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Mining in Canada's North - A Technical Overview

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MINING IN CANADA'S NORTH - A TECHNCAL OVERVIEW

by

John E. Udd*

ABSTRACT

Mining in the Canadian north, especially in the high Arctic, poses a number of exceptionally challenging problems. The logistics of receiving supplies and delivering products are greatly affected both by remote locations and by very short shipping seasons. Mining equipment must withstand very severe climates and operating conditions. Personnel must be rotated at great expense. Mining techniques must be adapted to suit these factors.

In this paper, the author presents an overview of mining in Canada's far north and identifies some key areas for future research and technical innovation.

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Keywords

Artic, Canada, Mining, Mining Technology

EXPLOITATIONS MINIÉRES DANS LE GRAND NORD CANADIEN - UN SURVOL TECHNIQUE

par

J.E. Udd*

RÉSUMÉ

Exploiter des mines dans le Grand Nord canadien, spécialement dans l'Arctique, pose une série de problèmes exceptionnellement stimulants. Prendres livraison de l'approvisionnement et livrer le minerai ou concentré sont des activités fortement influencées par l'isolement des sites et la très courte saison navigable. Le matériel minier doit prouver sa fiabilité dans les conditions climatiques et d'opération extrêmes. La rotation du personnel entraîne des coûts additionnels. Les techniques d'exploitation doivent s'adapter à ces facteurs.

Dans ce texte, l'auteur fait un survol des exploitations du Grand Nord canadien et identifie des secteurs clés pour de futures recherches et innovations technologiques.

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INTRODUCTION

Canada, the world's second largest country, after the Soviet Union, is an immense land. Bounded by the Atlantic, Pacific, and Arctic Oceans and the United States of America, it occupies a land area of 9,922,335 square kilometers. Slightly larger in area than all of Europe, the country extends over 5,000 kilometers from east to west and 4,600 kilometers from the northernmost to southernmost points.

From the southern border with the United States, which follows the 49th parallel of latitude between the Great Lakes and the Pacific Ocean, to the Arctic ocean, Canada is divided into provinces and territories as political subdivisions (Figure 1). The territories include all of the Arctic archipelago and the land west of Hudson Bay which is north of the 60th parallel of latitude. The westernmost Territory, the Yukon, is bounded to its west by the State of Alaska.

Geographically, much of Canada is comprised of the great precambrian "Canadian Shield". With the centre more-or-less at Hudson Bay, the Shield extends over most of the Provinces of Québec, Ontario, and Manitoba, and much of Saskatchewan and the Northwest Territories (Figure 1). The rugged shield has been called "the mineral storehouse of the nation". It has also been called, less charitably "the land God gave to Cain" (Jacques Cartier, 1534) and "a few acres of snow" (Voltaire, "Candide", 1759).

Canada, one of the world's northernmost nations, is located mostly in either the Sub-Arctic, Arctic, or High Arctic climatic zones (Figure 2). Long winters and snow are facts-of-life for most Canadians. Snowfall in the High Arctic and Arctic, however, is very much less than one might suppose - because of the intense cold (Figure 3) and lack of moisture in the air. The land of the High Arctic may be described as a cold, arid, semi-desert.

