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THE GRANDUC OPERATION

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ABSTRACT

The Granduc Mine is an underground copper mine located in northwestern, B.C. near Stewart.

This paper will give an over view of the operation, outlining some of the inherent problems which are unique to this particular mining property. The mill and concentrator building is located at Tide Lake which is serviced from Stewart by a 30 mile year round gravel road constructed through mountainous terrain. High precipitation and heavy snowfalls present a challenge for transportation of personnel, supplies, snow removal and avalanche control techniques.

Access to the mine workings is provided by a 10.3 mile haulage tunnel. The blasted ore is removed from the draw-points by trackless equipment and hoisted by an internal shaft to an underground crusher. The crushed ore is then trammed through the 10 mile tunnel to the Tide Lake concentrator. The copper concentrate is trucked to storage and port facilities at Stewart.

Between 1970 and 1978 the Granduc orebody was mined by Newmont using sublevel caving. After purchasing the property in 1979, Esso began converting to a new mining method referred to as "slot and mass blast". The initial results achieved by the method fell short of those achieved in the past with sublevel caving. Continuing improvements, however, are now yielding stope recoveries which qualify the method as a success.

INTRODUCTION

The Granduc Copper Mine is certainly unique in itself as its location has imposed logistic problems of an unusual nature. The major pioneering tasks undertaken were:

- Construction of a 30 mile access road
- Developing two tunnels for a total of 11.6 miles
- Construction and rehabilitation of the Tide Lake Camp and concentrator complex
- Severe climatic conditions
- Operation in an isolated area

The mine is located in the Coastal Mountain Range of British Columbia. It is 25 air miles north-northwest of Stewart, B.C., a small town at the head of the Portland Canal and east of the southern tip of the Alaskan Panhandle. The communities of Terrace and Smithers are 220 road miles, and Vancouver is 550 air miles to the south.

The property was acquired from Granduc Operating Company Ltd. (a subsidiary of Newmont Mining Corporation) in 1979 and is operated by Canada Wide Mines Ltd., a wholly owned subsidiary of Esso Resources Canada Limited.

In spite of the rugged location, natural hazards and severe weather conditions (annual snowfalls of up to 90 feet), the Granduc Mine has continued to operate with minimal delays and interruptions. At the time of this writing, the production has been maintained at a rate of 4000 tons per day. It is expected to continue at this rate of production for the duration of the operation.

HISTORY

The records indicate that the first claims staked in the area of the Leduc River were in 1931. However, it was not until 1950 that the claims were staked covering the out-crops and surrounding area of the Granduc orebody. In 1952, the property was optioned by Granby who were joined in 1953 by Newmont Mining Corporation. Sometime later the mine was leased to "Granduc Operating Company" under a joint venture agreement between Newmont and American Smelting and Refining Company.

By 1956, sufficient exploration had been conducted to establish the potential of the orebody. The original ore reserves were calculated and estimated to be 43 M tons of ore at an undiluted grade of 1.73% copper.

In 1964, Granduc Operating Company decided to construct an access road between the concentrator facilities at Tide Lake and the town of Stewart. Plans were also approved for driving a 10.3 mile tunnel from Tide Lake to the orebody at Leduc.

On February 18, 1965 a natural disaster struck, whereby a snow slide destroyed a major portion of the Leduc Camp, claiming 26 lives. This event forced the closure of the Leduc Camp and changed the original plan of driving the tunnel from both ends. The tunnel was driven in its entirety as a single heading from Tide to Leduc. The development of this 54,500 foot haulage tunnel, which passed beneath 3 glaciers and 2 mountains, was one of the major engineering feats at that time. The haulage tunnel was started in June of 1965 and completed in December of 1968. The performances achieved during driving of this tunnel are noteworthy. (Best single day - 115 feet; 6 consecutive days - 601 feet).

Production started in November, 1970 after expending in the magnitude of $120 M with the first concentrate being shipped in January, 1971. The mine ceased operation in 1978 as a result of high operating costs, coupled with declining metal prices. Granduc Operating Company produced and milled approximately 14.5 M tons of ore at a head grade of 1.29% copper.

In 1978, Esso Minerals Canada undertook an evaluation of the property as Newmont continued to proceed with dismantling and salvaging operations. During the winter of 1978/79, the roof of the concentrator building collapsed causing considerable damage.

In May of 1979, Esso Resources finally received approval from F.I.R.A. to proceed with rehabilitation and exploration of the Granduc property. An extensive rehabilitation program was required as the mobile equipment had been removed from the mine and transported to various locations thoughout B.C. Some of the fixed machinery had been dismantled, discarded or sold.

Canada Wide Mines Ltd. resumed production again in September, 1980 at a rate of 2000 tons per day or approximately 50% of their designed capacity. This reduced rate of production continued into 1983 in order to advance the development ahead of the production operations. Mine development was completed during the first half of 1983, blocking out 2.0 M tons of ore. The remainder of the existing mineralization was not economical to develop and process at the current and forecasted metal prices. Therefore, at a throughput rate of 4000 tons per day, the production reserves will support the operation until mid-1984.

As a result of poor metal prices over the past two years, there has been a substantial operating loss since start up. To date we have processed approximately 2.2 M tons of ore at a head grade of 1.46% Cu.

1979-1983
Production

ACCESS ROAD

A 30 mile access road was constructed through mountainous terrain between the concentrator site at Tide Lake and the town of Stewart. The road, a 10 mile portion of which passes through the southeast corner of the Alaskan Panhandle, has many steep gradients and hair pin curves.

This road is the main artery for transportation of supplies and personnel to the Tide Lake concentrator and trucking of concentrates to the dock and harbor facilities in Stewart. Scottie Gold Mine, which is located approximately 1 1/2 miles from Tide Lake, also utilizes the road as access to their mining property.

