Sullivan has been a good investment. But, the mine that made Trail what it is today could be all mined out in 2001. How will the city of Kimberley and Cominco cope?

DOWNWINDING

BY PATRICK WHITEWAY

The Sullivan mine, in southeastern British Columbia, 95 km from the Alberta border, is truly a great Canadian mine. It has probably created more wealth and more colourful stories than any other mine in the country. It has also created several challenges for winding the operation down.

Ever since the company which was to become Cominco Ltd. acquired the deposit in 1909, Sullivan has supplied ore and concentrates to the Trail smelter, 270 km to the west. Today, Sullivan supplies 40% of Trail's zinc concentrates and 80% of its lead concentrates.

Winning lead, zinc, copper, bismuth, cadmium, and indium from these mineralogically complex, but high-grade concentrates literally created the integrated metallurgical complex at Trail — the largest such complex in the world. But now, the end is in sight for the Sullivan mine. Finding new sources of concentrates for Trail has occupied much of Cominco's recent efforts.

The Sullivan deposit is a shallow-dipping, saucer-shaped orebody of massive sulphides hosted by argillaceous quartzites of Precambrian age. The deposit sits at the nose of an anticline just below surface on the gentle, eastern slope of the Purcell Mountains. Since 1923, when the concentrator, near the Bavarian city of Kimberley, started treating ore from the Sullivan deposit, an incredible 153 million tons of ore grading 6.2% lead and 5.6% zinc have been milled.

Since 1949, ore has moved by rail from the main 3,700-ft. haulage level through an adit directly to the concentrator which sits at the base of the mountain on the valley floor. The mill presently treats 7,800 tons of ore per operating day (five days per week), or 1.8 million tons per year.

In total, about 15 million tons of zinc concentrates (at an average grade of 48% zinc and 2 oz. silver per ton) and 12 million tons of lead concentrates (grading 66% lead and 21 oz. silver per ton) have been produced and sold to Trail.

At today's metals prices, that represents an estimated value of production of about $6 billion.

Today, the Sullivan mine has five years left. Reserves are 10.8 million tonnes, averaging 8.0% zinc, 4.5% lead and 26 grams silver per tonne as at December 31, 1995.

How will Cominco replace this valuable source of high-quality concentrates? What plans are being made to reclaim the massive tailings pond created by 87 years of mining? And how will the city of Kimberley (population 7,000) survive when the annual payroll of $40 million disappears from the region's income? These are just some of the challenges facing the city, the company and its 615 Sullivan employees.

Discovered in 1892 by prospectors Ed Smith, John Cleaver, Pat Sullivan and Walter Burchett, before the technology needed to separate lead and zinc minerals even existed, the Sullivan deposit was subsequently leased in 1909 by Consolidated Mining & Smelting Co., the predecessor of what is today Cominco Ltd. The following year, the company commenced the purchase of the property, which was completed in 1913.

The deposit's complex mineralogy proved to be the singly most significant defining factor in Cominco's corporate development. In fact, Sullivan's mineralogical complexity explains why Cominco has such a wealth of metallurgical expertise in Trail today.

While the principle ore minerals are galena and marmatite (a dark brown ferriferous variety of sphalerite), the company has developed the know-how to recover several so-called "minor" metals as well. And thanks to the metallurgical know-how developed in Trail over the past 100 years to do just that (see separate story, page 10), these "minor" metals have yielded significant revenue for the company (accounting for 11% of Trail's revenues in 1995).

As Cominco sets course for the next millennium, that metallurgical expertise will be a major asset, says President and CEO, David A. Thompson.

SULLIVAN'S ROLE

Mark Brown, the present Superintendent of Engineering and Geology at Sullivan says employees have a very important mission. They (of which 28 are technical staff) would like to see the Sullivan mine closed down in a dignified manner.

The mine is still very profitable. In the

in the process of establishing new work practices."

"This allowed us to make significant progress and full credit goes to the union for that."

