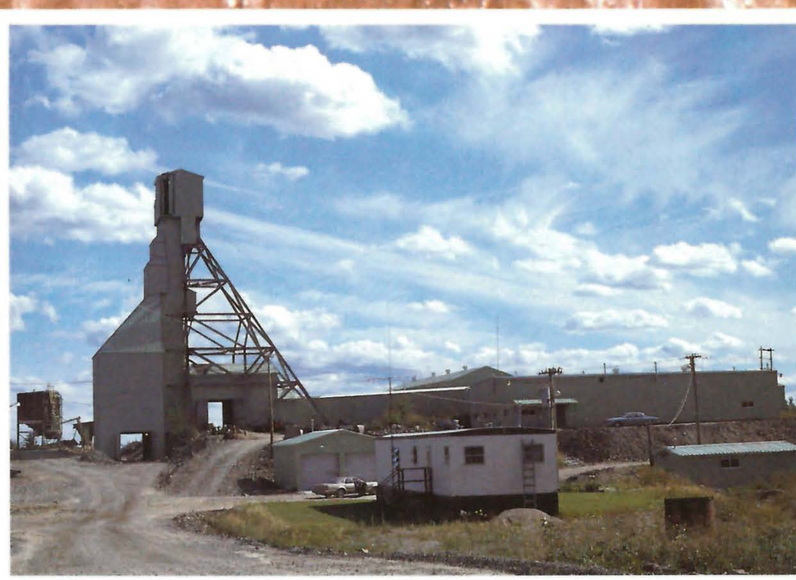
MINERAL EDUCATION SERIES



Copper And Zinc In Manitoba

Manitoba
Energy and Mines

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Cover photo: Rod Mine — Snow Lake.

1986

Message From The Minister Of Energy and Mines

Manitoba's abundant mineral resources form a vital part of our province's rich natural resource heritage. It is almost impossible to spend even a day in our province without using some item which contains a tiny part of this heritage. Your home or workplace, no doubt, has concrete which includes our abundant sand and gravel. Or perhaps it uses building stone from one of Manitoba's quarries. Somewhere in your home there is likely to be copper pipe or wire which may well have originated from a northern Manitoba mine. The same mines produce the zinc which is used to galvanize much of the metal in your car to retard rust. You probably sit down to dinner with stainless steel cutlery which require nickel — one of Manitoba's richest mineral resources. Your car may use gasoline refined from Manitoba oil. You may even use Manitoba's gold when you exchange rings on your wedding day.

In getting these resources out of the ground and into your life, Manitoba's mining, quarrying and oil industries create thousands of jobs for Manitobans, including everything from clerks to miners to executives. These people, in turn, spend their salaries on goods and services which provide the lifeblood for countless more employees and businesses. In total, these industries and their spin-off benefits make a major contribution to Manitoba's prosperity and stability.

These resources also provide a significant source of income for the provincial government. Royalties and taxes ensure that revenues from our natural resource heritage contribute to maintaining the level of services Manitobans expect. These revenues help pay for the quality schools, hospitals and roads which make Manitoba a fine place to live.

In the Mineral Education Series, we hope to increase Manitobans' awareness of the wealth and variety of our mineral resources and their importance. Each booklet in the series explains one aspect of our mineral industry, describing the mineral resources, the history of its development in Manitoba and the industry today. We hope the series will convey some of the importance and excitement of exploiting Manitoba's mineral resource heritage.

In **Copper and Zinc in Manitoba** we look at two metals whose story stretches from ancient copper tools and early brass castings, to galvanized steel and micro-chips. While Manitoba's aboriginal peoples shaped copper implements for thousands of years before the arrival of Europeans, significant commercial mining of copper and zinc began in Manitoba during the 1930's. Since then Manitoba's mines have provided a steady flow of these essential minerals to the marketplaces of the world.

Throughout this history, Manitoba Energy and Mines and its provincial predecessors have played a role in strengthening Manitoba's mining industry, and ensuring our mineral heritage is carefully developed. In **Copper and Zinc in Manitoba** Bruno Esposito, a geologist with the Department, provides us with an overview of a vital part of our mining industry. I would like to thank him, and all the other staff of our Department, for sharing this part of Manitoba's mineral resource story.

Wilson D Parasiuk

Wilson Parasiuk
Minister
Energy & Mines

Copper And Zinc In Manitoba

Introduction

Copper (Cu) is a reddish to brownish-coloured, bright, durable metal with excellent electrical and heat conducting properties. It is among the oldest metals known to man and since ancient times it has been used for making a variety of implements, weapons, ornaments and coins. In nature, a small amount of copper exists in the native form, but most of the metal is today recovered from such minerals as chalcopyrite, bornite, cuprite, chalcocite and malachite (Table 1).

The special combination of physical and chemical properties of copper and its alloys makes this metal irreplaceable in many industrial uses.

Zinc (Zn) is a silvery-bluish coloured metal which is very lustrous when freshly cut but which dulls rapidly when exposed to air, because of the formation of a thin film of oxide. This film acts as a protective coating against any further weathering of the metal. Although zinc has been known as part of the alloy brass since ancient times, the pure metal was only separated in relatively recent times. The most important zinc ores include sphalerite or zincblende, smithsonite and zincite (Table 1).

Zinc has a wide variety of uses due primarily to its resistance to corrosion.

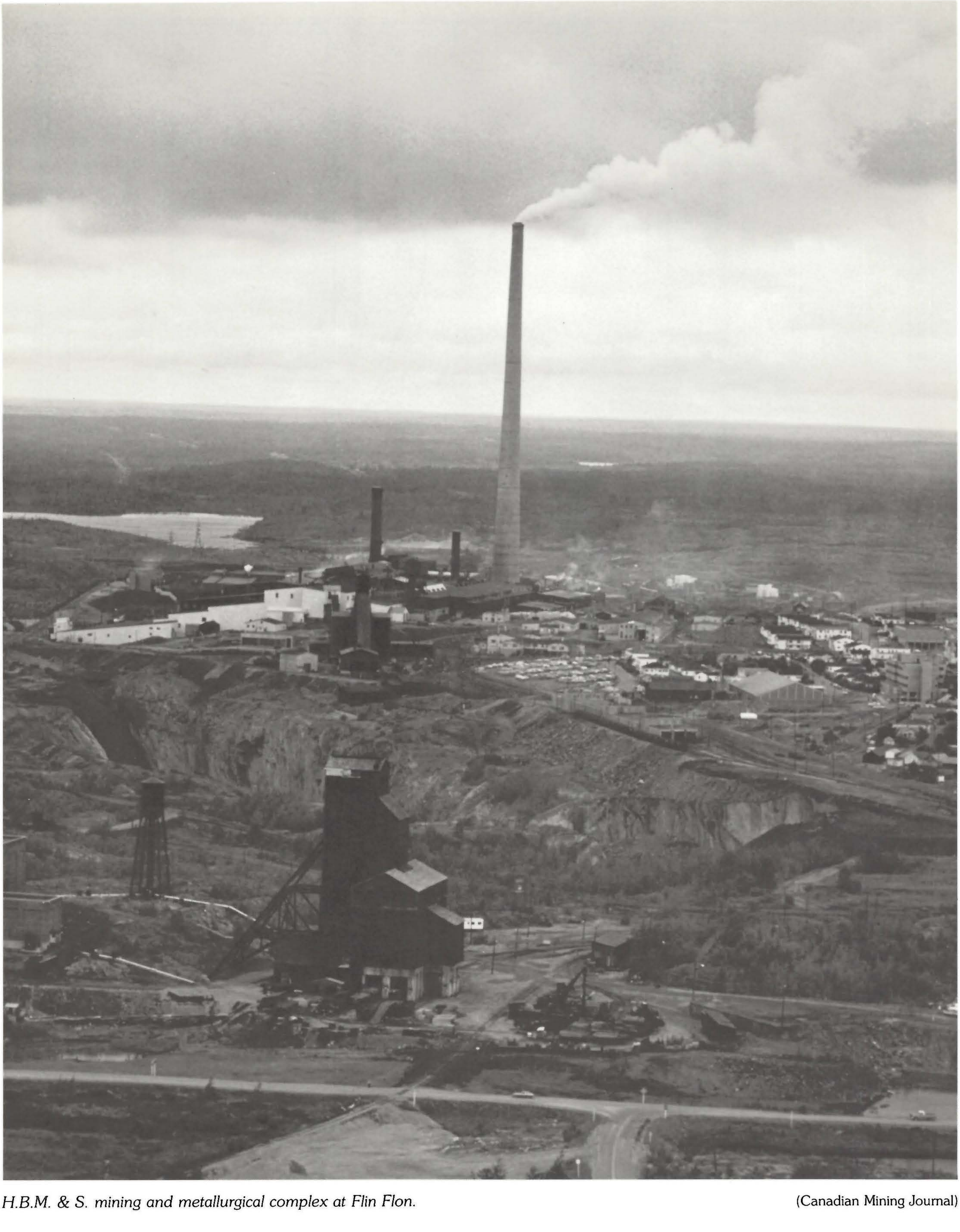
Chalcopyrite and sphalerite commonly occur together in the natural state and are the only copper and zinc minerals found in economic concentrations in Manitoba. They are mined in the northern part of the Province (Figure 1) where important mines are located in the Flin Flon and the Lynn Lake Belts. Some copper is also obtained as a by-product of nickel mining in the Thompson area of northern Manitoba.

In nature, copper and zinc sulphides are found mixed in varying proportions with uneconomic minerals such as pyrite, pyrrhotite, quartz, calcite, graphite, chlorite, mica, etc. A series of complex processes are necessary to recover the metals in useful forms (Figure 2). The first of these processes separates economic from non-economic minerals, and usually takes place in concentrators located near the major mines. The next stage of processing, which separates the copper and zinc metals from the sulphides, is done in a copper smelter and zinc refinery plant, such as the one in Flin Flon After further refining both metals are finally ready for use in the fabricating industry.

