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TS -> Golden Bear

Golden Bear

By David Scott*

New ownership focuses on intensive development and the introduction of heap leaching

The outcrop of the Golden Bear Main Zone was discovered by Chevron Minerals, a wholly owned subsidiary of Chevron Standard, in 1981. Commercial production began in January 1990 at 360 t/d. Start-up problems in the mill limited gold production to 19,242 oz in 1990 but improved to 56,712 oz in 1991 and again in 1992 to 58,224 oz. A major change in corporate ownership July 1993 was the cause of a decline to 52,357 oz that year but the new owner's emphasis on intensive orebody development and the introduction of heap-leaching is expected to see production in the 70,000-75,000 oz range by 1995.

Most production to date has come from the now almost exhausted Bear Main Zone. Production for much of the second half of 1994 came from the property's first heap-leach facility. Heap-leach ore was open-pit mined from the Kodiak 'A' orebody, an orebody discovered October 1993, barely four months after the new company took over operations.

Golden Bear is one of Canada's more moderate sized gold mines. It has also experienced a Cinderella history. Explored by one of the world's largest oil corporations, brought to feasibility by an equity financed junior company, then launched into production by North America's most venerable gold mining company, the mine is now in the hands of Toronto-based Canadian independent Wheaton River Minerals.

Golden Bear's history

Fresh from its 1979 co-discovery of the world-class Hibernia oil field, 260 km off the coast of Newfoundland, Chevron became increasingly involved in hard rock mining. The company was then the lead partner in developing the Stillwater palladium-platinum mine in Montana (*MM*, November 1987, pp 418-427). until recently it was operator and majority owner; it has now sold its interest. At the same time, the 1979 gold price had reached US$455/oz and was rising. The price was to average $612 in 1980 and Chevron saw the time was ripe to expand its precious metals interests. The company subsequently selected one of the most remote regions of northwest British Columbia (B.C.) for its thrust into gold exploration. Clearly, Chevron believed that by selecting this difficult-of-access, relatively unexplored, tract of mountain terrain, the odds of finding a multi-million-ounce gold deposit were more favourable than in better known territory.

Field work started in 1980. Numerous gold showings were located and early work concentrated on the outcropping Bear Main Zone and the 'Ophir Break', a 20 km-long fault zone along which all the main ore zones have been found. By December 1985, a resource of 1.02 Mt grading 13 g/t gold had been delineated in two, separate, mineralised zones. Chevron's exploration expense at this point was $C10.9 million.

Early in 1986, North American Metals, a Vancouver listed company, entered into a joint-venture with Chevron and acquired a 50% interest in the property. By spring 1987, North American had spent $C4.5 million on surface and underground exploration. The subsequent feasibility study projected a capital cost of $C36 million to bring the property into production at 360 t/d. Cash operating costs of $US136/oz were estimated on a production rate of 60,000 oz/y gold. Ore reserves, both zones, all ore categories, were 1.8 Mt grading 9.2 g/t gold.

A general view of Golden Bear.

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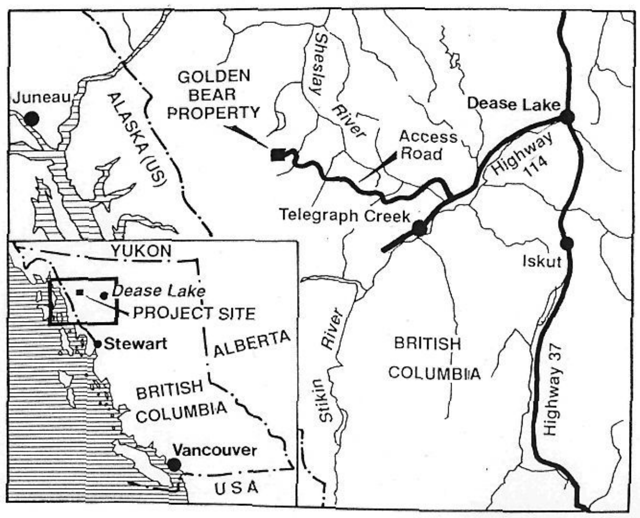


Fig. 1: The location of the Golden Bear property.