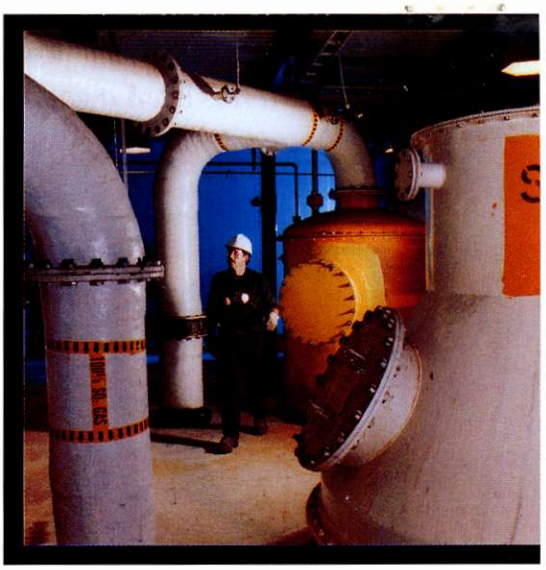
"Skills and capabilities can now be exercised by employees and they are not constrained by a rigid collective agreement to the degree they previously were." The efforts are begining to pay off.

"How employees can impact the bottom line was a revelation to me," says Mike Agg, Manager of Zinc Operations. "I see morale picking up by leaps and bounds. We're making our numbers and doing well."

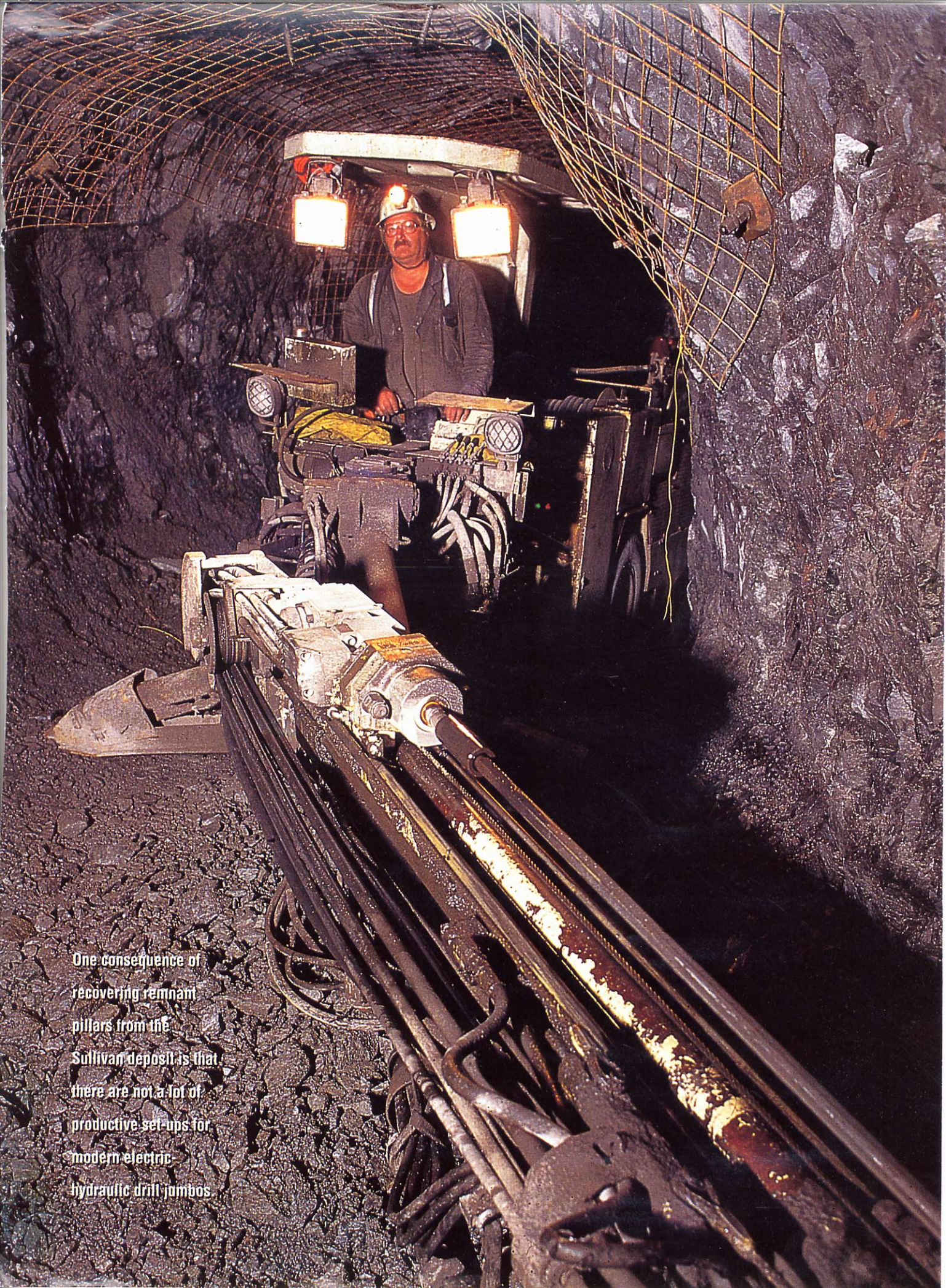
The key to this change in thinking was the realization that long-term job security arises from long-term business viability, Magoon says. And the result has been that information about business plans and opportunities are now exchanged more freely. The dialogue between union and management has changed.

