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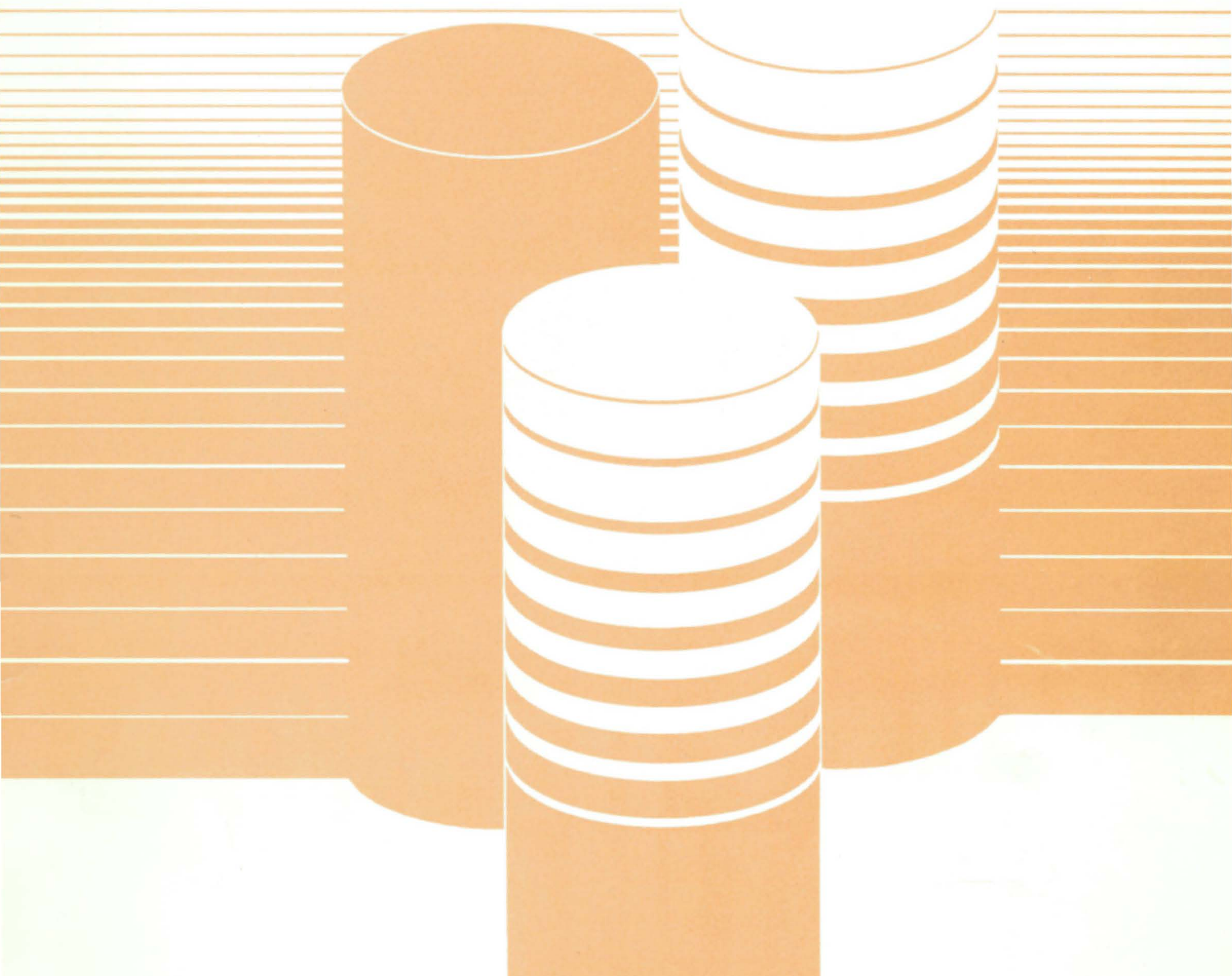
COPPER & ZINC IN MANITOBA

by B. Esposito



Manitoba
Energy and Mines

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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 free state, 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 the many uses it has in industry.

Zinc (Zn) is a silvery-bluish coloured metal which is very lustrous when freshly cut but which becomes dull rapidly on exposure 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 ores of zinc include sphalerite or zincblende, calamine, willemite 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 from the nickel mines in the Thompson area.