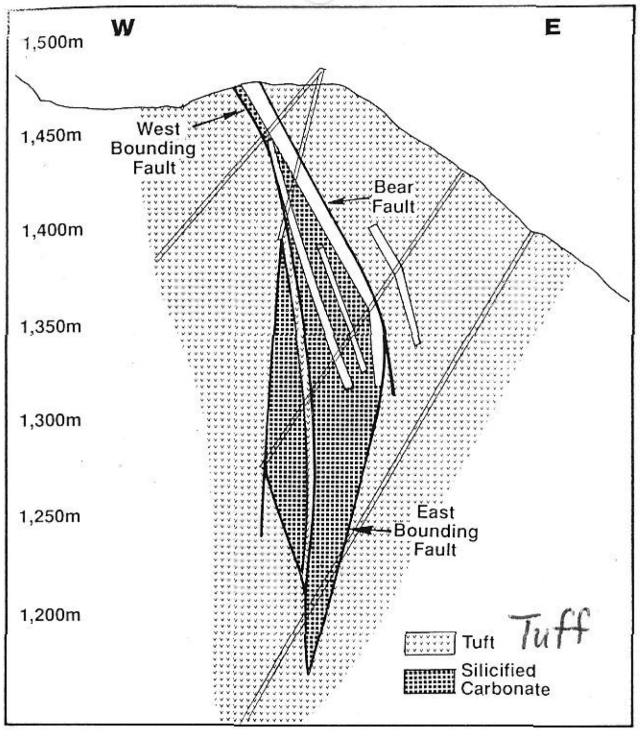
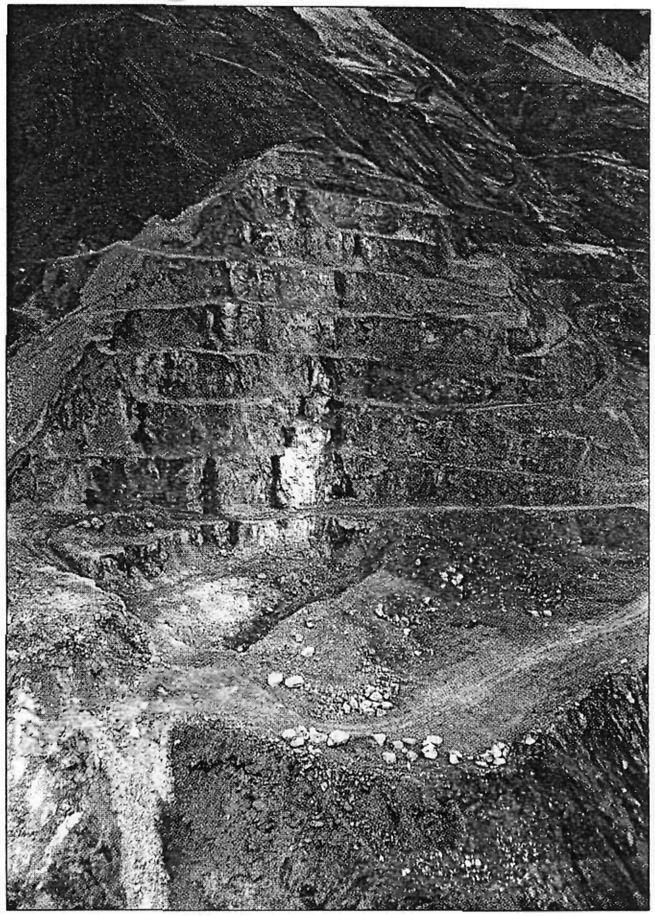


Fig. 2: Geological section, Main Bear Zone.



The Main Bear open pit.

Homestake Mining Co, then exploring in the Atlin area 160 km further north, became interested in the property's potential. The company launched a take-over bid for North American in March 1988. It acquired an initial 73% interest and proceeded with a revised $C70 million mine-building programme and 155 km of road construction. All access to this date was by float plane, helicopter or winter road.

Over the following years the gold price deteriorated. It dropped to an average $362/oz in 1991 and 50% owner Chevron became increasingly disenchanted. In December 1991, 24 months after mill start-up, the company sold its interest to Homestake for $C1 million.

