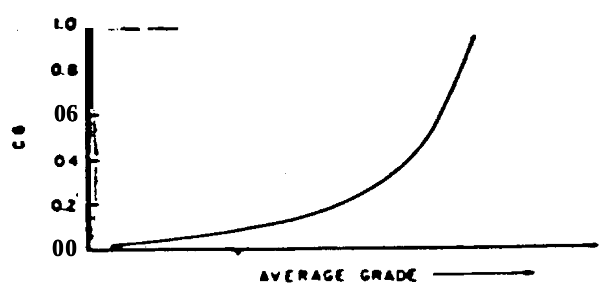


To be Calculated for a Range of Metal Prices



PHYSICAL CHARACTERISTICS





LEGEND

CG	Cut Off Grade
MP	Metal Price
ROR	Rate of Return
OC	Optimum Capacity

our philosophy: we shouldn't be buying mills nor should we be proving tonnage and grade; and the second thing is, two quantum leaps have been taken in arriving at the decision, given the level of accuracy that has been generated from the project.

Budgets and schedules are an indication of the type of programs to be commissioned. The budget for regional resource appraisal should be in the order of $10-20,000. The schedule would typically involve two to four months. Follow-up regional exploration could involve $50,000 over a period of three months. As part of that program and from the targets generated and properties acquired, a first-phase property exploration program should be in the order of $25,000, to be spent over one month. A target appraisal phase should cost in the order of $250,000, to be spent over a period of two months. At preliminary delineation, two million dollars and six months, and a final delineation, four million dollars and eighteen months. These are merely examples of what might be expected. Generally, as a rule of thumb, I suggest to clients that they should be spending around 10% of a proposed budget to determine whether or not they should proceed with that proposed budget. I have, however, seen examples of expenditures of $100,000 to determine whether or not a $40,000 decision should be taken.

An Example

At this time, it might appear that my greatest expertise is in being involved with disasters, which point reminds me of a person I worked with in the bush who, shall we say, displayed erratic character and behaviour. When determining who it was who should be allowed to drive the vehicles in the field, he presented his case very well by saying, "Let me drive, I've had experience in lots of accidents." I would, however, like to present an example that is in the process of developing into the successful completion of the work flow previously seen displayed on the chart.

We are now five years into this program. We have assisted, attracted and sold (as well as lost) a number of junior exploration company clients. We have also, however, had some who have been with us from the start of the program, and these companies are now beginning to reap some of the benefits. The name of the project is the Sicker Play on Vancouver Island.

We were able to identify through the study of the efforts of many past explorationists that one particular area on Vancouver Island was attractive for a number of reasons:

1) the properties that were believed to have the economic potential in the area were ones which we believed could be sold to major companies, if sufficient encouragement could be demonstrated. This was evidenced by the fact that a number which recently has reached thirteen major companies already had an active interest in the area;
2) The economics of exploration and access were excellent;
3) The economics and access given a production decision were excellent, ie port facilities, Pacific Rim marketing of products;
4) Geological models, economics and mineability were proven in this environment given the recent HW deposit discovery of Westmin Resources;
5) The area was essentially unprospected using modern techniques ;

6) A number of old prospects were available for option and new ground was available for staking.

There were, however, negative aspects as in any case, and it was equally important to understand the negative as well as the positive:

1) It was apparent that other areas, being Eastern Canada, particularly during the wake of the Hemlo discovery, were drawing tremendous amounts of high-risk venture capital;
2) Exploration incentives through tax breaks, government payback schemes, and general exploration costs, were better elsewhere;
3) Proven geological and/or mineral endowment were far greater in Eastern Canada, given the Abitibi-Greenstone beltand the history of that area, which by the way happens to be one of the richest mineral belts in the world;
4) A lack of sustained, proven production and exploration history was evident resulting in a lack of support by technical and investment analysts in the investment world;
5) Land status problems stemmed from historical railway grants that deeded base metal mineral rights to the CP Railway. Although these rights were essentially reverted to the Crown in the early '70s, there were a number of areas where the rights were maintained, the specific boundaries of which were not available for public review without extensive and expensive research.

To date, and following the regional resource appraisal, which is presented, we were able to identify numerous property targets, for which clients subsequently have acquired, through various means, the rights to explore. We have in some cases gone to target appraisal. We have identified a new platinum and paladium discovery for Western Canada for one client. This seems relevant and significant given recent developments in the platinum and paladium minerals industry. We have identified two massive sulphide targets which suit, to some degree models that will satisfy major company interests. We have acquired for our clients numerous claims by staking, which have yet to be explored, but which demonstrate good geology. Other discoveries in the area have been made by major companies, with feasibility study decisions pending on one particular deposit near Mount Sicker.

Summary

The junior company survives and the junior company industry survives because:

1) The senior executive recognize their biases and acquire expertise or advice in areas of weakness;
2) As a group they are superior high-risk explorationists in terms of both efficiency, (cost benefit) and effectiveness (proportionate numbers of economic discoveries);
   At the high-risk stage, the exploration company can make decisions more quickly and can apply limited resources in order to secure a much less limited potential return;
3) The successful junior exploration company does not set out to discover a mine, but acts with major investors and mining

companies to short-list viable exploration ventures with development potential.

It is essential to be aware of the status of the junior exploration company and where it fits into the exploration investment process. It is essential to ascertain the rationale or philosophy for survival. The one which I think is most obviously displayed in the statistics previously discussed has been presented today. It is up to the junior exploration company to carry out programs consistent with the philosophy that they have developed.

