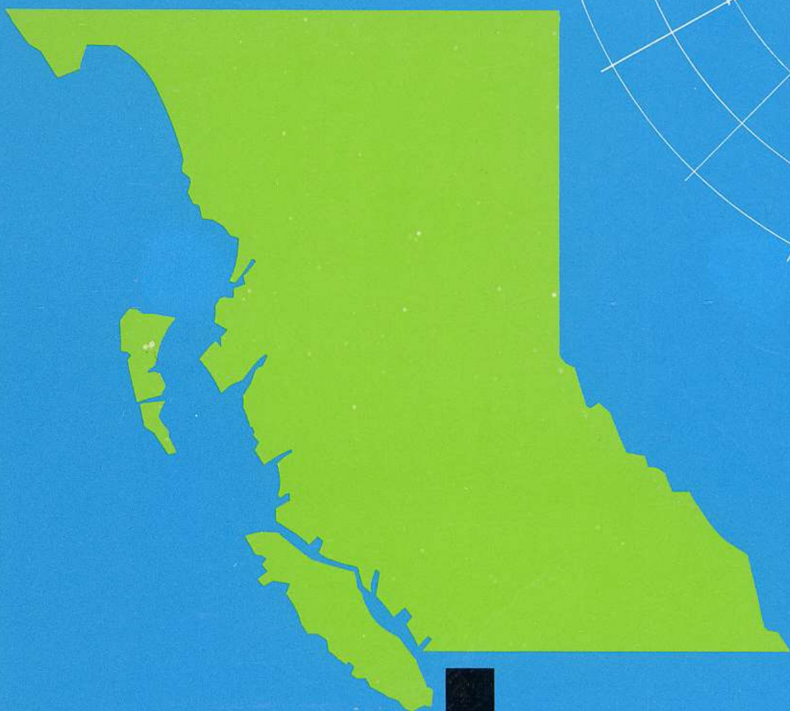
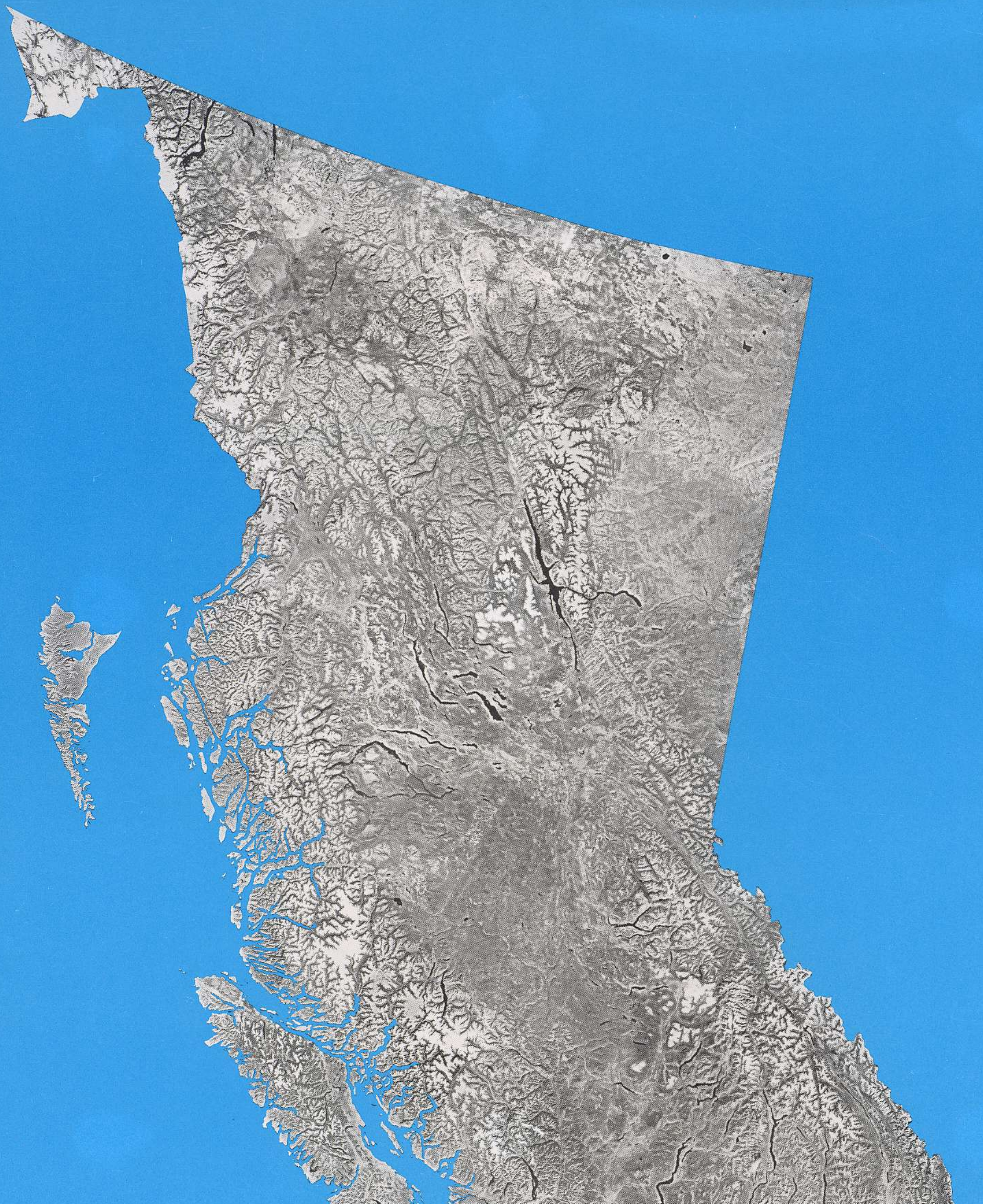


minerals

in British Columbia

Province of British Columbia Ministry of Mines and Petroleum Resources



Province of
British Columbia
Ministry of
Mines and
Petroleum Resources

minerals

in British Columbia

By Angus M. Gunn

Graphic Design by
Ted Baker

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Province of
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Ministry of
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British Columbia has a rich and varied mineral and fuel endowment which has played a vital role in the regional and economic development of the Province, and has made a significant contribution to the growth of Canada as a nation. Over the past two decades, there has been a remarkable expansion in exploration, development, and production of metals, coal, petroleum, and natural gas so that these form British Columbia's second largest resource industry and a major source of revenue to the Province. Continuous development of our abundant mineral and fuel resources is essential if we are to maintain the contribution this industry makes to the economy and welfare of British Columbia and of Canada.

Future mine and petroleum development must proceed in a society which is more socially and environmentally demanding than in the past. Because of this, we all have a responsibility to become aware of, and to understand as much as possible, the many complex factors associated with the exploration, development, and production of minerals so that the momentum of the industry can be maintained and balanced with the demands of our society.

This booklet has been developed to present a comprehensive overview of the mineral industry for the layman. I sincerely hope that it will be an interesting and valuable source of information and will contribute to a better understanding of the past, present, and future role of minerals in British Columbia.

JAMES R. CHABOT
MINISTER OF MINES AND PETROLEUM RESOURCES

James R. Chabot

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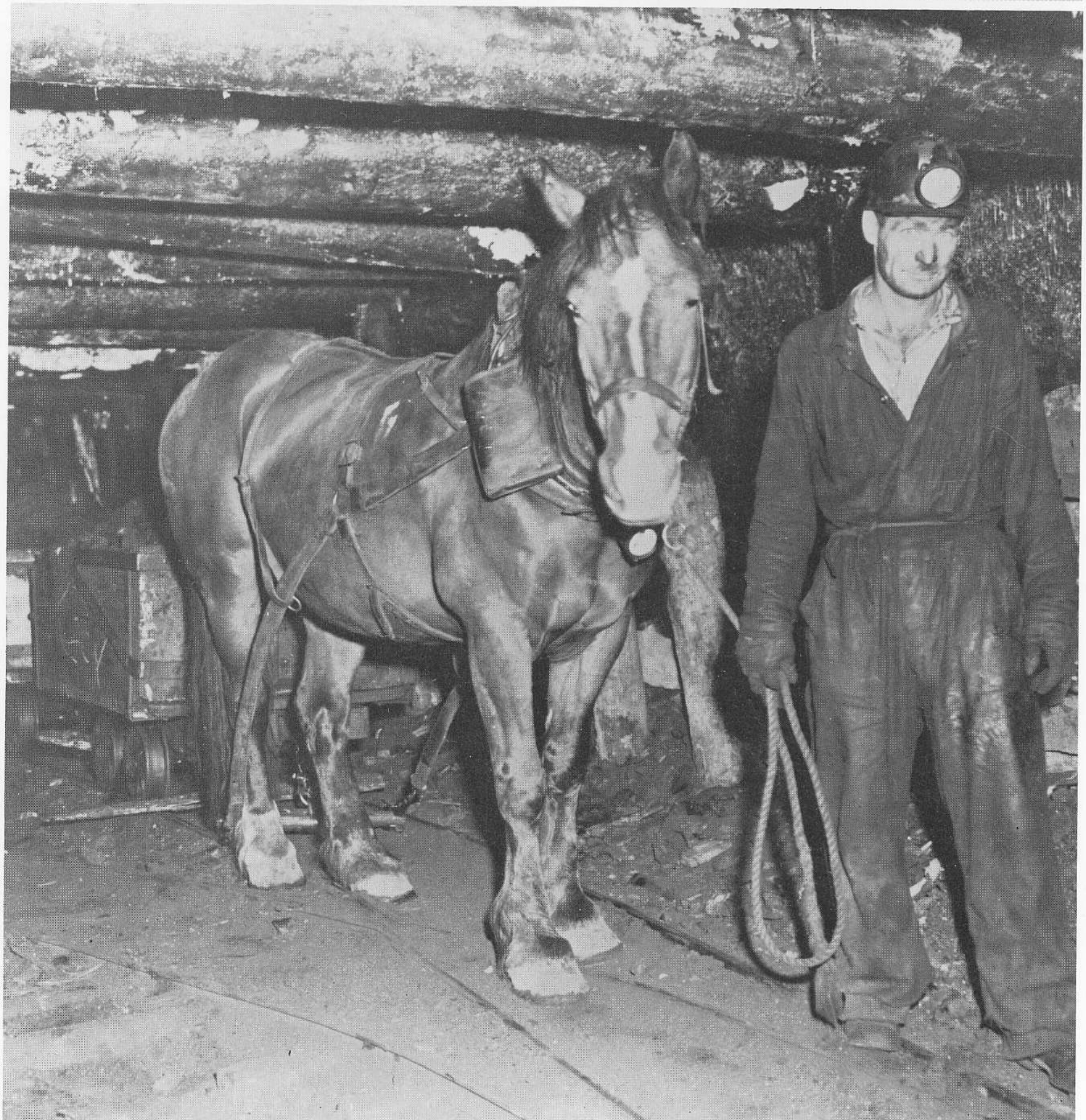


Coal mine around 1900

Historical Perspective

The Metal Age really began when man learned to melt metallic elements such as gold, silver, and copper from the rocks that contained them, and to pour the molten metallic mass into moulds of pre-arranged shapes. That development occurred around 5000 B.C. in Southwest Asia. Rocks are composed of combinations of minerals which in turn are usually chemical compounds — built up by atoms from some of the hundred-odd elements which comprise all matter. A few minerals, like gold, are found as uncombined elements instead of compounds.

Between 5000 and 4000 B.C., smelting of copper was achieved. Smelting is the separation by fusion of the pure metal from those impurities with which it is usually chemically combined in ore. That was one of the great turning points in history, comparable in significance to the discovery of ways of making fire. Today, copper plays a vital role as a conductor of electricity. In the coming century its value might be such that its chief use will be limited to wire for armatures of electric motors.

The discovery of alloying about 3500 B.C. was another important step. The smelting of copper ore along with some tin produced an alloy, bronze, that had qualities such as hardness that were superior to either pure metal. Bronze casting, a craft of the ancient Egyptian and Chinese cultures, was refined into a rare art by the Greeks. Later it was employed in the large-scale production of cannons and church bells.

The Bronze Age lasted until the start of the Iron Age which emerged about 800 B.C. Iron proved to be the most practical material for weapons and machinery. It has retained this primacy and probably always will because iron ores are so abundant.

Minerals are life-support systems in the modern world. Without them, our way of life would be impossible. Food and water supply, shelter, clothing, health aids, transportation and communication, plus a broad range of products used at home, at play, and at work, all depend on minerals.

Nowhere is the role of minerals more dramatic than in transportation and communication. Mineral-based technology has shrunk the world in size. We now travel more easily and faster than we have ever done, and we are constantly in touch with all corners of the earth.

Huge amounts of copper, lead, zinc, nickel, iron, titanium, concrete, sand, gravel, asbestos, and petroleum fuels are used in complex networks of roads, rail lines, air routes, pipelines, radio, and television linkages, These have made the world a 'global village.' Highly specialized metals and fuels have enabled mankind to carry out explorations in space, with journeys to the moon and beyond.

Canada's contribution to the world's mineral needs is a big one. It is the third largest mineral producer after the Soviet Union and United States and most of its production is exported.

Minerals, like all other 'natural' resources, are not simply parts of the environment. An item becomes a resource only when man needs it. Today's resources may be tomorrow's waste materials. The history of mining in British Columbia contains many examples of the changing character of resources, of the ways in which short-lived opportunities were seized to exploit a resource while it was in demand.

In the waning years of the fur trade, coal was mined on Vancouver Island as part of the operations of the Hudson's Bay Company. But the really big impact of mining on the area we now know as British Columbia dates from 1858 with the first gold rush into the Lower Fraser Valley.

Gold has always held a special fascination for mankind. It was probably one of the earliest metals used because it is easily recovered and refined, is intrinsically beautiful, and does not rust or change.

Medieval traditions of handling gold persist even today in the complex and mysterious world of international finance. Large reserves of gold were retained by both individuals and countries as a standard by which their relative wealth could be measured. Aeroplanes have been known to circle over international waters with loads of gold bars when gold prices were fluctuating.

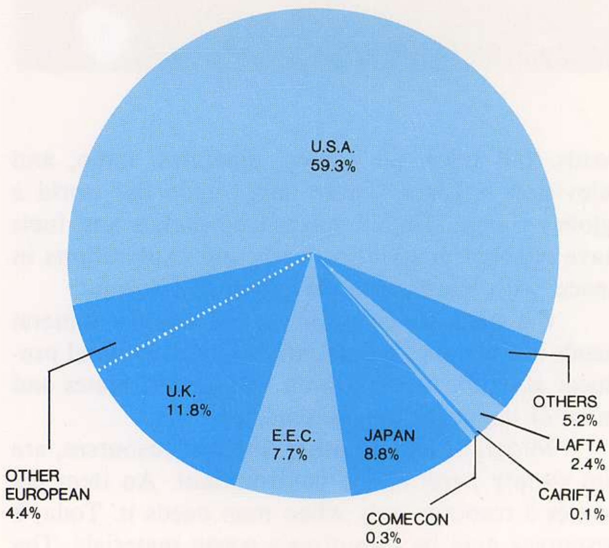
It was an international demand for gold that triggered the rash of gold rushes that swept the western United States, British Columbia, Pacific Rim countries, and South Africa in the second half of the nineteenth century.

International trade was exploding. Tonnage of exported and imported material doubled between 1838 and 1849. It doubled again in the following decade. Larger, faster, and better equipped ships plied the oceans of the world in the wake of Europe's industrialization. Barter systems had collapsed and gold was in high demand as a monetary 'standard' to back paper currencies.

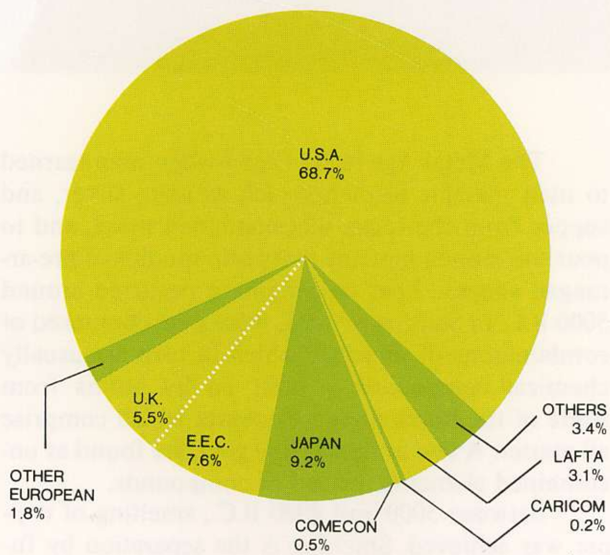
California was the first to experience the

CANADA'S MINERAL EXPORT MARKET (Including Gas and Oil)

1971 $5,039 Million



1976 $12,003 Million



U.K. — UNITED KINGDOM, E.E.C. — EUROPEAN ECONOMIC COMMUNITY, COMECON — COUNCIL FOR MUTUAL ECONOMIC ASSISTANCE (COMMUNIST COUNTRIES), LAFTA — LATIN AMERICAN FREE TRADE ASSOCIATION, CARIFTA, CARICOM — CARIBBEAN FREE TRADE ASSOCIATIONS.

modern scramble for gold in 1849. British Columbia was close behind, beginning in 1858. California miners stampeded northward with a zeal and recklessness that defies description. In April 1858, some 500 arrived, double that number in May, more than 7,000 in June, and another 7,000 in July. Most came by ship to Victoria. A further 8,000 arrived by land. In all, 30,000 Californians had made their way to the lower reaches of the Fraser River by the end of summer in that fateful year. That was quite a shock to an isolated, almost unknown area that had never known more than a few hundred fur traders at the peak of European and American penetration.

The Fraser Canyon was only the beginning. The fine gold that the Lower Fraser yielded indicated a potentially bigger haul fa' ther upstream at the site of the supposed 'mother lode.' Within a few months, 1,500 gold-seekers had made their way into the interior by way of the Fraser while another 1,500 travelled northward via the Harrison Trail.

By 1860 the miners had reached 'the Cariboo,' 500 kilometres north of the Lower Fraser, and the Barkerville area was being mined, first Antler and Lightning Creeks, then the richest of all, Williams Creek. The types of deposits that were being worked were still the same as those in the lower stretches of the Fraser River, loose gravels containing gold, originally deposited by water action. In the Lower Fraser these gravels lay close to the surface. In the Cariboo they were frequently covered with 20 or more metres of glacial debris. In both instances, the term 'placer' is used to describe these deposits.

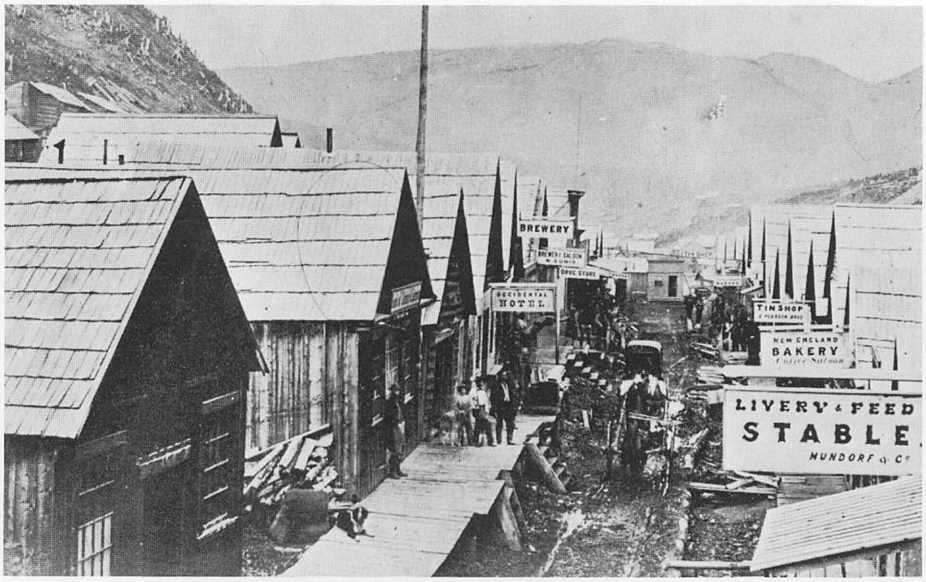
The gold rushes moved on to the Stikine and Peace Rivers, and then, late in 1863, to the Kootenays. In 1865 came still another find at the Big Bend of the Columbia River. All of British Columbia had become, it seemed, a single mine, and gold had permanently and profoundly altered the character of the Province for all time.

The glamour of the placers, the quests that drove men by the thousands into the pits and soaking, shallow mines of Barkerville, into the remote creeks of the Omineca and Cassiar areas in northern British Columbia, and still later far northward to endure the hardships and dangers of the Klondike, petered out before World War I.

Beginning around the turn of the century, lode gold — gold from the hard rock of underground mines — and silver began to dominate the field of mining. However, mines for gold and silver alone were short lived. It soon became evident that the best sources for these precious metals were also the best sources for the so-called base metals — lead, zinc, and copper.

In the years immediately following World War I, diversification was evident everywhere. Copper loomed large on the mining horizon and the mines at Britannia, Anyox, and Copper Mountain were active. The principal gold mine of that period was Hedley. Then in 1922 the big Sullivan lead-zinc deposit came into its own as a result of a new froth flotation separation process. The extent and quality of this deposit had been known for a quarter of a century, but the absence of a suitable separation technology held up production. By 1925 the value of lead production exceeded that of any other mineral.

The depression years saw a renewal of interest in placer gold mining. The old streams were eagerly



Street scene in Barkerville B.C. — before the fire of Sept. 1868

Freighting on the Cariboo Road — Nineteenth Century

Taking one inch cable up the trail to the Silver Dollar Mine, Nelson, 1906 reworked in response to a world demand for gold. With the advent of World War II, demand for gold gave way to an intense search for 'war' metals — chromium, molybdenum, mercury, tungsten.

Following World War II there was a profound change in the technology of the industry. Bulldozers, power shovels, and massive trucks opened up an entirely new world of open-pit mining. At the same time the aeroplane greatly accelerated the process of prospecting. These were the forerunners of a new technological era that was destined to revolutionize the structure of British Columbia's mining within a single generation, shifting it from an industry dominated by lead and zinc to one dominated by copper and molybdenum.

Mining is quite unlike other primary industries. Initial exploration only sometimes leads to discovery of minerals. Further, mineral discoveries very seldom lead to the development of a mine. The location, quantity, quality, and ease of extraction of ore, plus world market conditions, all influence the commercial viability of a mineral deposit. In addition, the unexpected appearance of new synthetic materials may provide cheaper substitutes for minerals and thus destroy the market for a particular mine. As an example, Chile dominated world trade in nitrates for many years. Then, in 1920 the Haber-Bosch process for the manufacture of a synthetic nitrogen fertilizer was introduced and Chile's share of the world's market dropped dramatically from 95 to 15 per cent.

Another unusual feature of a mine is that all the operations are intensely localized. Orebodies rarely occupy more than 50 hectares. The result is a concentration of equipment and people that can fundamentally change the character of the surrounding area. Still another feature is the problem of understanding mining. The operations are highly technical and commonly located in remote settings. The uncertainties of the industry compound the problem and its understanding.

Most of the metals found in concentrations sufficient enough to be mined in British Columbia — copper, lead, zinc, molybdenum, to mention a few — exist in less than 0.01 per cent of the earth's crust. Most of even that small amount of potential ore is too deep in the crust or is located in too remote a location to be mined at a profit.

There is no danger of British Columbia or Canada exhausting its major mineral resources in the next 100 years. In fact all the evidence points to expectations of finding new deposits in areas as yet untouched. This is not to imply that wise conservation measures can be ignored, or that the rate of growth should not be slowed down. The ores that will be in short supply on earth by the year 2100 are copper, lead, and zinc, whereas iron and aluminum will still be plentiful at that time.

Measures of ore reserves and resources provide some indication of British Columbia's future mining prospects. Reserves must be measured with considerable precision as to size and grade, and must be capable of being mined at a profit under current economic conditions. The term resources refers to the identified economic minerals in the ground that have sufficient grade and tonnage to be considered mineable in the future. Resources of the major metals mined in British Columbia are estimated to be many times greater than the total of present reserves and past production.

Even if existing mineral deposits were all we

THE WORLD'S TOP MINERAL PRODUCERS

Production of selected minerals in rank order

	NICKEL	ZINC	ASBESTOS	SILVER	TITANIUM CONC.
1	**CANADA**	**CANADA**	U.S.S.R.	U.S.S.R.	AUSTRALIA
2	NEW CALEDONIA	U.S.S.R.	**CANADA**	**CANADA**	**CANADA**
3	U.S.S.R.	U.S.A.	SOUTH AFRICA	MEXICO	U.S.A.
4	AUSTRALIA	AUSTRALIA	CHINA	PERU	NORWAY
5	CUBA	PERU	RHODESIA	U.S.A.	MALAYSIA

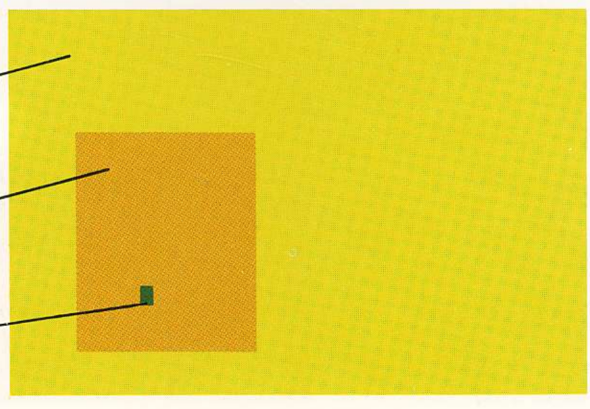
	MOLYBDENUM	ELEMENTAL SULPHUR	URANIUM CONC.	GOLD	COPPER
1	U.S.A.	U.S.A.	U.S.A.	SOUTH AFRICA	U.S.A.
2	**CANADA**	**CANADA**	**CANADA**	U.S.S.R.	CHILE
3	CHILE	POLAND	SOUTH AFRICA	**CANADA**	U.S.S.R.
4	U.S.S.R.	U.S.S.R.	FRANCE	U.S.A.	**CANADA**
5	PERU	MEXICO	NIGER	AUSTRALIA	ZAMBIA

	LEAD	ALUMINUM	IRON ORE
1	U.S.S.R.	U.S.A.	U.S.S.R.
2	U.S.A.	U.S.S.R.	AUSTRALIA
3	AUSTRALIA	JAPAN	U.S.A.
4	**CANADA**	W. GERMANY	BRAZIL
5	MEXICO	**CANADA**	**CANADA**

Portal of "Sunnyside" No. 2, Hedley, B.C., 1904. Note candle holders on caps

Hand sorting lead-zinc ore to select high lead-silver values before the advent of differential flotation. Sullivan Mine, about 1912

CANADA'S TOTAL LAND AREA 2 280 000 000 Acres — 922 703 350 Hectares



TOTAL FARM LAND
172 000 000 Acres — 69 607 446 Hectares

TOTAL FARM LAND DISTURBED BY HIGHWAYS
30 000 000 Acres — 12 140 833 Hectares

TOTAL LAND DISTURBED BY MINING
130 000 Acres — 52 630 Hectares

The B.C. Museum of Mining is located at the site of the former copper mine at Britannia Beach

Britannia Copper Mine — now closed

had left we could 'remine' some of the tailings and start all over again. In 1920 the average grade of copper mined in British Columbia was about 20 per cent compared with less than 0.5 per cent which is common today. The technology that enables mining companies to work 0.5 per cent copper economically is continuously under development. If we were able to go down to 0.2 per cent we would have enough copper to last for centuries. Unfortunately the energy cost per unit of metal rises sharply as the grade drops.

Scrap metal is one of the promising sources that as yet is only slightly tapped. As new technologies are introduced, substantial amounts of recycled metals will be available. A good example of a large scrap 'find' will be the Trans-Atlantic telephone cables as satellites take over their work. Even at present, about 50 per cent of copper used in the Western world is recycled metal.

