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TECHNOLOGICAL CHALLENGES IN THE '90's

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ABSTRACT

Mining and mineral processing in Canada's north poses a number of distinct challenges. Because of climatic conditions and isolation, costs are usually very high. Increasing concern for the environment will also continue to inflate costs. Reduction of costs through heat conservation, alternative energy sources, automation, expert systems and alternative processing methods such as heap leaching are seen as the key to success in the 1990s.

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INTRODUCTION

by

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In presentations about future trends, particularly concerning technology, one approach is to make far-reaching predictions about the development of new technologies without grounding the predictions in the present and the past. In a time span of a decade and in the areas of mining and mineral-processing technologies, such predictions would be irrelevant and of little or no value to those people - investors, managers, engineers, planners and policy markets - interested in mineral development in the north. Accordingly, in this paper the present state-of-the-art will be reviewed together with the technological and operational changes being introduced worldwide which are of potential application in the north, and the technological developments that are expected to meet specific northern conditions will be described.

The driving force behind these changes is generally economic, for the minerals industry has learned from the depressed metal prices of the early 1980s. "Lean and mean" are adjectives which describe most operations. But the fundamental challenge will be to optimize on economics, energy, environment, personnel, management and technology.

OPERATING MINES

The operating mines in northern Canada are indicated in Figure 1, and a brief description of the processing operations is given in Table 1.

TECHNOLOGICAL CHANGES

a) MINING

The economic considerations of developing a mineral deposit in the north extend far beyond the conventional ones. There are substantial additional costs to be borne because of: remote locations, climatic conditions, geotechnical and mineral-processing factors, and environmental considerations - to name but a few.

The location of an economically viable mineral deposit is a fact of of nature. A developer can only deal with what is at hand and apply the most cost-effective technology in order to improve the economics of mining to the greatest possible extent. With conventional operations in the more southern climes of Canada now "leaner and meaner" as the result of lessons learned during the early 1980s, operations in the north must be even more so. The costs of maintaining additional people at a remote site are so prohibitively expensive that the presence of every single individual must be justified. One simply cannot afford the luxury of carrying surplus staff.

i) <u>Personnel</u>

Many northern operations are now adopting a "fly-in, fly-out philosophy. It is said to be far less expensive to fly in personnel on a rotating schedule than it is to erect and maintain a townsite with all of the supporting infrastructure. Two of the northernmost mines, Polaris (on Little Cornwallis Island) and Nanasivik (on Baffin Island), are excellent examples of the differing approaches in that respect. At Polaris, a very well-appointed accommodation is maintained for personnel who are flown in and out on a "nine and three" schedule (that is, nine weeks - each of six 12-hour days with work on Sunday optional - on the site and three weeks out). Personnel are flown to and from the airport nearest their home. Conversely, at Nanisivik a townsite is maintained. There are, of course, pros and cons to both styles. People who have worked at both Polaris and Nanisivik are enthusiastic and complimentary about each. In general, though, the work schedule is preferred at Polaris while the lifestyle at Nanisivik is said to be better.

In the far north it has been stated that there are no problems in attracting a skilled labour force. Turnover is high - as much as 40% - but, because of exceptionally high wages, there are many applicants waiting for any particular opening.

At some of the smaller operations, notably the narrow-vein gold and silver mines, there are said to be severe problems in recruiting skilled vein miners. With the conversion of most of the industry in Southern Canada to highly mechanized methods of bulk mining, and a tendency to larger operations, the skills which were common in the gold camps of Ontario only a generation or two ago have literally disappeared. The shortage is so acute that there has been recent recruitment of vein miners from the tin mines of Cornwall in the United Kingdom.

Several mine operators have identified the training of skilled miners as one crucial need that must be addressed in the foreseeable future.

With the present buoyant mood of the industry, there may be shortages of personnel at all levels - including supervisors and management. With that in mind, perhaps northern operations should consider ii) "quality circle" approach used at one of the Hemlo camp operations. The reduction in the levels of supervision which results is an attractive feature, but the fly-in, fly-out nature of remote operations may preclude its use for operational reasons.

ii) Transportation

Transportation of both supplies and products is severely affected by remote locations. In the case of Polaris and Nanisivik, mineral concentrates must be stored for most of the year to be shipped during an exceptionally short period when the sea is ice-free. This causes problems not only of cash flow and the costs of carrying a large inventory but also of sales and marketing. Without prearranged sales contracts the markets could be disrupted by surges in the quantities of concentrates to be sold.

