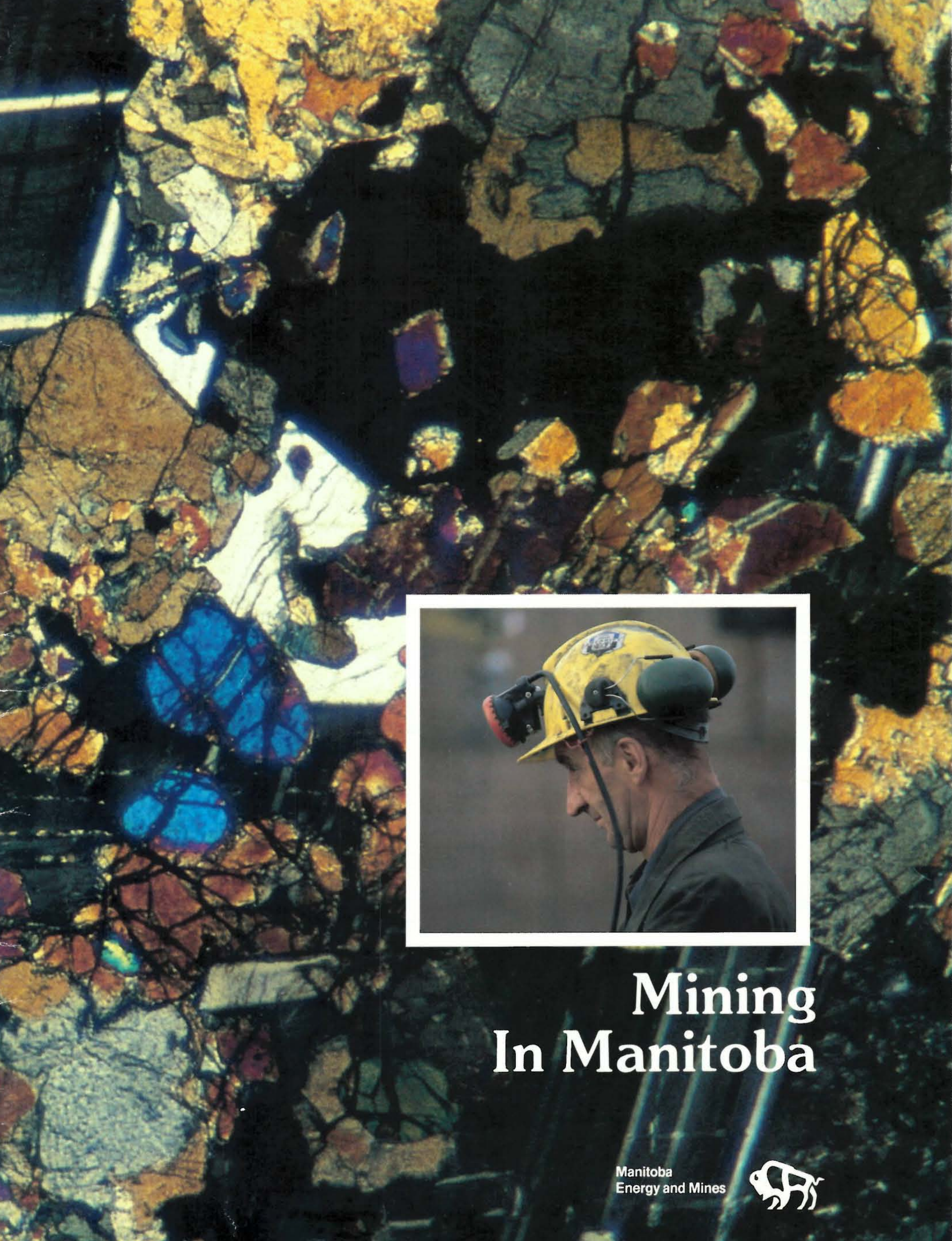


Mining In Manitoba

Manitoba
Energy and Mines

Metric Conversion

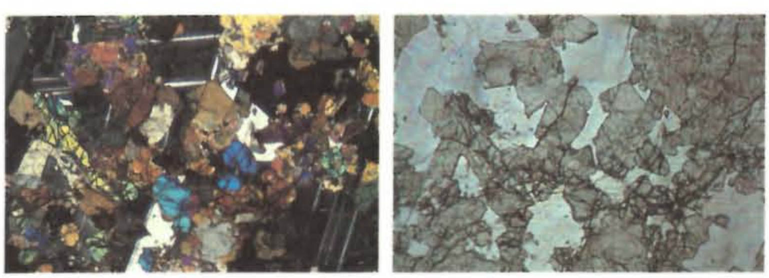
1 metre	=	3.28 feet
1 kilometre	=	0.62 miles
1 gram	=	0.03 troy ounces
1 kilogram	=	32.15 troy ounces
	=	2.20 pounds
1 tonne	=	1.10 tons (short)
1 hectare	=	2.47 acres
1 gram/tonne	=	0.02917 troy ounce/ton (short)

NOTE:

Unless otherwise stated, value of production is in unadjusted dollars, at prices current at the time of production.

ACKNOWLEDGEMENTS

Mining in Manitoba is based on two earlier publications; Mining in Manitoba by R.G. Zahalan (1980) and Mining in Manitoba-Past and Present by D. Fogwill (1983), which have been revised and updated by D. Fogwill and J. Bamburak with the assistance of many of the staff at Manitoba Energy and Mines.



Photographs of a paper-thin slice of igneous rock (diabase), from southeast of the Thompson nickel belt, taken through a microscope. The photo on the left is taken with a polarizing filter which produces the rainbow-like colours. Each mineral interferes with the light rays in a different way, allowing the colours to be used in mineral identification. The photo on the right is from the same thin section, but taken under plane light.

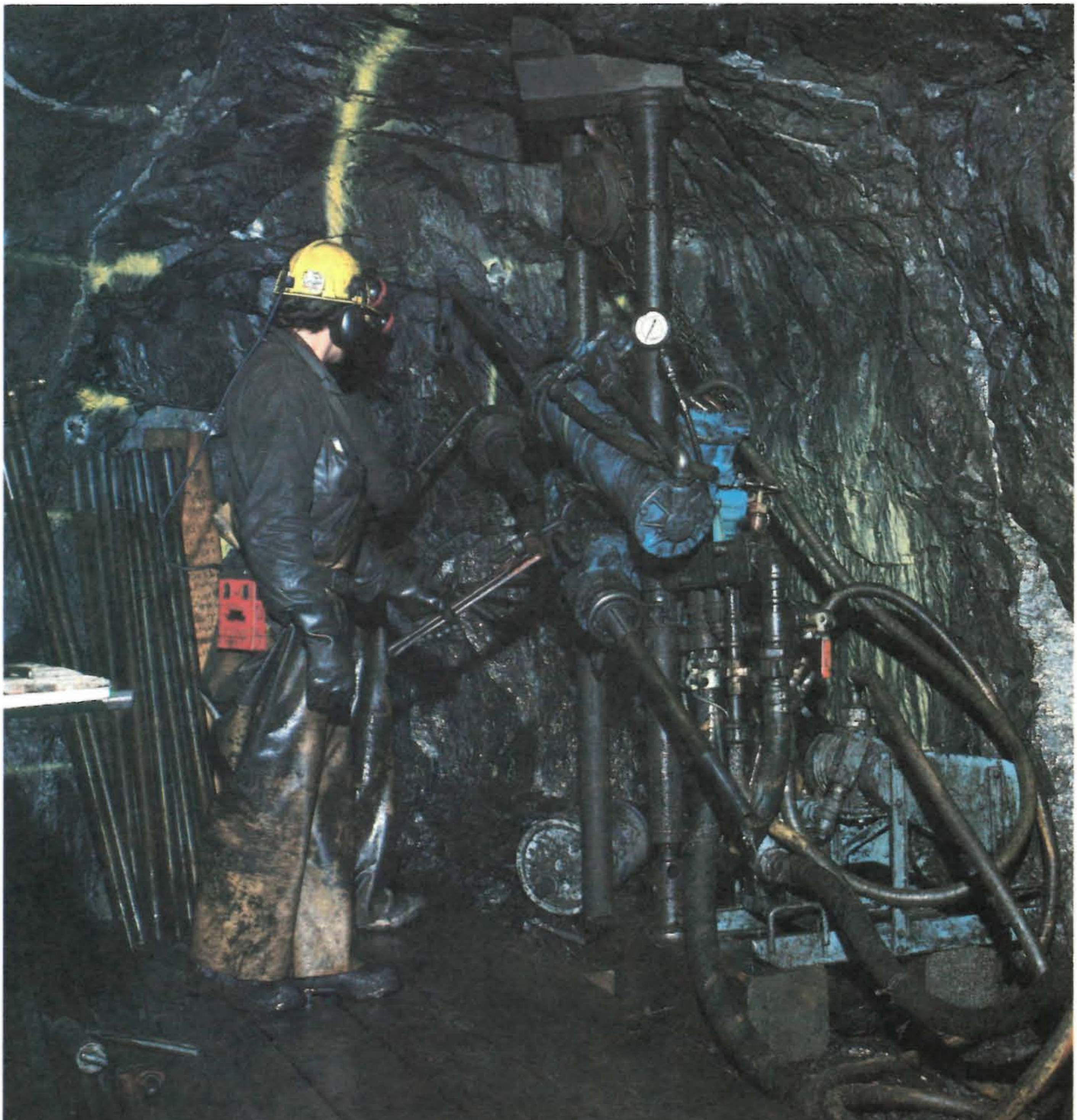
Welcome to the Mineral Education Series

Manitoba's abundant mineral wealth has been part of this province's heritage since the earliest period of human habitation. Over the centuries, our uses for minerals have multiplied, until today we use more minerals to produce more products than ever before in history. But while the stone axe has been replaced with the space shuttle's Canadarm, one vital ingredient remains the same. It takes human ingenuity and hard work to transform the natural wealth of our province into the tools and materials we need.

Manitoba Energy and Mines is proud of the record Manitobans have established in the minerals industry. In the Mineral Education Series, our staff members have attempted to pass on some of the history and geology which have combined to make our mining industry what it is today. The series introduces some of the province's most important minerals, and the people and companies which have translated the potential of our resource heritage into a vibrant and innovative industry.

In *Mining in Manitoba,* we take an overview of the mining industry in all its facets. Mining is as old as civilization, but in Manitoba, it is only over the past century that it has become an important part of our economy. You will be introduced to the challenge faced by exploration crews searching out minerals hidden hundreds of feet below the surface. As deposits are discovered and developed, you will learn about the ways we have devised to bring the ore from the ground and transform it into the raw materials that form the basis of industrial society.

Manitoba Energy and Mines has played an important role in fostering Manitoba's minerals industry. The department's goal is to help build a strong and prosperous mining sector in the economy, and to ensure that our precious mineral heritage is developed with care and wisdom. In *Mining in Manitoba,* geologists Douglas Fogwill and James Bamburak have provided Manitobans with a fascinating look at an industry which continues to be one of the cornerstones of our economy.



Underground drilling at SherrGold's MacLellan Mine, 1986.

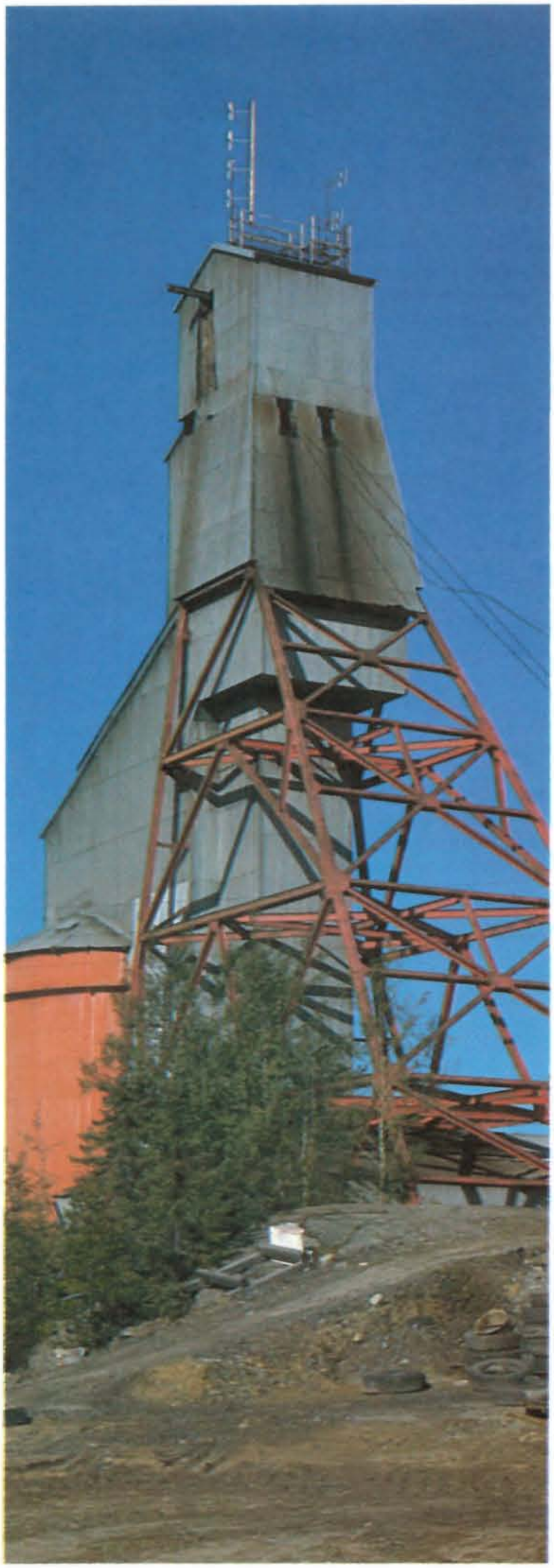
PREFACE

One hundred years ago, when the first transcontinental train reached Winnipeg, there were four brick plants, a building stone quarry and a salt works in southern Manitoba. Gypsum was being developed in the Interlake area and coal had just been discovered at Turtle Mountain.

Over the last century, our mining industry has come a long way, leading railways, roads and airports into the great northern reaches of Manitoba, and giving birth to the towns of Flin Flon, Snow Lake, Thompson, Leaf Rapids and Lynn Lake. The tourists, paper mills and hydro-electric projects came later, to further strengthen our north country. Mining is still an important contributor to the wealth of our province. While the north remains the main focus of the industry, over the years significant developments have taken place in southern Manitoba.

This publication offers an overview of Manitoba's mining industry past and present, with a look to the future. It provides non-technical explanations of how mining is carried out and the role of the Geological Services and Mines Branches of Manitoba Energy and Mines. A glossary at the end of the booklet explains some of the technical terms which are necessary in a publication of this kind.

Although fossil fuels are briefly mentioned in this publication, Manitoba's petroleum industry is explored more thoroughly in "Oil in Manitoba," another publication in the Department's Mineral Education Series. Similarly, aggregate resources are dealt with more extensively in "Sand and Gravel in Manitoba."



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Top: Thomas Creighton, staker of Flin Flon copper-zinc orebody with niece Beth Hutty, 1929.
Middle: Left to right: Art Corman, H.R. Drummond-Hay, Pete Kobar, Bob Jowsey, William Kobar at Herb Lake July 25, 1946.
Bottom: Duncan Twohearts, a guide who led Ephrem Pelletier in March 1911 to a showing which later became the San Antonio gold mine, circa 1930.

History of Manitoba's Mining Industry

The emergence of Manitoba from beneath the weight of the continental ice sheet some 12 000 years ago, and the draining of Lake Agassiz by 5000 BC, allowed the ancestors of Manitoba's aboriginal peoples to migrate into the province. Following the hunt, these early Manitobans brought with them tools, utensils and weapons made from stone and metal. Sources for many of the required raw materials were located in the province and Manitoba's "mineral industry" began with these primitive but effective tools. Raw materials not found within the province, such as jade, native copper, and volcanic glass, were imported through elaborate trade networks, from as far away as British Columbia and the Gulf of Mexico.

Pottery making led to the development of one of Manitoba's abundant mineral resources — clay. The clay was fashioned into a variety of shapes for use in cooking, eating and storage. In the Whiteshell region of southeastern Manitoba, stones and boulders were arranged in geometric and animal outlines called petroforms, possibly as part of religious practices. Rock paintings, or pictographs, of human and animal forms have been found throughout the Precambrian Shield, often along waterways.

European exploration and settlement of Manitoba marked the beginning of a new era in Manitoba's mineral development. Beginning with Henry Hudson's ill-fated voyage in 1610, and the extension of the fur trade from New France into the Winnipeg area in the eighteenth century, Manitoba became increasingly tied to European development.

Industrial Minerals

Early European explorers were far more interested in furs than minerals, and it is fitting that the first commercial mineral development in Manitoba was salt for the fur trading posts. In the early 1800s, former employees of the Hudson's Bay Company and the North West Company supplied the new Red River settlement, and trading posts from Norway House to Fort Qu'Appelle, with salt from brine springs on the west side of Lake Manitoba and Lake Winnipegosis. Evidence indicates that Plains Indians had long made use of these springs for their own domestic use.

By 1874, more than "1000 bushels" a year were manufactured at Monkman's Springs, near present day Winnipegosis. This industry was revived in the 1930s by Canadian Salt Company Limited and in the late 1960s by Dryden Chemicals Limited (later Hooker Chemicals Limited) at Neepawa and Brandon respectively (Fig. 12). Commercial salt operations continued in Manitoba until 1978.

Honourable John Bracken, first Minister of Mines (with pipe), visiting Deloraine Coal Mine, circa 1932.

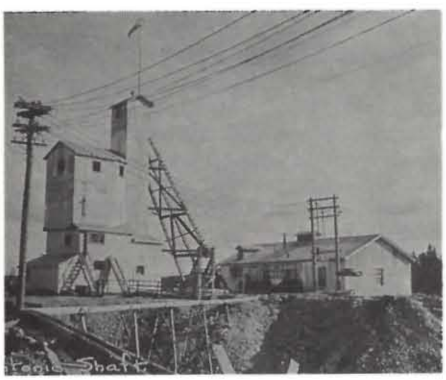
Quarrying of construction materials was the first significant mining during the period of European settlement. The first recorded use of local building stone in the Red River settlements occurred in 1830 when the now famous Tyndall stone, a mottled dolomitic limestone, provided the raw material for the northwest bastion of Lower Fort Garry. The fort is preserved as an historic site, 15 kilometres north of Winnipeg.

In 1895, William Garson opened the first commercial quarry in the Garson district to serve Canada's booming construction industry. Others soon followed. Structures across Canada were eventually to use Tyndall stone, including the Provincial Legislative Building in Winnipeg and the interior of Ottawa's Parliament Buildings.

Quarrying Tyndall stone near Garson. Straight lines were cut using tungsten carbide-toothed circular saw.

Making bricks from Manitoba's clay deposits was another early industry. By 1886 four brick plants were functioning in the province. The number of brick plants increased to sixteen between 1886 and 1910. However, the declining popularity of brick as a construction material and the relatively low quality of Manitoba's brick-making clay deposits known at the time, caused the common brick industry to subside from this peak.

The discovery of gypsum in the Interlake area during the 1850s eventually led to Manitoba's first gypsum plant, established in 1901 by Manitoba Union Mining Company Ltd. (later the Manitoba Gypsum Company). A railway line reached Gypsumville in 1910 and Manitoba Gypsum Company, now Domtar Construction Materials Ltd., produced gypsum in the area until 1984.



Headframe of San Antonio gold mine, 1933.

The province's first natural cement plant opened about 1900 at Arnold, 113 kilometres southwest of Winnipeg. A second plant operated at Babcock, west of Carman, from 1907 to 1924. The first portland cement plant opened in 1911 at Fort Whyte, just southwest of Winnipeg. The Inland Cement Company Limited (formerly Genstar Limited) plant is still producing cement at the Fort Whyte site.

Mines in the Turtle Mountain area of southwest Manitoba produced small amounts of lignite coal as early as 1883. The Manitoba Coal Company, incorporated in 1888, mined lignite coal commercially in the area for a short period in the 1890s. Lignite was mined again in this area on a small scale in the 1930s, but was soon abandoned for better deposits in southeastern Saskatchewan.

In 1920, gold prospectors discovered interesting rock formations, called pegmatites, to the east of Lac du Bonnet. Tin and beryl were recognized in the pegmatites, opening up new mineral potential for the region. Drilling for tin in 1929, Jack Nutt Mines Ltd. encountered the unique Bernic Lake pegmatite. The company sank a shaft and set up a 9 tonnes per day mill to extract the tin, but without success.

Large reserves of lithium were outlined in the Bernic Lake pegmatite during 1955 and 1956. In 1958, massive cesium ore was found in the pegmatite and tantalite was identified in 1960. Tantalum Mining Corporation of Canada Limited opened North America's first tantalum mine in 1969 producing tantalite concentrate until the end of 1982. Following a $6.4 million plant extension, the mine complex reopened in 1986 as a producer of spodumene concentrate. Spodumene, a lithium mineral, is used in the production of ceramic cookware.

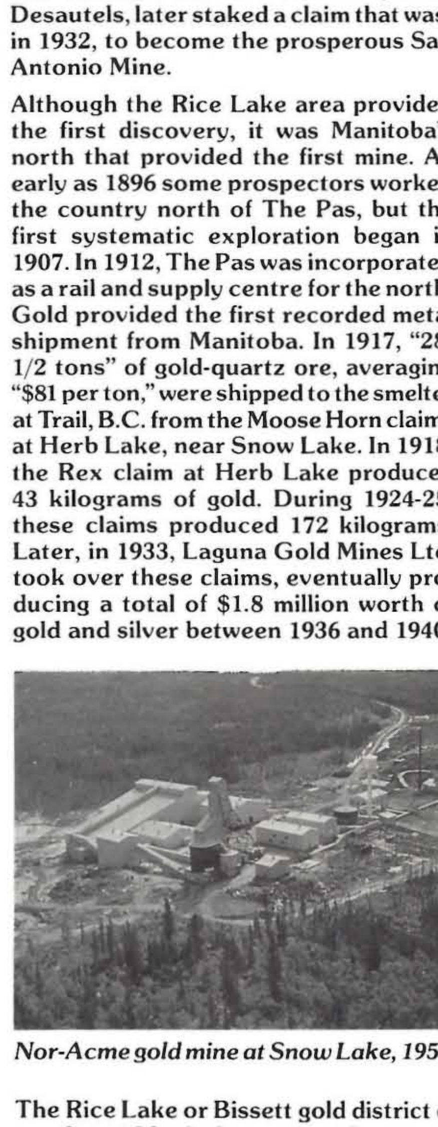
Petroleum

In 1877, Manitoba Oil Co. Ltd. drilled the first hole for oil in Manitoba, in the Dauphin region. Although there was intermittent drilling for oil from 1900 onward, a commercial pool was not discovered until 1951, near Virden, by California Standard Oil Company (now Chevron). This was the first oil discovered in the prolific, Canada — US, Williston Basin. The pool is still producing. The discovery was followed by a boom in exploration and development activities as new fields were discovered. Virden became the oil capital of Manitoba's small but active petroleum industry. At one point the town could boast sixteen producing wells within the town. Between 1981 and 1985, the Waskada area to the south experienced a "mini-boom" in exploration and development.

Precious Metals

Gold was often the catalyst that opened new lands in Canada's north and west, and Manitoba was no exception. Soon after gold was discovered in the Black Hills of South Dakota in 1879, prospectors moved north. Manitoba's first documented gold discovery took place in southeast Manitoba at Rice Lake, near the present town of Bissett. There, in 1911, Ephrem Pelletier staked the Gabrielle claims. Pelletier's assistant, Alex Desautels, later staked a claim that was, in 1932, to become the prosperous San Antonio Mine.

Although the Rice Lake area provided the first discovery, it was Manitoba's north that provided the first mine. As early as 1896 some prospectors worked the country north of The Pas, but the first systematic exploration began in 1907. In 1912, The Pas was incorporated as a rail and supply centre for the north. Gold provided the first recorded metal shipment from Manitoba. In 1917, "28-1/2 tons" of gold-quartz ore, averaging "$81 per ton," were shipped to the smelter at Trail, B.C. from the Moose Horn claims at Herb Lake, near Snow Lake. In 1918, the Rex claim at Herb Lake produced 43 kilograms of gold. During 1924-25, these claims produced 172 kilograms. Later, in 1933, Laguna Gold Mines Ltd. took over these claims, eventually producing a total of $1.8 million worth of gold and silver between 1936 and 1940.



Nor-Acme gold mine at Snow Lake, 1956.