New gain-sharing and profit-sharing programs have been established at Trail and more work is being contracted out. Since the company's focus is on the zinc and lead business, many of the services which used to be located on the metallurgical site were eliminated. This created considerable business development in the Trail area with some 25 to 30 new companies that didn't exist four years ago, springing up to provide services that at one time Cominco supplied itself.

"We've gone through a difficult period," Magoon says, "and we're now emerging from that." "We are well positioned in terms of cost performance and will continue to improve. We're not looking at price to be successful, we're looking at cost. Today, we are making money at US$0.45, but of course our actual break-even level is lower than this." The present union contract expires in May 1999.



As a pollution control measure, sulphur dioxide produced in the roasting process is converted to sulphuric acid for sale for fertilizer production or as liquid sulphur dioxide.



One consequence of recovering remnant pillars from the Sullivan deposit is that there are not a lot of productive set-ups for modern electric-hydraulic drill jumbos.

first six months of 1996, some 116,700 tonnes of zinc and 35,600 tonnes of lead concentrates were sold to Trail. Revenues during the period were $57 million and the operating profit (before the deduction of British Columbia mining taxes) was $14 million. The direct cost of producing a pound of zinc from the Sullivan mine is estimated to be US36¢ If economic conditions cooperate over the balance of the 1990s, the massive sulphides that remain in remnant pillars in the Sullivan deposit will be all mined out by 2001.

In keeping with the plan for a dignified closure, Cominco is putting down a 2.4-km diamond drill hole, about four kilometres east of the mine. The objective is to locate the faulted extension of the deposit. An earlier hole, drilled in the same vicinity, intersected sulphides but over narrow, uneconomic widths.

"It's quite a long-shot," says George Tikkanen, Cominco's Vice-President, Exploration, "but it's something we thought should be done before the mine closes."

The hole was about half complete at the time of our visit in late July 1996, and a new machine, capable of drilling to greater depths was being brought to the site.

In the company's search for new sources of concentrates David Thompson says the company is optimistic that production decisions can be made to develop two zinc-lead deposits — the Kudz Ze Kayah deposit in southeastern Yukon and the Pend d'Oreille deposit in Washington state.

Reserves at Kudz Ze Kayah presently stand at 11.3 million tonnes, grading 0.9% copper, 1.5% lead, 5.9% zinc, 133 grams silver per tonne and 1.3 grams gold per tonne while those at Pend d'Oreille are estimated at 6 million tonnes, grading 7.4% zinc and 1.2% lead.

Cominco picked up the former-producing Pend d'Oreille property in the second quarter of 1996 by acquiring the company Resource Finance Corp. of Toronto for $33.8 million (Inmet Mining Corp. held 73.4% of RFC's shares). The property is located just 40 km from Trail.

FINAL CHALLENGES

If it were discovered today, the Sullivan deposit would be developed as a large open pit mine. But in 1910, none of today's large earth-moving equipment nor the means to economically separate lead and zinc minerals existed. So miners went underground and mined the ore selectively, hand-sorting for high-grade galena which was then shipped to Trail.

A mill was not constructed at Kimberley until 1923. And that was only after two years of painstaking metallurgical research and three years of test milling under the direction of Randolph W. Diamond (who would later become Executive Vice President, Western Region of the company between the first and second World War and who is an inductee of the Canadian Mining Hall of Fame). Differential flotation was a novel technique at the time. Three years of work and

process refinement was required to establish an economic method of separating the two constituent minerals. This metallurgical success paved the way for a large expansion of the smelter at Trail.

Meanwhile, back at Sullivan, many different mining methods were implemented over the years — a legacy that presents the present mine operators with a special challenge. First pass mining left large irregular pillars in the upper part of the mine and long regular pillars dipping at about 30° in the lower areas, Brown says.

