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# The Brenda mine: The life of a low-cost porphyry copper-molybdenum producer (1970-1990), southern British Columbia

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## ABSTRACT

*Between 1970 and 1990 the Brenda mine milled 177 million tonnes of ore grading 0.169% Cu and 0.043% Mo from the calc-alkalic Brenda stock which at the start of production was estimated to contain 159.3 million tonnes grading 0.183% Cu and 0.049% Mo (0.082 $MoS_2$). The stock is a composite quartz-diorite/granodiorite body of Jurassic age which intrudes Upper Triassic sedimentary and volcanic rocks of the Nicola Group.*

*The initial extraction rate of 21 500 tonnes per day was gradually increased to 30 000 tonnes per day in 1986 to allow the extraction and processing of lower grades at a profit. A stripping ratio of 0.6:1 was attained over the life of the mine. Operating costs in 1989 were $4.39 per tonne.*

*Reclamation of the site included the contouring of all waste rock piles, seeding of all tailings pond slopes and the pumping of tailings water back into the open pit. The pit has the capacity to contain all the run off from the tailings pond and waste piles until the year 2003. The excellent environmental closure plan meets all provincial and local requirements.*

*Brenda's efforts in the human resources field make it a benchmark for the mining industry. When closure was announced in 1987, Brenda instituted a human resources program which was well received by the employees and general public. This core of the program was based on providing pertinent information about closure, job relocation and environmental reclamation programs.*

## Introduction

The Brenda mine is 225 km east-northeast of Vancouver and 22.5 km west of the Okanagan Valley (Lat. 49° 52′ 30″N, Long. 120°00′W; NTS 92H/16E). The area around the deposit is characterized by gently rolling, tree-covered upland, with scattered, glacially rounded outcrops. Elevations at the mine site range from 1450 m to 1700 m.

The new Coquihalla Connector highway passes 3 km east of the mine and direct access from the Connector is provided. In Figure 1 this highway can be seen running east-west just north of the pit. Brenda waste piles supplied rock to the highway construction and the road connecting the waste piles to the highway can be seen in the northeast portion of the figure. The nearest major city with regular air service is Kelowna, 60 km to the east.

## History

The Brenda orebody was discovered in the 1930s by the Sandberg family of Kelowna. Dr. H.M.A. Rice published the first known documentation in Geological Survey of Canada Memoir No. 243 in 1947. The property then became dormant until Bob Bechtel, of Penticton, staked the showings in 1954. Bechtel contacted Bern Brynelsen, manager of Noranda Exploration Ltd. in Vancouver. Various exploration programs were conducted by Noranda and other groups over the following years.

In 1965 the mineral inventory stood at 125 million tonnes grading 0.262% Cu and 0.066% Mo to a depth of 100 m. Noranda assumed control of the property in 1967 and the mineral inventory was increased to a proven reserve of 159.3 million tonnes grading 0.183% Cu and 0.049% Mo. The mill went into production in March of 1970 at a rate of 21 500 tonnes per day.

The operation recovered and sold 271 983 021 kg of copper; 65 469 525 kg of molybdenum; 112 814 kg of silver and 1777 kg of gold. The major expenses for this production were $449 million for supplies, $215 million for labour, $56 million for income and production taxes, $18 million for municipal and sundry taxes, $5 million for mining taxes and $22 million for dividends (all amounts are in Canadian dollars).

## Geology

The geology of the Brenda deposit was ably described by A.E. Soregaroli and D.F. Whitford (1976). No new significant geological features have come to light since that paper except for data on grade distribution developed during mining. The reader is referred to that paper for greater detail. Direct extracts from their paper are enclosed in quotation marks.

As stated by Soregaroli and Whitford the Brenda Cu-Mo deposit is within the Brenda stock described as a zoned and composite quartz diorite body. The Brenda stock is considered to be part of the much