The Rice Lake or Bissett gold district of southeast Manitoba may not be as well known as camps like Red Lake (its possible extension to the east in Ontario) or Timmins, but it has an equally interesting history. The first of many small to medium-sized gold mines in the Rice Lake area of southeastern Manitoba (Fig. 12), was the Kitchener Mine at Long Lake, operated by Central Manitoba Mines Ltd. from 1927 to 1937. Others followed, including the Tene, Growler and Hope Mines next to Kitchener, operated by Central Manitoba from 1932 to 1937; the Oro Grande from 1932 to 1934; the Gunnar Mine from 1936 to 1941; Ogama-Rockland 1941-42 and 1948-51; and the Jeep Mine from 1947 to 1950 (Table 3). The San Antonio Mine, by far the biggest operation in the district, ran continuously from 1932 to 1968 and was re-opened briefly by Brinco Limited from 1982 to 1983.

In the years following World War I, gold was also discovered northeast of Lac du Bonnet at the Diana-Gem Lake property which produced 236 kilograms from 1932 to 1938. Farther south, near Falcon Lake, the Sunbeam-Waverley gold prospects, first staked in 1912, produced 25 kilograms of gold and 5.7 kilograms of silver in 1940.

In remote northeastern Manitoba, high-grade gold was discovered at Island Lake in 1928, and Island Lake Gold Mines Ltd. produced 156 kilograms in 1934. The renowned prospector R.J. Jowsey, who discovered the Elk Island deposit at Gods Lake in 1932, established the prosperous Gods Lake Mine in this wilderness area in 1935. It eventually produced 491 000 tonnes of gold ore, then valued at $6 million, before closing in 1943.

The Gurney Mine, 40 kilometres east of what is now the town of Flin Flon, opened in 1937 and produced 778 kilograms of gold before ceasing operations in 1939. The large Nor-Acme deposit on the northeast shore of Snow Lake, discovered by C.R. Parres in 1925, produced 15 900 kilograms of gold and 1300 kilograms of silver between 1949 and 1958. This was Manitoba's largest gold operation, at 1800 tonnes per day, and second only to San Antonio in total production.

Drill set-up on the Sunbeam-Waverley gold prospect, 1944 (Provincial Archives).

Base Metals

The large and sophisticated base metal mining industry in Manitoba began in December 1914, when a local Indian, David Collins, showed Thomas Creighton a mineralized outcrop near what is now Flin Flon. Creighton and John Mosher returned in 1915 to stake 16 claims over the showings, one of which was called Flin Flon. The colourful name was taken from the hero of a novel the team had brought with them — Flintabbety Flonatin.

Residential development at Flin Flon, mine in background, 1933.

In October of 1915, Sidney Reynolds and Fred Jackson discovered the Mandy copper deposit, 5.6 kilometres to the southeast. In 1916, the first diamond drilling in northern Manitoba outlined a 22 675 tonne orebody with 20% copper. Mining began in 1916, with the ore shipped without milling to the Trail, B.C. smelter after spring breakup in 1917. Mining operations ceased in 1919, with the last ore shipped in early 1920. Mandy produced another 113 000 tonnes of lower grade ore in 1943-44.

In 1927, Hudson Bay Mining and Smelting Co., Limited (HBM&S) set up a pilot mill near the Creighton discovery. This later became the Flin Flon Mine, by far the largest copper-zinc deposit in Manitoba (Table 4). This deposit is mined on both sides of the Manitoba/Saskatchewan border. The railway reached Flin Flon in 1928, and in 1930 the HBM&S copper smelter and zinc plant produced its first blister copper and zinc slabs. Operations began at 2700 tonnes per day with an open pit that mined the upper 91 metres of the main Flin Flon deposit. In 1937 operations went underground when two shafts were sunk 1.6 kilometres apart. During World War II output was increased to a peak of 5400 tonnes per day.

The large capital investment by HBM&S in the late 1920s for rail, mine, smelter, refinery and a hydro-electric plant at Island Falls, Saskatchewan, laid the groundwork for opening up the prolific Flin Flon-Snow Lake belt and, later, the Lynn Lake belt to the north. Small satellite deposits were brought on stream between 1948 and 1960 at Cuprus, North Star, Don Jon and Schist Lake in Manitoba, and Coronation and Birch Lake in Saskatchewan.

In 1960, the first of the Snow Lake area mines, 120 kilometres east of Flin Flon, was opened at Chisel Lake, followed by Stall Lake in 1964, Osborne Lake in 1968, Dickstone and Anderson Lake in 1970, Ghost Lake in 1972 and Lost Lake, accessed from Ghost Lake workings, in 1977. More recently the Spruce Point and Rod deposits went into production in 1982 and 1984, respectively. In the Flin Flon area the White Lake Mine started in 1972, Centennial in 1977, Westarm in 1978 and Trout Lake in 1982. A concentrator, installed at the Stall Lake mine site in 1979, treated ores from all the Snow Lake mines prior to rail transport of the concentrates to the Flin Flon processing facilities. Ore from Spruce Point, 40 kilometres southwest of Snow Lake, is trucked directly to Flin Flon.

Even during the early years, prospectors kept pushing north and in 1922 Philip Sherlett (a Cree Indian), Carl Sherritt and Richard Madole discovered copper-zinc at Cold Lake, later to become the Sherridon Mine which was the beginning of Sherritt Gordon Mines Limited. A 64 kilometre railway from Flin Flon reached the Sherridon townsite in 1929. Eldon L. Brown, Sherritt Gordon's General Superintendent, brought the Sherridon Mine into operation in 1931, with a production rate of 1360 tonnes per day. Falling copper prices caused mining to be suspended in 1932, but operations resumed in 1937 and 7.7 million tonnes of ore were milled with a then market value of about $59 million before the ore was exhausted in 1951. The town of Sherridon, established to serve the mine, grew to 1500 people at its peak.

Knowing that Sherridon would eventually run out of ore, Brown launched an active exploration program. Between the wars, prospectors and geologists continued to push north into the Lynn Lake area. The first discovery in the Lynn Lake greenstone belt was a gold showing discovered in 1937 at Lasthope Lake, 32 kilometres south of the present town of Lynn Lake. In 1942, Austin McVeigh found mineralization assaying 1% copper and 1.5% nickel near what became the Sherritt Gordon "A" Mine at Lynn Lake. The small nickel-copper discovery, near the present town of Lynn Lake, was staked and explored after the war. From 1943 to 1950, magnetic and electromagnetic surveys and drilling outlined 11 nickel-copper ore zones totalling more than 12.7 million tonnes. Three main groups of ore bodies, "EL," "A" and Farley, were eventually outlined by geophysics and exploration drilling.

In a novel and courageous move, Sherritt decided to transport the entire mine facilities and townsite of Sherridon to the new Lynn Lake site when the Sherridon Mine was exhausted. From 1946 to 1953, 208 buildings weighing 36 000 tonnes, including the mill, school and bank, were moved 265 kilometres by tractor train over winter ice and trails.

The railway reached Lynn Lake in 1953 and the "A" and "EL" copper-nickel mines were put into production in 1953 and 1954, respectively. The nearby Farley Mine subsequently opened in 1961. All of the known economic Lynn Lake nickel deposits were exhausted in 1976. In the 1960s copper and zinc deposits were found by Sherritt Gordon at Fox Lake, 45 kilometres southwest of Lynn Lake, and at Ruttan, 25 kilometres east of Leaf Rapids. The Fox Mine began production in 1970 and the Ruttan Mine in 1973. The Fox Mine closed in 1985.

T.E. Burke-Gaffney performing a magnetic survey over Sherritt Gordon's Lynn Lake orebody, 1947.

After the Lynn Lake discoveries, the next important development began in 1946 when the International Nickel Company of Canada, Limited (now Inco Limited) initiated an extensive 10-year exploration program in the Mystery-Moak Lakes area of north-central Manitoba. In 1956 Inco announced the discovery of the major Thompson nickel-copper deposit. Work on the earlier discoveries at Moak Lake was suspended in 1956 when the higher grade Thompson deposit was found and the site of a proposed town was moved to where the City of Thompson now stands.

Eleven months after the discovery of the Thompson orebody, Inco signed an agreement with the Manitoba Government that led to the development of the deposit. Work began immediately on a $400 million complex designed for 10 800 tonnes per day. As the first fully integrated complex of nickel mining, concentrating, smelting and refining in a single plant area, Thompson became the non-communist world's second largest nickel producing centre. Thompson, currently the third largest city in Manitoba, with a population of about 14 000, was built to service the complex.

The railway spur reached Thompson in 1957 and the first electrolytic nickel was produced in 1961. Other deposits, ranging from seven to 70 kilometres southwest of Thompson, at Soab North and South, Pipe No. 1 and 2 and Birchtree, were discovered and put into production between 1967 and 1971. These are presently closed. Further southwest, Falconbridge Nickel Mines, Limited discovered a number of nickel deposits, and opened the Manibridge Mine, which operated from 1970 to 1977.

Inco's Thompson mine original development shaft (T-2), 1956.

While the major activity was in the north, base metal exploration and mining also occurred in the southeast part of the province. In 1917 and 1920, small copper and nickel deposits were discovered in the Maskwa Lake and Bird River areas. These were drilled intermittently in the 1930s and 1950s and Dumbarton Mines Limited mined the small Dumbarton-Maskwa deposits, 130 kilometres northeast of Winnipeg, from 1969 to 1976.

General Geology of Manitoba

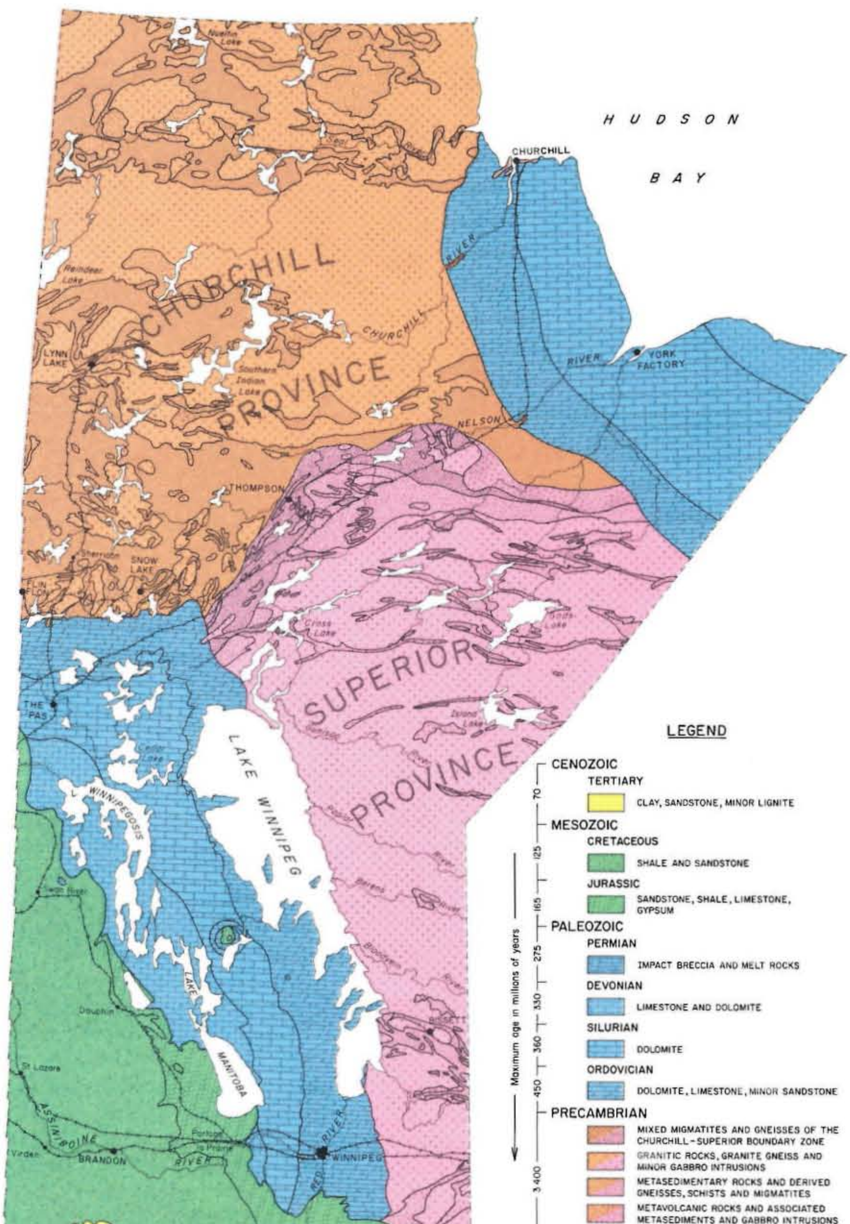


Figure 1 *Generalized geological map of Manitoba*

It is no accident that Manitoba has such a rich history of mineral exploration and development. Its geology has long been recognized as having excellent mineral potential. The province (Figs. 1 and 11) occupies 652 000 square kilometres and is underlain entirely by rocks of Precambrian age. Two-fifths of the Precambrian basement is concealed beneath rocks formed during the Paleozoic, Mesozoic and Cenozoic eras (Fig. 2 and Table 1). The surface geography of Manitoba is divided into four major regions that reflect the nature of the underlying bedrock and the effects of glaciers that covered much of the province in the Pleistocene age.

Precambrian Shield

The Precambrian Shield represents the largest region and is exposed in a relatively level, though hummocky, terrain flanked to the northeast by the Hudson Bay Lowland and to the southwest by the Manitoba Lowlands. The central part of the Shield, the Nelson depression or trough, slopes northeast towards Hudson Bay, drained by the waters of the Churchill, Nelson and Hayes Rivers. Much of the Nelson trough is less than 260 metres above sea level, but to the northwest, highlands rise to 506 metres and to the southeast to almost 380 metres.

Terrain typical of the Precambrian Shield in Manitoba.

Left: ***Rubble-covered contact of Precambrian with overlying Paleozoic limestone on the Churchill River.***

Above: ***Flat prairie, common to the Manitoba Lowlands.***

Local relief on the Shield is marked by numerous rivers and lakes, commonly 15-30 metres deep, and by rocky hills or morainal ridges formed by glacial debris. In northwestern Manitoba, the surface is hilly, with rock outcrop, eskers and drift ridges rising 100 metres above the valley bottoms.

The Precambrian Shield in Manitoba is divided into two geological or structural provinces (Figs. 1 and 11). The Archean rocks of the Superior Province, the oldest known in the Shield, have an easterly structural grain and were involved in the Kenoran mountain building that ended approximately 2.5 billion years ago. Isotopic studies of these rocks indicate they were formed approximately 2.5 - 3.0 billion years ago. To the northwest, the Churchill Province contains Proterozoic and Archean rocks that were involved in the Hudsonian mountain building, which ended approximately 1.7 billion years ago, and exhibit both an easterly and northeasterly structural grain. Isotopic ages for these rocks range from approximately 1.7 - 3.3 billion years.

A highly deformed boundary zone, where the Churchill and Superior Provinces meet, is characterized by complexly interfolded and faulted Archean gneisses and some supracrustal Proterozoic rocks. Part of this boundary zone is the Thompson Nickel Belt, which contains some of the world's largest nickel deposits. The Churchill-Superior boundary zone reveals a distinctive signature and trend when its gravitational and magnetic properties are mapped from the air, using modern instruments. With these techniques, the boundary zone can be traced underneath overlying Phanerozoic rocks far into Ontario to the east and North Dakota to the south.

Throughout most of Manitoba, the Precambrian Shield was reduced to an almost featureless plain by the time the initial sediments of the Phanerozoic era were deposited.

Manitoba Lowlands

The Manitoba Lowlands lie southwest of the Precambrian Shield (Fig. 1) and are bounded to the west by the Manitoba Escarpment and the Southwestern Upland (Fig. 2). Although elevations range between 217 and 300 metres above sea level, the variation, or relief, is generally less than 8 metres. The region is drained by the Saskatchewan, Red and Assiniboine Rivers and the principal lakes are Winnipeg, Winnipegosis and Manitoba. In the extreme southeast, south of the Trans-Canada Highway, sandy glacial deposits cause variable drainage and relief, forming large areas of peat bog and swamp.

The Manitoba Lowlands are underlain principally by sedimentary rock of Paleozoic age (Table 1) that constitutes the northeastern flank of the Williston Basin, a major sedimentary basin centred in northwestern North Dakota. Below the surface, the Paleozoic strata dip progressively southwest towards the centre of the Williston Basin, to a depth of 2300 metres in the southwest corner of the province (Fig. 2). Paleozoic strata consist almost entirely of dolomite, limestone and dolomitic limestone with minor clay, limestone and/or sandy intervals. The Paleozoic formations are overlain with marked angular unconformity by younger Mesozoic strata that progressively overstep Paleozoic strata to rest directly on Precambrian basement in the area southeast of Winnipeg.

Southwestern Upland

Mesozoic rocks and Pleistocene morainal deposits underlie the Southwestern Upland (Fig. 2). The Porcupine, Duck and Riding Mountains, whose eastern sides form the steepest parts of the Manitoba Escarpment, are separated in turn by broad gentle valleys. Turtle Mountain, on the border with North Dakota, is an erosional remnant capped by Paleocene sandy silty shales containing sub-economic deposits of lignite, and by Pleistocene glacial moraines.

Mesozoic formations consist almost entirely of shales and sandstones, with some limestone and gypsum. The Mesozoic beds dip gently to the southwest, towards the Williston Basin. Maximum thickness of Mesozoic beds in the southwestern corner of the province is approximately 1070 metres. Numerous outliers, or channel-fill deposits, of Mesozoic sediments also occur within the Paleozoic outcrop belt.

Hudson Bay Lowland

The Hudson Bay Lowland (Fig. 1) is an undulating plain of subdued relief and low elevation. Erosion by the continental ice sheet deranged the drainage, resulting in a maze of swamps, lakes and streams. The Churchill and Nelson Rivers, which developed upon the new topography, have cut 18 to 50 metres into till and bedrock.

Paleozoic strata of the Hudson Bay Lowland region dip gently to the northeast, towards the bay. The maximum onshore thickness of Paleozoic strata is 884 metres, but in the central part of Hudson Bay the thickness probably exceeds 1800 metres. These strata, as in the Manitoba Lowlands, consists mainly of limestone, dolomitic limestone and dolomite. The formations of the Hudson Bay Basin are partially correlative with the Paleozoic sequence of the Williston Basin of southwestern Manitoba (Table 1).

Left: *Varying topography common to the southwestern Upland.*
Right: *Succession of beach ridges on the margin of Hudson Bay.*

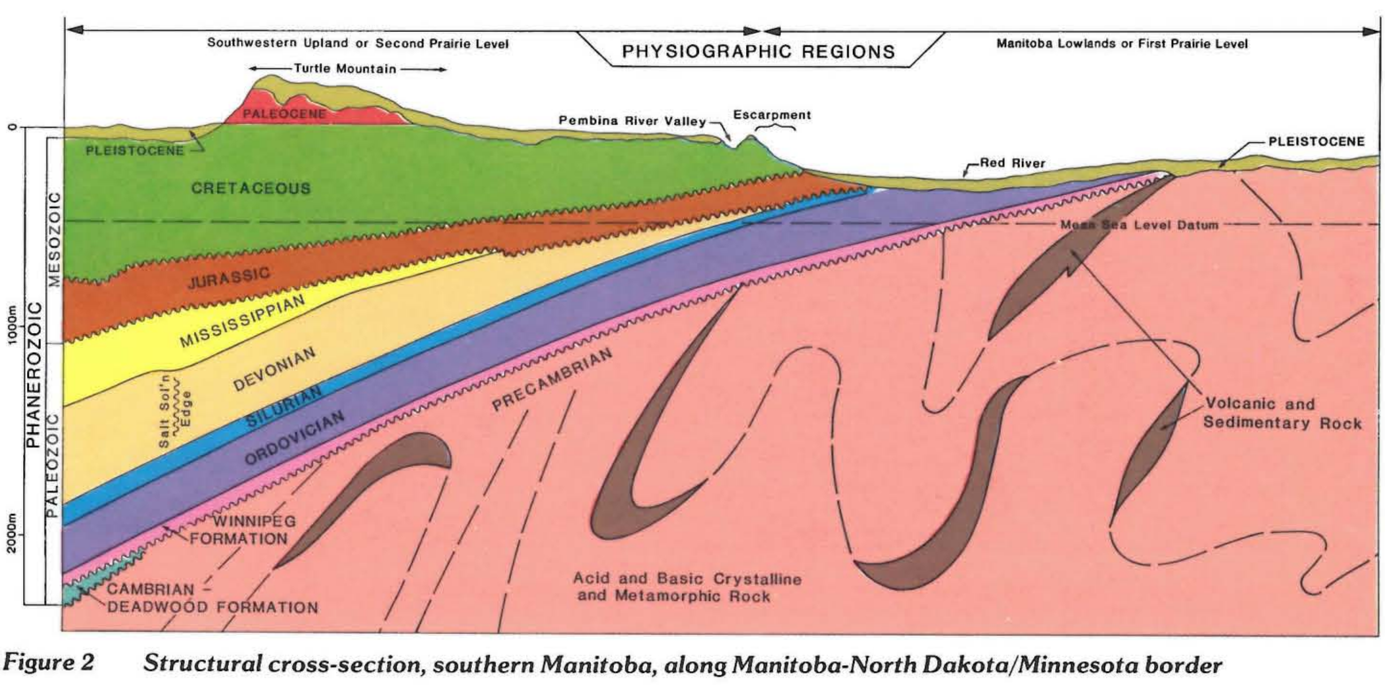


Figure 2 *Structural cross-section, southern Manitoba, along Manitoba-North Dakota/Minnesota border*

AGE *M.Y.B.P.	ERA	PERIOD	EPOCH	FORMATION	MEMBER	MAX. THICK (m)	BASIC LITHOLOGY
	CENOZOIC	QUATERNARY	RECENT				Top soil, dune sands
			PLEISTOCENE	GLACIAL DRIFT		140	Clay, sand, gravel, boulders, peat
		TERTIARY	PLIOCENE				
			MIOCENE				
			OLIGOCENE				
50			EOCENE				
			PALEOCENE	TURTLE MTN.		120	Shale, clay and sand. Lignite Beds; located only in Turtle Mountain
65	MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	BOISSEVAIN		30	Sand and sandstone, greenish grey; located only in Turtle Mountain
				RIDING MTN.	COULTER ODANAH MILLWOOD	310	Grey shale — non-calcareous, local ironstone, bentonite near base, gas found
				VERMILION RIVER	PEMBINA	155	Shale, dark grey carbonaceous non-calcareous; bentonite bands
					BOYNE		Shale, grey speckled calcareous, bentonitic; slightly petroliferous
					MORDEN		Shale, dark grey non-calcareous, concretions, local sand and silt
				FAVEL		40	Grey shale with heavy calcareous specks, bands of limestone and bentonite
100				ASHVILLE ASHVILLE SAND		115	Shale, dark grey, non-calcareous, silty quartz sand or sandstone
			LOWER CRETACEOUS	SWAN RIVER		75	Sandstone and quartz sand, pyritic shale — grey non-calcareous
		JURASSIC	UPPER JURASSIC	WASKADA		200	Banded green shale and calcareous sandstone
150				MELITA			Bands of limestone, vari-coloured shale
			MIDDLE JURASSIC	RESTON		45	Limestone, buff, and shales, grey
				AMARANTH	UPPER: EVAPORITE	45	White anhydrite and/or gypsum and banded dolomite and shale
					LOWER: RED BEDS	40	Red shale to siltstone, dolomitic, oil producing
200		TRIASSIC		ST. MARTIN COMPLEX		300	Carbonate breccia, trachyandesite (crypto-explosion structure) Permian-Triassic (?)
250	PALEOZOIC	PERMIAN					
300		PENNSYLVANIAN					
		MISSISSIPPIAN		MADISON GROUP: CHARLES		20	Massive anhydrite and dolomite
				MADISON GROUP: MISSION CANYON		120	Limestone, light buff, oolitic, fossiliferous fragmental, cherty, bands of shale and anhydrite, oil producing
				MADISON GROUP: LODGEPOLE		185	Limestone and argillaceous limestone, light brown and reddish mottled Zones of shaly, oolitic, crinoidal and cherty limestone Oil producing
				BAKKEN		20	Two black shale zones separated by siltstone. Oil show
350		DEVONIAN		QU'APPELLE GROUP: LYLETON		35	Red siltstone and shale, dolomitic
				SASK. GROUP: NISKU		40	Limestone and dolomite, yellow-grey fossiliferous, porous, some anhydrite
				SASK. GROUP: DUPEROW		170	Limestone and dolomite, argillaceous and anhydritic in places
				MAN. GROUP: SOURIS RIVER 1-ST RED		120	Cyclical shale, limestone and dolomite, anhydrite
				MAN. GROUP: DAWSON BAY 2-ND RED		65	Limestone and dolomite, porous, anhydrite — local shale red and green
				ELK POINT GROUP: PRAIRIE EVAP.		120	Salt, potash and anhydrite, dolomite interbedded
				ELK POINT GROUP: WINNIPEGOSIS		75	Dolomite, light yellowish brown, reefy
				ELK POINT GROUP: ELM POINT			Limestone, fossiliferous high-calcium
				ELK POINT GROUP: ASHERN		12	Dolomite and shale, brick red
400		SILURIAN		INTERLAKE GROUP		135	Dolomite, yellowish-orange to greyish-yellow, fossiliferous silty zones
		ORDOVICIAN		STONEWALL		15	Dolomite, greyish-yellow, bedded
				STONY MOUNTAIN	WILLIAMS GUNTON	30	Dolomite, yellowish-grey, shaly
					PENITENTIARY		Dolomite, dusky yellow, fossiliferous
					GUNN	20	Shale, red-green; fossiliferous, limestone bands
450				RED RIVER	FORT GARRY SELKIRK CAT HEAD DOG HEAD	170	Dolomitic limestone, mottled, and dolomite
				WINNIPEG		60	Shale, green, waxy; sandstone interbedded
500							Sand and sandstone, quartzose
		CAMBRIAN		DEADWOOD		60	Glauconitic sandstone and siltstone, and shale; green-grey to black; very edge of S.W. Manitoba only
550							
PRECAMBRIAN (EON)							Acid and basic crystalline and metamorphic rocks

*Millions of years before present

Table 1
Geological formations of Manitoba

Exploration Methods

Early Geological Reconnaissance

Systematic geological exploration in Manitoba dates back one hundred and thirty years. In 1857, the British and Canadian governments launched two exploration expeditions with a mandate to conduct geological observations of what was to become southern Manitoba. Professor Henry Youle Hind was the geologist on the Canadian expedition, while James Hector M.D. undertook this task on the British expedition, better known as the Palliser Expedition.