In recent times it has been suggested that perhaps the role of the junior company is diminishing due basically to the fact that the easy discoveries closest to surface have already been found. The developments that we see going on today at Hemlo in Ontario, at Red Dog in Alaska belie this assumption. We are also, I think, mislead by the assumption that our mineral endowment is superior; it is not in any way superior to the undeveloped and underdeveloped parts of the world. What is great is our ability to convert our resources to reserves 'and the first phase of that process is the realm of the junior exploration company.

The first step in improving junior company performance is developing informed executives. You are all commended for taking this step.

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EXPLORATION AND MINING FOR JUNIOR COMPANY
EXECUTIVES AND INVESTORS

JANUARY 27 & 28, 1986

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COMPANY DIRECTORS RESPONSIBILITIES

These materials were prepared by Jurgen T. Lau of Messrs. Bull, Housser & Tupper, 3000 Royal Centre, 1055 West Georgia Street, Vancouver, B.C., V6E 3R3, Phone #(604) 687-6575

COMPANY DIRECTORS' RESPONSIBILITIES

The Corporation is the dominant business organization in our society. While in most other areas of business, corporations are closely held private (non-reporting) corporations, the most common organization in the mineral exploration and mining business is the public, (reporting) widely held corporation whose shares are trading on any one or more Canadian or U.S. Stock Exchanges.

On the Vancouver Stock Exchange there are approximately 1,700 companies which have their shares listed. If one assumes that 75% of those companies are junior exploration and mining companies and each has the statutory minimum of three directors, they collectively have about 3,825 directors.

A corporation cannot function on its own. It can only act through its agents which are its directors. While the company shareholders have ultimate authority over the company, it is the board of directors that is charged with the responsibility of guiding and overseeing the actual operations of the company.

It is always flattering to be asked to become a member of a board of directors. However, it is becoming more and more of a dangerous honour to be invited to become a member of the board. As noted by J.M. Wainberg and Mark I. Wainberg in Duties and Responsibilities of Directors in Canada (CCH Canadian Limited, 1984):

> "For, with the position, the director automatically assumes some very onerous duties and responsibilities. He impliedly undertakes that he has reasonable skill and will exercise reasonable diligence in carrying out his duties. Before accepting the position, serious consideration should be given to the hidden aspects, not only to the superficial prestige.
>
> Most prudent businessmen will not hesitate in refusing to guarantee a friend's loan but will readily fall for the dubious prestige of being invited on the board of a company with results infinitely more disastrous, "

The message I would like to convey to you at the beginning is this. Don't treat becoming a director in a corporation lightly, Consider who your co-directors are. Know what your responsibilities are and make sure that your fellow directors' treat them with the same degree of respect that you have set for yourself.

I propose to examine the classic responsibilities of company directors and to discuss recent changes in legislation which extend the civil liability of directors.

To accept the position of director is to subject oneself to many responsibilities. It has been said that:

> "Directors and the board of directors have responsibilities in both senses of the word: they have an obligation (duty) to see that everything is done in accordance with the law; they must accept the blame (liability) if things are not done in accordance with the law, especially if someone suffers loss or damages as a result." (Wainberg, page 9).

Not only are the responsibilities many and onerous, but they are owed to such diverse parties as the company, fellow directors, the shareholders, government agencies, creditors, employees, and the public at large. The late Chief Justice of the Supreme Court of Canada, Bora Laskin, explained the reasons for the Courts' insistence upon enforcing these responsibilities:

> "Strict application [of the law] against directors and senior management officials is simply recognition* of the degree of control which their positions give them in corporate operations, a control which rises above day-to-day accountability - an acknowledgment of the importance of the corporation in the life of the community and of the need to compel obedience by it and by its promoters, directors and managers to norms of exemplary behavour." (Canadian Aero Services v. O'Malley (1973), 40 D.L.R. (3d) 371 at 384).

While it is flattering to be cut out from day-to-day accountability and held to norms of exemplary behavour in the execution of one's responsibilities, it is well to be clear on the nature and parameters of these responsibilities. The relevant sections of the federal Canada Business Corporations Act, S.C. 1974-75, c.33 and the British Columbia Company Act, R.S.B.C. 1979, c.59 are not overly edifying. Section 97(1) of the Canada Business Corporations Act provides that:

> "Subject to any unanimous shareholder agreement, the directors shall manage the business and affairs of a corporation."

Section 141(1) of the B.C. Company Act provides that:

> "The directors shall, subject to this Act and the articles of the company, manage or supervise the management of the affairs and business of the company."

All that really emerges from these sections is that the directors are empowered to "manage the business", or "supervise the management of the affairs", However, other sections provide further specifics,

Section 117 of the federal Act states:

> "(l) Every director and officer of a corporation in exercising his powers and discharging his duties shall
>
> (a) act honestly and in good faith with a view to the best interest of the corporation; and

(b) exercise the care, diligence and skill that a reasonably prudent person would exercise in comparable circumstances."

Section 142(1) of the Company Act modifies only slightly the provisions of its federal counterpart:

> "Every director of a company, in exercising his powers and performing his functions, shall
>
> (a) act honestly and in good faith and in the best interest of the company, and
>
> (b) exercise the care, diligence and skill of a reasonably prudent person."

Clearly, this is too general to give any guidance to a prospective director and one must look beyond the statutes. Historically, the Courts have regarded directors as acting as both agents and trustees with respect to the corporation. As agents, they are given the authority and responsibility of managing the assets of the company so as to gain profits. As trustees, they are vested with the responsibility of preserving the assets and they occupy a position of trust with respect to the corporation and its shareholders. The Supreme Court of Canada recognized in Canadian Aero Services Ltd. v. O'Malley [1974] S.C.R. 592 the position of directors as trustees:

> "however, is very different from that of ordinary trustees whose primary duty is to preserve the trust

property and not to risk it. Directors have to carry on business and this necessarily involves risk. . ."