POLITICAL SUBDIVISIONS AND CANADIAN SHIELD

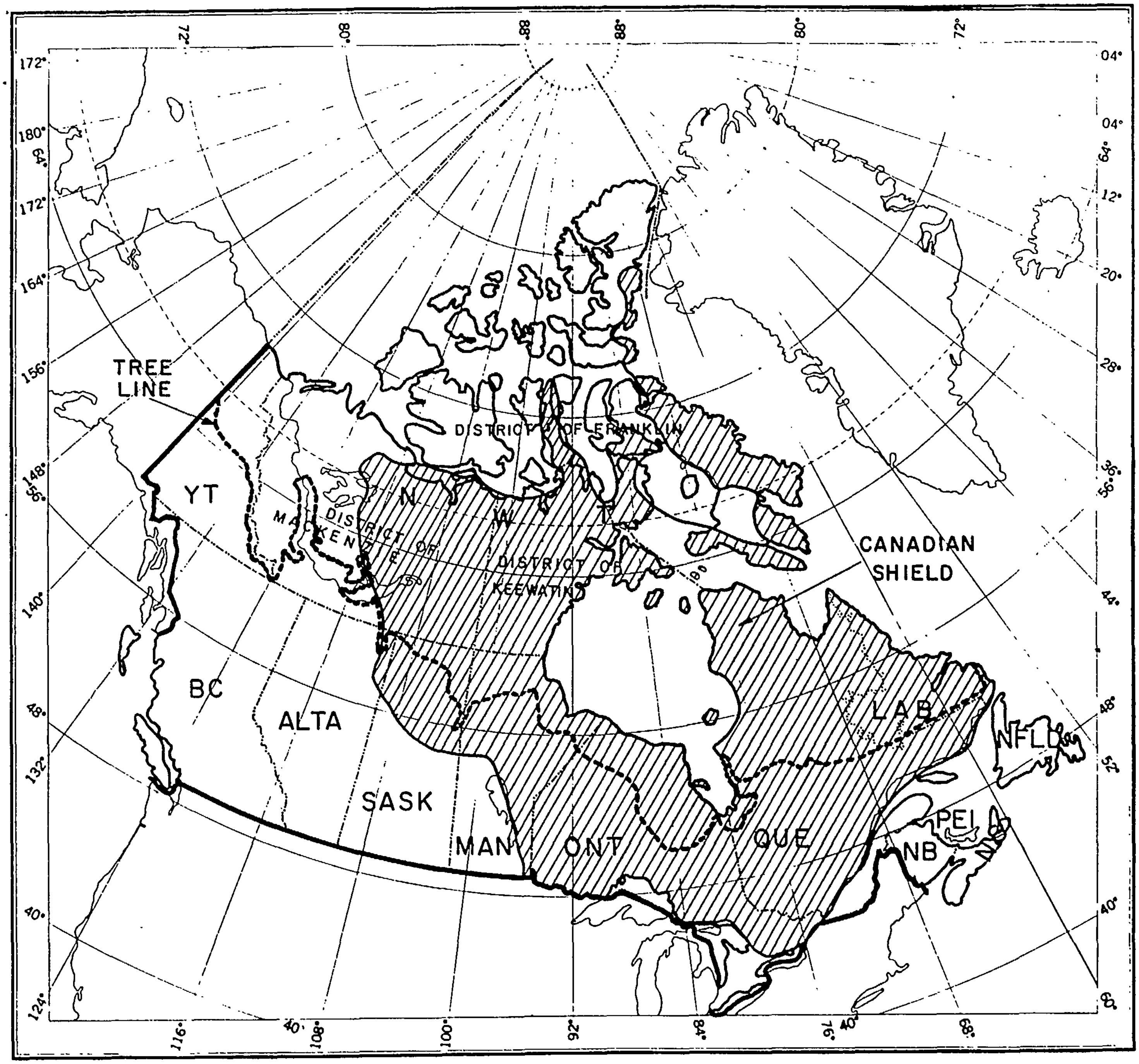

FIGURE 1