"In areas of the deposit which were mined by room-and-pillar methods, we have to come up with ways to recover the 30% of the ore which remains without losing stability," Brown says.

To accomplish this, the company is using the latest numerical modeling technology. N-Fold, a computer software program developed by Golder Associates, is used by mine planners to model optimum mining sequences from a rock mechanics perspective. Greatly assisting them in this process are the excellent plans and sections which have been produced over the years by the technical staff and which are preserved in the Sullivan vault.

Cemented rock fill may also be used in the mine for the first time. Placed in mined-out stopes, this would greatly facilitate the recovery of adjacent pillars.

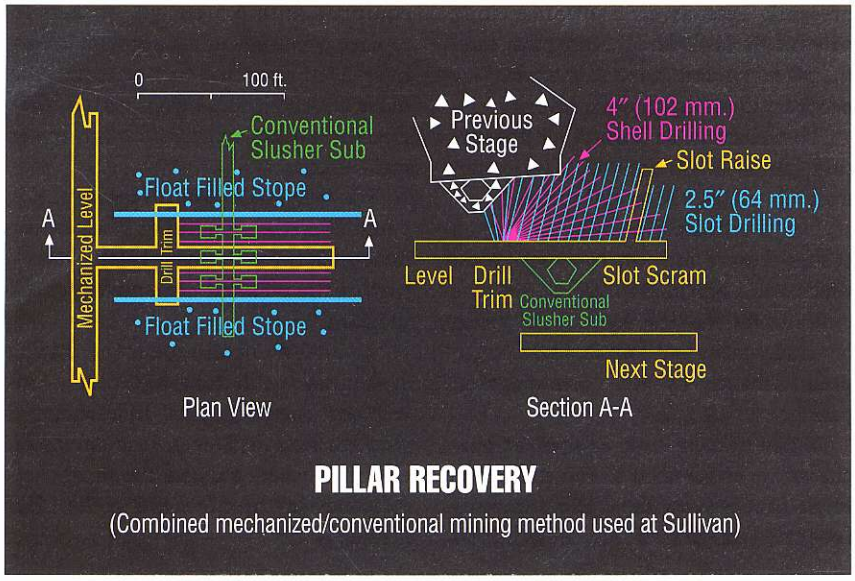
For the past 40 years, the majority of production has come from the recovery of rib pillars. As the pillars are systematically mined downdip, the ground caves, creating a so-called "retreat front" in much the same way as longwall mining. This front presently extends for a distance along strike of about 1.2 km, meaning that careful planning and stope sequencing are necessary to maximize ore recovery.

Today, about 65-75% of all production (about 5,500 tons per day) comes from rib pillars, 150 to 400 metres below surface. The balance of daily production comes from a million-ton mass blast which was made in 1989. Development is either in the footwall beneath the pillars or within them and long-hole drilling is predominantly up-holes (see diagram, page 22).

While no new mine equipment purchases are anticipated to the end of the mine life, Brown says, the company recently purchased six new LHDs equipped with 6.5-cu.-yd. buckets to replace 5-cu.-yd. units, some of which have been operated for 20 years. The move cut about $1.50 from per-ton production costs, mainly through lower maintenance.

The only major capital expense anticipated over the remaining years of the mine's life is for a cement batch plant — part of the planned cemented rock fill program.

About 70% of all production drilling at Sullivan is still done with older, conventional pneumatic BBC drills, equipped with modern drill steel. In many cases, electric slushers are also the most cost-effective way to move ore to the LHD loading points.



PILLAR RECOVERY

(Combined mechanized/conventional mining method used at Sullivan)

Not only is the Sullivan operation a mixture of old and new mining technology, it is also a model operation when it comes to efficiently and safely loading upholes with explosives. Mine operators come from around the world to see how Sullivan's miners accomplish this demanding task.

All ore is crushed underground to about 80% minus 1.5 inches and is hauled by train on the 3,700-ft. level to the concentrator.

"Our challenge will be to control costs in the last few years of production," Brown says. Production is presently about 1.8 million tons per year, but that will decline to 1.7 million tonnes in 1998 and 1.2 million tonnes in 2001, so unit costs could increase significantly. Total concentrate production costs are split about 75% for mining and 25% for milling.