As a result of many court cases dealing with thousands of cases involving specific, often unique, circumstances and personal relationships, conflicts of interest and responsibilities, there has evolved a body of case law relating to directors' responsibilities, I use the term "responsibility" as it was used in my introductory quotation: in the dual sense of obligation and liability. It is said that directors have a duty to be honest, loyal, to take care, to be diligent, to act to the best of their ability and to be as prudent as a prudent businessman and to give their whole ability, business knowledge and attention to the best interests of the company, These are fundamental and in many ways "motherhood-type" responsibilities, Few would argue with them as they appear. However, it might be useful to indicate the frequently stiff standards behind the seemingly innocuous phrases,

Duty of Honesty

The British Columbia Company Act requires directors, in exercising their powers, to "act honestly and in good faith and in the best interests of the company" . The federal Act modifies the requirements only by the addition of the qualification "with a view to the best interests of the company". Much case law has been distilled into these provisions. Directors must be open and candid about their dealings affecting the company. Toward the company, they occupy a position analogous to that of a witness toward the court – they must tell the truth, and the whole truth. Should they fail to observe these standards, they can be held personally liable to the company for misuse of company funds, misappropriation of funds, knowledge of illegal or improper acts of employees, making improper loans to fellow directors, declaring dividends which render the company insolvent, etc.

Duty of Loyalty

The duty of loyalty ("to act in good faith and in the best interests of the company" or with a view thereto) imposed upon a director is absolute. Unlike the duties of a care or skill, it cannot be varied by such factors as the background or experience of the director. A director must not allow his personal interest to be brought into conflict (and he should be equally vigilant about confluence) with those of the company. As a trustee, as a fiduciary, a director must not make a personal profit from his position.

The Courts are not the least shy about upholding this standard. In fact, they generally celebrate it. Mr. Justice Cardozo commented in an American case (Meinhard v. Salmon 249 N.Y. 458, 464, 164 N.E. 545, 546 (1928)):

> "A trustee is held to something stricter than the morals of the market place, Uncompromising rigidity has been the attitude of the courts of equity petitioned to undermine the rule of undivided loyalty by the disintegrating erosion of particular exceptions . . . Only thus has the level of conduct for fiduciaries been kept at a level higher than that trodden by the crowd."

If the Court determines that a director has breached his duty of loyalty, the director will be required to account to the company for the profits realized, And the Court will make its determination after consideration of many factors, It was said in Canadian Aero Service Ltd. v. O'Malley, (1974) S.C.R. 592 at 620:

> "The general standards of loyalty, good faith and avoidance of a conflict of duty and self-interest to which the conduct of a director or senior officer must conform, must be tested in each case by many factors which it would be reckless to attempt to enumerate exhaustively Among them are the factor of position or office held, the nature of the corporate opportunity, its ripeness, its specificness and the director's or managerial officer's relation to it, the amount of knowledge possessed, the circumstances in which it was obtained and whether it was special or, indeed, even private, the factor of time in the continuation of fiduciary duty where the alleged breach occurs after termination of the relationship

with the company, and the circumstances under which the relationship was terminated, that is whether by retirement or resignation or discharge."

Duty of Care

While the duty of care is yet another strict ethic, it may be mitigated should the background and lack of experience of a director so warrant, The duty of care requires that a director act with prudence and diligence, The standard of prudence required here is an objective one, that based on common sense (while the standard required with respect to the duty to act to the best of one's ability is a subjective one based on individual experience) ,

Duty of Diligence

The statutory duty of diligence imposed upon . directors is that of "the reasonably prudent person". The case law would indicate that what is required of a director is that he keep himself informed as to the activities, policies, business and affairs of the company, by attending and participating in meetings of the board, by frequent examination of corporate records and/or by conferring with co-directors and with company officers. It would appear that unquestioning reliance upon co-directors, officers and outside experts will not meet the standard. A director is required to exercise his own judgment when seeking information and assurances from such parties, A director who is on the boards of several companies which may be dealing with each other may be well advised to advocate the retention of separate independent experts. A director will be deemed to have consented to improper or illegal resolutions or acts of the board even if not present at the meeting concerned unless upon learning of such he takes immediate and effective steps to dissociate himself therefrom,

Duty of Skill

At common law, a director was not required:

> "to exhibit in the performance of his duties a greater skill than may reasonably be expected from a person of his knowledge and experience". (In re City Equitable Fire Insurance Co. Ltd. [1925] 1 Ch. 407),

The Courts have qualified this subjective standard somewhat by holding that the act of accepting the position of director is an implied undertaking by the director that he had such reasonable skill and ordinary diligence as would be necessary for the business of the company to be carried on. This is known as the "business judgment" rule and it still applies in some jurisdictions.

However, the federal and B.C. Acts (among others) have imposed a minimum objective standard of skill, that of the reasonably prudent person. Wainberg in Duties and Responsibilities of Directors in Canada ventures that:

> "Apparently no allowances will be made for any shortcomings: lack of skill, knowledge or intelligence. The director must always act as a 'reasonably prudent person' would act 'in comparable circumstances'. In determining whether the director has passed the test the courts will probably give consideration to the following factors:
>
> (a) the qualifications of the director,
>
> (b) the significance of the action,
>
> (c) the information available to the director,
>
> (d) the time available for making the decision,
>
> (e) the alternatives open to him,
>
> (f) whether he is a representative of a special interest group (shareholders, creditors, employees), and
>
> (g) whether he is an advisor to the corporation (lawyer, accountant, engineer)." (page 24)

And just what is a "reasonably prudent person" in the context of these statutes? It seems safe to venture that such a person would act cautiously, carefully and deliberately, ever mindful to the possible consequences, desired and otherwise, of a proposed course of action.