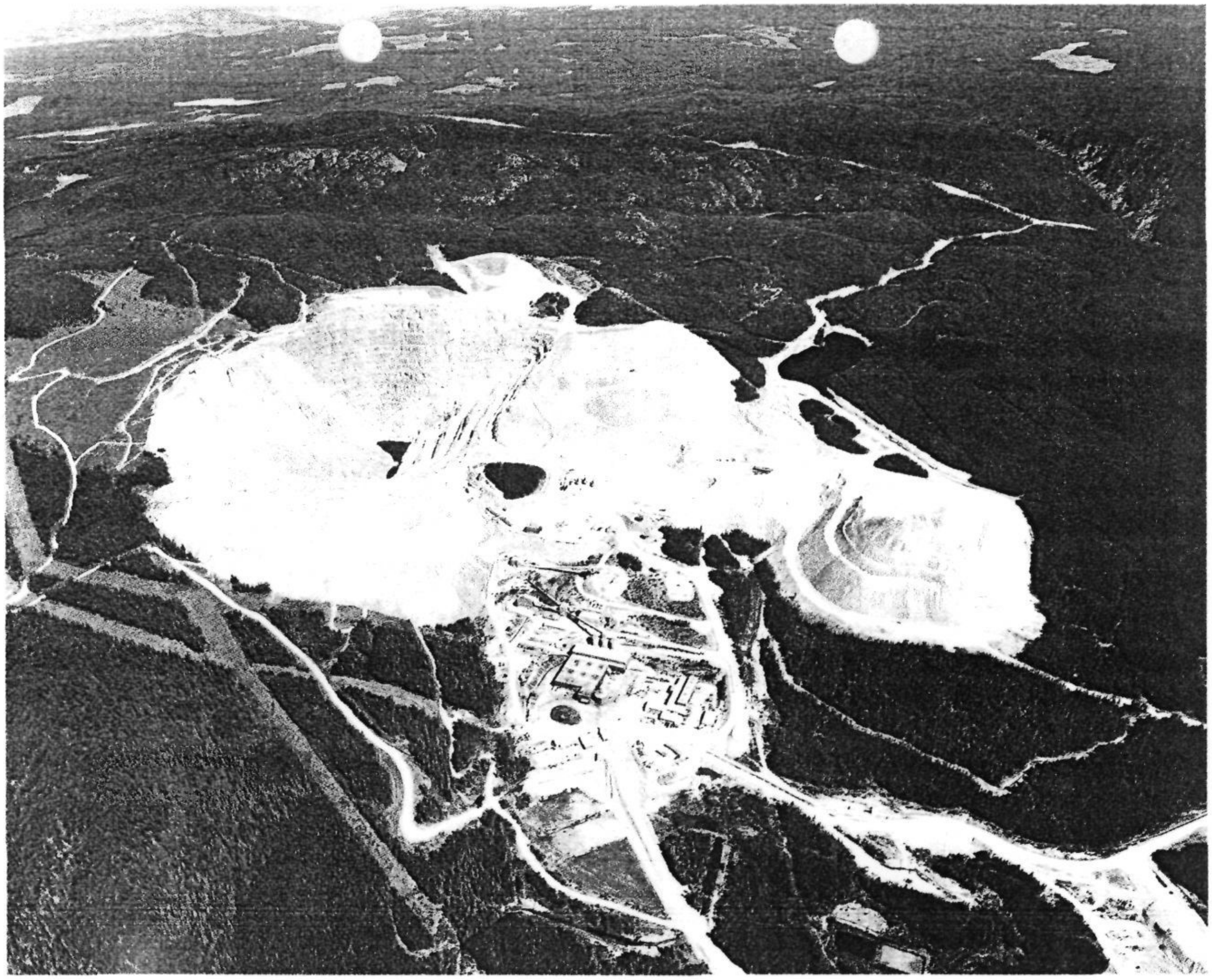

**FIGURE 1. Aerial photograph of the Brenda mine pit taken in June 1990, two months after the failure of the west wall.**

larger Pennask batholith of Jurassic age but the field relationship between these two bodies has not been established (Fig. 2).

"Several major linear features cut the Brenda stock and older rocks. Many of these are related directly to the faults exposed during the excavation of the pit" (Figs. 3 and 4).

## Structure

"Structural features of the deposit include veins, faults and joints. Only veins and faults have been studied in detail. Veins are described in the section on Mineralization."

### Faults

"Faults in the Brenda pit are expressed as fractured zones in which the rock is intensely altered to clay minerals, sericite, epidote and chlorite. These fracture zones range in width from a few cm to 9 m. Most strike 070°E and dip steeply southward. Northwesterly striking faults exhibit left-lateral movement. In Figure 4, the major faults exposed in the pit on November 1, 1974 are shown. The faults transect all mineralization, except some calcite veins. Sulphides, especially molybdenite, have been smeared along fault planes."

"Shear zones are wider and more numerous in the north half of the pit, where they control bench limits" (Fig. 4).

The fracture pattern weakened the west wall of the pit. The pit at Brenda was instrumented for movement and daily inspection tours were standard. Bill Scribner, the mine superintendent, closely monitored the situation and one week prior to the collapse of the west wall he closed the pit to all personnel. Because of the impending danger only the mobile mining equipment was removed from the bottom of the pit. The caving of the west wall terminated operations two months ahead of schedule. The 9 million tonne cave was estimated to contain 0.12% Cu. This cave of the west wall can be seen in Figure 1. This photo was taken some time after the cave in as water can be seen in the pit bottom.

## Mineralization

"The Brenda orebody is part of a belt of copper-molybdenum mineralization that extends north-northeasterly from the Nicola Group - Brenda stock contact at least to Long Lake (Fig. 3). Mineralization of economic grade is confined to a somewhat irregular zone about 720 m long and 360 m wide (Fig. 4). Ore-grade mineralization extends more than 300 m below the original surface."

"Primary mineralization is confined almost entirely to veins, except in altered dyke-rocks and in local areas of intense hydrothermal alteration which may contain minor disseminations. The grade of the orebody is a function of fracture (vein) density and of the thickness and mineralogy of the filling material."

"The average total sulphide content within the orebody is 1% or less. Chalcopyrite and molybdenite, the principal sulphides, generally are accompanied by minor, but variable, quantities of pyrite and magnetite. Bornite, specular hematite, sphalerite and galena are rare constituents of the ore."

Two 600 m vertical drill holes were drilled from the 4660 bench in the high-grade core. Both these holes indicated that mineralization decreased with depth. All mineralization ceased about 60 m below the 4160 bench.

