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Mill throughput at Carolin Mines' new gold operation has already exceeded the design capacity of 1,500 tons per day. Ore is mined using long hole open stoping; all crushing is done underground

Smooth startup at western Canada's largest gold mine

By **Kelson G. Collins,** general manager, **Rod Samuels,** mill superintendent, and **John R. Bogert,** director, Carolin Mines Ltd.

After ten years and an expenditure of C$37,000,000 ($30,000,000), the first doré bullion bar was poured at the Carolin mine of Carolin Mines Ltd. on February 3, 1982. The mine is now operating smoothly and efficiently. The current production rate of 1,500 tons per day will soon be increased to reach 2,400 tons per day. Daily production of 175 to 200 ounces of gold should then increase to 300 ounces.

Drill indicated reserves in the Idaho ore zone of the Carolin mine now exceed 2,000,000 tons grading 0.12 ounce per ton, on a cutoff grade of 0.05 ounce per ton. The ore is open down plunge.

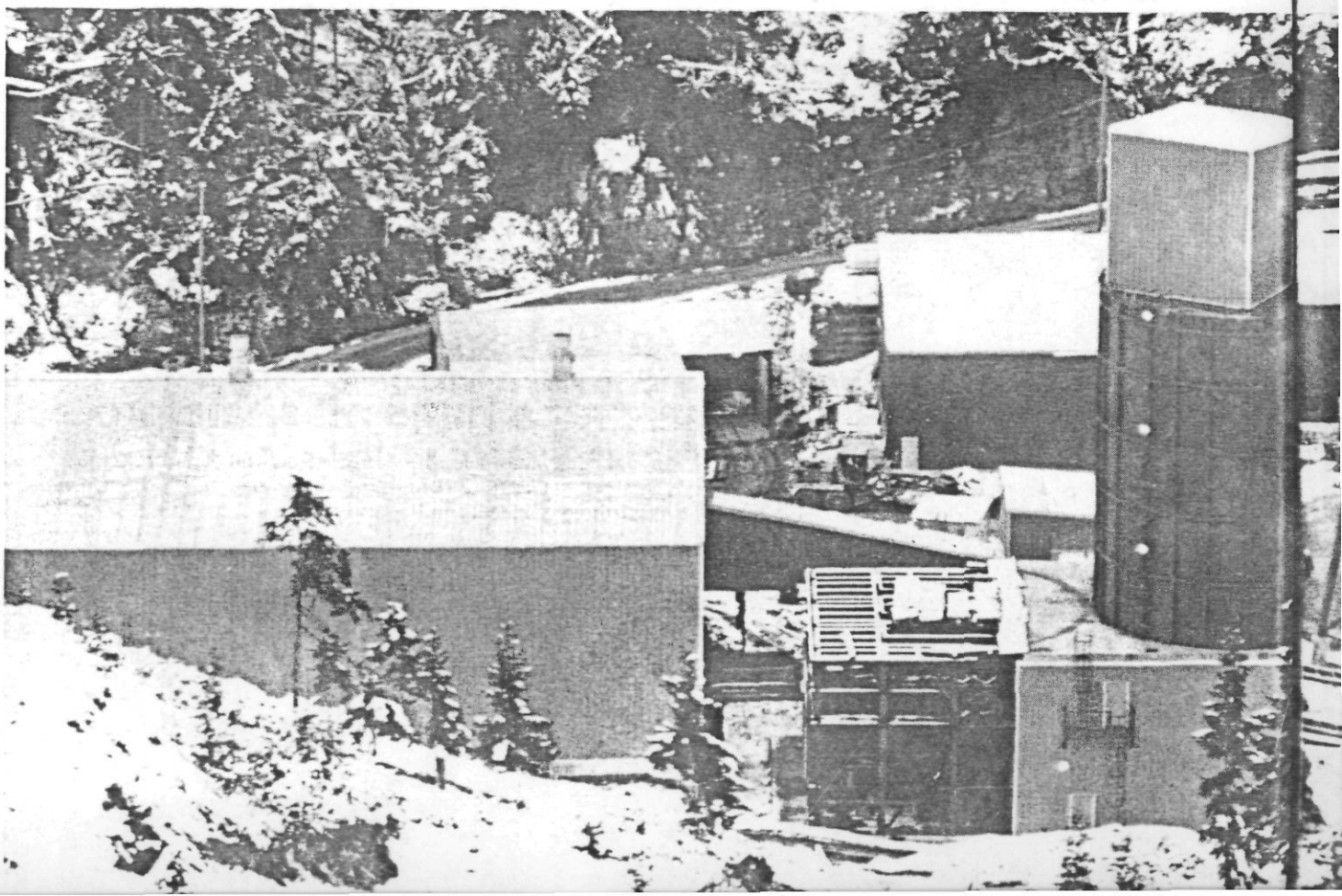
Area History Traced 100 Years

The Carolin mine is in the Cascade Mountains of southern British Columbia, 20 kilometers (12 miles) northeast of Hope and 150 kilometers (90 miles) east of Vancouver. The mine is at an elevation of 850 meters (2,500 feet) in heavily forested, mountain terrain typical of western Canada. The concentrator is in a narrow valley of the southwest fork of Ladner Creek, which flows some 5 kilometers (3 miles) southeast to the Coquihalla River, which in turn feeds the Fraser River.