Given the ups and downs of modern business life and given the Courts' articulated and demonstrated commitment to enforcing the norms of exemplary behaviour required of directors, the "liability" sense of the word responsibility looms large. Potential actions against directors include derivative actions brought by shareholders on behalf of the corporation, actions brought by shareholders for their own losses or damages, applications for compliance or restraining orders and actions brought by third parties (government agencies, employees, creditors, customers, etc).

J.M. Wainberg suggests the following defensive practices for directors in Duties and Responsibilities of Directors in Canada to limit their exposure:

"1. Attend all meetings of the board,

2, Insist on receiving, before the meeting, all documents and reports on which he will be expected to vote.

3. Read them,

4. Review with care all minutes of meetings.

5. Keep notes of your own impressions of the meetings.

6. Keep a loose-leaf note book in which you collect minutes and other important documents,

7. Insist on written legal opinions for any important step about to be taken,

8. Insist on written professional opinions from specialists, accountants, engineers, etc. on whose advice the board is expected to act.

9. Insist on the minutes recording any disclosure made by you or your refraining from voting or your dissent.

10. Vote against any disbursement if there is any question of insolvency of the corporation,

11. Send a letter by registered mail to the Corporation (with a copy to the Director of Corporations) if the secretary (or the chairman) refuses to record your disclosure, your refraining from voting, or your dissent, " (pages 60-61)

Insurance

Both the federal and the B.C. Acts permit a corporation to indemnify directors and officers in certain circumstances , The Acts permit indemnification – they do not order it. Moreover, both Acts authorize a company to purchase and maintain insurance in order to cover indemnification.

Directors and officers may themselves take out insurance against some of the claims which might be made against them. However, due to public policy and reluctance of insurers, not all risks can be insured against.

Specific Responsibilities

Apart from the general responsibilities outlined so far, the directors of corporations face numerous statutory responsibilities arising from breach of those statutes by the corporation. For instance, where a corporation is guilty of an offence under the British Columbia Company Act, every director or officer of the corporation who authorized, permitted or acquiesed in the offence is guilty of an offence and is liable to a fine of $2,000.

Conflicts of Interest

The duties imposed on a director by law give rise to a number of conflicts of interest situations where:

(a) a director makes a decision or acts on behalf of the Company other than in the best interest of the Company;

(b) a director personally contracts with the corporation of which he is a director;

(c) two corporations of which he is a director contract with each other;

(d) a director learns of an opportunity for profit which might be valuable to him personally and to the corporation;

(e) a person serves as director on more than one corporation in the same business.

In conflict of interest situations the common law rules are very strict and require the director to account for profits made and the accountability does not depend on proof of bad intent or whether the company has lost or benefited from the actions of the directors.

This strict common law rule has been modified by statute in most jurisdictions (Sections 144 and 145 of the Company Act). However, contracting with a corporation of which he is a director, being a director of more than one company in the same business and making personal use of opportunities which presented themselves in the course of one's office as director, remains potentially very dangerous and should be avoided.

If a conflict cannot be avoided it will be necessary to adopt the strictest of disclosure practices and, in the case of a director wishing to make use of a

corporate opportunity, the opportunity should be presented first to the board of directors and the shareholders and resolutions should be passed refusing the opportunity.

The foregoing has been an overview of company directors' responsibilities as they have evolved in the case law and as they are prescribed in federal and B.C. company Acts. These Acts are, of course, not the only Acts to impose duties and liabilities on directors, Securities legislation, in the course of mediating between the investing public and those companies that offer their shares to the public, has historically sought to regulate some aspects of the conduct of officers and directors of public companies where such conduct affects the public and is particularly relevant to junior mining company directors, We in British Columbia will soon have a new Securities Act, Now Bill 37-1985, it has passed Third Reading, received Royal Assent and is, according to the Ministry of Consumer & Corporate Affairs, to be proclaimed into force in March of this year. This Act will substantially increase the exposure of public company directors to civil liability for misrepresentations in prospectuses, Directors have long been liable to some degree for untrue statements in prospectuses. The Directors Liability Act, 1890 in the United Kingdom imposed upon directors liability in damages to those who had invested in a new issue of securities and had suffered loss because of an "untrue statement" in a prospectus. A number of defences were provided, the most significant of which was that the director

"had reasonable ground to believe, and did believe"

in the truth of the impugned statements.

Bill 37 owes much to Ontario The Securities Act, R.S.O. 1980, c. 466 which was proclaimed into force from August 1, 1981. The current Ontario Act has broken much new ground and Bill 37 has followed happily in its footsteps.

Section 114 of Bill 37 confers the remedies of rescission or damages upon a purchaser who purchases the securities offered by a prospectus during the period of distribution if the prospectus contained a misrepresentation of a material fact at the time of purchase. Sub-paragraph 114(1)(a)(iii) confers upon the purchaser a right of action for damages against every director of the issuer at the time the prospectus was filed,

Let's put this into perspective. Section 1 of Bill 37 contains the following definitions:

"misrepresentation" means

(a) an untrue statement of a material fact; or

(b) an omission to state a material fact that is

(i) required to be stated, or
(ii) necessary to prevent a statement that is made from being false or misleading in the circumstances in which it was made;

"Material fact" means, where used in relation to securities issued or proposed to be issued, a fact that significantly affects, or could reasonably be expected to significantly affect the market price or value of those securities;