Copper and zinc mining is an important source of revenue to the Province and is the main reason for the existence of several northern communities — Flin Flon, Snow Lake, and Leaf Rapids. Yearly production of copper and zinc in Manitoba is shown in Figure 3. In 1984 production of 61 224 tonnes* of copper and 48 564 tonnes of zinc was valued at $116 million and $68 million respectively. In order to maintain and develop this valuable industry, which in 1984 directly employed about 3,000 people, new ore deposits must be found to replace depleted ones.

Several companies are involved in exploration for new deposits in various parts of the province. Exploration is concentrated in the Precambrian Shield and particularly in the Flin Flon-Snow Lake Belt (Figure 1), which appears to have the highest potential for copper and zinc deposits.

*One tonne = 1000 kilograms
One kilogram = 2.20462 pounds avoirdupois



H.B.M. & S. mining and metallurgical complex at Flin Flon. (Canadian Mining Journal)

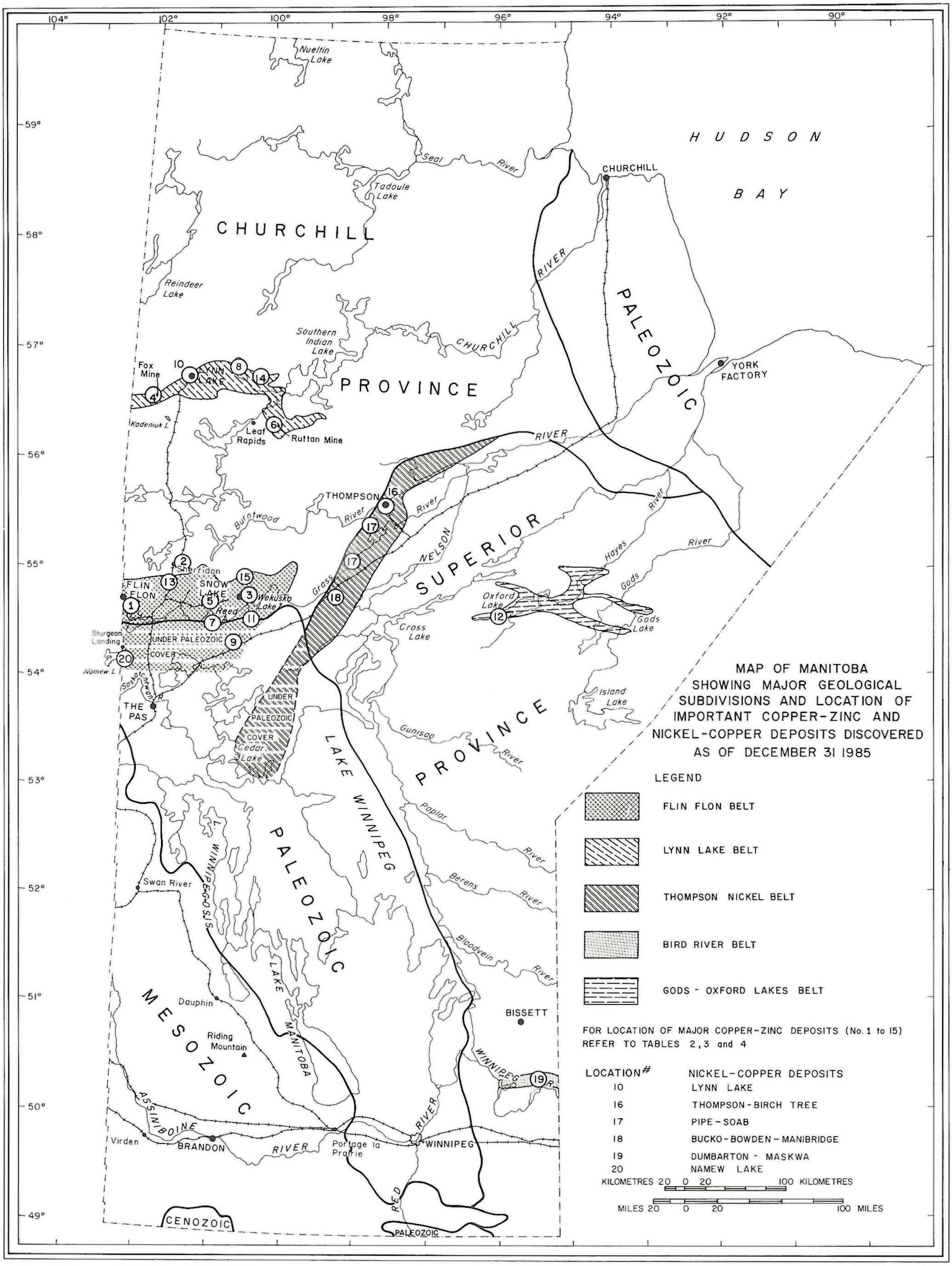
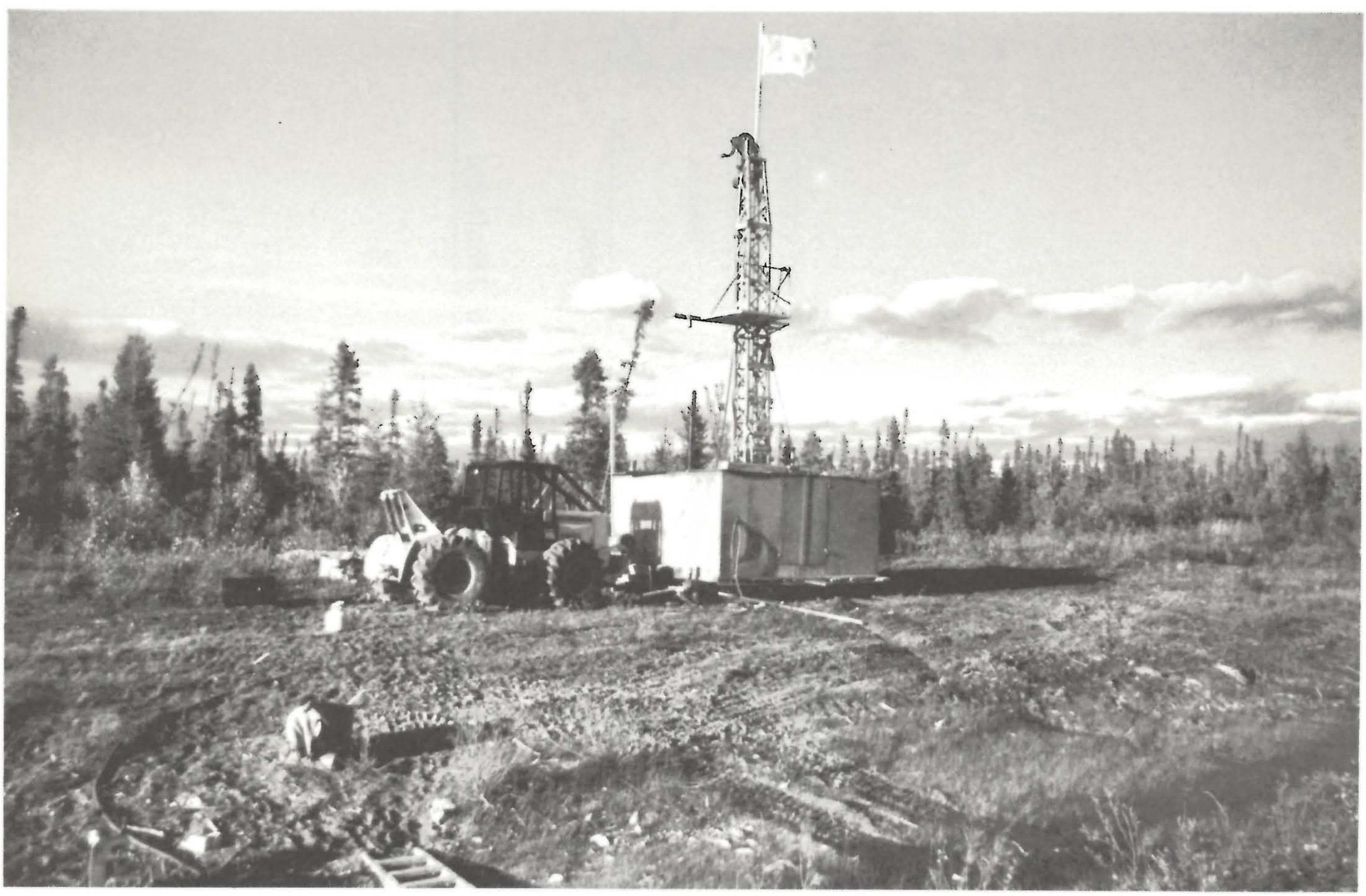


Figure 1.
Map of Manitoba showing major geological subdivisions and location of important copper-zinc and nickel-copper deposits.

TABLE 1: MOST COMMON COPPER AND ZINC MINERALS

MINERAL	COMPOSITION	METAL CONTENT	HARDNESS	COLOUR
chalcopyrite	$CuFeS_2$	34% Cu	3.5-4	Brass-yellow
bornite	Cu_5FeS_4	63% Cu	3	Bronze-red
cuprite	Cu_2O	89% Cu	3.5-4	Bright red or reddish black
chalcocite	Cu_2S	80% Cu	2.5-3	Blackish lead-grey
malachite	$CuCO_3Cu(OH)_2$	57% Cu	3.5-4	Bright green
sphalerite	ZnS	67% Zn	3.5-4	Brown, black or yellow
smithsonite	$ZnCO_3$	52% Zn	4-4.5	Usually dirty brown
zincite	ZnO	80% Zn	4-4.5	Deep red or orange-yellow



Cominco drilling on Manfor Road, The Pas.