In the immediate area of the Carolin mine there are a number of lode gold deposits that comprise the Coquihalla Gold Belt. Discovery of gold in this area was made during the 1858 Fraser River gold rush. Placer miners working the tributaries of the Fraser found gold in the Coquihalla River, and follow-up prospecting soon revealed the lode deposits.

The first recorded workings in the Coquihalla Gold Belt were on the Ward claim on Siwash Creek, and from 1913 to 1942, there was intermittent production from the Emancipation, Aurum, Georgia No. 2, Pipestem, and Idaho mines. The total recorded production was 3,913 ounces of gold from an unknown tonnage, although the Arum has a recorded production of 500 ounces from 500 tons.

Production in the area ended during World War II, and the area remained relatively dormant until Carolin Mines Ltd. acquired eight crown-granted min-



200 meters (660 feet), and in vertical height from less than 10 to 100 meters (33 to 330 feet).

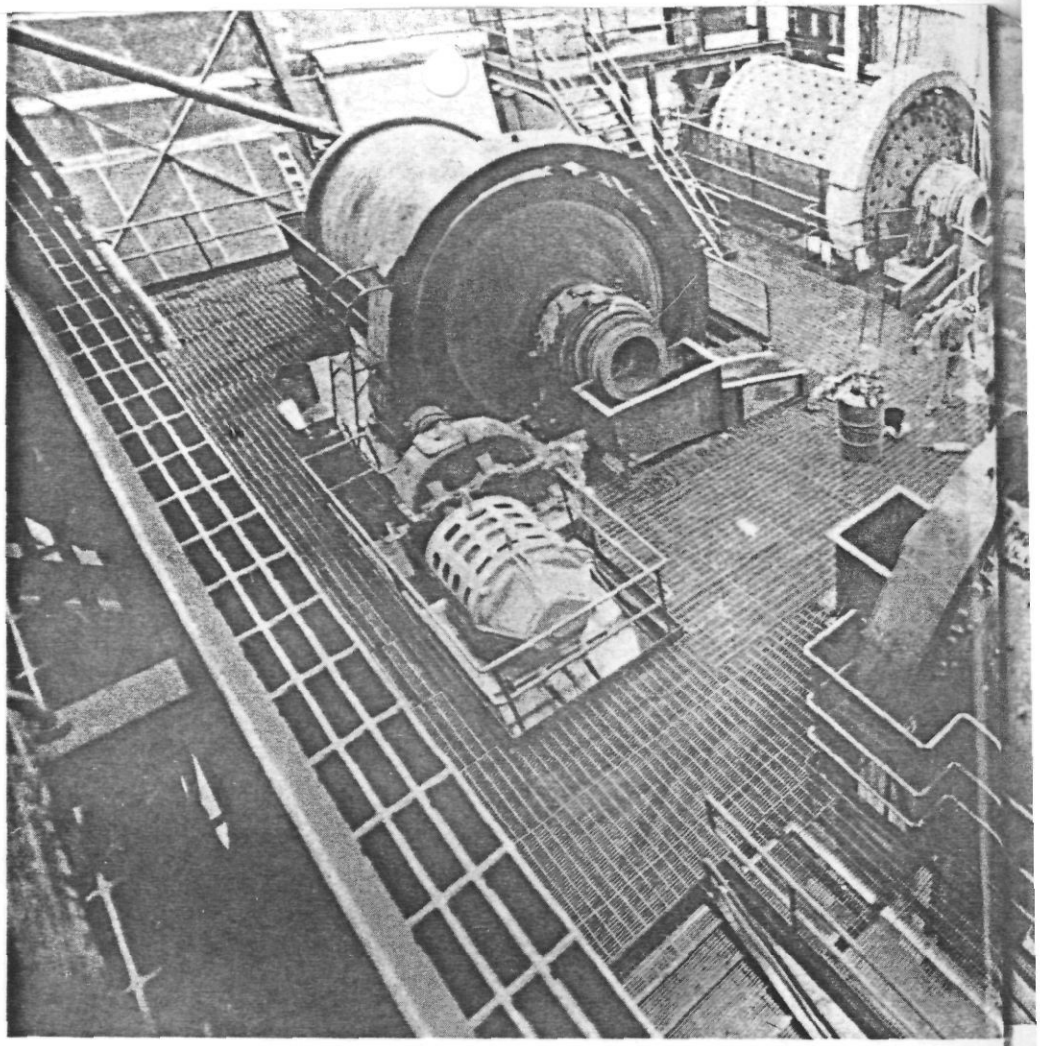
In the feasibility study, drill indicated ore reserves, based on a cut-off grade of 0.08 ounce per ton gold, were estimated at approximately 1,650,000 tons grading 0.14 ounce per ton. Silver content is 0.03 ounce per ton. Subsequent calculations using the 0.05 ounce cutoff grade increased marginal reserves to approximately 2,000,000 tons grading 0.12 ounce per ton gold. This should provide more than four years of mill feed. Based on geology and structural trends, it is highly probable that ore reserves will be increased by future exploration drilling. The Idaho zone is open and untested north of the reserve area, where it continues to plunge to the north.