The number of vehicles and frequency of trips on the road necessitated the implementation of a two way radio controlled communications system. A precariously located repeater station on a remote mountain peak at Mount Bayard provides a clear and reliable radio signal for all road traffic. Stringent road rules and carefully monitored traffic locations ensure a safe and almost accident free transportation system.

The commodities transported over the road for an average operating month at Granduc consists of:

Road Miles	65,000 Total (All Vehicles)
Passengers	7,300
Bunker "C" Fuel	400,000 Gallons
Diesel Fuel	30,000 Gallons
Gasoline	4,000 Gallons
Freight	20 Loads
Concentrate	5,000 Tons

ROAD EQUIPMENT

The equipment required for transportation of personnel, fuel, supplies, concentrate, snow removal and road maintenance consists of:

7 - Buses - Western Flyer - 40 Passengers
2 - Mack - Semi Tractors
3 - Mack 20 ton concentrate haul trucks with 1450 gallon capacity saddle tanks - for back hauling Bunker "C"
2 - 16G Caterpillar graders with extended wing blades
1 - 14G Caterpillar grader with extended wing blade
1 - 12E Road Grader
2 - 980 Front End Loaders
1 - 966 Front End Loader
2 - D-8-K Bull Dozers
1 - Dump Truck
1 - Maintenance Truck
3 - Crew Cabs
1 - Avalanche Control Pickup

WEATHER CONDITIONS

The north coastal weather brings with it heavy precipitation in the form of snow between mid October and the end of April. Annual record snowfalls at the mine site over the past several years has averaged approximately 55 feet, although much heavier snowfalls were recorded in 1976 (78 feet) and 1972 (+90 feet). (Guiness Book of Records). During recent operations, the largest snowfall for a single month was 20 feet in December, 1979.

Snowfall generally takes place at a temperature of +25 °F, hence it is very wet and heavy. Snowfall intensities of 3 to 4 inches per hour and up to 30 inches in a 24 hour period have been experienced. Temperatures are generally above zero but temperatures of -40°F have been experienced for short durations at the mine site.

AVALANCHE CONTROL

The heavy snowfalls along the road to Tide Lake induce many slides which block the roadway. Several active slide paths require constant monitoring and attention during heavy snowfalls. There are 60 different avalanche zones identified along the length of the access road. A section of the road where snow slides were unmanageable and relocation of the road was not practical required the driving of a 5,700 foot by-pass tunnel.

Avalanche control and snow removal crews provided 24 hour coverage, seven days a week to ensure safe passage of vehicles with minimum delay. The five members of the avalanche control team are skilled in skiing, mountaineering, artillery, emergency rescue and meteorology.

The local snow conditions are carefully monitored and an assortment of explosives and artillery equipment is utilized to release avalanches. To predict the likelihood of impending avalanches, the avalanche control personnel analyse core samples and test pits from the surrounding mountains. During heavy snowfalls, the avalanche experts travel the roadway by vehicle, monitoring conditions and identifying potential avalanche paths. The snow is induced to slide by employing blasting techniques dependent upon the conditions and the desired results. All road traffic is cleared and the road barricaded and guarded during blasting exercises.

(a) Concussion Blasts - Range 500 feet

Bags of amex or case charges are placed adjacent to the road and are used to control snow slides close to the roadway.

(b) Avalauncher - Range - 500 feet to 1000 yards

The avalauncher is an economical and relatively maintenance free device used to place 1 kg. or 30 oz. charges in an avalanche starting zone. The avalauncher system consists of a welded metal chamber with a stub barrel, loading tray, extended 2.5 metre barrel, nitrogen bottle and projectile which includes the explosive pentolite with nose cone and fin assembly. The propellant is compressed nitrogen with variable pressure. The unit is mounted on a turn table with traverse and elevation settings.

(c) 75 mm Recoilless Rifle - Effective range 2000 yards

This is a stationary unit with a pay load of 1.2 kg.

(d) 105 mm Recoilless Rifle - Effective range 3500 yards

This is also a stationary unit with a pay load of 3.4 kg. and very accurate for long distance and blind firing.

(e) Hand Charges

Hand charges are used infrequently and utilized mainly for cornice control and helicopter bombing.

An example to illustrate the annual consumption of explosives for avalanche control methods is:

Amex	1000 bags
Avalaunchers	400 rounds
Artillery	100 rounds

The various types and sizes of avalanches are classified and recorded as shown below:

Size 0 - Sluff, small slide not reaching road.
Size 1 - Sluff, small slide on edge of road.
Size 2 - Sluff, small slide across road.
Size 3 - Slide, holding up traffic.
Size 4 - Avalanche - large enough to cause injury or death to occupants of a vehicle.
Size 5 - Climax avalanche - involving several snow layers.

For example, during the winter of 1980-81, there were 206 Size 3 and 16 Size 4 avalanches released by the avalanche crews and 15 Size 3 and 1 Size 4 avalanches which were released naturally.

Winter operations at Granduc would be extemely risky and dangerous without properly trained avalanche personnel. Road closures and operational delays are a rarity due to the use of avalanche control techniques. The avalanche control team receives all their training at Granduc and many former avalanche control employees have used their skills in similar applications around the world.

TIDE FACILITIES

The facilities at Tide Lake include a main concentrator complex, power plant, family trailers, ski-hill, gravel emergency air strip and storage buildings.

Power Plant

Granduc is an isolated mine not serviced by B.C. Hydro, which dictated the need to generate power on site. The capacity of the power plant is 30 mw although only one unit is in operation at one time. The other unit is available on a standby basis.