A purchaser has 180 days from the date of his purchase to bring his action for rescission, but he has the earlier of three years after the date of his purchase and 180 days after he first had knowledge of the facts giving rise to the cause of action to bring an action for damages. A purchaser who exercises his right of rescission against the issuer, the selling security holder or the underwriter has no right of action for damages against the person from whom he claimed rescission, Thus it would appear that the remedies of rescission and damages are not alternative for all purposes as a purchaser could technically rescind his purchase from his vendor and sue others in damages. There are five classes of persons who may be subject to an action in damages: the issuer or selling security holder; some or all of the underwriters depending upon the organization of the underwriting firm; every director of the issuer at the time the prospectus was filed; every expert who files a consent to the inclusion of his opinion, statement or reported in a prospectus; and every signatory of the prospectus, The liability of all of these five classes is joint and several between themselves and they are not liable for all or any part of the damages that do not represent the depreciation in value of the security resulting from the misrepresentation,

Paragraph 114(1)(a) provides that where a prospectus contains a misrepresentation, a person who purchases a security offered by the prospectus during the period of distribution shall be deemed to have relied upon the misrepresentation if it was a misrepresentation at the time of purchase, Thus , no issue can arise regarding the existence of a causal connection between the misrepresentation and the purchaser's loss. However, none of the potential defendants in an action for either rescission or damages is liable under subsection 114(1) if he proves that the person who purchased the securities had knowledge of the misrepresentation. There are, of course, different types of knowledge: actual, constructive and imputed, Moreover, subsection 114(14) provides that the right of action for rescission or damages conferred by this section is in addition to and not in derogation from any other right the purchaser may have, However, the defence of due diligence is available to underwriters, directors & signatories to the prospectus. Assuming always that the prospectus was filed with his consent and knowledge, a director is not liable under subsection (1) if he establishes that after reasonable investigation he had reasonable grounds for believing that there was no misrepresentation in respect of the nonexpertised part of the prospectus and that he had no reasonable grounds for believing and did not believe that there was a misrepresentation in respect of the expertised part of the prospectus. Section 116 provides that:

> "in determining what is a reasonable investigation or what are reasonable grounds for belief for the purposes of section 114 and 115, the standard of reasonableness shall be that required of a prudent person in the circumstances of the particular case".

Neither the Ontario Securities Act nor Bill 37 makes any distinction between due diligence standards between inside directors and outside directors. As a matter of practice, inside directors take a much more active and investigatory role in the preparation of a prospectus than do outside directors. And the distinction between the roles of insider and outsider directors in such activities as preparing a prospectus is reflective of more than time constraint on outside directors. The distinction is related to what has been referred to as an

> "iron paradox which governs corporate affairs. . . Only those who are involved in an enterprise full-time has sufficient knowledge to direct an enterprise, while only those who are not involved full-time can be trusted to monitor those who direct" (Eisenberg, "Legal Models of Management Structure in the Modern Corporation: Officers, Directors and Accountants, 63 Calif. L Rev. 375 at 398-402 (1978), quoted in Ralph L. Simmonds, "Directors Negligent Mis-Statement Liability in a Scheme of Securities Regulation, 11 Ott.L.Rev 633 at 640).

It has been suggested in that the standard of reasonableness in the investigation as set out in the Ontario Securities Act equivalent provision to Bill 37's section 116 may result in the application of different standards of care between directors. He suggests that director members of the audit committee may have a higher standard of care than other directors in reviewing any unaudited interim statements that are to be included in the prospectus, just as a director who is a lawyer may have a higher duty than other directors in scrutinizing the prospectus disclosure on important legal matters and a director who is a geologist may be subject to a higher standard of care in reviewing the disclosure of reserves in the prospectus of a natural resource issuer,

Two American securities cases, Escott v. BarChris Construction Corp (1968), 283 F.Supp. 643 (U.S.D.C., S.D.N.Y) and Feit v, Leasco Data Processing Equipment Corp. (1971), 332 F.Supp. 544 (U.S.D.C., E,D.N.Y.), acknowledged a distinction in the standard of "reasonable investigation" required of insider and outsider directors, It must be added that the courts held that generalized non-specific inquiry was not "reasonable investigating" as required by section 11 of The Securities Act 1933.

In his commentary on the current Ontario Securities Act, **Alboini** concludes (pp. 22-21 and 22-22):

> "It is difficult to assess the impact that the due diligence standard will have on the preparation of prospectuses in final form for approval by directors. The following matters may be considered:
>
> 1. If at all possible an individual should delay becoming a director if the issuer is in the process of finalizing a prospectus;
>
> 2. The directors' due diligence defence is not established if their "reasonable investigation" is limited to the directors being led through a prospectus at the meeting called to approve its execution;
>
> 3. Directors could receive proofs of the preliminary prospectus and the prospectus as they approach final form - perhaps the second to last draft at least 7 days before the board meeting called to approve the prospectus;
>
> 4. Directors could be given an opportunity to contact independently the senior officers involved in the preparation of the prospectus or company counsel or to attend a special due diligence meeting with the senior officers;
>
> 5. In very special cases where there is a serious concern regarding the disclosure in a prospectus, a director could retain his own counsel to inquire into the matter at issue;
>
> 6. Directors who are members of the audit committee may be advised to ask the auditors for the issuer for a comfort letter on interim financial statements to be included in a prospectus;
>
> 7. It does not appear to be necessary for the audit committee to meet and review the financial statements before the filing of the preliminary prospectus and before the filing of the prospectus, A meeting of the audit committee prior to the filing of the prospectus may suffice. However, any material events that

occur in the red herring period should be deal with;

8. Counsel for the issuer could attend the board meetings called to approve the preliminary prospectus and the prospectus."