There are always new frontiers in mining. The change to lower grade ores is one of these frontiers, one that will continue to challenge the industry for decades to come.

The ocean floor is another frontier. Metals accumulated on even the deepest ocean floors will be available to mankind before the year 2000. New agreements at the United Nations Law of the Sea conferences have given hope that some system of sharing will be developed in time.

Among the known undersea riches are manganese nodules lying in the large beds in widely separated parts of the oceans. Manganese is used in steel making and in aerospace materials. The nodules contain other minerals of value, including iron, copper, nickel, and cobalt. These nodules can be brought up from the beds by a vacuum system or they can be dredged.

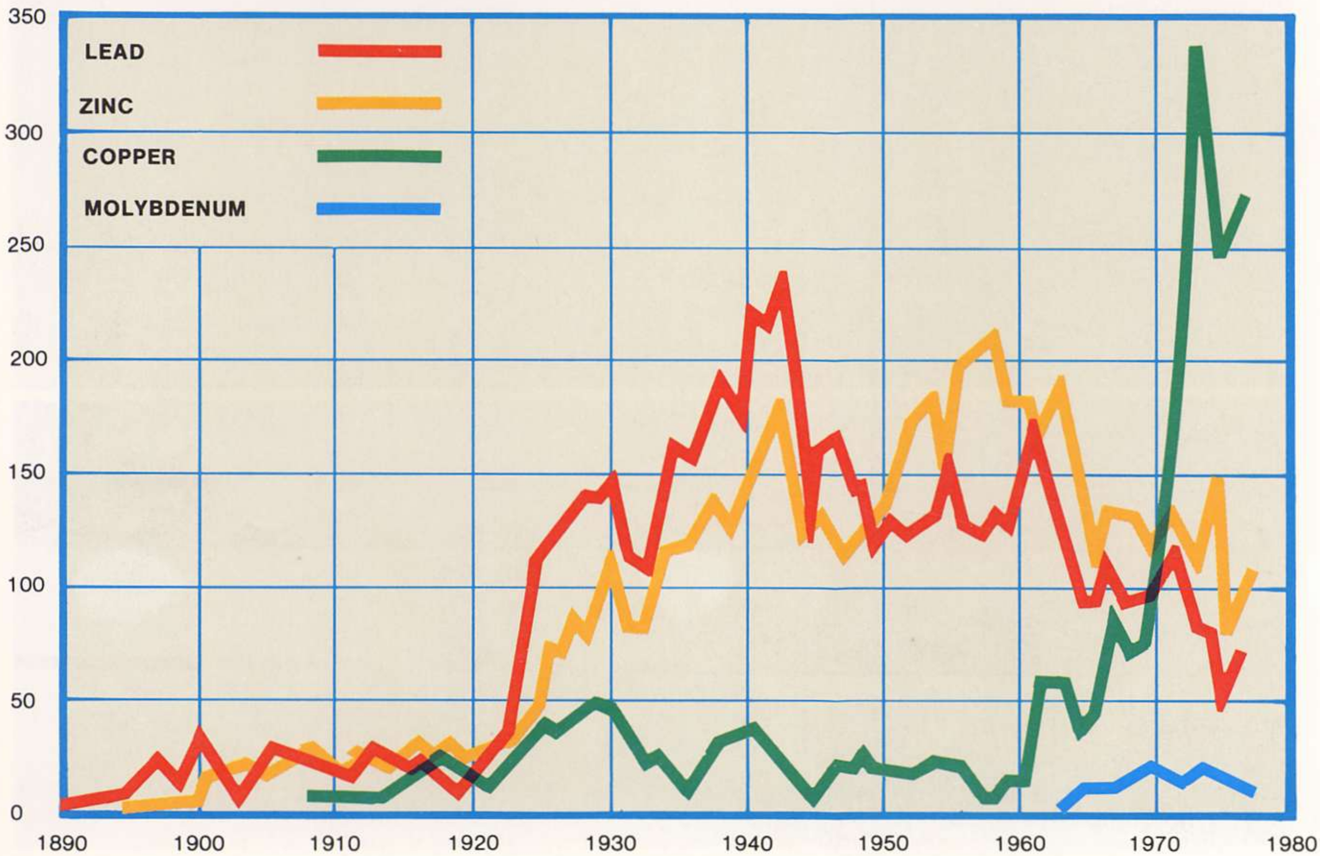
For the present it is clear that technological developments are making possible an accelerating increase in British Columbia's capacity to harvest its mineral resources. In 1927 the total value of production was $61 million; in 1937, $74 million; in 1947, $113 million. Since 1947 the pattern has changed fundamentally with the development of oil and gas and the recent revival of coal mining. The total values of production have reflected these changes.

TOTAL VALUE OF BRITISH COLUMBIA'S MINERAL PRODUCTION ($ MILLION)

	Metals	Industrial Minerals	Structural Materials	Coal	Petroleum and Natural Gas	Total
1957	125	11	26	7	1	170
1967	236	29	44	7	67	383
1977	727	75	106	372	557	1,837

PRINCIPAL METALS PRODUCTION IN BRITISH COLUMBIA

Annual Output in Thousands of Tonnes



Endako molybdenum Mine

Mineral Deposits

The common ore minerals, those that contain mineral concentrations in economic quantities, are rare. Eight common elements comprise more than 98 per cent of the earth's crust and, although three of these eight — aluminum, iron, magnesium — have commercial value, they seldom occur in economic concentrations. Metals such as copper, lead, zinc, and molybdenum — key components of British Columbia's mining industry — comprise less than a third of 1 per cent of the earth's crust. Furthermore, many ore deposits must lie beneath oceans, too deeply buried on land, or in inaccessible jungle, desert, and arctic areas.

It is known that the earth as a whole consists of three layers: the crust, composed of light granitic and sedimentary rocks rich in aluminum and silica oxides, averaging 35 kilometres in thickness; the mantle, almost 3,000 kilometres in thickness, composed of denser, ultrabasic rocks rich in iron and manganese; and the core, considered to be mainly native iron and nickel in a molten state (see page 21).

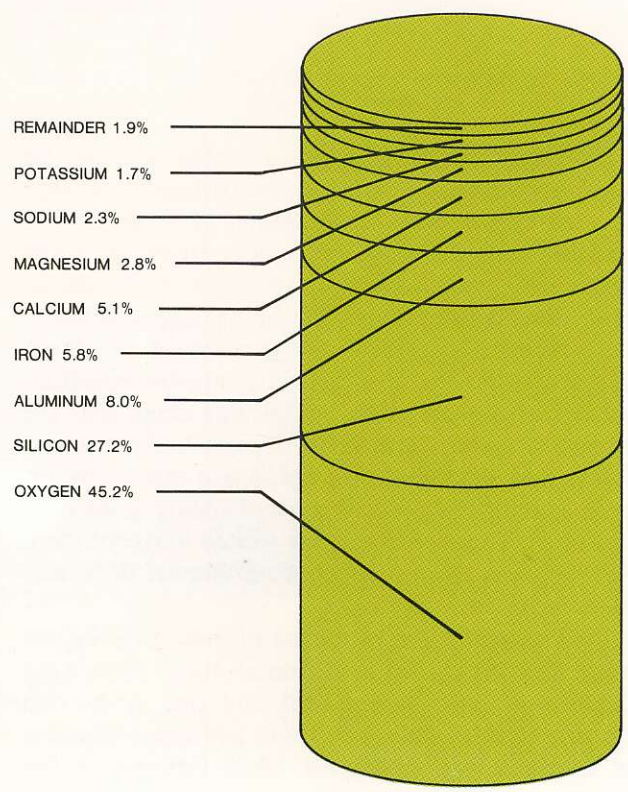
The earth is constantly changing. These changes are gradual and result from occasional volcanic eruptions plus the slow, steady deposition of sand and mud in lakes and oceans. Convection currents in the mantle produce movement in the crust. Shifting of the crust results in fracturing which releases molten material called magma from deep inside the earth. The magma, which may contain valuable minerals, rises into the crust where it is cooled and crystallized. The result is an earth that is constantly renewing its surface, quite unlike the pock-marked 'dead' planets like Mars or the Earth's moon.

The Canadian Cordillera, a mostly mountainous terrain extending from the United States border to the Arctic, is a small part of the world's continental crust. It includes most of British Columbia and the Yukon Territory plus some parts of Alberta and the Northwest Territories. The name 'Cordillera' is a Spanish term which means a chain of mountains. The average width of the western Canadian 'chain' is more than 800 kilometres and average length more than 2,400 kilometres. Total area is 1.5 million square kilometres.

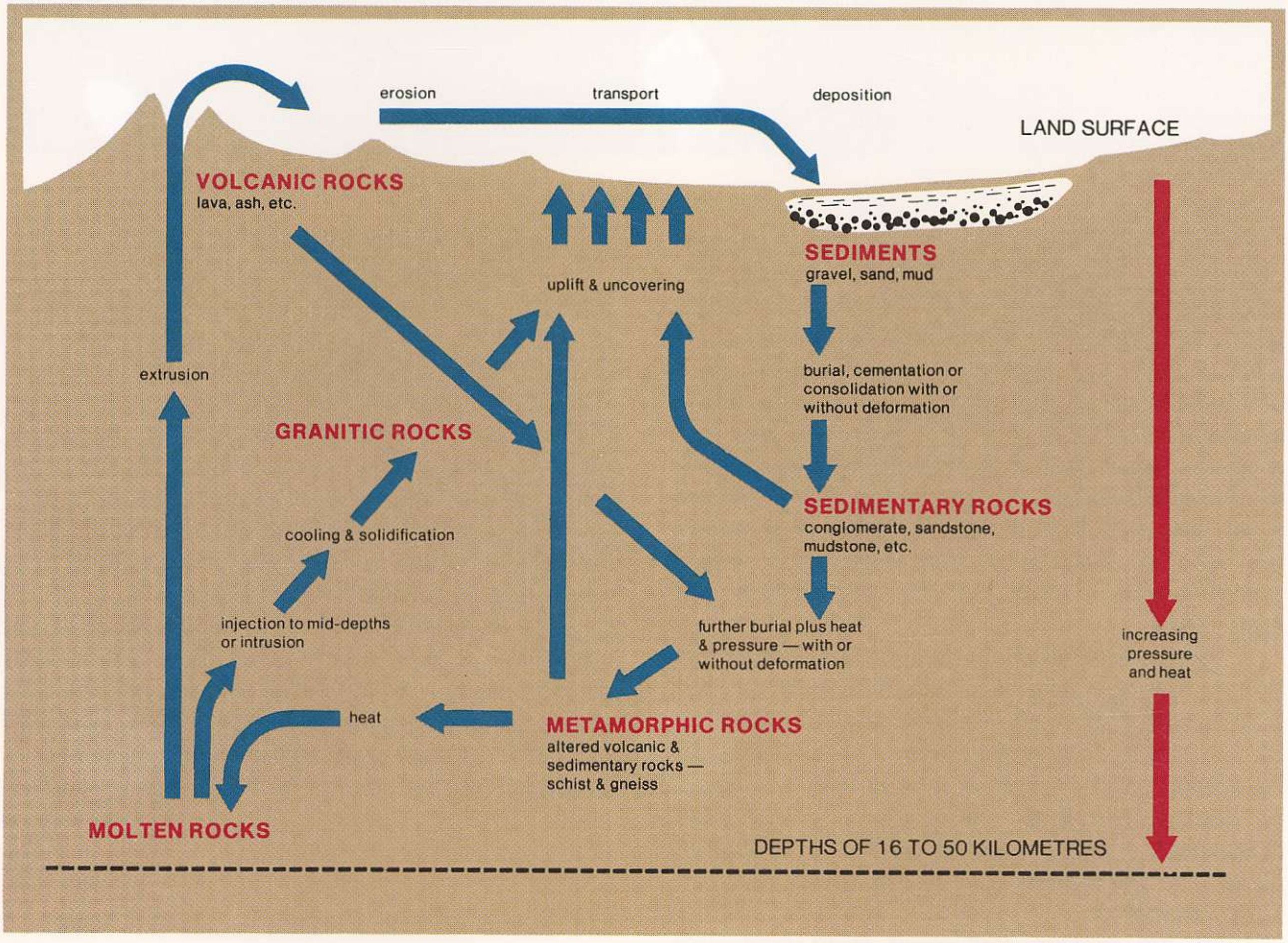
The distribution of metal deposits in this vast area is closely related to the geological history. There are five tectonic (structural) belts and, within each, the geology is dominated by rocks similar in type, age, and evolutionary history (see page 18).

The Eastern Marginal Belt is composed of folded sedimentary rocks and occupies the general area of the Rocky Mountains. The western margin of British Columbia is called the Insular Belt. It includes the Alaska Panhandle, the Queen Charlotte Islands, and Vancouver Island. Adjacent to these two regions lie two crystalline belts, the Coast and the Omineca. Each belt is a chain of continuous alpine mountains in which the rocks have been transformed by great heat and pressure so they are recrystallized, and penetrated, particularly in the Coast Belt, by intrusions of formerly molten rock. In the centre of the Cordillera is the Intermontane Belt, an area of plateaus underlain by complex geology. Page 18 shows the distribution of metals within these five belts. If fossil fuels were added, their dominant concentrations would appear in the Eastern Marginal Belt.

CHEMICAL COMPOSITION OF THE EARTH'S CRUST



THE GEOLOGICAL CYCLE — simplified



Sooner or later most rocks are exposed to erosion — by wind, water or ice. The resulting products accumulate to form **sedimentary** *rocks such as sandstone. These may be buried to great depths and converted by heat and pressure into* **metamorphic** *rocks such as marble. At still greater depths they may be melted to form* **magma,** *which if crystallized forms* **igneous** *rocks such as basalt; if exposed these renew the cycle of erosion, burial and conversion. The cycle may, however, be interrupted and follow any of the paths shown in the diagram. (after W. H. Matthews)*

The geological evolution of these belts can be summarized as follows. The two eastern belts were formed by the slow accumulation of sands, muds, and lime carbonates on the former edge of the North American continent. These were later metamorphosed and/or folded during the mountain building processes related to the creation of the three western belts. These latter belts initially consisted mostly of oceanic crust. A volcanic chain like the Aleutian Islands formed on the site of the present Coast Belt and submarine volcanism was active on both flanking belts, modifying and adding to the original crust. These processes are related to recent theories of ocean floor spreading, continental drift, and plate tectonics.

The deposition of metals in these five regions has a long history. In Precambrian times there were deposits of iron, copper, lead, and zinc in the two eastern belts. In Paleozoic times additional deposits of lead and zinc developed. More recently, in the Mesozoic era, volcanic action resulted in extensive deposits of copper and molybdenum in the three western belts. This was repeated in Teritiary times.*

The natural processes that concentrate metals in economic quantities are quite varied. Most basic of all is the original physical/chemical process which separated out the lighter rocks at the crust and left the denser material nearer the centre of the earth. The large metal atoms were, in effect, squeezed out of the very dense core and its surrounding layers and so they migrated to the outer layers of the earth.

A second powerful process is by melting and 'freezing' of rocks. Since rocks are not pure substances there is a range of temperature during which each of the minerals in a given rock melts. At certain temperatures crystals may be seen floating in liquids as one section remains solid while another melts. Metals are sometimes concentrated in the last rocks to freeze. If these rocks are remelted, the metals are among the first elements to melt.

*See geological time chart page 66.

Some new perspective on large-scale melting has come with theories of plate tectonics. The earth's crust is apparently divided into a number of plates that 'grow' in some places, and are destroyed at other places as they plunge under continents and are melted by the heat of the deeper layers of the earth's interior.

Other important processes of metal concentrations are related to the sorting actions that take place during deposition of the mineral grains in sands and muds which are later compacted into rocks.

These and other processes result in a considerable array of types of mineral deposits but they can all be divided into two major classes: (1) those that are bedded and formed during the deposition of the enclosing sedimentary rocks (for example, many lead-zinc deposits of the eastern belts) and (2) those that are related to volcanic or igneous rocks (for example, the large 'porphyry' copper and molybdenum deposits of the Intermontane Belt).

The metallic minerals of British Columbia that provide the biggest monetary returns in metal production are: chalcopyrite and bornite (copper minerals), galena (a lead mineral that often also contains silver), molybdenite (a molybdenum mineral), sphalerite (a zinc mineral), and native gold.

Copper is British Columbia's most widely distributed metal in economic concentrations and its most valuable metal in terms of total annual production. All five belts of the Canadian Cordillera contain copper ores but the three western belts contain the most. Great concentrations have been located in the 'porphyry' deposits of the Highland Valley southwest of Kamloops, possibly as much as 10 million tonnes of copper in all. Copper can be found in association with almost any other Cordilleran metal. It is most frequently found in association with molybdenum. These combinations are most common in the Intermontane and Insular tectonic belts.

Molybdenum is also widely distributed in the three western belts as pure low-grade porphyry deposits of molybdenite. The Endako mine of central British Columbia is one of the three largest such mines in the world.

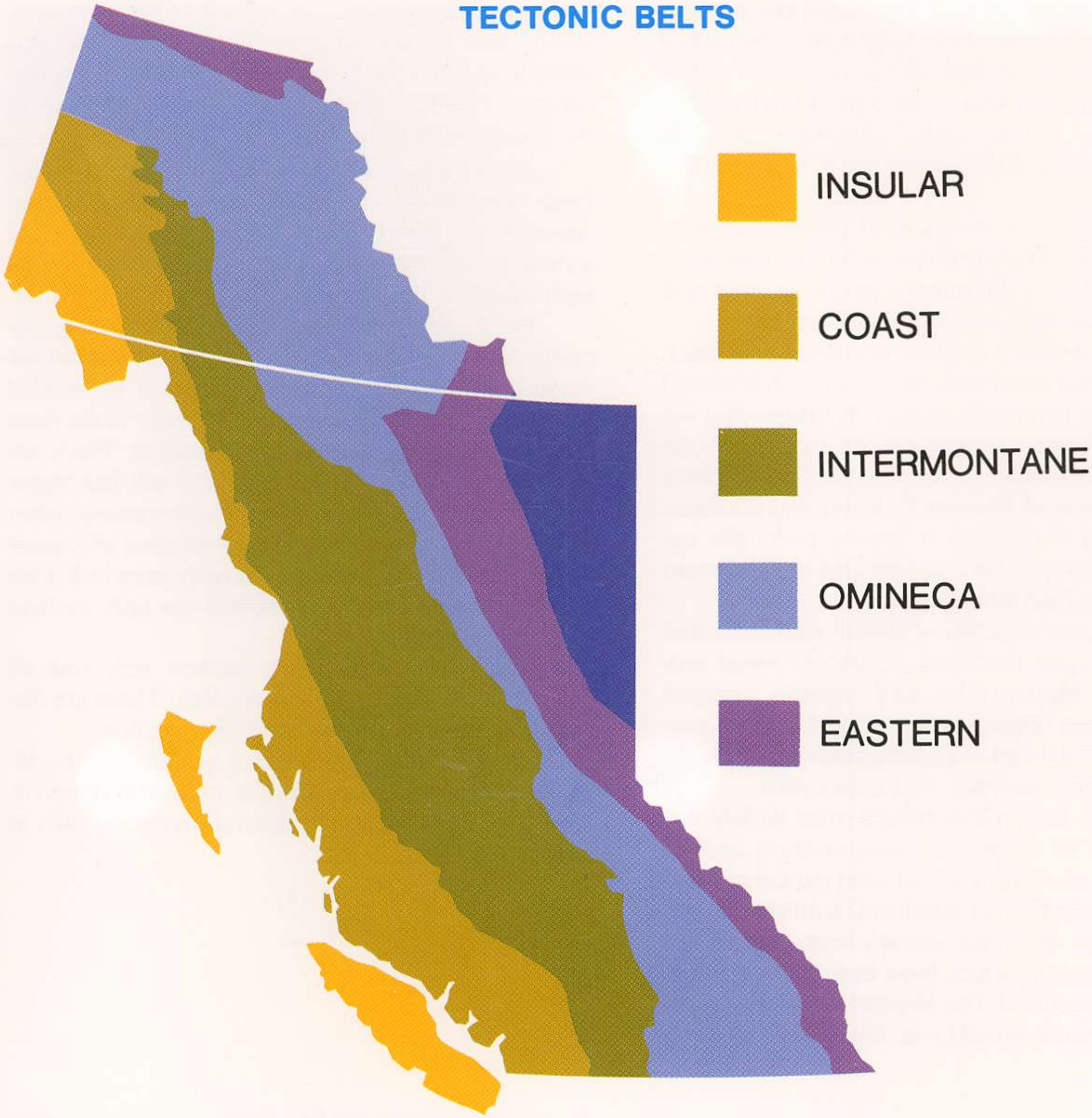
Lead, zinc, and silver are concentrated primarily in the Omineca Belt. These three minerals are commonly found together, most often as bedded deposits. The Sullivan mine at Kimberley is the focal point of the Omineca Belt concentration. There are also substantial gold deposits in this belt but bigger concentrations are found in the Intermontane. Most of the gold output comes as a by-product of copper mining, in sharp contrast to the early days in British Columbia when placer mining was the only method of extracting gold.

There are major coal, natural gas, and oil deposits in the Eastern Marginal Belt. These are discussed in more detail in the Energy section.

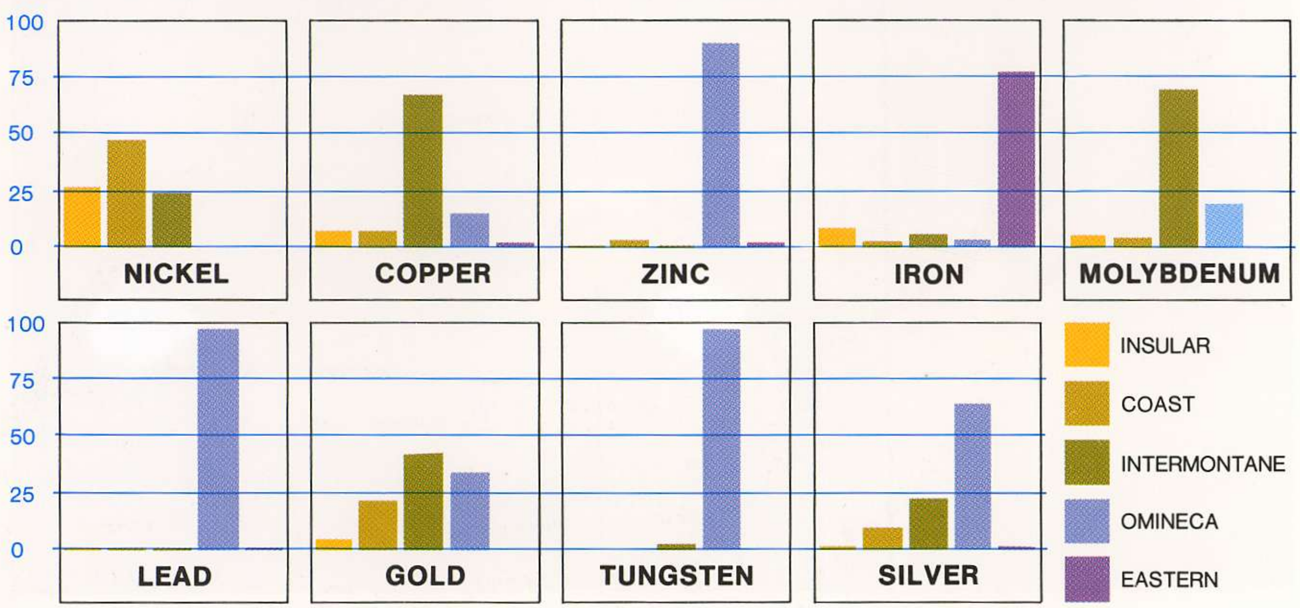
British Columbia's mineral production also includes considerable quantities of industrial minerals, especially asbestos, and structural materials, such as sand and gravel.