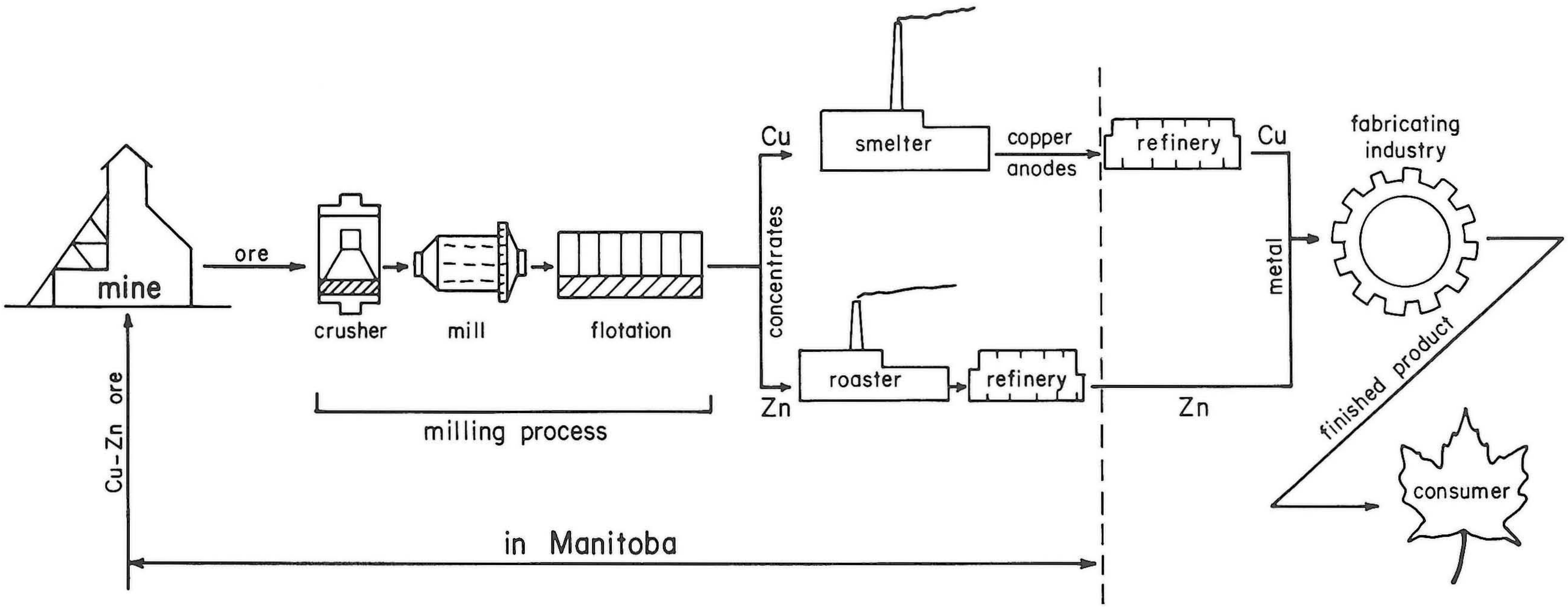


Figure 2.
Flow diagram showing movement of copper-zinc ore from mine to customer.

Occurrences In Manitoba

The Precambrian Shield, which forms 60% of the bedrock in Manitoba, is divided into two geological provinces (Figure 1). Rocks of the Superior Province are of Archean age (older than 2,500 million years) while rocks of the Churchill Province are mainly of Proterozoic age (2,500 to about 1,700 million years).

All the economic and most of the subeconomic copper and zinc deposits found to date in Manitoba occur in the Churchill Province and more specifically in metamorphosed volcanic and sedimentary rocks of the Flin Flon and the Lynn Lake Belts (Figure 1). Their average age has been measured at around 1,800 million years.

Sulphide deposits with uneconomic levels of copper and zinc have been found in every part of the Manitoba Precambrian associated with volcanic rocks, intrusives (gabbros, granites) and sedimentary rocks.

The nickel (Ni) deposits located in both the Churchill and the Superior Provinces (Figure 1) contain amounts of copper ranging from about 0.1% in the Thompson Nickel Belt and approximately 0.3% in the Bird River area of southeastern Manitoba, to slightly over 0.5% in the Lynn Lake nickel deposits. The newly discovered Ni-Cu deposit at Namew Lake appears to contain almost 1% Cu. Known economic nickel deposits in the Bird River and Lynn Lake areas have been depleted.

Manitoba Energy and Mines has compiled a list of the important mineral properties of Manitoba with locations, ownerships, tonnages and grades, where available, as well as descriptions of a number of metallic mineral locations in the Province. For more detailed information on copper and zinc occurrences, the reader is referred to the Manitoba Mineral Inventory Cards available for inspection and duplication at the office of the Exploration Services Section, Mines Branch, Winnipeg, or at the Mining Recorder's office, The Pas.

History Of Copper And Zinc

Historical Background

The word **copper** is derived from the name of the island of Cyprus, in the eastern Mediterranean Sea, which before and during Roman times was an important producer of this metal. The Romans in fact referred to copper as "Aes Cyprium" or "Cyprian metal". Pronunciation of the word "Cyprium" in classic Latin was probably close to "cuprum" from which the word copper and the symbol "Cu" were derived.

Copper may be found in nature in its native state and, together with gold and silver, it was one of the first metals used by man. Traces of copper workings, dating back as far as 7,000 years Before Present (B.P.) have been found in a number of locations in Eastern Mediterranean countries, Mesopotamia and North America. First attracted by the bright and pleasing appearance of copper, man soon discovered that its ductility enabled him to beat it into almost any shape that he required; in the process it became sufficiently hardened to enable him to sharpen it into implements and weapons of lasting quality.

In Asia and Europe three main stages marked the development of copper usage. In the first stage, copper found in its native state was hammered into shape; in the second, it was melted and cast; and in the third stage, smelted from its ores. Eventually, copper was also used to produce bronze, an alloy of copper and tin, and brass, an alloy of copper and zinc.

In North America, numerous deposits of copper, in its native form, exist around Lake Superior where thousands of prehistoric mining pits have been found on Isle Royale and on the Keweenaw Peninsula. The "Old Copper Indians" were the first users of the copper in this region, and perhaps in the whole world. As early

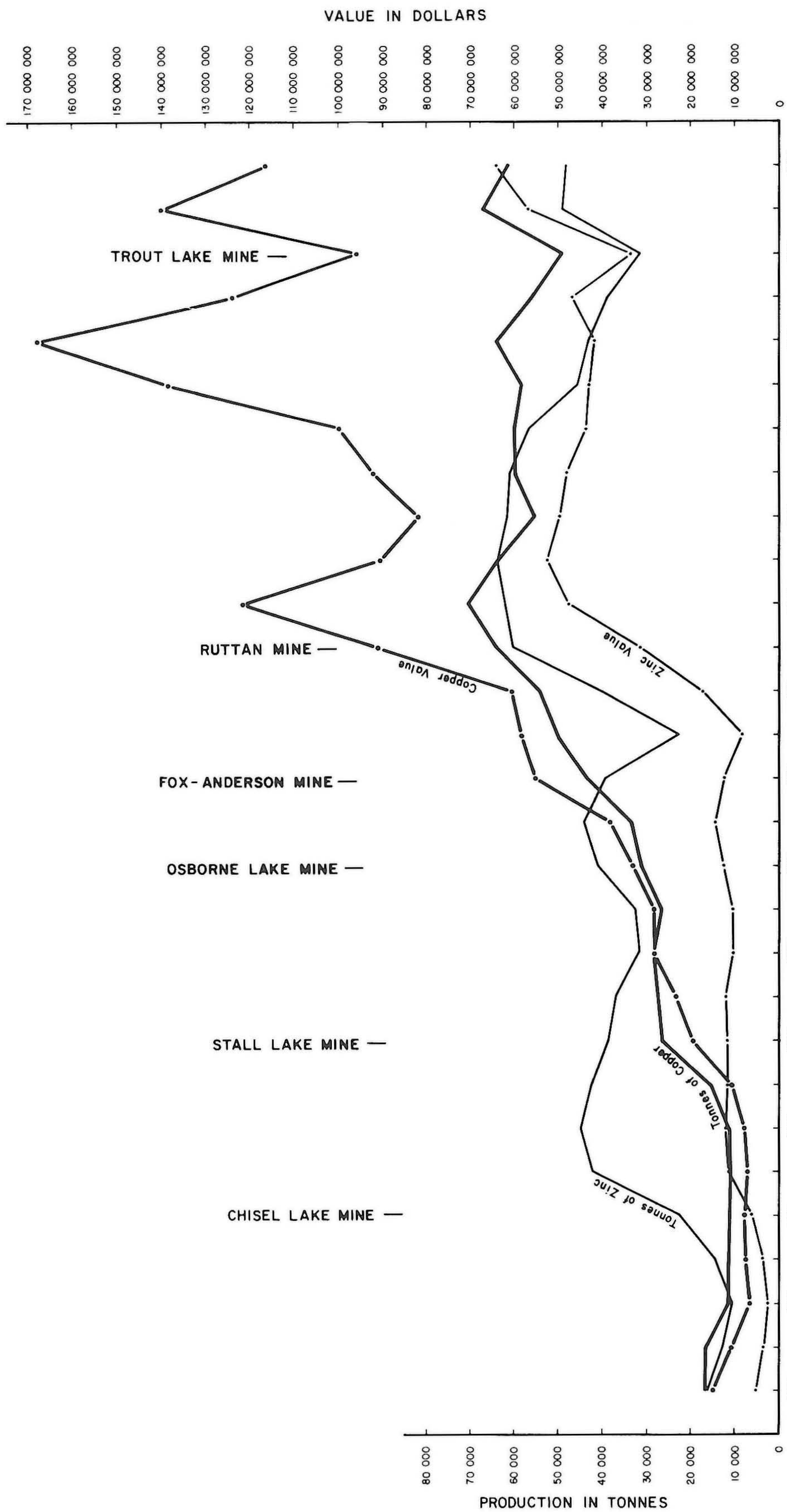


Figure 3.
Manitoba copper and zinc production, 1956-1984.