Two oil fired boilers rated at 260,000 lb. per hour generate super heated steam at 600 p.s.i. and 725°F to evaporating condensing turbines driving 15 mw generators. In addition, there are five auxilliary diesel generators located on the ground floor which are rated at a total output of 2.3 mw. The diesel generators provide auxilliary emergency power in the event of breakdowns and are also used to start up the turbo-generators. These standby generators are not in use during normal operating conditions. The power is distributed at 4160 volts and 600 volts throughout the surface facilities and the underground operation is supplied by two 25 kv feeder cables running the length of the tunnel.

Bunker "C" fuel for the power plant is trucked from Stewart and unloaded into two 700,000 gallon storage tanks which measure 60' in diameter by 40' high. Consumption of heavy fuel for the current operation is approximately 16,000 gallons per day.

The power plant is connected to the main concentrator building by an 8 foot diameter, 372 foot long underground tunnel.

Concentrator Complex

The concentrator building measures 240 feet wide by 442 feet long with a vertical height of 150 feet. The building was constructed on the side of a steep hill having a roof dipping at a 25° angle. The roofing material consists of corrugated metal sheathing with a sandwich panel of insulation. The heavy snowfalls were a major consideration engineered into the design. The natural convection of warm air inside the building causes the snow to slide from the roof thus avoiding snow build ups.

The concentrator complex contains the following facilities:

> Secondary crushing, fine ore storage, grinding circuit, flotation, drying, concentrate storage, general offices for engineering, administration and purchasing, receiving, warehousing, laboratory, equipment re-build shop, mine dry, machine shop and a railway terminal which is connected to the main access tunnel to the mine.

Milling

Milling takes place in the upper section of the concentrator complex. Minus 6" size ore from the mine is dumped into a 3000 ton storage pocket. A conveyor then takes it to the crushing plant where it is crushed and screened to give a minus 1/2" product for feed to the rod mills. Crushing is done in a 7' secondary cone crusher and a 7' tertiary cone crusher manufactured by Nordberg.

Grinding pebbles are obtained by screening out +2" - 4" material from the secondary crusher feed material. The grinding section consists of two 10'6" by 16' rod mills and three 12'6" by 18' pebble mills supplied by Dominion Engineering. The rod mills are in open circuit and the pebble mills are in closed circuit with three pairs of D20KREB cyclones. The rod mill discharges and pebble mill discharges are combined and pumped to the cyclones. Cyclone underflow provides the feed for the pebble mills and the cyclone overflow feeds the flotation circuit. The flotation circuit consists of six banks each of twelve 60 cubic foot cells and two banks each of twelve 120 cubic foot cells for rougher flotation. The rougher flotation concentrates are reground in a 7'x 13' regrind mill then upgraded by cleaning in two banks each of eight 60 cubic foot cells and recleaning in two banks each of four 60 cubic foot cells respectively. All cells are Agitair models.

The recleaned concentrate then flows by gravity to a 70' diameter thickener which has a storage capacity of 1000 tons. The underflow from the thickener is pumped to an Eimco Agidisc 8'10" diameter disc filter. The filter is designed to produce a cake of not more than 12% moisture. After discharge from the filter discs, the cake is transferred by short conveyor to the dryer.

The dryer itself is a Lougheed Haggarty, 80 inches in diameter and 40 feet long. The heater is a Lougheed Haggarty rated at 9.6×10^6 B.T.U. per hour. The dried product, not exceeding 8% moisture, is transferred by conveyor to a 7000 ton capacity concentrate storage area. The concentrate is slushed with a 75 H.P. electric 3 drum slusher up a ramp to a 20 ton hopper for loading into the concentrate haulage trucks.

Tide Accommodation

During the construction and development phases, approximately 250 single status employees were accommodated in bunkhouse facilities at Tide Lake. Recently the bunkhouses were removed and the employees relocated to the town of Stewart where residence had to be provided for some 100 single status employees.

A 17 unit trailer site is located in Tide Lake flats approximately 1 mile from the concentrator. This provides accommodation for both married and single personnel who are considered essential as back up for the operation in the event of an emergency or road closure. Also located at the trailer site, affectionately referred to as "Happy Valley", is a ski tow and a gravel emergency landing strip.