New underground machine that loads, hauls and dumps ore and waste

TECTONIC BELTS



PERCENTAGE DISTRIBUTION OF METALS IN THE CANADIAN CORDILLERA



(after A. Sutherland Brown)

MAJOR MINES IN BRITISH COLUMBIA
Greater than 1000 tonnes ore

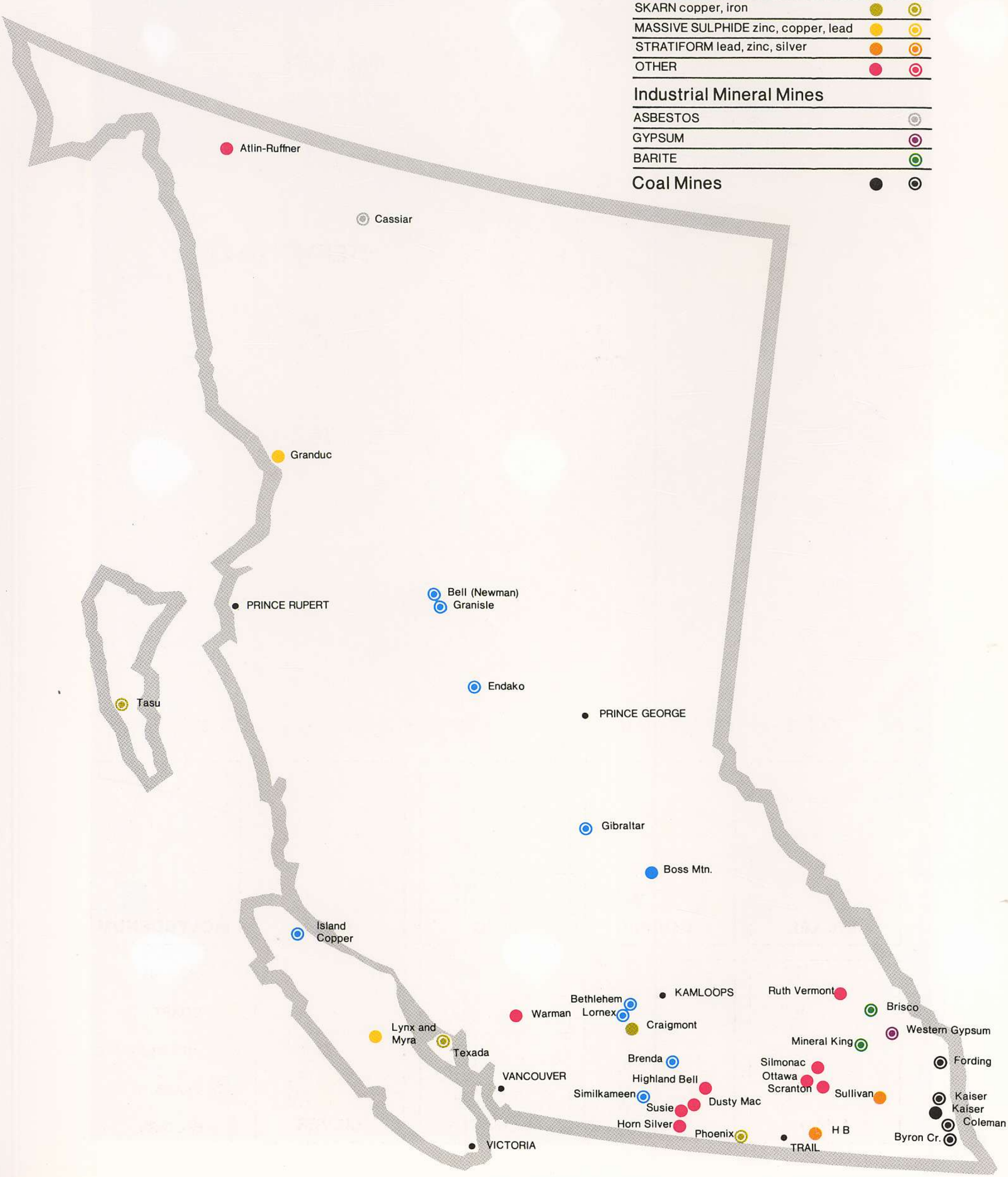
Metal Mines

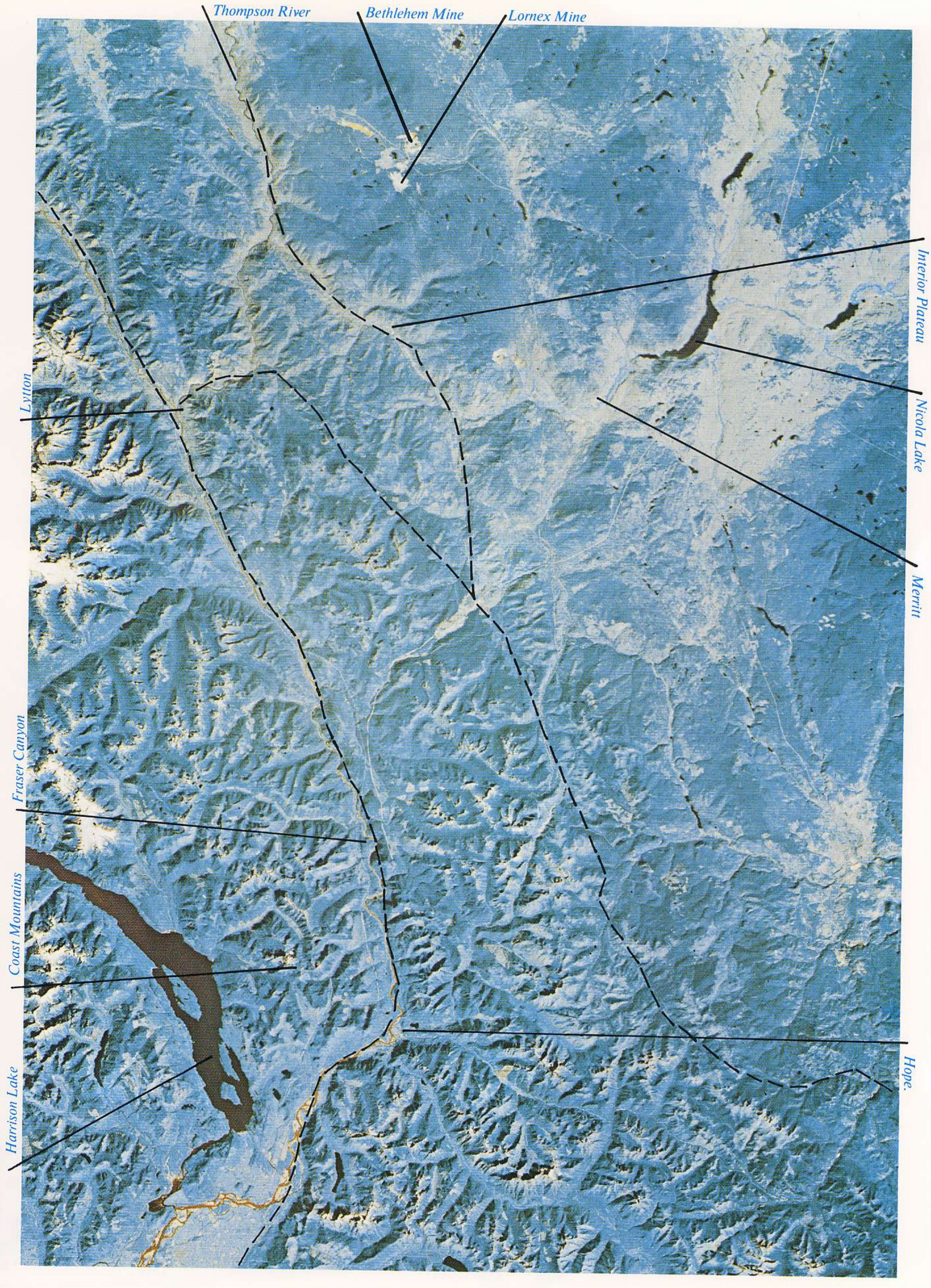
Geological Class	underground	open pit
PORPHYRY copper, molybdenum		
SKARN copper, iron		
MASSIVE SULPHIDE zinc, copper, lead		
STRATIFORM lead, zinc, silver		
OTHER		

Industrial Mineral Mines

ASBESTOS	
GYPSUM	
BARITE	

Coal Mines




Thompson River
Bethlehem Mine
Lornex Mine
Interior Plateau
Nicola Lake
Merritt
Lytton
Fraser Canyon
Coast Mountains
Harrison Lake
Hope.

Exploration

The romantic picture of the prospector lingers on in British Columbia because the first big mining thrust, that of the mid-nineteenth century, was very much a story of high adventure and extreme optimism. Conditions in San Francisco in the summer of 1858 provide clear examples of the gold fever of that time.

Numbers of companies working California pay claims had sent agents to investigate the British Columbia gold finds. They returned with optimistic reports and this triggered a general stampede. Large numbers of people headed north. Throughout the month of June, all roads leading to San Francisco were jammed with people on their way to the new gold fields. All the San Francisco hotels were crowded. Tens of thousands headed north within a two-month period.

First diggings in the Lower Fraser were simple operations. Gravel was lifted out of the river bed and sifted either in a pan or rocker until the lighter gravel was washed away and the heavier gold was left behind.

This style of placer mining gave way to much more complicated diggings when the miners settled in Barkerville. Ancient rivers, now overlaid with more than 15 metres of glacial deposits, had to be exposed before the gold-bearing gravels could be reached. It was a much tougher job than California had ever been because the glacial deposits were so much deeper in this northern setting.

Exploration for placer gold dominated the second half of the nineteenth century. In the years that followed the waning of the Barkerville fields, a series of smaller rushes moved steadily northward. Then in 1896 came the Klondike, one of the biggest placer finds in all mining history.

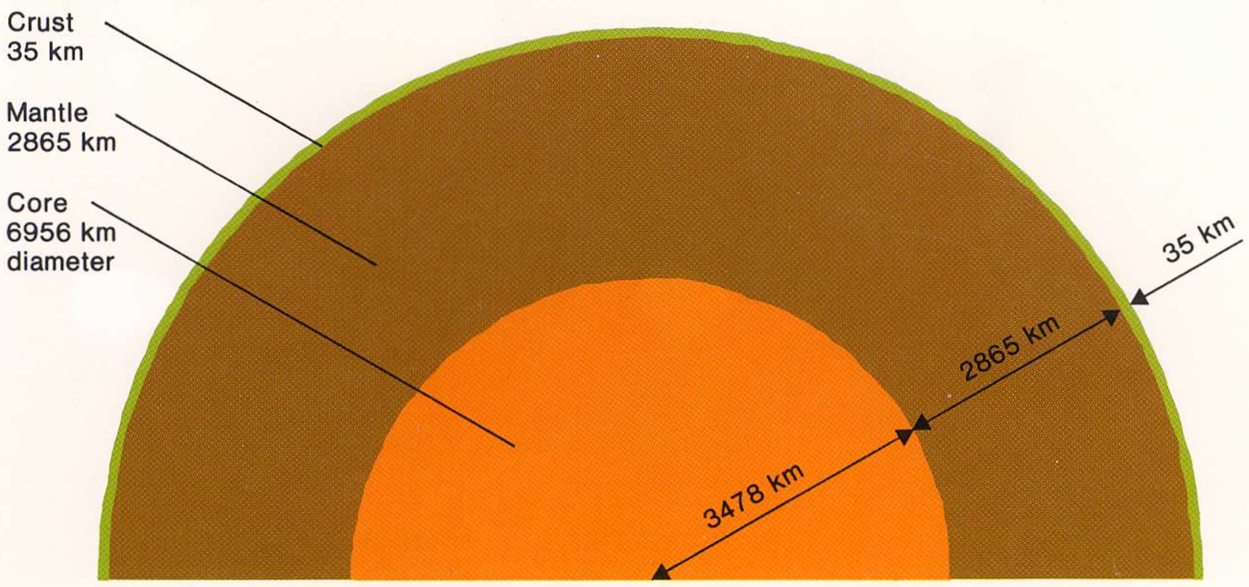
By 1898, every hotel and lodging house in Vancouver was full with gold-seekers en route to the Yukon. Tents were pitched on every available waterfront lot. It was a boom time for the city. The gold rushes were moving on and Vancouver was experiencing the same excitement that was evident in San Francisco in 1858.

Yukon gold, mainly the rich placers on the Klondike, yielded $22 million in the year 1900. In the following half century the Yukon continued to produce placer gold in substantial quantities, in all a total of $240 million in a 60-year period. That is an average of $4 million a year. British Columbia's average for the 30-year period from 1858 to 1888 was less than $2 million annually.

The exploration scene in British Columbia

EQUATORIAL SECTION THROUGH THE EARTH

(after J. A. Fortescue)

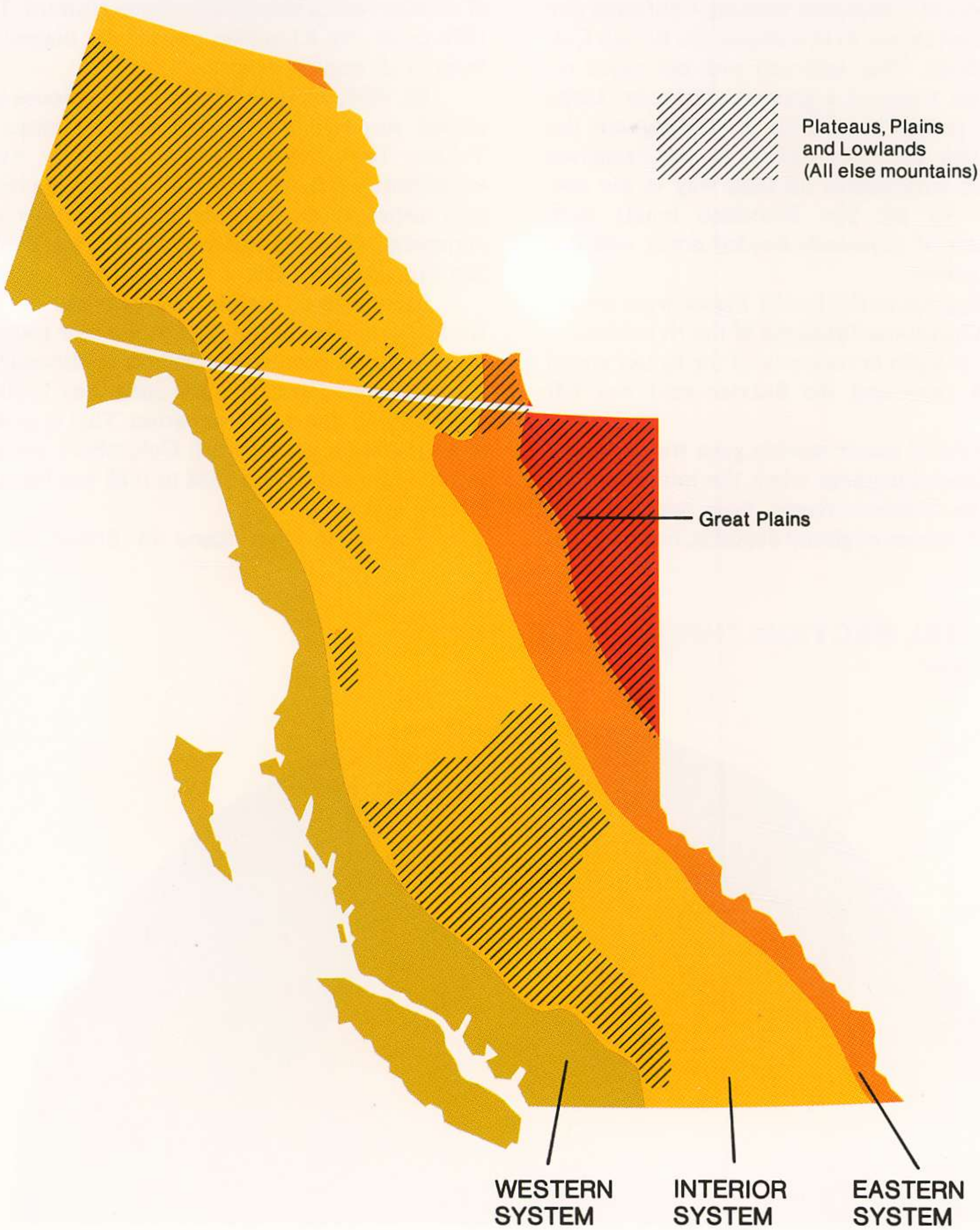


shifted dramatically in the final decade of the nineteenth century. Gold gave way to other metals, especially the so-called base metals — copper, lead, and zinc. Between 1891 and 1902 eight smelters appeared, processing the widespread findings of one metal — copper.

In some ways it can be said that most of our present important ore districts were discovered during these years of exploration at the turn of the century. Some of the early finds remained unexploited until technology developed — modes of treatment of complex ores and mass production techniques for low-grade deposits.

Yet exploration goes on. It has greatly intensified in recent decades because the deposits now being mined must be replaced by new ones if the industry is to be kept alive. Such exploration has, in fact, been very successful. A large number of new mines have been put into production since 1970, and many significant prospects have been found. Some now await more favourable conditions such as better metal prices and improved transportation networks before mine development is undertaken. The successful search and development of copper deposits in

PHYSIOGRAPHIC DIVISION OF CANADIAN CORDILLERA *(after Stuart S. Holland)*

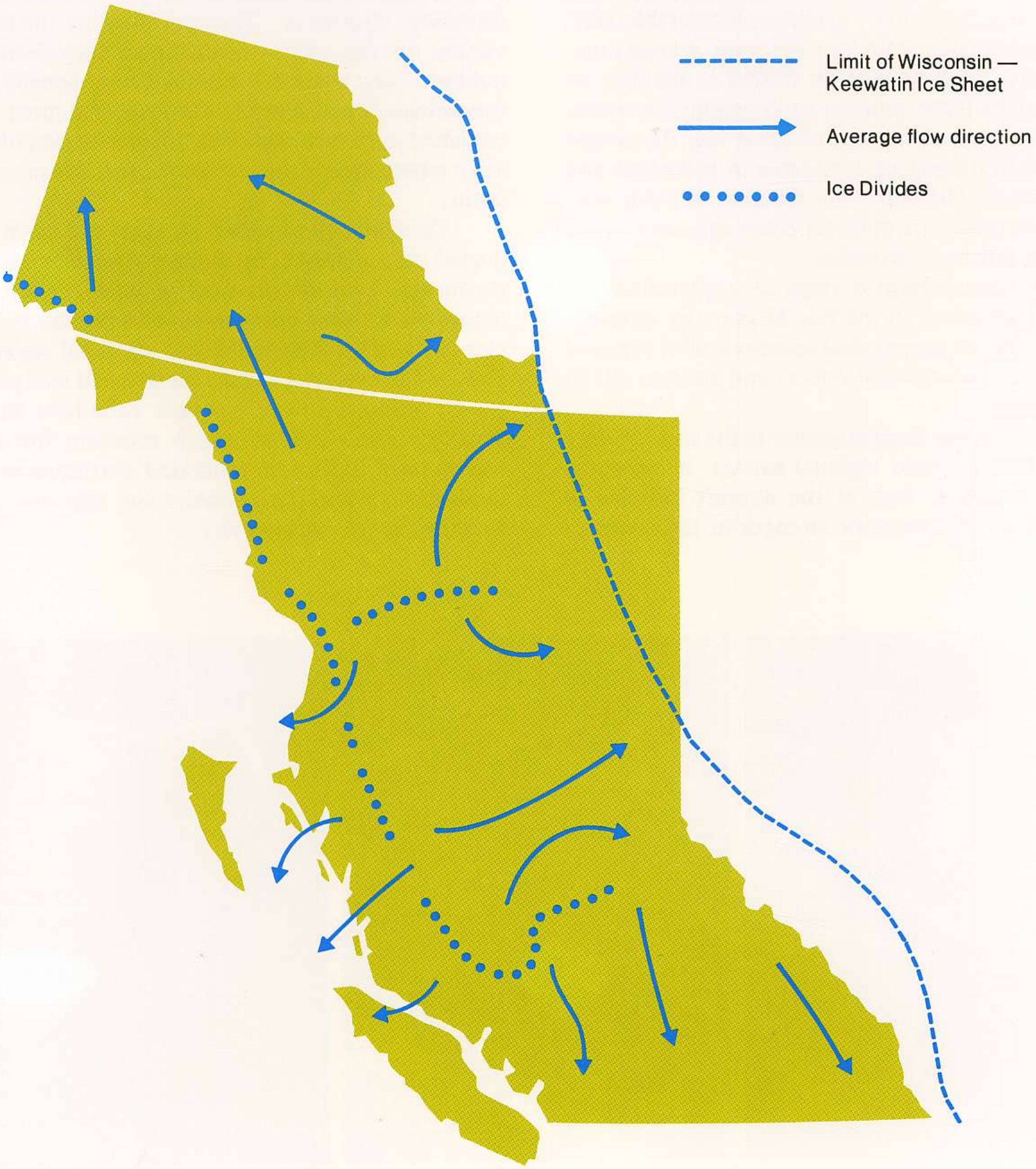


British Columbia ensure a long lasting supply of this metal. Currently, exploration initiatives are concentrating on the search for uranium, molybdenum, and multi-element, massive sulphide deposits that are generally smaller but of higher grade than the 'porphyry' deposits developed in the recent past. The potential for new discoveries of a wide variety of minerals continues to make British Columbia an attractive area for exploration.

The quest for new deposits is a 'needle-in-a-haystack' type of search. Determination, skill, and luck are all important. Success is rare, the expense and risk high. There are almost 10,000 known mineral showings in the Province but less than a hundred have led to significant mines in the history of mining in this area. In Western Canada, the average expenditure to find a major viable mine is about $30 million.

Modern exploration tends to advance by orderly stages. The first involves selection of regions of favourable geology for the metals sought. A large amount of geological information is analysed from government mapping and accumulated data together with company information. The second stage in-

ASPECTS OF CANADIAN CORDILLERAN GLACIATION



volves field surveying on a regional scale by geological, geochemical, and/or airborne geophysical reconnaissance. The third stage involves detailed surveys in more specific target areas with ground geophysics, geochemical sampling of soils, exposing bedrock by trenches, and additional analysis of the geology. The areas selected for detailed work normally show above average values with respect to geophysical or geochemical properties and such an area is said to be an anomaly. These areas are normally considerably larger than the actual mineral concentration causing them. If there are strong indications of encouragement in these investigations, small areas are designated for drilling programs.

Most anomalies do not have sufficient concentrations of minerals to form an orebody. Even in those anomalies that do, it takes considerable skill, luck, or persistence to find the ore zone. A large number of holes may have to be drilled to identify an orebody and a larger number to determine its extent.

Each type of mineral deposit has its unique characteristics requiring variations in technique and interpretation. The search for massive sulphide concentrations requires a quite different approach to the search for porphyry deposits.

The reconnaissance stage of exploration has been revolutionized in the last 25 years by development of airborne geophysical surveys and by regional geochemical surveys that collect and analyse silt in small streams.

The airborne magnetometer is the most widely used method of rapid regional survey. It measures the total magnetic field at the aircraft but this is influenced by the magnetic strength of the underlying rocks. For example, iron deposits are readily spotted by such an instrument. By trailing a magnetometer below an aeroplane or helicopter, and matching its continuous readings with locations from aerial photographs, a large area can be accurately explored in a few hours.

Regional geochemical programs are effective because the silt in a small stream, in effect, represents a combined sample of the whole drainage area. If any part of this large area contains anomalous metal concentrations it should be present and measurable in the silt.

The specific techniques used when a potential hidden target has been narrowed down to one locality measure, indirectly, properties of the rocks and minerals themselves in contrast to those of surrounding structures. These properties include a variety of rock characteristics including chemistry, radioactivity, electrical conductivity, density, and magnetism. An accurately surveyed grid must be established over such localities in order to pinpoint exactly where significant variations in rock properties occur.

Detailed geophysical surveys are then conducted on the ground by magnetometer or other instruments. Two of the most popular current techniques are induced polarization and resistivity. They measure electrical potential and electrical resistance. Three additional techniques for detailed analyses are gravity meters, which measure variations in rock density; seismometers, which measure the shock waves from artifically generated earthquakes; and the well-known geiger counters and scintillometers, which measure radioactivity.

Prospector with scintillometer checking gneissic rock for radioactivity

Field geochemical test for metals

Ronka EM instrument for detecting mineral concentrations

Another of the specific approaches, one that has been very useful in the Cordillera, is the detailed geochemical survey, in which the soils and foliage of an area are analysed to determine the concentrations of metals present. The theory behind this approach is that the metals from underlying mineralization are gradually incorporated into the soil horizons above, usually close to the mineralization or in a dispersion pattern that can be traced back to the metallic source.

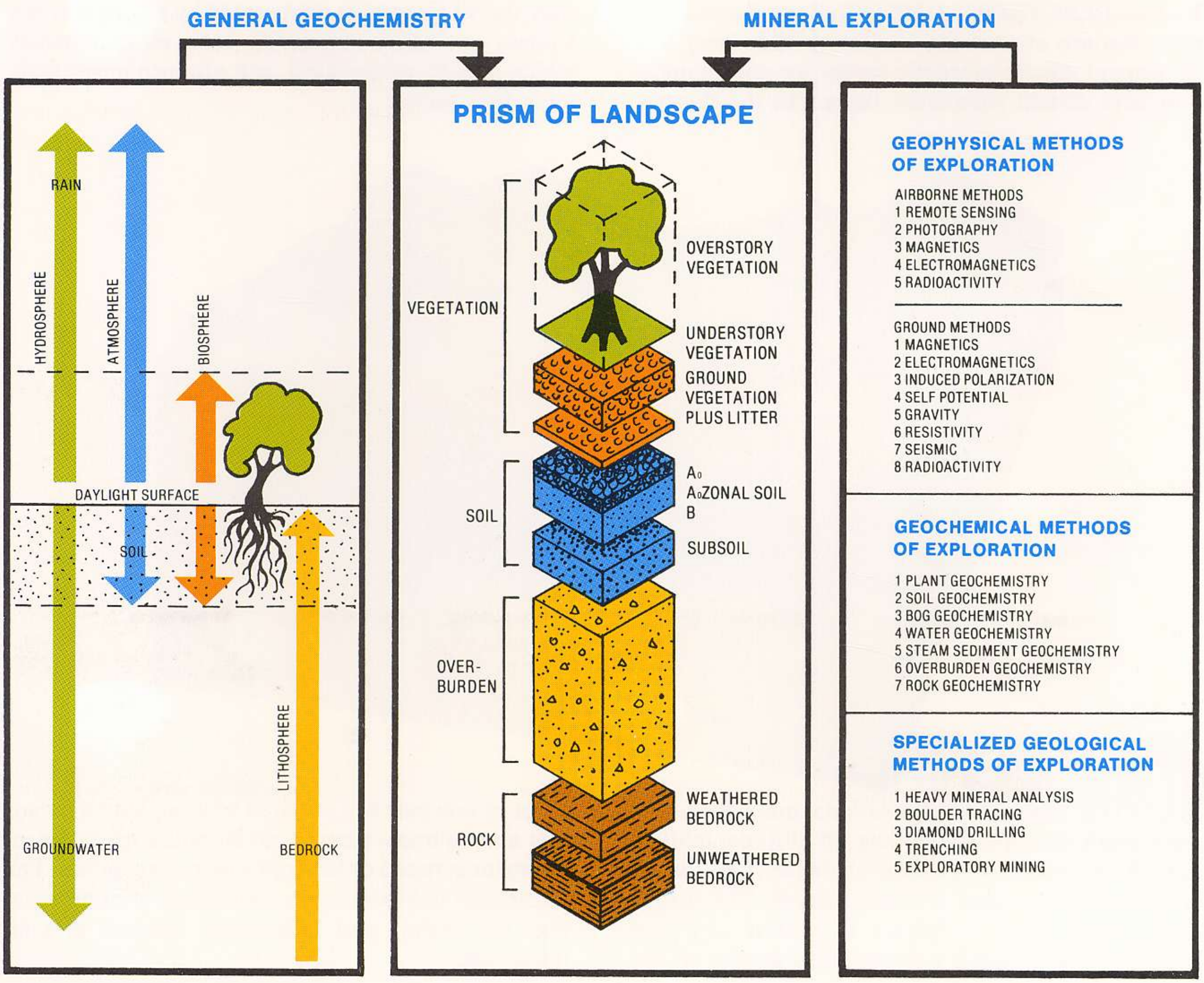
Exploration and the discovery of an orebody, even a rich one, are only the preliminaries to the long process of development. The property has to be investigated in greater detail. This may involve sinking shafts and digging underground adits or small open pits, all with the purpose of finding out how large and what grade the deposit is, how it can best be removed from the ground, and whether the ore is amenable to separation, concentration, and smelting.

Detailed studies of the mine can establish three things: the time required to get ready for production, the ideal rate of ore output, and the life of the mine based on that output.

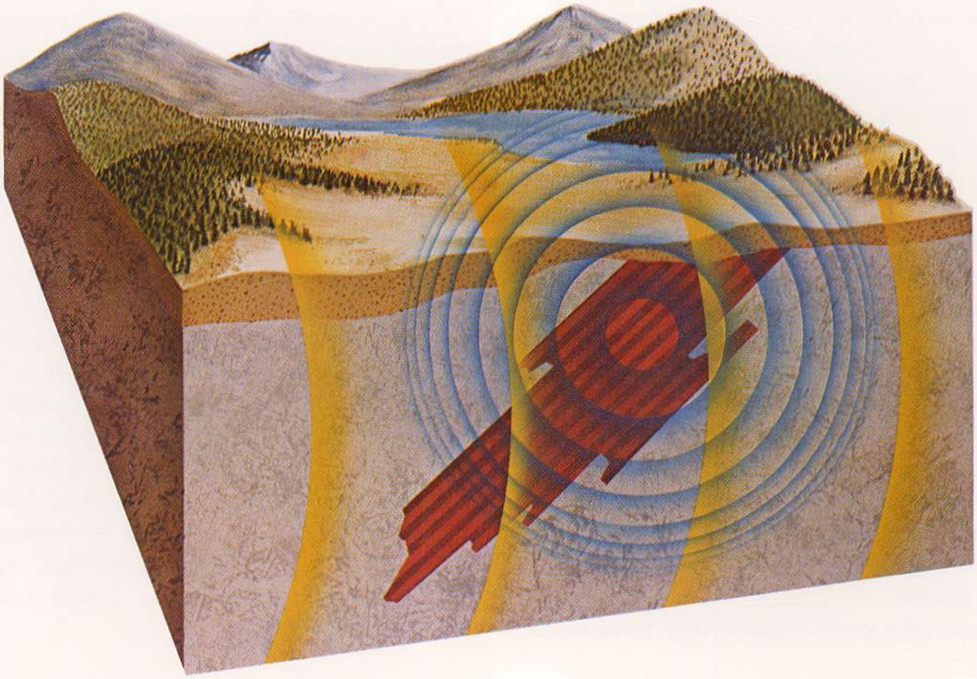
These steps take years because they have to be matched with another set of developments: financing, ensuring markets, building roads, establishing all the accommodations and services needed, and providing for proper environmental controls before and during operations and after the mining cycle is completed.

There is one particularly difficult phase of development — fixing the market price of the mineral. The future prices of the metals have to be estimated. This is because firm contracts have to be made several years ahead of delivery. Future price estimation is a tricky business. Tariffs can be imposed in metal-importing countries, trade restrictions can be made at source, and inflation can hit a country unexpectedly and completely upset price levels. New mines opening in other countries can change the existing pattern of international supply and demand.

When the oil crisis hit the world in 1973 and all costs soared, the prices of British Columbia's mineral exports to Japan had to stay at previously agreed levels. Mining profits dropped. This was not foreseen, nor could it have been. It was just part of the risk factor in mining.