Mining by Sub-level Stoping

Development mining began in December 1979 with portals collared at the 900 and 820 meter (2,970 and 2,700 foot) levels. The 900 level access has dimensions of 3.5 meters (11.5 feet) wide by 4 meters (13.2 feet) high to allow entry of 5-cubic-yard (3.5-cubic-meter) load-haul-dump equipment. It was driven horizontally for a distance of 915 meters (3,000 feet) from which point ramps turn upward and downward to establish drawpoints and drilling sub-levels at the stopes. Maximum ramp inclination is 15 percent. The northern extremity of this drift intercepts the Idaho exploration decline. The Idaho decline, because of its location, is not suitable for mining development but is being utilized for ventilation and as an escapeway.

The crusher portal is collared at elevation 795 meters (2,625 feet), and this 4 by 3.4-meter (13.2 by 11.2-foot) decline slopes at 18 percent to elevation 780 meters (2,575 feet), where it is enlarged to house the primary and secondary crusher rooms. The primary jaw crusher room is joined to the 820 meter (2,700 foot) haulage level by a 1,200-ton coarse ore storage pocket and a raise required for ventilation and secondary access.

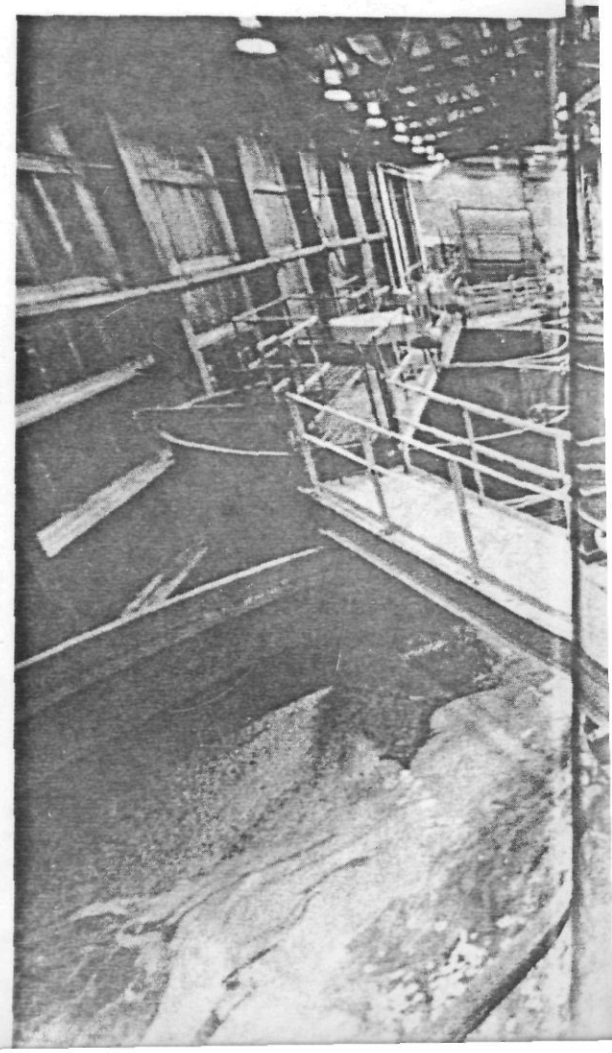
Long hole open stoping has been chosen as the mining method. Mining has started near the northerly end of the present known ore zone, and is proceeding sequentially upward toward the surface. This approach offers the probability of the quickest return of capital, because of marginally higher ore grades, maximum size of stopes, and minimum amount of stope development. When the stopes are mined out they will be backfilled with a mixture of deslimed tailings and cement in a 30 to 1 ratio. Later, it will be possible to mine out the pillars with an overall recovery of nearly 100 percent of the ore.