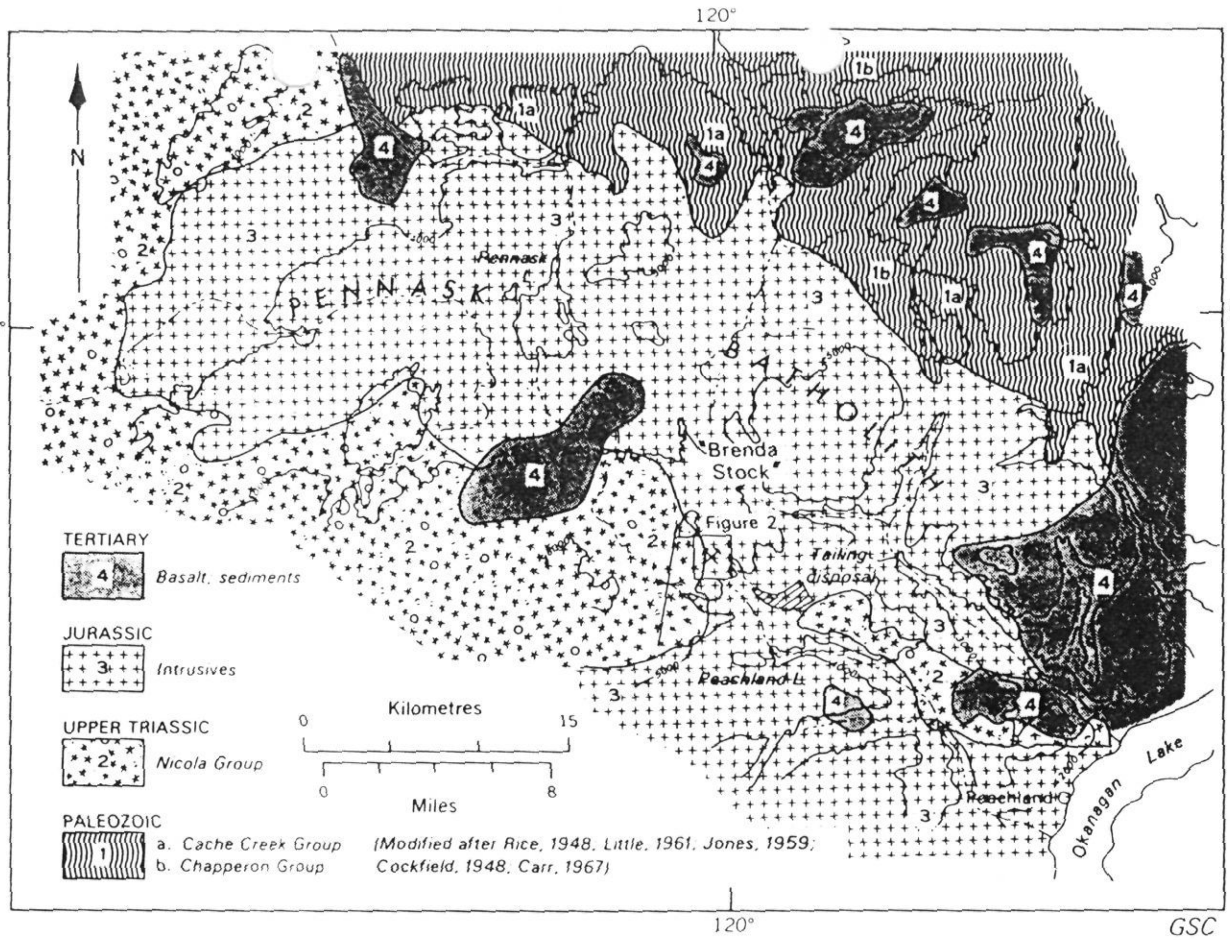


**FIGURE 2. Regional geology and location (after Soregaroli and Whitford, 1976).**

## Veins

"Because mineralization is confined almost entirely to veins in relatively fresh homogeneous host rock, the veins are divided into separate stages (Soregaroli, unpubl., 1968), based on cross-cutting relations and their mineralogy and alteration effects on the host rock. Oriel (unpubl., 1972) studied the veins in greater detail and showed that vein density within the orebody is not uniform. Ranges were recorded from less than 9 per m near the periphery of the orebody to 63 per m and occasionally 90 per m near the center of the orebody."

"Some veins have very sharp contacts with wall rocks, but most contacts are irregular in detail where gangue and sulphide minerals replace the wall rock. A vein may show features characteristic of fracture filling in one part and of replacement in another. Mineralizing solutions were introduced into fractures and, during development of the resultant veins, minor replacement of the wall rock ensued."

"The following chronological stages of mineralization (veins) are based on the work of Oriel (unpubl., 1972) and Soregaroli (unpubl., 1968). Stages 1 through 4 are all genetically related to a single mineralizing episode, which was responsible for development of the Brenda orebody. Stage 5 represents a later, probably unrelated, event(s).

Stage 1. Biotite-chalcopyrite (oldest)
Stage 2. Quartz-potash feldspar-sulphide
Stage 3. Quartz-molybdenite-pyrite
Stage 4. Epidote-sulphide-magnetite
Stage 5. Biotite; calcite; quartz."

## Mining

The feasibility having been established, James Kraft of Noranda Mines Ltd. designed the pit outline and operating plan. His results were correlated with a computer program developed by R.F. Hewlett and Associates of Tucson, Arizona. Brenda was one of the first mines to use this program. The program was run on the University of California's computer at Berkeley, California. The Kraft pit design proved accurate over the life of the mine and inspired management's confidence in computer use in all areas throughout the life of the operation.

Prior to commencement of mining, the mining equipment which had begun arriving at the mine site in April 1968 was utilized in constructing the Peachland Lake Dam and also the base of what was to become the tailings dam. This latter project required 9 million tonnes of sized waste rock to be hauled and placed under the supervision of Brenda's consultant. At the same time, the first mining areas were being stripped in preparation for production.

Mining was performed by conventional open-pit methods. Bench height was initially 15.1 m. Later, in order to preserve berms, double benching was permitted.

The blasthole pattern was 8.5 m by 8.5 m, staggered, utilizing a 0.3 m diameter hole 17.7 m deep. The powder factor was initially 0.20 kg per tonne with ANFO and was later reduced to 0.18 kg per tonne with slurry.

The main items of mining equipment included five electric shovels (three Marion M182, two Marion M190 and one P & H 2100 BL); 16 only M100 Lectrahaul trucks, three rotary blasthole drills (two Bucyrus Erie 60R and one Gardner Denver Mobile Drill); six Bulldozers (four Cat D9 and two Cat 824); three Cat 14G graders; two Cat 988 loaders and one Cat 631 water tanker.