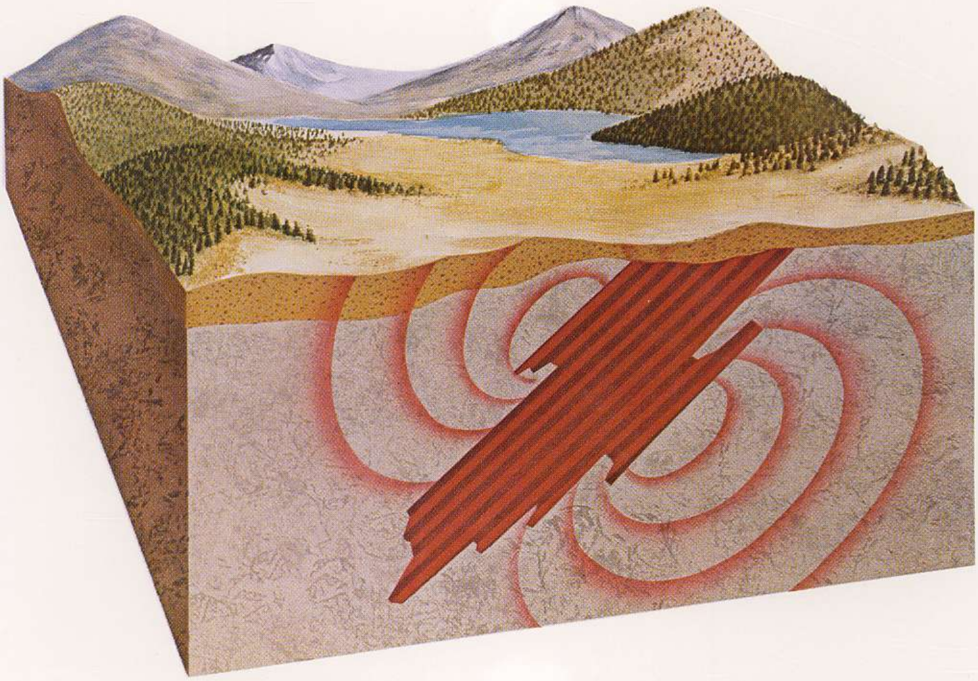


EXPLORATION TECHNIQUES (from Placer Development Limited)

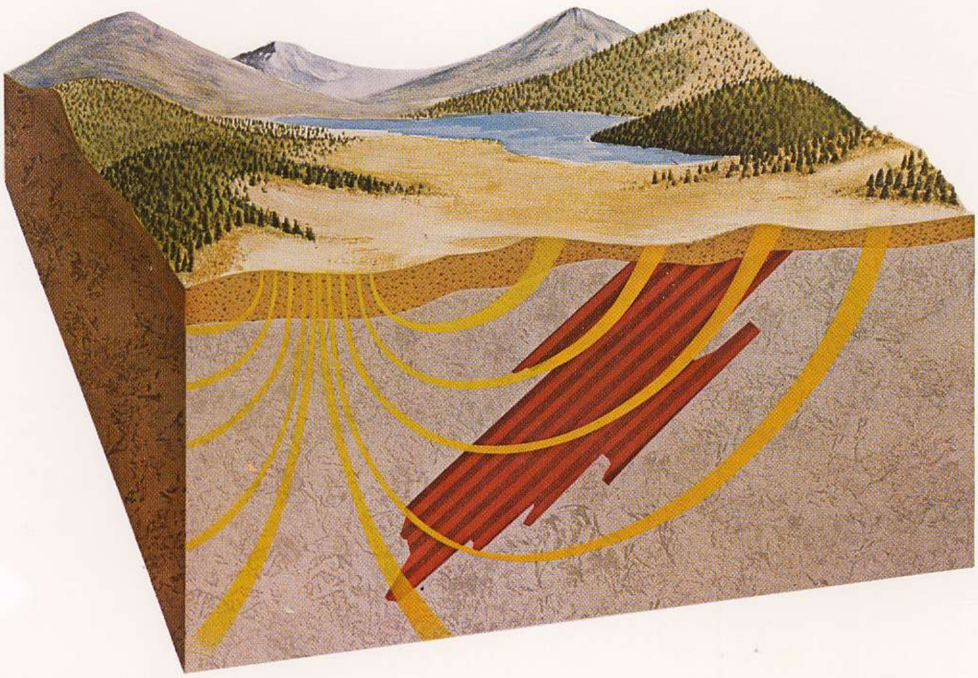


VLF — ELECTROMAGNETICS Powerful military radio stations around the world use VLF (very low frequency) electro-magnetic waves for communication with distant submarine fleets. (In the illustration, the VLF signal is represented by yellow waves). Certain geological structures, such as fault zones which may be mineralized, will produce measurable secondary waves.

GRAVITY The earth's gravitational pull changes by very small amounts depending on altitude, latitude and the presence or absence of dense rock formations under the point of measurement. The instrument which detects changes in gravity — a gravimeter — can register a variation in gravity on the order of one part per hundred million, which means that a measurable change can be noted when the instrument is raised or lowered a mere two inches. The illustration indicates how a dense area of mineralization will distort and measurably increase gravitational pull.



SELF-POTENTIAL Groundwater can act on a massive sulphide orebody to produce a weak electric charge (battery action). Systematic measurements of voltages at the surface may show a significant change when massive sulphide mineralization is present beneath the surface.



INDUCED POLARIZATION A field of electricity can be created in the ground by passing a measured amount of electric current through it using two electrodes and a generator. By measuring the voltage caused by this field with a second pair of electrodes a known distance away, the geophysicist can calculate the electrical property of the ground known as resistivity. Where metallic minerals are present, even in concentrations as low as 0.5%, the ground can also become charged by the electric field. This charging phenomenon is called induced polarization (I.P.) and can be measured in several ways.

Sullivan Mine, underground railway station and ore train

Underground Operations

Underground mining varies in complexity all the way from a simple, single level operation with a few lateral workings to a deep complex mine with many levels, and with underground networks of communications and several rock crushers. British Columbia's biggest underground operation is Sullivan, Cominco's huge lead-zinc-silver mine near Kimberley. Over the past 70 years more than 100 million tonnes of ore have been extracted, and 55 million tonnes still remain to be taken out.

The story of the discovery of the Sullivan as told by one of the original discoverers, Walter Burchett, gives a picture of exploration in the 1890's. It also reveals something of the casual nature of an initial discovery.

I was born in Springfield, Illinois, in 1867. My parents had come from England in the late fifties and had settled in that part of the United States. Later we were to move to Kansas, and eventually to Spokane, Washington, where I grew up and became infected with the prospecting fever that was spreading everywhere with the discovery of the great mines both east and north of Spokane.

Probably influenced by the example of my parents, I took out a pre-exemption, while still in my very early twenties, a few miles from Colbert, Washington, in the northern part of Spokane County; but the prospect of finding a mine and becoming rich was a strong desire in me and, just before my 25th birthday, I set out for Clarks Fork, Idaho, which was the jumping-off place for many a venturous prospecting party.

It was in Clarks Fork that I met E.C. 'Ed' Smith. He was a man who has prospected much of Idaho and had become one of the better-known citizens of the northern section of that state — to the point of being elected to the Idaho legislature. Smith suggested the trip into British Columbia. Rumors of great strikes were reaching south and there was the possibility of getting in on the ground floor of something good.

We boarded the little boat which plied between Bonners Ferry and Kootenay Lake at 3 a.m., loaded with provisions and supplies calculated to keep two men in wild country for a month or two, and journeyed north to Kaslo. Kaslo was a raw mining town, a junction point for working through the Slocan or out of Nelson. Working back behind the town, we were soon over the watershed and prospecting in the Slocan Country.

The hike over to Fort Steele from the east shore of Kootenay Lake was no child's play in these days. It was a major undertaking through little-known country. The rough country we were traversing had been anticipated but as day lengthened into week and week into month we wondered if we had been too optimistic of our chances after all.

With some help from Indians at St. Mary's Mission who gave us food, we were able to make it to Fort Steele. 'The Fort' talked of great dumps of galena ore at the North Star and the prettiest showing ever seen in that part of the country. That settled our eventual destination. We must see this North Star.

The people of Fort Steele had not exaggerated. When we reached Mark Creek and looked at the showings on the open cuts in the North Star they seemed too good to be real. Great piles of rich-looking ores lay all about. After a hasty conference we decided to cross the creek, split our party into two, and prospect the opposite hillside.

Here it was that I made the discovery that was to be the Sullivan. The float I picked up on my way up the hill looked just as good as anything I had seen on the other side of the creek, and I called my partner up to where I was. He too, was impressed and we wasted no time getting into contact with the others and tracking down the source of this promising lead.

That initial discovery was made in 1892. Between 1896 and 1899 some surface stripping was carried out on the property and several small drifts were driven. In 1900 an extension of the Canadian Pacific Railway from Cranbrook to Kimberley made possible the shipping of Sullivan ores to smelters at Marysville and Trail. By 1914 the Sullivan was the largest lead producer in Canada in spite of a great deal of difficulty encountered in separating out the lead content from the sulphide ores.

Zinc sulphide is found in large quantities in the Sullivan ores and, around 1915, attempts were made to extract this mineral. But traditional mechanical and magnetic methods failed and the breakthrough in processing this mineral had to await the discovery of a new method, that of froth flotation.

Finely ground sulphide minerals are treated with chemicals which make them water-repellant and 'air-loving.' When a stream of fine bubbles is introduced, the mineral particles attach themselves to the bubbles and rise to the surface. This is the basic principle of flotation separation.

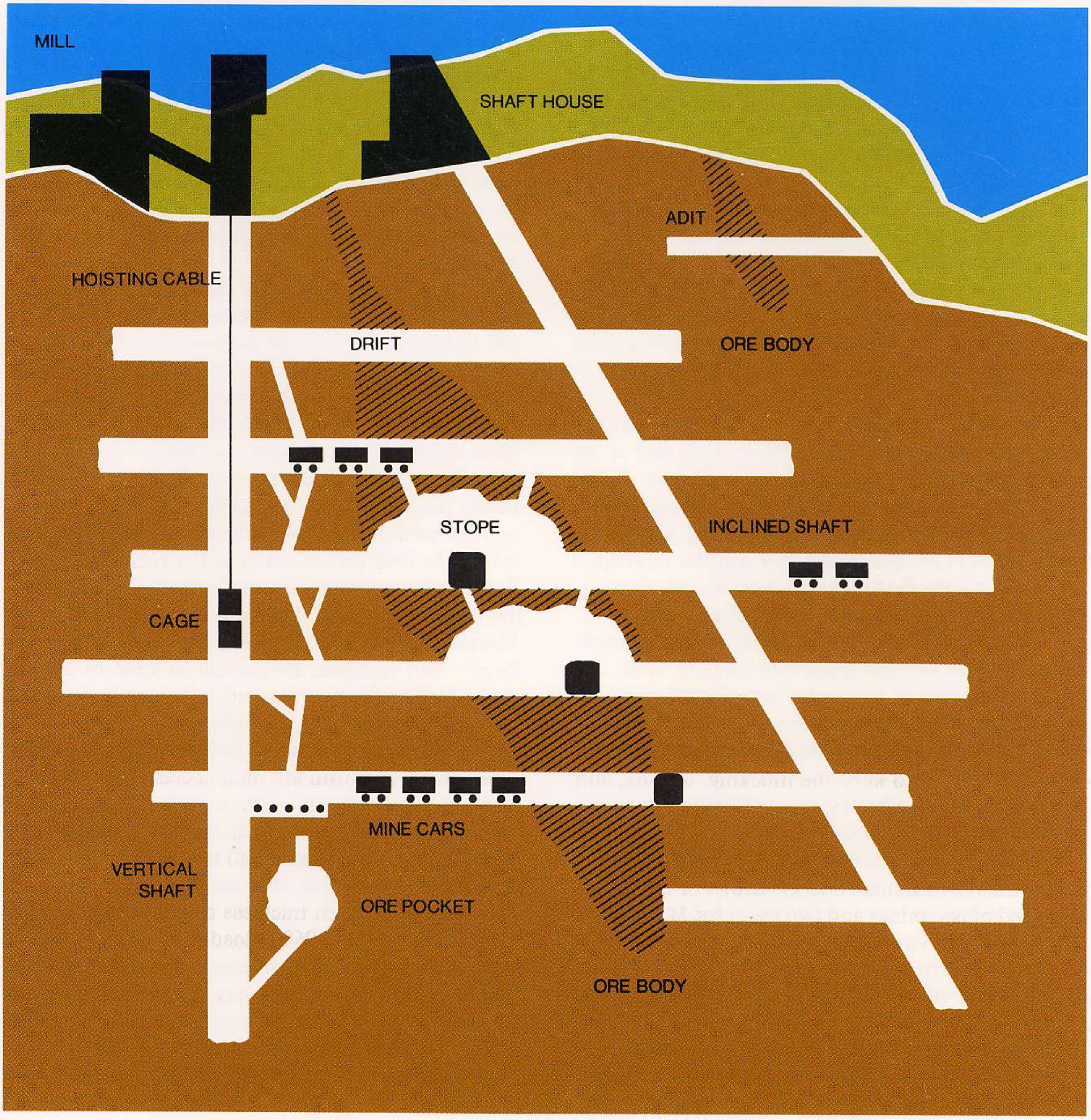
The process can be refined by the addition of other chemicals. Pine oil, for example, when added to water, makes a stable froth so that, when air is blown into the flotation cell, the froth carries the minerals to the surface where they are skimmed off.

Other chemicals refine the process still further by allowing some sulphides to rise to the surface ahead of others. In this way the various minerals are separated out both from the waste material and from one another.

The kinds of operations found in an underground mine are illustrated on page 30. In the case of the Sullivan, the main portal leading into the 'hill' is an adit at approximately 1,200 metres above sea level. Ore extraction is carried on both upward and downward. There are fourteen levels, from approximately 1,400 metres to 830 metres. Three underground crushers reduce the ore to 5 centimetres diameter before it is taken to the surface.

The underground terminus of the rail line leading in through the main portal looks like a major railway switching yard moved indoors. Many kilometres of trackage fan out to serve the interior of the mine. From the main crushing station the broken ore is moved to the concentrator, 6 kilometres away, by 36-inch (91.44-centimetre) gauge mine trains, each forty

CROSS-SECTION OF AN UNDERGROUND MINE



Drilling, Sullivan Mine

Preparing blast, Sullivan Mine

ore cars in length.

A great deal of the productivity of underground mining is due to the changing technology of the past 40 years. Shaft sinking, for example, has come a long way since the 1930's. Practically all of the mucking in those days was done by hand shovels. Today it is done by bucket loaders.

Think of the human energy required to shovel 96 tonnes of wet muck off the rough confined rock bottom of a shaft. The work was so back-breaking that it was common to employ sixteen miners on every shift in order to keep the mucking, drilling, and blasting cycles on schedule.

Lateral mine development was not quite as demanding as shaft sinking. However, it too required large amounts of human energy. Crews of the 1930's consisted of one miner and two muckers. Working as a team they advanced their 2-metre by 2.5-metre headings 2 metres at a time.

It required a lot of skill and perseverance to complete a round with the 'water leyners,' the newly invented wet-drilling machines of those days. They were much slower than the pneumatic rock drills in use today. They were fitted with a hand-operated crank to advance the drillsteel. They were capable of drilling twelve 2-metre holes in hardrock each shift.

In 1932 an air-powered mucking machine was invented. In 1939, when many British Columbia mines began to re-open at the end of the Depression, there was a shortage of underground labour, and these mucking machines were placed in all mines. It then became the practice to employ one miner and one mucking-machine operator. Thus the mucking machine replaced one hand shoveller in each shift.

Later, with the 'jumbo drilling' employed in some mines and with six high speed hydraulic rock drills fitted to a mobile carriage and operated by one drill operator and one mucking-machine operator at the face, it became possible to quadruple production in every shift.

Still later, when trackless mining came into extensive use in the 1960's, load-haul-dump vehicles operated by one man increased production quotas far beyond the fondest dreams of earlier underground miners. (See page 17).

Because of the fantastic lead-zinc-silver wealth of the Sullivan, British Columbia's metallurgical industry is concentrated in that region of the Province.

The Trail complex has become a world-scale industrial centre. The zinc refinery alone is the world's largest. It handles 5 per cent of the world's zinc production. Trail also refines almost all of British Columbia's lead and silver output plus varying amounts of gold, bismuth, cadmium, indium, tin, and antimony. It also produces chemical fertilizers and industrial chemicals.

Zinc has been used as a steel coating for over 130 years. It effectively prevents rust by one unique property. When any scratch exposes the underlying steel, the action of rusting attacks the zinc in preference to the steel. Lead has been used since Roman times for water pipes and to cover roofs. These are still important uses. Use for batteries, pigments, and additives for petroleum are modern uses that are decreasing while use as sheathing, sound proofing, and shielding are increasing.

Finely ground lead and zinc concentrates arrive in covered railcars to be smelted and refined in the Trail metallurgical complex. The lead is first 'sintered' before entering the blast furnace, the first step in the smelting process. Sintering removes the sulphur dioxide, to be used in the manufacture of sulphuric acid. It also reduces the lead concentrates to lead oxide. The lead then passes through the blast furnace and the drossing plant to emerge as lead bullion ready for electrolytic refining.

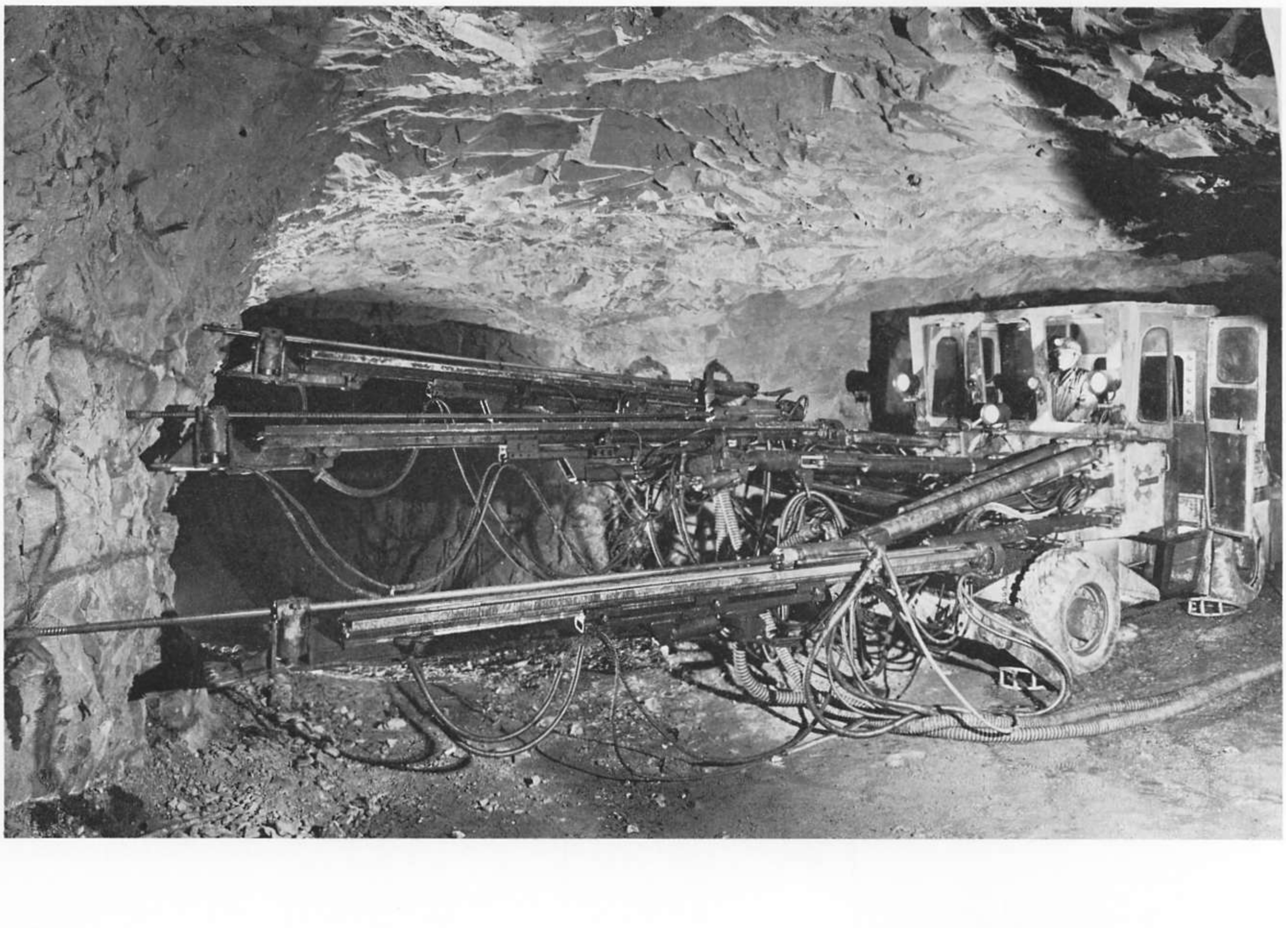
At the lead refinery an electric current carries anode lead into solution and plates it on cathodes. These cathodes are removed, cleaned, remelted, purified further, and finally cast into lead pigs for market.

The zinc goes through a different process in preparation for electrolytic refining. The roasters first dry the concentrate and burn off the sulphur. The heat from the roaster also converts the zinc sulphide into a zinc oxide. The sulphur dioxide gas is again used to make sulphuric acid which in turn is used to manufacture industrial chemicals and chemical fertilizers.

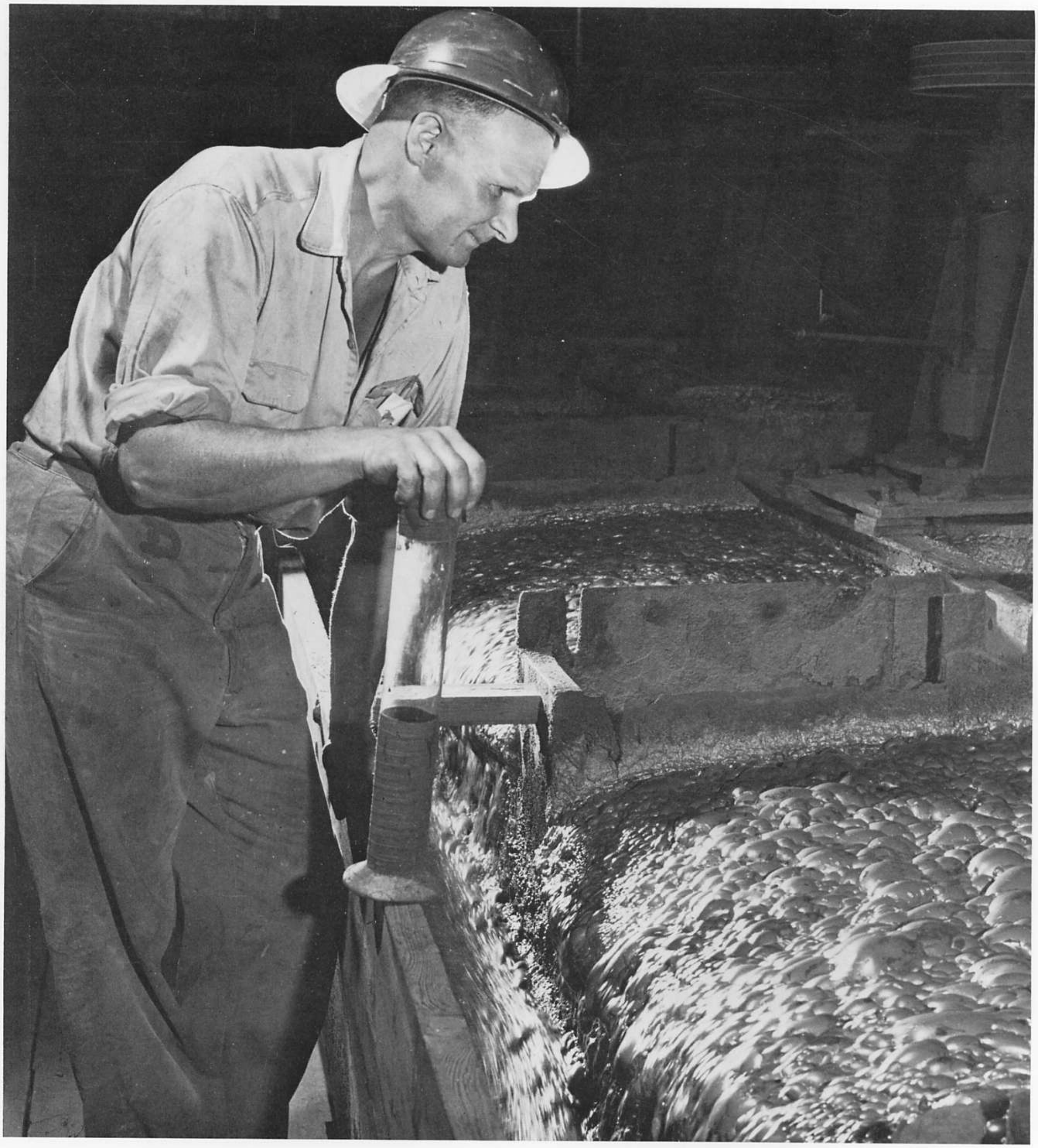
At the zinc refinery, an electric current passes from each anode of silver-lead alloy to a cathode of high-grade aluminum. The zinc is deposited on both sides of the cathode which is then remelted and cast into a slab for shipment to world markets.

Almost all of the zinc, lead and silver mined in British Columbia, plus substantial quantities of ore imported from other parts of Canada, Africa, Europe, United States, Latin America, and other areas, are manufactured into metals at Trail.

Jumbo drill machine, Sullivan Mine

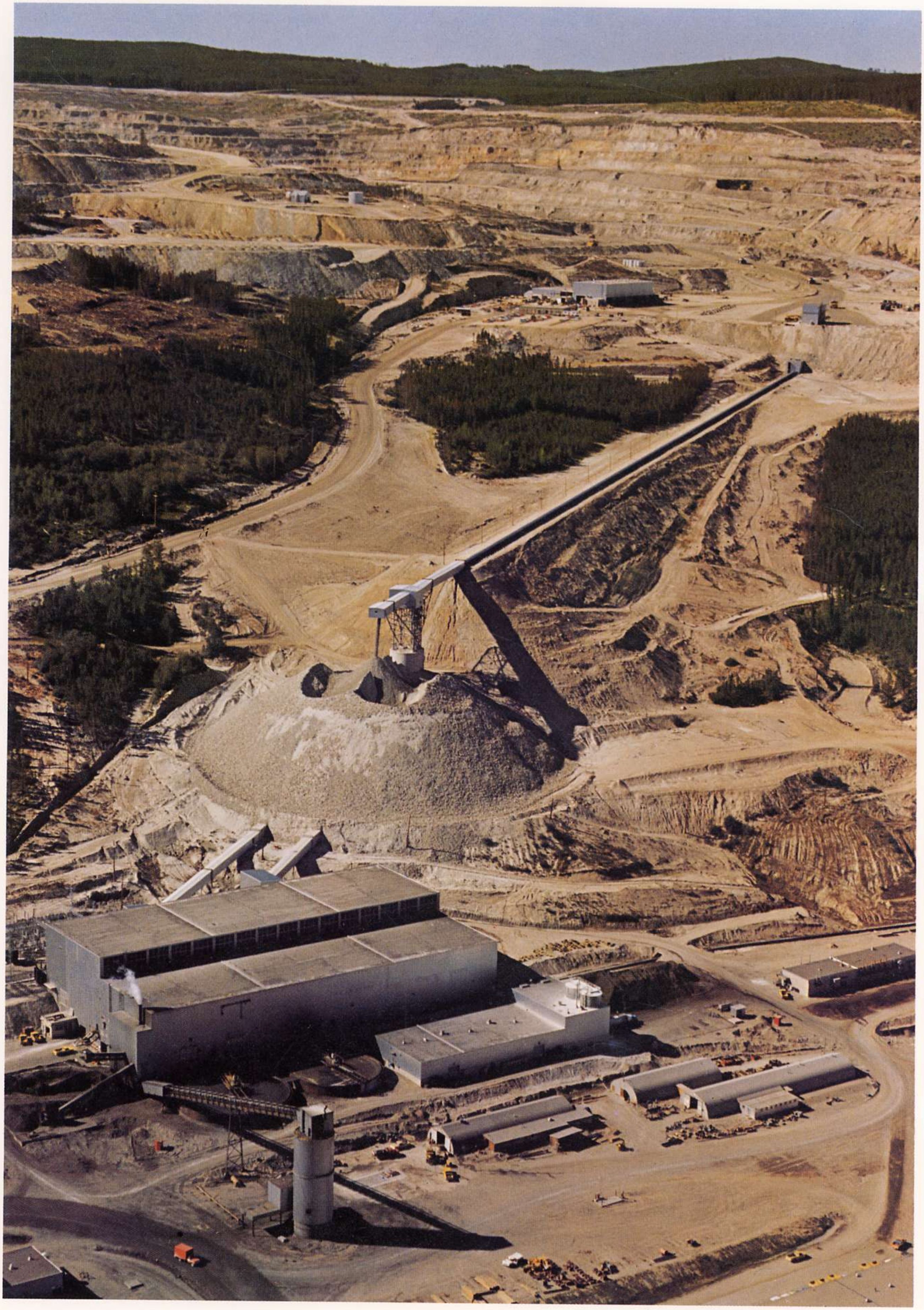


Trail, B.C., site of one of the world's major lead-zinc smelting complexes



The Metal Flotation Process —
lead/zinc flotation cells,
Kimberley concentrator

The zinc electrolytic process room
at Cominco's Trail metallurgical operations



Lornex Mining, Highland Valley, showing concentrator plant in foreground, coarse ore stockpile beyond, and conveyor carrying crushed ore from bottom of open pit in background.