(Energy, Mines and Resources, Ottawa)

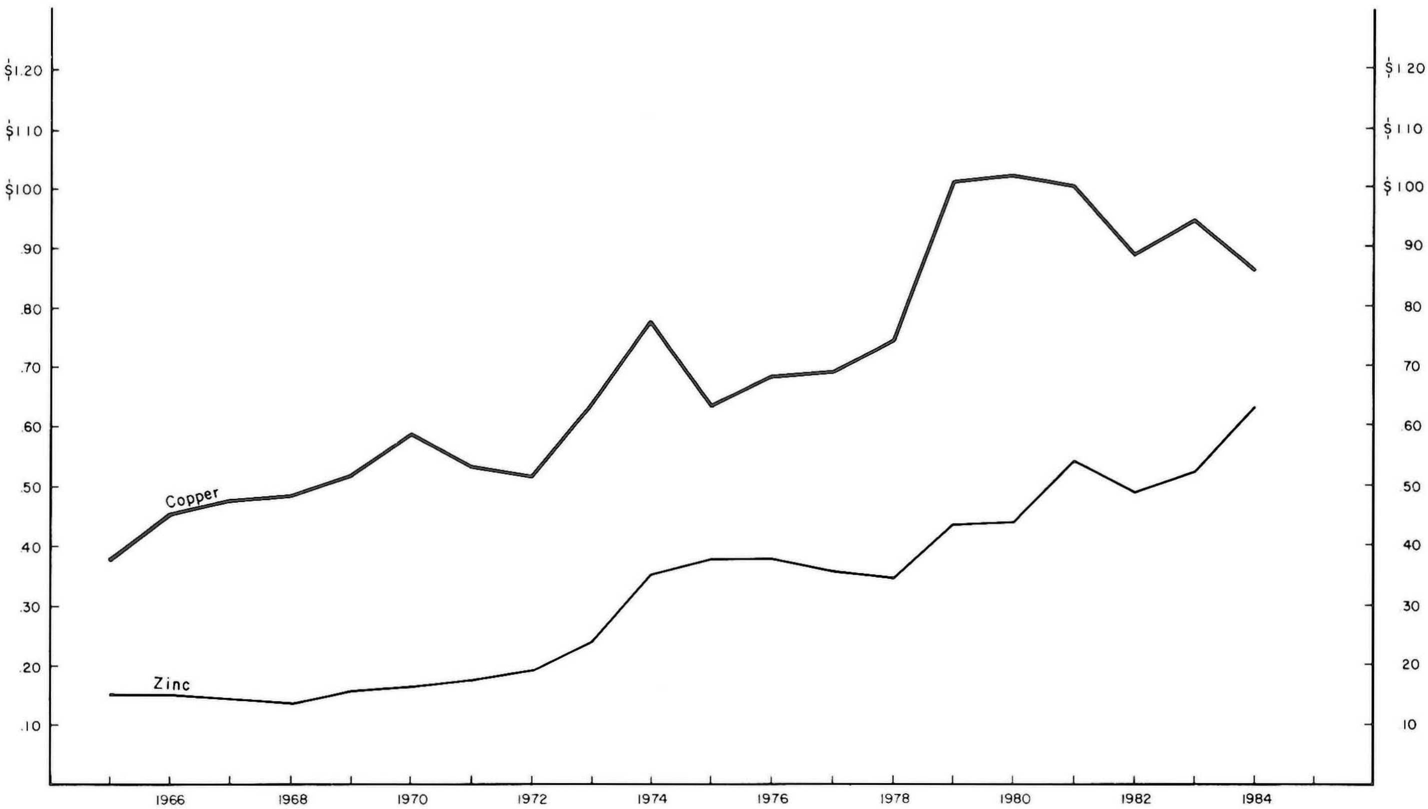


Figure 4.
Average yearly price per pound of copper and zinc, 1965-1984.

(Energy, Mines and Resources, Ottawa)

as 7,000 years B.P. their territory extended to Southern Manitoba where copper artifacts have been found along the Winnipeg, Red, and Assiniboine Rivers and up to Riding Mountain. These Indians appear to have used most of their copper for tools and weapons, rarely for ornaments.

Copper artifacts, as old as 4,000 years B.P., believed to belong to a different Indian group were discovered in 1978 around Caribou Lake in southeastern Manitoba.

Due to the abundance of native copper, North American Indians never needed to discover other sources of the metal. Smelting and casting were unknown. Native copper was shaped into the intended form by cold-hammering and by heating and chilling to keep it from becoming too brittle.

Zinc is not found in its native state. Its use in ancient times, as a component of the alloy brass, probably started accidentally when zinc ore was mixed with copper ore. Brass was extensively used by ancient Greeks and Romans for decorative metal work and for coinage. It was not until the latter part of the 17th century that zinc metal was produced in Europe. In China, however, metallic zinc had been produced by at least the 10th century A.D. and there is a suggestion that zinc was produced even earlier in India or Persia.

History Of Copper-Zinc Mining In Manitoba

Interest in copper and zinc mining in the Province was first aroused in 1915, when a property staked in northern Manitoba on a weathered gossan containing gold values, turned out to be primarily a copper-zinc sulphide deposit. The discoverers named the deposit "Flin Flon" from the first syllables of the last two names of Josiah Flintabbatey Flonatin, the leading character in a novel entitled "The Sunless City". A copy of the book (which tells the story of Flintabbatey Flonatin reaching an imaginary underground gold mine and city) had come into the hands of the prospecting party shortly before the Flin Flon discovery. The deposit is near the Saskatchewan border, with part of it extending into that Province.

That same year the Mandy deposit was discovered 5½ kilometres southeast of Flin Flon. This was a much smaller deposit but it had an exceptionally high grade of 18% copper, with 3 grams of gold and 71 grams of silver per tonne.

Systematic drilling was carried out on the Flin Flon deposit and by the end of 1918, was calculated to contain 15 million tonnes of ore averaging 1.68% copper and 3.49% zinc. At that time the nearest railway was at The Pas, 130 kilometres to the south and the market price for copper was low, so the Flin Flon deposit remained undeveloped for a few years. The Mandy deposit on the other hand was so rich that the ore did not require concentration and could be shipped directly to a smelter at a profit, even though the transportation was lengthy and an unusual affair. The ore was hauled by sleigh 65 kilometres to Sturgeon Landing in winter, and then in summer was barged, 200 kilometres through Namew Lake, Sturgeon-Weir River, Cumberland Lake, Saskatchewan River to The Pas and finally from there, taken by train, to the smelter at Trail, British Columbia. The operation lasted from 1916 to 1919 during which time 22 885 tonnes of ore averaging 20% copper were mined.

The Flin Flon deposit was developed in the late 1920's by the Hudson Bay Mining and Smelting Co., Limited after the railway to the site had been completed. The cost of erecting the hydro-electric power plant 80 kilometres away on the Churchill River, the transmission line and the mine and metallurgical plants amounted to over $25 million in 1930. This was estimated at that time to be one of the most expensive initial mining plants ever established in the history of mining. Production from the Flin Flon mine started at the end of 1930 and at the time of writing, 55 years later, is still continuing from deeper parts of the same deposit up to 1 100 metres below surface. The Flin Flon orebody is the largest known copper-zinc massive sulphide deposit in Manitoba and one of the largest in Canada.

In 1931 the importance of copper and zinc to the development of northern Manitoba was confirmed when Sherritt Gordon Mines, Limited brought the Sherridon mine, 70 kilometres northeast of Flin Flon, into production. Except for a temporary closure between 1932 and 1935 due to a low copper price of 5½¢ per pound, the Sherridon mine operated continuously until 1951 when its orebodies were exhausted.

Between 1948 and 1955 Hudson Bay Mining and Smelting Co. Limited, opened up several small mines in the Flin Flon area, such as Cuprus, Schist Lake, North Star, and Don Jon. In 1960 this company brought Chisel Lake, the first copper-zinc mine in the Snow Lake area, into production, and between 1964 and 1970 developed, in the same area, the Stall Lake, Osborne Lake, Anderson Lake and Dickstone mines.

In 1970, Sherritt Gordon Mines, Limited brought the Fox mine, the first copper-zinc mine in the Lynn Lake area, into production. This was followed, in 1973, by the Ruttan mine.

In recent years Hudson Bay Mining and Smelting Co., Limited has continued to bring new mines into production in the Flin Flon area, including the White Lake mine in 1972, the Centennial mine in 1977, the Westarm mine in 1978, the Trout Lake mine in 1982, and in the Snow Lake area, the Spruce Point mine in 1982 and the Rod No. 2 mine in 1984 (Table 2).

Uses

Industrial demand for copper and zinc, after increasing considerably in recent decades, was somewhat reduced as a result of the world wide recession of 1982 and 1983. Copper and zinc, however, have unique properties which make them indispensable to modern industry and the demand for these two metals is expected to remain high for the foreseeable future.

Inside a drilling rig at Namew Lake.

Copper

The properties which make copper indispensable to modern industry are:

Electrical conductivity — Except for silver, copper is the best conductor of electricity and the international standards of electrical conductivity are based on this metal. Approximately half of all copper consumed is for electrical applications, including power transmission, electronics and electrical equipment.

Thermal conductivity — Copper conducts heat better than any other metal except silver. It is, for instance, about six times as efficient as iron in this respect. It is used whenever heat conductivity is important, such as in automobile radiators, heating or cooling apparatus, cooking vessels and hot water heaters.

Malleability and Ductility — Copper can be rolled into flat sheets less than 0.050 millimetres in thickness or drawn into wire having a uniform thickness of only 0.025 millimetres; one half kilogram of copper is enough to produce over 100 kilometres of such wire.