Safely extracting the remaining ore from the Sullivan deposit is just another in a long string of challenges faced by mine. Operators have weathered many diverse challenges in the past, says General Manager Donald Boyle. The more recent challenges included an extensive mechanization program in the 1980s and a nine-month shutdown followed by a sizable downsizing of the workforce in the early '90s.

EVER-IMPROVING

In the Sullivan mill, one of the early challenges was to reject waste rock from the mill feed. About 30% of the feed material to the concentrator is now eliminated in a heavy media separation plant, which was constructed in 1949. Reject material (with a specific gravity of less than 2.95) is a very hard siliceous chert, typically grading 0.15% lead and 0.25% zinc. At one time, this material was used by Canadian Pacific as railway ballast. Today, it is stockpiled in the tailings impoundment area.

A string of technological improvements in the mill, including the installation of OK-16 flotation cells in 1988; a Fisher Provox distributed control system in 1990; two (800-hp) tower mills in the lead regrind circuit in 1993; a four-metre-diameter lead column flotation cell in 1993; and a hyperbaric filter for dewatering lead concentrates in 1993, have all contributed to an increase in concentrate grades to 52% for zinc and 64% for lead. Lower grades in the lower portion of the orebody require a finer grind to 80% passing 17 microns.

John Egan, the recently-appointed

Operating Manager of the Sullivan concentrator is optimistic that recoveries can be improved further and that concentrate grades can also be improved over the remaining life of the mine. Better recoveries would mean less metal would go to the tailings pond.

Over the years, an estimated 125 million tons of tailings have been deposited in several impoundment areas west of the mill. The total area affected is about 916 acres.

In 1991, Cominco produced a detailed closure plan for the Sullivan operation and presented it to the various provincial ministries responsible for ensuring an orderly closure of the mine and mill. A public liaison committee reviewed the plan over a period of two years, says Bruce Dawson, Superintendent Services and Reclamation. Various concerns and deficiencies were pointed out by the committee and the plan was improved. The committee continues to meet twice per year. Cominco expects to spend $54 million to reclaim the mine and mill site ($24 million has been spent on various environment projects so far).

THE TWILIGHT YEARS

If the current exploration drilling east of the faulted-off Sullivan deposit does not locate sulphides of sufficient thickness and grades to allow economic mining, one of the greatest lead/zinc deposits in the country will be all played out in 2001.

To that end, a new labour contract was negotiated in 1995 without any production disruption. The contract was the longest ever concluded at Sullivan and provides employees with the certainty and stability they need to concentrate on the job at hand — making sure that the queen of lead-zinc deposits goes out like a lady.

Many long-time Sullivan employees plan to retire and remain in Kimberley (about 800 Cominco pensioners already reside in the East Kootenay area); plans are well advanced to construct a residential subdivision west of the city; and there is a possibility that a silicon metal plant will be constructed in the area. For these reasons, town officials are very optimistic that the community will survive and thrive, as a tourist/golf/ski resort destination.

"Cominco's role in this future may be diminishing, but we are committed to helping make the transition happen," says General Manager Boyle.

Red Dog On the RISE

Specialized milling technology and ore blending have improved recoveries at Cominco's once-troubled Red Dog mine in Alaska. Performance has improved so much the operation is solidly in the black financially. By chalking up high-grade reserves at an accelerated pace, Red Dog will soon supply increasingly more concentrate to Trail.

BY DAVID M. SCOTT, P.ENG.

While seemingly at the end of the earth at latitude 68° N, 240 km north of the Arctic Circle and 85 km from the Chukchi Sea, Red Dog is the world's largest zinc orebody and will soon be supplying 7% of the world's zinc demand. Although it got off to a rocky start, operating five years without a profit, the mine is now in the black and Cominco Ltd.'s managers are optimistic about its future.

Including the contiguous Aqqaluk orebody, discovered in 1995, reserves at Red Dog now stand at an impressive 138 million tonnes grading 16.2% zinc, 4.4% lead and 82 grams silver per tonne. Besides the high zinc grades, an initial stripping ratio of 1.2:1 will ultimately decline to less than 1:1.

At an expanded production rate of 3.2 million tonnes per annum scheduled for October 1998 (the current production rate is 2.3 million tonnes per year), reserves are sufficient for more than 40 years. And there may be even more ore. Recent drilling intersected what could represent extensions to the Aqqaluk orebody. A hole put down in June 1996 returned 12% zinc, 4% lead and 2 ounces silver per ton over 190 ft. in a mineralized zone that occurs at a greater depth and immediately north of the Aqqualuk deposit.