Open Pit Operations

Copper is by far the most valuable metal in the British Columbia mining world. Its total value of production is four times that of its closest competitor — zinc. Eighty per cent of British Columbia's copper output now comes from open pit operations.

First recorded production was in 1894 from the Silver King property in Nelson. The mine produced a mixture of silver and copper and hence the name Silver King. The Rossland mines followed in 1895. Rossland ore was most valuable for gold, with copper a minor component.

These were all small underground operations. Big changes took place after 1890 when smelters were installed at Greenwood and Phoenix. These two areas provided most of the Province's copper until World War I.

For most of the period 1914 to 1960, total British Columbia production maintained a steady level, with only minor changes — a response to world prices. Then, in the 1960's, came the big open pit operations, especially those in the Highland Valley, and production soared.

The opening of the Bethlehem porphyry copper open pit operation in the Highland Valley in 1962 marked the beginning of a new phase of large volume, low-grade ore extraction.

The first signs of copper were spotted by prospectors in 1889. Hopes raised by these first finds were soon crushed because, while the copper was there, it was widely scattered in small quantities, 5 kilograms of it in every tonne of ore, much too little for economic development at that time.

For more than 50 years the ore lay untouched, except for some mining of two vein deposits. Then, in early 1950's, it became clear that, if large-scale open pit mining could be carried out, like similar ventures in southwestern United States, Chile, and Peru, the large volume of ore would make the operation economically worthwhile. Prospector-developer H.H. (Spud) Huestis is credited with the foresight and dedication which resulted in the successful production of this first Canadian low-grade porphyry open pit mine.

In the open pit method, ore and waste rock are taken out in a series of benches extending completely around the pit. Step by step, the pit is deepened and enlarged as each bench is drilled and blasted and the broken rock is trucked to the concentrator for processing.

In the blasting operations the bench rock is drilled in 8-metre by 8-metre patterns of vertical holes, each 25 centimetres in diameter and 12 metres deep. Each blast shatters 60,000 tonnes of rock.

Ore delivered to the concentrator is processed by crushing, grinding, and flotation. By separating the waste products, the original 5 kilograms copper per tonne in the ore is thus upgraded to 300 kilograms per tonne.

Crushing and grinding is a 12-stage operation in which each stage reduces the particle size of the incoming rock. Finally, the big rock fragments from the mine have been reduced to a fine powder ready for the flotation process.

Flotation is the usual method of separating copper mineral particles from waste materials. It is similar to the method described for the lead-zinc ore of the Sullivan.

At the surface the coated mineral particles plus some waste materials are fed through additional flotation stages to remove more of the waste. The waste materials are transported as a slurry to the tailings pond. One primary stage and three further stages of flotation are necessary to produce a concentrate meeting the required copper standard.

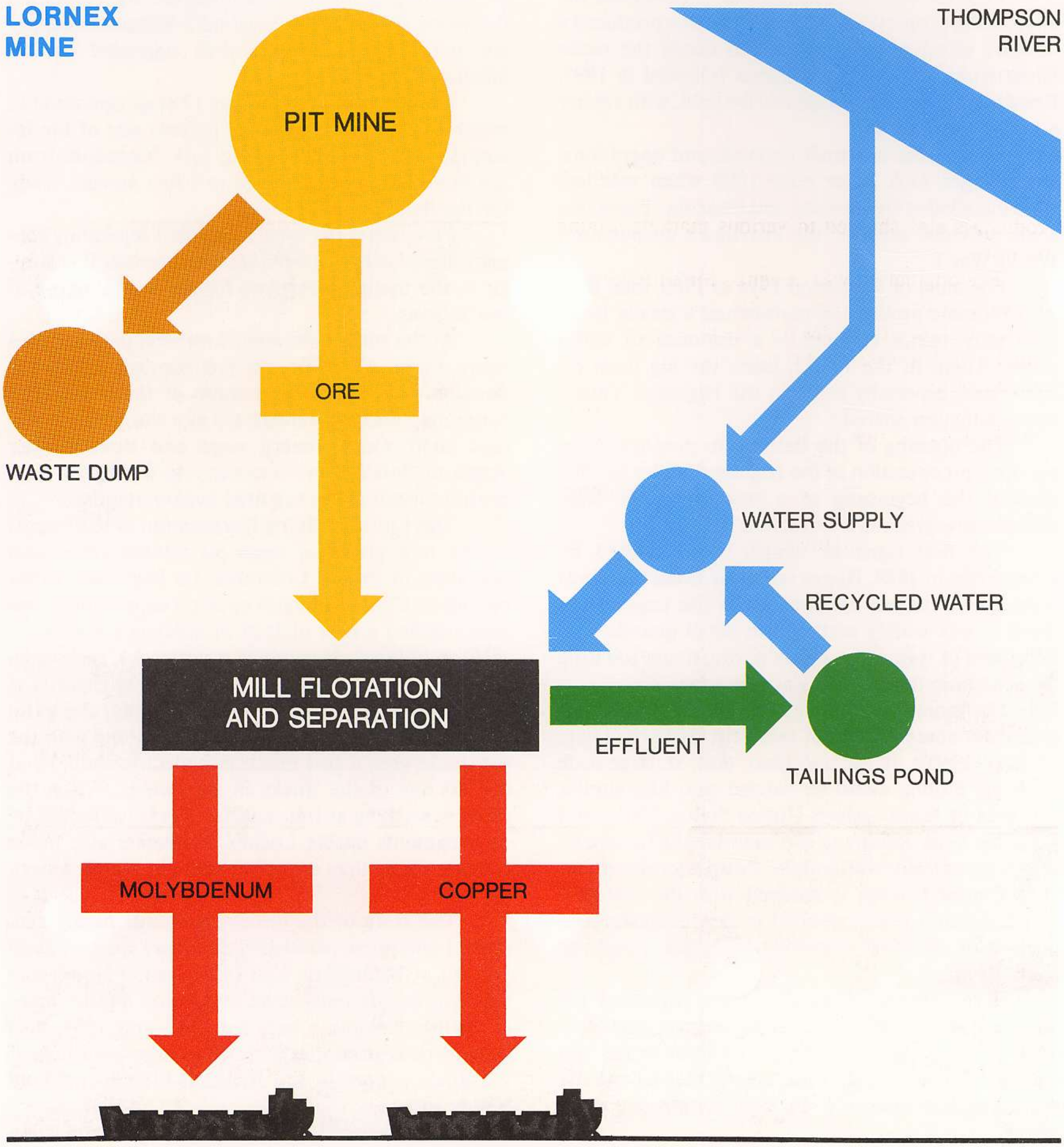
The Lornex Mining Corporation is the biggest of the new group of open pit mining companies operating in British Columbia. Its Highland Valley operation, Canada's largest open pit copper mine, has now reached a new plateau of efficiency and large-scale technology. It employs supertrucks, each capable of carrying 235 tonnes. This carrying capacity is twice that of the earlier type of truck but the extra fuel costs are only 50 per cent more. Along with the big trucks goes a new mammoth electric shovel that can fill one of the trucks in six swipes. When the mine is working at full capacity, these technological developments enable Lornex to operate at a lower cost per tonne than any other mine in North America.

The story of the discovery of this highly successful enterprise parallels the pioneer work of Spud Huestis at Bethlehem. Egil Lorntzsen, a Norwegian who thoroughly prospected the central interior areas of British Columbia between 1934 and 1954, also became convinced that there were large quantities of low-grade copper in the Ashcroft-Merritt-Highland Valley area.

In January of 1955 he began compass and chain surveying in the area. The geology of the north side of the valley, mapped by Dr. J. M. Carr for the Ministry of Mines and Petroleum Resources, indicated to Lorntzsen that the favourable terrain already being explored at Bethlehem Copper extended some kilometres southward. Wide distribution of low-grade copper in the valley had been known since World War I. This was further documented in 1957 by professors White, Thompson, and McTaggart of the University of British Columbia. Lorntzsen knew that only major companies with ample capital for exploration could afford to carry out the necessary work, for the district was covered with glacial till, moraines, and eskers.

Because of an absence of capital, he decided to explore the properties as best he could in the old-fashioned way of closely scrutinizing all of the meagre number of outcroppings. Wherever he broke open rock where the granite was highly fractured, he discovered that the planes of the fractures were coated with minor amounts of copper mineralization. Yet there were no outward signs of copper.

As he was tramping along the edge of one wide, deep gully, Lorntzsen noticed that the opposite side



was strewn with altered granite of a type that commonly was associated with ore, barely protruding through the glacial moraine. That was the final piece of evidence that convinced him to take action. He hired a bulldozer and started digging.

After trenching 250 metres in one direction, then another 250 metres in a parallel trench nearby he was able to uncover part of a high low-grade porphyry copper orebody. A consulting geologist and former professor of geology, Dr. A. C. Skerl, confirmed the find. It was not long before the significance of the find attracted large amounts of venture capital. Financing snowballed.

Full operations began in 1972. Eventually the pit will be 600 metres deep, 3 kilometres long, and 1.5 kilometres wide. Every 24 hours, 110,000 tonnes of rock and overburden, plus 48,000 tonnes of ore flow continuously from the pit to the concentrating plant.

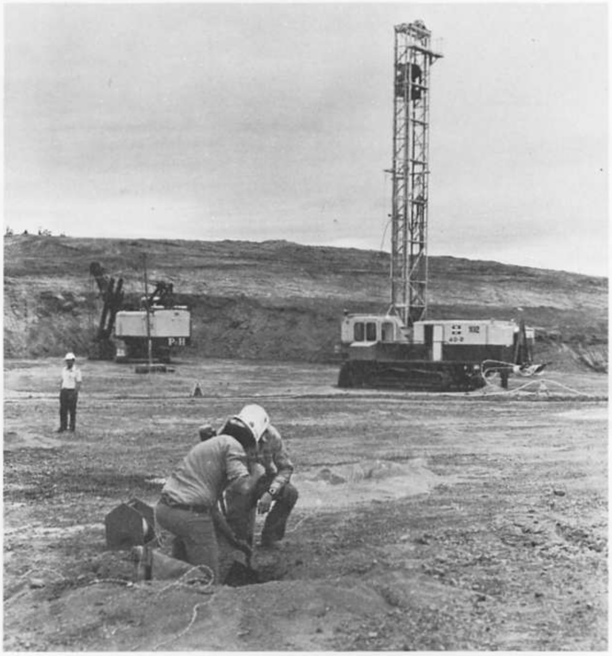
Large quantities of copper concentrate are produced from these ores to fill major contracts with North American and overseas consumers. Molybdenum concentrate, which is the most important by-product, is also shipped to various markets around the world.

The original pit was designed for a life-term of 21 years with total recoverable reserves of 292 million tonnes. Ore grades for this body were determined to be 0.427 per cent copper and 0.014 per cent molybdenum.

After the mine came into production, Lornex was able to do further exploration work, particularly to the south of the existing pit. As a result, ore reserves were increased, first by 150 million tonnes and, more recently, by a further 100 million tonnes. These new finds extend the mine life well beyond the year 2000.

In the mine environment protective system there are water recycling installations, dust control systems, ground maintenance, and reforestation. The amount of water drawn from the Thompson River is a fifth of the total plant requirements. Four-fifths is recycled from the tailings pond, the long 'lake' seen below the Ashcroft-Highland Valley road by the traveller as he approaches the mine. Tests are carried out to make sure that no toxic substance is escaping into the valley streams.

The dumps of waste rock and overburden, as well as the tailings pond, will all be replanted as they



Preparing for blast at Afton open pit mine — note electric shovel and drill machine

Open pit blast at Afton Mine

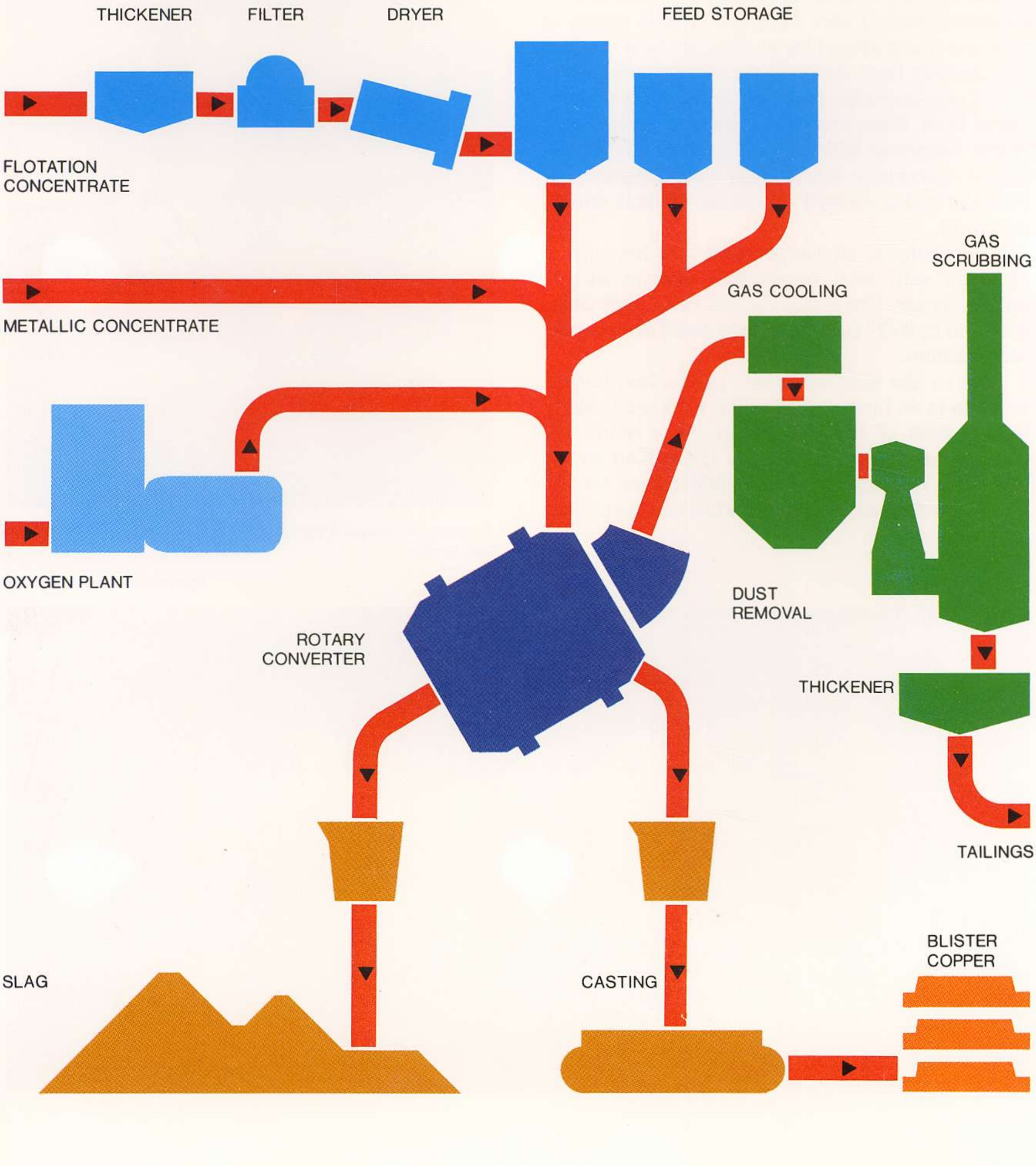
become inactive. Large plastic pipes are used to carry the tailings by gravity from the mill to the pond.

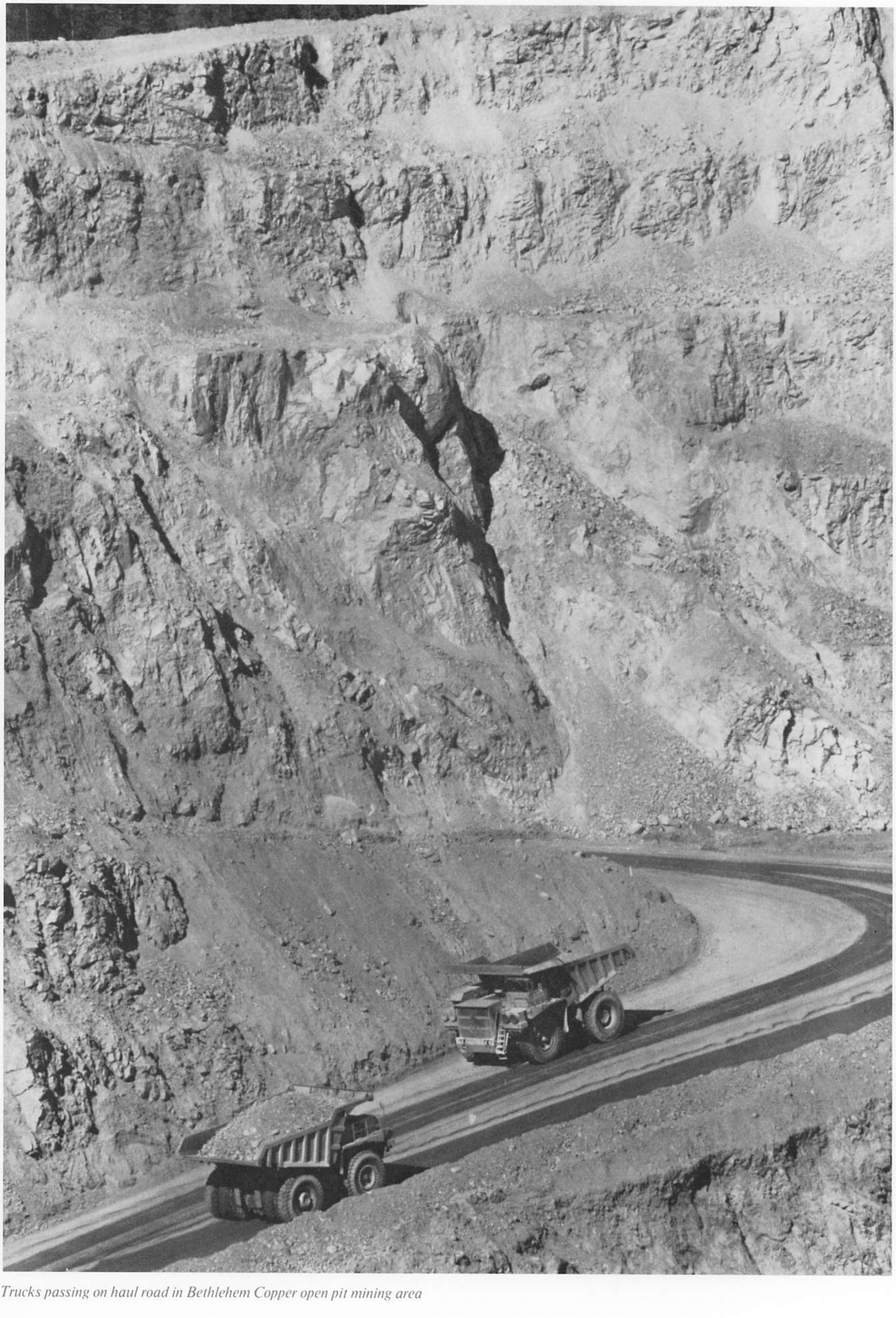
Demand for copper stems from its physical characteristics of conductivity, ductility, malleability, and corrosion resistance. It is an excellent conductor of heat and, except for high-cost silver, it is the best conductor of electricity. It can be drawn out in wires as fine as a human hair or worked into sheets as thin as paper. It is highly resistant to corrosion.

In the post World War II period, copper extraction in British Columbia stopped at the point where the ore had been concentrated into a fine sand of copper minerals that contain a total of 30 per cent copper. Now with the new Afton smelter near Kamloops, the Province is once again involved in the next stage — processing concentrate to metal.

The Afton mine is an open pit operation in its initial stages, but present plans indicate a shift to underground methods in 1992. Proven ore reserves are

AFTON SMELTER FLOWSHEET





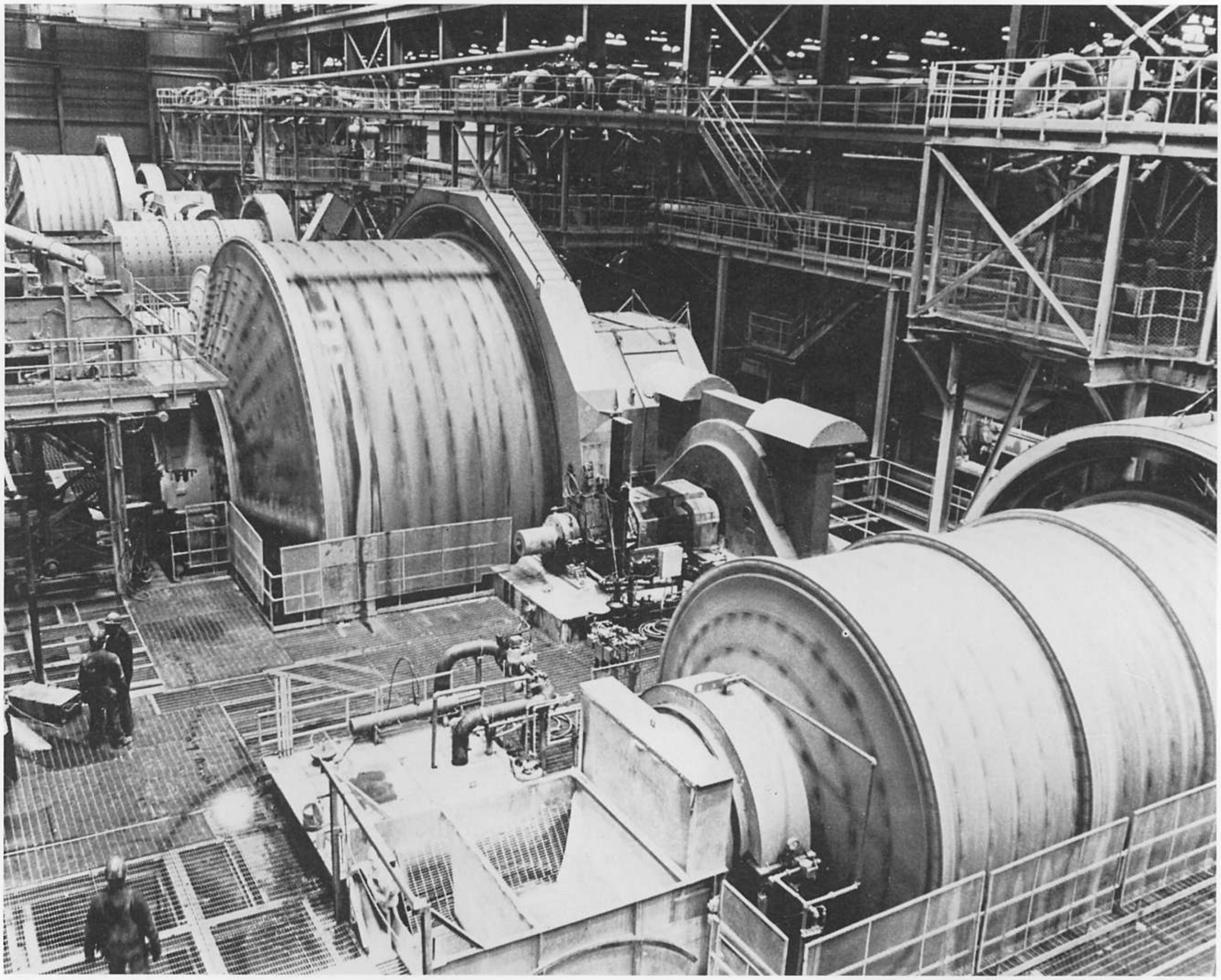
Trucks passing on haul road in Bethlehem Copper open pit mining area

34 million tonnes of 1 per cent copper.

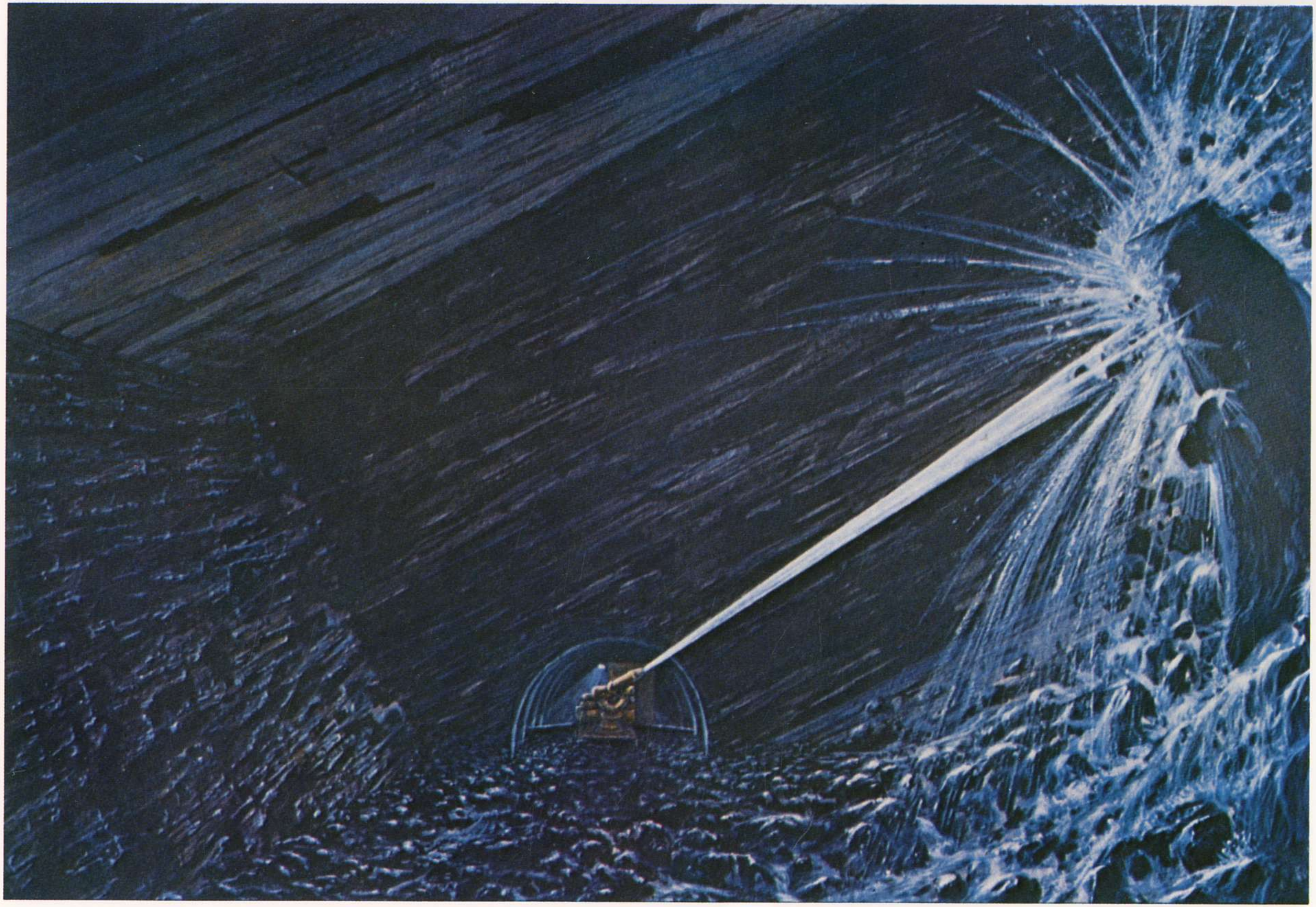
In the refining processes of the smelter, copper concentrate from the mill is first blended with iron and lime to form a suitable charge. This is fed to the conversion furnace and melted. The charge separates into a liquid slag on molten copper. The slag is lighter and floats on top of the copper so it can be skimmed off, cooled, crushed, and recirculated through the mill to recover any remaining small amount of copper. The molten metal is poured into blister copper billets weighing 600 kilograms each. These billets are 99 per cent pure copper.