Workability — Copper lends itself to both cold and hot working, including stamping, swaging, spinning, shearing, forming, bending, drawing and forging. It is readily joined by soldering, brazing and welding.

Durability — Copper and its alloys — brass and bronze are resistant to corrosion and virtually indestructible under normal conditions, providing another reason for the use of copper is automobile radiators. Use of brass and bronze for ships propellers shows the metal's ability to withstand salt water's corrosive action. Copper pipe that carried water to the Egyptian pyramids 5,500 years ago is still in good condition today, so little has the passage of time affected this enduring metal.

Versatility — The most versatile of metals, copper has countless uses ranging from roofing to electrodeposited microcircuits; from the nose cones and vital guidance relays of space rockets to agriculture where copper sulphate is used as a fungicide. Copper is also the predominant metal in hundreds of alloys in commercial use. For example, the addition of less than one per cent of cadmium considerably increases the tensile strength of copper without seriously affecting its conductivity. The addition of 5% of tin is sufficient to double the strength of copper, while the inclusion of a small percentage of beryllium makes it as hard and as strong as highgrade steel. The latter alloy has an exceptional resistance to fatigue with rapidly varying load stresses, and is particularly suitable for the manufacture of springs.

Beauty — Except for gold, copper is the only metal that has natural, warm, glowing colours, a characteristic that it transmits to its alloys. Beauty, strength and durability make copper and its alloys ideal for statues, doorknobs, lamps, pots and pans, fireplace accessories and jewellery. "Solid" 14 karat gold is an alloy of 58 per cent gold and 42 per cent copper.

Zinc

This metal has a wide variety of uses due primarily to its corrosion-resistant property. Its main uses, totalling 80% of the zinc consumption, are in galvanizing, die casting and brass. Other uses include zinc based chemical additives in the making of paints, rubber and pharmaceuticals.

Galvanized iron or steel is iron or steel that has been given a protective coating of zinc by being dipped into molten zinc. Galvanized products are primarily used by the construction, automotive and building industries for roofing, siding, appliance castings, office equipment, decking, heating and ventilation ducts, automobile door panels and underbody parts.

In die casting, zinc is used to make door and window handles, carburetors, pumps, door locks and other mechanical components in automobiles. The automobile industry consumes two thirds of the zinc used in die casts in the United States (the major importer of Canadian zinc).

The manufacturing of brass is the third major area of zinc consumption. Brass is used in applications ranging from decorative hardware to plumbing and heat exchange units. Brass ranges from 5 to 40% zinc by composition.

TABLE 2: PAST & PRESENT COPPER-ZINC MINES IN MANITOBA

Name of Mine	Operator (Abbrev.)	Area	Locality on Figure 1	Operation Starting Date	Closure Date	Tonnages mined out to Dec. 1984 TONNES			Ore Reserves as of Dec. 31, 1984 TONNES			Production in 1984 TONNES		
						Tonnes	%Cu	%Zn	Tonnes	%Cu	%Zn	Tonnes	%Cu	%Zn
Mandy	Tonopah Mining Co.	Flin Flon area	1	1916	1919	22 885	20.18	—						
Flin Flon	H.B.M.&S.[1]	Flin Flon	1	1930		61 069 239[2]	2.19	4.2	1 377 495[2]	1.93	1.0	480 760[2]	1.54	2.0
Sherridon	Sherritt Gordon	70 km NE of Flin Flon	2	1931	1932	7 737 936	2.37	2.00						
Sherridon	Sherritt Gordon	70 km NE of Flin Flon	2	1935	1951									
Mandy	Emergency Metals Ltd.	Flin Flon area	1	1943	1944	102 231	5.63	13.95						
Cuprus	H.B.M.&S.	Flin Flon area	1	1948	1954	462 002	3.24	6.42						
Schist Lake	H.B.M.&S.	Flin Flon area	1	1954	1976	1 877 813	4.21	7.00						
North Star	H.B.M.&S.	Flin Flon area	1	1955	1958	241 643	6.11	—						
Don Jon	H.B.M.&S.	Flin Flon area	1	1955	1957	79 313	3.07	—						
Chisel Lake	H.B.M.&S.	Snow Lake area	3	1960		5 061 059	0.60	10.94	2 238 757	0.32	9.5	190 409	0.42	7.0
Rod No. 1	Stall Lake Mines Ltd.	Snow Lake area	3	1962	1964	22 675	5.00	4.5						
Stall Lake	H.B.M.&S.	Snow Lake area	3	1964		4 158 096	4.29	0.57	2 105 683	4.42	0.3	249 174	4.11	0.5
Osborne Lake	H.B.M.&S.	Snow Lake area	3	1968	1983	2 852 007	3.14	1.52	528 054	2.45	1.28			
Fox	Sherritt Gordon	40 km SW of Lynn Lake	4	1970		11 210 539	1.81	1.77	631 401[3]	N.A.	N.A.	663 152	1.62	2.20
Anderson Lake	H.B.M.&S.	Snow Lake area	3	1970		2 193 546	3.41	0.1	996 055	3.54	0.1	164 691	3.51	0.1

TABLE 2: PAST & PRESENT COPPER-ZINC MINES IN MANITOBA (Cont)

Name of Mine	Operator (Abbrev.)	Area	Locality on Figure 1	Operation Starting Date	Closure Date	Tonnages mined out to Dec. 1984 TONNES			Ore Reserves as of Dec. 31, 1984 TONNES			Production in 1984 TONNES		
						Tonnes	%Cu	%Zn	Tonnes	%Cu	%Zn	Tonnes	%Cu	%Zn
Dickstone	H.B.M.&S	Snow Lake area	5	1970	1975	775 210	2.47	3.13	308 380	2.36	4.0			
White Lake	H.B.M.&S.	Flin Flon area	1	1972	1983	849 598	1.97	4.63						
Ghost Lake & Lost Lake	H.B.M.&S	Snow Lake area	3	1972		478 277	1.34	8.87	127 413	1.02	7.5	40 743	1.13	4.9
Ruttan	Sherritt Gordon	90 km SE of Lynn Lake	6	1973		24 350 440	1.23	1.50	19 321 226	1.46	1.3	1 413 394	1.47	0.91
Centennial	H.B.M.&S.	Flin Flon area	1	1977	1983[4]	1 012 818	1.42	2.31	1 353 113	1.48	2.0			
Westarm	H.B.M.&S.	Flin Flon area	1	1978		1 053 861	3.34	1.25	525 542	3.54	1.8	122 452	3.39	1.1
Spruce Point	H.B.M.&S.	Reed Lake	7	1982		428 774	2.64	3.50	1 164 508	2.24	1.7	169 934	2.69	2.9
Trout Lake	H.B.M.&S.	Flin Flon area	1	1982		1 053 018	2.00	4.36	4 196 413	2.43	5.5	447 461	2.45	3.8
Rod No. 2	H.B.M.&S.	Snow Lake area	3	1984		42 621	6.39	2.2	602 406	6.13	2.9	42 621	6.39	2.2

[1] H.B.M.&S. = Hudson Bay Mining & Smelting Co., Limited
[2] Include the Saskatchewan portion of the Flin Flon deposit
[3] The Fox Mine is scheduled to be closed in late 1985
[4] Production was resumed in 1985

Ore Deposit Types

The average abundance of copper and zinc in the earth's crust has been estimated at 0.007% and 0.008% respectively. The grades of the copper-zinc ores mined in Manitoba in 1984 ranged from 6.39% Cu and 2.2% Zn at the Rod mine to 1.47% Cu and 0.91% Zn at the Ruttan mine and 0.42% Cu and 7.0% Zn at the Chisel Lake mine.

A natural phenomenon is required to mobilize the copper and zinc minerals in the earth's crust and redeposit them in concentrations high enough to be economically mined. Various theories have been advanced over the years to explain the concentration of the metals:

Volcanogenic Deposits — Today it is believed that the volcanic exhalative theory satisfactorily explains the origin of known Manitoba copper-zinc ores. These deposits are bodies of rock containing 50% or more sulphide minerals. Generally the iron sulphides (pyrite and pyrrhotite) are the most abundant; however, in some deposits or in parts of them, chalcopyrite and/or sphalerite may be more abundant than pyrite and pyrrhotite. Small but valuable amounts of gold, silver and locally lead, cadmium, selenium and tellurium are associated with the copper and zinc sulphides. The most common non-metallic minerals found with the "massive sulphides" are quartz, sericite, calcium and iron carbonates, graphite, chlorite and talc.

The **volcanogenic massive sulphide** deposits are associated with thick piles of volcanic rocks or of sedimentary rocks derived from volcanic terrains. They are believed to have formed from the action of fumaroles on the floor of an ancient ocean which, at that time, covered Manitoba. Comparable land based activity can be observed today in hot springs and geysers, e.g. Yellowstone National Park.

Metal-bearing fumarolic exhalations originating within the crust of the earth rose along fractures in the underlying volcanic rocks. Upon reaching the ocean floor, the rapid cooling of the metalliferous solutions resulted in the precipitation of massive sulphides (Figure 5). These were deposited right above the fumaroles or may have been transported by sea currents and deposited a limited distance from the exhalations. Following the deposition of the sulphides, a series of complex geological events brought the sulfide deposits to their present location. These included burial under thick piles of volcanic lavas and sediments, folding, faulting, metamorphism and deep erosion, and took place over a period of millions of years.

It should be noted that although this type of activity was widespread, only a few ocean floor volcanic events produced copper and zinc deposits. The correct temperature and chemical conditions had to be present in order for the deposits to form.