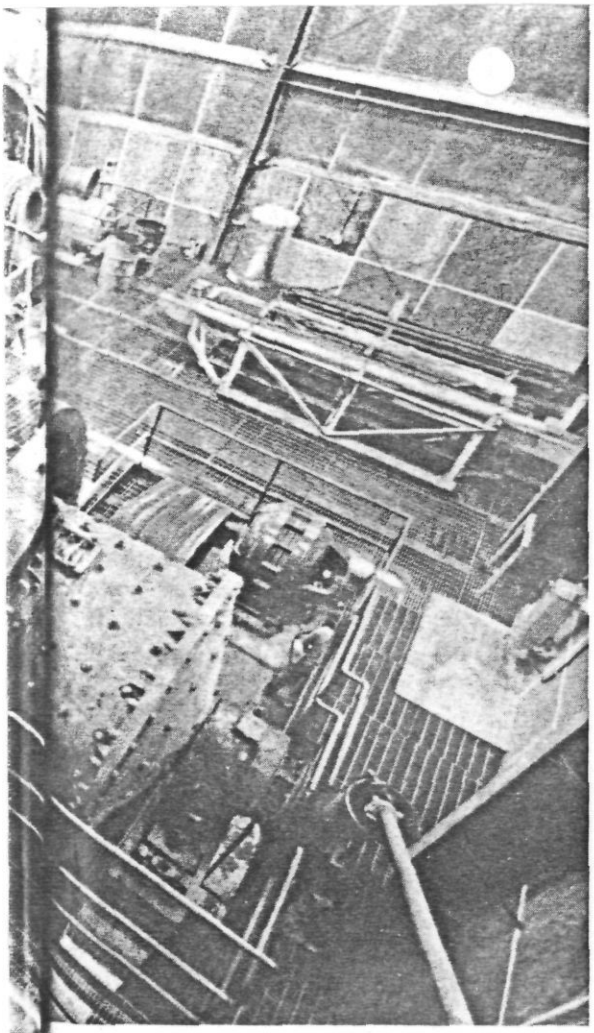


Due to the differences in size of the various ore lenses and their irregular wall outlines, it is not possible to introduce a standard stoping pattern. Each stope must be individually engineered.

Production drilling of the 2-inch (50-millimeter) diameter longholes is done with a Simba H-221 electric-over-hydraulic drill at a current rate of 150 meters (495 feet) per drill shift. Ring burden is 1.5 meters (5.0 feet) and toe spacing is 3.5 meters (11.5 feet). This will break 2.35 tons (2,130 kilograms) per foot drilled with an initial powder factor of 0.6 pound (0.3 kilogram) of explosive per ton broken. Changes in both burden and spacing of drill holes can be expected after initial blasting results have been evaluated.

Ore recovery from the stope drawpoints is done with four Jarco JS-500 5-cubic-yard (3.5-cubic-meter) LHD's, and distances to the ore passes will range from 120 to 240 meters (400 to 800 feet). Ore is then drawn on the 820 meter (2,700 foot) level from the ore pass chutes and transported to the coarse ore pocket above the primary crusher. The haulage equipment includes a 10-ton





GRINDING SECTION, here under construction, houses both a rod mill and a ball mill.

(9,070-kilogram) electric trolley, or battery-operated locomotive and a fleet of 165-cubic-foot (4.7-cubic-meter) capacity side-dumping ore cars. Waste dumps will be located outside the mine portals. These dumps will be constructed to provide a stable base for ultimate revegetation. Drainage control should ensure that erosion of fines is prevented.

The mine will operate two shifts a day, five days a week, to produce enough ore to sustain a continuous seven day per week milling operation at over 1,500 tons per day.