By early 1993 Homestake too had become discouraged. Final capital costs had come in well over budget at $C89 million, 1992 cash operating costs of $US292/oz were double those projected and future prospects for the property paled in comparison with the company's other ventures. These were a controlling interest in the 3.1 Moz gold, and gold-equivalent, Eskay Creek deposit, 225 km to the southeast, acquired in July 1992. There was also Homestake's 20% indirect interest in the Snip mine's 150,000 oz/y gold production, an interest acquired in December 1992 (Snip is about 50 km west of Eskay Creek). With its future in B.C. thus firmly secured, Homestake sold its now 85% interest in North American to Wheaton Minerals for $C1.54 million.

Wheaton today owns 81.4% of the company, a virtually debt-free balance sheet, and has approximately $C40 million available in tax-losses to charge against future income. North American on the other hand carries a shareholder deficit of $C56 million, the greater part of which comprises 111,886 oz of gold due to Homestake. Sale of the metal was Homestake's primary means of financing its subsidiary but North American found itself unable to deliver the metal from its Golden Bear production. The gold sales were unhedged and are considered unlikely to be called.

To complete the corporate picture, Wheaton produced 23,917 oz of gold during the six months of 1993 in which it was owner/operator and reported $C1.82 million net profit for the period.

The geological setting

Golden Bear mine and mill lie in the Tahltan Highlands 75 km northwest of the hamlet of Telegraph Creek, B.C. The city of Juneau, Alaska, on the Pacific coast is 125 km to the west and Whitehorse, Yukon Territory, 310 km northwest.

Most of the Highlands is a Miocene peneplain carved by glaciers into a characteristic Alpine landscape of cirques, U-shaped valleys and hanging valleys. Immediately to the west are the mountains and icefields of the Coast Range. To the east are the undulating lands of the Stikine Plateau.

The mill elevation is 975 m and on the tree-line. The mine's highest working is the back-wall of Kodiak open pit, 3 km from the mill (plan distance) at 1,960 m elevation. Patches of perennial ice occur on north facing slopes above 1,800 m.

Geologically, the property lies at the northwestern margin of the Stikine Arch and includes parts of the Coast Plutonic Complex and the Inter-montane Belt. A sequence of Permian dolomitic limestones is overlain by mafic tuffs and flows of Permian-Triassic age. The pile is intruded by Cretaceous granitic batholiths and their satellite stocks, Cretaceous felsic volcanics, and basalt dykes of Miocene and Recent age. The region has undergone greenschist metamorphism and two or more phases of folding and faulting are interpreted.

All development to date has focused on the 'Ophir Break,' a north-south striking, 20 km long, mineralised fault. Most of the surface trace of the fault is covered by the company's leases and claims, which total 2,140 ha. The Ophir Break has an overall width of about 3,500 m. It is defined by shear zones accompanied by intense fracturing, abundant slickensiding, gouge and silicification. Beyond the zones of fracturing but still within the 3,500 m wide break there are extensive masses of unaltered rock.

Ore grade mineralisation, ranging to 10 m widths, makes up the Bear Main

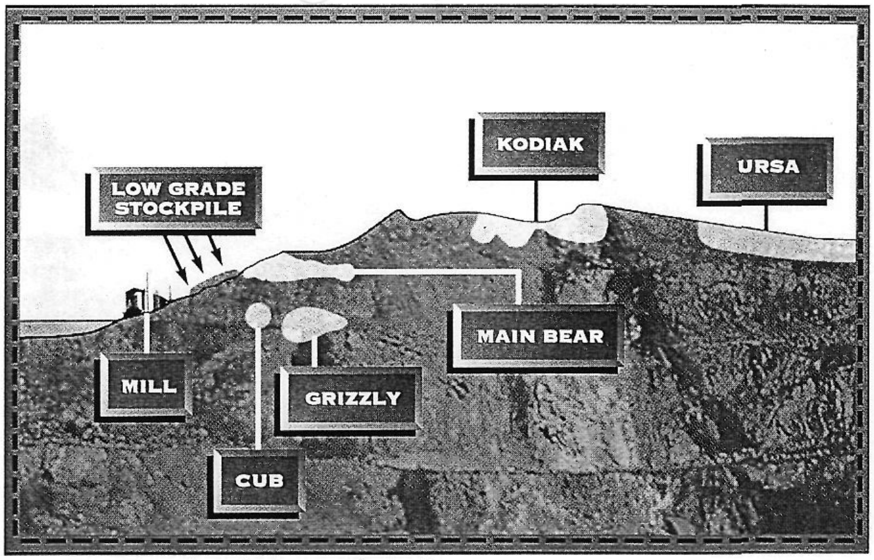


Fig. 3: The various mineralised zones at Golden Bear.