Following the expedition, Hind published the first geological map of the southern prairies. In it he identified a sequence of younger geological formations as he travelled west from the Red River. Hind's speculation that absent Mississippian beds might be masked by glacial drift on the flanks of Riding Mountain has since been discounted, although they do occur further west in the subsurface. However, his accurate evaluation of glacial moraines and other geological features as the products of glacial action was correct, but in opposition to the then prevailing view that floating glaciers were the cause. In 1858, Hind investigated the limestone plateau now known as Stony Mountain and examined the Monkman salt springs on the west side of Lake Winnipegosis.

Hector's geological report, published in 1863, delineated the three great prairie levels, or steppes, shown in Figure 2. The top of Turtle Mountain is an erosional remnant of the third prairie level, known as the Missouri Coteau, which extends west into Saskatchewan. Hector's report, the result of three years of field work, provided a comprehensive description of the prairie region and the Rocky Mountains between the 49th and 54th parallels.

Geological exploration was considered important enough to be mentioned in the arrangements that brought Manitoba into Confederation in 1870. The federal government made a commitment to continue geological surveys in the new province. The Director of the Geological Survey of Canada, Alfred Selwyn, travelled by canoe from Lake Superior to Lake Winnipeg in 1872 to familiarize himself with rock formations and travel conditions. The next year he trekked as far west as the Rocky Mountains, then back to Winnipeg using Red River carts. Following Selwyn's preliminary surveys, such men as George Dawson, Robert Bell, Joseph Tyrrell, and Donaldson Dowling produced a succession of geological reports on northern Manitoba by the turn of the century. One important result was the report of extensive gypsum deposits in the Interlake region.

The first geological exploration in the Flin Flon-Snow Lake greenstone belt (Fig. 11) was conducted by Tyrrell in 1896. Dowling's work around the Grass, Burntwood, Goose and Kississing Rivers and Athapapuskow, Reed and Sisipuk Lakes followed in 1899. Dowling speculated that prospectors would eventually find orebodies and precious metals in the region. Discoveries of major orebodies at Flin Flon occurred fifteen years later.

Prospecting

The gold discoveries of South Dakota's Black Hills in 1879, Ontario's Lake of the Woods in the 1880s, and the Yukon's Klondike in 1897 stimulated interest in gold prospecting. The first record of any mining company organized in Manitoba is that of Winnipeg Consolidated Gold Mining Company Ltd., incorporated September 2, 1882, to explore in the Lake of the Woods region in Ontario.

Interest was next shown in prospecting and boring for oil, coal and salt in Manitoba with the incorporation on August 4, 1884 of the Nelson Prospecting and Mining Company Limited by "residents of the village of Nelson, in the County of Dufferin." Currently a "ghost town," Nelson was located northwest of Morden.

Just after the turn of the century, discoveries of gold, silver and cobalt at Cobalt and Porcupine, in Ontario, aroused keen interest in the metallic mineral potential of northern Canada. A wave of prospecting swept the land, and its ripples reached Manitoba. Almost overnight, Manitobans realized that the non-agricultural areas, constituting most of the province, could be a major source of Manitoba's wealth. Reports from early explorers, comments by surveyors, water-power officials, geologists, trappers, and Native people, all helped to shape this new view of Manitoba's non-agricultural resources. With the transfer of what is now northern Manitoba to the province, in 1912, this new perspective led to serious investigation of northern Manitoba's mineral potential.

To oversee the orderly development of mining in northern Manitoba, R.C. Wallace was appointed Commissioner of Northern Manitoba in late 1918. Wallace and his successor, J.S. DeLury, authored a number of mineral bulletins describing the geology and mineral prospects of various regions of the province. Published by the Government of Manitoba, and later the Industrial Development

Fred Heidman, Mining Recorder in The Pas demonstrating claim staking procedures, 1987.

Board of Manitoba, which was chaired by the Premier, John Bracken, the bulletins also contained a "Synopsis of Regulations Governing the Granting of Mineral Rights" by the federal government, which administered the province's resources until 1930.

In anticipation of the transfer of resources from the federal to the provincial government, the Department of Mines and Natural Resources was established in 1928. The Honourable John Bracken was the first Minister of the new department and J.S. DeLury became Provincial Geologist. Later in the year, D.G. McKenzie was sworn in as Minister of Mines and George E. Cole was appointed Chief Inspector of Mines. The work of the department consisted of map and report sales, advertising and exhibits, fieldwork such as mapping and examining occurrences, mine inspections and schools for prospectors.

To encourage exploration during the depression, in 1936 the department published the first edition of "A Guide for Prospectors in Manitoba." The Guide presented a review of mining development, a description of prospecting equipment, instruction on staking and recording of mineral claims, prospecting maps and a summary of the geology of the province. The Guide was so popular that it was updated and reprinted in 1937, 1945 and 1952. In 1962 the format was modified and it became "Geology and Mineral Resources of Manitoba" with a detailed description of the geological framework of the province and an in-depth review of its mineral deposits and occurrences.

The federal government, through the Geological Survey of Canada, publishes "Prospecting in Canada," which has become a basic reference text in the field. The booklet was originally authored in 1970 by A.H. Lang and was reprinted in 1976 and 1980. Prospectors' sets of mineral chips and rock chips, with descriptive notes, are still available at reasonable cost from Ottawa.

Regulations under The Mines Act have evolved over the past sixty years since they were copied largely from the rules of the province of Ontario. "The Mineral Disposition Regulation, 1981" and "Quarrying Mineral Regulation, 1976" set out the rules for metallic and industrial mineral prospecting and exploration. In general, metallic mineral prospecting involves staking claim posts around a suspected mineral deposit and recording this claim. Industrial mineral prospecting requires only the application for the rights to a particular piece of ground in the mining recording office.

To retain exclusive control of mining and quarrying dispositions, it is necessary to report work done on the property. These progress reports become available to the public once the disposition is cancelled, usually after the former holder is no longer interested in the property. Active dispositions are shown on maps maintained in the recording offices in Winnipeg and The Pas.

Prospecting involves the examination of these "claim maps" and the study of geological, geophysical and geochemical maps, usually produced by the federal and provincial governments. Air photographs and topographic maps of interesting areas, and other information gathered by the prospector, are used to select sites with a good possibility of mineralization at or near surface.

Only then does prospecting begin to fit the popular concept. The prospector travels to the site using a variety of methods — plane, boat, snowmobile or on foot — to examine, firsthand, the site. This may involve stripping moss, trenching or blasting. Interesting rock samples are collected and brought back to be assayed to determine the presence and quantity of valuable elements such as copper, zinc, gold, silver, or other indicators such as arsenic or mercury, which can lead to such mineralization. If the assay results and geological indications are good, further work will be done using geophysical methods and diamond drilling to determine the extent and nature of the mineralization.

At this point, work is sometimes supported, or taken over, by other individuals in syndicates or by junior and major mining companies. The prospector can option the property to these groups with payments at certain intervals, if the additional work is encouraging.

Some famous prospectors who have found interesting mineralization and/or staked ground in Manitoba are: Duncan Trueheart, E.A. Pelletier and Alex Desautels — San Antonio Mine; David Collins and Tom Creighton — Flin Flon Mine; Philip Sherlett, Carl Sherritt and Richard Madole — Sherridon Mine; Chris Parres — Nor-Acme Mine; Austin McVeigh — Lynn Lake Mine; and Bob Jowsey — Gods Lake Mine.

Mineral Exploration

Prospecting by mining companies is usually called mineral exploration. Whereas prospecting usually involves examination of mineralized sites at or near surface, mineral exploration is normally the hunt for economic mineral deposits that may be situated well below the surface. Airborne geophysical instruments are flown over a large area to select targets for follow-up ground work, including geological, geophysical and geochemical investigation, sampling and drilling. The airborne surveys are usually beyond the financial resources of the individual prospector. However, the survey results can become available for inspection after the companies lose interest in the ground.

Airborne geophysical surveying involves the use of magnetic, electromagnetic or radiation equipment mounted on and/or towed by planes or helicopters (Fig. 3). Anomalous values, recorded as peaks on a chart, indicate an unusual variation in either the magnetism, induced electromagnetic field or radioactivity of the rock in the surveyed area. An anomaly does not guarantee that a mineral deposit exists. They are often the result of worthless minerals or rock formations that yield a similar response.

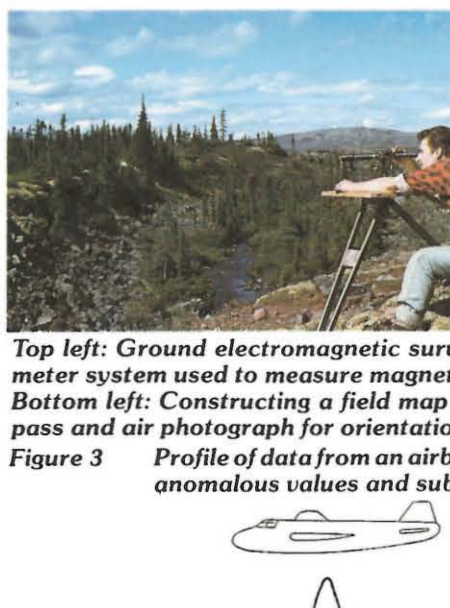
A geologist determines drill targets by studying hundreds of anomalies and rating them on the basis of their geophysical strength, shape and geological environment. The best locations are staked immediately. Detailed ground geophysical surveys then define the location and size of the anomaly.

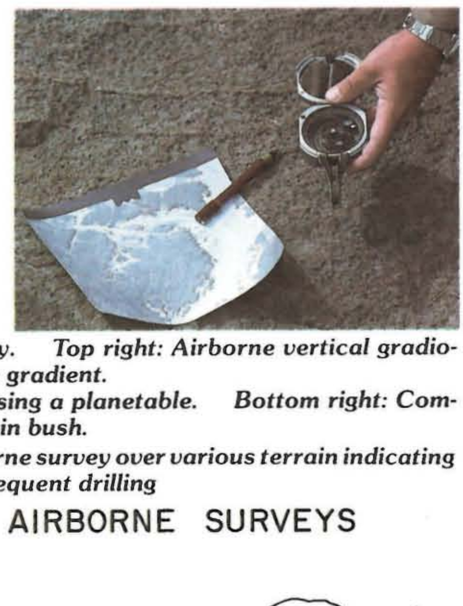
Mining companies usually finance large exploration programs through the sale of shares in the company. The company will advertise a proposed program. Individuals, interested in the proposal, purchase shares at a set amount and wait for the results. If results are good, investors are rewarded with increased share prices and potential dividends. Poor results mean lower share values, and the initial buyers can either sell at a loss or hope that an economic find will eventually be made.

Diamond drilling of the anomaly, the final and most expensive phase in mineral exploration, is the only sure way to find out the amount of mineralization present. If the first holes indicate a mineral deposit, a series of holes are drilled to determine its length, depth, thickness and grade.

If the mineral deposit can be economically removed from the surrounding waste rock, the term orebody is used. Sometimes one mine can tap several orebodies. Orebodies are usually of irregular size and shape and mining them requires a great deal of capital. A mining company that has established an orebody through detailed diamond drilling, may elect to sell its interest or option the property in a way similar to the individual prospector. If the owners decide to develop the property on its own, a new set of shares may be issued for this purpose, either directly, or through a subsidiary company.

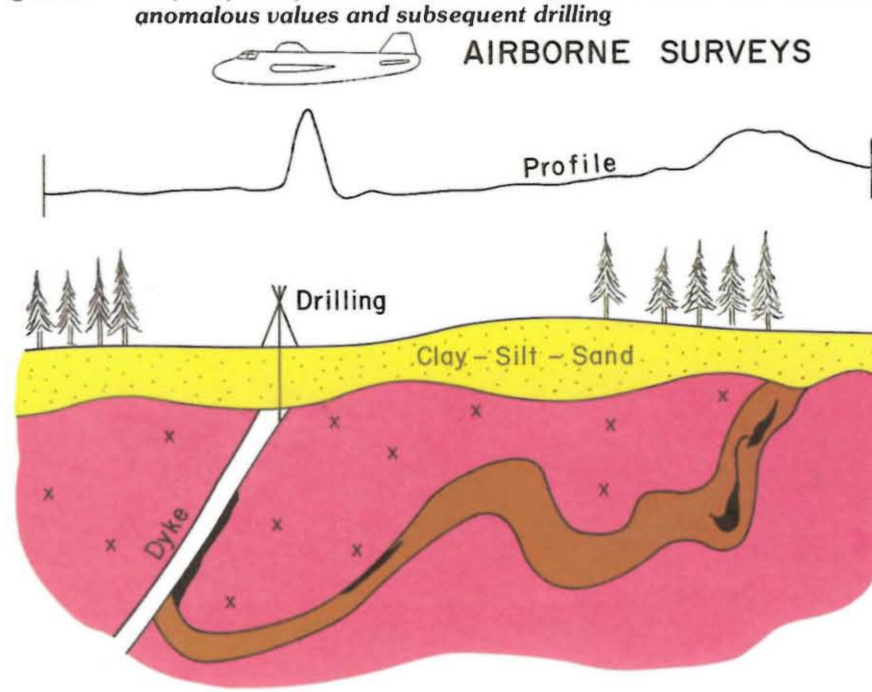
Granges Exploration Ltd., which brought a gold orebody into production in May, 1987 at Tartan Lake, or Pioneer Metals Corporation which is developing one at Puffy Lake, are typical junior mining companies. An example of a subsidiary company is SherrGold Inc., owned by the much larger Sherritt Gordon Mines Limited. SherrGold was established to bring the MacLellan gold mine into production in 1986. Two other major companies that have conducted extensive exploration surveys in Manitoba are Inco Limited and Hudson Bay Mining and Smelting Co., Limited. The latter conducts its exploration programs through its subsidiary Hudson Bay Exploration and Development Company Limited.





Top left: Ground electromagnetic survey. Top right: Airborne vertical gradiometer system used to measure magnetic gradient.
Bottom left: Constructing a field map using a planetable. Bottom right: Compass and air photograph for orientation in bush.

Figure 3 Profile of data from an airborne survey over various terrain indicating anomalous values and subsequent drilling



Inco Limited's Pipe Open Pit and No. 2 Headframe in background. Large steam shovels, drills and trucks are dwarfed by the size of the pit. Access road spirals upward along pit walls (circa 1980).

Mining and Quarrying Methods

Surface Mining

Economic rocks and minerals are extracted from the ground by either surface or underground methods (Fig. 4). If an orebody is near the surface, an open pit generally provides lower operating cost. The term 'quarry' is used to describe the opening if the orebody is an industrial mineral such as limestone or gypsum, but the term 'pit' is often used for sand and gravel. Open pit mining usually involves removal of material, such as water, mud, muskeg, or rock, from above the orebody.

In sand and gravel operations, draglines or large shovels scoop the 'ore' and load it on trucks for transport to a plant for further processing such as sorting according to size. For quarrying industrial minerals, such as gypsum or Tyndall stone, drilling and blasting or diamond sawing may be used.

The outline of open pits is usually circular and from the air have the appearance of a 'bull's-eye,' with the deepest 'ore' removed from the centre. The sides of the opening provide access roads and must be stable enough to prevent caving. The ore is removed in a series of slabs or benches from five to ten metres (or more) high. Explosives are used to break up these slabs into blocks which are usually much less than a cubic metre in size. As additional ore is removed, spiralling roads are constructed for ore trucks, or 'rock wagons,' to haul the ore to surface. The ore is broken down into chunks usually less than a quarter of a cubic metre by this time. Some benches of commercial grade ore may have to be left if the opening is not large enough at surface. This remnant is sometimes removed through a raise driven upward from an underground mine.

Underground Mining

A typical underground mine, as illustrated in Figure 4, may include a decline which gradually spirals downward to reach the various levels beneath the surface, or it may be accessed through a vertical shaft. The ore is removed from areas in the mine called 'stopes.' Explosives are placed into holes drilled into the ore, and set off after ensuring that the miners are safely away from the working face in the stope. The blast breaks up the ore into chunks, usually no larger than a quarter of a cubic metre. Large vehicles on rubber tires, known as 'load haul dump vehicles' (LHD), are often used to move the ore to the 'ore pass.' The ore pass angles the ore down to the base of a shaft where it can be hoisted to the surface, or to an underground ore train which hauls it to a shaft for hoisting. At this point the ore is crushed to a diameter of less than a few centimetres in a jaw or gyratory crusher situated either at the base of the shaft or in a 'crusher house' at the surface.

In metallic mines, like Inco's at Thompson and HBM&S' at Flin Flon, the crushed ore is a mixture of metallic sulphide minerals and common or 'country' rock. In order to extract metals such as nickel, copper and zinc, the ore goes through a three step process: (i) the concentrator, where sulphide minerals are separated out of the country rock, (ii) the smelter, where iron and sulphur are removed

Conveyor belt with crushed gypsum at Harcus, 1987.

Hudson Bay Mining & Smelting complex in Flin Flon.

from the sulphide minerals and (iii) the refinery, where the elemental metal is captured and purified.

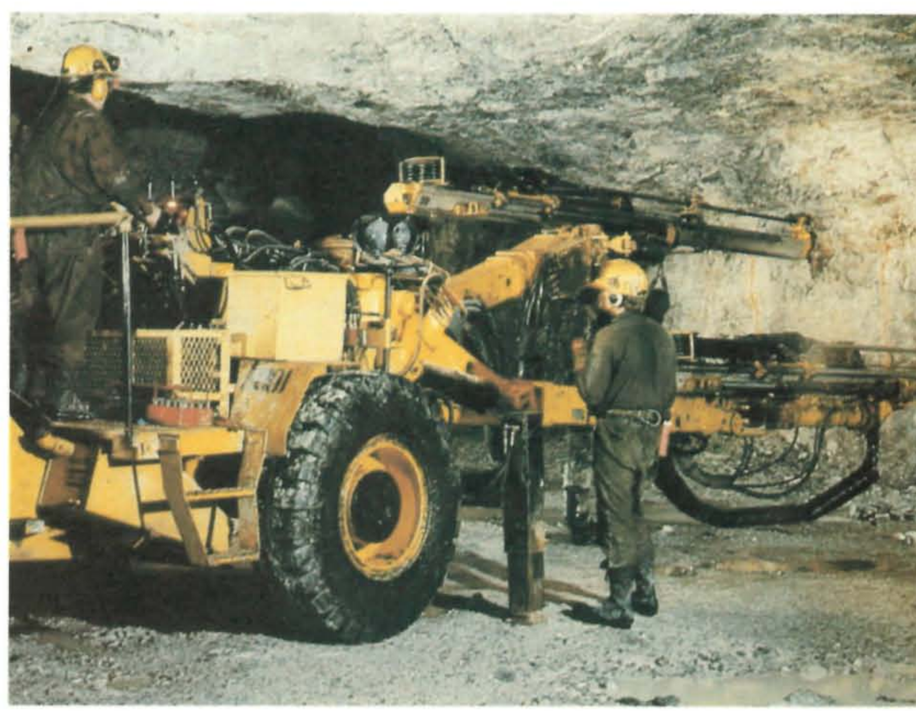
In the concentrator the ore is reduced by crushing and grinding steps to a very fine powder in a water slurry. Ball or rod mills, containing four to eight centimetre diameter steel balls or rods, rotate like cement mixers and pulverize the ore. The slurry then enters mill flotation cells where the addition of small amounts of organic compounds, called frothers, modify ore particle surfaces to resist wetting. Air is bubbled through the slurry and selective froths containing specific reagents are successively removed into different concentrates. Gravity separators, cyclone classifiers, and shaking tables may also be used to improve the grade of the concentrates. The waste products of the concentrator, called mill 'tailings' are deposited in contained 'tailings ponds' and often used for mine backfill.

The concentrates are delivered to the smelter where they are roasted to change sulphides to oxides. They are then either dissolved in acid in a process called leaching or smelted in a sand flux in blast, reverberatory or electric furnaces. If the concentrates are leached, the dissolved metallics are recovered from the resultant liquor by precipitating them into a residue. This is filtered and thickened and then sent to electrolytic cells where an electrical current is used to deposit metal on a cathode. Continuous purification of the electrolyte removes dissolved impurities. The metal is stripped from the cathode, melted and cast into shapes for handling and shipment.

If the concentrates are smelted, the material melts, separating into two layers of different chemical compositions. The lighter layer of iron and silica flux, called slag, is drained from the furnace. Usually the slag is a waste product sometimes used for mine backfill. However, if the molten slag contains zinc, powdered coal is blown over it to boil off the zinc to form zinc oxide powder. The powder is filtered out of the gas stream and returned to the zinc plant for further processing, and the remaining slag is then discarded.

Matte, the heavier layer containing metals, is transferred to converters where air and silica are used to remove the remaining iron and associated sulphur. The converter product is cast into anode shapes for shipping to the refinery.

In the refinery, the anodes are dissolved electrolytically to produce very pure cathodes in a process similar to that described after leaching of the concentrates. But in this case, the starter cathodes are of the same pure metal as that being plated. From the refinery the cathodes are shipped to various manufacturing industries.



Above: A pour of molten copper in the smelter, Hudson Bay Mining and Smelting, 1986.

Right: Underground drilling at Tanco's Bernic Lake Mine, circa 1980.

Top Right: Dragline for scooping sand and gravel at Birds Hill, 1982.