Western Canada's Largest Au Mill

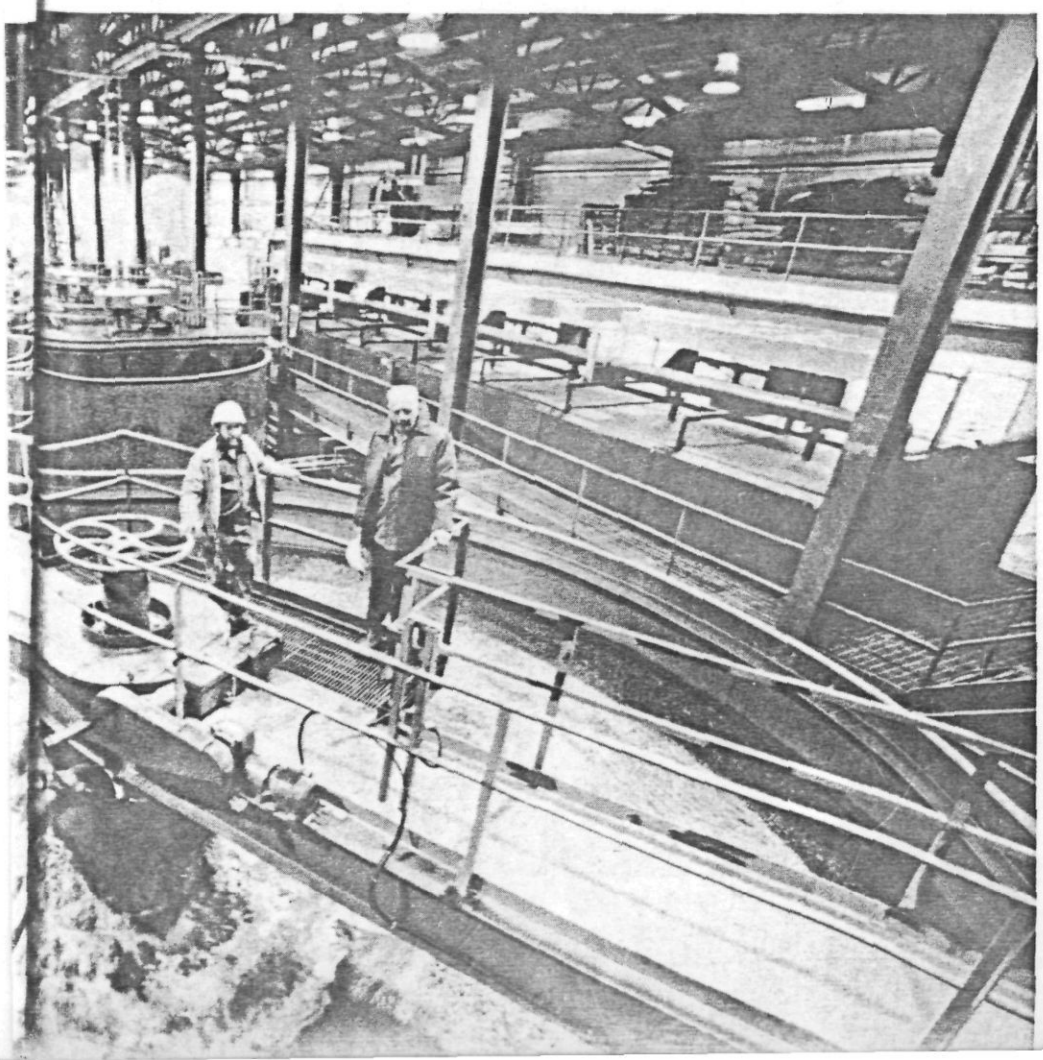
Based on design throughput, the Carolin mill is the largest gold mill in western Canada, and ranks fifth among the largest gold concentrators in Canada. Carolin's modern facility is unique in construction and design. However, like most of Canada's larger gold mills, which have been in production for many years, the metallurgical flowsheet has remained conventional, particularly in the area of cyanidation and gold precipitation—the Merrill-Crowe process.

Location of the crusher is not typical. The steep valley and lack of working area prompted a decision to construct the total crushing operation underground. The high cost of excavating rock limited the facility to two-stage open circuit crushing. The flow of minus-24-inch (minus-60-centimeter) material from the coarse ore pocket is controlled by pneumatic fingers and chains. The controlled tonnage is fed to a 36 by 48-inch (0.9 by 1.2-meter) Birdsboro Buchanan jaw crusher. Minus-4-inch (minus-100-millimeter) crusher discharge is conveyed to, and sized by, a 5 by 8-foot (1.5 by 2.4-meter) rod deck vibrating screen with ⅜-inch (16-millimeter) openings. The screen oversize is then reduced by a 5½-foot (1.7-meter) Symons shorthead cone crusher with a closed side setting of ½ inch (13 millimeters). A combined product of screen undersize (minus-⅜-inch or minus-16-millimeter) and cone crusher discharge (minus-1-inch or minus-25-millimeter) is moved by conveyor belt up the decline and over the valley to a 2,200 tons live capacity, fine ore storage ore bin. The design calls for two 2,200-ton fine ore bins, but construction of one was delayed until this summer.