The successful computer experience, referred to earlier, encouraged the metallurgical staff and instrumentation technicians to introduce a far greater degree of automation than was to be found

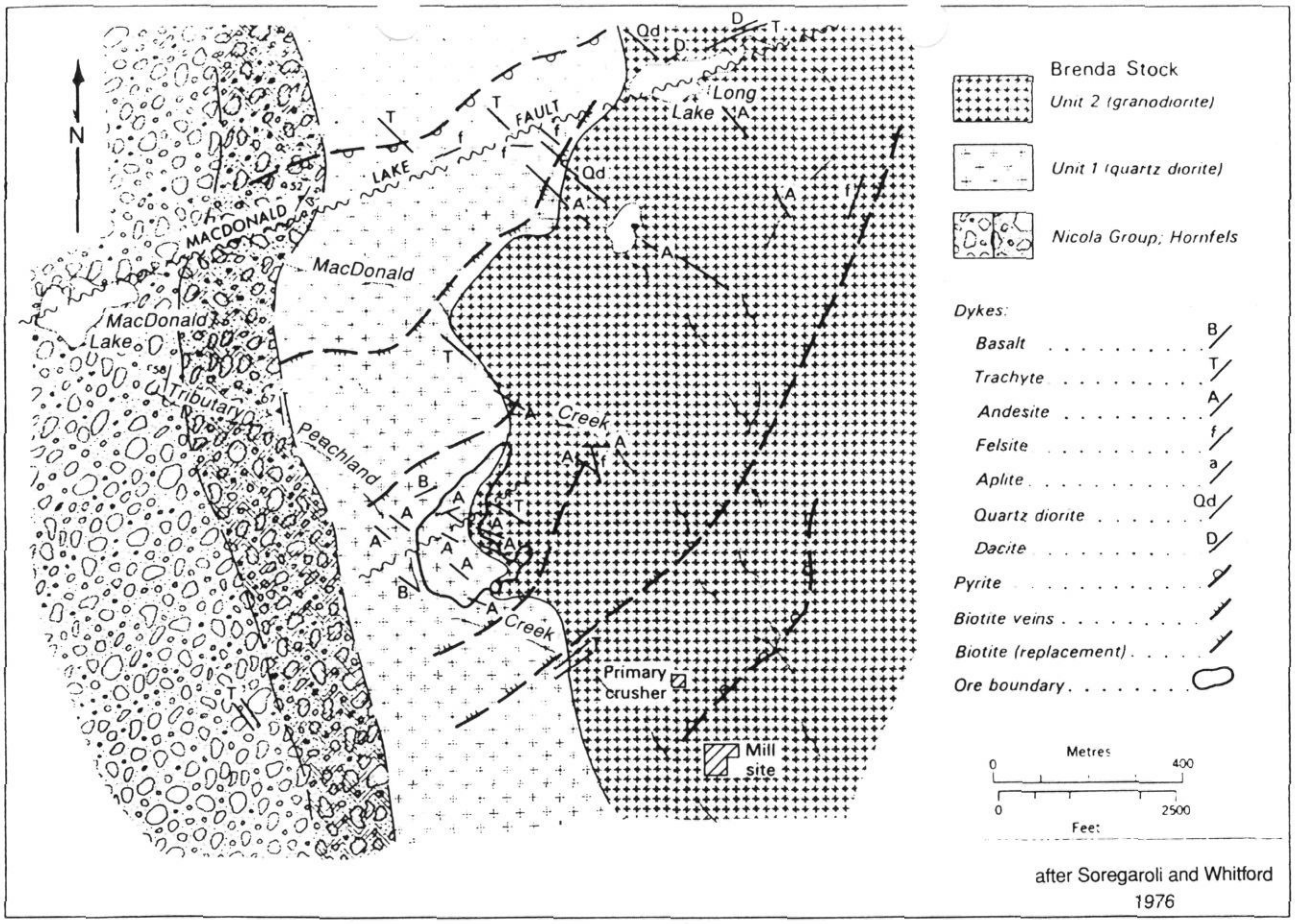


**FIGURE 3. Geology of the Brenda mine area (after Soregaroli and Whitford, 1976). Symbols for biotite and pyrite indicate their outer limits of occurrence.**

elsewhere in the industry and consequently throughput was gradually increased to 30 000 tonnes per day in 1986.

This increasing demand, together with the increasing depth of the mine as well as haulage distances, required additional shovels and trucks to be added to the equipment fleet. Ultimately, there were four shovels and 16 trucks available for use at the time of mine closure. The Lectrahaul truck fleet was the oldest complete fleet in the world at that time but was still providing a 70% availability.

The workforce never ceased the search for more throughput and during the mine's final full year of operation in 1989 the milled tonnage was an average of 31 775 tonnes per operating day, at an average grade of 0.161% Cu and 0.034% Mo. Operating costs were $4.39 per tonne milled (1989 dollars) and the stripping ratio over the life of the mine was 0.6:1.

As previously noted the mine was shut down twice and the second of these interruptions was brought to a close by an initiative of the British Columbia government known as the "Critical Industries Commission". The Commission was empowered to reduce the cost of Hydro-electric power to the mine provided the work force and the company also contributed. An agreement was reached under the guidance of Commissioner Art Phillips and work resumed in May 1984, continuing without further interruption until final closure.

## Mining Statistics and Studies

From the time of inception until completion Brenda was a marginal low-grade producer. In the mid-1980s Brenda shut down twice because of low mill heads and low metal prices, both of which altered the value of the mineralization to a point where it was non-profitable.

Based on eight months of the initial production data (about 4.2 million tonnes), Kraft and Whitford (unpubl., 1971) concluded that "the grade predicted by the 'Radius of Influence' studies will probably be exceeded by production mill heads and as computer grades become more accurate with depth". The results were as follows:

**Grade Comparison**

| Computer | | Blastholes | | Mill heads | |
|---|---|---|---|---|---|
| Cu % | Mo % | Cu % | Mo % | Cu % | Mo % |
| 0.196 | 0.053 | 0.227 | 0.066 | 0.221 | 0.064 |

These computer estimates were approximately 11% low on copper and 17% low on the molybdenum.

By the end of 1985 the mining history to date indicated that the pit would only mine to the preplanned 4260 bench and the closure date would be late 1989. For some years before 1985 Brenda Mines Ltd. was utilizing a standard kriging method to forecast production figures. This kriging method was based on the assay result from the blastholes in the previously mined benches. The method was only accurate for three benches below the last drilled bench. In 1986 Brenda was mining the 4660 bench; however, kriging could only accurately forecast grade down to and including the 4560 bench, which was located about 100 m above the floor of the proposed pit. Because mining was now in the area of the bottom of the widely spaced diamond drill holes, management was not confident of the accuracy of the many grade forecasts developed for the 1985 to August 1990 period.