In an article in the Globe and Mail's Report on Business on October 7, 1985, Claire Bernstein echoes many of the above recommendations and adds:

"But since it is impossible to foresee how stringent a Court will be in evaluating responsibility of any one director all directors, including the insider ones, should arm themselves with a heavy covering of directors' and officers' liability insurance, particularly around public offering times",

In the case of Lac Minerals Ltd. v. New Cinch Uranium Ltd. et al, Lac Minerals relied partly upon section 141 of the Securities Act, R.S.B.C. 1979, c. 380 to name the directors of New Cinch as co-defendants along with the company, the Vancouver Stock Exchange and others. Section 141 'provides the purchaser of securities to which a prospectus containing a material false statement relates with a remedy in damages against, among others, every person who was a director at the time of the issue of a receipt for the prospectus. During the latter half of 1979, New Cinch conducted a drilling exploration programme for gold in their leasehold Orogrande, New Mexico property, using the services of El Paso Chem-Tec

Laboratories to assay portions of the cores. The initial assay reports indicated that the samples contained significant gold values. Press releases and letters to shareholders were prepared disclosing the assay results. At the same time, a Vancouver firm of consulting geologists was retained by New Cinch to prepare a further report on the Orogrande property. The Vancouver firm obtained from Chem-Tec samples of drill ore and submitted 10 of the samples to an independent laboratory in Vancouver for assaying. This assay report indicated negligible gold content, and was confirmed thereafter by reassaying at the same independent laboratory. The Vancouver consulting firm reported the discrepancies between the assay result of the two Vancouver assay laboratories and those of ChemTec to two New Cinch directors. These directors then arranged for further , portions of the 10 samples and some additional samples of drill core to be assayed at the Ontario assay laboratory of yet another corporate defendant. The assay results again indicated negligible gold content. Shortly thereafter the VSE advised the same two New Cinch directors that it had learned of unexplained discrepancies in the assay results. The VSE indicated that it would hold the matter in its current files but indicated its concurrence with New Cinch's decision to publish the assay results received from Chem-Tec.

In 1980, a Statement of Material Facts was prepared by New Cinch. The Statement was approved by the VSE and filed in August 1980, The Statement referred to the Orogrande property and the 1979 exploration programme and based its predications of potential gold and silver tonnage on the Chem-Tec assay results. The certificate concluding the Statement was signed by six New Cinch directors and by the authorized signing officers of 2 corporate promoters (later defendants), The Statement received wide distribution throughout Canada in connection with the proposed public offering of shares and warrants of New Cinch. The 1980 drilling exploration programme was commenced at Orogrande in the fall of 1980 and Chem-Tec was again used as the assayer. Press releases reporting on the asay results indicated very significant deposits of gold.

Public interest was high. The price of New Cinch shares rose from $2.00 to $29.20 over a 5 month period. Lac Minerals Ltd. was the largest buyer of the shares, spending $25,7 million through its subsidiary Willroy Mines Ltd. In early 1981, Lac Minerals allegedly learned that there were no significant quantities of gold in the drill cores from the Orogrande, requested a halt in trading of New Cinch and publicly disclosed what it had learned, When trading resumed, Lac Minerals sold all its shares and warrants of New Cinch for $4 million. Lac Minerals then brought suit against New Cinch, its directors, the two corporate Promoters the VSE, and others. The suit was settled for $4 million, of which New Cinch paid $1.32 million, the two corporate promoters each paid $1.04 million and the VSE, while vigorously denying the charges, paid $275,000. An outside director of New Cinch then brought suit in British Columbia against New Cinch, the other defendant directors and the two corporate promoters for breach of contract-to indemnify him for costs, charges and legal fees incurred by him with respect to the Lac Minerals claim. He claimed to have acted honestly and in good faith with a view to acting in the best interests of New Cinch and that he had not been advised of the inaccuracies and discrepancies in the facts contained in the Statement. The suit was settled out of Court.

As a postscript: the yet unsolved (in spite of the involvement of the RCMP, FBI and Scotland Yard) murder in November of 1982 of a former employee of Chem-Tec has been reported in The Globe & Mail as having been linked to the Lac Minerals lawsuit. The victim's father found a statement under the rug in his son's room purporting to outline in detail the victim's beliefs about the New Cinch affair and Chem-Tec's involvement. The statement was described in the article as:

> "a curious mixture of startling and sordid detail - much of it factual - only slightly inaccurate; some outlandish".

As one of the defendant New Mexico promoters concluded:

> "Perhaps the greatest tragedy of all, other than the human frailty, is that none of us in this room, or any room, might ever know who concocted this whole damn thing."-

1 hope I have not painted such a dark picture that it discourages you from acting as directors in the junior mining and exploration sector, There is no doubt in my mind that, over time, the standards of behavior required from directors both by statute and common law, will see greater and greater enforcement and from my observation of the Vancouver junior mining and exploration scene, the areas of conflict of interest and true and plain disclosure in public financing documents are likely to receive the greatest attention,

January 28, 1986

al65/12

FLOW THROUGH SHARE

FINANCING

JANUARY 28, 1986

RANDALL YIP, C.A.

222 - 470 GRANVILLE

ST. VANCOUVER, B. C.