CLIMATIC ZONES

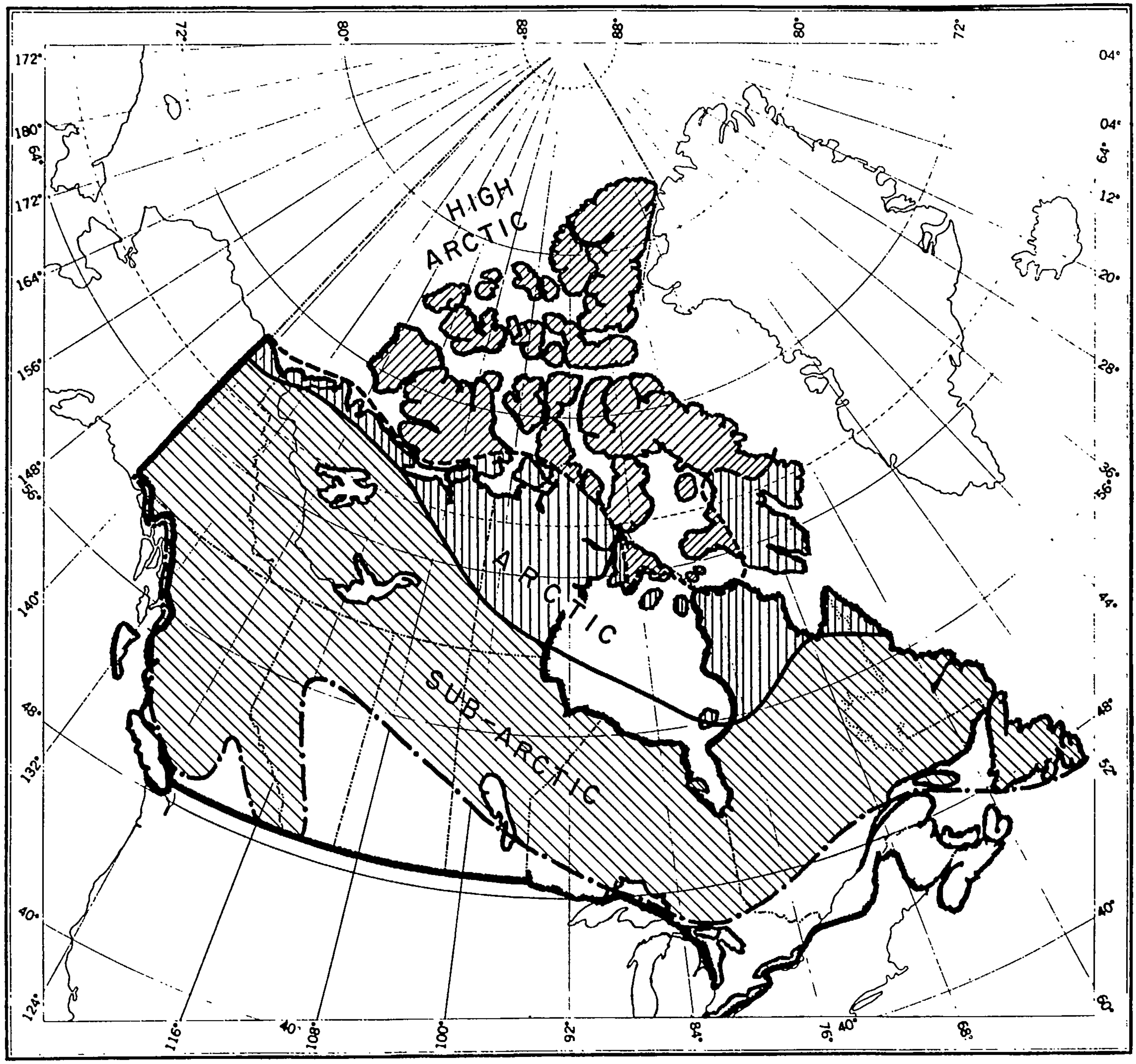

FIGURE 2

MEAN ANNUAL AIR TEMPERATURE (^{O}F)