Manitoba's Mining Industry: An Overview

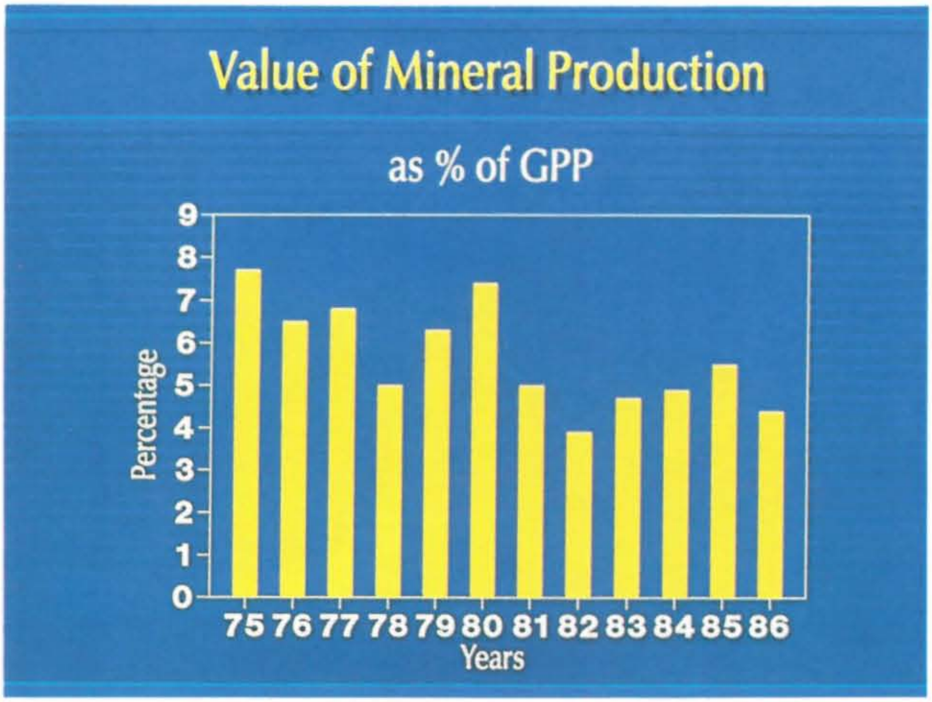
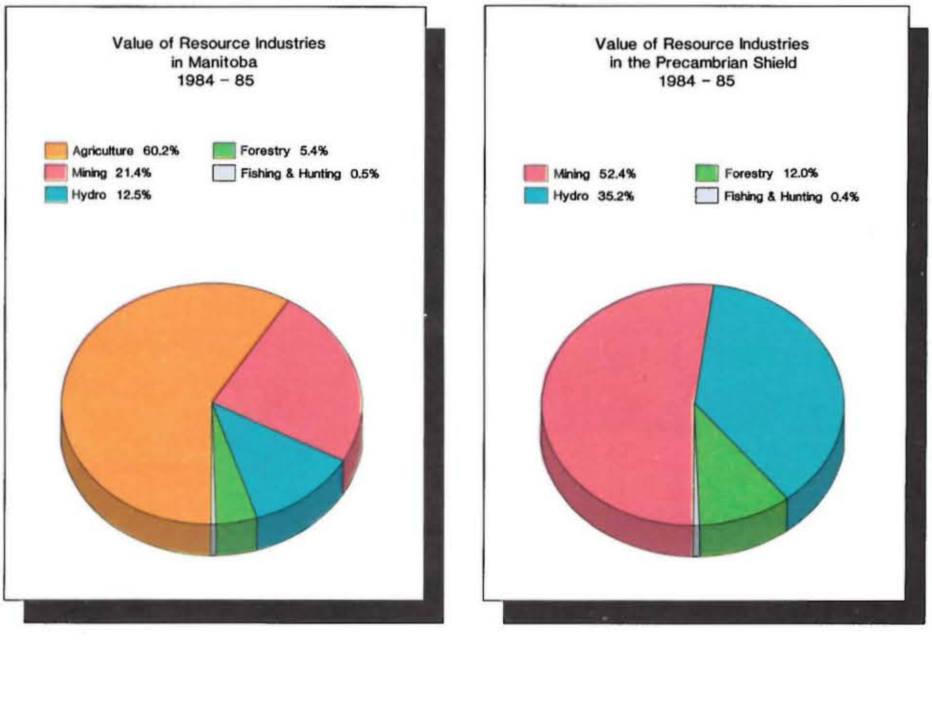


Figure 5 *Value of Manitoba's mineral production as a percentage of the gross provincial product, 1975 - 1986*

Figure 6 *A. Value of resource industries in Manitoba, 1984 - 1985*
B. Value of resource industries in Precambrian Shield of Manitoba, 1984 - 1985



Manitoba Mineral Production in 1985 and 1986

After agriculture, mining is Manitoba's second leading resource industry, accounting for an average of 5.7% of the gross provincial product (GPP) over the decade, 1977-86 (Figs. 5 and 6).

In 1984, minerals production was 4.9% of GPP, or approximately $773 per capita. The 1985 estimate is $781 per capita. Total employment in Manitoba's minerals industry, both directly in operations and indirectly in "spin-off" services and industries dependent on the minerals industry, averaged an estimated 28 000 people over the last decade. This represents approximately 6.3% of the employed labour force. As of December 1986, 4157 people worked in metal mines, smelters and refineries. With wage levels traditionally second only to the construction industry, the minerals industry provides an important source of income for Manitobans.

Revenue to the Province of Manitoba from direct minerals industry taxes and royalties in the last 10 years ranged from a high of $57 million in 1983-84 to a low of $14 million in 1977-78. This is in addition to the indirect benefits the province receives through income, sales and corporation taxes.

Manitoba's total value of mineral production, including petroleum, was $861 million in 1985 (Table 2). The preliminary figure for 1986 is $758 million, a possible decrease of more than $100 million (Fig. 7). The large decreases of 1981 and 1982 (Fig. 8) reflect the deep, world-wide economic recession, which hit the metals sector particularly hard. Output in recent years, ranging from almost $468 million in 1978 to a 1980 total of over $800 million, clearly illustrates the cyclic nature of the minerals industry. Manitoba is particularly sensitive to price and production levels of nickel and copper, which have accounted for about three-quarters of Manitoba's mineral value over the last 20 years. During the

COMPARISON OF MANITOBA MINERAL PRODUCTION AND VALUE 1985 AND 1986				
	1985		1986*	
	Value ($ 000)	Quantity	Value ($ 000)	Quantity
Metals		(000 kg)		(000 kg)
Cadmium	660	182	441	115
Cobalt	11 526	336	7 777	334
Copper	137 175	69 071	141 389	69 274
Lead	427	741	334	496
Nickel	286 627	38 937	259 609	43 595
Selenium	1 025	47	1 162	68
Tantalum	3 045	39	2 124	39
Tellurium	247	7	99	3
Zinc	81 120	64 689	71 369	57 742
Other**	1 876		2 986	
Precious Metals		(000 g)		(000 g)
Gold	30 118	2 162	35 851	2 187
Platinum Group	6 885	666	9 873	881
Silver	11 205	40 179	8 707	34 227
Total Metals	571 936		541 721	
Industrial Minerals		(000 tonne)		(000 tonne)
Cement	35 725	343	46 104	431
Clay Products	2 364		2 700	
Gypsum	1 997	196	2 146	162
Lime	5 866		5 417	
Peat Moss	10 563	87	13 808	73
Quartz	2 808		2 979	
Sand/Gravel	33 949	12 224	35 100	12 200
Stone	15 787	4 155	13 100	3 466
Sulphur	211	2	356	3
Total Industrial Minerals	109 270		121 710	
Fuels		(000 m³)		(000 m³)
Petroleum	180 049	821	95 000	825
Grand Total	861 255		758 431	

* Estimated
** Includes bismuth, cesium, lithium

Source: Manitoba Energy and Mines

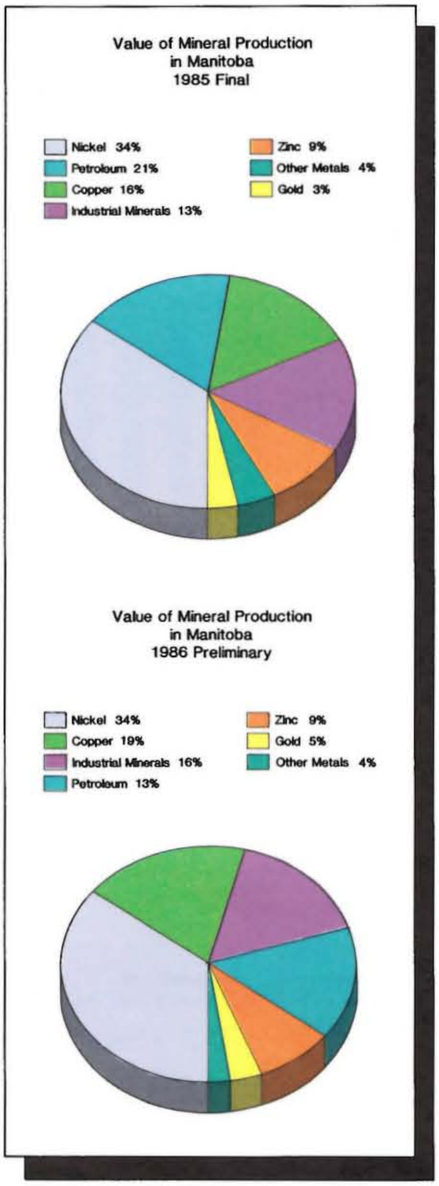


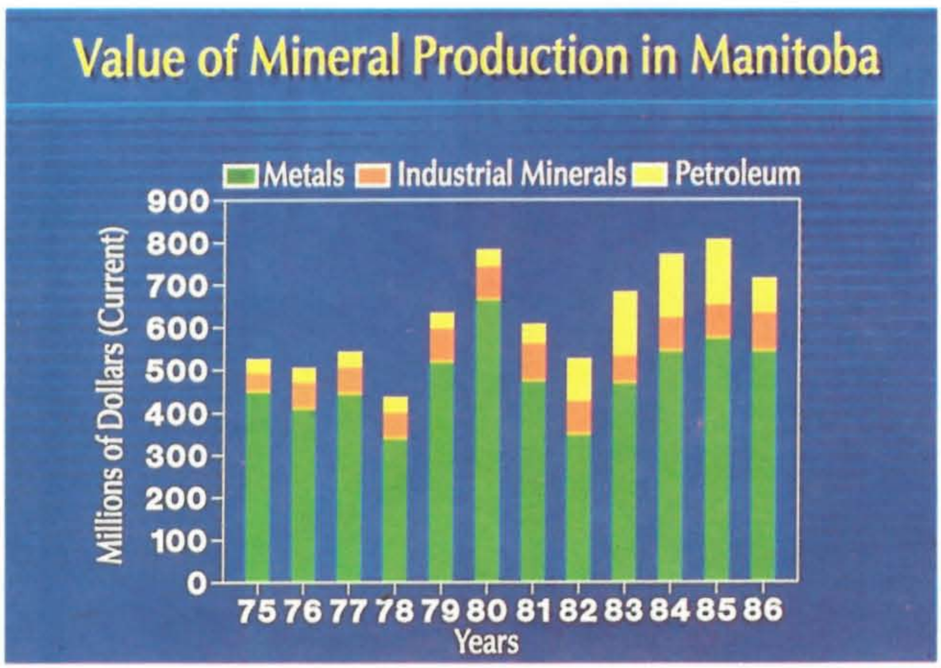
Figure 7 ***Value of mineral production in Manitoba:***
A. 1985 (final)
B. 1986 (preliminary)

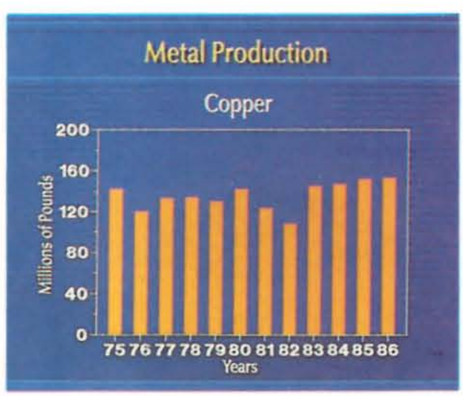
Table 2 ***Comparison of Manitoba mineral production and value — 1985 and 1986***

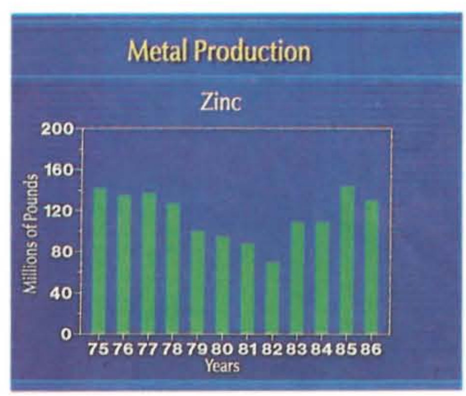
early 1980s, petroleum became an increasingly important sector of minerals production, rising from 10% of total value in 1981 to 23% in 1984. This trend was reversed in 1985, with the collapse of international oil prices.

Manitoba's recent share of Canada's total value of mineral production has ranged from 4.0% in 1975 to 1.6% in 1982. The preliminary figure for 1986 is 2.2% (Fig. 9). The province has maintained, for many years, a seventh ranking behind Alberta, Ontario, Quebec, British Columbia, Saskatchewan and Newfoundland.

These numbers tend to mask Manitoba's major role in the production of individual commodities. In 1986, Manitoba produced 24% of Canada's nickel, 14% of its cobalt, 12% of its peat, 9% of its copper, 5% of its zinc, 4% of cement, and 2.1% of Canada's gold.







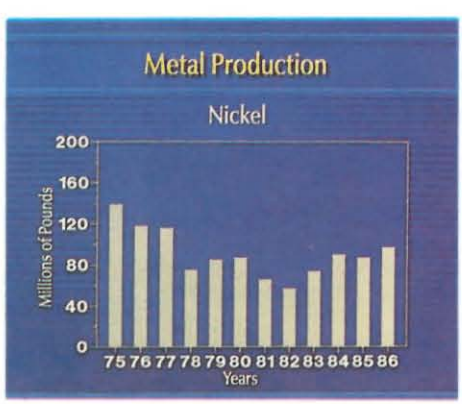
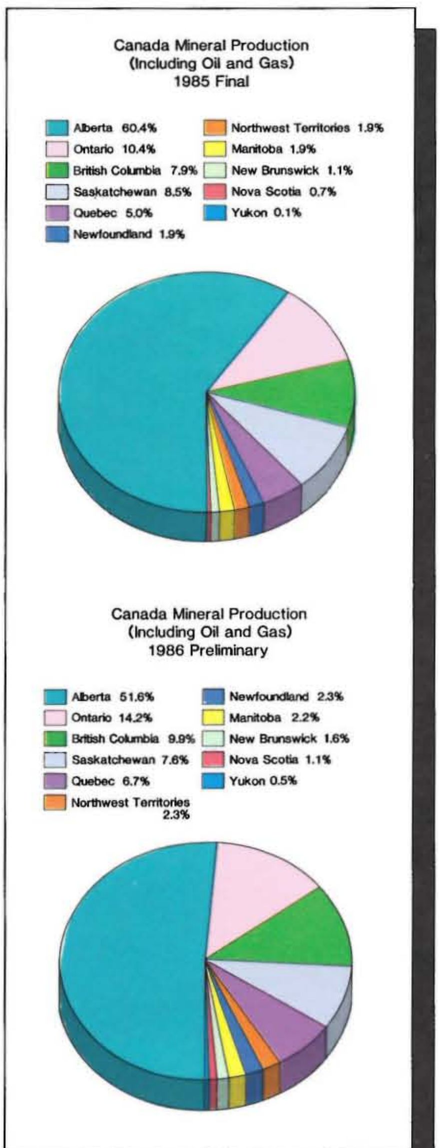


Figure 8 *Mineral production in Manitoba, 1975 - 1986*

Operations in 1986

The locations of Manitoba mines and quarries operating in 1986 are shown in Figure 10. The 'hardrock' metal mining industry of Manitoba's Precambrian Shield is composed predominantly of three companies in three major mining districts (Fig. 11). This has been true since the mid-1950s. They are Inco Limited, producing nickel, copper, cobalt and some precious metals in the "Nickel Belt" of north-central Manitoba; Hudson Bay Mining and Smelting Co., Limited, producing copper, zinc, gold, silver, lead, selenium, tellurium and cadmium in the Flin Flon-Snow Lake greenstone-base metal district; and Sherritt Gordon Mines Limited, producing copper, zinc, gold and silver in the Lynn Lake-Leaf Rapids greenstone belt.

Other producers, operating in the Precambrian Shield of southeast Manitoba, are the spodumene mine of Tantalum Mining Corporation of Canada Limited (Tanco) at Bernic Lake; the San Antonio gold mine at Bissett, operated by San Antonio Resources, where further exploration was underway in 1986 despite a halt in production in 1983; and two



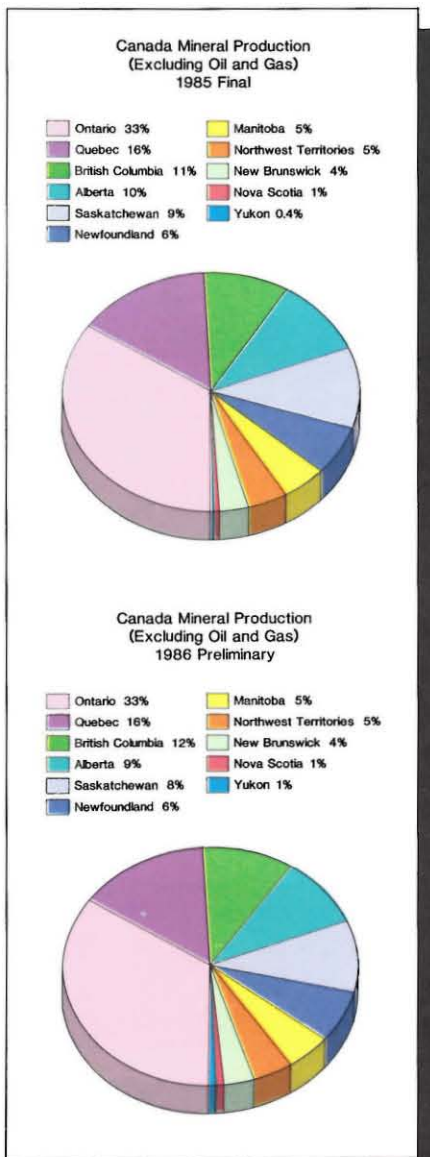


Figure 9 *A. Canada mineral production, 1985 (final) and 1986 (preliminary) including oil and gas*
B. Canada mineral production, 1985 (final) and 1986 (preliminary) excluding oil and gas

granite building stone quarries operated by Cold Spring Granite (Canada) Ltd. and Shield Quarries of Canada Limited.

Moving off the Precambrian Shield onto the younger sedimentary Phanerozoic rocks that underlie the Manitoba prairies, a number of Manitoba's "softrock" resources provide viable industrial mineral operations. Minerals quarried include limestone for cement and lime, by Steel Brothers (Canada) Ltd. and Inland Cement; clay for brick, by Red River Brick and Tile Ltd.; dolomitic limestone for building stone (Tyndall stone), by Gillis Quarries Limited; bentonite clays by Pembina Mountain Clays Inc.; gypsum for wallboard, by Westroc Limited and Domtar Construction Materials; and quartz sandstone for silica, by Steel Brothers (Canada) Ltd.

Glacial action during the last million years of the Cenozoic Age resulted in sand and gravel deposits over much of the province. As the glaciers advanced they ground up the surface soils and rocks. When the glaciers retreated, meltwater formed glacial lakes and rivers that washed away the fine mud and clay, leaving rich beds of sand and gravel as their legacy. Drawing on these resources, a number of operators quarry sand and gravel for building and road construction material.

Deeper within this sedimentary basin are the oil fields of southwestern Manitoba. Although modest in comparison with Alberta and Saskatchewan, oil is an important part of the province's minerals industry and it experienced a "mini-boom" from 1981 to 1985, with production increasing by 36%. Exploratory drilling in the Hudson Bay sedimentary basin, to date, has not discovered significant oil or gas.

Above the bedrock and glacial deposits, peat moss for horticultural use is quarried in southeastern Manitoba by Fisons Western Corporation and Premier West Peat Moss Limited. As only dead sphagnum moss is recovered, it is considered an industrial mineral resource.

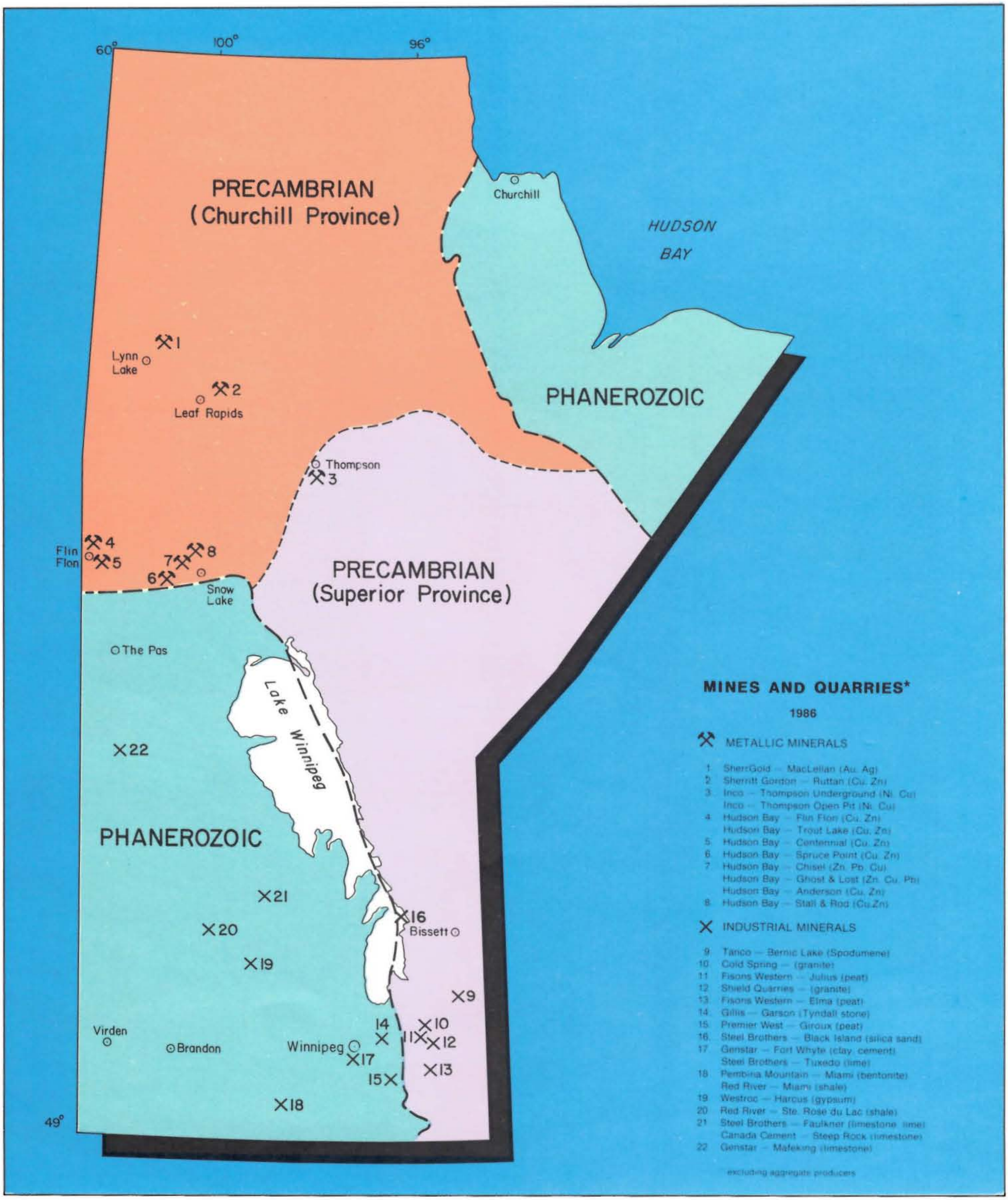
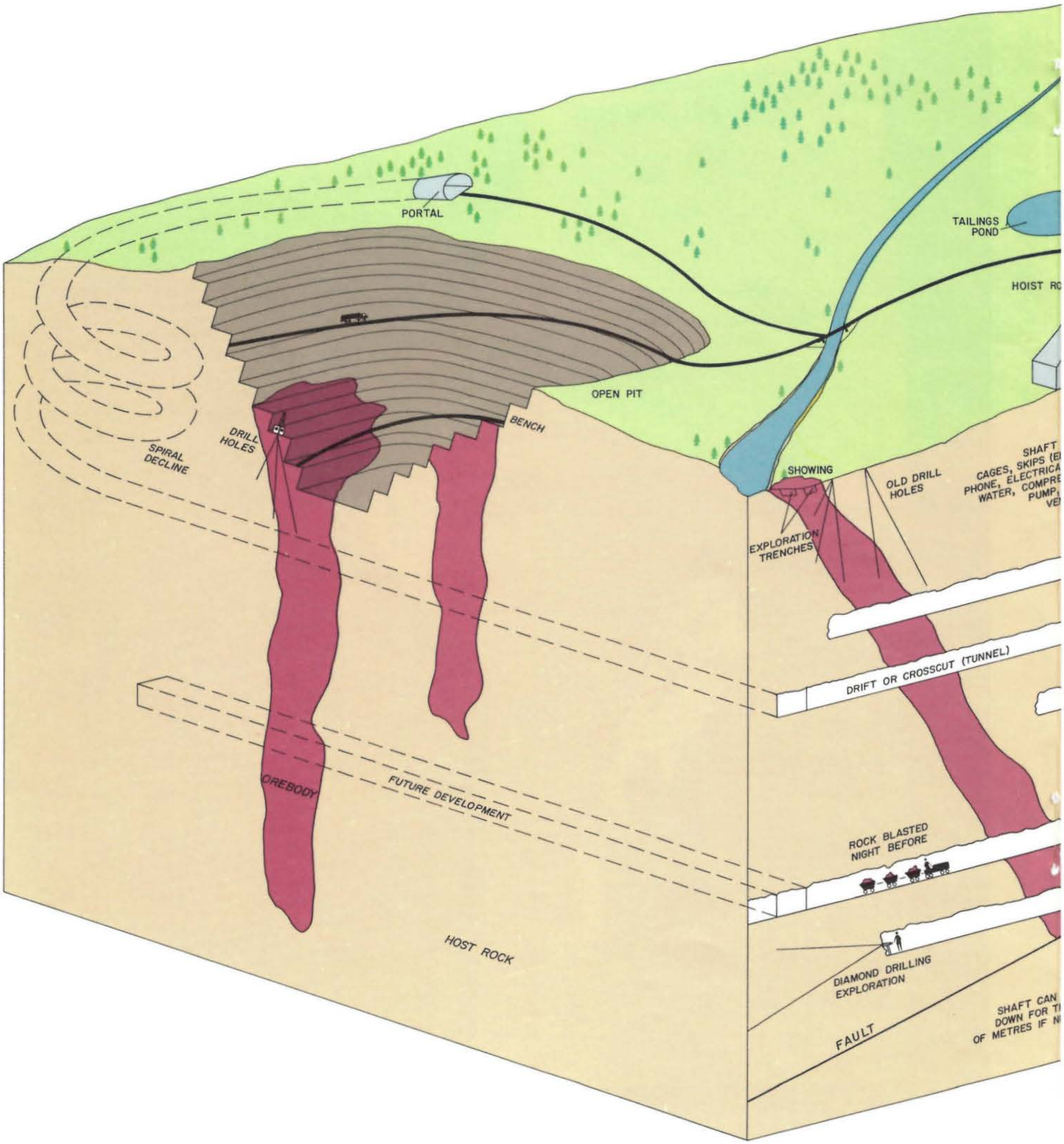