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.; and therefore, 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, where the copper and zinc metals are

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	79% Cu	2.5-3	Blackish lead-grey
malachite	$CuCO_3Cu(OH)_2$	71% CuO	3.5-4	Bright green
sphalerite	ZnS	65% Zn	3.5-4	Brown, black or yellow
calamine	$ZnCO_3$	63% Zn	4-4.5	White to dark grey, greenish, bluish, yellow, brown
zincite	ZnO	80% Zn	4	Deep red or orange-yellow

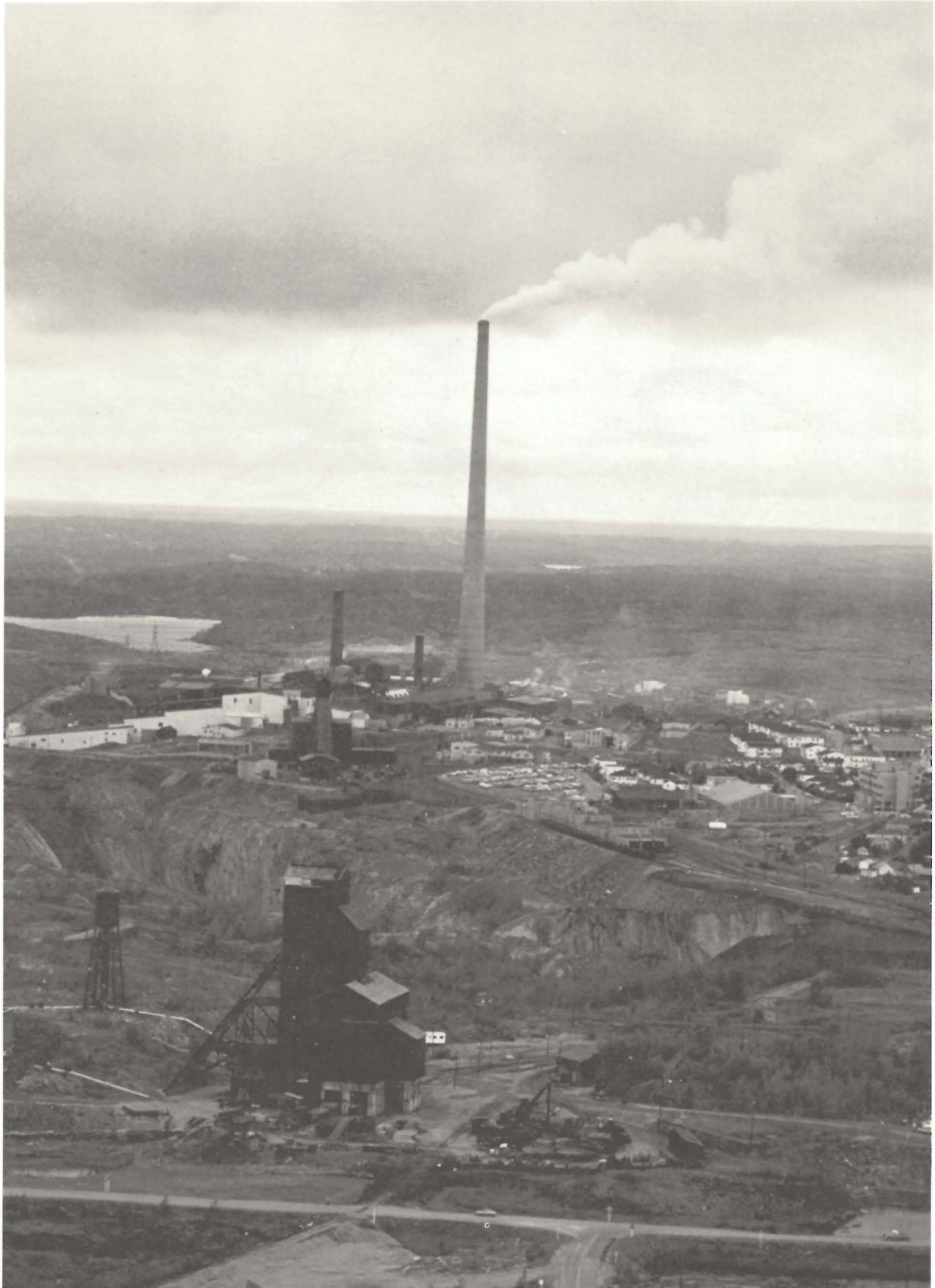

Plate 1. H.B.M. & S mining and metallurgical complex at Flin Flon. (Published with the permission of the Canadian Mining Journal)