Also in 1986, mill heads were higher than forecast and reasons for this could not be pinpointed. In addition, ore grade mineralization was being left behind in the south wall which prompted a feasibility study.

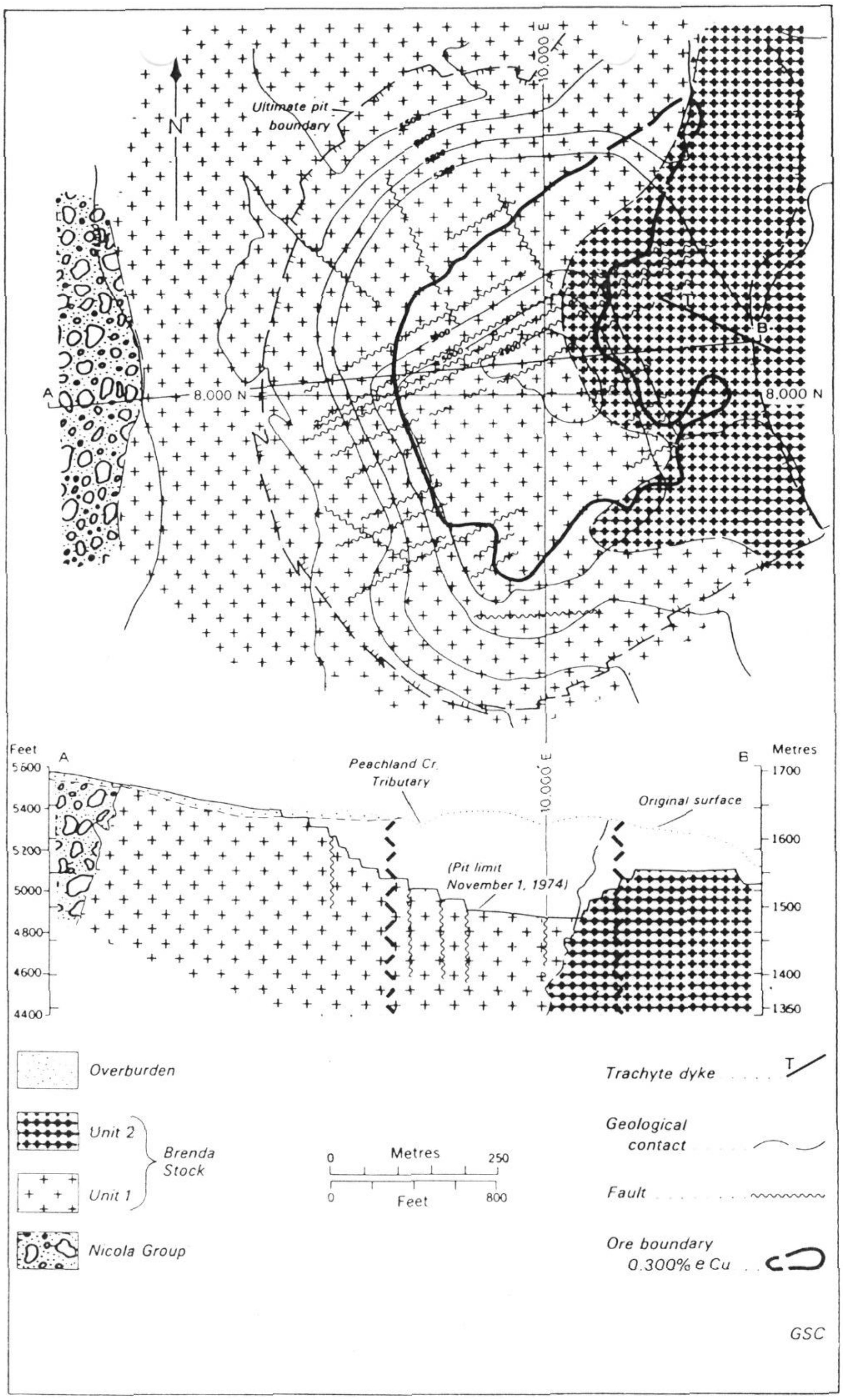


FIGURE 4. Geology of the Brenda deposit (after Soregaroli and Whitford, 1976).

The mine kept excellent production records and Table 1 compares the yearly average mill heads and some selected mine grades. This table also indicates the yearly average price for copper and molybdenum in U.S. currency. The mine grades are based on blasthole results.

The mill was originally designed for a throughput of 21 000 tonnes per day, but in the early seventies Brenda Mines Ltd. developed a computerized process control system (one of the first such systems in the world) which made it possible to increase throughput to over 30 000 tonnes per day (Harris, 1992). While increasing throughput, it put a strain on the physical mining plant. The stripping ratio and the distance of the ore haul from the bottom of the pit to the mill were increasing. It was rationalized that when a load of rock containing mineralization reached the "top of the pit" it would be milled if it paid the milling and other designated costs. This rock had to be removed to get at the higher grade "ore". If