Figure 10 ***Locations of present mines and quarries in Manitoba, excluding aggregate producers, 1986***


PORTAL
TAILINGS POND
HOIST RO
OPEN PIT
BENCH
DRILL HOLES
SPIRAL DECLINE
SHOWING
OLD DRILL HOLES
EXPLORATION TRENCHES
DRIFT OR CROSSCUT (TUNNEL)
OREBODY
FUTURE DEVELOPMENT
ROCK BLASTED NIGHT BEFORE
HOST ROCK
DIAMOND DRILLING EXPLORATION
FAULT

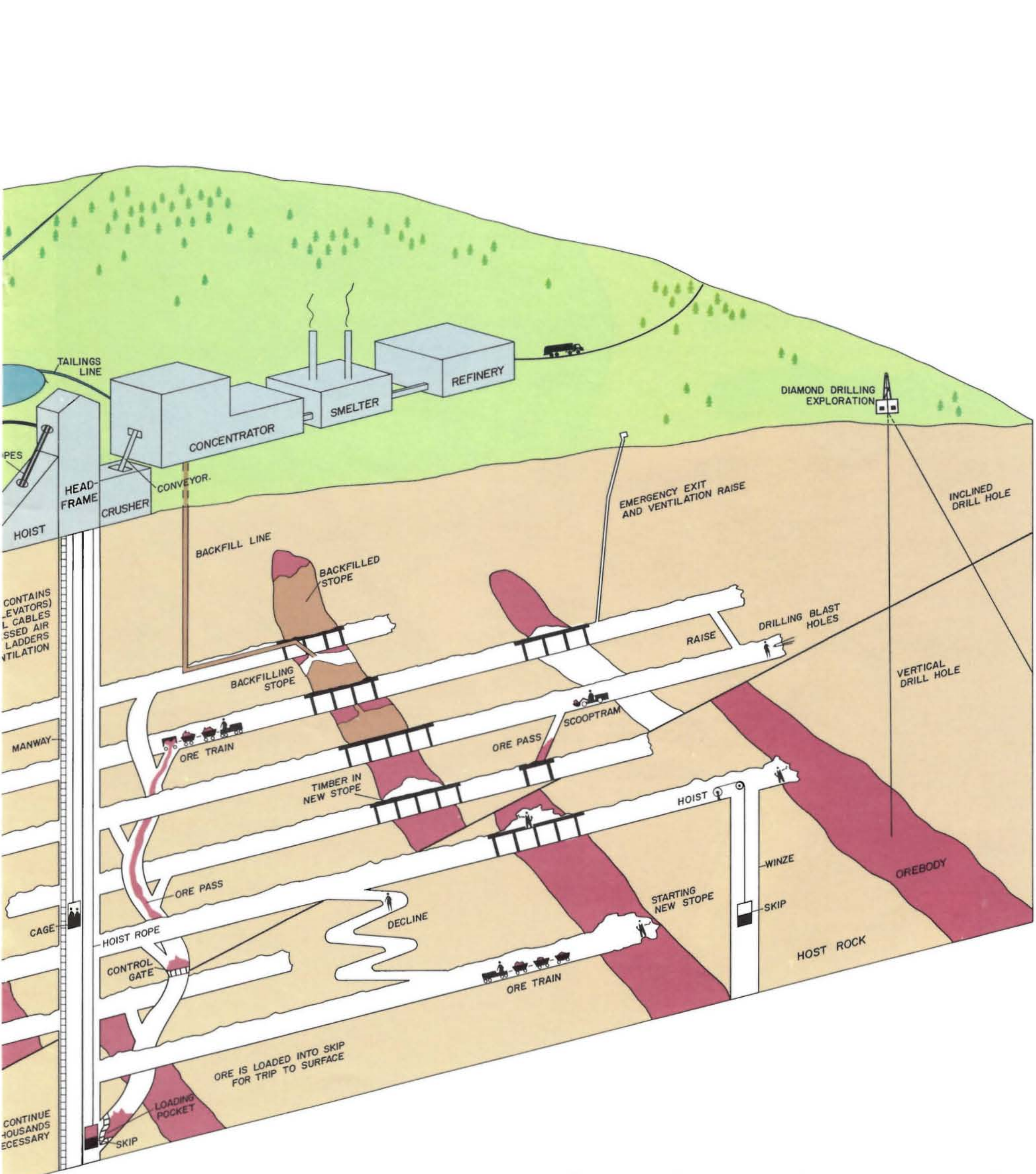


Figure 4 Cross-section of a typical underground mine

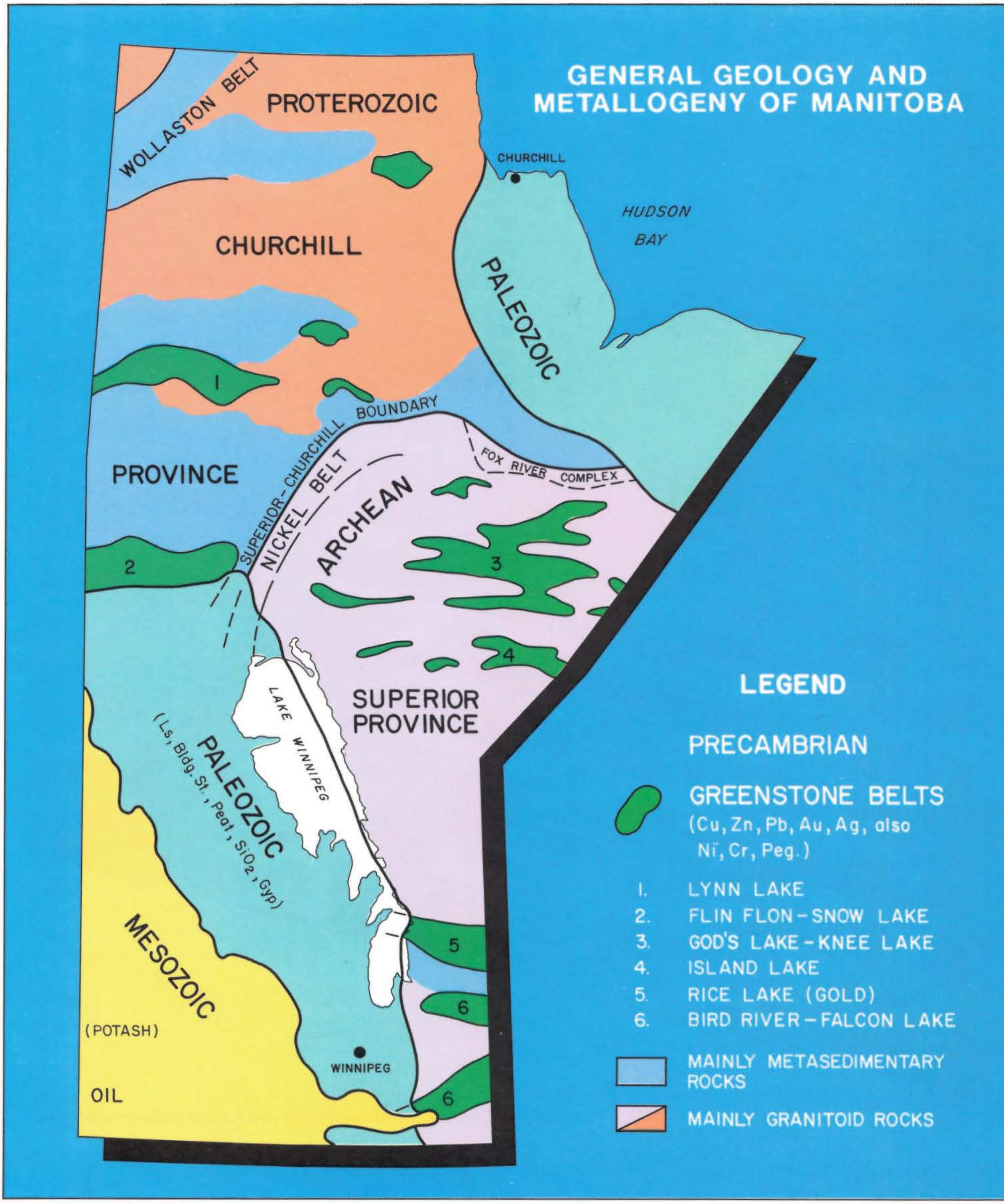


Figure 11 ***General geology and metallogeny of Manitoba***

Drilling the working face for setting of explosives at Sherritt's Ruttan Mine, 1986.

Dumping ore at Hudson Bay's Trout Lake Mine, 1986.

Far Right: Crushing and grinding ore in mills at Inco's Thompson concentrator, 1980.

Iron and sulphur are removed from matte in Inco's smelter, 1976.

In Hudson Bay's tankhouse zinc is deposited on cathodes in 1180 electrolytic cells. A set of cathodes is being transported in the picture, 1986.

Molten copper is cast into anodes weighing approximately 240 kilograms for later transport to a refinery in Montreal.

Present Mines and Quarries of Manitoba*

*as of December 31, 1986.

Metallic Operations

Inco Limited (Nickel — Copper)

Rotten claim posts, probably dating back to the 1920s or 1930s offer the earliest evidence of prospectors in this flat, muskeg, spruce and pine wilderness, 645 kilometres north of Winnipeg. There is only one known outcrop of nickel sulphide in the region, at Mystery Lake, northeast of Thompson.

In 1946, International Nickel Company Ltd. began a 10-year, $10 million airborne (240 000 line kilometres) and ground (17 700 line kilometres) geophysical and geological exploration program. The program, which included 725 kilometres of core drilling, culminated in the February 1956 discovery of the large Thompson nickel-copper deposit. At least six other deposits were located by the mid-1950s (Fig. 13).

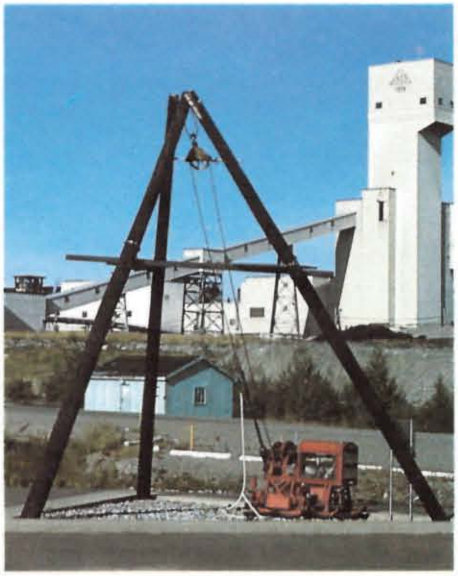
The official opening of the Thompson Mine took place on March 25, 1961 and the deposit has since been mined continuously. The Soab North and Soab South Mines to the southwest, connected to Thompson by a 77 kilometre railway, operated from 1969 to 1971. The Pipe No. 1 Mine, 32 kilometres southwest of Thompson, operated during 1971 and the Birchtree near Thompson from 1969 to 1977. From 1961 to 1971 Inco spent $270 million on expansion, to mine and process the ore from these new mines. Except for the Birchtree Mine, which is on standby, all of these are now shut down. The Pipe No. 2 open pit mine produced 6000 tonnes of ore per day from 1971 to 1984, and shipments from the stockpile were made in 1985.

In 1960, the Thompson deposit was estimated at 22.7 million tonnes of ore, averaging 2.97% nickel. The grade at the Pipe Lake open pit was lower, ranging from 0.5 to 1.0% nickel. In March 1968, Inco estimated their total Manitoba reserves at 60.8 million tonnes grading 1.89% nickel and 0.13% copper. Reserves have been maintained since then and at least 25 years of ore is "in sight." Manitoba Energy and Mines (Table 3) estimates the total Inco production to 1985 to be about 60 million tonnes, at 1.8% nickel and 0.1% copper.

The ore contains the minerals pentlandite, pyrrhotite, and chalcopyrite, with minor amounts of cobalt and precious metals. The ore and host rock lie in linear zones of metamorphosed sedimentary and volcanic rocks at the boundary of the Superior and Churchill geological provinces (Fig. 11). As an example, the Thompson orebody is a tabular deposit, striking northeast in a tight fold which plunges 65 degrees east.

The Thompson orebody is mined from two shafts, T-1 and T-3, about 3.2 kilometres apart. After primary crushing underground, approximately 5800 tonnes of ore per day are hoisted through the 1323 metre deep T-1 shaft, which has a rated capacity of 9000 tonnes per day.

An 1100 metre shaft sunk near the Pipe No. 2 open pit will allow mining of the downward extension of that deposit when it becomes economic to do so. The shaft at the 'standby' Birchtree Mine, 5 kilometres southwest of Thomp-



Discovery hole into Inco's Thompson orebody. T-1 headframe and complex in background, 1984.

Aerial view of Western World's first fully-integrated nickel mining and processing complex, 1985.

son's T-1 shaft, reached 1020 metres. In May 1983, Inco announced its decision to proceed with a 122 metre deep, open-pit mine, located between Thompson shafts T-2 and T-3, to recover the top or "crown pillar" of the Thompson ore body, grading 2.7% nickel. This $73 million first phase involved dredging 15 million cubic metres of mud and muskeg, covering an area 1554 metres by 244 metres. Production from this large new pit began at a rate of 726 tonnes per day in November 1985, rising to 2721 tonnes per day in 1986. A second phase will require dredging of a further 16 million cubic metres of material for access to the remainder of the ore.

The concentrator at Thompson, originally designed in 1960 for 5442 tonnes per day, was expanded in the late 1960s to its current rated capacity of about 12 700 tonnes per day. Its present feed comes from the Thompson mines. In the

Table 3 ***Summary data: Lynn Lake, Nickel Belt mines, gold mines and others***

Mine	Area	Company	Production Dates	Commodities	Capacity in Tonnes Per Day	Production (P) + Reserves (R) × 000 Tonnes	Average Grades
Fox	Lynn Lake	Sherritt G.	1970-85	Cu, Zn, Au, Ag	2300	11933 (P + R)	1.8% Cu, 1.8% Zn
Ruttan	Lynn Lake	Sherritt G.	1973-86*	Cu, Zn, Au, Ag	8100	36811 (P + R)	1.3% Cu, 1.4% Zn
'A' Mine & Farley 'EL' Mine	Lynn Lake	Sherritt G.	1953-76	Ni, Cu, Co, Au Ag	2707	20147 (P)	1.0% Ni, 0.5% Cu
Thompson	Nickel Belt	Inco	1960-86*	Ni, Cu, Co, Pt Pd, Au, Ag	7256		
Pipe No. 2 Open Pit	Nickel Belt	Inco	1970-84	Ni, Cu, Co, Pt Pd, Au, Ag	3628		
Pipe No. 1	Nickel Belt	Inco	1970-71	Ni, Cu, Co, Pt Pd, Au, Ag	970	60000 (P)	1.8% Ni, 0.1% CU
Soab North	Nickel Belt	Inco	1967-71	Ni, Cu	907		
Soab South	Nickel Belt	Inco	1967-71	Ni, Cu	2721		
Birchtree	Nickel Belt	Inco	1969-77	Ni, Cu, Co, Pt Pd, Au, Ag	3628		
Manibridge	Nickel Belt	Falconbridge	1971-77	Ni, Cu	771	983 (P)	2.0% Ni, 0.2% Cu
Gods Lake	Gods Lake	Gods Lake	1935-43	Au, Ag	180	491 (P)	10.2 g/t Au 1.8 g/t Ag
Island Lake	Island Lake	Island Lake	1934-35	Au	31	8 (P)	25.4 g/t Au
San Antonio	Rice Lake	San Antonio	1932-68	Au, Ag	300	5110 (P + R)	7.4 g/t Au
		Brinco	1982-83		317		1.45 g/t Ag
Central Manitoba	Rice Lake	Central Manitoba	1927-37	Au, Ag	136	414 (P)	12.0 g/t Au 1.96 g/t Ag
Oro Grande	Rice Lake	Oro Grande	1932-34 1938-40	Au, Ag	36	15 (P)	11.2 g/t Au 1.08 g/t Ag
Gunnar	Rice Lake	Gunnar	1936-42	Au	136	271 (P)	11.6 g/t Au
Ogama-Rockland	Rice Lake	Ogama-Rockland	1942, 1948-51	Au	136	126 (P)	11.2 g/t Au
Jeep	Rice Lake	San Antonio	1948-50	Au	24	15 (P)	26.6 g/t Au
Diana	Rice Lake	Diana	1928-32 1934-41	Au, Ag	45	23 (P)	11.4 g/t Au 0.70 g/t Ag
Lotus	Rice Lake	Esso Resources	1982	Au	91	included in San Antonio 1982-83	
Bernic Lake	Bird River	Tanco	1969-82	Ta, Cs, Li, Be	900	3444 (P + R)	0.132% Ta_2O_5
		H.B.M. &S.	1986*	Li	90	7000 (P + R)	2.76% Li_2O
Dumbarton	Bird River	Maskwa	1969-73	Ni, Cu, Pt		1539 (P)	0.81% Ni, 0.30% Cu
Maskwa Open Pit	Bird River	Maskwa	1974-76	Ni, Cu		1182 (P + R)	1.28% Ni, 0.22% Cu
Sunbeam	Falcon Lake	Sunbeam	1940	Au		501 (R)	10.4 g/t Au

* mine presently producing but figures only available to year stated

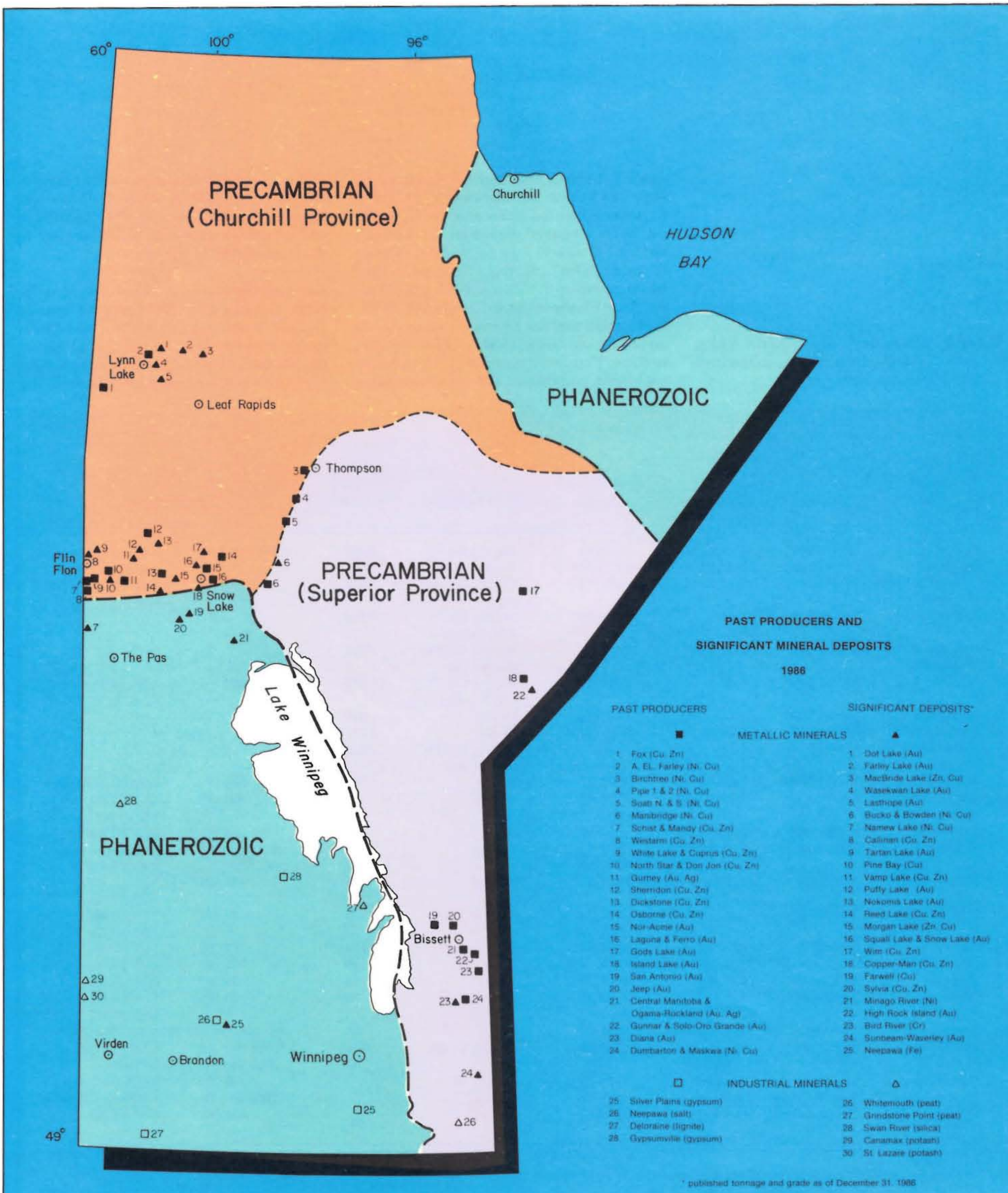


Figure 12 Past producers and significant mineral deposits, 1986

past, the Shebandowan Mine in northwestern Ontario, which suspended operations in 1986, also supplied feed. The Thompson smelter produces cathodes grading about 75% nickel and has five electric arc furnaces, although some are currently shut down.

Inco's Thompson facilities are capable of producing approximately 49 million kilograms of nickel a year, as well as copper, cobalt and precious metals byproducts. In 1985, Inco milled 1.89 million tonnes of Thompson ore grading 2.49% nickel, 0.24% copper, 0.10 grams of gold and 5.14 grams of silver per tonne. The complex produced concentrates containing 42.7 million kilograms of nickel, 4.2 million kilograms of copper, 118 kilograms gold and 7575 kilograms of silver.

While the bulk of production is refined at the Thompson complex, part of the company's nickel production is sold as pentlandite concentrate to Sherritt Gordon's refinery at Fort Saskatchewan, Alberta. Copper from Thompson ore is shipped in the form of a high copper-nickel matte, which also carries the platinum group metals. Colbalt oxide is sent to Clydach, Wales for further refining and material is also shipped to Acton, England where platinum-group metals and minor quantities of gold and silver are refined.