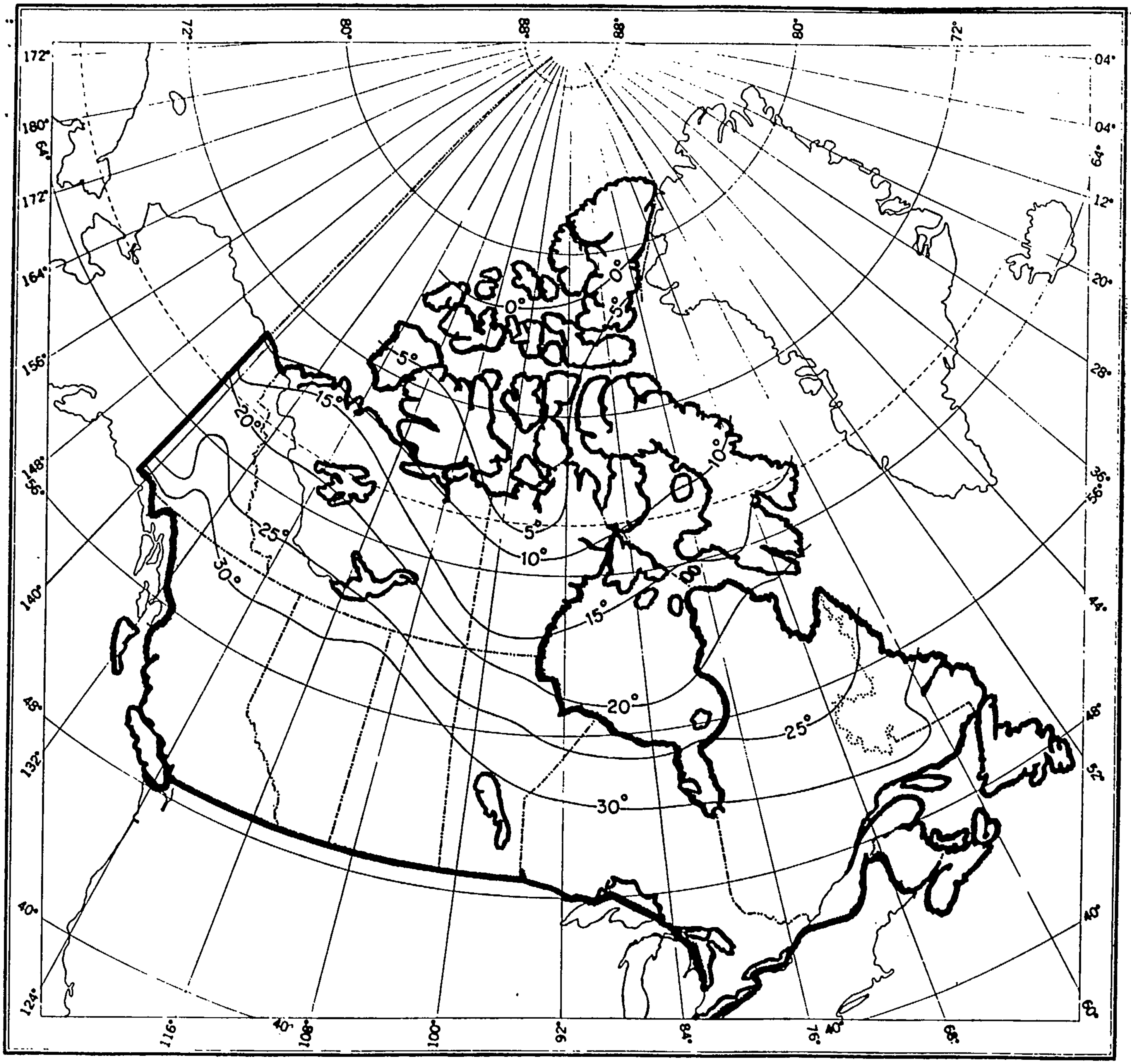

FIGURE 3

For some appreciable part of the year, at least, most mining in Canada takes place under the cold conditions of winter. Of necessity, Canadians have become skilled in adapting to both the cold and isolation of the north, and in developing technologies and mining operations which are viable under these conditions.

The purpose of this paper is to provide descriptions of some of the key problems which confront the operations of mines in Canada's most northerly regions, and to identify a few opportunities for technical developments and innovations. The problems and challenges which are described, while being applicable to many mining operations in Canada, are of the greatest importance to those situated within the permafrost zones (Figure 4).

THE CANADIAN MINING INDUSTRY

The mining industry is a major economic force in Canada. In 1987 it was estimated that some 75,750 people were employed in Canada's mines (not including mills), and that this first step in producing minerals contributed about C$14.6 billion to the economy. On a per-capita basis, Canada is the world's leading producer of minerals. It ranks: first in production of uranium and zinc; second in production of potash, nickel, elemental sulphur, asbestos, and gypsum; third in production of titanium concentrates, cadmium, aluminum (metal), gold, and platinum group metals; fourth in production of copper, molybdenum, lead, and cobalt; and fifth for silver (1).

When "smelting", "refining", "semi-fabricating" and "fabricating", are added to "mining" and "processing", the total economic contribution in 1987 is estimated to have been about C$56.4 billion - or, almost 6% of the total Gross Domestic Product.