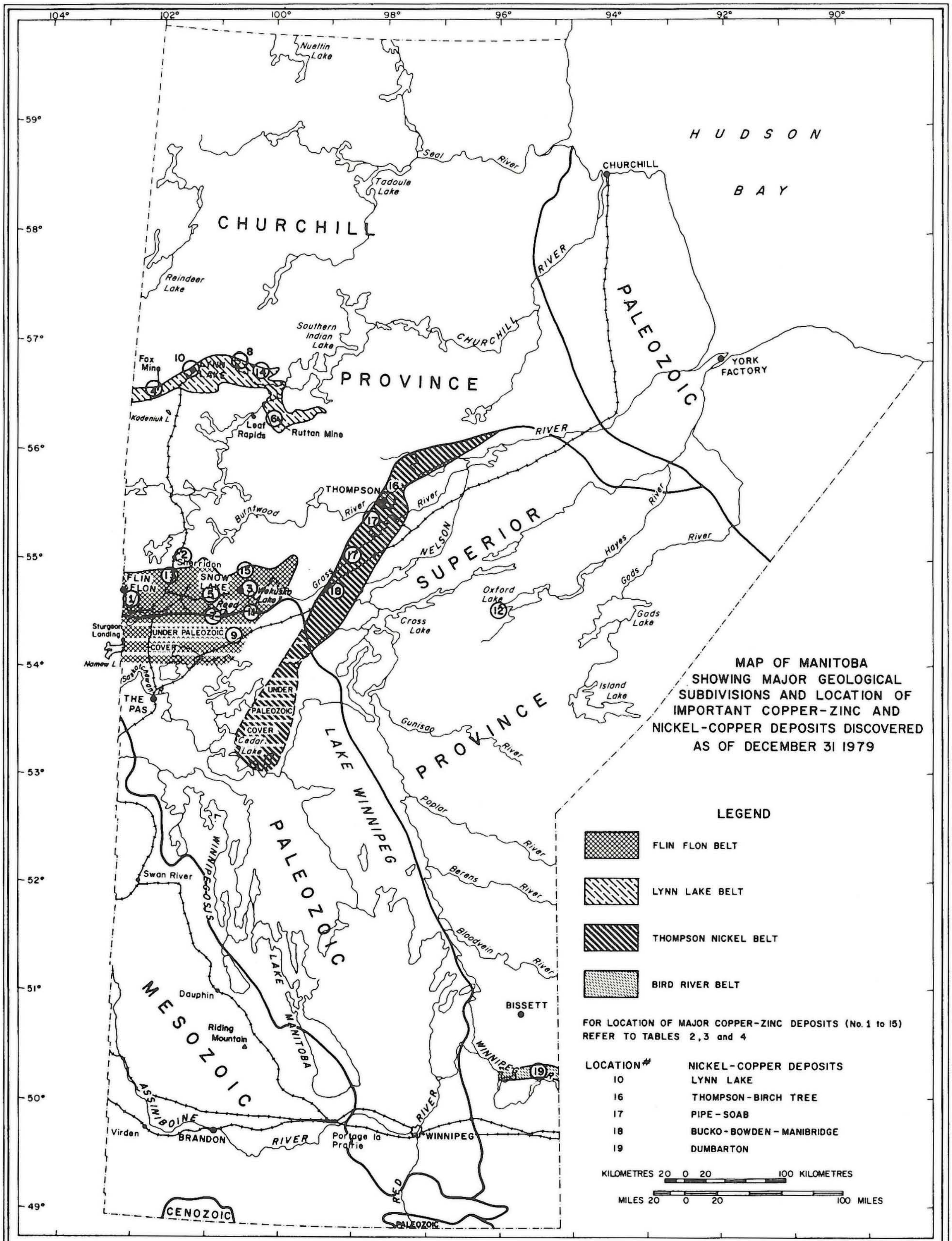

Figure 1. Map of Manitoba showing major geological subdivisions and location of important copper-zinc and nickel-copper deposits.