Shaken by losses, layoffs and temporary closures from 1981 to 1983, Inco achieved dramatic productivity gains in 1984, with a 14% increase in nickel and copper produced per person-shift. The new Thompson open pit mine, Inco's lowest-cost source of sulphide ore, has made the Thompson complex one of the lowest-cost producers in the world. The current workforce has stabilized at 1850 employees, with 545 underground and another 60 to 70 in the open pit. The future health of nickel mining in Manitoba depends on a general world-wide economic upturn, but Thompson, with a modern, efficient mine and plant and an experienced, skilled workforce, is well prepared to succeed.

Dredge at work removing mud and muskeg above "crown pillar" of the Thompson orebody, 1983.

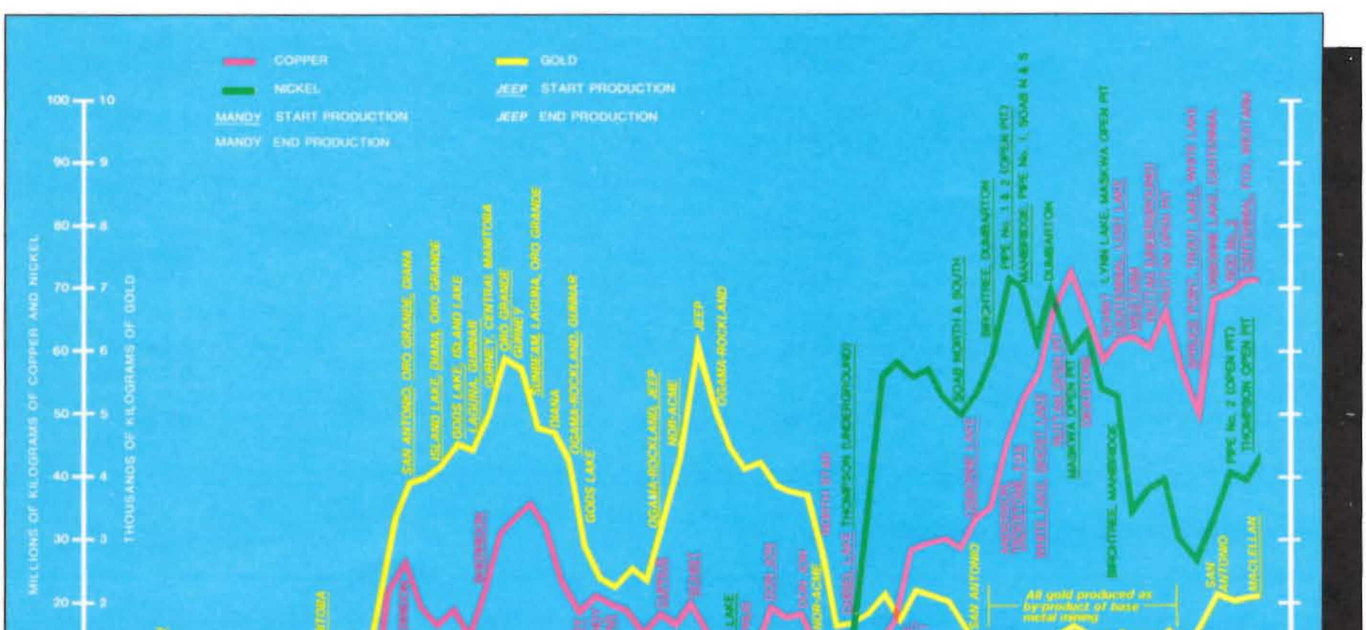


Figure 13 Annual production of copper, nickel and gold in Manitoba, 1912 - 1986

Mine	Area	Company	Production Dates	Commodities	Capacity in Tonnes Per Day	Production (P) + Reserves (R) × 000 Tonnes	Average Grades
Flin Flon	Flin Flon	H.B.M. & S.	1930-84*	Cu, Zn, Au, Ag Se, Te, Cd	1810	62447 (P + R)	2.2% Cu, 4.1% Zn
Centennial	Flin Flon	H.B.M. & S.	1977-84*	Cu, Zn, Au, Ag	540	2366 (P + R)	1.5% Cu, 2.1% Zn
Westarm	Flin Flon	H.B.M. & S.	1978-84*	Cu, Zn, Au, Ag	540	1579 (P + R)	3.4% Cu, 1.4% Zn
White Lake	Flin Flon	H.B.M. & S.	1972-82	Cu, Zn, Au, Ag	450	850 (P + R)	2.0% Cu, 4.7% Zn
Spruce Point	Flin Flon	H.B.M. & S.	1982-84*	Cu, Zn, Au, Ag	650	1593 (P + R)	2.4% Cu, 2.2% Zn
Trout Lake	Flin Flon	H.B.M. & S.	1982-84*	Cu, Zn, Au, Ag	1810	5249 (P + R)	2.3% Cu, 5.3% Zn
Chisel Lake	Snow Lake	H.B.M. & S.	1960-84*	Zn, Pb, Cu, Au Ag	700	7300 (P + R)	0.5% Cu, 10.5% Zn
Stall Lake	Snow Lake	H.B.M. & S.	1964-84*	Cu, Zn, Au, Ag	950	6264 (P + R)	4.3% Cu, 0.5% Zn
Osborne Lake	Snow Lake	H.B.M. & S.	1968-83	Cu, Zn, Au, Ag	590	3380 (P + R)	3.0% Cu, 1.5% Zn
Anderson Lake	Snow Lake	H.B.M. & S.	1970-84*	Cu, Zn, Au, Ag	630	3189 (P + R)	3.5% Cu, 0.1% Zn
Ghost Lake/	Snow Lake	H.B.M. & S.	1972-84*	Zn, Pb, Cu, Au	120	606 (P + R)	1.3% Cu, 8.6% Zn
Lost Lake	Snow Lake	H.B.M. & S.	1977-84*	Ag			
Rod No.1	Snow Lake	Stall Lake	1962-64	Cu, Zn, Au, Ag	140	23 (P)	5.0% Cu, 4.5% Zn
Rod No. 2	Snow Lake	H.B.M. & S.	1984*	Cu, Zn, Au, Ag	360	645 (P + R)	6.2% Cu, 2.9% Zn
Mandy	Flin Flon	Tonopah	1916-19	Cu, Zn, Au, Ag	16	23 (P)	20.2% Cu
		Emergency M.	1943-44	Cu, Zn, Au, Ag	130	102 (P)	5.6% Cu, 14.0% Zn
Sherridon	Flin Flon	Sherritt G.	1931-32 1937-51	Cu, Zn, Au, Ag	1750	7738 (P)	2.4% Cu, 2.0% Zn
Schist	Flin Flon	H.B.M. & S.	1954-76	Cu, Zn, Au, Ag	180	1871 (P)	4.3% Cu, 7.3% Zn
Cuprus	Flin Flon	H.B.M. & S.	1948-54	Cu, Zn, Au, Ag	180	462 (P)	3.3% Cu, 6.4% Zn
North Star	Flin Flon	H.B.M. & S.	1955-58	Cu, Zn	160	242 (P)	6.1% Cu
Don Jon	Flin Flon	H.B.M. & S.	1955-57	Cu, Zn	70	79 (P)	3.1% Cu
Dickstone	Snow Lake	Dickstone	1970-75	Cu, Zn, Au, Ag	540	1083 (P + R)	2.4% Cu, 3.4% Zn
Nor-Acme (Au)	Snow Lake	Nor-Acme	1949-58	Au, Ag	1800	4893 (P)	3.9 g/t Au 0.32 g/t Ag
Laguna (Au)	Flin Flon	Laguna	1936-40	Au	60	93 (P)	17.7 g/t Au
Gurney (Au)	Flin Flon	Gurney	1937-39	Au, Ag	110	92 (P)	8.5 g/t Au 24.2 g/t Ag

* mine presently producing but figures only available to year stated

Table 4 Summary data: copper-zinc and gold deposits, Flin Flon — Snow Lake district

Hudson Bay Mining and Smelting Co., Limited (Copper — Zinc)

Since Tom Creighton's first claim in 1915 and the incorporation of Hudson Bay Mining and Smelting Co., Limited (HBM&S) on December 27, 1927, the Flin Flon-Snow Lake volcanic greenstone belt has grown into a prolific world-class copper-zinc metal mining district. A multitude of base and precious metal deposits of various sizes have been found in this comparatively small belt, only 250 kilometres long and 32 to 48 kilometres wide (Table 4). To the south the belt is covered by Paleozoic sedimentary rocks.

At present there are nine mines in production, with three in the Flin Flon area and six in the Snow Lake area. A tenth, Westarm in the Flin Flon area, is temporarily shut down pending shaft deep-

ening. Trout Lake and Spruce Point opened in 1982, making them the most recent mines in the district.

Mine	Area	Production (tonnes per day)
Flin Flon	Flin Flon	1810
Centennial	Flin Flon	540
Trout Lake	Flin Flon	1810
Stall Lake	Snow Lake	950
Chisel Lake	Snow Lake	950
Anderson Lake	Snow Lake	630
Rod	Snow Lake	360
Ghost Lake-Lost Lake	Snow Lake	120
Spruce Point	Snow Lake	650

The Flin Flon complex includes a concentrator with a rated capacity of 10 500 tonnes per day, a copper smelter that produces 290 kilogram anodes (30% copper) for Noranda's copper refinery in Montreal, and a zinc refinery which produces refined zinc and cadmium. Small amounts of gold, silver, selenium and tellurium are recovered during copper processing. HBM&S purchases copper and zinc concentrates for plant feed, with Sherritt Gordon's Ruttan Mine currently the primary source. In the past, the complex also processed zinc concentrates from Cominco's Pine Point Mine in the Northwest Territories.

The company opened a second concentrator at Stall Lake in 1979. With a capacity of 3450 tonnes per day, the Stall Lake concentrator mills ore from mines in the Snow Lake area. The concentrate is shipped by rail to the smelter and refinery at Flin Flon, except for lead concentrates which are shipped to Trail, British Columbia. The Snow Lake concentrator treats approximately 2200 tonnes per day of copper ore, averaging 4% copper and 0.6% zinc from Stall Lake, Anderson Lake and Rod Mines in its 'copper circuit.' A 'zinc circuit' processes about 900 tonnes per day of zinc ore from Chisel Lake and Ghost-Lost Lake, grading 7% zinc and 0.5% copper.

Total 1985 mine production from Flin Flon and Snow Lake was 1.54 million tonnes grading 2.46% copper and 3.02% zinc, with 1.5 grams of gold per tonne and 17.6 grams of silver per tonne. Total metal production in 1986, from company and purchased ores, was 62 million kilograms refined copper, 84 million kilograms slab zinc, 2053 kilograms of gold, 38 972 kilograms of silver plus minor quantities of cadmium, lead and selenium.

From 1930 to 1986, the Flin Flon complex recovered 2.31 million tonnes of copper, 3.04 million tonnes of zinc, 171 000 kilograms of gold and 2.54 million kilograms of silver, plus substantial amounts of lead, cadmium and selenium. The bulk of this was recovered from the more than 87.2 million tonnes of ore mined in the district.

The company has maintained an impressive discovery rate in the belt. From 1950 to 1977, 16 economic deposits were discovered, at an average cost of $4.6 million each, with a total tonnage of 25 million tonnes at 2.8% copper and 3.7% zinc. Nine of the 16 were located by drilling on sites located by electromagnetic surveys.

Notable discoveries by competitors in the district include Trout Lake, discovered in 1976 by Granges Exploration Aktiebolag. Manitoba Mineral Resources Ltd., a provincial Crown Corporation owns 27% of the operation. The Spruce Point

Statue of Flintabbety Flonatin, the hero of a novel which gave Flin Flon its name.

Aerial view of the Stall Lake concentrator of Hudson Bay Mining and Smelting, 1986.

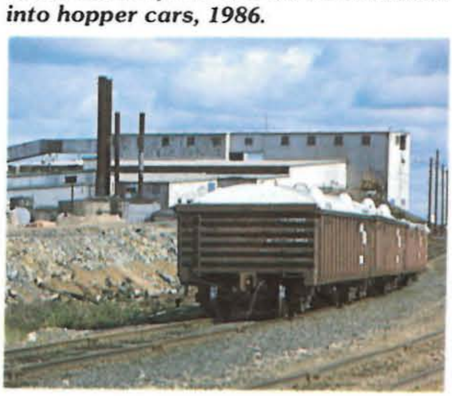
deposit was discovered by Freeport Canadian Exploration Company and Bethlehem Steel Corporation in 1973. HBM&S purchased the Spruce Point deposit and operates the Trout Lake Mine as a joint venture partner. Both of these mines reached scheduled production rates in 1982. The Rod deposit, developed by HBM&S, is under lease from Stall Lake Mines Limited and Falconbridge Limited.

HBM&S has employed about 2200 people in recent years in their Manitoba-Saskatchewan operations but, as with base metal companies world-wide, they were seriously affected by the 1982-83 recession.

The company's proven and probable ore reserves for its active underground mines in the Flin Flon-Snow Lake district, including a 44% interest in Trout Lake Mine, were 8.3 million tonnes at the end of 1986, with 2.34% copper, 4.93% zinc, and 1.65 grams of gold and 21.94 grams of silver per tonne. Reserves on inactive properties total 3.3 million tonnes averaging 1.91% copper and 3.70% zinc.

Two exploration properties hold excellent potential for development in the near future; the Callinan North zone, adjoining the Flin Flon Mine (drill indicated reserves of 1.54 million tonnes grading 1.4% copper, 4% zinc and 1.9 grams gold per tonne); and the Namew Lake deposit 60 kilometres south of Flin Flon (proven and probable reserves of 2.58 million tonnes, grading 2.44% nickel and 0.90% copper).

Concentrate from Ruttan Mine loaded into hopper cars, 1986.



Sherritt Gordon Mines Limited, (Copper - Zinc)

The story of Sherritt Gordon began with the staking of a promising copper showing by Carlton W. Sherritt in 1923 near Kississing Lake, north of Flin Flon. John P. Gordon, an engineer, took the first option on the property and in 1927 Sherritt Gordon was incorporated. Production at Sherridon, begun in 1931, ended in 1951 when the ore was exhausted. However, after a new nickel-copper discovery was made at what is now Lynn Lake, most of the town was moved 265 kilometres to the north.

After completing the move to Lynn Lake, Sherritt Gordon opened the "A" Mine in 1953. It produced 12.6 million tonnes of 1.2% nickel and 0.62% copper ore before closing in 1969. The "EL" deposit produced 2.2 million tonnes averaging 2.5% nickel and 0.93% copper between 1954 and 1964. The Farley Mine opened in 1961 and closed in 1976, ending mining in the immediate vicinity of Lynn Lake, a town that grew to 2500 people in the early 1970s.

The three mines produced concentrates containing 166.1 million kilograms of nickel and 94.8 million kilograms of copper, as well as 1.7 million kilograms cobalt, 447 kilograms of gold and 9019 kilograms of silver. Nickel concentrates were shipped to Sherritt's nickel refinery at Fort Saskatchewan, northeast of Edmonton. Copper concentrates were shipped to HBM&S's Flin Flon complex, or to Noranda's copper refinery in Montreal. During the 1960s, Sherritt's exploration efforts again paid off with the discovery of the Fox and the Ruttan copper-zinc deposits. The Fox deposit, 48 kilometres southwest of Lynn Lake, was discovered in 1961. With reserves of 11 million tonnes of 1.74% copper and 2.35% zinc, a shaft was sunk to 714 metres in 1970, and produced 2700 tonnes of ore per day. Capital costs of developing the mine amounted to $25 million. Using Lynn Lake as an operating base, the copper concentrates were shipped to Vancouver for export to Mitsubishi Metal Mining Co., Ltd. of Japan. Zinc concentrates were sold to Hudson Bay Mining and Smelting Co., Limited. The mine reached 820 metres before ore reserves were exhausted in late 1985.

Sherritt Gordon's Fox Mine, 1983.

In April 1969, Sherritt geologists tracing interesting airborne electromagnetic survey results, discovered the large Ruttan copper-zinc deposit. Located 121 kilometres southeast of Lynn Lake, the deposit contained about 46 million tonnes of ore. The Ruttan Mine began in 1973 with an open pit and a 9070 tonnes per day concentrator. Open pit production ceased December 1, 1980, with production continuing from an underground operation.

Ruttan Open Pit, headframe in background, 1987.

Between 1971 and 1974, the Manitoba Government, with help from Sherritt, built the modern northern town of Leaf Rapids for about $18 million to serve the mine and surrounding area. The present population of Leaf Rapids is approximately 1800.

Sherritt invested about $150 million in the Ruttan operation. A project to deepen the mine to the 920 metre level, at an estimated cost of $28 million, was completed in 1985 with the assistance of a $10 million loan from the Manitoba Government. In 1986, the miners at Ruttan achieved the distinction of having the highest output in North America, in tonnes per person-day. Cash costs averaged as low as 55¢ (U.S.) per pound of copper. However, due to persistent low base metal prices, the carrying value of the mine was written off and no further exploration conducted on the property in 1986. Copper and zinc concentrates from Ruttan are trucked to the railhead at Lynn Lake and shipped to Flin Flon (copper and zinc) and Noranda's Montreal refinery (copper).

Sherritt's Ruttan Mine produced, in 1986, 30 million kilograms of copper, 10 million kilograms of zinc, 808 kilograms of gold and 14 836 kilograms of silver, all in the form of concentrates. The mining rate of 1.6 million tonnes per year in 1985 was increased to 2.0 million tonnes in 1986.

The future health of production (reserves of 8 045 000 tonnes grading 1.64% copper and 1.21% zinc in 1986) at the Ruttan Mine is directly related to the world prices of copper and zinc. To offset this dependence, a Sherritt subsidiary, SherrGold Inc., opened the MacLellan gold mine in 1986, five kilometres northeast of Lynn Lake.

SherrGold Inc., MacLellan Mine (Gold)

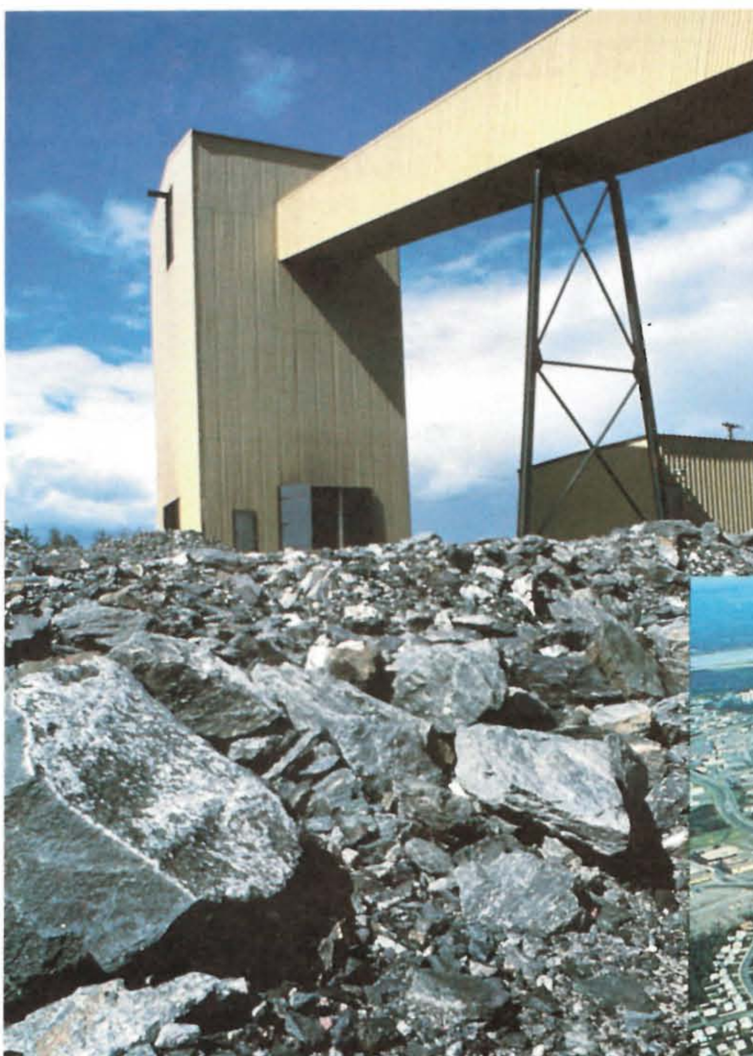
The property was first staked in 1946 by J.W. Boiley and J.G. Webb; and restaked in 1950 by Roy and J.W. Rundle, who transferred the claims to Agassiz Mines Limited. Several companies had options on the property during the ensuing years. In late 1979 Comiesa Corporation, who held controlling interest in the property, optioned it to Sherritt Gordon Mines. By this time, a three compartment shaft had been sunk to a depth of 149 metres, with 803 metres of lateral work divided between three levels. From 1979 to 1985, Sherritt spent $12 million on diamond drilling, shaft sinking and drifting. Ore grades in the 1.49 million tonne "Main Zone" deposit average 7.17 grams per tonne.

In September 1985, Sherritt transferred the MacLellan Mine (formerly known as the Agassiz Mine) to a new company —SherrGold — along with fifteen other gold projects. A total of $40 million was spent sinking the production shaft to 457 metres and refurbishing the old Farley mill at Lynn Lake.

Planned capacity for the plant is 2022 kilograms of gold and 3110 kilograms of silver per year. The first two gold bricks from the MacLellan mine were poured on August 25, 1986. Each brick, valued between $120,000 and $160,000, was 60% silver and 40% gold and weighed 19 kilograms. Commercial production commenced on January 1, 1987.

Development costs at MacLellan were assisted by a $2 million forgivable loan from the Manitoba government and a $4 million grant from the federal government's Canadian Jobs Strategy program. During 1987 SherrGold will spend $7.3 million to identify additional ore reserves in the vicinity of the MacLellan Mine.

Sherritt Gordon's MacLellan Mine headframe, 1986.



Top left: *Inco's Birchtree mine, south of Thompson, 1970.*
Top right: *Spruce Point headframe of Hudson Bay Mining and Smelting on Reed Lake, 1986.*
Bottom left: *Hudson Bay's Trout Lake Mine ore conveyor and truck loadout, 1986.*
Bottom right: *Aerial view, the City of Thompson, 1983.*

Industrial Minerals

Industrial mineral operations are normally located near populated and industrial areas, primarily southern Manitoba. Most industrial minerals like cement, brick, stone, lime, gypsum, sand and gravel, are used by the construction industry. Others produced in Manitoba include spodumene, silica, peat, fluxstone and special clays, all with varied industrial uses. These minerals are produced from two geological ages of rock — the Precambrian, more than 1.5 billion years old and the Phanerozoic, which includes the Paleozoic and Mesozoic, which are less than 550 million years in age (Figs. 1 and 11). Sand and gravel are recovered from deposits of the Pleistocene glaciation.

Precambrian

Bernic Lake Pegmatite

Spodumene (a lithium ore), tantalum and cesium have been produced from the Bernic Lake pegmatite, in the Bird River greenstone belt, 60 kilometres east of Lac du Bonnet. This tabular world-unique pegmatite occupies a nearly horizontal fracture zone about 1220 metres long, up to 457 metres wide and 18 to 24 metres thick. The pegmatite has been developed by a shallow mine, accessed by a 20-degree decline. The mine utilizes a room-and-pillar method to achieve a 95% extraction rate, with the ore hoisted through a 169 metre vertical shaft. Tantalum ore occurs in a variety of mineralized zones. Cesium occurs with spodumene, lepidolite and feldspars. Two lepidolite zones contain lithium, tantalum, rubidium and gallium. Over 60 trace and rare minerals have so far been identified in this amazing pegmatite.

Explored for tin in the late 1920s, interest in the pegmatite was renewed between 1954 to 1957, this time for lithium. Drilling outlined more than 6.3 million tonnes of 1.85% lithium oxide ore. Massive pollucite containing 35% cesium oxide was also encountered. From 1962 to 1967 cesium ore was mined, stockpiled and sold to the USA and USSR space industries, providing the first cash commodity from the pegmatite. The pegmatite is believed to hold the world's largest reserves of cesium.

In 1966, new markets in the electronic components and the tool-die industries emerged for the tantalite recognized in the pegmatite. Initial reserves outlined were 1.8 million tonnes of 0.23% tantalum oxide. Plant work began in 1967 and production reached 450 tonnes per day in September 1969. Plant capacity was increased to 680 tonnes per day in 1974, and it maintained a fairly constant annual production of 159 000 kilograms of tantalum oxide, about 20% of the non-communist world's tantalum production, in the late 1970s. Shipments from Tantalum Mining Corporation of Canada Ltd. (Tanco) to refineries in several countries fell to 103 951 kilograms of tantalum oxide worth $23 million in 1981 and to about 59 000 kilograms in 1982, when production ceased due to declining markets and falling tantalum prices. Spot sales of cesium ore, spodumene for ceramics and rubidium contained in lepidolite, have also been made over the years.