Transportation costs to the north are very great - especially when shipment is made, as in the winter, by air. Thus transportation of supplies, in order to be cost-effective, requires careful planning and precision. During the recession of the early 1980s the industry learned to reduce its inventories to the greatest extent possible. Because of the greatly increased cost of supplies, this need is especially acute in the north. At the other end of the scale, however, are the costs asssociated with inadequate inventories. When vital supplies run out they must be replaced at great cost. Planning, forecasting and inventory control are "critical issues".

iii) Climatic Conditions

Climatic conditions impose a number of interesting and technically challenging constraints. The severe arctic and sub-arctic conditions of Canada's north necessitate exceptionally high consumption of fossil fuels - all of which cost very much more because of transportation problems.

Fuel consumption and effective use of the heat produced are "critical technical issues". To be fully cost-effective, what would be waste heat in many southern operations must be recovered. A good example of energy conservation is the use of exhaust gases from the diesel-powered, electricity-generating plant at Polaris to dry the mineral concentrates in rotary kilns. Every source of potential heat loss must be examined with a view toward achieving greater utilization.

The concept of recirculation ventilation is now being given serious consideration by Canadian mine operators. Even in major mines situated near our southern border it has been estimated that millions of dollars could be saved annually by recirculating previously heated mine-ventilating air. The use of this technology in Canada will have an especially great impact on operations in the far north.

At CANMET's Mining Research Laboratories, a leading-edge approach to the reduction of diesel engine exhaust emissions has been developed. An auto-regenerative ceramic filter, now being marketed by Engine Control Systems, of Aurora, Ontario, effects reductions as great as 90% in the amounts of solid particulates emitted. The result is a substantial improvement in the quality of mine air. Downstream benefits may be reductions in ventilation costs either through curtailing the quantities of air required, or through recirculating the air because of improved quality.

With respect to ventilation practices, mining in the far north can result in some unique problems. Near-surface mineral deposits, located in zones of continuous permafrost, may be frozen to very great depths. If the local rock mass is structurally weak or blocky, the frozen state may improve local stabilities in the mine openings. Heated ventilating air, while creating a more comfortable working environment, might have the effect of reducing local stability. Rather than heating an entire mining operation, a better approach might be to provide local heating, as necessary, for the comfort of workers - such as in the cabs of equipment, lunch rooms, and so on. One of the truly unique features of a mine located in the high Arctic is that, at Polaris, ventilation air is <u>refrigerated</u> during the period when ambient temperatures are above freezing.

The severe climatic conditions in Canada's north have an impact on all aspects of mining operations. Often, what would be routine and straightforward at a more southern location attains added dimensions of challenge and complexity. Mine operators would probably be unanimous in identifying the maintenance of equipment as their most pressing operational problem. Conventional equipment, from the most simple to the most complex, is not designed to withstand the rigours of the Canadian north. Steels become so brittle at below-freezing temperatures that, as at Syncrude, in Fort MacMurray, some items are shut down when especially low temperatures make this necessary (specifically, the draglines are stopped when the temperature plunges to below -40°C). The development of improved alloy steels, designed especially for sub-zero conditions, has been identified by mine managers throughout the Yukon and Northwest Territories as one of their greatest needs. The costs of continually welding fractured components are very high.

iv) Mining Technology

With particular reference to the process of mining, there are special problems associated with rock reinforcement practices and backfilling. The cement grouts normally used for rockbolting and cablebolting either freeze or do not set up properly under very cold conditions. Accelerators, which can have a corrosive effect, must be used.

Backfilling practices, especially the problems of handling mill tailings and water under su-zero temperatures, present some of the interesting technical challenges that will have to be addressed during the 1990s. Through the Canada/Ontario Mineral Development Agreement (COMDA), CANMET is funding research at both INCO and Dome Mines to develop the technology of delivering backfill to stopes which are being filled. At INCO, densified fill is delivered directly by pipeline from a trial surface plant. At Dome, a "TAILSPINNER", or centrifuge-like device, is used to spin much of the water out of the fill at the point of delivery. The INCO approach results in much less water being delivered underground - with downstream savings in pump costs. The Dome approach results in easier delivery of the densified fill.

In the north, the handling of water results in obvious technical problems. Thus, while the COMDA research, and its implications for reducing the quantities of mine waters are of great interest, there are different approaches that will be attempted in the north. At United Keno Hill Mines, in the Yukon, trials will be made of pneumatically delivered fill, with water being injected into a blown pre-mix at the last possible moment. At Polaris, in the high Arctic, there are simply too many technical problems associated with attempting to deliver mill tailings to stopes to be filled. While this may be desirable from a long-range environmental point of view, it is simply not possible at present. As a consequence, waste rock is quarried on the surface and dropped down raises directly into the stopes. Water is then sprayed on the broken rock to create a frozen backfill.

The results of the backfill projects in Ontario, combined with the present frozen backfill projects in the north, will undoubtdly result in the development of innovative technologies of backfilling with frozen materials in the next decade.