Gases from the smelter are collected and cleaned to meet provincial air emission standards. The design of the Afton smelter is expected to make it the cleanest in North America.

Primary crusher at Lornex Mine at bottom of open pit



Grinding mills at Lornex concentrator



Graphic illustration of hydraulic coal mining (Kaiser Resources)

Energy

The Arab Oil Crisis of 1973 was a turning point in Canadian attitudes toward energy minerals. At that time some of the countries of Southwest Asia cut off oil exports to North America because of alleged support for Israel in the 1973 Arab-Israeli war. Accelerating rates of consumption of Canadian oil and natural gas resources soon became a matter of serious concern, and alternatives took on new priorities.

Coal and natural gas are British Columbia's main energy minerals. Coal was therefore one of the first to receive renewed consideration as a alternative to oil and gas. Coal had been king of mineral commodities in British Columbia for most of this century but in the 1950's it had been eclipsed by oil and gas — energy resources that were cheaper, cleaner, easier to transport and to use.

Between 1951 and 1961, Canadian coal production fell from 19 million tonnes to 10 million. The chief cause of this was the change from coal-fired to diesel locomotives on all Canadian railways. In the same period, oil consumption increased 400 per cent and gas 800 per cent. A similar trend continued throughout the 1960's.

The 'rediscovery' of coal seemed, at first glance, to be a very reassuring thing in the light of the energy crisis. At present, the known Canadian reserves represent 8,000 tonnes of coal for every man, woman, and child in the country. It is a huge resource, bigger in energy equivalent than all of our oil and gas reserves and more than 90 per cent of it lies beneath western Alberta and eastern British Columbia. In fact it is large enough to provide for our energy needs for 1,000 years if we assume present rates of consumption.

Why then need there be such concern over our depleting oil and gas reserves? Can we not turn to coal? By the time coal is used up we may have solved all the problems of nuclear power generation, or perhaps solar energy will be available on a cost competitive basis.

Unfortunately it is not as simple as that. Most of British Columbia's coal is of the metallurgical variety, used for coking coal in the steel making industry. At present, 90 per cent of production goes to Japan as coking coal. A small amount of non-coking, thermal coal, used for generating electricity, is shipped to Ontario. At present, coal makes almost no contribution to energy production in this Province. However, it does offer a real alternative to oil and natural gas in the future. It can be burned directly in coal-fired thermal electric generating plants, as is now done extensively in Alberta and Ontario. It can also be converted to synthetic gasoline or synthetic natural gas. New technology is needed to make these conversions economical, but the process is virtually the same as that used by Germany during World War II when oil and gas supplies were unavailable to them. Detailed studies are now under way by British Columbia Hydro and Power Authority to utilize the excellent reserves of thermal coal at Hat Creek and to use the thermal coal left over from the mining of metallurgical coal in the Crowsnest field. British Columbia should soon have its first coal-fired electric generating station.

Obviously the old ways of burning coal caused too much ash and smoke for today's pollution-conscious consumers. One experimental approach to this problem proposes to crush the coal, expand it in a special type of burner in such a way that it behaves more like a liquid than a solid. This lowers the flame temperature and thereby reduces pollution.

Mining techniques pose another problem. The large quantities of coal needed today demand methods and machines of a new order. This is especially true when mining is done in mountain areas, and almost all of British Columbia's coal lies in mountain areas.

Fortunately there are developments underway that may resolve the problem of volume production. At the Kaiser Resources operations at Sparwood, for example, very large quantities of metallurgical coal are being extracted and shipped to Japan and other places. Their methods may prove to be the kind of technology needed if coal is to become a major source of energy.

Kaiser Resources is mining a coal deposit that is located at the base of 600 metres of rock in which there are about a dozen other coal seams ranging in thickness from 2 to 15 metres. Shale and sandstone overlie the coal seams.

Volatile contents of the coal range from 18 per cent to 38 per cent and vary with depth — the greater the depth, the lower the volatile content. Kaiser Resources mines a seam from the base of the rock formation which is a low volatile coal. Because erosion has removed the upper seams at the north end of the mine site it is possible to excavate the bottom seam by surface methods.

To reach the coal, overlying shale and sandstone have to be removed; about 13 tonnes for every tonne of coal. Surface mining is continuous with 480 persons employed on production and 420 on equipment maintenance. There are several pits. Mining equipment includes four 19-cubic-metre and four 11-cubic-metre electric shovels; 22 haul trucks each with a capacity of 200 tonnes; 28 haul trucks each with 100 tonnes capacity; seven 30-centimetre drills and one 25-centimetre drill; and a supporting fleet of crawler and rubber-tired dozers and graders.

The mining area includes 350 hectares of mountainous terrain, most of it more than 2,000 metres above sea level. The climate at this elevation and the terrain present special problems. The snowfall averages more than 7.5 metres a year and snow removal is required to maintain haul and access roads. Spring breakup creates a demand for special road maintenance procedures. Low cloud formations and fog occur in late fall or early spring and lighting has been installed on haul roads to improve visibility.

Drilling and blasting is the first stage in removing the overlying rock. Large rotary drills produce 30-centimetre blastholes, 15 metres deep. Eight rows of holes and an average of 140,000 kilograms of explosives are the requirements for each blast. The blast produces 180,000 cubic metres of fragmented rock for removal by shovels and trucks. As more and more rock is removed and the pit floor lowered, the haul roads and the disposal areas are relocated and lowered at intervals of 30 metres.

As much rock as possible is removed near the seam. Then bulldozers push the remaining rock from the hangingwall. They work parallel to the strike of the seam with special hydraulic slopers mounted on the blades along the dip of the coal seam to remove the hangingwall without wasting coal. Although the coal is too hard for free digging, it does not require blasting. Bulldozers break it up and push it down the dip. The loose coal is loaded into trucks and hauled to a central breaker station where it is crushed. It is then transported by means of a conveyor belt through a tunnel, to the raw coal silos at the preparation plant.

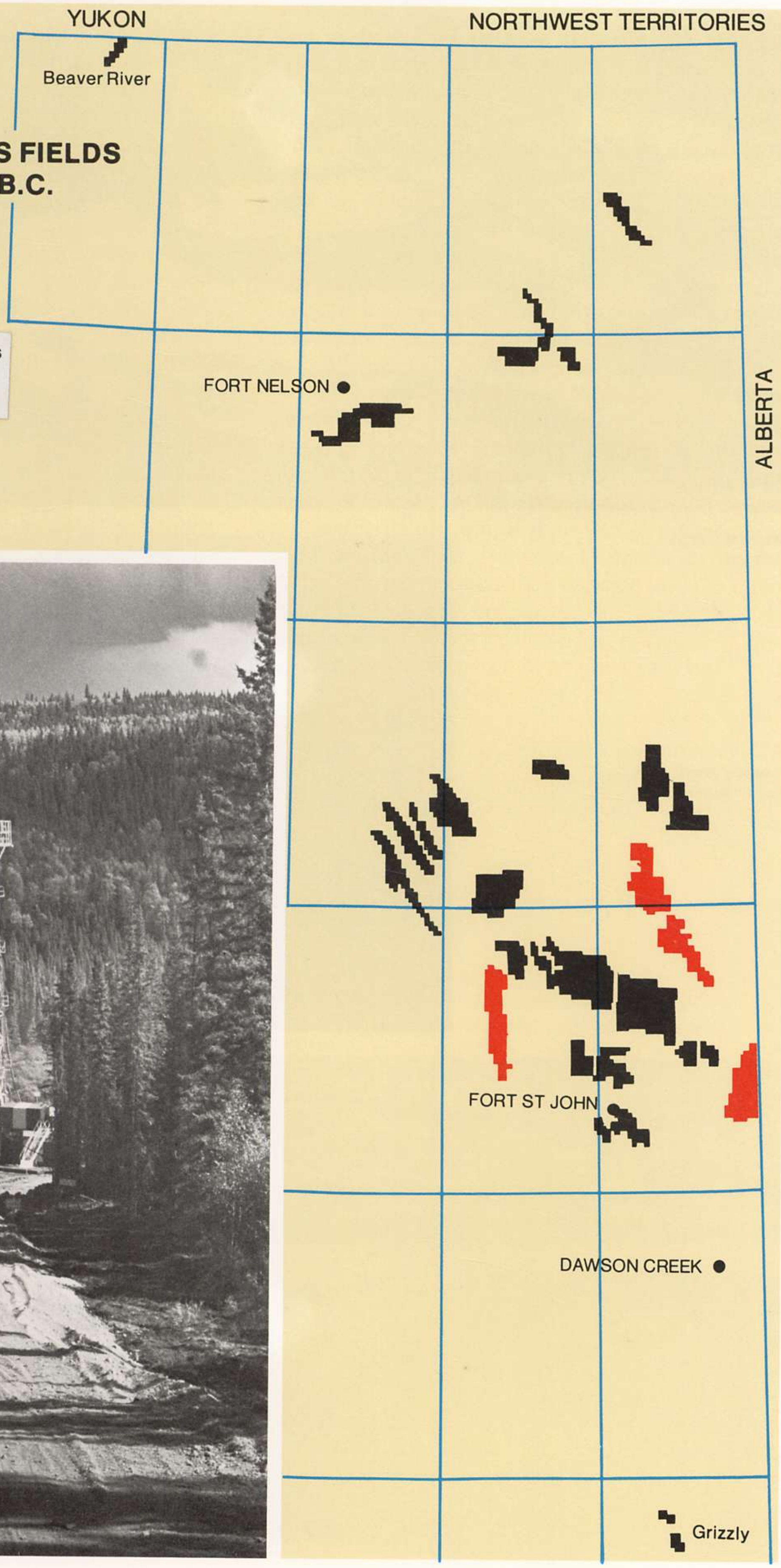
Underground hydraulic mining is quite a different kind of operation. It uses a high-pressure water-jet to dislodge the coal. Combined with water, the coal is flumed out of the mine to a dewatering plant on the surface. The water is separated from the coal by screening and is then recycled into the mine. Hydraulic mining is considered one of the most advanced underground coal mining systems. It provides a greater recovery of the coal seam at lower cost, and with increased safety. Safety is increased because employees are not required to work at the coal face and healthier working conditions are created by the elimination of dust. The operator's cabin is situated 15 metres behind the production area and

Loading coal from face — Kaiser Resources, Sparwood, B.C.

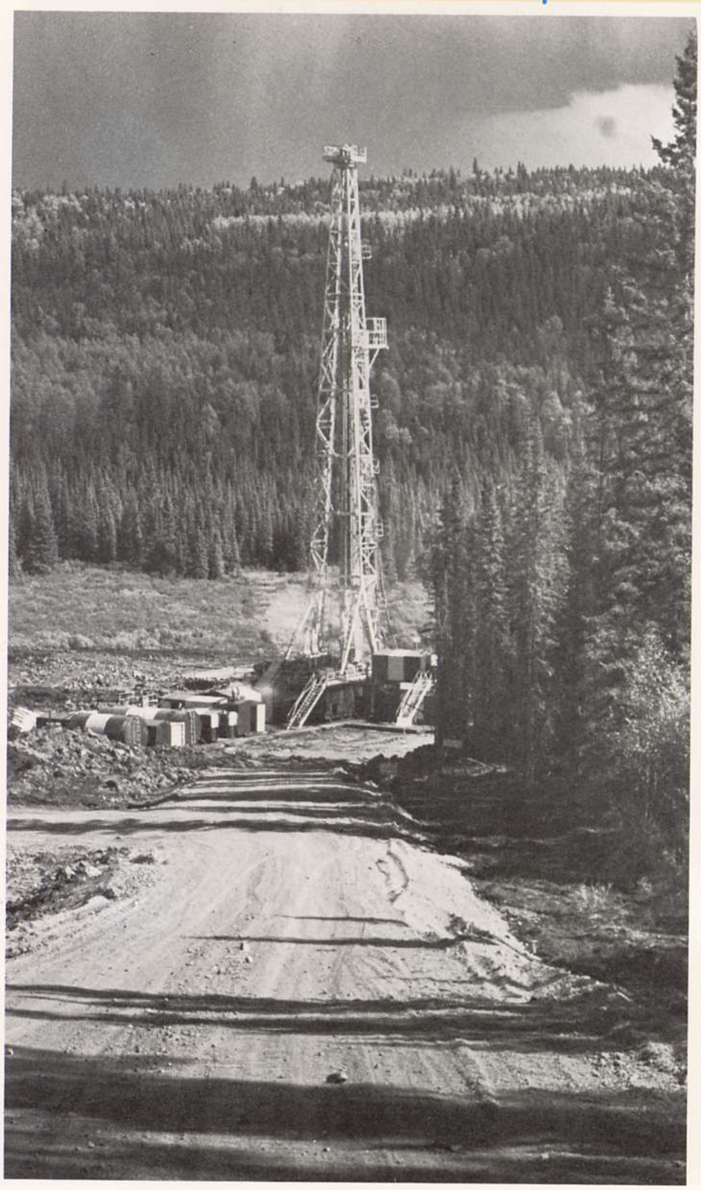
Canadian Pacific unit train.

Removing overburden (Kaiser Resources)

Blast holes on open pit bench (Kaiser Resources)



Oil rig, British Columbia



is in an area of fresh air intake at all times.

Raw coal from both the surface and hydraulic mining operations is washed in the preparation plant to reduce the ash content. The washing medium is denser than coal but not more dense than the shale which therefore sinks. After washing, the coal is conveyed to a thermal dryer to reduce the moisture content. From the dryer, the coal is taken to the clean coal silos.

The clean coal is transported by unit trains from the plant to Roberts Bank, south of Vancouver. Each unit train has 106 cars which are loaded with 100 tonnes per car.

At the port, dumping is automatic. The cars have swivel couplings to allow rotary dumping without uncoupling the cars. As the railway track loops around the terminal site, no backing of trains is necessary. From a hopper underneath the dumper, the coal is taken to ground level where it can be either stockpiled or loaded on to ships.

The distribution areas of Western Canada's coal are shown on page 52. These represent the major coal resources of the nation. The best coals are confined to a belt in the foothills on the eastern flank of the Rocky Mountains. This belt includes the Fernie and Elk basins within the Rockies. Most of this rich coal area is in Alberta but large areas are also in British Columbia — in the Crowsnest Coalfield and in the Peace River area in the northeastern section of the Province.

In the Crowsnest there are four operating mining properties, Kaiser, Fording, Byron Creek, and Coleman, as well as several potential mining properties. In the Peace River there are a number of potential producers and these will be operational as soon as markets and transportation facilities are adequate. At present, the best known Peace River properties are Sukunka and Quintette.

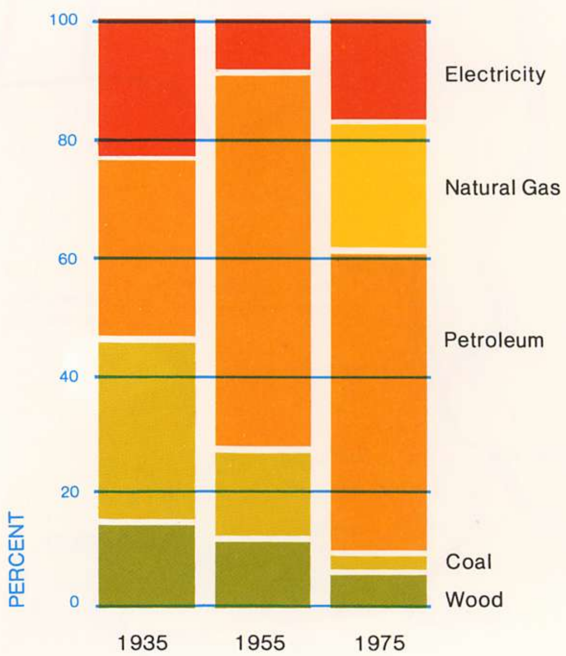
In small basins in the interior, there are lignite fields of which the most important is the thick deposit at Hat Creek. Vancouver Island coalfields were exploited for nearly a hundred years but new reserves have been identified recently near Quinsam Lake in the Comox Coalfield.

Lignite is a dull, brownish earthy material containing 40 per cent moisture. It is the least expensive type of coal. Farther up the cost scale comes bituminous and then anthracite. Anthracite is rich in carbon content — as much as 98 per cent. That means high potential for heat generation.

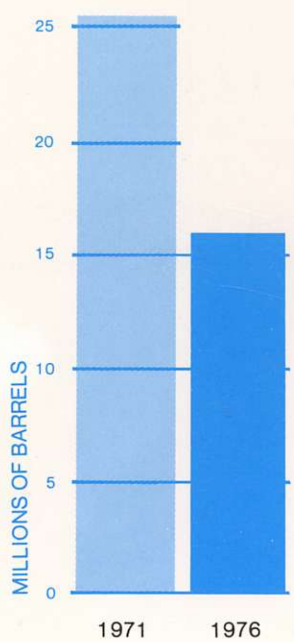
In blast furnace operations, bituminous coal is first heated in coke ovens where no air is present. Liquids evaporate and coal gas is driven off in this process and the residual material is a high carbon content, porous substance that can be used in the smelting of iron ore.

The coal gas by-product from blast furnaces has long been in use in Europe for heating homes and factories. Now, as a result of new refining processes, a type of coal gas has been developed that could substitute for natural gas in British Columbia — just as clean, just as easy to use, and probably just as cheap to produce once it is available in large enough quantities.

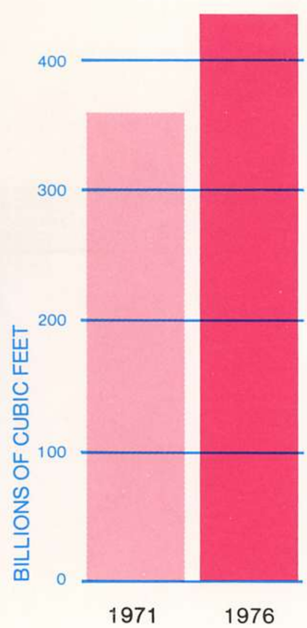
ENERGY USE IN BRITISH COLUMBIA



OIL PRODUCTION IN BRITISH COLUMBIA



GAS PRODUCTION IN BRITISH COLUMBIA



PIPELINES OF BRITISH COLUMBIA
GAS PIPELINE
OIL PIPELINE
ALASKA HIGHWAY
FORT NELSON
Westcoast Transmission Company Limited
Blueberry-Taylor Pipeline Co.
Trans-Prairie Pipelines (B.C.) Ltd.
FORT ST. JOHN
TAYLOR
Northland Utilities Limited
Peace River Transmission Company Limited
CHETWYND
HART HIGHWAY
HIGHWAY 16
PRINCE RUPERT
KITIMAT
Pacific Northern Gas Ltd.
PRINCE GEORGE
Peace River Oil Pipe Line Co. Ltd.
EDMONTON
Trans Mountain Oil Pipe Line Company
Alberta Gas Trunkline Co. Ltd.
KAMLOOPS
CALGARY
KINGSVALE
VERNON
VANCOUVER
Alberta Natural Gas Company
Inland Natural Gas Co. Ltd.
NELSON
KIMBERLEY
VICTORIA
OSOYOOS
TRAIL
Columbia Natural Gas Limited

Natural gas processing plant, Taylor

Westcoast Transmission pipeline welding

Westcoast Transmission pipelaying

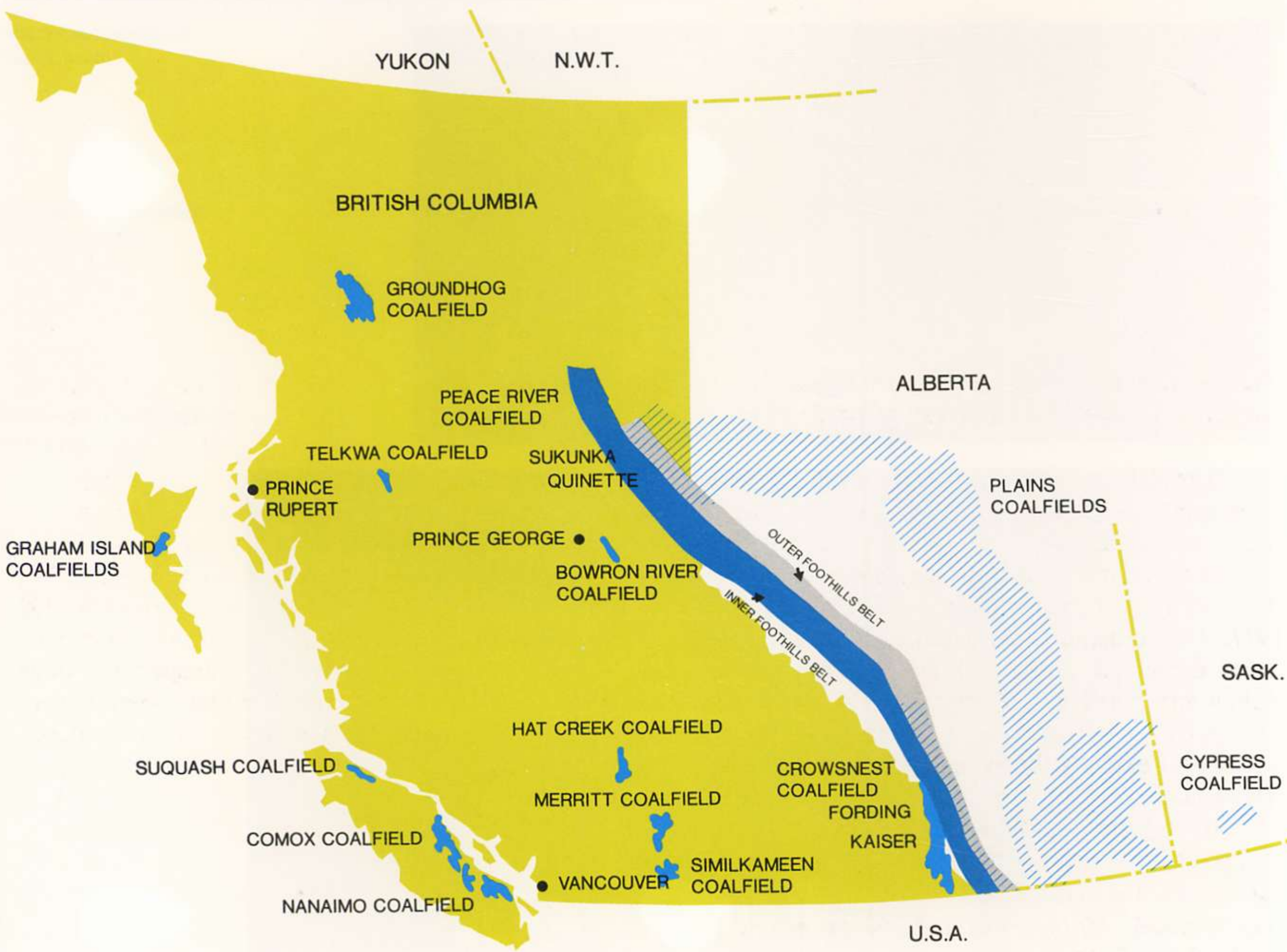
There are several regions of British Columbia that are geologically suitable for the accumulation of oil and gas. To date, however, discoveries of these energy forms have been limited to the northeast part of the Province underlain by a portion of the Western Canadian Sedimentary Basin.

Although exploration for oil and gas in British Columbia has been carried out sporadically for some 80 years, it was not until the late 1940's and early 1950's that drilling began in earnest. The first commercial discovery of gas in the Province was made in 1948 in a well drilled as an extension to the Pouce Coupe gas field in adjacent Alberta. That particular field enabled Dawson Creek to be the first town in British Columbia served by natural gas.

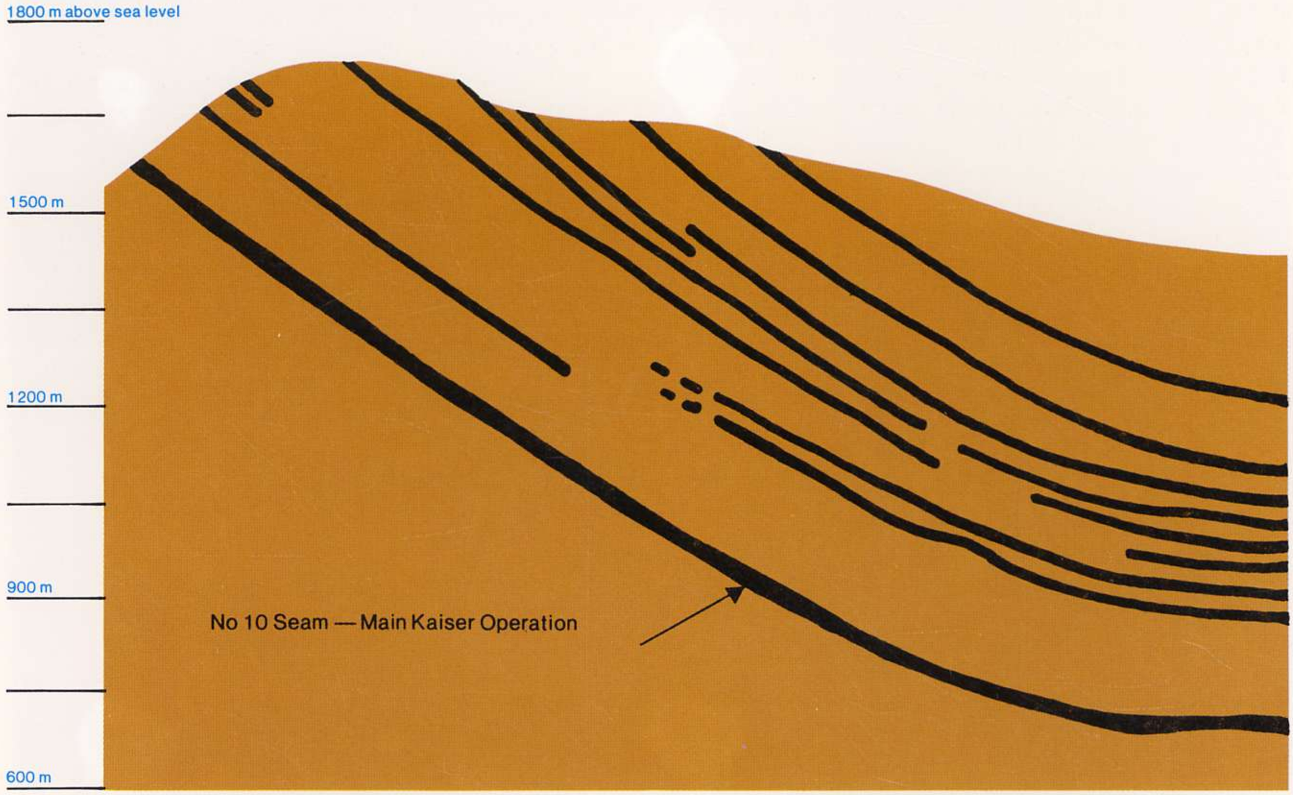
Oil in commercial quantities was discovered in 1952 in a well drilled near the town of Fort St. John. The discovery well was, however, originally completed as a gas well in another zone. Consequently, the first commercial oil well completion was not made until early 1955, when oil was discovered in the Boundary Lake field.