Left: Drilling granite on property of Shield Quarries of Canada, 1986.

Top right: Load haul dump machine in Tanco's "cathedral-like" Bernic Lake Mine, 1987.

Bottom right: Surface plant of Tanco's Bernic Lake Mine, 1987.

The Tanco operation is owned by Cabot Berylco Industries Ltd. (37.5%), Manitoba Mineral Resources (25%) and Hudson Bay Mining and Smelting Co., Limited (37.5%); the latter operates the mine through their Canadian Metals Division. The stated reserves at December 31, 1981 were one million tonnes of tantalite ore grading 0.144% tantalum oxide and 674 000 tonnes in the tailings at 0.065% tantalum oxide, 7 million tonnes of lithium ore grading 2.76% lithium oxide, and about 272 000 tonnes of cesium ore grading 23% cesium oxide. As of December 31, 1986 proven and probable spodumene ore reserves were 1.5 million tonnes averaging 2.72% lithium oxide. There are also interesting values of beryllium, gallium and rubidium, metals used in specialty products for the aerospace industry.

In 1984, the federal Department of Regional Industrial Expansion awarded

Tanco a grant to help construct a $6.4 million extension to the tantalum concentrator dedicated to the production of ceramic grade spodumene. Tests were successful and a contract was signed for spodumene concentrate. The concentrate is used by Corning Glass Works in France and the U.S.A. to make Visions cookware.

The new plant, which began operation in 1986, is rated at 12 000 tonnes of concentrate annually. The plant enhances Tanco's marketing position by diversifying its output. In 1986, 17 tonnes of spodumene ore was mined, averaging 3.01% lithium oxide.

Granite

Two varieties of granite are quarried in southern Manitoba for use as 'dimension stone.' Cold Spring Granite (Canada) Limited, near Pinawa, extracts an attractive brownish-red quartz monzonite that is finished on site and is shipped mainly to the U.S.A., for use as monument stone. Shield Quarries of Canada Limited (formerly Midwest), near Whitemouth, produces rough granitic blocks which are shipped to Quebec where they are cut, polished and used for monuments.

Quartzite

About 20 kilometres southwest of Thompson, Inco Limited extracts a silica-rich quartzite from the Manasan quarry. A coarsely crushed product is used as fluxstone for the smelter furnaces and a more finely crushed product as a converter flux where the sand's 80% silica content removes impurities from the molten mixture.

Phanerozoic

Cement

Cement is Manitoba's most important industrial mineral with 1986 cement production estimated at $46.1 million (Table 2). Inland Cement operates a large cement plant on the southwest outskirts of Winnipeg, at Fort Whyte. In 1985, it initiated a $4.5 million upgrading of the 20-year-old plant to fulfill a contract for the Limestone hydro-electric project. Another plant, formerly operated by Canada Cement Lafarge Limited, was closed in October 1982.

Floating twin clam-shell excavator operating in Birds Hill gravel deposit, 1982.

The production of portland cement, the industry standard, requires a carefully controlled slurry of pulverized limestone, iron oxide, sand and clay that is heat treated in a kiln. Gypsum is then added to the resulting 'clinker,' and this mixture is ground in ball mills to create the fine powder that characterizes the finished product.

Portland cement must have less than 5% impurities. Most of the limestone used comes from quarries near Steep Rock, 240 kilometres northwest of Winnipeg (Fig. 10). The limestone, with 95-99% usable calcium carbonate, has been quarried there since 1913 from the Devonian Elm Point Formation. It is shipped by rail from the quarry to Fort Whyte.

Clay for the cement is quarried near the plant from the fine clays of glacial Lake Agassiz. Silica sand comes from a quarry at Beausejour and gypsum from Harcus, on the west side of Lake Manitoba (Fig. 10).

Inland Cement also has a limestone quarry near Mafeking, south of The Pas. This operation, which began in 1956, extracts the Point Wilkins Member of the Devonian Souris River Formation, which contains 95-98% usable calcium carbonate. The crushed limestone is shipped to Regina, Saskatchewan by rail.

Aggregate

Producing aggregate (crushed stone, sand and gravel) for roads, construction fill and concrete is a significant industry in any populated region. In total, it forms the second most important industrial mineral category in terms of value. Manitoba's preliminary production value for sand and gravel for 1986 was $35.1 million, reflecting only the main operators. A 1986 estimate indicated there were more than 80 companies producing crushed stone, sand and gravel from hundreds of small quarries in the province. Manitoba Highways, Manitoba Hydro, Canadian National Railway, provincial parks and such cities as Winnipeg and Brandon are large producers and users.

Control room in Inland Cement's plant at Fort Whyte, 1987.

Lime

Lime is produced by Steel Brothers (Canada) Ltd. at Faulkner, in the Interlake region, from its rotary kiln plant that opened in 1976, at a cost of $4 million. The plant, rated at 318 tonnes per day, uses Elm Point limestone to produce both high-calcium and high-magnesia lime for the construction industry, steel processing, the pulp and paper industry and for municipal water softeners. Limestone is also quarried for crushed stone, poultry feed and mineral fillers.

Clay

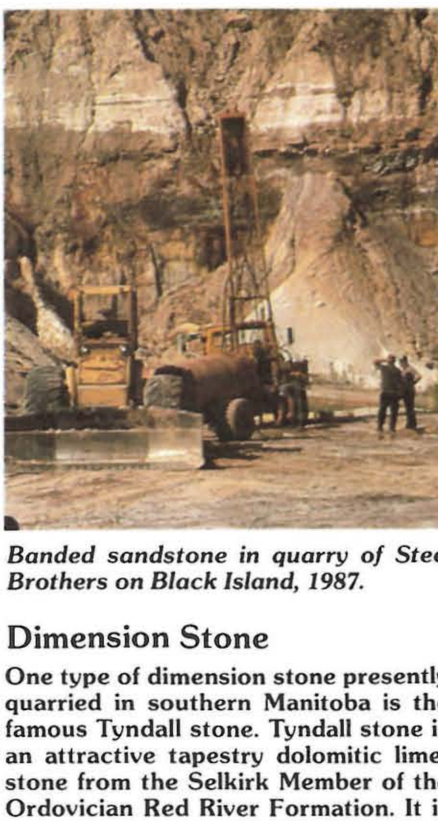
Besides the clay quarried for cement, there are two other types of clay operations — for brick making and for bentonite clay. Red River Brick and Tile Limited operates a brick plant at Lockport, using Cretaceous and Jurassic deposits from its Ste. Rose du Lac quarry, which opened in 1979. The ground clay is mixed with other brick ingredients such as silica, then shaped under pressure. The product has various textures applied, is cut with fine wires, dried and fired for 60 hours in a tunnel kiln before packaging. The final product is a high quality brick that is primarily used as decorative facing for buildings. The markets are in mid-Canada and the central and northern U.S.A.

The bentonite clay produced by Pembina Mountain Clays Inc. in the Miami-Morden area of southern Manitoba since 1940, is the only calcium-base non-swelling bentonite in Canada. This small successful operation draws from 6 to 7 thin beds, interlayered with black shale, in the Pembina Member of the Cretaceous Vermilion River Formation along the Manitoba escarpment. The clay is used in its natural dried state for binder in stock feeds, foundry sand, pesticide carrier, animal fur cleanser and kitty litter. When activated by treatment with sulphuric acid, it is used to purify and decolour petroleum, vegetable oils, animal fats, waxes, beverages and syrups.

Gypsum

Gypsum, which is used mainly for gyprock wallboard, plaster of Paris and as a cement additive, has been quarried since 1978 from the Amaranth Evaporite Formation at Harcus, 16 kilometres north of Amaranth (Fig. 10). Westroc Industries Limited operates the quarry on a seasonal basis, trucking the gypsum to its wallboard plant in Winnipeg. The old Amaranth underground mine operated in the same area from 1932 to 1963.

At Gypsumville, near Lake St. Martin in the Interlake region, mining of the gypsum ridges began in 1901. Domtar Construction Materials Limited operated a quarry there from 1953 to 1984. The gypsum was shipped by rail to the company's wallboard plant in Winnipeg. These Jurassic deposits accumulated within the 25-kilometre-wide Lake St. Martin crater, probably formed by a meteorite during Permian time (Table 1). South of Winnipeg, the Silver Plains underground gypsum mine produced from 1964 to 1975, when flooding forced it to close.



Banded sandstone in quarry of Steel Brothers on Black Island, 1987.

Dimension Stone

One type of dimension stone presently quarried in southern Manitoba is the famous Tyndall stone. Tyndall stone is an attractive tapestry dolomitic limestone from the Selkirk Member of the Ordovician Red River Formation. It is composed of a matrix of light buff limestone, with mottled areas of brownish dolomitic limestone distributed uniformly throughout. Gillis Quarries Limited, incorporated in 1925, extracts slabs that are cut and finished at its Garson plant. The original rail shipping point for the stone was the nearby town of Tyndall, and the name has stuck to the final product to this day. The stone is used primarily as building, monument and ornamental stone, with small or irregular pieces used as flagstone and crushed rock. It is shipped by rail and truck, mainly to markets in Manitoba, although the stone is marketed across Canada. The interior of the Parliament Buildings in Ottawa, Legislative Buildings in Winnipeg and Regina, the Lake Louise Chalet, Royal York Hotel in Toronto and Eaton's in Toronto and Montreal are all examples of the beauty and function of Manitoba's Tyndall stone.

Silica

Silica is produced during the summer months by Steel Brothers (Canada) Limited from a quarry that began in 1956 on the southeast side of Black Island in Lake Winnipeg. The silica comes from a 10 to 15 metre thick sandstone bed in the Ordovician Winnipeg Formation that outcrops for 2125 metres along the shore. The sandstone is quarried, then hauled to a nearby washing plant that separates the sand grains and removes impurities. This is one of the purest deposits in North America, averaging 95.5 to 97.5% silica oxide before processing. The sand is barged to the company's Selkirk plant, where it is processed for foundry sand or sent to Redcliff, Alberta, where it is used in glass making. The finished glass sand contains 99.5 to 99.7% silica oxide. The Selkirk plant operates year round, using sand stockpiled during the summer months.

Peat Moss

Peat moss is a significant industry in Manitoba, with production valued at $14 million in 1986, about 19% of Canada's production. Until 1983 the only major producer was Fisons Western Corporation that operates east of Winnipeg from four bogs: Evergreen, North Julius and Moss Spur in the Julius area, and the Elma bog farther south. Harvesting began in 1939 and the company now has two processing plants, at Elma and Moss Spur. At the height of the season it employs well over 200 people and has 80 hectares in production. In the spring of 1983 a new operator, Premier West Peat Moss Limited, started production from the Giroux bog, 50 kilometres southeast of Winnipeg. Manitoba peat is good quality sphagnum moss, used primarily for horticultural purposes. About 90 per cent of the product is shipped to the United States, as far as Texas and California.

Future Mineral Potential

Manitoba has an established mining industry, and the province's mineral potential is excellent. Large areas have yet to receive detailed prospecting and some areas have barely been touched.

Precambrian

All of Manitoba's 652 000 square kilometres is underlain by igneous and metamorphic Precambrian rocks (Fig. 11), a treasure house of economic minerals. The 60 per cent that is exposed, constitutes what is commonly called Manitoba's Precambrian Shield. In the remaining 40 per cent of the province, the Precambrian is concealed by the Phanerozoic sedimentary rocks of the prairies (198 000 square kilometres) and the Hudson Bay Lowland (67 000 square kilometres), each with its different potential.

The three main indicators of the level of mineral exploration activity are the annual levels of claim staking, expenditures on exploration and metres of diamond drilling (Fig. 14). These indicators show three recent boom periods in Manitoba. The first followed the discovery of the huge Inco nickel deposits in the mid-1950s, the second followed the discovery of the deposit that became the large Ruttan Mine in the mid-1960s. The third, in the late 1970s — early 1980s, was due to intensified gold exploration across Canada following the dramatic rise in the price of gold. Depressed figures for 1982 and 1983 reflect the recent recession. Indicators rebounded in 1984-86, again due to increased gold exploration.

The generalized geology and 'metallogeny' of Manitoba is illustrated in Figure 11. The principal features of the Precambrian are the volcanic-rich greenstone belts, the Nickel belt, and metasedimentary belts, such as the Wollaston Belt.

The Flin Flon-Snow Lake belt rivals any copper-zinc district of its type and size in the world. There is every reason to believe its prolific rate of discovery will continue. Discoveries, to date, have been primarily in the near-surface deposits that are more easily detectable by geophysical instruments. In the future, geological deduction will be used to probe deeper into the Precambrian Shield, and techniques are improving for finding deposits under the flat-lying Paleozoic sediments that cover this belt to the south.

New nickel deposits have been found under the Paleozoic in recent years on the southwest extension of the nickel belt. An example is the Minago River deposit of approximately 4.5 million tonnes (Fig. 12). It grades about 1.0% nickel and is covered by 120 metres of overburden and Paleozoic cover rocks.

In the northeast extension of the nickel belt, the large intriguing Fox River complex has potential for chrome, platinum minerals and nickel. This remote glacial till-covered complex received limited exploration until 1986, when BP Resources Canada Limited and International Platinum Corp. completed a diamond drill program for platinum group elements. One hole intersected 0.27 grams of platinum/palladium per tonne over 18.9 metres. A $500 000 exploration program is planned for 1987 that will include airborne geophysical surveys and drilling.

The Lynn Lake greenstone belt and others, such as the Great Island belt to the east and north, may yet furnish base and precious metal deposits in the future. The remote Archean greenstone belts at Gods-Oxford Lakes and Island Lake (Fig. 11) have not been thoroughly examined, mainly because of difficulty of access. They host many interesting base metal prospects and past producing gold mines. The more accessible Rice Lake, Bird River and Falcon Lake belts also hold future promise for gold and base metals.

The extension of Saskatchewan's uranium-rich Wollaston sedimentary fold belt into northwest Manitoba attracted attention in the 70s and some uranium occurrences were found.

Gold has attracted considerable attention in Manitoba in recent years. The MacLellan Mine, five kilometres east of Lynn Lake, commenced production at 900 tonnes per day capacity in mid-1986 and the first pour of bullion was on August 25, 1986. With reserves of 3 084 000 tonnes at 5.38 grams per tonne, the mine is expected to produce 2000 kilograms of gold from 327 000 tonnes of ore a year for at least five years. To the west of the main zone of the MacLellan Mine, additional tonnage has been outlined on the Dot property. Exploration is also continuing at Wasekwan and Cartwright Lakes. Additional reserves are present in other zones. SherrGold and its partners spent $2.65 million on exploration projects in 1986 and expect to spend $3 million in 1987. At Farley Lake geological reserves of 635 000 tonnes, averaging 6.86 grams per tonne, have been developed near surface by Manitoba Mineral Resources Ltd. and Hudson Bay Mining and an open pit might be used to mine the ore.

At Tartan Lake, 16 kilometres northeast of Flin Flon, a gold deposit went into production in May 1987. Current reserves are estimated to be 545 000 tonnes, at 13.03 grams per tonne. East of Tartan Lake, at Alberts Lake, interesting gold values were found in a 20 hole drill program by Granges Exploration Ltd. Granges also got interesting results in a drill hole to the south, at Pine Bay. East of Tartan Lake, at Puffy Lake, Pioneer Metals Corporation is spending $18 million to develop a mine. Current estimated reserves are 2 250 000 tonnes at 7.99 grams of gold per tonne and production is scheduled for December 1987. East of Puffy Lake, the Nokomis occurrence contains 90 000 tonnes of ore, at 10.28 grams of gold per tonne.

Three Snow Lake area gold properties have shown some promise: the Snow Lake Mines Ltd. prospect, with 732 000 tonnes at 9.12 grams of gold per tonne; the old Nor-Acme Mine, with estimated remaining reserves of 2.5 million tonnes at 5.48 grams per tonne; and the Squall Lake prospect, with an estimated 680 000 tonnes at 3.43 grams per tonne. Agassiz Resources, through its subsidiary Comiesa Corporation, hopes to recover an estimated 2177 kilograms of gold from the Nor-Acme concentrates stockpile.

At High Rock Island, near Island Lake, Bighorn Development Corporation has

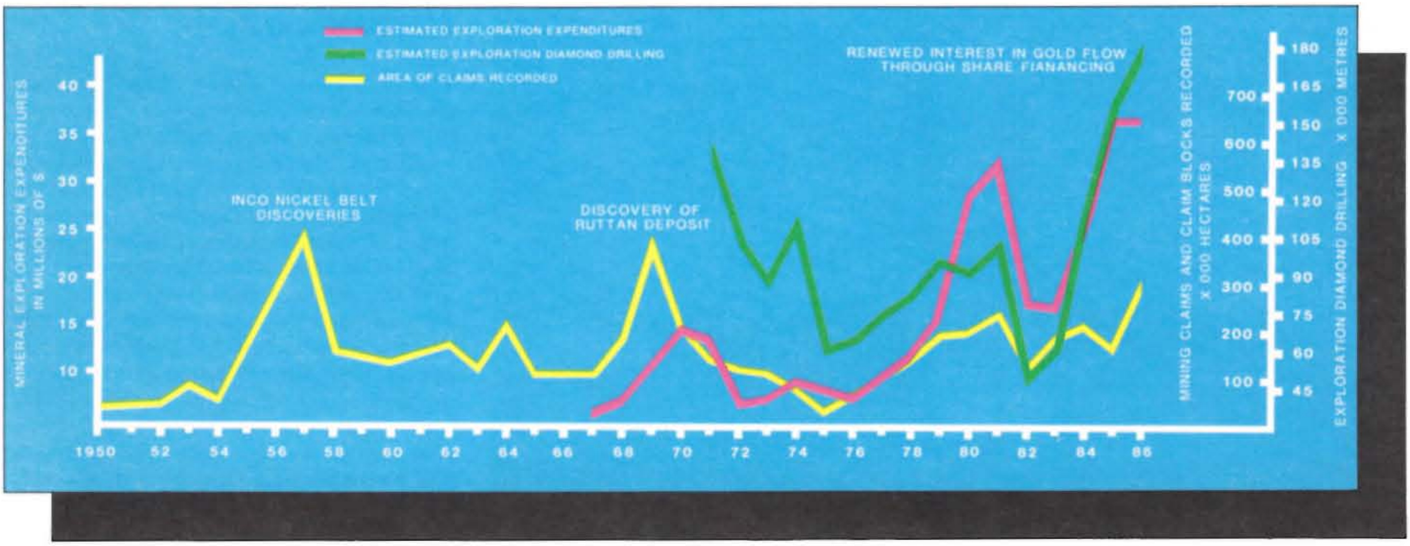


Figure 14 Claim staking (1950 - 1986), diamond drilling (1971 - 1986) and exploration expenditures (1967 - 1986) in Manitoba

developed a geological inventory of 316 000 tonnes, grading 15.43 grams of gold per tonne. To the end of 1986 the company has spent $1 million on the property and plan a pilot mill in 1987.

The San Antonio mine, at Bissett, has experienced several exploration attempts since its closure in 1968, and a short production period in 1982 and early 1983. Reserves in the upper levels of the mine include 750 000 tonnes grading 7.20 grams of gold per tonne, while in the lower levels, 191 000 tonnes averaging 8.57 grams per tonne have been outlined, including 136 000 tonnes with 11.31 grams per tonne. Despite the deep, inefficient workings of this old mine, it has excellent potential for future re-development.

Other potential gold areas receiving exploration attention are: Oxford Lake, Gods Lake, Lasthope and Beaucage Lakes (south of Lynn Lake), Assean Lake (northeast of Thompson), Seal River (west of Churchill) and the many prospects in the Rice Lake district. Efforts are also being made to reopen the old Sunbeam-Waverley deposit near Falcon Lake.

While gold has received the most public attention, a number of newly discovered base metal deposits are attractive for future development. In 1985, Hudson Bay Mining and Smelting announced the discovery of a significant nickel-copper deposit under Namew Lake, 60 kilometres south of Flin Flon. Present reserves are estimated at 2.4 million tonnes of 2.58% nickel, 0.9% copper and minor amounts of platinum and palladium. During the fall of 1985, the company completed a five kilometre access road to the mine site, and by the end of 1986 had sunk a mine shaft to 320 metres. A new copper-zinc deposit has recently been outlined less than one kilometre north of Flin Flon. Current reserves of this Callinan deposit are 1.5 million tonnes grading 4% zinc and 1.4% copper. Also in 1985, a copper-zinc discovery was made at Morgan Lake, 24 kilometres southwest of Snow Lake.

The economic feasibility of four low-grade chromite deposits in the Bird River area of eastern Manitoba is being explored. The deposits total 40 million tonnes averaging 9.6% chromium oxide. This strategic commodity is not mined anywhere in North America. About 80% of current production in the non-communist world is from South Africa. Rare-element-bearing pegmatites in the Bird River area and in the other parts of the province also continue to receive attention.

Aerial view of Tartan Lake Mine developed by Granges Exploration, 1987.

Aerial view of Pioneer Metals' Puffy Lake Mine, 1986.

Phanerozoic

The Phanerozoic rocks of the province also hold considerable mineral potential, in particular the potash deposits in southwest Manitoba, near the Saskatchewan border. These compare favourably with producing Saskatchewan deposits in grade, thickness, depth and structure. The estimated mineable ore reserves are 176 million tonnes. After allowance for estimated losses in processing, this reserve is equivalent to 64 million tonnes of commercial grade potassium chloride, a component in fertilizer. Feasibility and marketing studies are underway that will determine when the deposits will be developed. Canamax Resources Inc. in partnership with the Manitoba Government plans to spend $1.6 million to complete these studies.

Southwest Manitoba continued to see a high level of petroleum activity until mid-1986, as discoveries in the Waskada area indicated further exploration potential. The Paleozoic of the Hudson Bay Lowland has also received renewed interest with recent geophysical surveys and offshore drilling.

In the Paleozoic of the prairies, possible Mississippi Valley-type lead-zinc deposits have been indicated by lead-bearing specimens deposited by glacial action. The potential of southern Manitoba's silica sand deposits is also being investigated by Manitoba Energy and Mines geologists.

Although Manitoba' minerals industry has recently gone through trying economic times, the province has the infrastructure and geology, not only to regain losses, but to expand in the future. Manitoba Energy and Mines is working with the mining industry to ensure that this vast potential is realized.

Hudson Bay Mining and Smelting's Namew Lake Mine, under development in the Precambrian beneath the Phanerozoic.

Close-up of potash core from exploration drill hole into deposit near Russell.

Manitoba Energy and Mines

Minerals Division

Through its Minerals Division, Manitoba Energy and Mines provides support for mining and mineral exploration activities and administers regulations governing exploration, mines and quarries in Manitoba. The work of the division is divided between two branches.

Geological Services Branch

This branch undertakes geological mapping and research, designed to provide a geological framework and data base for the province. The mineral industry and the various levels of government use this data base in mineral resource appraisal, management and exploration. The branch also undertakes detailed and regional geological mineral deposit and other geoscientific investigations. Findings are made available to the public through maps and technical reports. Mapping and research concentrates on areas judged to be favourable for economic mineralization, on the geological setting of known ore deposits and on the updating of geological mapping used in current mineral exploration activities.

Mines Branch

Administration of all matters under The Mines Act governing the minerals management of operating mines and quarries and the recording and collection of relevant fees and royalties, is done by the Mines Branch. Regulations under The Mines Act govern the acquisition of claims, permits and leases for the right to prospect, develop and mine Crown minerals. The mining recorders, located in Winnipeg and The Pas, process applications for mining claims, monitor staking activities, collect performance deposits, maintain records, and respond to inquiries relating to these functions. Many of the record keeping and data gathering functions are being computerized. The result will be faster, more accurate service, and increased ability to provide a variety of timely data to Manitoba's minerals industry.

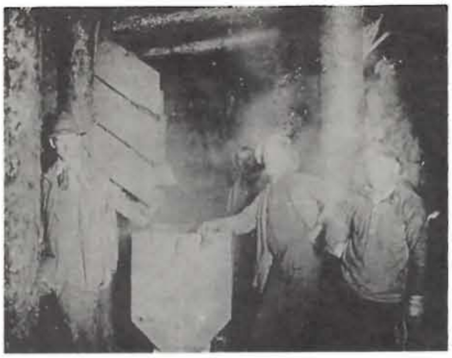
The branch collects and stores exploration data and drill core samples and conducts aggregate resource inventory studies. Geophysical, bibliographic and mineral inventory reports are compiled and distributed. Branch responsibilities also include monitoring the rehabilitation of mining lands and the implementation of the provincial land use policy concerned with the conservation of mineral and aggregate resources.