UNDERGROUND

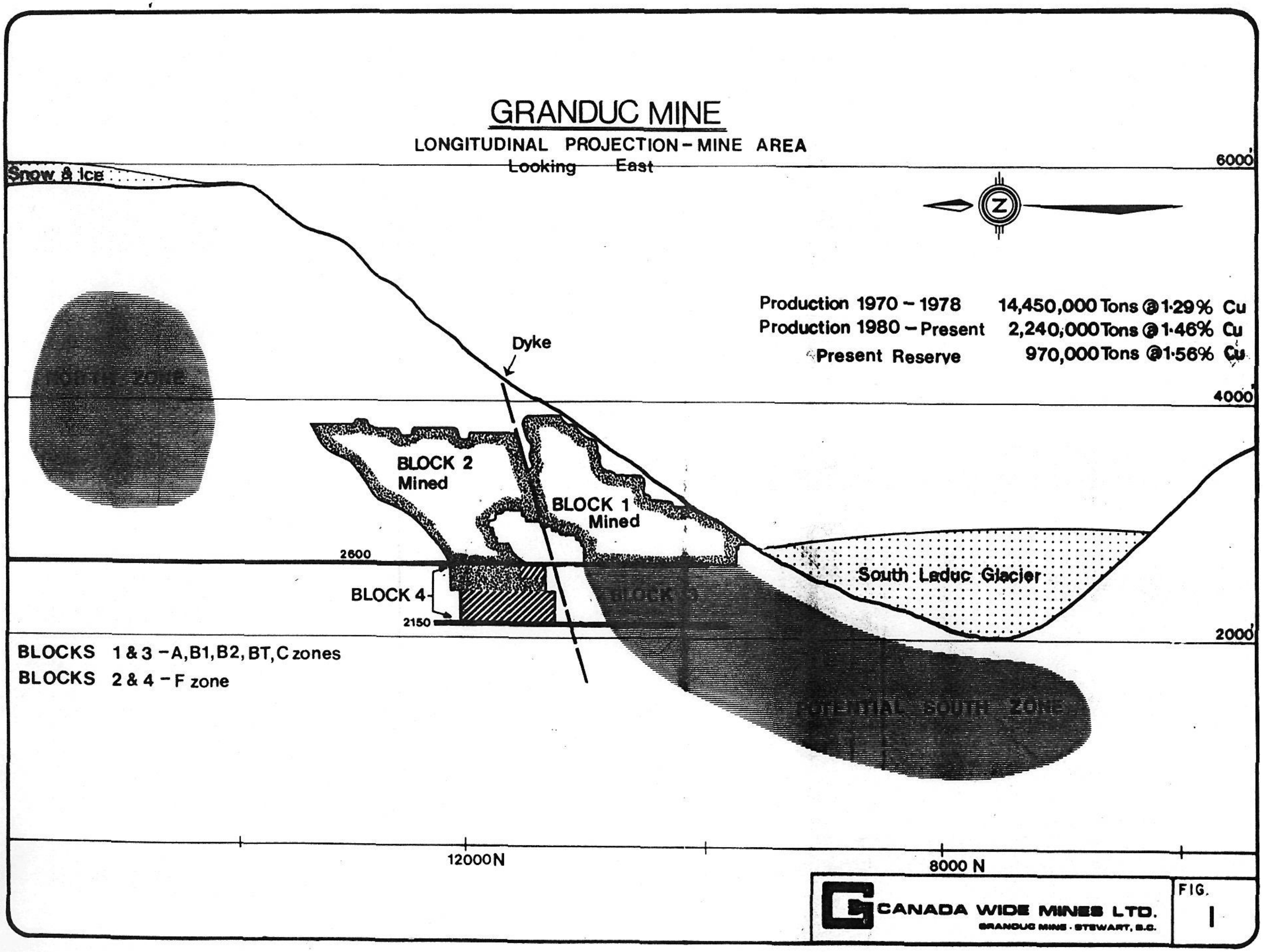
GEOLOGY

The Granduc orebody is located within a cataclastic, metamorphosed succession of volcanic and sedimentary rocks which form part of the Unuk River Formation. The tuffaceous and silicious host rocks are extensively faulted and cross fractured. The hanging wall is composed of arkose, greywackes and sediments, with andesites in the footwall. Mineralization consists mainly of chalcopyrite and pyrrhotite, with associated pyrite and minor amounts of magnetite, galena and sphalerite. Ore grade averages 1.8% Cu. The mineralized area, which outcrops on surface, extends at least 2000 feet vertically and 4000 feet laterally. Although the main ore zones pinch out to the north, another parallel zone of mineralization has been found here recently. The orebody is also open both at depth and to the south under the Leduc glacier.

The mine contains five major ore zones; the A, B1, B2, C and F. These are grouped into four mining blocks. Blocks 1 and 3 contain the A, B1, B2 and C zones above and below 2600 level. Blocks 2 and 4 contain the F zone above and below 2600 level. (see Fig. 1) These orebodies occur as streaks and irregular semimassive stringers which vary in dip from near vertical to 60 degrees.

LAYOUT

The Granduc mine is accessed by a 10.3 mile tunnel from the Tide Lake plant site. This tunnel is equipped with a railway system for the transporting of men and materials to and from the workings, as well as for hauling ore to the mill. The underground train loading area is located on the 2600 level of the mine. This is the main level housing the compressor room, maintenance shops, electrical distribution center, warehouse, first aid, mine rescue room,



GRANDUC MINE

LONGITUDINAL PROJECTION - MINE AREA

Looking East

Production 1970 - 1978	14,450,000 Tons @ 1·29% Cu
Production 1980 - Present	2,240,000 Tons @ 1·46% Cu
Present Reserve	970,000 Tons @ 1·56% Cu