The handling of fills and wet concentrates also presents problems to mill operators. If tailings are to be delivered to surface tailings ponds, these must be maintained at temperatures sufficiently warm to prevent freezing of the lines. Concentrates, unless dried to below 4% or 5% moisture content, will freeze - resulting in handling, storage and transportation problems.

v) General Technological Developments

Finally, there are many technological innovations needed by the Canadian mining industry as a whole, and which are not applicable to northern operations only. Mine information and communications systems, opportunities for automation, and improved mining practices are foremost amongst these. All have great potential for improving operational efficiency and productivity. The impact on the "bottom line" will, however, perhaps be greater in remote operations than elsewhere.

Mine information systems are needed not only to facilitate communications between all aspects of an operation but also to permit real-time treatment of monitoring data. The ideal system would permit instantaneous voice communication with every worker in the mine. Simultaneously, an operator would be able to monitor from a central location the status of the conditions at key points and of important equipment. Remedial actions could be taken immediately in the event of accidents, dangerous conditions, or malfunctions. The impact upon the safety and efficiency of mining would be enormous.

At INCO in Sudbury basin, efforts are being made to break free of the traditional mining cycle - and all of the bottlenecks which it causes - through the development of a continuous mining cycle for hard rock. This necessitates a new approach to equipment, and to applications of automation. Once again, the improvements in productivity that will result from enhanced automation will have an especially great impact on northern mines.

In the Canadian industry generally, a conversion is being made to bulk methods of mining. This implies larger openings and a need for a much more engineered approach to mine design. In this context, controlled blasting will have many applications because of reductions in damage to the rockmass and in remedial actions. In the next decade developments in controlled fragmentation will be one of the essential requirements in the integration of a total mining system. By the end of the next decade the combination of artificial intelligence, sensors, mine communication systems, automation, controlled fragmentation, improved mine design and geostatistics will probably have begun to result in significant increases in productivity through organization of the separate processes within the overall mining optimization.

b) MINERAL PROCESSING

The processing methods employed at the mining operations shown in Figure 1 and described in Table 1, are by and large considered as conventional processes. The base metal operations use conventional two or three stages of crushing, two or three stages of steel mill rod ball and semi-autogenous grinding, and then standard flotation separation. The gold circuits employ gravity separation followed by conventional cyanide leach, followed by Merrill-Crowe or carbon in pulp gold recovery processes. Polaris could be considered unique in that the mill is mounted on a barge, is highly automated and incorporates new processing methods, including column flotation separation. Polaris is also starting to use artificial intelligence systems and has remotely controlled key operating variables.

In the near future, we expect to see implementation of heap-leaching practices for gold ores; further development of expert systems and image analysis; increased use of energy efficient tower grinding mills and column flotation cells; remote control of operating variables; and implementation of zero discharge standards for environmental licensing.

i) Heap Leaching

There are several examples where low-cost heap-leaching technology has been investigated for possible implementation in the far north. For example, Citigold Inc. completed in 1987 Alaska's first heap leach test program, extracting about 3800 oz of gold in the Fairbanks area. Neptune Resources recently completed a 1500 tonne vat leach test program on the Colomac project, located 300 km knortheast of Yellowknife. This program recovered 100 oz of gold and employed a unique concept in which the walls of the vat were made from waste rock overlain with a sand base and a plastic liner. Some 80% of the gold in the minus 10 mesh agglomerated ore was recovered in the first 30 days of leaching. Additional pilot plant engineering and feasibility studies are underway to investigate the return on investment when incorporating fully autogenous grinding to minus 200 mesh, followed by conventional CIP cyanide leach. Numerous prefeasibility, laboratory and site studies have been undertaken on other deposits including heap leaching of the Archer Cathro Ltd. property.

The operation of a heap leach in cold climates is seriously affected by ice formation. Much has been learned from: 1) the Peagasus Zortman Montana operation where freezing of the pregnant solution is inhibited by incorporating the pregnant pond liquor at the bottom of the leach pile; and 2) the Coeur d'Alene operations at 6000 foot elevation near Lovelock, Nevada - where a drip irrigation system is used in which lines are placed 3-10 feet below the top of the ore for year-round operation with minimal evaporation. Propane, oil and geothermal energy have been used through heat exchangers to heat leach solutions at various operations including Florida Canyon and Smokey Valley Mining in Nevada. Decisions to utilize conventional gold-processisng techniques yielding 90+ % recovery or heap-leaching methods yielding generally less than 80% recovery are largely dependent on the selling price of gold and the difference in capital cost requirements - since operating costs for heap leach milling in the high north may not be significantly lower than those for conventional milling.