**TABLE 1.** Production statistics and comparisons

| Year | No. of emp. | Tonnes (× 1000) | Mill (% Cu) | Heads (% Mo) | Blastholes (% Cu) | (% Mo) | Av. Price US $/lb (Cu) | (Mo) |
|---|---|---|---|---|---|---|---|---|
| 1970 | 391 | 6,660 | 0.178 | 0.054 | | | 0.80 | |
| 1971 | 395 | 8,151 | 0.212 | 0.062 | | | 0.48 | |
| 1972 | 396 | 8,619 | 0.208 | 0.061 | | | 0.45 | 1.81 |
| 1973 | 405 | 8,043 | 0.203 | 0.058 | | | 0.60 | 1.80 |
| 1974 | 433 | 8,661 | 0.186 | 0.051 | | | 0.72 | 2.19 |
| 1975 | 439 | 9,147 | 0.188 | 0.052 | | | 0.56 | 2.87 |
| 1976 | 442 | 10,046 | 0.167 | 0.045 | | | 0.64 | 3.31 |
| 1977 | 463 | 9,633 | 0.190 | 0.047 | | | 0.59 | 5.04 |
| 1978 | 470 | 9,994 | 0.165 | 0.040 | | | 0.62 | 9.53 |
| 1979 | 464 | 9,074 | 0.144 | 0.036 | 0.139 | 0.036 | 0.90 | 23.95 |
| 1980 | 468 | 8,278 | 0.128 | 0.033 | 0.126 | 0.034 | 0.99 | 9.55 |
| 1981 | 456 | 9,251 | 0.137 | 0.033 | 0.137 | 0.035 | 0.79 | 6.60 |
| 1982 | 432 | 8,602 | 0.139 | 0.032 | 0.141 | 0.033 | 0.67 | 4.20 |
| 1983 | 430 | 7,424 | 0.143 | 0.032 | 0.140 | 0.034 | 0.72 | 3.81 |
| 1984 | 406 | 5,541 | 0.151 | 0.039 | 0.149 | 0.037 | 0.62 | 3.62 |
| 1985 | 394 | 2,726 | 0.177 | 0.047 | 0.173 | 0.043 | 0.64 | 3.32 |
| 1986 | 386 | 10,180 | 0.184 | 0.048 | | | 0.62 | 2.94 |
| 1987 | 387 | 10,289 | 0.192 | 0.041 | | | 0.81 | 2.95 |
| 1988 | 406 | 11,284 | 0.180 | 0.035 | | | 1.18 | 3.49 |
| 1989 | 395 | 11,560 | 0.161 | 0.034 | | | 1.29 | 3.35 |
| 1990 | N/A | 4,281 | 0.162 | 0.034 | | | 1.21 | 2.83 |
| Total | | 177,444 | 0.169 | 0.043 | | | | |

it were not milled, the mill's unit cost would increase because mill throughput would be decreased. Such practice resulted in very low grade mill heads during the period 1980 to 1983. However, starting in 1984 mill heads rebounded although there was no apparent reason for this because mining practices had not changed. At that time part of the production was coming from the 4660 bench. Neither trend surface analysis nor kriging could explain the cause for this increase.

In early 1986 the results to date were evaluated and a drill program was designed to confirm the ore reserves for the remaining life of the mine. This included a possible push back of the south wall to extract the south-trending lobe of ore extending into the south wall. In his report Weeks (unpubl., 1987) stated, "At present a method of Kriging the blasthole assays is being employed but the limit of this Kriging is about three benches below the present bench and is not adequate for long range planning". At the time of the study the portion of the diamond drill holes below the present pit bottom indicated an ore reserve too low-grade for profitable extraction. Mine management also thought that the central high-grade core was migrating out of the pit and the then proposed lower benches of the pit would not be in the high-grade core.

Because of the negative conclusions of this study, coupled with the lack of confidence in the assays provided by the diamond drill holes, a down-the-hole drill program utilizing a 150 mm hammer was performed. To evaluate the mineralization extending into the south wall, 150 mm angle holes, plus the existing bench blastholes, in the area were utilized (Fig. 5).

This study compared the four areas of management's concern which were:

1. Comparison of blasthole data with mill heads. As indicated in Table 1, tonnes and grades based on blasthole assays compare favourably with mill heads for the period 1979-1985.
2. Comparison of diamond drill assays with blasthole assays. Because the blastholes compared so favourably with the mill heads, it was decided to compare the diamond drill assays (over bench heights) with the blastholes in the same volume. The 5060, 4960, 4860, 4760 and 4660 bench production data were utilized.

Polygons were drawn around the drill holes by standard methods. The assays of the drill hole were then compared with the arithmetic average of all the blasthole assays which fell within that polygon. Of the 298 polygons studied, 59% of the diamond drill holes gave lower copper values than the average of the blastholes. Only 28% of the drill holes gave copper values in the plus to minus 10% range of the blasthole. Also of the 298 polygons studied 57% of the diamond drill holes gave lower molybdenum grades than the blastholes and only 12% of the drillholes gave molybdenum assays within the plus or minus 10% range of the blastholes. Also of significance is that 27% of the copper assays and 59% of the molybdenum assays in the polygons differed by more than 30% from the blasthole averages.

**TABLE 2.** Comparison of the 4360 bench area grades at other bench elevations

| Bench | Central core area (% Cu) | (% Mo) | 4360 bench area (% Cu) | (% Mo) |
|---|---|---|---|---|
| 5060 | 0.203 | 0.058 | 0.230 | 0.070 |
| 4960 | 0.194 | 0.056 | 0.225 | 0.069 |
| 4860 | 0.196 | 0.056 | 0.218 | 0.062 |
| 4760 | 0.195 | 0.053 | 0.217 | 0.059 |
| 4660 | 0.210 | 0.052 | 0.223 | 0.049 |

3. Comparison of the planned pit outline in reference to the location of the high-grade core was based on the contouring of the copper grades on each bench and selecting that mineralization of greater than 0.199% Cu as the core. Figure 5 shows the location of this core area on each of the 5060, 4960, 4860, 4760 and 4660 bench elevations. It is evident from these outlines that the core of the mineralization is essentially vertical and the proposed 4360 bench would be within the high-grade zones. The northeast/southeast trend of the mineralization, controlled by the major faulting and fracturing patterns, is also evident in this figure.

This core study also answered why the mill heads were increasing for unknown reasons. The central high-grade core is a larger percentage of the total area of the 4660 and lower benches than it was on the benches above. Therefore there was not as much low-grade mineralization evaluation which went to the mill because of the "top of the pit" evaluation of the material. This elimination of the low grade allowed the mill heads to come closer to the grade of the core.