Magmatic and Hydrothermal Deposits in which copper is subordinate to nickel are quite common. Nickel-copper deposits of this type have been mined at Lynn Lake, in the Bird River area in southeastern Manitoba and are being mined in the Thompson area. Potential for additional deposits of this type exists in these areas and in other parts of the province, i.e. at Jackfish Lake north of Reed Lake and northeast of Wekusko Lake in the Snow Lake region. The new Ni-Cu deposits, found by Hudson Bay Exploration and Development Company Limited at Namew Lake (Figure 1) in 1984, appear to belong to this category.

Sedimentary Deposits — Copper showings associated with rocks of sedimentary origin have been found and studied in recent years at Kadeniuk Lake, 50 kilometres south of Lynn Lake. Further investigations in the area have failed, so far, to produce any promising results.

Porphyry Copper Deposits — This type of environment, in which the sulphides (mainly pyrite and chalcopyrite) are finely disseminated in granitic rocks, has been recognized in Manitoba in recent years. Large deposits of this type are known in British Columbia; in Manitoba, however, results of exploration have not been very encouraging.

Paleozoic Limestones — These are thick sequences of sedimentary rocks mainly consisting of calcium and magnesium carbonates and shales overlying the Precambrian (Figure 1). In other parts of Canada, important zinc-lead and copper deposits have been found in similar rock types. Investigations carried out in Manitoba on this type of environment have so far been limited.

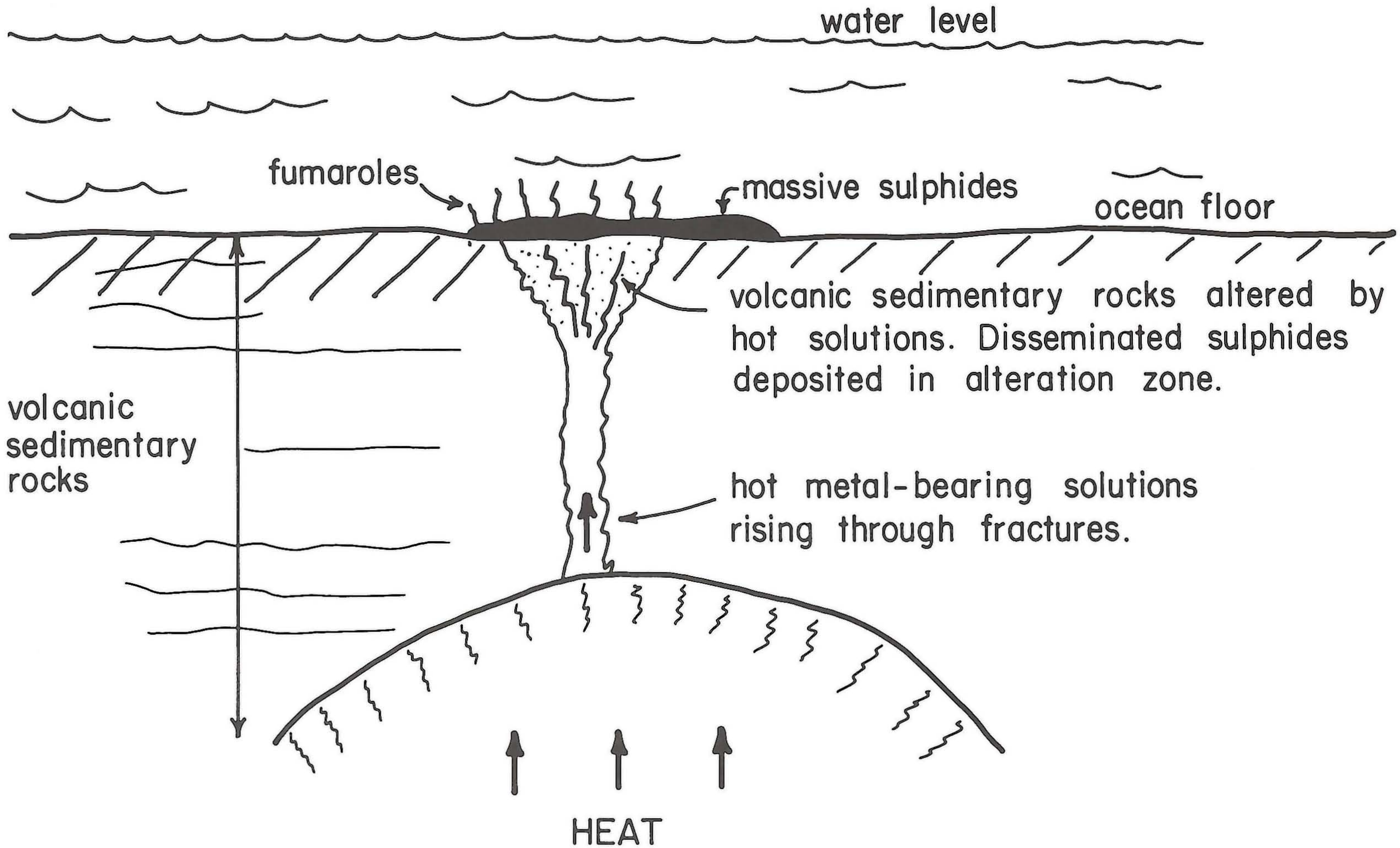


Figure 5.
Simplified diagram showing formation of a volcanogenic massive sulphide deposit by metal-bearing fumaroles.

Exploration For Copper-Zinc Deposits

The massive sulphide deposits in Manitoba occur in a wide variety of shapes but generally appear as flattened lenses or groups of lenses, parallel with the local rock strata. Precambrian rocks and associated sulphide deposits may be upturned and steeply dipping. If exposed at the surface a deposit will look like a vein with a width varying from a few metres to a few tens of metres and with a length extending up to several hundred metres.

Most sulphide deposits, however, do not outcrop because they are either covered by overburden (sand, gravel, clay, top soil), by water (lakes, rivers) or else they pinch out within the host rock before reaching surface. To discover these buried deposits the mining industry has developed a series of geophysical and geochemical survey methods based on the electrical, magnetic and chemical properties of the sulphides.

Using geophysical methods, an exploration company will try to locate buried conductors normally down to a depth of 150 metres. In contrast to their host rocks which usually do not conduct electricity, chalcopyrite is an excellent conductor and sphalerite, although a poor conductor when pure, is generally associated with other conductive sulphides. Unfortunately, other geological features such as uneconomic iron sulphides, graphite, fault zones and water seams in overburden are also conductive and occur far more frequently than the copper and zinc sulphides. Therefore, a conductor does not necessarily indicate a copper-zinc deposit.

Geophysical anomalies are normally interpreted by a geophysicist and only the favourable ones are selected for further testing by diamond drilling. Drilling is necessary to find the real nature of a buried conductor. A drill hole in fact will provide a continuous core sample from surface down to a depth of 100-200 metres across the conductor (Figure 6).

The ratio between anomalies drilled and a successful hole intersecting economic sulphides has been estimated in the Canadian Shield at 700:1. Drilling costs, currently running at approximately $80/metre, form the most expensive component of an exploration program. The average cost of finding a mine has been estimated at between 20 and 40 million dollars.

Treatment Of An Orebody

Mining

After the initial discovery of a deposit, a great number of holes will have to be drilled to define its shape, size and grade, and ascertain a minimum tonnage of ore. This information forms the basis for a feasibility study, which will enable the company to decide whether or not it is economically viable to develop the deposit to the production stage.

Development for production involves a considerable outlay of capital before any income is generated. An access road, hydroelectric power to the property, site clearing, a shaft head frame, a hoist to operate the shaft cages and skips, a crusher, a concentrator, an office, and then a shaft and an underground system of tunnels (drifts, cross-cuts, raises, ore passes, etc.) all have to be completed before production begins.

The upper portions of the Flin Flon and the Ruttan deposits were large enough to be economically mined by open pit down to approximate depths of 100 and 200 metres respectively. Shafts were later sunk at both localities to mine the deeper portion of the ore from underground. Open pit mining becomes too expensive below a certain depth and it normally is uneconomic if the orebody is too narrow. Most Manitoba copper-zinc deposits are not suited for open pit mining and all present Cu-Zn mining is carried out underground.

In a typical mine (Figure 7) the ore is broken at various levels with dynamite charges, then loaded into cars, hauled underground to the main ore pass and dumped. The ore collected at the bottom of the ore pass is sent through a primary crusher. It is then hoisted to the surface where it goes through a secondary crushing operation before entering the concentrator.