MINING OPERATIONS IN PERMAFROST ZONES

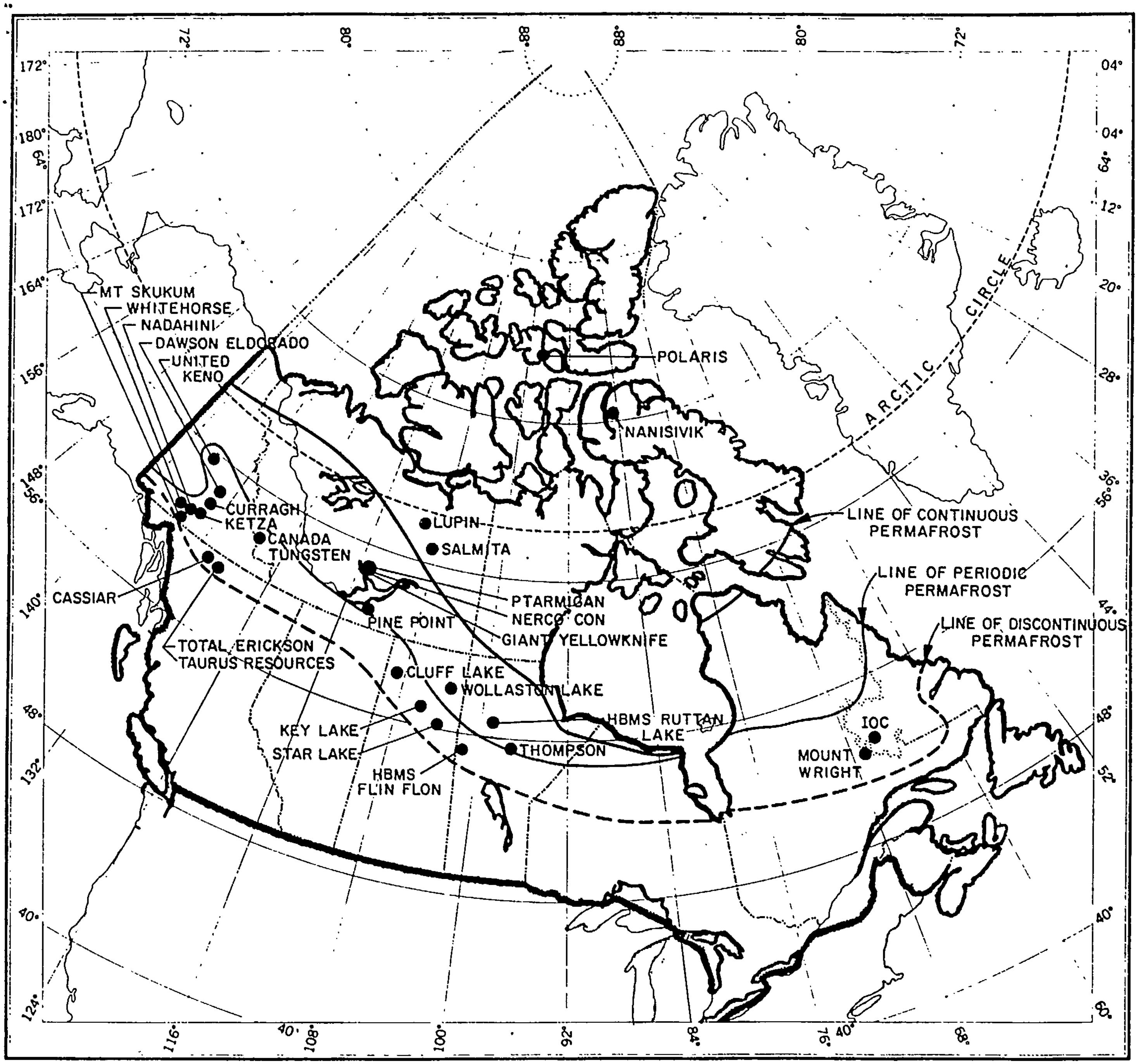

FIGURE 4

The Canadian mining industry is very large and diverse. Today, in 1989, there are probably about 375 mines in operation, as well as 200 placers and 275 sand and gravel pits and quarries. Of the mines, approximately 200 are producers of metallic ores. Mining plays an important part in the economies of most of Canada's provinces and territories - the sole exception being the Atlantic province of Prince Edward Island.

Historically, the exploration and development of Canada followed the major waterways - which were fur trade routes - and the transcontinental railways. Mining has been important from the earliest days in the nation's history, and is mentioned frequently in the reports of the explorers and colonizers. Most of the early mining took place in the provinces of Québec, Ontario, Nova Scotia, and British Columbia. The gold rushes in the latter two provinces, in 1862 and 1858, respectively, were followed by the famous discoveries in the Klondike, in 1896. Placer mining is still important to the economy of the Yukon.

Today, Canada's mining industry is experiencing a period of relative prosperity. In the early 1980's, in the aftermath of metals prices that were depressed to near-historic lows, the key word in the industry was "survival". The period of cost-control and cost-reduction which followed left the industry well-positioned to benefit from the recoveries in metals prices that followed. There is nowhere in the industry that it is more important to be cost-effective than in the northern operations.

MINING IN CANADA'S NORTH

For the purpose of this paper the "north" is defined as that part of Canada which lies within any of the permafrost zones. These zones, and the mining operations within them, are illustrated in Figure 4, and listed in Table 1. In the eastern part of Canada these include the iron ore deposits of the Labrador Trough located at latitudes of only about 53° North. In the west, in the province of British Columbia, the southern boundary of the discontinuous permafrost zone is located at about 59° North - which is quite close to the provincial/Territorial boundary.

With very few exceptions, all of the northern operations are remote from major centres of population. Thus, isolation and the costs of maintaining the infrastructure of a complete community are common features.

The key problems associated with mining in the north may be grouped under a few broad headings:

1) The fragile environment,
2) Climatic conditions,
3) Conservation of energy,
4) Isolation and personnel,
5) Transportation,
6) Mining and mineral processing technology,
7) Waste disposal,
8) Costs.

TABLE 1

MINES OPERATING IN CANADA'S NORTH

Name of Mine	Location	Type	Capacity	Commodities
Within the zone of "continuous permafrost"				
Lupin	Contwoyto Lake, NWT	U/G	1,500 TPD	Au, Ag
Nanisivik	Baffin Island, NWT	U/G	2,200 TPD	Pb, Ag
Polaris	Little Cornwallis Island, NWT	U/G	2,600 TPD	Zu, Pb
Salmita*	Courageous Lake, NWT	U/G	160 TPD	Au, Ag
Within the zone of "periodic permafrost"				
Birchtree Mine	Thompson	U/G	2,500 TPD	Cu, Ni
Cigar Lake	Wollaston Lake area, Sask.	U/G	Development	U
Eagle Point	Wollaston Lake area, Sask.	U/G	Feasibility	U
Giant Yellowknife	Yellowknife, NWT	U/G	1,100 TPD	Au, Ag
MacLellan	Lynn Lake, Man.	U/G	900 TPD	Au
Midwest	Wollaston Lake area, Sask.	U/G	Feasibility	U
Nerco Con	Yellowknife, NWT	U/G	650 TPD	Au, Ag
Pine Point*	Pine Point, NWT	O/P	10,000 TPD	Pb, Zu
Ptarmigan	Yellowknife	U/G	Development	Ag
Ruttan Lake, HBMS	Leaf Rapids, Man.	U/G	9,000 TPD	Cu, Zu, Au, Ag
Thompson, Inco	Thompson, Man.	U/G, O/P	12,700 TPD	Cu, Ni,
Wollaston Lake	Wollaston Lake Area, Sask.	U/G	Feasibility	U