Red Dog is an unusual type of sedimentary exhalative (Sedex) deposit. Most Sedex deposits are believed to originate from mineral solutions expelled from the ocean floor in a manner similar to modern undersea 'smokers' in the Red Sea and Pacific. Contemporaneous with the precipitation of lead, zinc, iron and precious metals on the ocean floor, slowly-moving oceanic currents deposit clays, silica particles and other rock-forming minerals within a metallic melange transmitting sedimentary features and laminated textures to the ore. Red Dog mineralization on the other hand is massive, fragmental and frequently in replacement forms with little evidence of sedimentary structures. High-grade, zinc/lead veining is also extensive.

A zone of oxidized mineralization, 20 to 30 metres thick, forms a cap over the outcropping sulphides, primary lead sulphide altered to insoluble lead sulphate and plumbiferous jarosites. Under normal, temperate conditions zinc sulphide would first oxidize to soluble zinc sulphate then to insoluble basic zinc carbonates. But in a permafrost regime mineral solutions cannot progress downwards because of the ice barrier and their only course is to migrate back to surface through the outcrop. Consequently the uppermost benches of the pit are heavily charged with crystallized zinc and iron sulphates the latter forming from the oxidation of pyrite.

The two water-soluble salts in combination with bitumen and up to 4% bacteria-generated sulphur caused serious metallurgical problems during the first years the mill was in operation. Low recoveries and poor concentrate grades resulted. The first year Red Dog generated an operating profit was 1995, five years from the start of milling.

The initial pit has now mined through the oxidized zone and the extensive capping still remaining is mined in strictly metered increments and blended with unoxidized ore to provide a satisfactory mill feed. Specialized milling procedures have also been developed that ameliorate most of the problems presented by the ore's unusual mineralogy.

GENERAL GEOLOGY

Much has yet to be learned of the deposit's genesis. Current thinking postulates capping of the 'smokers' by an initial, massive effusion of barite effectively impounding the later zinc, lead, iron and silica solutions (iron content averages 5.7%, a low figure for Sedex

At three-quarters of a billion pounds of zinc a year and rising, Red Dog will partially replace Sullivan as a source of concentrates to Trail.

mineralization). Heavy metals therefore precipitated in an essentially closed environment relatively free of rock-forming detritus. Demonstrating the effectiveness of the conjectured barite impounding structure, ore reserves at the grades previously quoted translate into 41% metallic sulphides.

Both the Main and Aqqaluk deposits are flat-lying sulphides hosted in late Mississipian black shales, cherts and

Third Time Lucky

Red Dog mineralization was "discovered" no less than three times. It was first reported by prospectors in 1953, then in 1968 by Bob Baker, a bush pilot from Kotzebue who had flown over the area on several occasions. Baker advised the U.S. Geological Survey of rusty alteration in what became known as Red Dog Creek and the showing was examined soon after by USGS geologist Irving Tailleur who was mapping in the vicinity. Tailleur found abundant barite, silica and iron oxide at the site and his rock samples assayed significant values in lead and zinc. The creek actually cuts through the deposit. A USGS Open File report was subsequently made available in 1970.

The name Red Dog incidentally derives from Baker's canine companion who accompanied him on many of his flights. Baker never saw the outcome of his timely observation, he was killed in a search-and-rescue mission soon afterwards.

It might be asked why such obvious signs of mineralization could go untested for so long in a state that has an established mining tradition. However the red scar of Red Dog Creek and nearby iron-stained mineralized rock is not unique in the region but the cost of investigating all such showings would have been prohibitive for the average, privately bankrolled syndicate. The mountains are as castles surrounded by a 50-miles-wide moat of waterlogged tundra and swamp and access is possible only by helicopter.

The third 'discovery' came about in 1970 when much of northwest Alaska was being assessed in terms of native land claims and land withdrawals for wilderness parks and wildlife refuges.

The mineralization exposed in the banks of the creek had aroused much interest. There were several mining companies in the area besides Cominco and a confusing period of conflicting land and mineral claims ensued. To compound the problem the local Inupiat Eskimo band, later incorporated as NANA had the prior right to legally define its land entitlement under the 1971, Native Claims Settlement Act.