BLOCKS 1 & 3 - A, B1, B2, BT, C zones

BLOCKS 2 & 4 - F zone

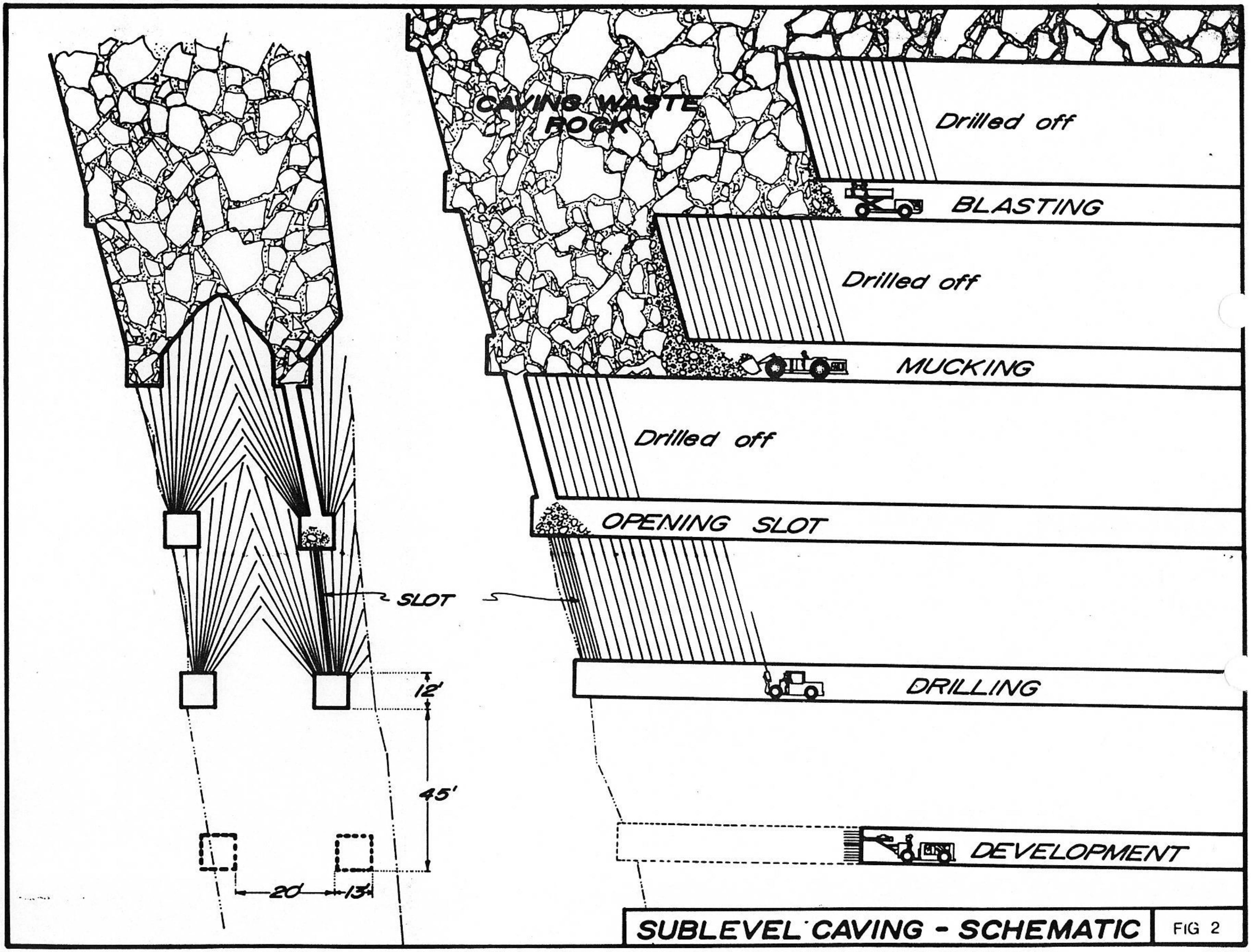
offices and ore load-out bins. In the past all mining has been above 2600 with ore being fed by 5 yd. scooptrams through ore passes to a tracked gathering haulage and then trammed to the crusher.

During 1981 and 1982, a major development program was undertaken to allow mining of ore reserves below 2600. A total of $17 million was spent on 11,447 feet of ramping and primary development, an 815 foot internal production shaft, 2,470 feet of 10 foot diameter bored ventilation raises and ore passes and additional mechanical and electrical equipment. Presently 90% of the 4000 tpd production comes from Block 4. The ore is dropped through 10 foot diameter ore passes to the 2150 level, loaded through chutes into 20 ton Volvo haulage trucks and trammed to the production shaft. After passing through 12" by 20" grizzly openings the ore is loaded into a 16.5 ton skip. A 10 foot diameter ASEA friction hoist lifts the ore up to the 2600 level and discharges it into the crusher. The ore is crushed and conveyed into two storage bins, and is finally loaded into 50 ton rail cars for the trip to Tide.

SUBLEVEL CAVING

Production at Granduc first started in 1970 from the upper C and F zones. Mining widths varied from 12 feet in the longitudinal stopes to over 100 feet in the transverse stopes. Over the next eight years 14.5 million tons were processed at a production rate which varied between 4000 and 8000 tpd and at an average head grade of 1.29% Cu. Of this amount, 11.2 million tons came from the sublevel cave stopes, 3 million from development and the remainder from test stopes . Mining activity progressed from the 3800 elevation down to the 2800 elevation.

Newmont chose sublevel caving as their mining method for several reasons. The technique was very flexible. It could be used for a variety of ore widths, and a high production rate was possible. Weak wall rocks were used to advantage and the need for support pillars and fill emplacement was eliminated. Basically the method consisted of driving a drift in ore and then, after opening a slot at the extremity, retreating out blasting rings of upholes. Ore was mucked from under the brow after each ring was blasted, with the caved waste running in from the sides and the top. (see Figure 2)



SUBLEVEL CAVING - SCHEMATIC

FIG 2

The disadvantages of the method were not unique to Granduc. Rather, they were characteristic of the sublevel caving method itself and are felt to some extent by all mines employing this method. The need to limit deviation of their 2 inch upholes made it necessary to keep the level interval down to 45 feet. The result was that over 20% of their production came from costly development headings.

Eighty-three percent of the blasted tonnage was recovered by overdrawing the stopes. This resulted in a dilution factor of approximately 37% and an overall metal recovery of 88%. Even though this performance is comparable with other sublevel caving operations (see Table 1), at the current copper price, it did not yield a mill feed grade high enough to support Granduc's high cost load. Mining was expensive with not only a townsite, a 30 mile road and power plant to maintain, but a 10.3 mile tunnel which limits the effective work shift to 5.5 hours.

TABLE 1 - Sublevel Caving - Ore Recoveries and Dilutions*

	% Recovery	% Dilution
Frood Mine, Ontario	80	55
Stobie Mine, Ontario	85	26
Craigmont Mine, B. C.	92	40
Norita Mines, Quebec	95	30

* Figures as reported in the 1979 Canadian Mining Journal Reference Manual

SLOT AND MASS BLAST

When Esso decided to reactivate the Granduc Mine, two objectives were set:

1. To make the operation economically viable through the use of a new mining system, and
2. To identify additional ore reserves to extend the life of the mine.