TABLE 1 (Cont'd)

MINES OPERATING IN CANADA'S NORTH

Name of Mine	Location	Type	Capacity	Commodities
Within the zone of "discontinuous permafrost"				
Canada Tungsten*	Fort Simpson, NWT	U/G	1,000 TPD	W
Cassiar	Cassiar, B.C.	O/P	4,000 TPD	A
Chisel Lake	Snow Lake, Man.	O/P	700 TPD	Cu, Zn
Cluff Lake (4 mines)	Cluff Lake, Sask.	U/G O/P	850 TPD	U
Collins Bay	Collins Bay, Sask.	O/P	1,800 TPD	U
Curragh Resources	Faro, YT	O/P	13,500 TPD	Pb, Zn, Ag, Au
Iron Ore Co. (3 mines)	Carol Lake, Labrador	O/P	13,000,000 TPA	Fe
Ketza	Ross River, YT	U/G	320 TPD	Au
Key Lake	Key Lake, Sask.	O/P	650 TPD	U
Main Mine	Flin Flon, Man.	U/G	2,000 TPD	Cu, Zn Pb, Au, Ag
Mount Skukum	Whitehorse, YT	U/G	270 TPD	Au, Ag
Mount Wright	Mount Wright, Que.	O/P	14,000,000 TPA	Fe
Namew Lake	Flin Flon, Man.	U/G	2,100 TPD	Cu,Zn
Puffy Lake	Sherridon, Man.	U/G	900 TDP	Au
Rod Mine	Snow Lake, Man.	U/G	400 TPD	Cu, Zn
Spruce Point	Reed Lake, Man.	U/G	700 TPD	Cu, Zn
Stall Lake	Snow Lake, Man.	U/G	1,000 TPD	Cu, Zn

TABLE 1 (Cont'd)

MINES OPERATING IN CANADA'S NORTH

Name of Mine	Location	Type	Capacity	Commodities
Star Lake	La Ronge, Sask.	U/G	200 TPD	Au, Ag
Tartan Lake	Flin Flon, Man.	U/G O/P	300 TPD	Au
Taurus Resources	Cassiar, B.C.	U/G	180 TPD	Au, Ag
Trout Lake	Flin Flon, Man.	U/G	2,000 TPD	Cu, Zn
Total Erikson*	Cassiar, B.C.	U/G	180 TPD	Au, Ag
United Keno Hill*	Elsa, YT	U/G	450 TPD	Pb, Zu, Ag

Notes: * Recently closed (within 3 years)
capacities in tonnes per day

SOME KEY PROBLEMS

1) The fragile environment

One of the most impressive features of the north is the incredible fragility of the ecosystem. Even in the high Arctic there is a surprising abundance of animal, vegetable and marine life. The balance which has been achieved after thousands of years, or more, is very susceptible to even the slightest change in ambient conditions. Fortunately, man has become increasingly aware of this and has recently approached development from the point of view of minimal or acceptable impact on the surroundings.

This is in sharp contrast with the "brute force" approach of the post-war years which has left tractor tracks which are still visible in the muskeg.

Modern development is approached, in many respects, in a way similar to "no trace" camping. At the Polaris Mine, on Little Cornwallis Island, for example, the mine offices, maintenance shops, warehouses, and mill are all contained in a barge which was floated to the site during the brief shipping season and moored in a lagoon which had been cut into the island shoreline. The intent is to remove this, and the living accommodation, once mining has been completed.

From an engineering point of view, the challenge is to design mine plant facilities that are compact, transportable, energy efficient, and livable.

Another challenge of much longer-lasting implications, is to find methods by which mine waste rock and tailings can be rendered inert in perpetuity. In warmer climates the sulphide minerals in mine wastes result in the production of acid drainage. In the

Arctic environment, because of the much lower temperatures and the short summers the rate of conversion would be much slower but the period over which it would take place would be much longer. Because of the fragility of the environment, every possible effort must be made to ensure that long-lasting potential damage is precluded. Properly engineered protective covers, to keep rock wastes permanently frozen and unreactive may be one of the most effective means of achieving the long-term protection required.

2) Climatic conditions

There are probably very few aspects of a mining operation in the north which are not affected in some way by the climate - which is one of the harshest on earth. Every season of the year presents its own special set of challenges.