Zone, occupying fracture zones within a lenticular mass of Permian, magnesian limestone. The carbonate lens is 20-30 m wide, 500 m high and 1,000 m long and has been thrust into place by faulting which juxtaposed it against a sequence of Triassic mafic tuffs. A repeat of similar geology down-dip is tentatively proposed for the Grizzly Ore Zone now in the early stages of underground development.

Mineralised zones comprise quartz-dolomite breccia, or, alternatively, quartz-dolomite stockworks, and as distance from the fault zone increases fracturing diminishes. The breccia, or stockwork, grades into massive quartz veining, then into weakening quartz stringer zones and finally into unaltered rock. Hydrothermal alteration pervades the strongly foliated tuffs and comprises carbonatisation (ankerite), chlorite, clay minerals and pyrite. Locally, the green chrome mica, fuchsite, is also present. Macroscopic alteration does not usually reach beyond 25 m into the foot and hanging walls. Alteration in the limestones is composed essentially of calcite, dolomite and quartz. Pervasive silicification is superimposed on both forms of alteration mineralogy.

Sulphide mineralisation is mainly pyrite, encapsulating sub-micron-sized gold. Subordinate pyrrhotite and minor arsenopyrite are also present and antimony and mercury occur in trace amounts. Run-of-mine ore approximates 2-7% sulphur. The average gold/silver ratio for the mine's doré bars is 3:1 but individual bars can vary widely. A given bullion pour can range anywhere from 11 to 42% in silver content.

Most of the ore mined from the Bear Main Zone is refractory but about a third of the near-outcrop tonnage was oxidised and 'free milling.' About 90% of the gold values are found within the hanging wall tuffs and fault breccia /stockwork. An unusual and significant ore source is a 0.5 - 1.0 m-wide zone of black-gouge. The fault gouge carries considerable fine pyrite and returns values to 60 g/t Au (1.75 oz/ton). It is associated with a fault-splay that traverses the hangingwall tuffs.

The Bear Main Zone was the sole source of gold production to June 30, 1994, yielding 211,030 oz (6,563 kg). Tonnage milled for the same period was 429,000 t indicating a recovered grade of 15.3 g/t gold (0.45 oz/t).

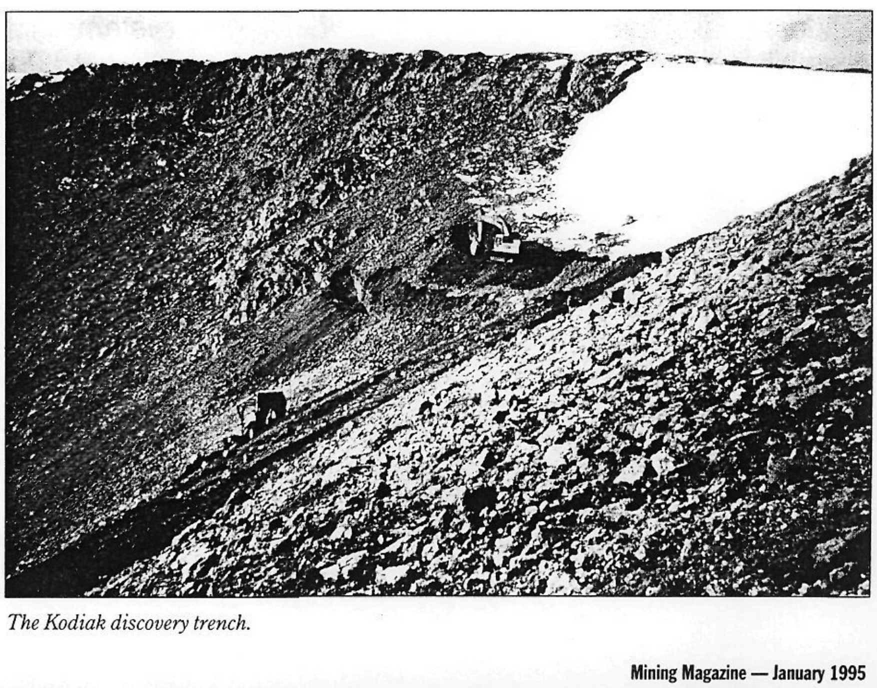
At December 31, 1993, the Bear Main Zone reported remaining mineable reserves of 94,000 t grading 15.4 g/t and 105,000 t lower-grade ore assaying 8.3 g/t. There are also 2.4 Mt of open pit stripping waste presently being tested to determine if it is suitable for heap leaching. This material grades 1.34 g/t gold.