The new mining technique chosen was a combination of blasthole, shrinkage and caving techniques referred to as "Slot and Mass Blast" (S & MB). Basically the method consists of blasting 4 1/2" diameter holes to create a 30% void in a stope and then mass blasting the remaining ore into the opening. The slot and void were to be taken up with vertical crater retreat (V.C.R.), keeping the stope as full as possible. While the mass blast is being loaded, the void is mucked empty. After the rib and crown pillars are mass blasted the muck is removed allowing the caved waste from above to flow in and keep the stope full. S & MB appeared to offer several advantages over sublevel caving. The level separation could be increased due to the improved accuracy of 4 1/2" down-the-hole drills. By delaying any inflow of waste until after the mass blast, and then drawing the ore down evenly from all drawpoints, it was felt the dilution could be reduced to 20%. The uniform explosives column achievable with large diameter downholes as compared to small upholes would produce more consistent fragmentation.

The original S & MB concept called for two levels 150 feet apart. Each consisted of a footwall undercut drift joined by regularly spaced drawpoints to a hangwall drift. The undercut drift served as access to drill and blast an undercut trough. Rings of 2 1/8" upholes were spaced five feet apart with a five foot toe spacing. The hangwall drift served first as a haulage way for mucking out the stope above and second, as a drill drift for the stope below. Drilling here consisted of 2 1/8" upholes and 4 1/2" downholes. The downhole rings were spaced 10 feet apart with a 10 foot toe spacing. (see Figure 3)

The primary initial concerns with this new mining method were:

1. After blasting and mucking out the slot, it was possible that the weak hanging wall might cave before the mass blast was fired.

2. In relatively flat or thin orebodies (less than 70 degrees or less than 50 feet wide), the hangwall might cave prematurely, leading to early dilution and low recoveries.
3. Increased ground pressures in the temporary pillars next to and above the slot opening could lead to squeezing holes and difficulty loading the mass blast.
4. Increased ground pressures in both the stope development and permanent openings could lead to serious ground control problems.

EARLY EXPERIENCES

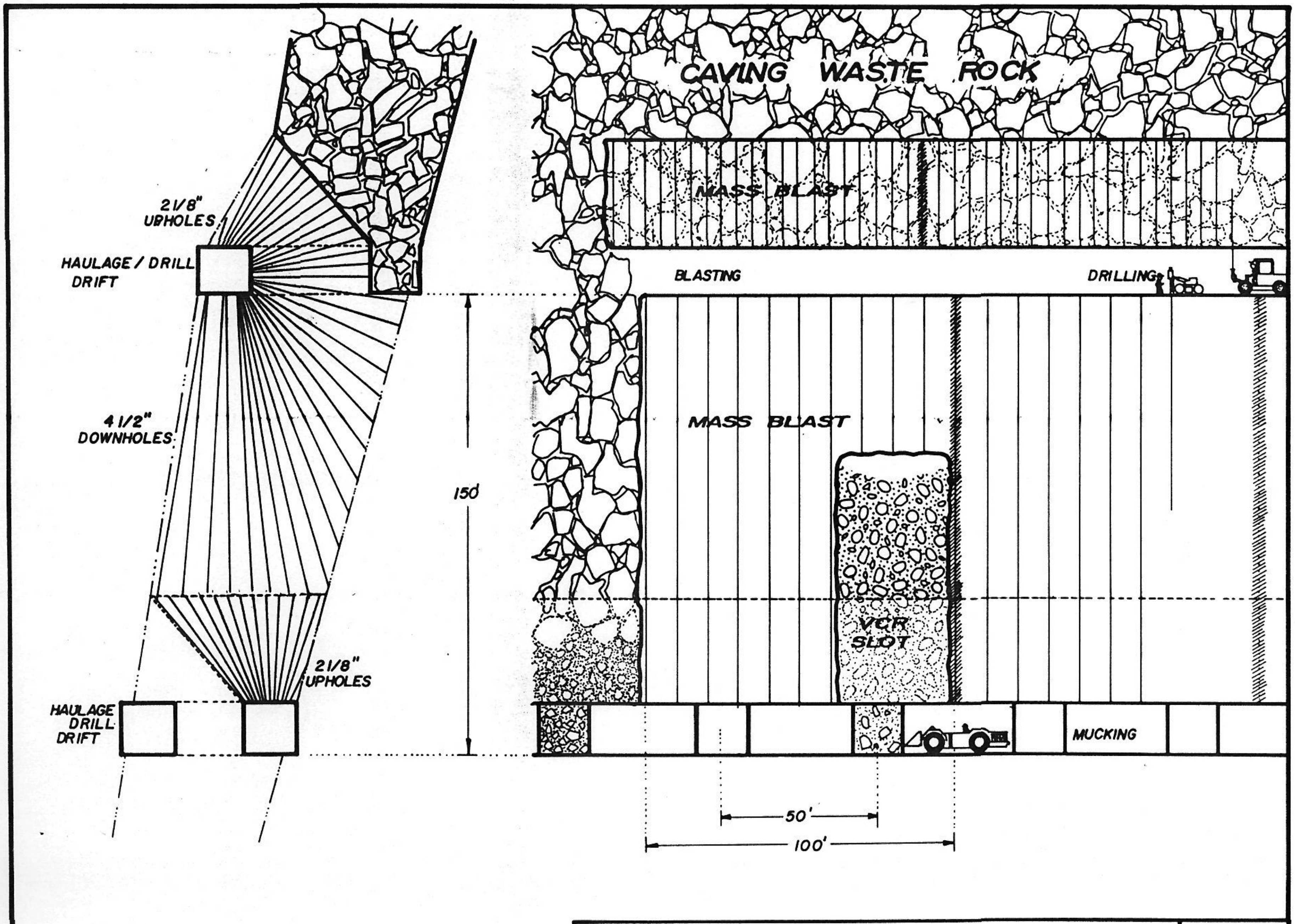
Stoping in 1980 and 1981 began with sublevel caving in the previously developed areas. Although the tonnage removed was only 224,878 tons, the results (shown below) were similar to Newmont's.