In the long winter months, the extreme cold and day-long darkness combine to make it both impractical and dangerous for people to venture outside. Consequently, all aspects of living conditions and working schedules must be designed to prevent boredom, or "cabin fever", and to allow acceptable alternative activities.

In the short summer months insect populations in the breeding seasons are so great as to almost defy description.

In between the summer and winter seasons, the climate conditions are very changeable and unpredictable. Travel, for example, can be delayed for many days because of unsettled weather and/or fog.

The effects of climate on personnel are probably most reflected on morale. The effects on equipment, however, are reflected in greatly increased maintenance costs. Conventional equipment is simply not designed to withstand the rigors of the far north. Steel, for example, can become so brittle at very low temperatures, that it is pointless to operate equipment because of the certainty of brittle fractures and equipment failures. At the Syncrude tar sands operations, near Fort McMurray, Alberta, for example, it was mentioned to this writer that the draglines are normally shut down for this reason when temperatures plunge to -40°C (or, -40°F; the temperature scales cross at this point).

From a technical point of view, one of the great challenges is to design equipment and materials which are better suited to the climatic conditions of the north. Even specially-forumulated oils, greases, and lubricating fluids are needed!

The climate in the north also results in some unique mining problems. Mineral deposits located in the zone of continuous permafrost, as at both Nanisivik and Polaris are entirely frozen. Because of this, it becomes very difficult to use water underground. This has implications on both drilling and backfilling practices. During the brief summer, the entry of outside air at above-freezing temperatures can cause the thawing and degradation of wall rocks. This, in turn, can result in local instabilities and falls of ground. To prevent such changes, the air entering the Polaris mine, Canada's northernmost operation, at about 76° north, is actually refrigerated when outside temperatures are much above freezing.

3) Conservation of energy

Because of the severe climatic conditions, energy is a major cost item for all northern Canadian operations. The costs are influenced not only by consumption but also be transportation. The distances involved are great and it is very difficult and costly to transport goods and supplies. Consequently, energy efficiency is a "critical technical issue". Heat wastage is simply too expensive to be tolerated.

Energy conservation can be approached from a number of perspectives. Facilities can be grouped into single buildings to reduce wall exposures. The buildings can, and often are, aligned parallel to the direction of prevailing wind to achieve still further reductions in possible heating losses. Exhaust gases can be, and are, recirculated through heat exchangers and mineral concentrate dryers in order to recover heat. In underground workings, ventilation air can be recirculated in order to prevent heat losses in cases where this is desirable. Recirculation ventilation is a high priority research topic in Canada at present because of the potential savings offered in respect of ventilation costs. Complementary research is also taking place on methods of air purification since recirculated air must not be of such a quality as to compromise standards of health and safety.

4) Isolation and personnel

For the most part, northern Canadian mining operations are located far distant from centres of population. The isolation is a major factor in both the recruitment and retention of personnel. To compensate for this, many mine operators offer rotating work schedules and exceptionally high wages. It was said to the author, at Polaris, that even though annual turnover of employees is greater than 40%, the wages and the possibilities of overtime are such that there are waiting lists for many positions.

The "fly-in, fly-out" philosophy is becoming much more common in northern Canada as it is believed to be less expensive to fly personnel to a temporary camp on a rotating schedule than to construct a "permanent" townsite with all of the necessary supporting infrastructure. Our two most northerly mines, Polaris, on Little Cornwallis Island, and Nanisivik, on Strathcona Sound on northwestern Baffin Island, are examples of the two contrasting philosophies. At Polaris, a well-appointed single accommodation structure is maintained for personnel who are flown in and out to work on a "nine and three" schedule (i.e., nine weeks, each of six 12-hour working days on site, and three weeks out. Working on Sundays is permitted, (and optional). At Nanisivik, a townsite with "semi-detached" and "four-plex" housing is maintained and the in-and-out cycles are longer (12 and 3). People who have worked at both operations are enthusiastic and complimentary of the two. In general, though, the advantages at Polaris and Nanisivik, respectively, are said to be the working schedules and the on-site lifestyle. Both operations are very modern and offer the amenities necessary to a northern lifestyle.

In some of the smaller mining operations, particularly in the Yukon, there have been great difficulties in recruiting skilled narrow vein miners. The conversion of much of the industry in southern Canada from labour-intensive selective methods to lower-cost bulk-mining has resulted in the disappearance of skills which were common a generation ago. Canadian miners today, more commonly, are skilled operators of specialized equipment often costing in the hundreds of thousands of dollars per unit. The shortage of vein miners is so acute that active recruitment has taken place overseas.