Ore is recovered from the fine ore bin with three slot feeders discharging to three parallel belts, one of which is variable speed for fine control of the rod mill feed. The feeder belts discharge to a fixed speed belt, which in turn feeds minus-⅜-inch (minus-16-millimeter) ore into the rod mill. A weightometer monitors tonnage on the rod mill feed belt for metallurgical accounting purposes.

Primary grinding is done with a 9½ by 12-foot (2.9 by 3.7-meter) Dominion rod mill with an inventory of 3½-inch (90-millimeter) rods. The rod mill discharge, along with the discharge from a secondary 10½ by 12-foot (3.2 by 3.7-meter) Dominion ball mill is pumped to a 24-inch (0.6-meter) cyclone in open circuit with the rod mill and closed circuit with the ball mill. The ore, with a Bond Work Index of 12.0 kilowatts per ton, is ground to 66 percent minus-200-mesh. A jig and table will be installed in the grinding circuit because gold particles have been found in the rod mill discharge and these particles would not be recovered by flotation.

After conditioning at pH 8.7 with 0.33 pound (150 grams) per ton of copper sulphate, 0.33 pound (150 grams) per ton potassium amyl xanthate, 0.01 pound (4.5 grams) per ton Aerofloat 31 and 0.08 pound (36 grams) per ton pine



FLOTATION CELLS recover bulk concentrate grading some 1.8 ounces gold per ton.

oil, a bulk rougher concentrate totalling 6 percent by weight of the feed is recovered in four 300-cubic-foot (8.5-cubic-meter) flotation cells. The metallurgical testwork showed only 91 percent of the gold was recovered by flotation, and therefore, 50 percent more retention time than was actually used in the laboratory tests was designed into the circuit. The slurry is scavenged in four 300-cubic-foot (8.5-cubic-meter) cells, and the scavenger concentrate is discharged back to the conditioner tank. Scavenger tailings are pumped to the tailings pond.

At this point all that remains is 100 tons per day of bulk concentrate assaying 1.8 ounces gold per ton. The flowsheet now becomes typical of most small gold mill operations. Rougher concentrate reports to a 10-inch (250-millimeter) cyclone and the underflow goes to a 7 by 6-foot (2.1 by 1.8-meter) regrind mill for reduction to 98 percent minus-325-mesh. Regrinding is done with high lime addition to neutralize the acid products formed by pyrrhotite, which would otherwise consume excessive cyanide. Fuel oil is also added in the regrind mill to deactivate any carbonaceous material in the concentrate. The ore body does contain minor amounts of graphite.

The reground and thickened pulp is agitated in leach tanks with cyanide reagent and dispersed air for 72 hours. Anticipated reagent consumptions are 1.28 pounds (0.58 kilogram) per ton sodium cyanide and 2.6 pounds (1.2 kilograms) per ton lime. Gold dissolution in the testwork was 91 percent for an overall recovery of 83 percent. Experience has shown that better recoveries can be achieved in a plant environment versus bench testing, and we believe that the 83 percent overall recovery predicted in the feasibility study is a conservative figure.