Although the Bear Main Zone is largely mined out, limited surface drilling has identified a repeat of the structure, the Grizzly Zone, about 400 m down dip. Mineralisation and structure appear to be similar and values ranging from 6 to 15 g/t gold over 1.5-16 m widths have been cored. Steep topography and accumulations of talus prevented systematic drilling from surface and a minus 15% ramp is now being driven to establish a suitable exploration base in the zone's hanging wall. The ramp is collared at 1,080 m elevation (compared to 1,360 m for the lowest mining level on the Bear Main) and diamond drill holes are to be fanned from stations in the ramp at 50 m centres along strike. The entry will later serve as the mine's main production access.

At a map distance of 2.5 km north of the mill a 0.75 km section of the Ophir Break hosts four ore-making structures, the Kodiak 'A,' 'B' and 'C' zones and the recently discovered 'Ursa Zone'.

The Kodiak A zone was being stripped in late 1994, preparatory to open pit mining. Kodiak B and C are separated by an 80 m barren gap. They were previously interpreted as one and the same structure and called the Fleece Zone at that time. Both Kodiak B and C are to be mined by underground methods. Kodiak B is scheduled to be developed in 1995. Both zones host dominantly oxidised, non-refractory ore. Drill-indicated reserves are 415,400 t at 8.15 g/t gold. The greater part of the ore will be heap leached.

Kodiak A is unlike other fault-controlled deposits on the Ophir Break. It lies approximately 125 m north of Kodiak B and is hosted entirely by dolomitic limestones. The mineable zone is fault breccia comprising clasts of silicified, hematitic limestone in a limonitic,



The Kodiak discovery trench.

calcareous matrix. Foot and hanging wall are similarly limonitised. The fault zone is 2-7 m wide and contains quantities of red, hematitic gouge. High gold assays can locally reach well into the hanging wall but gold mineralisation generally favours the gouge and breccias on the footwall side of the fault. The highest grades are invariably found where the breccia matrix is most intensely limonitised. Sulphur assays are less than 0.1% and sulphide minerals are rarely visible. The ore is 'free milling' and is to be heap leached.

The zone is 160 m long and ore grade mineralisation carries below the limits of the presently planned pit. Open pit reserves, allowing for 15% dilution, are 473,000 t grading 4.6 g/t gold, equivalent to 2,176 kg (69,000 oz) of gold.

No underground or surface mining was under way at the time of *MM*'s visit in August 1994. Milling was suspended soon after the visit but is to resume at normal capacity when the refractory ores of the Grizzly Zone are brought on stream. Production in the interim will be from the Kodiak A heap leach referred to earlier.

Dry grinding and roasting

The Golden Bear mill is one of the very few operations in North America to employ dry grinding and roasting prior to cyanidation. Much of the ore to date has been refractory. Sub-micron size gold (60% is finer than 0.1 micron), very finely disseminated pyrite and carbonate gangue are the cause. Except for autoclaving and roasting none of the common processing methods gave acceptable gold recoveries and autoclaving was eliminated because of high capital and operating costs.

Metallurgical test work demonstrated that the oxidised ores cyanided with ease. Gold recoveries were 85%-95% but dropped to 35%-40% when refractory mineralisation was processed. That portion of the gold which was extracted was solubilised within the first four hours but there was no further transfer thereafter, despite cyanidation being continued for a further 68 hours.

Flotation testing was also unsatisfactory. Concentrates gave recoveries up to 75% and an additional 6% was obtainable from cyanidation of the tailings. However, the flotation concentrates were too low grade, assaying no more than 20-60 g/t gold.