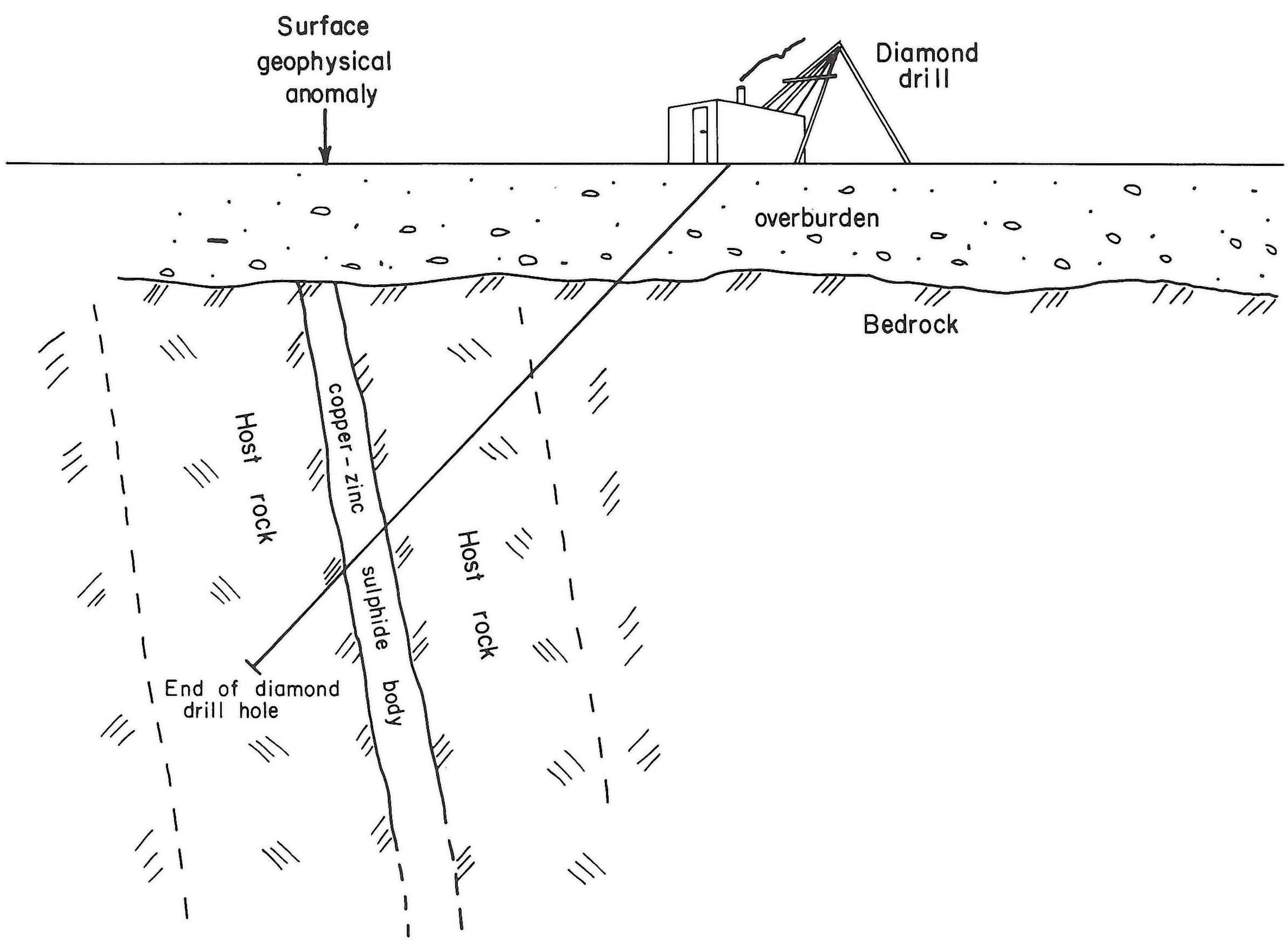


Figure 6.
Diamond drill hole testing of a geophysical anomaly caused by a sulphide body.

Plate 4.
Ruttan open pit.

(Sherritt Gordon Mines Limited)

Milling

The ore extracted from a mine contains comparatively little copper and/or zinc. It must be concentrated and processed to obtain the pure metal.

Concentrators, also referred to as mills, are usually built as close as possible to the mines to avoid costly transportation of ore material which averages over 90% waste. The ore fed into the mill, is ground to a very fine powder and mixed into a water slurry. The valuable sulphides are separated from the waste by the froth flotation process. Organic compounds are added to the water slurry causing differences in surface properties of the fine particles. Some are entirely coated by water while others are not. Air bubbled through the slurry sticks to the selected sulphide particles and makes them float. Froths containing either copper or zinc sulphide plus other valuable elements are successively removed into different concentrates. A lead concentrate is also produced from the ore of the Chisel Lake and Ghost Lake mines and is shipped to Trail, B.C. for processing.

The ore from the Snow Lake area, previously milled in Flin Flon, is now treated in the Snow Lake concentrator, officially opened in June 1979. Other copper-zinc concentrators are located at the Fox and the Ruttan mines in the Lynn Lake area.

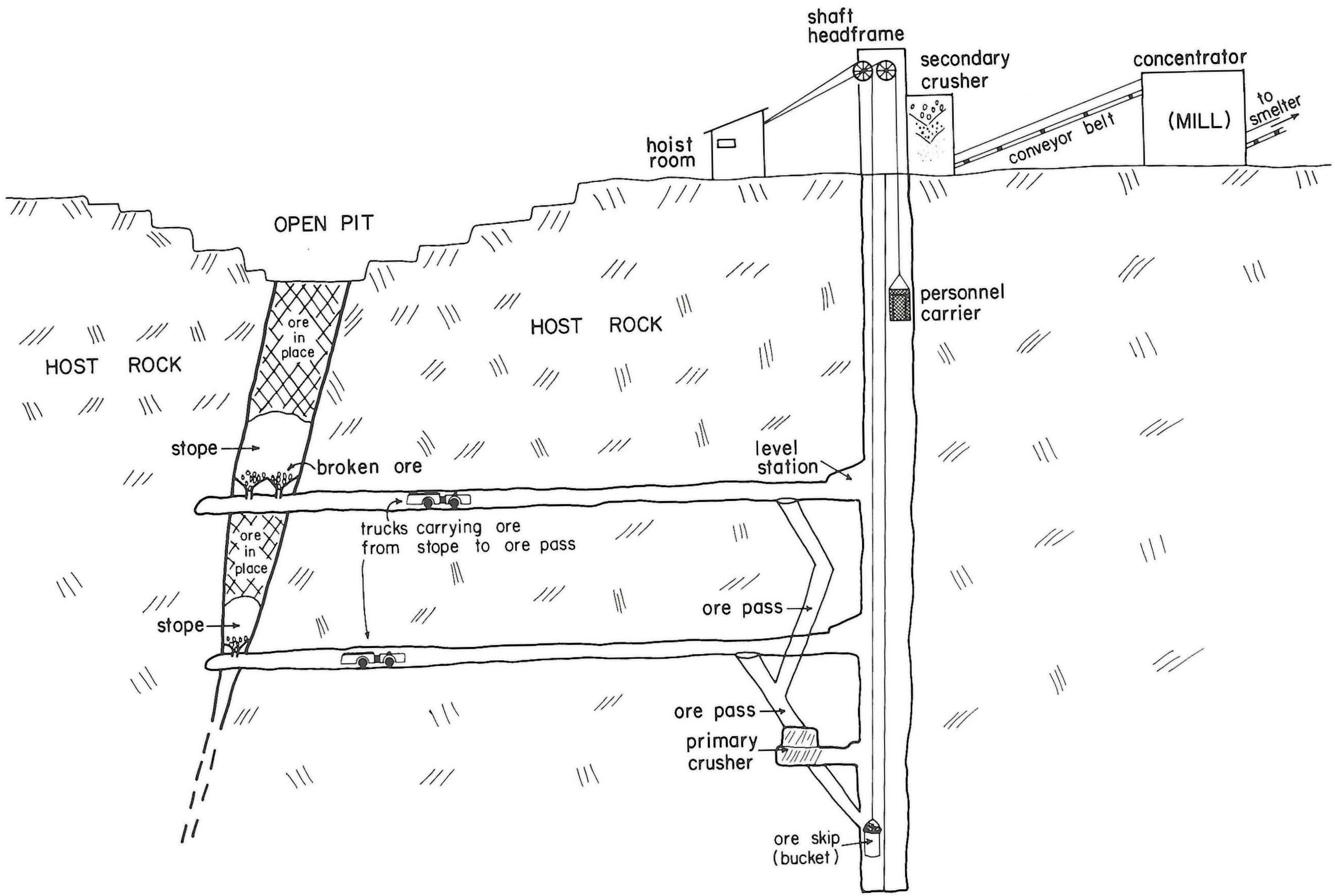


Figure 7.
Simplified section of a typical mine.

Smelting – Refining

The copper concentrate is blended with silica sand and melted in a furnace at temperatures above 1 000°C. Two products are obtained. The heavier one is referred to as matte and contains copper, gold, silver, selenium and tellurium, along with some iron and sulphur. The lighter one is referred to as slag and contains some zinc, iron and silica. The copper matte is purified and then shipped to a refinery in eastern Canada where pure copper, gold, silver, selenium and tellurium are recovered. The zinc-bearing slag is processed and sent to the zinc refinery at Flin Flon for recovery of the metal. The zinc concentrate is roasted and then treated with chemicals to dissolve the zinc and the associated cadmium. An electrolytic process is used to recover these two metals which are then melted, cast into convenient shapes and shipped out of the province for use in the fabricating industry.

The only copper smelter-zinc refinery complex in Manitoba is located in Flin Flon and is operated by the Hudson Bay Mining and Smelting Co., Limited. It processes all the copper and zinc concentrates from the Flin Flon-Snow Lake mines and most of the concentrates from the Fox and Ruttan mines of Sherritt Gordon Mines Limited. Some of the copper concentrate from the Ruttan mine and the copper concentrate produced in Thompson as a by-product of the nickel mines are shipped outside of Manitoba for further treatment.

Environmental Control

Contrary to what may have happened in the past, the control and the preservation of the natural environment are today a major concern for mining companies and various levels of governments.

Starting from the exploration camps, strict control is kept to avoid any unnecessary damage to nature, with tree cutting kept to a minimum and garbage either buried or brought back to town. New mining towns like Leaf Rapids are built in such a way as to preserve as much as possible of the natural bush and provide a natural setting and more pleasant living conditions. Efforts are made to build new mining structures away from highways or major lakes in order not to interfere with the natural landscape. Solid waste material from mining operations is normally used for back-filling mined out stopes or for other filling jobs such as the construction of road beds. Liquid waste from various plants is purified to minimize the effect on water life in surrounding bodies of water. A new flue system, including a 250 metre smoke stack, was completed by Hudson Bay Mining and Smelting Co., Limited in 1974 to alleviate the effects of fumes from the smelting and roasting plant in the Flin Flon area.

Problems still exist in the amount of sulphur dioxide (SO_2), a major environmental contaminant and cause of acid rain, emitted by smelters. The provincial and federal governments and industry are studying various options, including the use of electricity, to reduce or eliminate SO_2 emissions.