ii) Image Analysis

Currently, assays from circuit samples plus on-site interpretive skills are used to determine if circuits are properly functioning. Image analysis is a new tool which identifies the amount of free and locked particles and, together with material balance calculations, can determine the improved revenues that would be obtained by changing the grinding, classification and separation stages. In the next decade as equipment is optimized and costs reduced, automated image analysis may well find application in many processing plants.

iii) Expert Systems

Concerning expert systems, as mentioned earlier Polaris has experience with Comdale Technology Expert Systems Ltd. and has remotely controlled key operating variables, through a microwave relay satellite hookup. CANMET is working on expert system projects with several companies, including Canada Cement Lafarge and Kidd Creek, and it is forecasted that the 1990s will see rapid introduction of expert systems in processing operations.

iv) Zero Discharge

With regard to zero discharge of cyanide and metallic ions from mill tailings, the California effluent standards would require approximately $100/oz gold additional operating costs to obtain these levels in our Canadian plants, as opposed to natural degradation in tailing ponds like that employed in the Hemlo Ontario area. Furthermore, the proposed jointly funded federal, provincial, and industrial reactive acid tailings program has made both industry and governments very aware of the long-term problems associated with the covering of mill tailings and neutralization of acid water leaving the impoundment site. Considering the arid climate in the high arctic and the sensitivity of its ecological systems, due in part to the reduced bacterial action in cold water, it is anticipated that our new processing plants will have zero discharge standards. The water phase will be stripped of reagents, metallic, cyanide and arsenic contents, then stored or recycled, and the filtered tailings conveyed to impoundment areas for future seed covering. Most of the technology now exists to accomplish the aforementioned scenario; however, refinements must be introduced to reduce associated costs.

v) Energy Costs

Because of high drying and transportation costs of concentrates, development of future base metal operations in the high north will be restricted to areas accessible by sea. Nanisivik, Polaris and the future Red Dog Alaska operations are examples. Polaris has conducted tests to reduce energy costs, which account for 25% of total expenses, by using centrifuged crude oil from the nearby Cameron Island Panarctic well. Modular refineries may be developed for far north consumers. The $500 million Polar 8 icebreaker will be equipped with wire line drilling capabilities to define our northern shorelines and hopefully to identify future harbours and transportation jump-off points.

Mining operations not accessible by sea will continue to haul expensive oil or propane into their operations using winter roads or air. Developments of a slowpoke-type reactor capable of generating high-pressure steam for electrical generation continues to be an elusive goal, and is not expected to be used in this century. The Cominco Red Dog and Polaris plants include the use of energy efficient processes such as belt filters to minimize moisture content in dryer feed, tower grinding mills in final grinding stages, and column flotation cells in concentrate cleaning stages.

vi) Plant Design and Operation

Cominco and Echo Bay have pioneered the concepts of building and transporting milling modules from lower cost, highly skilled labour markets into the far north. This, plus the fly-in, fly-out operator rotational programs, are seen as the preferred method for building and operating future mills in the far north.

CONCLUSIONS

1. Personnel costs will be reduced not only by improving productivity through technological change but also by increased training and innovative processes such as quality circles.

2. Energy costs will be reduced by increased efficiency, improved recuperation and alternate sources, i.e., oil and gas from the north.

3. Environmental costs will have to be minimized as standards change eventually to zero discharge. This will require innovative technologies including biotechnology in the destruction and reclamation of reagents and by-products.

4. Capital and technology costs will have to be optimized to provide rapid payback in terms of productivity and reduction of the cost of environmental protection technologies.

TABLE 1

OPERATING MINES IN NORTHERN CANADA

Name	Location	Mine tonnes per day	Mill	Product
Curragh Resources	Faro, Yn	pit	13 500	zinc,lead, silver
Mount Soukum	Whitehorse, Yn	u/g	270	gold
United Keno	Elsa, Yn	u/g	150	silver,lead
200+/- Placers	Dawson, Yn	u/g + placer	-	gold
Nadahini Mine	Ross River, Yn	pit	-	coal
Whitehorse Coal	Whitehorse, Yn	pit	-	coal
Dawson Eldorado	Ross River, Yn	pit	-	silver,lead
Ketza/Camamax*	Ross River, Yn	u/g	320	gold
Canada Tungsten**	Ft. Simpson	u/g	1 000	tungsten
Polaris	Little Corn-wallis Island	u/g	3 000	zinc,lead
Echo Bay Lupin Mines	400 mine, Yellowknife	u/g	1 000	gold,silver
Giant Yellowknife	Yellowknife	u/g	1 000	lead,silver
Nanisivik	Baffin Island	u/g	2 000	lead,silver
Nerco Con Mine	Yellowknife	u/g	750	gold
Pine Point**	Great Slave Lake	pit	9 100	zinc,lead

*starting up mid-88

**recently shut down