Tons ore blasted	=	172,540	@	1.66% Cu
Tons recovered	=	224,878	@	1.40% Cu
% Dilution	=	34%		
% Ore recovery	=	86%		
% Metal recovery	=	110%		

The excellent metal recovery was probably due to a very high grade dilution material coming from upper stopes where, during their last months of production, Newmont had raised their cutoff grade.

The initial results of S & MB, however, were not nearly as successful. In fact the learning process turned out to be trying and costly.

The first stope prepared for S & MB was the F1 in Block 2. As it turned out this area had the most difficult water and ground conditions of the entire mine. Due to the need to retreat from the extremities of the orebodies there was no alternative to this location. Crews worked in a perpetual downpour that kept blastholes full of mud and water. The soft, fractured, faulted ground was very susceptible to blast damage and sloughing which resulted in difficulty in keeping the holes open. The fanned drill pattern dictated that many holes be collared close together. These collars quickly broke into each



ORIGINAL SLOT AND MASS BLAST

FIGURE 3

other to create trenches across the drift making maneuvering very difficult, not to mention the hand mucking. The need to bring in a machine to redrill caved holes further aggravated the situation. Finally through perseverance and a technique locally referred to as "back door blasting", a void was created. (Back door blasting involves opening a slot in a sinuous manner, using portions of adjacent blastholes, to get around areas with caved holes.) The remaining open holes were then mass blasted.

As a result of poor fragmentation due to excessive hole deviation experienced in the Fl stope, with 150 foot fanned holes each intersecting the rock structures at a different angle, it was necessary to modify the stope design. An intermediate drill drift was driven to limit the hole length to 100 feet. The object was not only to reduce oversize problems, but to prevent premature inflows of caved material by fragmenting the ore finer than the waste with a more consistent hole pattern.

Although this brought an improvement, it did not completely solve the fragmentation problem. What it did do was demand more drill footage from the down-the-hole drills. Performance from these machines was good while in operation, but the availability was poor. They had been purchased with "fire resistant fluids compatibility" as one of the specifications (as required by B.C. Law). However, with no operating experience under these conditions, the modifications made by the manufacturer were inadequate. It took a year of experimentation with pumps, hose sizes and oil coolers before the drills were operating at an acceptable level.

By the time the Fl stope was completed, the production schedule was demanding a continual flow of ore from the new S & MB stopes, and V.C.R. blasting had to be abandoned in favour of bore-hole slashing to a slot raise to speed the creation of broken muck. Sloughing from the hanging wall and ore body just prior to mass blasts made it necessary to open a bell shaped void to improve stability. To avoid closely spaced blasthole collars breaking into each other, alternate holes were drilled on split rings each spaced five feet from the main rings. It became necessary to leave thin rib pillars between stopes, not for ground support, but to control the flow of fine caved waste into active drawpoints. Eventually the stope layout evolved to that shown in Figure 4.

COMPARISON OF MINING METHODS

Throughout the development of S & MB at Granduc, the method's performance has been varied (see Table 2). In many of the areas above 2600 level where the technique was first tested, the results were poor. This was caused by a number of factors.

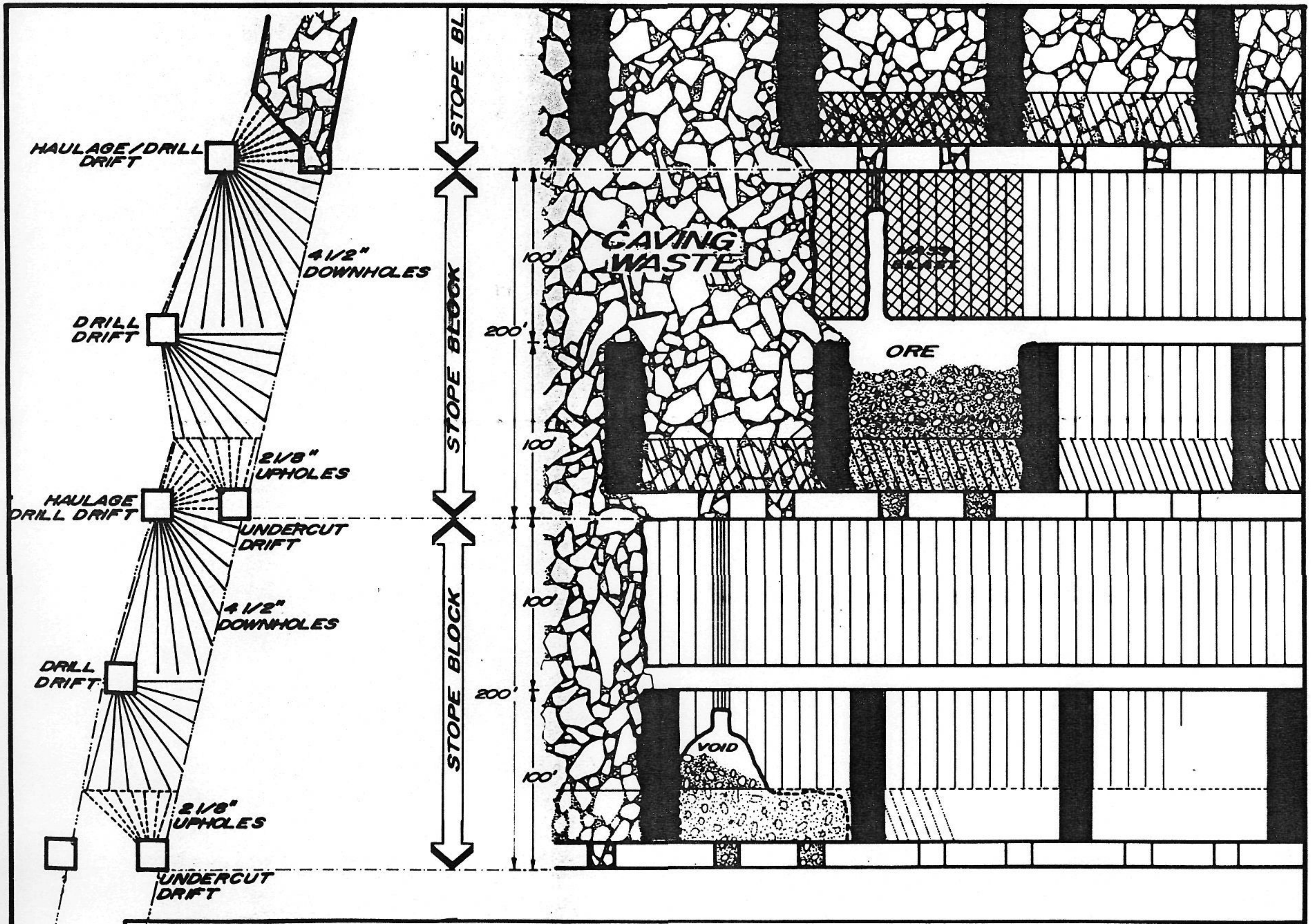
1. Inexperience of the crews and supervision had an effect. Much of the early development of drilling and blasting techniques which required relatively high skill levels was done by trial and error. Now, however, with crews that have matured with the method and machinery, the system works quite well.