4. Average bench grades utilizing the grades falling within the 0.199% Cu contour were calculated for each of the 5060, 4960, 4860, 4760 and 4660 production benches. Copper grades remained steady while the molybdenum grades fell steadily from 0.058% to 0.052% (Table 2).

Based on the outline of the proposed 4360 bench, tonnages and grades were calculated for each bench. As shown in Table 2 the copper grade remained steady while the molybdenum grade fell from 0.070% to 0.049%. Mill heads from 1987 to the end of production confirm the decreasing molybdenum grade with depth.

The 15.2 cm down-the-hole drill ram performed on a 120 m by 120 m grid confirmed that the 4560 bench would be in the central high-grade core. The Brenda mine engineering department evaluated the results of the south wall drilling and estimated the area contained 11.9 million tonnes grading 0.156% Cu and 0.041% Mo at a stripping ratio of 0.65:1. This constitutes approximately one years' mill production, thus moving the closure date to August 1990.

## Milling

The Brenda concentrator is described in some detail in the publications by Bradburn (1978), Concentrator staff (1975) and Flintoff et al. (1989). Designed to treat 21 500 tonnes of ore per day, the mill was commissioned in January 1970.

The Brenda ore was very low grade which meant that the viability of the operation was dependent on maintaining low production costs. In the mill this translated to high productivity and good metallurgy. It is very important to note that all of the changes that were undertaken in the pursuit of these goals, were driven by the philosophy that was enshrined in the Brenda operations by the first mill superintendent, J.B. Knapp:

1. Ensure that everything runs as well as it can, i.e., the operating objectives must be clearly known by everyone, staff at all levels must be properly trained, maintenance practices must be such that high availability is maintained.
2. Continually look for operational/design and technological changes that will improve productivity and metallurgical performance. In effect, Brenda instituted TQM and employee empowerment long before these became formal management tools.

Through the twenty-year life of the concentrator many changes were made which, when taken together, helped to ensure the survival of this marginal operation until the orebody was exhausted. These changes are too numerous to document fully and what follows is a representative sampling of some of the more important innovations.

### Concentrator Transformation

At the Brenda Mine, reductions in production costs could be obtained through cost cutting and revenue enhancement. It was quickly apparent that cost cutting had its limitations, and the real benefits were to be achieved through increased revenue. The mineralogy of the Brenda ore was such that increased tonnages, resulting from coarser grinds, led to only minor losses in metal recovery. The net effect of higher throughputs was higher metal production and, overall, lower production costs. The confirmatory experimental work was completed in the early 1970s and, as was typical at Brenda, university researchers employing modern process analysis tools were invited to work on these projects. In 1973 it was decided that Brenda's operating strategy should not be one of fixed tonnage, rather, the goal should be to maximize tonnage. Moreover, the initial efforts were to be focused in grinding, the production bottleneck at the time. The economic success of this first optimization venture effectively drove the subsequent projects which transformed the Brenda concentrator to a 30 000 tonnes per day mill with excellent metallurgy.

To give some sense of the course of events one must go back to 1974. Brenda was one of the first milling operations to explore computer-based process control. This technology was applied to the grinding circuit tonnage maximization problem. By 1976 throughputs had risen by 10% to 30%, depending on the nature of the feed ore. Economically, this was a very significant change. However, increases in the grinding circuit throughput put pressure on the crushing plant. Following the same methodology, process control was then extended to the crushing plant with very similar results. This moved the bottleneck back to grinding where mill speed was increased (pinion replacement) to gain further production increases.

Fueled by the successes in comminution, process control was extended to the flotation circuit. Brenda was among the first mills to implement assay-b optimizing control utilizing an on-stream X-ray fluorescence analyzer. Most design changes were implemented in the flotation area. For example, Brenda installed large flotation cells shortly after they had been introduced into the market. The old cells were then used to construct a sand/slime circuit which recovered coarse, liberated molybdenite and chalcopyrite grains that would have otherwise been lost to tailings. In addition, with the re-emergence of column flotation in the early 1980s, both the molybdenum and copper cleaning circuits were modified to incorporate these devices. All of these changes in flotation served to improve metallurgy and reduce operating costs.

Not all of the changes related to process technology. For example, the higher productivity in the comminution circuit, with little or no change to the original equipment, meant that good equipment condition and availability were crucial to success. Brenda adopted a preventive maintenance program at the start of operations and added predictive maintenance in the early 1980s. These programs, coupled with innovations in procedures were aimed at reducing downtime which led to overall availabilities approaching 98% in the final years of the mine. This is impressive when one considers that most of the equipment had been operating nearly continuously for 20 years. Similarly, Brenda instituted formal operator training programs in the early 1970s where the emphasis was placed on process understanding. The advantage of this was twofold. First, these operators had the knowledge to make production decisions, which influenced economic performance. In addition, when the pressures of the early 1980s led to shutdowns and staff reductions, Brenda was well equipped to do more with less.

The success of the Brenda milling operation over the years arose not from radical change, but, rather from an incremental and evolutionary process that was governed by economics, and based on sound scientific and management principles. The flowsheet did not change in form, but in substance. If one looks for the reason why this operation is recognized for its achievements, it lies in the intangible, the operating culture which was established by John Knapp.

## Environmental Reclamation

The objectives of decommissioning are to reclaim the 804 hectares of land disturbed by the operation in an environmentally acceptable manner, with regard to the long-term future land use. Water quality and land stability for future land use are the main items of research and application.

The operation produced four rock piles containing about 106 million tonnes of blasted rock in addition to the 170 million tonnes of tailings. All the surface rock piles and tailings pond have been checked for long-term stability by seismic methods. They were then contoured and seeded. Many of the seeded areas are being tested as graze for local cattle, especially the area of the tailings pond. A full scale round-up of about 200 cattle was completed in the fall of 1993.