The oil and gas area of interest covers approximately 142,000 square kilometres of northeastern British Columbia and lies east of the Rocky Mountains and north of the 54th parallel. It embraces both the northern foothills belt of the Rocky Mountains and the northwestern extension of the Interior plains part of the Western Canadian Sedimentary Basin. The sediments suitable for the accumulation of oil

COALFIELDS OF BRITISH COLUMBIA



NORTHEAST SECTION OF KOOTENAY FORMATION



and gas range in thickness from approximately 1,800 metres in the plains area to greater than 6,000 metres in the foothills belt.

The 1957 pipeline was the key to huge increases in natural gas production. Province-wide markets could now be served in addition to the markets in Northwest United States. Natural gas output jumped from 562 million cubic metres in 1967 to 9 billion in 1977. At the same time, exploration and development expanded northward and eastward in the Yukon and Northwest Territories. The latest development — the linkage with the Alaska gas pipeline — extends the system to the shores of the Arctic Ocean.

By the end of 1977, a total of 4,150 oil and gas wells had been drilled in British Columbia. This drilling has resulted in the discovery and development of approximately 80 oil pools and 250 gas pools. The production of these developed resources has provided the Province with all its natural gas requirements and approximately 25 per cent of its oil requirements. Most of the short fall of crude oil requirements is made up by importing Alberta oil through the Trans-Mountain oil pipeline system.

In 1957 Westcoast Transmission completed a 1,000-kilometre pipeline from the Peace River area to Vancouver. This line is distinguished not only as British Columbia's main gas pipeline, but also as Canada's first 76-centimetre natural gas pipeline. It represented an important step in the history of transportation in Canada. For export purposes it connected at the international border with United States pipelines. The extension of the line to the Fort Nelson area in 1965 added an additional 360 kilometres to its length. Pipelines are the most economical means available for transporting large volumes of liquids overland. Lines operate continuously. Overhead costs are therefore minimized.

Open pit reseeded area (Kaiser Resources)

Environment

The Environment is what is all around us, not just water, land, and air. It also includes people, the built environment, and social forces. The maintenance of this total environment represents a major concern and problem for the mining industry because the work is all concentrated in pin-sized spots on national and provincial maps. Locally, at these spots, it sometimes looks as though everything is changing.

Canada has a billion hectares of land. Of these, farms take up 70 million hectares, highways 12 million. In contrast, all mining activities in the entire nation are focussed within one-quarter of 1 million hectares.

Frequently a mining community is remote from population centres, and the mine may be the sole economic base for the community. Whatever happens in the mine is therefore a high profile activity. The company is faced with a big challenge as it attempts efficient production with minimal harmful effects on the surrounding environment.

Today, after several decades of experimentation, measures for the protection of the physical environment are well in hand. They are buttressed by government regulations that guarantee minimum standards. Plans for environmental protection including proposals for land reclamation have to be approved by the provincial government before the first shovel touches the ground.

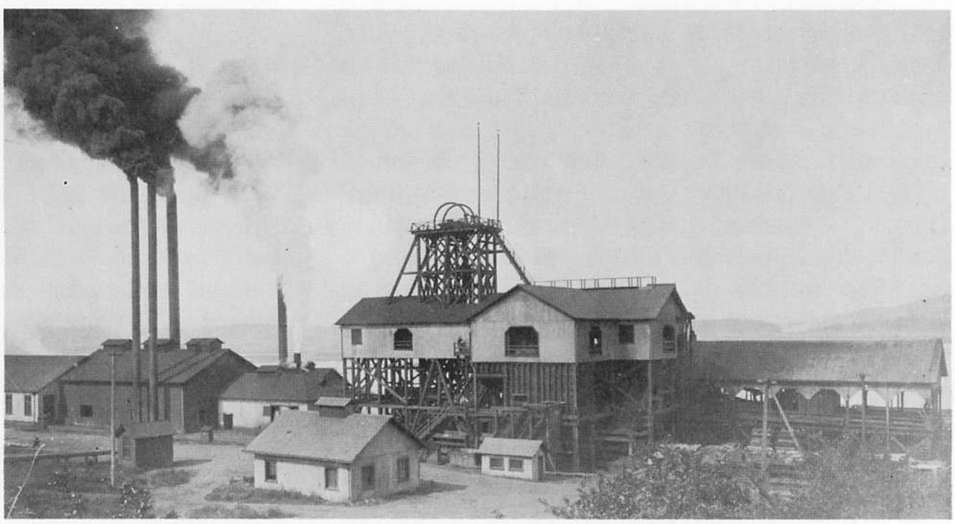
Water quality control and conservation are high priorities. A typical mine will use approximately 2,400 litres of water for every tonne of ore, but 2,200 litres are re-cycled back to the mill so the net use is only 200 litres.

A large tonnage of finely ground rock material known as 'tailings' is carried from concentrators in a water slurry. These tailings are contained in an impoundment area. In some cases, it is necessary to treat the water with lime to neutralize acidity, and to remove small amounts of heavy metals.

Land pollution problems vary according to the type of mining — underground or open pit. In the underground method waste rock can be returned to areas where mining has been completed. With open pit mines the waste rock must be permanently removed from the mining area. When a mine closes, the whole area can be returned to an aesthetically acceptable state. A number of methods have been tried to stabilize loose surface material. Planting grasses and trees has proved to be the best method for permanently rehabilitizing these areas.

The excavations created by open pit mining can sometimes be converted into ponds and lakes or used for recreational purposes. In the Kaiser Resources open pit coal areas the ground is resloped, contoured, and generally made to conform with the surrounding terrain to provide proper drainage and a stable seed bed. After fertilizing and seeding, the area is cross-harrowed to break up the soil, cover the seed, and help to retain moisture. Following seeding and har-

Western Fuel Company,
Nanaimo, B.C.
Last century



Hope-Princeton slide. Note major rough area at top left. This is the scarp of a previous major slide

rowing, trees are planted — mostly cottonwood, willow, and conifers.

These underground and open pit problems are man-made. There are other, much bigger land problems caused by natural hazards. Rockfalls, landslides, mudslides, earthquakes, avalanches, floods, hazards of mountain roads, or poor flying conditions — all confront the British Columbia miner. Other parts of Canada have some of these problems. British Columbia has them all.

The principal cause of these is the terrain. Almost everywhere there are steep mountains, products of the last ice age in which valleys were gouged out by glaciers and mountain peaks sharpened into needle points.

In turn, these mountains and valleys created their own varieties of climates. Within a distance of 30 kilometres it is possible to move from dense forest into stretches of sagebrush and shrub.

The British Columbia mountains are young in geological terms. They are still being eroded rapidly. Every so often they will shudder as the big masses adjust to new stresses and tensions. The result — an earthquake — something that the miners and mining companies dread. This is quite unlike the much older, stable Canadian Shield of northern Manitoba, Ontario, or Quebec where masses of rock are rarely disrupted any more by faulting and earthquakes.

The normal day-to-day risks of mining in difficult terrain can be handled by industry. It is the rare occurrence that is the problem, the 25 centimetres of rain that falls in one day or the earth tremor that triggers a rockfall in a mine.

Air pollution is mainly a problem of smelters, not mines. Sulphur dioxide is the usual villain. It is not really a serious problem anywhere in Canada and it is less serious in British Columbia than in other parts of the country.

Altogether sulphur dioxide from smelters adds up to about 6 per cent of the total amount of that chemical compound in the atmosphere. The remaining quantity comes from decayed vegetation. The average life of sulphur dioxide in the atmosphere is less than one week.

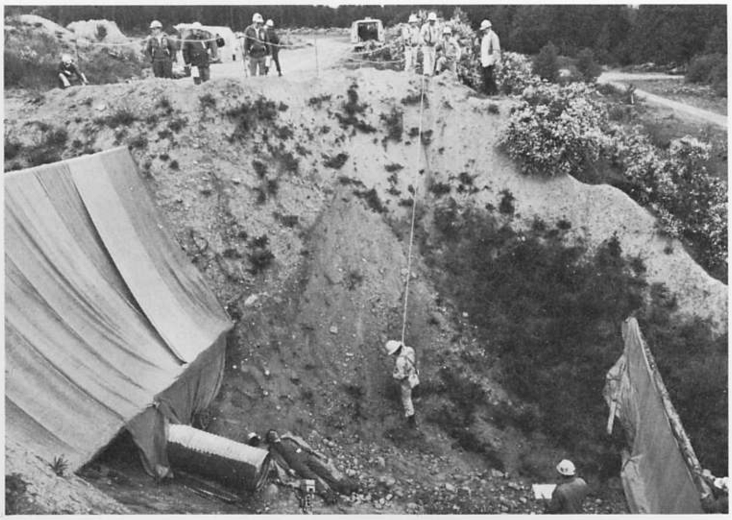
British Columbia's lead-zinc industry is centred in the Trail region. The Trail smelter is located in rugged mountain country, some 20 kilometres from the United States border. The fight against pollution began when company scientists developed a process for making sulphuric acid from smelter gas.

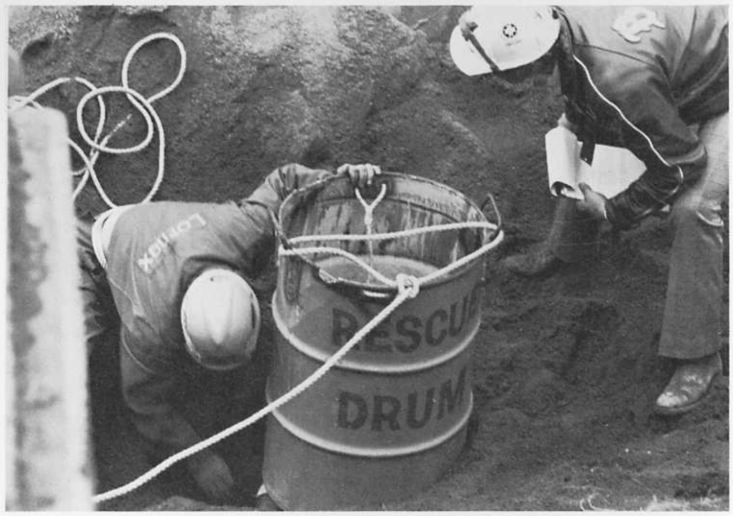
The breakthrough came at a time when the surrounding area was being turned into a wasteland because there was no smoke control in the smelter operations. The problem was made more difficult because of mountainous conditions which compounded the usual problems of dispersion.

Restoration of the surrounding countryside began in the 1930's and to date over 1 million trees have been planted and large areas grassed within a 5-kilometre radius of the plant at Trail.

All of these things — air, water, and land pollution — are the sorts of things we used to group together as the sum total of our concerns. But today there are so many additional considerations. The individual and social well-being of people is paramount.

The health of miners has long been a problem and a concern. As new research turns up newer dangers, this field becomes a bigger and bigger consideration in environmental quality. It is not an easy problem to grapple with. Health hazards are usually documented over long periods of time. With the





Training for mine rescue operations

rapid turnover in mine personnel, and continuously improving mine standards, reliable longitudinal studies are difficult to maintain.

A few years ago a big shadow hung over Cassiar and other asbestos operations in North America. It was the fear of cancer. It was thought that asbestos fibre would greatly heighten the risk of cancer among mill workers. Extensive research projects were launched.

It is now becoming clear that the risk from the mine environment is no greater than many other external hazards encountered in an industrial society as far as non-smokers are concerned. It is quite a different story for smokers. For them the risk is evidently high. This has led to intense activity on the part of asbestos mining companies to improve the quality of the environment in which the work is carried on.

At Cassiar, new filters have been installed and the suction power of the main air ducts greatly increased in order to reduce the amount of fibre in the air.

Beyond the mining and milling sites there are concerns at the user's end of the process. Some have suggested that chrysotile asbestos should not be used as sprayed insulation inside certain kinds of highrise buildings. In one instance a United States company launched a court action against Canadian asbestos producers because of alleged harmful effects when asbestos was used as insulation in office buildings.

Preserving and enhancing the total environment of mining is a stupendous task. In times of great prosperity the clamour for happy communities in idyllic settings is loud and insistent. When economic slowdowns occur, enviromental cries are muted. At the Stockholm United Nations Conference on the Environment in 1972, the indifference of the poorer countries was obvious. They wanted economic strength and growth, no matter what the cost to the environment.

Conservationists everywhere, as well as social reformers have to recognize to some extent what these less industrialized countries recognize — the necessity for a trade-off between economic and ecological realities.

Fording Coal Company dragline in Fording River Valley in Southeastern British Columbia

Mineral Products

The following notes identify important characteristics or major events in the development of minerals. They are arranged in alphabetical order and they include all of the economically significant minerals and associated metals that have been extracted from the mines of British Columbia over the past 100 years.

ANTIMONY Antimony is used in type metal and other alloys, mainly alloys of lead and tin. It adds strength and hardness. The metal also has numerous uses in compounds. It is produced at the Trail smelter. It occurs in nature in sulphide form and is a by-product of silver-lead mining. Antimony sulphide ore was produced as early as 1907 from the Slocan and more recently from Stuart Lake and Bridge River. The Trail production started in 1939 and is now the only source of the metal.

ARSENIC Arsenic is used in the chemical industry. In the past it was recovered at foreign smelters in the oxide form, chiefly from the arsenical gold ores at Hedley.

ASBESTOS Asbestos is a term applied to a variety of fibrous silicate minerals, of which the most important industrial type is chrysotile, found normally in serpentine rock. All British Columbia production consists of chrysotile from the Cassiar mine near the Yukon border. This deposit is noted for its high percentage of valuable long fibre and for its low iron content. The original claims were located at Cassiar in 1950, and the first fibre was shipped out two years later, by truck to Whitehorse, and then by rail to tidewater at Skagway. Since 1978 asbestos fibre has been moved by truck to tidewater at Stewart along the Stewart-Cassiar Highway.

BARITE Barite is a heavy, insoluble non-metallic sulphate of barium, used chiefly in oil-well drilling muds and to a lesser extent in chemical and ceramic industries. In the upper Columbia Valley it has been mined from veins. It has also been recovered from old lead-zinc mill tailings ponds.

BENTONITE Bentonite is an unusual clay that swells to several times its original volume when wet and so is used to thicken oil-well drilling muds. Occasionally small quantities have been mined from coal measures near Princeton.

BISMUTH Bismuth is used in type metal and low-melting-point alloys, and its compounds have various medicinal and industrial uses. The metal is recovered at Trail as a by-product of refining lead. Bismuth was first produced in 1929.

BUTANE Butane is a member of the paraffin series of hydrocarbons. It is a gas under normal conditions but is converted by pressure to a liquid, in which form it is sold for use as a fuel. It is a consistuent of natural gas, from which it is recovered at the gas-processing plant at Taylor.

CADMIUM Cadmium is a metal recovered at the zinc refinery at the Trail smelter and at foreign zinc refineries. It was first produced in 1928. Cadmium occurs in variable amounts in the zinc ore mineral sphalerite, and can be recovered from most silver-lead-zinc ores.

CEMENT Cement is made from a mixture of about 76 per cent limestone, 20 per cent rock containing silica, alumina, and iron oxide, and 4 per cent gypsum. It has been produced in British Columbia since 1905. At present there are three producers — two in the southwest which mainly use limestone from Texada Island and one at Kamloops.

CHROMITE Chromite is a chromium-bearing mineral. It occurs in ultrabasic rocks, and is used in making chrome steel alloys and refractory brick. Not much has been produced in the Province and none since 1929.

CLAY AND SHALE PRODUCTS These include common brick; face, paving, and sewer brick; firebricks and blocks; structural and drain tile; sewer pipe and pottery; lightweight aggregate; and ***pozzolan.*** The term 'pozzolan' refers to a number of natural and manufactured additives including volcanic ash, tuff, slag, etc., which impart strength and chemical resistance to cement. Local surface clay is used at Haney to make common red brick, tile, and flower pots. Shale and fireclay from Abbotsford Mountain are used to make firebrick, facebrick, sewer pipe, flue lining, and special fireclay shapes in plants at Kilgard, Abbotsford, Barnet, and South Vancouver. A plant on Saturna Island made lightweight expanded shale aggregate from a local shale deposit and a plant on Saltspring Island produces pozzolan from a nearby shale. A small plant near Quesnel makes pozzolan from burnt shale quarried south of Quesnel. Com-

MINERAL PRODUCTION IN BRITISH COLUMBIA

		1971		1976	
		Quantity	$ Value	Quantity	$ Value
METALS					
Antimony	kg	146 748	243,614	447 001	1,636,871
Bismuth	kg	37 431	388,674	20 261	226,462
Cadmium	kg	470 243	2,011,223	356 422	1,530,800
Cobalt	kg	51 503	103,099	—	—
Copper	kg	127 286 040	131,037,918	263 618 197	378,984,941
Gold — placer	kg	6	4,647	26	115,613
lode, fine	kg	2 668	3,031,844	5 393	21,761,502
Iron concentrates	t	1 750 738	18,153,612	1 255 277	14,760,526
Lead	kg	112 865 575	34,711,408	85 407 582	32,796,533
Molybdenum	kg	9 926 694	36,954,846	14 088 686	94,109,138
Nickel	kg	1 153 742	3,497,420	—	—
Silver	kg	238 670	11,968,046	239 721	32,532,836
Tin	kg	144 695	421,079	102 262	712,912
Tungsten (WO_3)	kg	605 909	3,012,540	—	—
Zinc	kg	138 549 629	49,745,789	106 498 987	65,499,108
Others		—	5,774,192	—	2,083,161
Sub-Totals		—	301,059,951	—	646,750,403
INDUSTRIAL MINERALS					
Asbestos	t	79 032	17,800,406	70 433	40,727,296
Diatomite	t	—	—	2 737	182,159
Fluxes (quartz, limestone)	t	24 258	98,426	11 378	33,263
Granules (quartz, limestone, granite)	t	26 524	519,192	31 476	1,219,884
Gypsum and gypsite	t	312 791	930,348	556 134	4,434,471
Jade	kg	76 094	196,332	483 796	1,535,030
Sulphur	t	261 691	2,147,778	231 704	4,296,189
Others		—	217,285	—	488,850
Sub-Totals		—	21,909,767	—	52,917,142
COAL					
Sold and used	t	4 141 496	45,801,936	7 537 695	298,683,679
Total solid minerals		—	437,711,987	—	1,099,289,872
STRUCTURAL MATERIALS					
Cement	t	822 329	21,629,385	846 548	34,973,746
Clay products		—	5,981,785	—	6,995,917
Lime and limestone	t	1 650 658	3,037,222	2 173 831	5,610,063
Rubble, riprap, crushed rock	t	3 327 758	3,670,583	2 485 215	5,205,973
Sand and gravel	t	26 598 612	25,612,396	36 073 618	48,138,635
Building-stone	t	2 057	8,962	657	14,314
Sub-Totals		—	59,940,333	—	100,938,648
PETROLEUM AND NATURAL GAS					
Crude oil	m^3	3 999 254	66,471,856	2 367 450	116,595,050
Field condensate	m^3	17 331	287,781	18 309	901,711
Plant condensate	m^3	181 907	293,287	167 576	7,198,957
Sub-Totals		—	67,043,924	—	124,695,718
Natural gas delivered to pipeline	10^6m^3	825	31,946,372	8 800	287,997,059
Butane	m^3	50 590	101,822	109 781	4,591,832
Propane	m^3	74 547	150,040	88 195	3,688,955
Sub-Totals		—	32,198,234	—	296,277,846
Totals petroleum and natural gas		—	99,251,158	—	420,973,564
Grand Totals		—	527,963,145	—	1,520,263,436

CONVERSION TABLE

Kilograms	Kg ÷ .45358 = pounds
Cubic Metres	$m^3 \times 6.29$ = barrels
Tonnes	t ÷ .90718 = short tons
Kilograms	Kg ÷ .031103 = troy ounces
Millions cubic metres	$10^6m^3 \times 35\ 496$ = thousand standard cubic feet

mon clays and shales are abundant in British Columbia, but fireclay and other high-grade clays are rare.

COAL Coal, a carbonaceous rock derived from compaction of organic debris, is almost as closely associated with British Columbia's earliest history as is placer gold. It was discovered at Suquash on Vancouver Island in 1835 and at Nanaimo in 1850. The yearly value of coal production passed that of placer gold in 1883 and contributed a major part of the total mineral wealth for the next 30 years.

The Nanaimo and Comox fields produced virtually all of the coal until Crowsnest production started in 1898. The Crowsnest field contains coking coal and it boomed in the early years of smelting and railroad building. Mining started in the Nicola-Princeton Coalfield in 1907, at Telkwa in 1918, and on the Peace River in 1923. The Nanaimo field was exhausted in 1953 when the last large mines closed, and only small operations on remnants were left. The colliery at Merritt closed in 1945 and at Coalmont in 1940.

Undeveloped fields include basins east of the Rocky Mountains south of the Peace River, Groundhog in north-central British Columbia, Hat Creek west of Ashcroft, Sage Creek southeast of Fernie, and near Quinsam Lake on Vancouver Island. Present production comes almost entirely from the Crowsnest field.

COBALT Cobalt metal was recovered in 1928 from a 25-tonne test shipment of ore from the Victoria mine on Rocher Deboule Mountain.

CONDENSATES Condensates are crude oils of low specific gravity which exist as gases in the ground under pressure. Upon coming to the surface from a well, the pressure is released, and these light oils condense as liquids. They are recovered in the field or at the gas plant.

COPPER Copper ore has traditionally been shipped to Japanese and American smelters because there has been no copper smelter in British Columbia since 1935. The ore minerals are chalcopyrite and bornite. The ore in many deposits is low in grade, and consequently the costs of mining and marketing must be low to permit a successful operation. Small amounts of gold and silver are commonly present and add value to the ore, but some ores contain important amounts of gold (as at Rossland), silver (Silver King mine), lead and zinc (Tulsequah), or zinc (Britannia mine). Most of the early smelting in British Columbia was done on 'raw' ore but modern practice is to concentrate the ore first.

Most of the copper production has come from southern British Columbia — Rossland, Nelson, Greenwood, Copper Mountain, Merritt, Highland Valley, Britannia, Texada Island, and Vancouver Island.

In September, 1961, the Craigmont open pit mine near Merritt started to produce and later, in 1962, the Bethlehem mine in the Highland Valley. These important mines are the result of extensive exploration that started in the general Merritt-Ashcroft-Kamloops region in 1955 and is still continuing. Copper is now the most valuable single metal commodity in British Columbia.

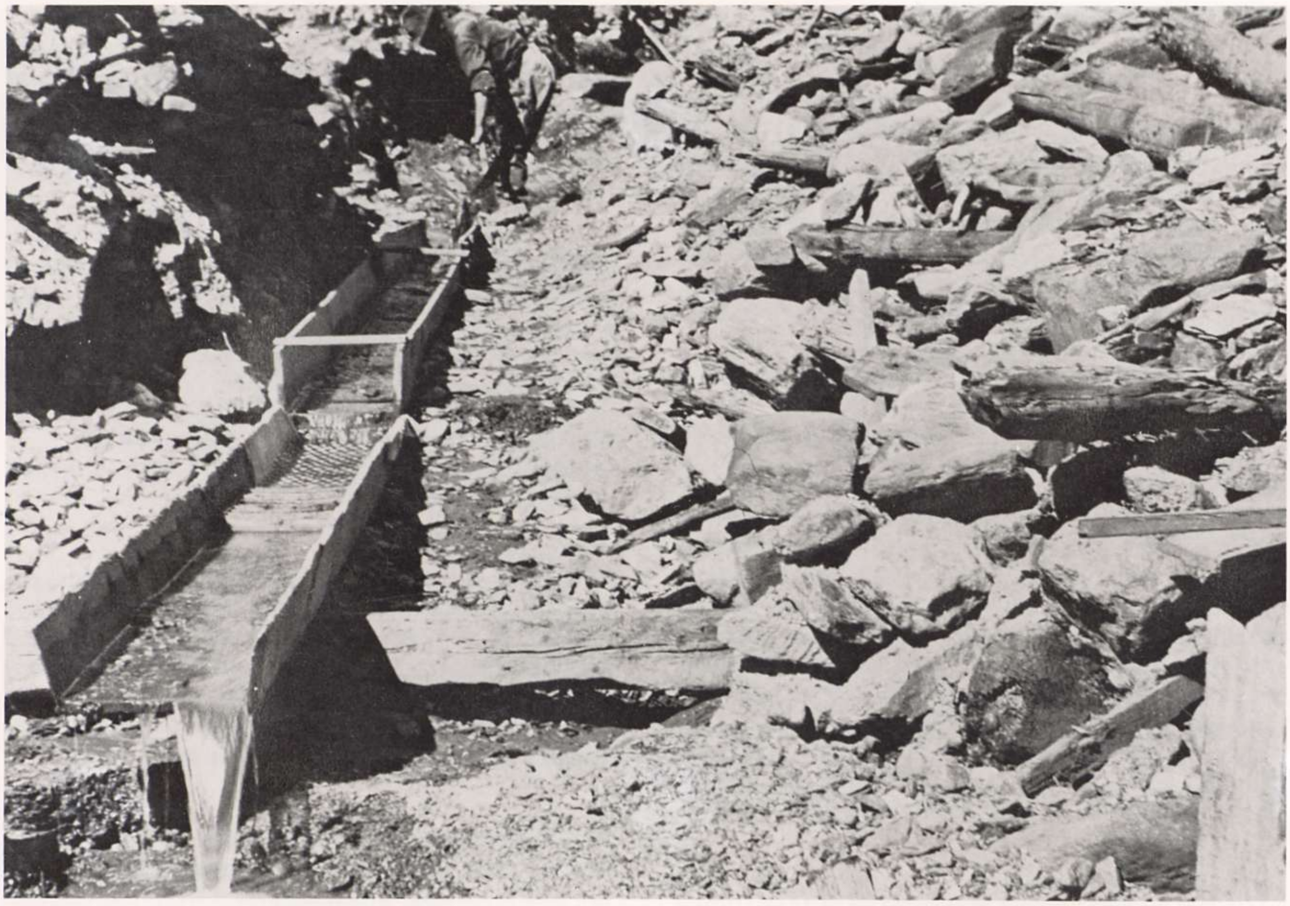
DIATOMITE Diatomite, or diatomaceous earth, is opaline silica which occurs as a fine porous aggregate of grains that are the remains of minute aquatic plants called diatoms. Large deposits are found near the Fraser River in the Quesnel area, and small deposits are widespread through the Province. Diatomite is used as an insulation material and filter aid. Small amounts have been quarried near Quesnel periodically since 1928.

FLUORSPAR Fluorspar or fluorite is calcium fluoride, a white to green or purple non-metallic mineral. It is used as a source of fluorine for the chemical industry and in iron and aluminum smelting and lead refining. Between 1918 and 1929 fluorite was mined at the Rock Candy mine north of Grand Forks for use in the Trail lead refinery.