V6C 1V5

685-8769

}7

PRINCIPLES

(1) INVESTORS BECOME "THE PROSPECTORS"

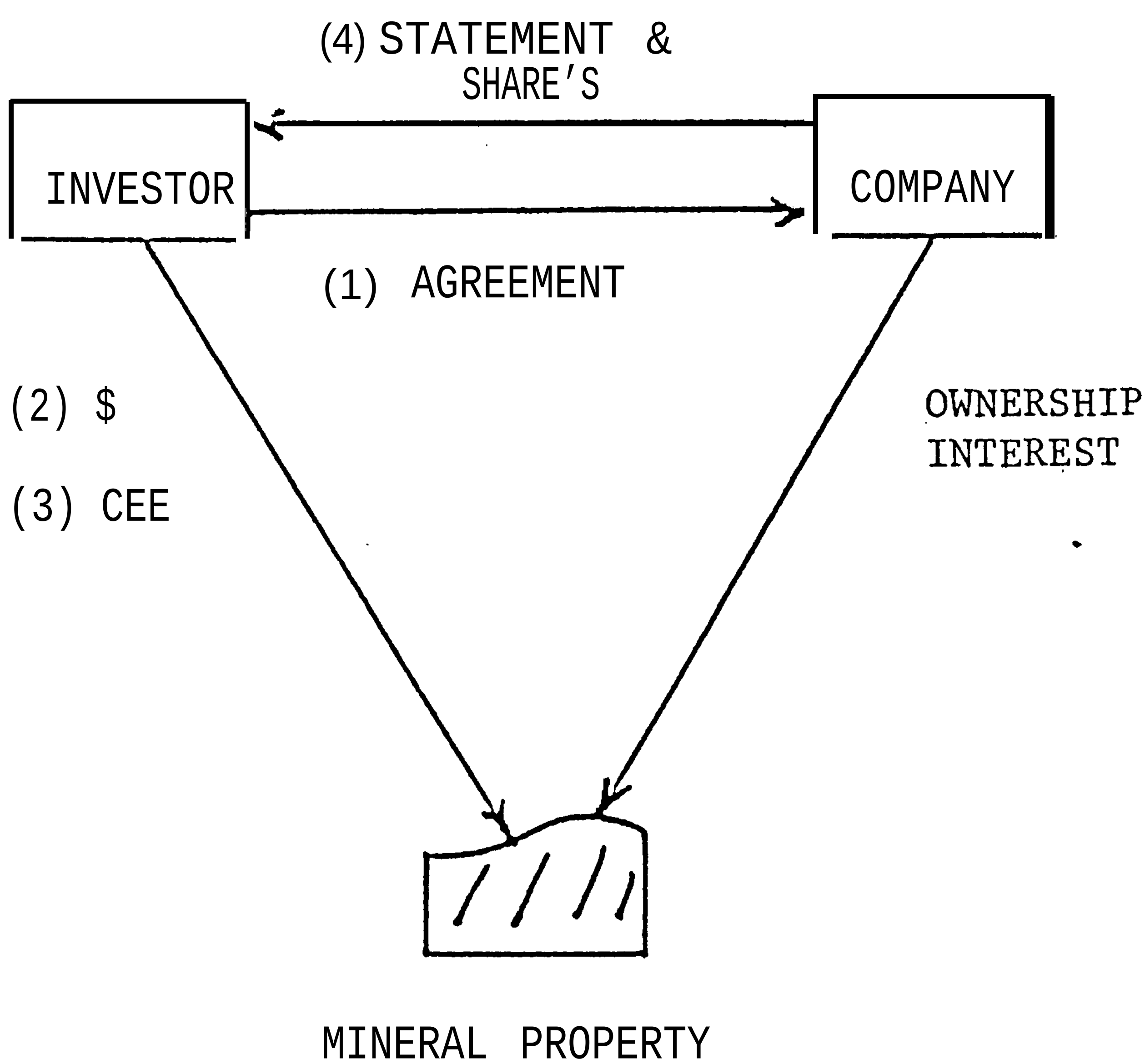
(2) COMPANY IS THE AGENT OF THE INVESTORS

(3) PLANNING IS IMPORTANT

WHAT IS A FLOW THROUGH SHARE?

INVESTORS ENTER INTO AN AGREEMENT WITH A COMPANY IN WHICH INVESTORS INCUR CANADIAN EXPLORATION EXPENSE (CEE) SOLELY AS CONSIDERATION FOR SHARES OF THE COMPANY.

FLOW-THROUGH SHARES DIAGRAM



INVESTOR

WHERE CAN I BUY FLOW-THROUGH SHARES?

1. PUBLIC ISSUES - STOCK BROKERS

2. LIMITED PARTNERSHIP

CMP 110 MILLION--WOODGUNDY

NIM 100 MILLION--BROKERS

681-7493

MIN TAX - 10 MILLION--

DON GRAHAM 681-0418

3* PRIVATE PLACEMENTS

- RESOURCE COMPANIES

INVESTOR

WHEN ARE FLOW-THROUGH SHARES IS SUED?

1. RELATED CANADIAN EXPLORATION EXPENSES EXPENDED .

2. PRIVATE PLACEMENT ONE YEAR HOLD PERIOD .

DOCUMENTATION TO SIGN?

1. SUBSCRIPTION AGREEMENT AUTHORIZING THE COMPANY TO CARRY OUT EXPLORATION ON THE INVESTORS BEHALF.

INVESTOR

LIMITS TO DEDUCTION?

1. CEE 100% AGAINST NET INCOME - ANY NOT DEDUCTED CAN BE CARRIED FORWARD.

2. EARNED DEPLETION 33 1/3% OF GRASS ROOTS CEE (CANADIAN EXPLORATION EXPENSE) - LIMITED TO 25% OF NET INCOME AFTER DEDUCTING CEE--ANY NOT DEDUCTED CAN BE CARRIED FORWARD.

INVESTOR

TAXATION ON DISPOSAL?

- USUALLY CAPITAL GAINS BASIS UNLESS DEALER OR TRADER IN SECURITIES.

- COST FOR TAX PURPOSES DEEMED = 0

- SHOULD QUALIFY FOR PROPOSED CAPITAL GAINS EXEMPTION.