Autoclaving was metallurgically the most effective method, achieving consistent recoveries in the 94%-96% range. However the paucity of sulphide in the whole-ore process was insufficient to counter the ore's carbonate content and up to 160 kg/t of sulphuric acid was required to drive the oxidising reaction to completion. High acid consumption and the high capital costs relative to the size of plant would have made the process uneconomic.

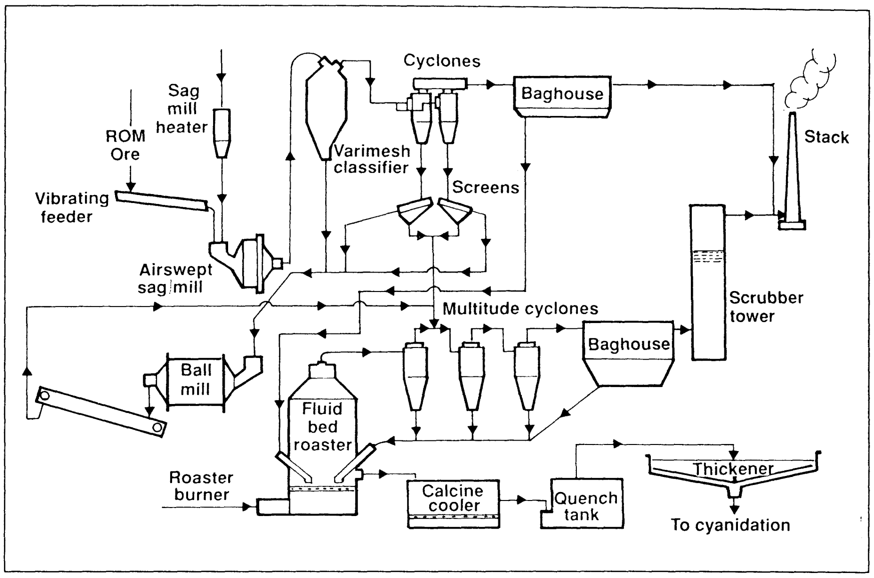


Fig. 3: The flowsheet for the dry grinding and roasting section.

Chlorination, bioleaching, ammonium thiosulphate leaching and ultra-fine grinding were also tried but few of the methods registered recoveries greater than 50%. Roasting proved to be the only option and gold recoveries of the operating plant since start-up have averaged 88%-90%. Cash operating costs in 1993 were $US275/oz.

The mill circuit comprises ore drying and simultaneous single-stage grinding to 60% minus 200 mesh; single-stage roasting; CIP leaching; electrowinning; and finally bullion smelting and bar casting. Current operating capacity matches design capacity of 360 t/d.

The sulphur content of each block of underground or open-pit ore is known from assays of drill core and/or percussion drill cuttings. Freshly broken ore in the pit or underground may thus be separated as being in either the 'high' or 'low sulphur' category, and subsequently trucked to the appropriate stockpile. A wheel loader takes from each pile according to a previously set ratio and the resulting blend is delivered to the grinding circuit. Ideal roaster feed carries 2.5%-3.5% sulphur, though the sulphur content of underground ore from some stopes may run as high as 7% on occasion.

Minus 305 mm ore is drawn from the ore bin at 15-20 t/h by vibrating feeder and delivered to a 224 kW, 4.1 m diameter by 1.2 m long SAG mill. Grinding balls, 100 mm in diameter, make up 8% of the total mill volume. In conjunction with the coarse incoming ore, the ore is ground to about 35% minus 200 mesh (74 micron). The pulverised product exits the mill when fine enough to be carried as a windswept charge.