These examples and many other efforts made in recent years tend to indicate that a modern mining industry in Manitoba can well be compatible with the natural environment and with other northern industries, i.e. tourism, fishing, trapping, lumbering and particularly with pleasant human living conditions.

Conclusion

Several northern Manitoba communities are thriving on copper and zinc mines. If these mines were to close down, towns like Flin Flon, Snow Lake, Lynn Lake and Leaf Rapids would probably undergo considerable depopulation similar to that experienced by Sherridon in 1951 when the mining operations there shut down. As of 1984 Manitoba's copper and zinc ore reserves are estimated to be sufficient to maintain current mining production for less than 10 years under favourable economic conditions. To extend this projected life and to maintain a healthy mining industry in the province, new deposits must be discovered and developed.

Exploration for copper and zinc is mainly centered in the Flin Flon-Snow Lake and Lynn Lake Belts and on similar volcanic belts in other parts of the Province. It should be kept in mind, however, that different types of rock environments do exist which may have potential for copper and zinc deposits.

In the last ten years over $170 million have been spent in Manitoba by companies exploring for copper and zinc deposits with the hope of opening up new mines or extending the life of the existing ones. With new ideas and improved exploration techniques new regions are being explored all the time, although traditional areas continue to attract the major interest.

In 1984 the governments of Manitoba and Canada signed a five year, $24.7 million agreement designed to stimulate mineral development in the Province. The agreement includes studies on mineral deposits, mines safety, and mining and minerals processing technology. These studies are aimed at helping industry focus exploration programs upon areas with high potential and at increasing mine productivity while protecting workers and the environment.

The potential for finding new copper-zinc deposits in Manitoba is high and with a favourable economic environment the mineral industry in the Province should be heading for many bright years ahead.

Manitoba Energy And Mines

Manitoba Energy and Mines is continually working to increase our understanding of Manitoba's geology and its mineral resource base. Energy and Mines fieldworkers and analysts, working with private industry and their federal counterparts, have amassed a wealth of technical reports. More detailed information on copper and zinc in Manitoba can be obtained by contacting:

Exploration Services
Manitoba Energy and Mines
555-330 Graham Ave.
Winnipeg, Manitoba R3C 4E3
(204) 945-6541

TABLE 3: IMPORTANT COPPER-ZINC DEPOSITS FOUND FROM 1970 TO 1985

Name of Deposit	Company (Abbrev.)	Area	Locality on Figure 1	Tonnage Reported TONNES	%Cu	%Zn	Year of Discovery	Status
Centennial	H.B.M.&S.[1]	Baker's Narrows	1	see Table 2			1970	in production
Barrington	H.B.M.&S.	East of Lynn Lake	8	111 040	2.63	—	1972	undeveloped
Westarm	H.B.M.&S.	Schist Lake	1	see Table 2			1973	in production
Spruce Point	Freeport Can. Expl. – H.B.M.&S.	Reed Lake	7	see Table 2			1973	in production
Farewell Lake	M.M.R.[2]	SE of Reed Lake	9	256 681	2.03	—	1974	undeveloped
Lost Lake	H.B.M.&S.	Snow Lake	3	reserves included in Ghost Lake Mine's			1974	in production through Ghost Lake Mine
Trout Lake	Granges Expl. – H.B.M.&S.	Flin Flon	1	see Table 2			1975	in production
Frances Lake	Granges Expl. – M.M.R.-Sherritt Gordon	Lynn Lake	10	281 000	0.6	7.1	1976	undeveloped
Sylvia Zone	M.M.R. – H.B.M.&S.	SE of Reed Lake	9	907 185	2.4	0.8	1977	undeveloped
Namew Lake	H.B.M.&S.	60 km S of Flin Flon	20	2 340 000	0.9	2.44% Ni	1984	under development
Callinan	H.B.M.&S. – Consolidated Callinan Flin Flon Mines	Flin Flon	1	1 542 000[3]	1.41	4.0	1984	Underground drilling in progress
Morgan Lake	Granges Expl.	SW of Snow Lake	3	High zinc values reported			1985	exploration stage

[1] H.B.M.&S. = Hudson Bay Mining & Smelting Co., Limited

[2] M.M.R. = Manitoba Mineral Resource Ltd.

[3] 45% of this tonnage is in Saskatchewan

TABLE 4: IMPORTANT COPPER-ZINC DEPOSITS FOUND BEFORE 1970 AND UNDEVELOPED AS OF DECEMBER 31, 1985

Name of Deposit	(Company (Abbrev.)	Area	Locality on Figure 1	Tonnage Reported TONNES	%Cu	%Zn	Date of Discovery
Copper-Man	Falconbridge	S of Wekusko Lake	11	221 308	2.63	4.46	1928
Bob Lake	Sherritt Gordon	Sherridon	2	2 158 660	1.33	1.18	1941
Hyers Island	W.B. Dunlop	Oxford Lake	12	317 450	2.5	—	1943
Sherlynn (Goodenough)	Sherlynn Mines	Lynn Lake	10	165 074	2.63	1.21	1947
"FL" Group (Gods Lake zone)	Granges Expl. – MMR[1] – Sherritt Gordon	Lynn Lake	10	453 500	0.9	2.2	1947
"Z"	Sherritt Gordon	Lynn Lake	10	138 771	1.11	2.49	1947
Vamp Lake	H.B.M.&S.[2]	Vamp Lake	13	421 840	1.66	2.2	1950
Rail Lake	H.B.M.&S.	NW of Reed Lake	5	294 775	3.0	0.7	1958
Jungle	H.B.M.&S.	Sherridon	2	3 355 900	1.42	1.1	1958
MacBride Lake	Knobby Lake Mines	MacBride Lake	14	484 338	0.35	8.77	1958
Wim	H.B.M.&S.	N of Snow Lake	15	988 630	2.91	—	1962
Pinebay	Pinebay Mines	Sourdough Bay	1	1 360 500	1.3	—	1967
Reed Lake	H.B.M.&S.	Reed Lake	7	1 035 794	2.18	—	1969

[1] M.M.R. = Manitoba Mineral Resources Ltd.
[2] H.B.M.&S. = Hudson Bay Mining & Smelting Co., Limited

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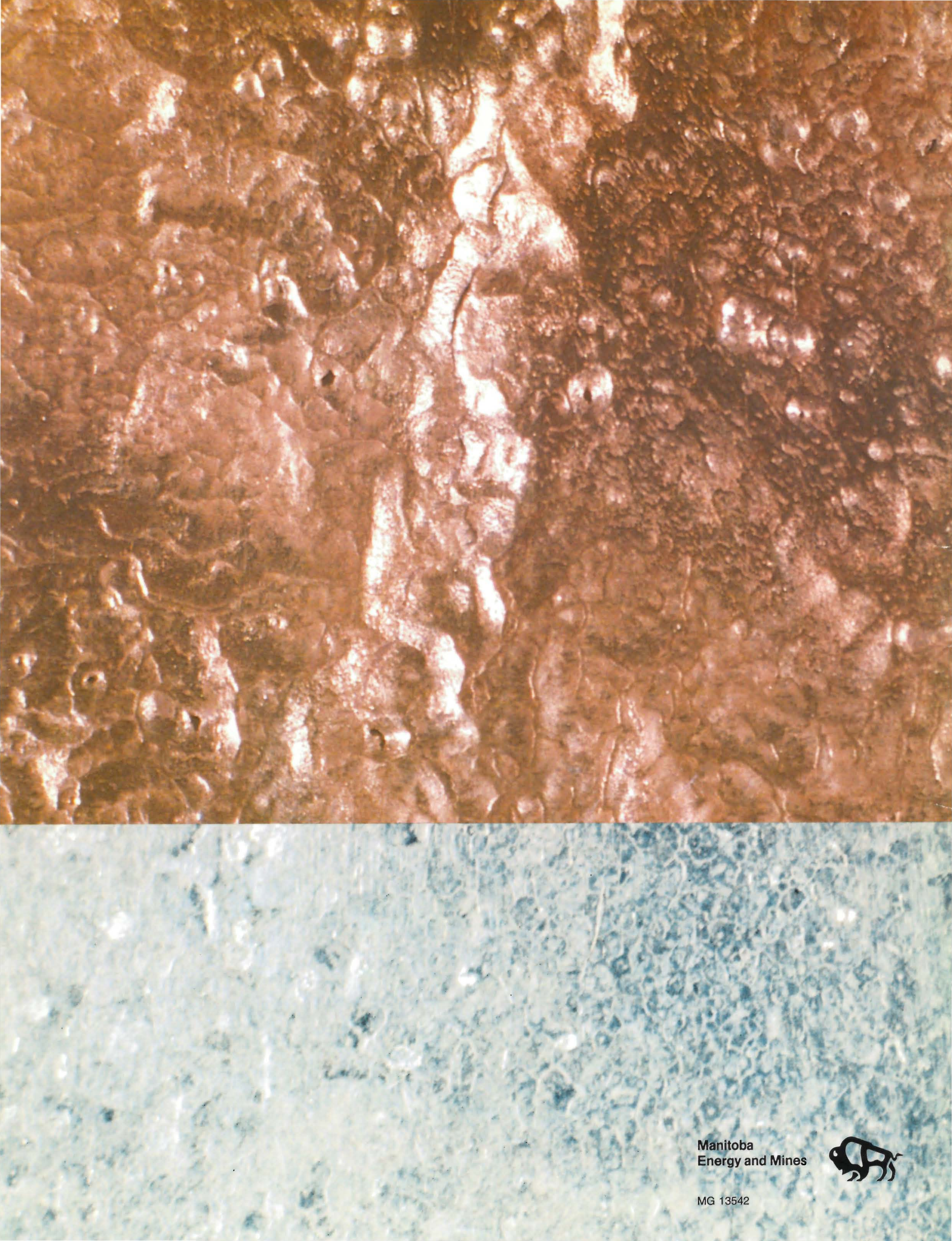

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