Since the start of operations all run-off water from the disturbed areas of the property including the rock piles, roads and tailings pond has been collected and put into the tailings pond where it became part of the water requirements of the mill. This water was found to have an average pH of 8.0. At this pH, molybdenum is dissolved and this causes the major portion of Brenda's reclamation problems. Leaching is enhanced due to the increased surface area exposed by the mining and milling operation.

While the British Columbia Ministry of Environment's objectives for irrigation of poorly draining soil used for forage crops is less than 0.5 mg/l, Brenda's proposed discharge will meet drinking water objectives of 0.25 mg/l.

Brenda has thoroughly investigated at least nine major water treatment methods since 1984, including Engineered Wetlands. While this method may prove useful at some future date, a water management program centred on the well known iron precipitation process for molybdenum is currently proposed.

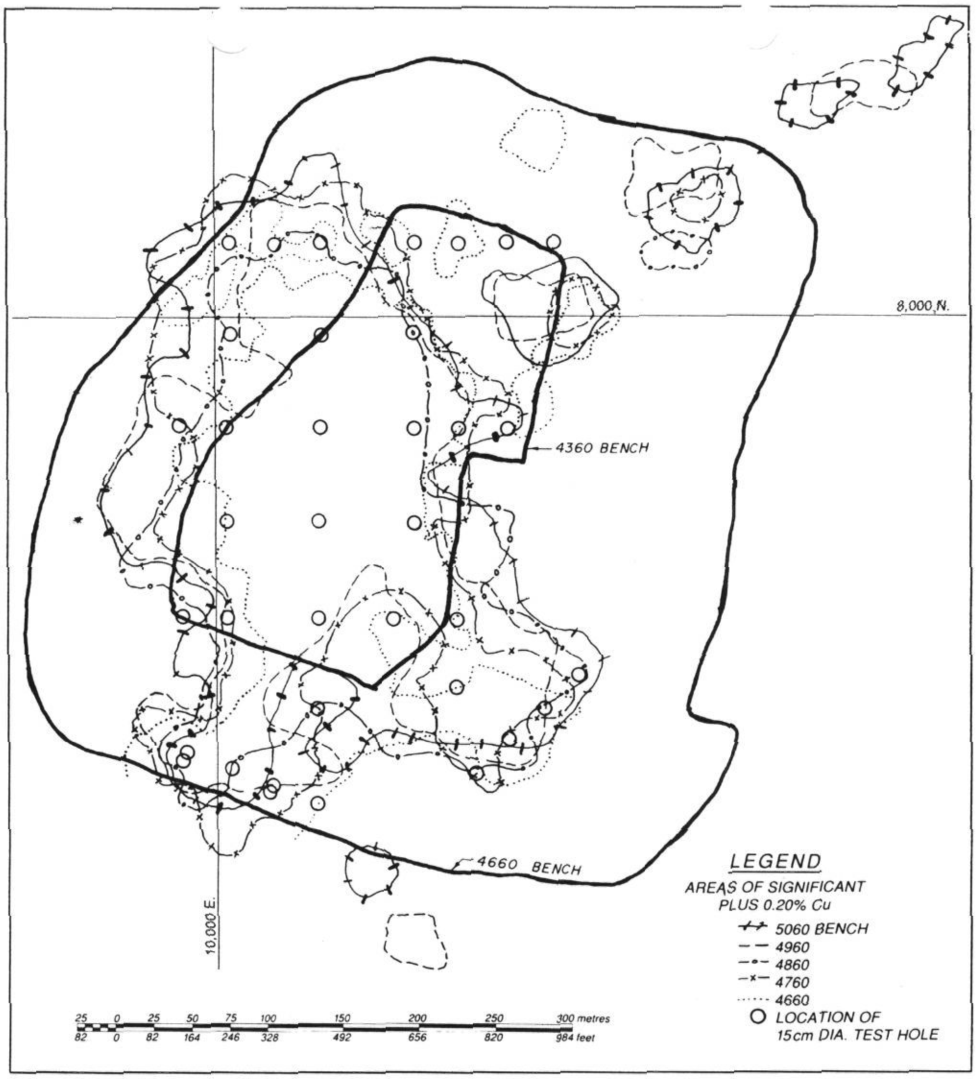


**FIGURE 5. Location of significant areas of plus 0.20% Cu on the 5060, 4960, 4860, 4760 and 4660 benches.**

There appears to be no adverse effect, due to molybdenum, to any of the cattle now grazing over the property, nor to any of the migrating waterfowl which frequent the area.

The decommissioning plan was made public in June 1993. Reclaiming the site is part of the mining cycle.

## Human Resources

In 1986 it was announced that due to the depletion of its ore reserves the Brenda mine would close in the fall of 1989. The following year a feasibility study determined that economically mineable ore existed under the south wall of the pit and the life of the mine was extended for one more year.

Many of the 400 employees had grown up in the Okanagan with an average mine service exceeding 10 years. Concern for employee welfare was constructively addressed at Brenda by choosing to adopt the Industrial Adjustment Service (IAS) Program sponsored by Employment and Immigration Canada. The Program is based on the principle that the people most directly affected by a problem will bring the highest level of commitment to its solution.

A partnership between the company, departments of both the federal and provincial governments, Local 7618 of the United Steelworkers of America and the employees themselves was implemented and a program developed. Over the two-year period before the closure approximately 70% of the employees participated in a great number of courses and seminars: high school upgrading, business and college courses, trades training and upgrading, financial, retirement and family counselling, résumé preparation, job search and interview skills were also taught.

When the mine closed in June 1990 Brenda Mines Ltd. opened a Job Search Office to handle the special needs of the former employees. It remained open for eight months. A year after the closure approximately 85% of the employees actively seeking employment had found work.

The foregoing, together with what was one of the most generous severance packages in the industry, proved very successful and was applauded by several public bodies and associations, not the least of which was the Canadian Mental Health Association which presented Brenda with an award for "Excellence in Employee and Family Assistance". This was to recognize the effort the company had put into helping the employees develop the skills and the confidence to "help themselves" with a job search in a very tight and competitive market.

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