Eventually lands and minerals ownership were resolved. NANA was given title to the Red Dog deposit and Cominco Alaska subsequently negotiated a lease to mine, manage and operate the mine-to-be. Negotiations leading to the agreement were lengthy and intricate but the final result is a landmark in the innovative sharing of a natural resource in a manner that is fair and to the long-term benefit of both parties.

It might be noted that 21 years elapsed before Baker's first reporting of Red Dog mineralization became an operating mine.

limestones. They are part of a Devonian to Cretaceous sequence of similarly constituted rocks. No volcanics are present. The black shales are extensively silicified and contain up to 2% bitumen. The Main deposit outcrops and is about 1,500 metres long by 500 metres wide and 120 metres thick. The adjacent Aqqaluk deposit approaches within a few meters of outcrop and while it is about 30% lower in zinc and lead values it contains 20% greater tonnage. Cretaceous age thrust faulting forms the base of both deposits. A stack of three, thrust repeated ore horizons occurs. The middle repeat contains most of the Main deposit and the lower contains all the Aqqaluk.

LONG-TERM BENEFITS

At 6,300 tonnes per day, the current mining rate is relatively low for an open pit vis-à-vis the size of the orebody but the output was negotiated as an integral part of the agreement between the Inupiat Eskimo band and Cominco. The purpose was to ensure a regular, long-term source of revenue to the Eskimo community through NANA (see below), and equally important to allow the indigenous people to acquire the skills modern technology requires over a period for what amounts to very nearly two generations of lifetime employment. Restricting the mining rate was the guarantee. Since signing the agreement, discovery of the Aqqaluk deposit has substantially expanded reserves and Cominco is now able to increase mill throughput without in any way diminishing its long term commitments to NANA.

NANA is the Northwest Alaska Native Association. It represents 6,500 people located in the 11 coastal, river and interior villages of the region. Kotzebue is the seat of the 98,400-sq.-km area. Each native is a 'shareholder' of the Association and under the terms of the 1982 Cominco agreement NANA received US$1.5 million that year and an annual US$1 million until production began in 1989. Since then, NANA has received a 4.5% Net Smelter Return. When Cominco has recovered its capital investment (US$415million plus the current mine expansion estimated at US$200million) NANA will begin sharing in the net proceeds starting at 25% and increasing 5% each five years until

NANA and Cominco share equally in the venture.

In addition, Cominco is bound to a strict environmental code and maximization of NANA shareholder training and employment. The original goal of both parties was to achieve 100% manning and management of the Red Dog operation within 12 years by NANA shareholders, skill levels permitting. NANA acknowledge the time frame will need to be extended. Fifty percent of the payroll is now filled by 'shareholders.' Each new employee receives 80-168 days training depending on job classification before they are certified as a skilled operator. Technical school or university education is also on offer to those who are interested in pursuing a professional career.

MINE OPERATIONS

The pit operates two, 12-hr. shifts per day 365 days per year. Pit benches are 7.6 metres high. They are drilled-off by two, D40K in-the-hole, Driltecht machines on 3 x 3.7 metre patterns for ore and varying up to 5.2 x 5.8 metre patterns in waste. Holes are 16.5 cm in diameter. ANFO accounts for about 70% of explosive usage and emulsified blasting agent the remainder. Pit slope in competent ore and waste is 45° but reduced to 26° in an overlying, ice-rich shale which can slough on thawing. A 30-metre-wide berm is also established at the base of the shale as an additional safety measure. Haul roads are 18 metres wide providing a 15-metre-wide driving surface.

Maximum road grade is usually 8%. A relatively small mobile fleet comprises three, Cat. 992, 13-cu.-yd. loaders and six, Cat. 777, 76-tonne trucks. In each case, one unit is kept spare to function as a replacement in the event of an in-pit breakdown. Other equipment includes the usual ancillary bulldozers, graders, blockholers etc.

Ore haul to the blending stockpile is about 500 metres while the distance to the waste dumps can range to 3.0 km depending upon the mineralogical constitution of the waste. Particular care is taken to deliver mineralized waste to specific dumps which are so located to ensure run-off water exits to the closed circuit tailings pond.