- MAY BE AFFECTED BY PROPOSED MINIMuM TAX .

INVESTORS

DISADVANTAGES ?

1. LIQUIDITY - ISSUED AFTER CEE EXPENDED.

   - ONE YEAR HOLD ON PRIVATE PLACEMENTS.

2. LIABILITY -

   SOLUTIONS:

   - LIABILITY INSURANCE
   - LIMITED PARTNERSHIP.

3. PRICE FLUCTUATIONS DURING HOLD PERIOD.

4. INVESTMENT MUST BE MADE PRIOR TO YEAR END.

5. MINIMUM TAX.

INVESTORS

ADVANTAGES ?

- UP TO 133 1/3% DEDUCTION FROM TAX.
- LOWER RISK DUE TO LOWER AFTER TAX COST.
- SHOULDQUALIFY FOR CAPITAL GAINS EXEMPTION .
- ACQUISITION OF MARKETABLE SHARES.
- CMP , NIM & MIN TAX UNITS NOT SHARES " LIQUIDITY FOR CMP & NIM--CONVERSION TO MUTUAL FUND UNITS , MIN TAX UNDERLYING SHARES ISSUED .

EXAMPLE : MR. TAX PAYER

15,000 SHARES @ $1/SHARE =	$15,000
CEE DEDUCTION	$15,000
ED DEDUCTION	5,000
TOTAL DEDUCTION	$20,000*

AFTER TAX COST

COST	$15,000
*TAX REDUCTION @ 53.47%	10,694
NET COST	$ 4,306
NET COST/SHARE	$ .29

ASSUMPTIONS

- TAX PAYER AT MAXIMUM TAX RATE OF 53.47%
- ALL OF INVESTMENT SPENT ON CEE & ED AND WAS ALL DEDUCTIBLE.

SUMMARY

INVESTORS

1. LIQUIDITY
2. LIABILITY
3. COMPANY
4. TIMING OF PURCHASE
5. TAX DEDUCTION

28

RESOURCE COMPANIES

WHY?

- ATTRACTIVE TO INVESTORS.

- ISSUE SHARES AT A PREMIUM.

- CEE & ED USUALLY NOT NEEDED BY JUNIOR RESOURCE COMPANIES.

RESOURCE COMPANIES

SEQUENCE

1. BUDGETING AND PLANNING

   - EXPLORATION & ADMINISTRATION .

2. OFFERING DOCUMENTATION

   - SUBSCRIBER AGREEMENTS
   - TRUST AGREEMENT
   - LETTER RE TAX CONSEQUENCES
   - USE OF FUNDS.

3. SET-UP ACCOUNTING , SEPARATE BANK ACCOUNTS .
4. DOCUMENTATION SIGNED, MONEY COLLECTED .
5. EXPLORATION (CEE)[1].
6. $ FROM SEPARATE BANK ACCOUNT TO PAY FOR (CEE).
7. STATEMENT OF CEE[1] & ED[2] TO INVESTORS.
8. SHARES ISSUED .

---

1. CANADIAN EXPLORATION EXPENSE.
2. MINING EARNED DEPLETION 1/3 OF QUALIFIED CEE .

RESOURCE COMPANIES

HOW?

PLANNING

(1) PROPERTIES - $/WHEN .

(2) ANY $'s NEEDED FOR ADMINISTRATION

(UNIT OFFERING) .

(3) ACCOUNTING REQUIREMENTS

- TRACE FUNDS , REVENUE CANADA AUDIT.
- STATEMENTS TO INVESTORS.
- FINANCIAL STATEMENTS REQUIREMENTS .

RECOMMENDATIONS--SEPARATE ACCOUNTS

- SEPARATE GENERAL LEDGER ACCOUNTS
- SEPARATE BANK STATEMENT

3/

RESOURCE COMPANIES

PLANNING

- LIABILITY INSURANCE .
- TRUST AGREEMENT (IF DESIRED).
- SUBSCRIPTION AGREEMENT
  - APPOINT COMPANY AS AGENT
  - MAY BE UNIT OFFERING.
- OFFERING DOCUMENT
  - OPINION LETTER
  - SUBSCRIPTION AGREEMENT
  - BACKGROUND/USE OF FUNDS
  - TAX CONSEQUENCES .

RESOURCE COMPANIES

PLANNING

SEQUENCE IS IMPORTANT--$ COLLECTED AND AGREEMENTS SIGNED BEFORE COMMENCE EXPLORATION ,

POSSIBILITY

DISALLOW INVESTORS DEDUCTIONS.

SEE PAGE 14 OF KIT FOR SEQUENCE.

RESOURCE COMPANIES

WHAT EXPENSES QUALIFY?

CANADIAN EXPLORATION EXPENSE

- IN CANADA
- SEE TAX ACT, PAGE 8 OF MANUAL.

WHEN MUST EXPENSES BE MADE?

DURING CALENDAR YEAR.

IF $ ADVANCED AND AGREEMENT SIGNED BEFORE DECEMBER 31ST WITHIN 60 DAYS OF CALENDAR YEAR END .

RESOURCE COMPANIES

INFORMATION TO INVESTORS

- STATEMENT OF CANADIAN EXPLORATION EXPENSE" FOR INVESTORS TO INCLUDE IN PERSONAL INCOME TAX RETURNS (SEE PAGE 11 OF MANUAL) .

SHOULD BE MAILED TO INVESTORS BY END OF FEBRUARY IF POSSIBLE.

SUMMARY

RESOURCE COMPANIES

1. PLAN--EXPLORATION AND ADMINISTRATION,

2. DOCUMENTATION AND SEQUENCE ARE IMPORTANT.

36