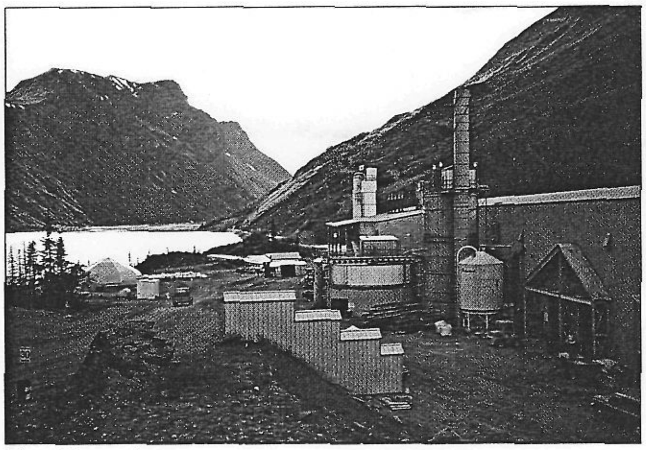
SAG mill feed contains 4-15% moisture and ore drying and crushing are carried out simultaneously. A 5.0 million Btu rated heater, fuelled by either diesel or propane, delivers some 566 m^3/min of hot air to the throat of the mill at 220 °C. Moisture levels are reduced to 0.5% or less.

Airborne discharge from the mill is sorted by a Varimesh classifier followed by two 1.7 m diameter cyclones in parallel. Residual dust is extracted by bag filters. A 224 kW fan powers the classification circuit and exhausts filtered air from the baghouse directly to the mill stack. Product from the two cyclones is sized on twin 40 mesh screens (400 micron). Screen oversize and the entire, coarse, Varimesh product is directed to the secondary ball mill. Minus 40 mesh screen material and baghouse dust pass directly to the roaster feed bin.

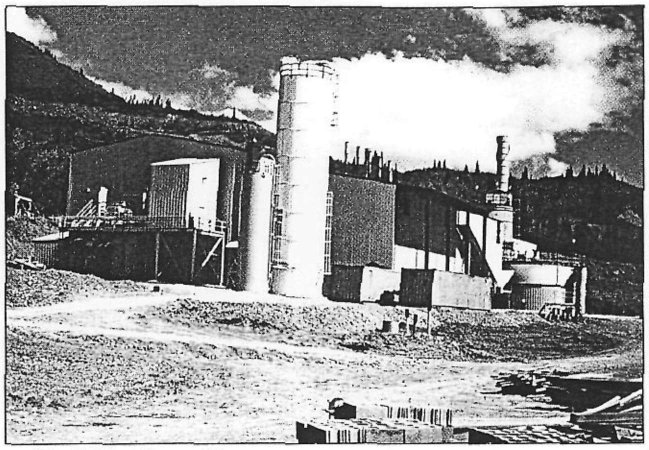
Secondary grinding is carried out by a 224 kW, 2.4 m diameter by 3 m long, grate discharge ball mill. The charge of 50 mm balls makes up 42% of the mill volume. Open circuit grinding is practised and the product is transferred to the roaster feed bin by drag conveyor.

Noise produced by a dry ball mill is excessive and the mill is enclosed in a sheet-steel housing lined with 50 mm thick rock-wool insulation to bring decibel levels into the comfort zone. The SAG mill is not so affected because of its far smaller ball load.

A single stage Allis Mineral Systems fluosolids roaster calcines the ore at 500 °C. It is a cylindrical, steel shaft, roaster measuring 3.4 m diameter inside the refractories, with an internal height of 9.1 m (11 m to the cap of the outlet cone). The bottom 1.8 m of the shaft is the windbox. Combustion gases from an external burner are tempered in the windbox (plenum) by metered volumes



Two different views....



...of the Golden Bear mill.

of cold air to bring the roaster air to the required temperature. Windbox temperatures range from 700 to 950 °C and vary inversely with the ore's sulphur content. Optimum roaster feed contains 2.5-3.5% sulphur at which level the windbox approximates 790 °C. Sulphur contents of 5-7% need no external heat, roasting being then autogenous.

Separating the windbox from the roaster proper is the 'refractory arch'. This is a bridge-like construction of refractory bricks penetrated by 153 nozzles, or tuyeres, each of which is perforated by 16 small-diameter holes. The tuyeres evenly distribute roasting air at 5 kPa gauge pressure. They fluidise the finely ground ore into an aerated mass 1.5 m in depth. In the event there should be no fluidising air, the bed would slump to about half that thickness.

Feed is delivered to a point immediately above the refractory arch by a screw conveyor. Roasted solids exit through a chute 1.2 m above the arch at 13-18 t/h and pass into a fluidised-calcine cooler. Residence time in the roaster is approximately 30 minutes. Sulphur is reduced to 0.5% or less. The 500 °C calcines are cooled to 300-350 °C and part of their heat is transferred to the combustion air required by the furnace burner.