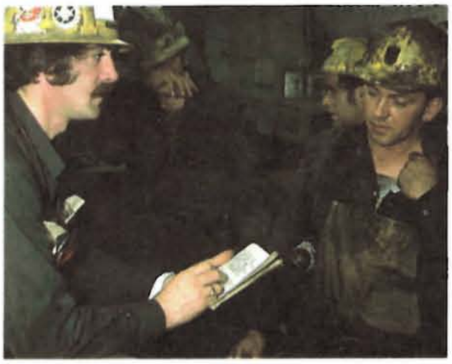
Canada — Manitoba Mineral Development Agreement

The work of the Minerals Division is enhanced by a five-year mineral development agreement between the Federal and Provincial Governments. Under the agreement, which began in 1984, $24.7 million is allocated for activities keyed to strengthening Manitoba's mineral industry. These include a number of geoscientific studies designed to stimulate and assist exploration for new reserves. Activities also include a variety of projects to strengthen the technology and efficiency of the industry and to explore new mineral products and markets.

Paul Lenton, Minerals Division geologist and field assistant Barbara King taking measurements at Cross Lake, 1986.
Aerial view of Drill Core Storage Library at The Pas, expanded with funds from the Canada-Manitoba Development Agreement, 1985.

Postscript





In an everchanging world, mining stands out as one of the most rapidly changing sectors of the economy. New ore bodies are discovered, old ones are exhausted. Corporate mergers shift ownership, and joint ventures form to bring new mines into production. As commodity prices fluctuate, what was uneconomical to mine yesterday is a prime mine site tomorrow. And all of this is in addition to a rate of technological change that is at least as rapid as in other parts of the economy.

While all of this makes Manitoba's mining industry a fascinating subject, it also makes it a difficult one to describe in print. A booklet such as Mining in Manitoba is essentially a snapshot of a moving object. Inevitably, parts of it are outdated before it leaves the printer. While we cannot prevent this, we have tried to keep the information in the booklet as timely as possible.

One of the ways we have done this is by adding this Postscript, where new information can be added, right up to press day, at the printer. If you need information on the latest developments in the mining industry, contact Manitoba Energy and Mines and we will be glad to help.

Some of the most important recent developments include pouring of the first gold brick at Pioneer Metals Corporation's Puffy Lake mine, southeast of Sherridon, on December 15, 1987. Near Lynn Lake, SherrGold is investing considerable funds to expand ore reserves at its MacLellan gold mine.

In July 1987 Hudson Bay Mining and Smelting Co., Limited announced they will spend $68 million, in partnership with Outokumpu Oy of Finland, to bring the Namew Lake nickel-copper deposit south of Flin Flon into production by late 1988. Hudson Bay Mining and Smelting will be investing $20 million to develop an open pit mine to extract the crown pillar from their Chisel Lake underground mine, near Snow Lake. As well, the company reports new ore bodies being discovered deeper in the Chisel Lake mine.

Hudson Bay Mining and Smelting has purchased the large Ruttan copper-zinc mine, near Leaf Rapids, from Sherritt Gordon Mines and is also planning to commence development of the Callinan copper-zinc deposit at Flin Flon. In Thompson, Inco Limited will spend $26.9 million to develop the deeper levels of the Thompson nickel mine.

Among industrial minerals, Tantalum Mining Corporation of Canada Limited is investing $4.7 million to resume tantalum production, in addition to spodumene, at their Bernic Lake mine, northeast of Winnipeg. Manitoba Potash Corporation, a joint venture of Canamax Resources (51%) and the Government of Manitoba (49%), completed a feasibility study on developing a major potash deposit near Russell. The study estimated a $500 million capital cost to develop the 172 million tonne (25.4% K_2O) deposit.

Other promising developments include: a pre-feasibility study on Manitoba Mineral Resources Limited's Farley Lake gold deposit, near Lynn Lake; Snow Lake Mines' announcement that they have outlined a 730 000 tonne deposit on their Snow Lake property grading 9.26 grams gold per tonne; High River Resources Limited's de-watering of the Nor-Acme mine workings in Snow Lake, with hopes of re-opening this old gold mine; and the announcement in late 1987 of a promising base-precious metals discovery by Westfield Minerals Limited, eight kilometres east of Flin Flon.

Open cut on the Penniac Reef gold prospect at Star Lake. Note jackhammer with cloud of steam in foreground, circa 1910.

Deep drill boring machine underground at Sherritt Gordon's Ruttan Mine, 1986.

Underground at the Mandy Mine south of Flin Flon. Note orecar and timbered roof supports, circa 1920.

Shiftboss lining up the crew at Inco Limited's Thompson Mine, circa 1985.

Drilling of the Tartan Lake gold prospect of Granges Exploration, 1985.

Glossary

Aeromagnetic Survey- a magnetic survey made with an airborne magnetometer.

Aggregate- materials such as sand, gravel and crushed stone used for mixing in various-sized fragments with cement or bituminous material to form concrete, asphalt, etc.; or alone for road base or railroad ballast; or in manufacturing processes.

Angular Unconformity- younger overlying sediments rest upon the eroded surface of tilted or folded older rocks.

Anode Copper- specially shaped copper slabs, resulting from the refinement of blister copper in a reverberatory furnace. Used as anodes (electrodes) in electrolytic refinement.

Anomaly- a deviation from uniform or normal geophysical, geobotanical or geochemical responses.

Archean- rocks formed during the earlier part of Precambrian time (older than 2.5 billion years).

Assay- to test ores or minerals to determine the amount of valuable minerals/metals/elements they contain.

Blister Copper- an impure, intermediate product in the refining of copper, produced by blowing copper matte in a converter. The name is derived from the large blisters on the cast surface that result from the liberation of gases.

Cage- an elevator-type conveyance that moves miners and materials up and down a mine shaft.

Cathode Nickel- electrolytically refined nickel that has been deposited on the cathode (electrode) in an electrolytic bath.

Converter- a furnace for oxidizing impurities in molten metals by blowing air through the metal. The impurities, mostly iron, form a slag that is removed, leaving pure metal suitable for refining.

Dimension Stone- naturally occurring rock material cut, shaped or selected for use in buildings, monuments, curbing, paving, flagging, bridges or other purposes.

Dolomitic Limestone- a limestone containing less than half dolomite and greater than half calcite.

Drill Core- a solid cylindrical sample of rock, usually 3-6 centimetres in diameter, produced by drilling with specialized diamond bits. Used for geological and/or chemical analysis.

Electrolysis- chemical change resulting from the passage of an electric current through a nonmetallic electric conductor so as to liberate matter from electrodes situated within an electrolytic cell.

Electromagnetic Survey- a survey made with an electromagnetometer that measures alternating magnetic fields associated with currents in the subsurface, the strength of which are dependent upon the nature of the rock.

Esker- a long, narrow, often sinuous, ridge or mound of sand, gravel and boulders deposited between ice walls by a stream flowing on, within, or beneath a stagnant glacier.

Flotation- a milling process in which certain minerals in solution adhere to bubbles and float to the surface of large tanks (cells). Other, less valuable, minerals sink to the bottom.

Flux- a chemical substance used in the smelting process to react with unwanted gangue materials so that they may float to the surface for easy removal as slag.

Foundry Sand- sand used to make molds for metal castings.

Gangue- the worthless minerals associated with valuable minerals in an ore deposit.

Geochemistry- all geological study involving chemical change.

Geological Province- an extensive region, all parts of which are characterized by similar geologic history or by particular structural, petrographic, or physiographic features.

Geologist- one who studies the constitution, structure, and history of the Earth's crust.

Geophysics- the study of the physical properties of the earth and its rocks, such as magnetism, density and conductivity.

Gneiss- a rock formed by regional metamorphism, in which bands of granular minerals alternate with flaky minerals.

Greenstone- generalized name given to Precambrian volcanic and associated sedimentary rocks.

Greenstone Belt- an elongated area of metamorphosed volcanic and sedimentary rocks in the Precambrian Shield.

Hardrock- a colloquial term for igneous and metamorphic rocks, as distinguished from sedimentary rocks.

Hoist- a machine which raises or lowers the cage and skip in a mine shaft, using large pulleys.

Hudsonian- refers to the mountain building episode that occurred between 1700 and 1820 million years ago during Precambrian time.

Igneous- rock or mineral that solidified from molten or partly molten material.

Isotopic Age- an age expressed in years and calculated by measuring the disintegration rate of radioactive elements.

Kenoran- refers to the mountain building episode at the end of the Archean time, about 2500 to 2670 million years ago during Precambrian time.

Kiln- a large furnace used for baking, drying or burning firebrick or refractories, or for heat-treating ore or other substances.

Magnetometer- an instrument that measures the Earth's magnetic field and its changes, or the magnetic field of a particular rock.

Matte- an impure mixture of sulphides that is produced in the smelting of sulphide ores such as nickel and copper.

Metallogeny- the study of the development and formation of mineral deposits, with emphasis on their relationship in space and time to the physical features of the Earth's crust.

Metamorphism- the mineralogical and structural adjustment of solid rocks to changes in physical and chemical conditions, usually deep within the Earth.

Metasediments- sediments that have undergone metamorphism.

Mineral Deposit- a mass of naturally occurring minerals, usually of economic value, without regard to mode of origin. Organic fuels such as coal and petroleum are sometimes called mineral deposits.

Mineral Disposition- a disposition under The Mines Act that takes the form of a permit, claim or lease.

Mineral Filler- a mineral substance added to a product to increase the bulk or weight of the product, or to dilute expensive materials, and often to improve the product.

Mineralization- the nature and processes of the concentration of minerals in rocks which may result in an economically valuable deposit.

Mining Claim- a plot of Crown land containing a mineral and staked out for mining purposes.

Mining District- a section of country having described or understood boundaries within which mineral deposits are found and worked under prescribed acts and regulations.

Mississippian- a period of the Paleozoic era about 345 to 320 million years ago.

Ore- naturally occurring material from which a mineral or minerals of economic value can be extracted.

Outcrop- that part of a geologic formation or structure that is exposed at the surface of the Earth.

Pentlandite- iron nickel sulphide, which is the principal mineral of nickel.

Phanerozoic- that part of geologic time (more recent than the Precambrian) for which, in the corresponding rocks, the evidence of life is abundant. The Phanerozoic includes the Paleozoic, Mesozoic and Cenozoic eras.

Physiography- physical geography; a description of the natural features of the surface of the Earth.

Pilot Plant- a small-scale concentrator in which representative tonnages of ore can be tested under conditions that imitate those of a proposed full-scale operation.

Pleistocene- that period of recent geologic time when glaciers covered much of northern North America.

Plutonism- formation of igneous rocks deep within the Earth under the influence of high heat and pressure.

Precambrian- all that very old geologic time before the Phanerozoic; it is equivalent to about 90% of geologic time and contains only very primitive forms of life.

Proterozoic- the more recent division of Precambrian time and its corresponding rocks (younger than 2.5 billion years).

Raise- a vertical or inclined opening from one level of a mine that is driven toward the level above.

Relief- the elevation or differences in elevations of a land surface.

Reserves- quantity of mineral calculated to lie within given boundaries. Deposit thickness, depth, quality, geological conditions and contemporary economic factors are limits on reserves.

Room-and-Pillar- a system of mining in which the ore is mined in rooms separated by pillars left at regular intervals. Spacing between pillars is determined by the geological and structural conditions of the surrounding rock. Sometimes the pillars are removed after the rooms have been backfilled.

Sediment- fragmental material, either inorganic or organic, that forms in layers on the Earth's surface at ordinary temperatures in an unconsolidated form.

Shaft- a vertical or steeply inclined excavation for the purpose of opening and operating a mine. It is usually equipped with a hoist at the top that raises and lowers the cage and skip. A shaft may also be used for ventilating underground workings.

Shield- a large region of exposed Precambrian rocks surrounded by younger sediment-covered areas, e.g. Canadian Shield.

Skip- a self-dumping type of conveyance or bucket used in a shaft for hoisting ore and rock.

Slag- gangue minerals and the flux that is removed in smelting operations.

Slurry- a thin, watery mixture containing fine, insoluble materials.

Softrock- a colloquial term for sedimentary rocks, as distinguished from igneous and metamorphic rocks.

Stope- an excavation in a mine from which ore is extracted.

Strata- layers of sedimentary rock of varying thickness, each of which possesses characteristics different from the layer above and below.

Strike- the direction or trend that a geologic formation or structure takes as it intersects the horizontal.

Tailings- materials rejected from the mill after the recoverable valuable minerals have been extracted.

Unconsolidated Sediments- rock material that is loosely arranged or unstratified, or whose particles are not cemented together, occurring either above or below the surface.

Volcanic Rock- any rock of volcanic origin. Volcanic igneous rocks erupted as molten masses, forming lava flows, dykes in the crater walls, volcanic plugs, etc. Volcanic sedimentary rocks are the fragmental materials ejected in explosive eruptions.

Mineral Identification Chart

Mineral	Composition	Colour	Streak	Lustre	Cleavage and/or Fracture	Hardness	Remarks
Albite	$NaAlSi_3O_8$	White, Pink	White	Vitreous	2 Good, 1 Poor -90°	H (6)	Blue colour play. Striations on cleavage faces.
Amblygonite	$LiAl(PO_4)F$	White	White	Vitreous	1 Good, 2 Poor	H (6)	Associated with granite pegmatites.
Apatite	$Ca_5F(PO_4)_3$	Green-Pink	White	Vitreous	Imperfect cleavage	M (5)	Pegmatites and other igenous rocks.
Arsenopyrite	FeAsS	Tin-White	Black	Metallic	Rough fracture	H (6)	Assay for Gold. // lines on crystals.
Asbestos	$Mg_3Si_2O_5(OH)_4$	Green	White	Vitreous	Fibrous	S (2½)	Alters from basic rocks.
Augite	$Ca(MgFe)Si_2O_6$	Brown, Black	White	Vitreous	Good cleavage at 93°	H (5½)	Intermediate and basic rocks.
Azurite	$Cu_3(CO_3)_2(OH)_2$	Blue	Blue	Dull, Earthy	Usually earthy	M (3½)	Weathered zone over copper deposits.
Beryl	$Be_3Al_2Si_6O_{18}$	Green-White	White	Vitreous	Cleavage indistinct	H (8)	Granite pegmatites.
Biotite	$K(MgFe)_3AlSi_3O_{10}$	Brown, Black	White	Vitreous	Perfect in 1 plane	M (3)	Found in igneous rocks.
Calcite	$CaCO_3$	White, Trans.	White	Vitreous	Perfect in 3 planes	M (3)	Sediments. Vein gangue. Optical uses.
Cassiterite	SnO_2	Dark Brown	Pale Brown	Resinous	Rough fracture	H (6½)	Tin ore. Test with zinc and hydrochloric acid. Pegmatites.
Chalcopyrite	$CuFeS_2$	Brass-Yellow	Green-Black	Metallic	No cleavage. Rough	M (4)	Assay for gold and copper. S.G. 4.2. Chief ore of copper.
Chlorite	$(FeMg)_5Si_4O_{10}$	Green	White	Pearly	Perfect in 1 plane	M (3)	Occurs abundantly in greenstone.
Chromite	$FeCr_2O_4$	Dark Brown	Pale Brown	Sub-Metallic	Even fracture	H (5½)	Segregations and replacements in basic rocks.
Corundum	Al_2O_3	Green, Variable	White	Vitreous	Parting almost cubic	H (9)	Syenite pegmatites.
Dolomite	$CaMg(CO_3)_2$	White, Trans.	White	Vitreous	Perfect in 3 planes	M (3½-4)	Sediments. Vein gangue. Tyndall stone.
Epidote	$Ca_2(Al, Fe)_3(SiO_4)_3(OH)$	Green	White	Dull	Indefinite cleavage	H (6½)	An alteration product. Usually in igneous rocks.
Fluorite	CaF_2	Variable	White	Vitreous	Perfect cleavage 3 planes	M (4)	Occurs as a vein gangue. Lesser amounts in pegmatites.
Galena	PbS	Silver-Grey	Black	Metallic	Perfect. Cubic	M (3)	Heavy. S.G. 7.5. Assay for *silver* and gold.
Garnet	$Fe_3Al_2(SiO_4)_3$	Red, Variable	White	Vitreous	No cleavage	H (7)	Usually found in metamorphic rocks.
Gold	Au	Yellow	Yellow	Metallic	No cleavage. Ductile	S (2½-3)	Occurs native. With many sulphide minerals.
Gossan	Weathered Mineral Outcrop	Red-Brown	Brown	Dull, Earthy	Usually earthy	S-M	Pan for gold.
Gypsum	$CaSO_4 + 2H_2O$	White	White	Pearly	1 Good, 2 Imperfect	S (2)	Sedimentary rock. (Vein gangue.)
Hematite	Fe_2O_3	Red-Black	Red	Metallic, Earthy	Scaly to rough	H (6)	S.G. 5.2. Principal iron ore.

Mineral	Composition	Colour	Streak	Lustre	Cleavage and/or Fracture	Hardness	Remarks
Hornblende	$CaFe_2Al_5Si_8O_{22}(OH)_2$	Green, Brown, Black	White	Vitreous	Good cleavage at 124°	H (5½)	Intermediate and basic rocks.
Kaolinite	$Al_2Si_2O_5(OH)_4$	White	White	Earthy	Compact, earthy masses	S (2)	Alters from feldspar. Forms clays.
Labradorite	$CaAl_2Si_2O_8$	Grey	White	Vitreous	2 Good at 86°	H (6)	Blue colour play. Striations on cleavage faces.
Lepidolite	$K(Li, Al)_3Si_4O_{10}(OH)_2$	Lilac	White	Vitreous	Perfect 1 plane. Scaly	M (3)	Lithium ore. Finely micaceous. Pegmatites.
Limonite	$Fe_2O_3.3H_2O$	Yellow	Light Brown	Metallic, Earthy	Rough. Uneven fracture	S-M	Occurs in oxidized zone of ore bodies.
Magnetite	Fe_3O_4	Black	Black	Metallic	Rough fracture	H (6)	Magnetic. Iron formation. An ore of iron.
Malachite	$Cu_2(CO_3)(OH)_2$	Green	Green	Dull, Earthy	Usually earthy	S (3½)	Weathered zone over copper deposits.
Molybdenite	MoS_2	Lead-Grey	Black	Metallic	Parallel, platy cleavage	S (1½)	Ore of molybdenum. Green streak on glazed paper.
Muscovite	$KAl_2Si_4O_{10}(OH)_2$	Pale Yellow	White	Pearly	Perfect in 1 plane	M (3)	Found in igneous rocks.
Olivine	$(FeMg)_2SiO_4$	Pale Green	White	Vitreous	No cleavage. Fractures	H (6½-7)	Basic rocks. Never with quartz.
Orthoclase	$KAlSi_3O_8$	White, Pink	White	Vitreous	2 Good, 1 Poor Rt angles	H (6)	No striations. Common to granite.
Pyrite	FeS_2	Brass Yellow	Black	Metallic	No cleavage. Rough	H (6)	Assay for gold. S.G. 5±. Most common sulphide.
Pyrrhotite	FeS	Bronze	Black	Metallic	Rough fracture	M (4)	S.G.-4.5. Slightly magnetic. May carry nickel values.
Quartz	SiO_2	Variable	White	Vitreous	No cleavage. Fractures	H (7)	Vein former. Has no cleavage. Harder than calcite.
Scheelite	$CaWO_4$	Cream White	White	Vitreous	3 Good cleavages	M (4½-5)	Associated with granite pegmatites.
Serpentine	$Mg_3Si_2O_5(OH)_4$	Green	White	Waxy	Fractures only	M (3-4)	Alters from basic rocks.
Siderite	$FeCO_3$	Yellow-Grey	White	Vitreous	Perfect 3 planes	M (3½-4)	Weathers rusty brown. A vein gangue.
Silver	Ag	Silver-Grey	Silver	Metallic	No cleavage. Ductile	S (2½)	Occurs native. With many sulphide minerals.
Sphalerite	$(Zn, Fe)S$	Yellow-Brown	Light Brown	Resinous	Prominent cleavage planes	M (4)	Assay for gold. Resinous lustre deceptive.
Spodumene	$LiAlSi_2O_6$	White-Grey	White	Vitreous	Platy cleavage	H (6½)	Associated with granite pegmatites.
Talc	$Mg_3Si_4O_{10}(OH)_2$	Grey, Green, White	White	Pearly	Perfect in 1 plane	S (1)	Alters from basic rocks.
Tellurides	Metal + Te	Bluish-Grey	Black	Metallic	Usually fair cleavage	S-M	Roast before panning. Assay for gold and silver.
Tourmaline	$CaFe_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$	Black, Variable	White	Vitreous	No cleavage	H (7-7½)	A pegmatite mineral.

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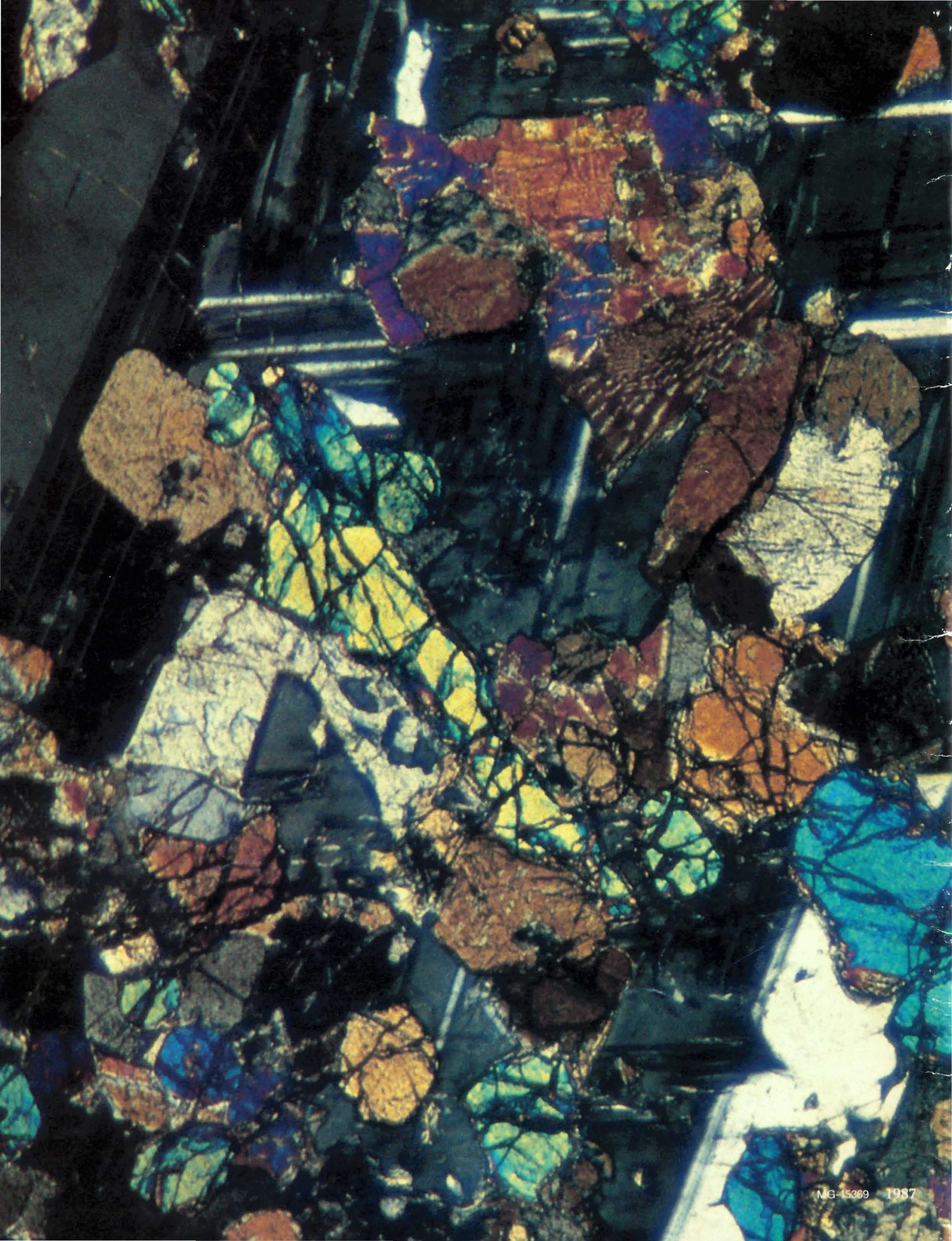
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