In order to simplify managerial and supervisory structures and to reduce dependency on critical skills, some mine operators in Canada, notably at Hemlo on the north shore of Lake Superior are using the "quality circle" approach. This, if it could be used in conjunction with the "fly-in, fly-out" style, might offer attractive possiblities for northern operators.

5) Transportation

Transportation is one of the most severe constraints on mines at remote locations. The costs of transporting goods and supplies are often as expensive as the very items. Because of this, inventories and requirements must be controlled to the greatest possible extent. Careful planning and military-like precision is needed to ensure that an adequate, but never excessive, inventory of critical parts and supplies are on hand. At the operations in the high Arctic the annual supplies of equipment and heavy goods are delivered by sea during a very short shipping season. At all other times, parts and supplies must be delivered by air.

The short shipping season also makes it necessary for the northernmost operators to store their production of metal concentrates for the greater part of the year. Ideally, the concentrate shed should be empty with the departure of the season's last ship and full on the arrival of the first the following season. To the other normal costs of mining, northern operators must also include the costs of carrying in inventory the greater part of a year's production. There can also be problems in obtaining the best possible returns when concentrate must be shipped during a fixed period each year.

For northern operations on the mainland, which are often served by railroad and/or highways, the problems are much less acute. Nonetheless, the costs of shipping, for example, to the mines of the Yukon, the Northwest Territories, and northern Alberta and Saskatchewan, are very high. Some of these operations are served by winter roads built across frozen lakes and muskeg. Even for mainland operators, transportation may be easier during certain seasons - in some cases, in the winter!

6) <u>Mining and mineral processing technology</u>

With particular reference to mining and processing, there are technical problems which are unique to the north. The inability to use water underground is probably the most serious problem from the perspective of a miner. This affects such aspects of the mining cycle as drilling, rock reinforcement, and backfilling.

Drilling, at both Nanisivik and Polaris, is by "dry methods". These necessitate adequate quantities of ventilating air for purposes of dust control. This in turn, necessitates protection of mine workers against cold ambient temperatures underground.

Rock reinforcement practices must also be modified since the cement grouts which are used routinely in more southerly mines do not set up properly in the far north.

Likewise, backfilling often involves the use of materials other than conventional mill tailings. Some of our northern operators have experimented with frozen rock fill, ice fill, and pneumatically-delivered "dry" mill tailings.

Northern conditions also influence mining practices in a number of other ways, including: the effects of ice lenses and frozen ground on both underground and open pit blasting practices, the stabilities of exposed pit walls and rock surfaces; the handling of frozen materials; and the exceptionally great "wear and tear" on equipment and the maintenance problems which these cause.

From a mineral processing point of view, there are problems not only in the treatment of ores but also in the handling of mill concentrates and tailings. Low ambient temperatures necessitate greater-than-normal costs of energy and problems in maintaining process control. Concentrates, if containing excessive moisture, will freeze solidly causing further materials handling problems at the time of shipment. Mill tailings must often be delivered to tailings ponds through insulated pipelines in order to prevent freezing.

Finally, the long-term treatment and stabilization of both tailings ponds and waste embankments presents some exceptionally challenging engineering problems.

7) Waste disposal

The disposal of industrial and domestic wastes is becoming a serious problem throughout North America. The nimby ("not in my backyard) syndrome seems to appear at any time that plans are made to select a waste disposal site. The core of the problem is the enormous amount of garbage generated by our consumer society daily - estimated at 0.5 tonne per annum per Canadian and much of which is not biodegradable.

In the north, because of the lower ambient temperatures, and the thereby reduced rates of reactions, the problem attains a much longer-lasting significance. Metal and wood have only been introduced into the Arctic, by explorers and their successors, within the last two hundred years. While the amount of refuse left behind is probably small when compared with elsewhere, better solutions than mere abandonment will have to be found as development becomes more extensive.

8) Costs

In most of the foregoing sections, mention has been made of the very high costs associated with any development in the north. Because of these it is only the highest grade deposits that have been economically viable up to the present. In the mining world one is unable to achieve much influence over the prices received for the products. The only alternatives, in maximizing returns, is to ensure that costs are held to the lowest levels possible.

Precise planning and effective cost control is particularly critical to the success of northern enterprises. There is very little room for waste and inefficiency.

SUMMARY

In this paper the author has presented a general overview of present-day mining in northern Canada. As the country has matured, the frontiers of development have been pushed ever farther to the north. A generation or so ago, economical mining much beyond the Territorial capitals or the ends of year-round transportation routes would probably have been considered impossible. Today, there are two medium-sized operations in the High Arctic and several more at lesser latitudes.

Successful mining under such conditions has required solutions to problems in a number of areas. A general review, not necessarily complete, of the most important factors has been made in this paper. All present challenges for future innovations.

In the words of Joseph Herschorn, a noted Canadian mining promoter "My name is opportunity and I am paging Canada" (2).

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