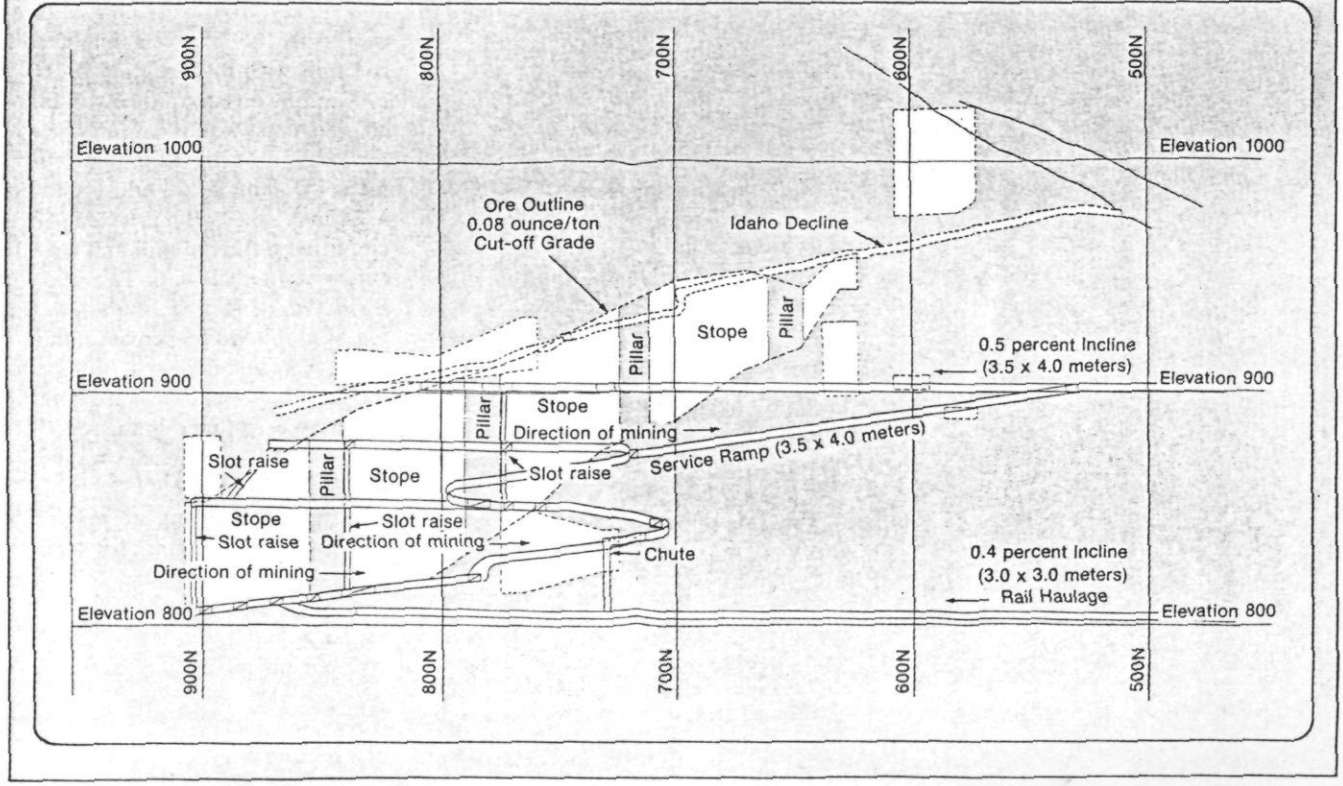
After it decants from the last leach tank, the pregnant solution is recovered in a 40-foot (12.2-meter) thickener as overflow. The thickener underflow is pumped to a primary 10 by 10-foot (3 by 3-meter) drum filter, where additional pregnant solution is recovered. The filter cake is repulped in barren solution and subsequently filtered in a secondary 10 by 10-foot (3 by 3-meter) drum filter. The filter cake is repulped and charged to tailings. All filtrates return to the pregnant solution thickener, where they are recovered as pregnant solution overflow. The overflow is pumped to a leaf clarifier to ensure the removal of finely divided, suspended solids, and passed through a deaeration tower. Zinc dust and lead nitrate are added to the deaerated solution and the gold-zinc precipitate is removed from the now barren solution by one of two 36-inch (0.9-meter) Perrin filter presses. The air dried gold-zinc precipitate is then fluxed and smelted to bullion in a single chamber, oil fired, smelting furnace.

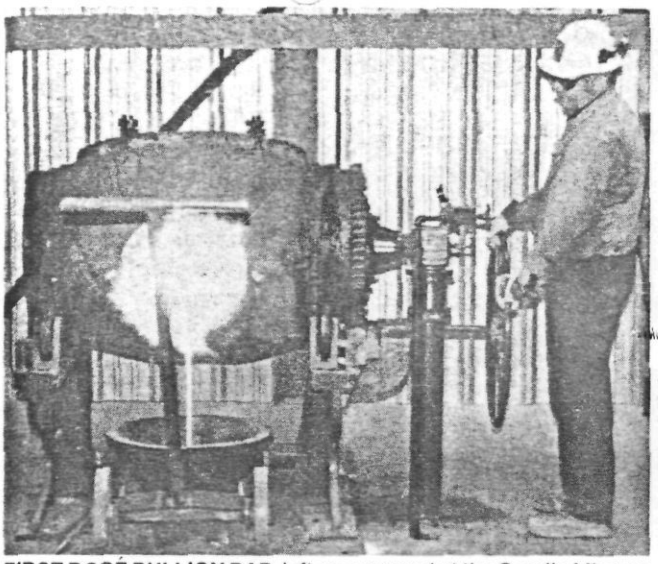
To avoid leach circuit contamination, a bleed from the barren stream must be continually removed. Cyanide must be destroyed prior to disposal of the solution to tailings. Carolin has elected to install an alkali chlorination system to oxidize and destroy cyanide. Chlorine gas is bubbled through the solution at a maintained alkaline pH. After retention in two 6 by 6-foot (1.8 by 1.8-meter) fiberglass tanks, the treated barren solution is passed through a carbon column for extraction of residual chlorine and other undesirable ions. In addition to its environmental advantage, it is felt that the carbon system will prove to be a profitable back-up for collecting gold not precipitated by zinc.