Cominco's success floating a complete, ready-to-run mill from the St. Lawrence and parking it on the beach at the Polaris mine site on Little Cornwallis Island in Canada's Arctic 15 years ago was clearly in the company's plans when it considered building a mill for Red Dog. The concept was the same but this time the mill's final destination was 84 km inland from the beach, demanding a lengthy road haul. The Chukchi Sea inshore was also too shallow for accepting deep-water vessels. Both circumstances compelled major changes in mill construction. Accordingly the mill was built in eight, separate, modules, each five stories high and having a maximum individual weight not more than 2,000 tonnes. The segments were built and fitted-out in the Philippines by Ralph M. Parsons Co. with mill components purchased from around the globe. They were then shipped 7,400 km by deep-sea carrier to Dutch Habour in the Aleutians, off-loaded and towed a final 1,700 km by flat-bottom barge to the newly constructed mine dock. A specialist Dutch company, Mammoet Gmbh., using one-of-a-kind wheeled trailers took up the load and inched the modules to their final destination.

Many of the first concrete-and-steel, western-style structures built on permafrost in the Arctic during World War II were inadequately insulated and the results were often disastrous. The per-

mafrost thawed, buildings tilted, they frequently collapsed, at worst they sank. It was an expensive learning process. Red Dog mill sits atop concrete-capped piles preserving a 1.5-metre air gap between mill floor and a ground level, crushed-rock blanket. Additional protection is provided by a grid of open corrugated culverts which allow arctic air to freely circulate within the blanket.

Red Dog's flowsheet is unique in two respects. It includes one of the mining world's largest tower milling installations and a pressure filtration plant of similar status. Tower milling is considered the most economic grinding system for the ore's fine grained mineralization and pressure filtration is a one-step process capable of producing the low-moisture concentrates mandatory for deep-sea transportation.

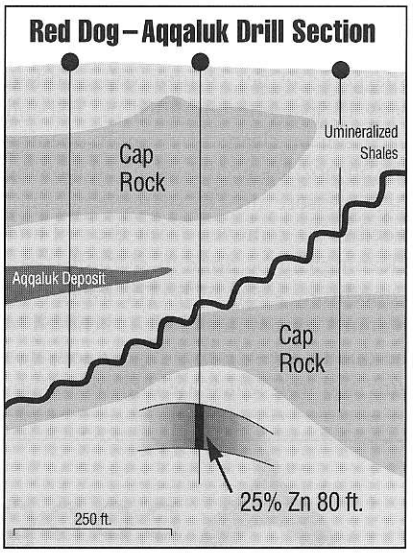
Blended stockpile ore is crushed to 15 cm by a 122 x 150 cm jaw crusher (to be replaced by a gyrator in the forthcoming mill expansion) and delivered to, two 6.6 x 2.4 metre SAG mills. Chrome steel balls 10 cm in diameter make up 8% of the load. SAG mill oversize (plus 14 mm material), is returned to the SAG circuit by a high-lift pocket conveyor. The undersize is cycloned and the underflow divided between SAG mills and a 3 x 5 metre ball mill. Cyclone overflow is processed by two, in-parallel, closed circuit 3 x 4 metre ball mills. Pulp from the grinding circuit is 80% minus 60 microns and is delivered to the flotation circuit.

Barite is the principal gangue for a portion of Red Dog mineralization and fine grained silica for another leading to major differences in ore hardness and grinding performance. SAG mill throughput, for example, can range from 80 to 200 tonnes per hour and such swings can take place in a matter of hours. The SAG mills are equipped with variable speed drives that allow close control of the grinding circuit and minimizing the impact of changes in ore hardness.

Flotation feed is given a minimum dosage of frother and flash floated to remove organic carbon and elemental sulphur. It then passes to a single line of 4.25 x 4.25 metre Maxwell cells (claimed to be the world's largest) where differential rougher flotation takes place. The rougher lead concentrate is normally cleaned directly by a single large column cell but may be given a prior tower milling if required. Zinc rougher concentrate is tower milled and cleaned by a circuit of column cells to produce a final concentrate grading 55.5% zinc.

TECHNICAL ADVANCES

Cominco is largely responsible for developing the column cell. Those at Red Dog are 3.6 metres in diameter and 12 to 15.8 metres high in the zinc circuit. In the lead circuit they are 4.1 metres in diameter and 12.8 metres high. A recent innovation is substitution of spargers perforated along their whole length to 'spargettes' possessing one only adjustable air nozzle at their tips. Formerly, up to two,



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Seals
Retaining Devices

Materials Handling

Materials Handling Bulk & Unit Conveyors
Materials Handling Equipment
Materials Handling Components
Waste Water & Water Treatment Components
Belting
Belting Accessories

Mechanical Power Transmission

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