2. The method itself has inherent disadvantages. When used in areas with flatter dips (south end of the B2 and C zones), the hanging wall caves quickly causing early dilution. When tried in areas that were not under previously caved stopes (parts of F zone above 2600 level), the unconfined hanging wall again caved, quickly diluting the ore. The mass blast technique as used with fanned, split 4 1/2" blasthole rings tends to produce oversize. The resulting hangups allow the ore to chimney up into the waste yielding low recoveries.

3. In many areas, the method had to be adapted to drifts previously driven for sublevel caving. In the A zone for example, the existing drifts along the footwall were used for drilling. The result was a jagged hanging wall and early dilution.

4. Ground conditions and increasing stresses from advancing stopes dictated a minimum 50 foot spacing on drawpoints. Closer spacing would have yielded higher recoveries.

5. A demanding production schedule allowed very little opportunity for optimization.



FINAL SLOT and MASS BLAST LAYOUT

FIGURE 4

TABLE 2 - S & MB Stope Performances to Date

Zone	% Dilution	% Ore Recovery
F	20	73
C	24	58
B2	23	55
BT	7	69
Bl	17	72
A	27	42
Overall performance to date	18	67

During the past year, production from F Zone below 2600 level has been steadily increasing to the point where it now contributes 90% of the total tonnage. These are the first stopes that have combined all of the elements of S & MB shown in Figure 4. Previous areas above 2600 have all been affected in some way by the original sublevel caving system. Results of the three completed stopes compare very favourably not only to those of sublevel caving (see Table 3), but to the original design parameters of 80% recovery and 20% dilution. The productivity efficiencies have also proved to be at least as good as, if not better than those of sublevel caving. These figures confirm that by delaying the inflow of cave material, dilution can be reduced without sacrificing recovery.

TABLE 3 - Mining Method Comparison

	1970 - 1978 Sub Level Cave	S & M B Below 2600 Level
% Ore Recovery	83	89
% Dilution	37	15
% Metal Recovery	89	91
Tons/ft of Development	75	113
Tons drilled/Manshift	550	600
Tons blasted/Manshift	400	448
Tons Mucked/Manshift	595	540

ORE RESERVES AND EXPLORATION POTENTIAL

When Esso first started mining at Granduc in 1980, there were 6.41 M tons at 1.76% Cu classed as recoverable reserves. Of that amount 2.24 M tons at 1.89% Cu have been mined to date, 0.97 M tons at 1.56% Cu are now developed and yet to be mined, and 3.2 M undeveloped tons at 1.77% Cu were removed from the reserve. This last reduction in ore tonnage was precipitated by the continued low price of copper. Even though Block 3 development had already started, revised price forecasts indicated that it was uneconomic.

This cancellation has had a major impact on the single remaining production area, Block 4. All drilling, blasting and mucking activities are now localized into one set of stopes. With almost zero flexibility in the operation, timing has become critical to avoid delays.

The objective of defining new ore reserves through exploration has also been affected by the depressed copper price. Even though a recent drilling program has indicated the presence of copper mineralization to the north of the existing workings, current economics prevent classifying this as ore. At depth as well, drilling and geological extrapolation have demonstrated the potential for large tonnages of copper mineralization. With current price forecasts and projected higher mining costs, this potential will remain untested.

SUMMARY

Throughout Granduc's history, the operation has been characterized by unique challenges. A 30 mile access road, combined with mountainous terrain and heavy snowfalls, has necessitated comprehensive avalanche control procedures. A 10.3 mile mine access tunnel, the excavation of which was a major accomplishment in itself, has placed constraints on productivity seldom if ever seen in other operations. Isolation, with its costs and effect on manpower, plays a continuing role in all activities. After rehabilitating and expanding the mine, a new challenge was faced: to turn a new untested mining method into an economically feasible system. Although the testing process has at times required considerable effort, steady improvements have made the method a success. The slot and mass blast technique is now a viable alternative to sublevel caving at Granduc.