FLUX Silica and limestone are added to smelter furnaces as flux to combine with the impurities in the ore and form slag, which separates from the valuable metal. Both materials have been mined at various places in the past. At present siliceous gravel for the Kimberley iron smelter is quarried near Marysville; siliceous rock from the waste dumps in the Sheep Creek area is shipped to the Trail smelter; and limestone from Texada Island is shipped to smelters in the United States.

GOLD (LODE) Lode gold is mined from lodes (veins and other deposits) in rock, as distinct from placer gold in streams. It may occur as visible metallic or free gold, but commonly as very fine particles intimately associated with one or more other metallic minerals. In the case of most ores which are mined for their gold and silver content alone, the gold is released from the rock by milling, dissolved in cyanide solution, and recovered as bullion. More than half the gold produced today is recovered from ores worked for copper and other metals and is shipped to smelters in concentrates of those ores.

The first discovery of lode gold was on Moresby Island in 1852, when some gold was recovered from a small quartz vein. The first stamp mill was built in the Cariboo in 1876, and it seems certain that some arrastras — primitive grinding-mills — were built even earlier. These and other early attempts were short lived, and the successful milling of gold ores began about 1890 in the southern part of the Province. The principal gold camps, in order of output of gold, have been Bridge River, Rossland, Portland Canal, Hedley, Wells, and Sheep Creek.



Sluice box used for placer gold mining

CEMENT MANUFACTURE CHART

RAW MATERIALS	LIMESTONE (12 million tonnes) SHALE (838,000 tonnes)	IRON OXIDE (81,000 tonnes) CLAY (1 million tonnes)	SAND (219,000 tonnes) GYPSUM (353,000 tonnes)
ENERGY	COAL (272,000 tonnes)	OIL (405,000 kilolitres) ELECTRICITY (1 billion KWH)	GAS (54 million m³)
LABOUR	PRODUCTION (2,500 people)	ADMINISTRATION (1,000 people)	SALES (300 people)
DISPOSITION OF PRODUCT (8 million tonnes)	READY-MIX (65%)	CONCRETE PRODUCTS (15%) CONTRACTORS (8%)	DEALERS (12%)

GOLD (PLACER) Placer gold is found as loose grains and nuggets in stream gravels and is recovered by various forms of sluicing. Originally occurring as lode gold, it has been freed from the enclosing rock by erosion and has been concentrated because of its high specific gravity. 'Placer' is a Spanish term originally used to describe such deposits.
Placer mining is an important part of onr background. The early exploration and settlement of British Columbia followed rapidly upon the discovery of numerous gold-bearing placer creeks across the length and breadth of the Province. The first horde of placer miners came in 1858 to mine the Lower Fraser River near Yale.
The year of greatest placer gold production was 1863, shortly after the discovery of placer in the Cariboo. Another peak year in 1875 marked the discovery of placer in creeks in the Cassiar. A minor peak year was occasioned by the discovery of placer gold on Granite Creek in the Tulameen River area in 1886. A high level of production ensued after 1899, when the Atlin placers reached their peak output. Numerous small placer mines exist in the Province but their total yearly production is very small now.

GRANULES Granules are rock chips used for exposed aggregate roofing, stucco dash, terrazzo, bird grits, etc. Roofing granules are used to coal asphalt shingles and roll roofing; they are commonly made from slate and are usually artificially coloured. Quartz, granite, limestone, and smelter slag are all used for other types of granules.

GYPSUM This is a soft light-coloured hydrated calcium sulphate that occurs in large beds. Most gypsum is calcined for use in plasters and wallboard, but it is also important as an ingredient of cement and for land dressing in agriculture. All present production comes from Windermere.

HYDROMAGNESITE This is an earthy or crusted form of hydrated magnesium carbonate that is used as a source of magnesia.

INDIUM This is one of the newest metals to be utilized in industry. It is used in bearings and in platings and alloys. It is commonly associated with sphalerite, the ore of zinc. Production as a by-product at the Trail smelter was first made in 1942.

IRON ORE Iron ore has been produced in small quantities as early as 1885, commonly under special circumstances or as test shipments. Steady production started in 1951 with shipments of concentrated magnetite ore to Japan from Vancouver and Texada Islands and now comes entirely from the Wesfrob mine at Tasu, Queen Charlotte Islands.
Iron ore of a totally different sort has been utilized at Kimberley to make pig iron in an electric furnace. This was the first manufacture of pig iron in British Columbia, starting in January 1961. The iron occurs as the sulphide minerals pyrrhotite and pyrite in the lead-zinc ore of the great Sullivan mine. In the process of milling, the lead and zinc minerals are separated out for shipment to the Trail smelter, and the iron sulphides are separated from the waste rock. This has been going on for years, with the knowledge that some day this by-product would be utilized, and when the decision was made to produce pig iron, there had been accumulated in a stockpile a reserve of about 18 million tonnes of iron ore. Production from this plant was suspended in 1972.

IRON OXIDE Including ochre, iron oxide has been mined since 1918, mainly from limonite deposits north of Squamish, principally for use in the glass industry. A small amount of selected material was mined for the paint and building industry. Production ceased in 1950.

JADE (NEPHRITE) Production of jade (British Columbia jade is actually nephrite, a metasilicate of iron, calcium, and magnesium) has been recorded since 1959. It is recovered from Mount Ogden and Dease Lake and from alluvial boulders found in the Fraser River and the Bridge River.

LEAD Lead was the most valuable single commodity for many years, but it was surpassed by zinc in value of annual production in 1920 and by copper in 1966. Lead and zinc usually occur together in nature although not necessarily in equal amounts in a single deposit. Zinc is the more abundant metal, but lead ore may be more valuable because it usually contains more silver. Most of the concentrated ore is smelted and the metal refined at Trail.
Almost all of British Columbia's lead comes from the southeastern part of the Province, and nearly 90 per cent from the Sullivan mine at Kimberley.

LIME and LIMESTONE Besides being used for flux and granules and in cement manufacture, limestone (calcium carbonate) is burned to make builders' lime and is used in the pulp and paper industry and in agriculture. Most of the production has come from northern Texada Island.

MAGNESIUM SULPHATE Epsomite or epsom salts (magnesium sulphate) has been recovered in small quantities at various times from alkali lakes near Clinton, Basque, and Osoyoos for medical and chemical use.

MAGNESIUM Magnesium metal was produced from a large deposit of rock magnesite (magnesium carbonate) near Kimberley in 1941 and 1942. This was a trial production and the deposit remains a potential source of metal. A large potential deposit occurs in the southern Rocky Mountains.

MANGANESE Manganese ore was shipped in 1918-1920 from a bog deposit near Kaslo and from surface oxidized material near Cowichan Lake.

MICA Commercial quantities of the hydrous silicate, mica, large and clear enough for splitting into sheets have not yet been found in British Columbia. Small amounts have been produced from deposits at Oliver, Armstrong, and Albreda.

MERCURY Mercury or quicksilver occurs in the bright red sulphide cinnabar, and is recovered by roasting the ore and condensing the resultant mercury vapour. Mercury is principally used in caustic chlorine cells in the pulp industry and for batteries. Mercury was first produced near Savona in 1895, and small amounts have since been recovered from the same source. The Pinchi mine near Fort St. James has been our most important producer but is now closed because of poor markets.

MOLYBDENUM Molybdenum is an important metal, chiefly used in the hardening of steel and in lubricants. For many years it was produced from one source, in Colorado, but production from other world sources has been gradually increasing.
The ore mineral is the sulphide molybdenite, a soft metallic mineral that is widely distributed. Recognition of the potential value of molybdenum in this Province has been slow in coming, but British Columbia is now a major producer of the metal. The Endako open pit mine and the Boss Mountain underground mine began operations in 1965. There are other important mines that produce molybdenum as a by-product of copper production: e.g. Brenda (1970), Island Copper (1971), and Lornex (1972).

NATRO-ALUNITE This is potassium alum that contains sodium. About 40 years ago an attempt was made to exploit a deposit of this mineral at Kyuquot for use as a source of potassium for fertilizer. The potassium content of the deposit was too low to be commercial.

NATURAL GAS Natural gas and petroleum usually are considered together because they both contain compounds of hydrogen and carbon, and are of common origin. Petroleum, by definition, includes gas and may exist in a number of physical states such as gas, liquid, semi-solid, or solid. Petroleum in its gaseous form consists mainly of methane or marsh gas; as a liquid it is known as crude oil; and in its semi-solid form is referred to as asphalt, pitch, or tar. Natural gas may occur with oil in a reservoir, or it may occupy a reservoir containing no oil whatsoever. Gas produced with oil is known as 'associated gas,' whereas gas produced from a gas reservoir is considered as 'wet' or 'dry' gas, depending on the volume of light liquid hydrocarbons associated with it, and is classified as 'sweet' or 'sour' on the basis of its hydrogen sulphide content.
Natural gas production began modestly in 1954 to supply the community of Fort St. John. In 1957 both the gas plant at Taylor and the 76-centimetre (30-inch) pipleine to Vancouver and Seattle were completed.

NICKEL Nickel in British Columbia was produced by one mine, the Giant Nickel deposit between Hope and Yale. It had been known for about 30 years, but in spite of development and ore testing, production did not begin until 1958. Nickel concentrates were at first shipped to Saskatchewan for refining, but after 1960 bulk nickel-copper concentrates were shipped to Japan. The mine closed in 1974.

OIL See natural gas.

PALLADIUM Palladium is one of the platinum group of metals.

PERLITE Perlite is a finely and concentrically fractured glassy volcanic rock that contains 2 to 5 per cent water. When flash heated it expands into a light porous product valued as an insulation material. Several deposits are known in west-central British Columbia, but all appear to be beyond reach of economical transportation.

PETROLEUM See natural gas.

PHOSPHATE ROCK Sedimentary deposits of calcium phosphate occur near Fernie and Crowsnest in strata of Jurassic and Late Paleozoic ages. Some of this rock was mined for test purposes, but the grade has proved, as yet, to be too low for commercial use.

PLATINUM Most of the platinum has come from placer streams, and a little has been recovered at the Trail refinery in past years. Two-thirds of all platinum has come from the Tulameen and Similkameen Rivers, and most of the remainder from streams in the Cariboo.

PROPANE Propane is slightly lighter than butane and, like butane, is a member of the paraffin series of hydrocarbons. It is converted under pressure from a gas to a liquid, in which form it is sold. It is recovered at the gas-processing plant at Taylor.

RHENIUM Rhenium occurs in significant quantities with molybdenite. It was first produced in 1972 by the Island Copper mine near Port Hardy and is extracted as rhenium oxide from fumes which are driven off during roasting of the molybdenite concentrate.

ROCK Rubble, riprap, and rock crushed for a variety of uses are all included in this category. Rock of this sort must be low priced, and so is quarried close to the place of use to minimize transportation costs. Most of it is quarried near Vancouver.

SAND and GRAVEL Sand and gravel are used as aggregate in concrete work of all kinds. The output varies from year to year, according to the state of activity of the construction industry but they form the most important non-metallic resource mined. Yearly production exceeds asbestos in value.

SELENIUM The only recorded production of selenium metal was from the refining of blister copper from the Anyox smelter in 1931.

SILVER Silver is won from silver ores or is recovered as a by-product of other ores. Most of it is refined in Trail. Invariably some silver is associated with galena, the ore of lead, so that many low-grade lead ores, if mined in quantity, produce a significant amount of silver.
Silver-bearing ores were intensively sought in the early days. A metal of high unit value was the only one worth finding in regions remote from market, and in the 1880's and 1890's there seemed little point in prospecting for ores that did not contain values in silver or gold. Prospecting for silver ores started in southeastern British Columbia in about 1883, and from 1894 to 1905 British Columbia produced most of Canada's silver, many of the early ores being mined primarily for their silver content. Half the silver produced in the Province has come from the Sullivan mine.

SODIUM CARBONATE Sodium carbonate salt for the soap and chemical industries has been recovered from alkali lakes in the Interior dry belt. Most of the production was from the Clinton area, and the rest from the Kamloops region.

STONE Building-stone of various sorts is produced at a number of places close to transportation. The kind and amount produced vary considerably with local demand and special projects.

SULPHUR Sulphur to make sulphuric acid is recovered as sulphur dioxide from the flue gases at the Trail smelter, from roasting pyrrhotite at the Kimberley fertilizer plant, and from roasting pyrite concentrate from Britannia mine. The chief source of elemental sulphur at the present is that removed from natural gas at the scrubbing plant at Taylor.

TALC Talc is a hydrous silicate of alumina, magnesia, and iron. Between 1916 and 1936, 1,805 tonnes of talc for dusting asphalt roofing was produced from quarries at Leech River near Victoria and at Anderson Lake near Lillooet. Soapstone is a massive, impure form of talc.

TIN Tin is a by-product from the great Sullivan mine, where it has been produced since 1941. The tin is in the form of cassiterite (tin oxide), which has a high specific gravity and so may be separated from the rest of the finely ground ore.

TUNGSTEN Tungsten metal is marketed in the form of concentrates of the mineral scheelite (calcium tungstate). The concentrates are sold to steel plants and to manufacturers of tungsten carbide and other products. Scheelite occurs in quartz veins. It was first minded in the Cariboo in 1937 and was produced in modest quantities during World War II at the Red Rose mine near Hazelton and the Emerald mine near Salmo. The Red Rose closed in 1954, and the Emerald in 1958. The adjacent property, the Invincible, came into production in 1970 and closed in 1973.

ZINC All the zinc mined in British Columbia comes from the mineral sphalerite (zinc sulphide). It is normally associated with lead, and most ores are mined for their combined values in zinc, lead, and silver, and rarely for the zinc content alone. Some zinc ores contain a valuable amount of gold, and zinc was associated with copper at the Britannia mine near Vancouver. Modern practice is to concentrate and to separate the zinc mineral (sphalerite) and the lead mineral (galena). Most of the zinc concentrates go to the zinc recovery plant at Trail, are roasted, and are converted by electrolysis to the refined metal. One great mine, the Sullivan at Kimberley, today produces most of British Columbia's zinc.

Simplified Geological Time Chart

ERA	AGE OF OLDEST ROCKS	PLACES WHERE YOU WOULD FIND ROCKS OF THIS AGE
CENOZOIC	Quarternary 2 000 000	Fraser Delta
	Tertiary 70 000 000	Chilcotin-Quesnel area, Coast Mountains
MESOZOIC	Cretaceous 135 000 000	Peace River area
	Jurassic 180 000 000	Hazelton area
	Triassic 225 000 000	Highland Valley, Vancouver Island, Prince George area
PALEOZOIC	Permian 270 000 000	Lower Vancouver Island, Williams Lake area,North Thompson River area
	Pennsylvanian 305 000 000	
	Mississippian 350 000 000	
	Devonian 400 000 000	Rocky Mountains
	Silurian 440 000 000	
	Ordovician 500 000 000	
	Cambrian 600 000 000	
PRECAMBRIAN	Proterozoic 2 500 000 000	Kimberley-Cranbrook area
	Archeozoic 4 500 000 000	Revelstoke-Shuswap area

Common Geological and Mining Terms

ADIT An opening driven horizontally into the side of a hill for the purpose of exploring or mining a mineral deposit. Strictly, an adit is open to the atmosphere at one end, a tunnel is open at both ends.

AERIAL SURVEY A survey made from a flying aircraft, such as photographic, magnetometer, or radio-activity.

AERIAL TRAMWAY A system for the transporting of ore in buckets which are suspended from a cable.

ALLOY A solid solution of two or more metals, usually produced by fusion.

ALLUVIAL, ALLUVIUM Deposits of sedimentary material laid down in river beds, flood plains, lakes, or in a fan at the foot of mountain slopes.

AMALGAM An alloy or mercury with another metal usually gold or silver.

AMORPHOUS A term applied to rocks or minerals that possess no definite crystal structure or form.

ANODE A rectangular plate of metal cast in a shape suitable for refining by the electrolytic process.

ANOMALY A term applied to a departure from the normal characteristics, commonly used in geophysical prospecting. Thus, in a magnetometer survey, an area showing higher or lower readings or magnetic intensity than the general level of the surrounding area would be identified as an anomaly.

ANTICLINE An arch in rock layers shaped like a crest of a wave, as opposed to a syncline which is similar to the trough of a wave. These structures are generally caused by horizontal compression.

ASSAY Testing minerals by chemical or other methods for the purpose of determing the amount of valuable metals contained.

BACK The ceiling of a drift, crosscut, or stope.

BACKFILL Waste material used to support the walls of a stope and provide a working platform after removal of the ore.

BACKSTOPE The initial lift or slice when commencing to stope or mine from a drift.

BALL MILL A piece of milling equipment used to grind ore into small particles. It is a cylindrical-shaped steel container filled with steel balls into which crushed ore is fed. The ball mill is rotated, causing the balls themselves to cascade, which in turn grinds the ore.

BANDED ORE (STRUCTURE) Layers of minerals in veins or beds differing in colour and texture.

BARITE A sulphate of barium ($BaSO_4$).

BASE METAL A metal inferior in value to gold and silver, generally applied to commercial metals such as copper, lead, and zinc.

BATHOLITH A large mass of igneous rock extending to great depth and with an upper portion shaped like a dome. Smaller masses of igneous rocks are known as plugs.

BEDROCK Solid rock forming the earth's crust, frequently covered by overburden.

BENEFICIATE To concentrate; generally applied to the preparation of iron ore for smelting, through such processes as sintering, magnetic concentration, or washing.

BIOLOGICAL LEACHING A process for recovering metals from low-grade ores by dissolving them in solution. The process is aided by bacterial action.

BIT The cutting end of a boring instrument. In rock drilling this cutting end is frequently composed of ultra-hard materials such as diamonds or tungsten carbide.

BLAST HOLE A hole drilled for purposes of blasting rather than for exploration. Strictly speaking it is the first hole to be exploded in a pattern of holes drilled for blasting.

BLISTER COPPER The product of the Bessemer converter furnace used in copper smelting. It is a crude form of smelting with 99 per cent pure copper as the outcome. Further refining is required before the product can be used for industrial pruposes.

BLOCK CAVING A cheap underground method of mining in which large blocks are undercut, thus allowing the ore to collapse under its own weight.

BORNITE A sulphide mineral of copper and iron, containing more copper than chalcopyrite. It is the next most important ore mineral of copper (Cu_5FeS_4).

BOX HOLE An opening driven above a drift for the purpose of drawing ore from a stope.

BREAST A working face, usually restricted to a stope.

BULLION Precious metal in bars, ingots, or other uncoined form.

CAGE The conveyance used to transport men and equipment in a shaft.

CATHODE A rectangular plate of metal produced by electrolytic refining. It is melted into such commercial shapes as wirebars, billets, or ingots.

CHALCOPYRITE A sulphide mineral of copper and iron. It is the commonest copper ore mineral ($CuFeS_2$).

CHRYSOTILE Fibrous serpentine, a hydrous magnesium silicate, one type of 'asbestos.'

CHUTE An inclined opening, usually constructed of timber and equipped with a gate. Ore is drawn through the chute from a stope.

CINNABAR A vermilion-coloured mercury sulphide, HgS, 86 per cent mercury.

CLAIM A portion of mining land held under federal or provincial law. The common size in British Columbia is 500 metres square (25 hectares).

COLLAR The term applied to the timbering around the mouth of a shaft. It is also used to describe the top of a drill hole.

COMPLEX ORE An ore containing a number of minerals of economic value. (A multi-element mineral deposit).

CONCENTRATE A product containing the valuable metal usually combined as sulphide or oxide, but from which most of the other waste material in the ore has been eliminated.

CONCENTRATOR A milling plant that produces a concentrate of the valuable metals. The concentrate must then be treated in a smelter to recover the pure metals.

CONVERTER A Bessemer furnace used to reduce copper and also to make steel.

CORE A long cylinder of rock, generally about 2 to 3 centimetres in diameter, that is obtained by means of a diamond drill.

CORE BARREL That part of a string of tools in diamond drilling in which the core specimen is collected.

CROSSCUT A horizontal opening driven across a vein or the strike of the rock.

CRUSHER A machine for crushing rock, such as a gyratory crusher, jaw crusher, or stamp mill. Generally used in the first step in freeing the valuable minerals from the ore.

CUT-AND-FILL A method of stoping in which ore is removed in slices. After each slice the excavation is filled with rock.

DEVELOPMENT The underground work of opening up a mineral deposit. It includes shaft sinking, crosscutting, drifting, and raising.

DIAMOND DRILL A rotary type of rock drill in which the cutting is done by abrasion rather than percussion. The cutting bit is set with diamonds and is attached to the end of long hollow rods through which water is pumped to the cutting face. The drill cuts a core of rock which is then recovered in long cylindrical sections, 2 centimetres or more in diameter.

DIFFERENTIAL FLOTATION A milling process using the flotation method in which the various valuable minerals in an ore are separated from waste (tailings) or each other.

DILUTION The process by which waste rock accompanies the ore as a result of the mining process. This process can be by accident or design.

DIP The angle at which a vein is inclined to the horizontal, measured at right angles to the strike.

DIP NEEDLE A compass whose needle swings in a vertical plane. It is used for determining the magnetic attraction of rocks.

DISSEMINATED ORE Ore carrying small particles of valuable minerals, spread more or less uniformly through the gangue matter; distinct from massive ore where the valuable minerals occur in almost solid form with very little waste material included.

DRIFT (DRIVE) A horizontal underground passage that follows a vein as opposed to a crosscut which crosses the vein.

Cassiar Asbestos Corporation's Mine at Cassiar, B.C.

Chrysotile asbestos, Cassiar Mine

DRIFTER A rock drill used for boring horizontal holes for blasting mainly used in development headings.

ELECTROLYTIC REFINING The process of refining metals by means of anodes which are placed in an electrolyte. The electrolyte is usually a salt of the same metal dissolved in water. Metal is deposited on a cathode by passing an electric current into the system.

ELECTROMAGNETIC (EM) One of the most important of the modern mineral-hunting techniques used especially to find massive mineralization. Most EM equipment introduces electrical currents from above ground into the earth, and this electrical activity is measured during and after the currents have passed through rocks or mineral deposits (see Anomaly and Induced Polarization).

FAULT A break in the earth's crust. Faults may extend for hundreds of kilometres, or be only a few centimetres in length; similarly, the movement or displacement along the fault may vary widely; ore deposits are eommonly associated with faults, as the movement provides a channel for ore-bearing solutions.

FERROUS Containing iron.

FLOAT Pieces of rock that have been broken off and moved from their original locations by such forces as frost, gravity, or glaciers.

FLOTATION A milling process in which some mineral particles are induced by certain chemicals to float, while others sink. In this way the valuable minerals are concentrated and separated from the gangue.

FLUX A chemical substance used in metallurgy to react with gangue minerals to form slags; examples range in scale from large tonnages of limestone or silica, in large furnaces, to small quantities of borax or soda, in laboratory assay fusions.

FOOTWALL The lower side of an inclined vein.

GALENA A sulphide mineral of lead, the common lead ore mineral (PbS).

GANGUE The other minerals associated with valuable minerals in an ore deposit.

GEIGER COUNTER An instrument used in the search for radioactive minerals, particularly uranium. It is capable of detecting the radiation emanating from such minerals during radioactive decay. It registers the intensity of these rays visually, audibly, or both. The scintillometer is a more sophisticated instrument to measure the same phenomena.

GEOPHYSICAL SURVEY A method of prospecting that utilizes the physical properties of minerals. Common properties investigated include magnetism, specific gravity, electrical conductivity, and radioactivity.

GLORY HOLE A steep-sided open pit from which ore is extracted downwards to underground workings.

GRAVITY METER, GRAVIMETER An instrument for measuring the gravitational attraction of the earth. This attraction varies with the density of the rocks.

HANGINGWALL The wall on the upper side of an inclined vein.

HEMATITE One of the commonest ores of iron (Fe_2O_3) but rare in commercial quantities in British Columbia.

HORSE A mass of waste rock lying within a vein.

HYDROMETALLURGY Separation of metal from the rest of the ore by means of an aqueous solution. This is followed by precipitation in metallic form.

INDUCED POLARIZATION (IP) A method of ground geophysical surveying employing a pulsing electrical current to locate disseminated sulphide mineraiization.

INDUSTRIAL MINERALS Non-metallic minerals and structural materials which are used in manufacturing processes in their natural state; examples include asbestos, barite, salt, gravels, building materials, talc, and sands.

LODE A tabular mineral deposit in solid rock. The term vein is sometimes used in preference to lode.

MAGNETITE The magnetic iron oxide (Fe_3O_4), the common iron ore of British Columbia.

MAGNETOMETER A sensitive instrument used to measure the magnetic attraction of rocks.

MINERAL A naturally occurring homogeneous substance having definite physical properties and chemical composition and, if formed under favourable conditions, a definite crystal form. A rock is generally an aggregate of several different types of minerals.

MOLYBDENITE Chief sulphide ore mineral of molybdenum (MoS_2).

MUCK Ore that has been broken by blasting.

MUCKING MACHINE A machine for loading ore.

It is generally driven by compressed air and used in a drift.

NATIVE METAL A metal which is found in nature in pure form (native gold, native copper).

OPEN CUT A surface working, open to daylight.

ORE A mixture of ore minerals and gangue from which at least one of the metals can be extracted at a profit.

OVERBURDEN Unconsolidated surface material covering a rock surface.

PLACER An alluvial deposit of sand and gravel containing valuable minerals such as gold.

PORPHYRY Any igneous rock in which large, conspicuous crystals are set in a fine-grained groundmass.

PORPHYRY COPPER A deposit of disseminated copper minerals in a large body of igneous porphyry.

PYRITE A hard, heavy, shiny, yellow mineral, a sulphide of iron (FeS_2). It is a common sulphide, sometimes known as 'fool's gold,' and only rarely contributes significant value to the ore, although it commonly accompanies valuable minerals.

PYRRHOTITE A slightly magnetic sulphide of iron, generally bronze in colour ($Fe_{1-x}S$). It sometimes contains nickel due to enclosed grains of pentlandite [(Fe, Ni) S].

REFRACTORY ORE Ore that resists the action of chemical reagents in the normal treatment processes. It generally requires roasting of high temperatures to recover the valuable minerals.

ROASTING The treatment of ore by heat and air to remove sulphur and arsenic.

ROCKBOLTING Consolidating roof strata by anchoring steel bolts in holes drilled for the purpose.

ROCK MECHANICS The study of stress conditions surrounding mine openings. It involves examination of the ability of rocks and underground structures to withstand various stresses.

SEISMIC PROSPECTING A geophysical method of prospecting on the basis of the speed and reflection of sound waves in rock.

SHAFT A vertical or inclined excavation for opening or servicing a mine similar to an elevator shaft in a building. It is usually equipped with a hoist at the top, which lowers and raises conveyances for handling men and materials and hoisting ore.

SCHEELITE Calcium tungstate ($CaWO_4$), a common ore of tungsten, containing 80.6 per cent tungsten trioxide (WO_3).

SINTER The heat treatment of fine ore particles to produce larger pieces for blast furnace feed.

SKIP A self-dumping type of bucket for hoisting ore from underground.

SLAG The vitreous mass separated from the fused metals in a smelting process.

SMELTING The recovery of metal from ore by heat and chemicals (fluxes).

SPHALERITE Chief sulphide ore mineral of zinc (ZnS).

STOPE A mine excavation in which ore is being extracted.

STRIKE The azimuth or direction of a horizontal line on an inclined plane such as a bed or vein.

STRIP Remove overburden from an orebody.

SYNCLINE A down-arched fold in stratified rocks.

TAILINGS Material rejected from a mill after the recoverable valuable minerals have been extracted. It is normally confined by a large dam near the mill.

TRAM A mechanism which hauls cars of ore in a mine.

TUBE MILL A revolving cylinder about half filled with steel rods or balls, into which crushed ore is fed for fine grinding. The material to be ground is mixed with water and comes out as a slurry to be fed into froth flotation cells in most mills.

VEIN A crack in a solid rock filled by minerals that have travelled upwards from some deep source or moved laterally from surrounding rocks.

ZONE OF OXIDATION The upper oxidized part of a mineral deposit.

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