Heat recovery is a feature of the Allis roaster system. By introducing feed at 60-70 °C from the grinding circuit into the roaster off-gas the ground ore is raised to 350-400 °C and requires only moderate heat input to reach the desired 500 °C calcination temperature. Similarly, combustion air for the 2.5 million Btu roaster burner is raised to 200 °C by passing the air through a labyrinth of tubes housed in the calcine cooler. The calcine cooler is itself used as a low-pressure fluidising unit.

Roaster gas exits at 500 °C at a negative pressure of 0.4-in water gauge. Windbox pressure of 5 kPa gauge is progressively diminished as the air expands in the roaster and the driving force of the air current is reinvigorated by a 224 kW exhaust fan located on the exit side of the baghouse. From the latter point the fan drives the dust-free air through a sulphur dioxide scrubber and thence to the mill stack.

The first equipment in-line to handle the hot roaster gases consists of three multitube cyclone clusters. Roaster feed is introduced into the gas stream between the first and second cyclones for preheating and the primary purpose of the downstream cyclones is to extract the hot material and deliver it to the roaster. A subsidiary function is to reduce the dust load of the gases entering the baghouse, where approximately 0.4 t/h of dust is extracted by filtration.

Temperature control of the gases entering the baghouse is essential and is adjusted automatically. Corrosive sulphurous and sulphuric mists form below 232 °C and must be avoided, while at greater than 260 °C the chemical finish of the fibreglass bags deteriorates and filtration suffers.

The mill operates three separate baghouses, one each for grinding and roaster circuits and a third for nuisance-dust recovered at several transfer points in the plant. A four-compartment baghouse serves the roaster. Each compartment houses 72 chemically treated fibreglass bags, each 3.7 m long and 153 mm diameter. At preset intervals a given compartment is isolated, the bags pneumatically pulsed, dust extracted via an airlock and the compartment brought back on-line.

After exiting the baghouse, approximately 10% of the particulate-free gas is diverted for cyanide detoxification by Inco's sulphur dioxide process. The greater part is delivered to a scrubbing tower where residual sulphur dioxide is absorbed by milk-of-lime and soda ash. Scrubbing efficiency is 99.95% and sulphur dioxide emissions usually average 90% below the allowance permitted. Scrubbed gases are essentially water vapour and air and are discharged into the atmosphere. Other potentially noxious contaminants are negligible.

After Golden Bear's refractory ores are calcined and made tractable for cyanidation, milling procedures cease to be uncommon. Cyanidation is by conventional CIP.

From the calcine cooler, calcines are quenched and pumped to a washer-thickener to remove soluble salts. Thickener underflow at 50% solids is delivered to the first of four, in series, cyanide leach tanks. Each tank is agitated by a dual impeller, the hollow drive-shaft of which delivers low-pressure air for pulp aeration.

The first stage of processing comprises two-and-a-half hours of agitation with lime to bring pulp pH to 10.2. Two-and-a-half hours pre-aeration and five hours cyanide leaching follow pH adjustment, after which the pulp flows from the final tank, through a trash screen, to the first of eight carbon adsorption tanks. Carbon, at 30 g/litre, moves countercurrent to the pulp flow. The coarse, granular carbon is pumped from cell to cell upstream and retrieved from the first cell, at which point the carbon has completed 12 hours of gold adsorption. Carbon loading runs to 8,060 g/t or greater.

Carbon is stripped to 52 g/t gold by hot caustic and returned to the circuit. After three adsorption/stripping cycles carbon is reactivated by heating to 600 °C for 30 minutes in an indirectly-fired gas kiln after which it is ready for reuse.

Pregnant solution flows to two electrolytic cells, in parallel with each other. A stainless steel anode and a packed stainless-steel-wool cathode are suspended in each cell and gold deposits at the cathode as a loose aggregate (0.45 kg of steel-wool packing can collect 480-650 oz gold). When a sufficient quantity has accumulated the cathodes are withdrawn and stripped by pressurised water. The resulting sludge is filtered and the black filtercake made ready for the bullion furnace. ❑