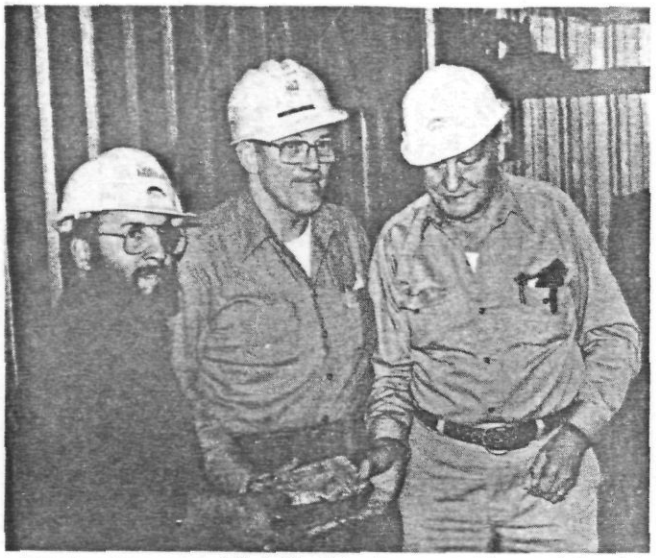
Solid tailings disposal is a significant operating cost. There are no downstream impoundment sites where effluent can be discharged by gravity from the mill.

The flotation tailings will not require any chemical treatment prior to disposal. However, it is proposed that the sand portion will be used as mine backfill, the need for which will not arise until early 1983. At that time, a backfill preparation plant will be required. This plant will consist of two stages of pumping and hydrocyclone classification. The coarse sands will be pumped to the mine and the overflow, comprising a product that is primarily fines, at approximately 17 per-

Section view of Ladner Creek







FIRST DORÉ BULLION BAR, left, was poured at the Carolin Mine on February 3, 1982, after ten years and $C37,000,000. **GOLD BRICK,** right, is held by Rod Samuels, mill superintendent, Kelson Collins, general manager, and Ted Worthington, consulting metallurgist. Mill output has already exceeded design capacity. Plans for the near future call for an output of some 300 ounces of gold per day.

cent by weight, will be delivered to the tailings pond.

Flotation and leach tailings are currently collected and pumped through a series of five 6 by 4-inch (150 by 100-millimeter) Warman pumps. A final discharge pressure of approximately 400 pounds per square inch (28 bar) boosts the tailings up a 6-inch (150-millimeter) pipeline through approximately 600 feet (183 meters) of head to the tailings impoundment area.

Tailings Containment

The tailings dam is an earthfill structure, constructed mainly of compacted boulder clay from a borrow pit local to the site. First stage construction includes a downstream zone of free draining shot rock, which will become a central chimney drain in the final design. The two zones are separated by filter cloth. In the summer and fall of 1981 approximately 350,000 cubic yards (270,000 cubic meters) of earthfill were placed on the dam to net one year of storage capacity. In the future, the dam will be raised annually to meet the production requirements.

Final dam crest will be 148 feet above the valley floor. It will require 1,140,000 cubic yards (872,000 cubic meters) of earthworks, which should provide 6⅔ years of tailings storage. This capacity will be substantially increased by implementing underground back filling. Seepage is controlled by a small downstream sump and pumping system. Pumps on a floating barge reclaim clarified water and pump it up to a head tank. From here the water flows by gravity back to the mill to meet much of the process water demand.

Make-up water for the process and for fire storage is pumped from Ladner Creek. The potable water system is charged by a separate upstream infiltration gallery.

Inflation Causes Cost Overrun

The 1979 feasibility study estimated that the Idaho zone ore body could be brought into production at an estimated cost of C$19,300,000 ($15,600,000). The actual production cost was about C$37,000,000 ($30,000,000). It can be appreciated that there is a significant difference between those second quarter 1979 dollars and the dollar's current purchasing power.

Although a good portion of the overrun can be attributed to inflation, there have been other contributing factors. Most notable of these was a C$1,242,000 ($1,006,000) extra cost to place a 10-foot (3-meter) diameter, precast concrete culvert to divert Ladner Creek past the mill site. After backfilling with mine waste, the culvert placement provided much needed office and shop space as well as reducing the environmental impact of the possible silting of Ladner Creek. In addition, the change to underground crushing from surface crushing increased the final cost. The requirement to shotcrete both crusher rooms was another major expense not covered by this study.

The Carolin operation is now making a significant contribution to the economy of the Hope area and adds another 63,000 annual ounces to Canadian gold production. With favorable geology, encouraging exploration results, a strong management team, and no debt, Carolin Mines Ltd. looks to the future with enthusiasm. ■