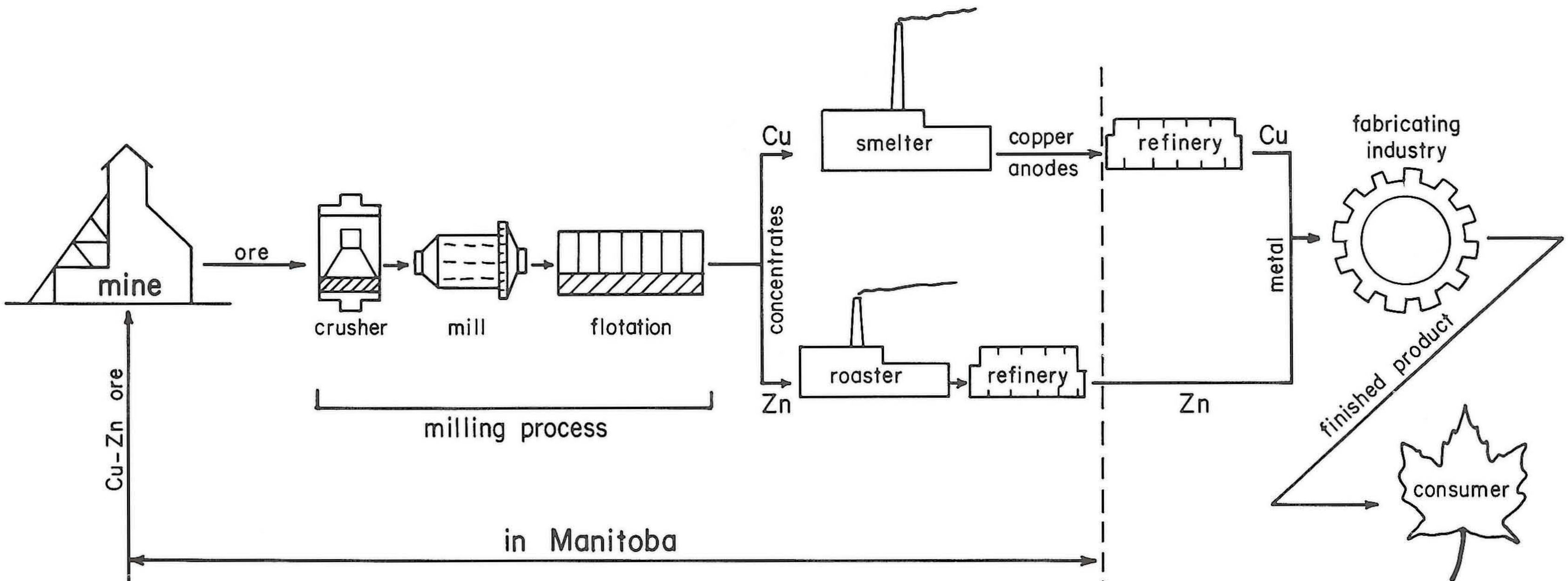

Figure 2. Flow diagram showing movement of copper-zinc ore from mine to customer.

separated from the sulphides, is done in the copper smelter and zinc refinery plant, such as the one in Flin Flon (Plate 1). 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, Lynn Lake and Leaf Rapids. Yearly production of copper and zinc in Manitoba is shown in Figure 3. In 1977, production of 60 000 tonnes* of copper and 61 500 tonnes of zinc was valued at $92 million and $48 million respectively. In order to maintain and further develop this valuable industry, which in 1977 directly employed over 3 000 persons, new ore deposits have to be found to replace depleted ones.

Exploration for new deposits is carried out by several companies in various parts of the province, but mostly in the Precambrian Shield and particularly in the Flin Flon and Lynn Lake Belts (Figure 1), which so far appears to have the highest potential for copper and zinc deposits.

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 2500 million years) while rocks of the Churchill Province are mainly of Proterozoic age (2500 to about 1700 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 1800 million years (Sangster, 1978).

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 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 to approximately 0.3% in the Bird River area, in southeastern Manitoba, to slightly over 0.5% in the Lynn Lake nickel deposits. Known economic nickel deposits of the Bird River and Lynn Lake areas have been depleted.

Bamburak (1977) has compiled a list of the important mineral properties of Manitoba with locations, ownerships, tonnages and grades, where available, while Phillips (1979) describes 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 Geoscience Data Section, Mineral Resources Division, Winnipeg, or at the Mining Recorder's office, The Pas.

HISTORY AND USES 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 it was, together with gold and silver, one of the first metals used by man. Traces of copper workings, dating back as far as 7000 years B.P.* have been found at a number of places in Eastern Mediterranean countries, Mesopotamia and in North America. Attracted by the bright and pleasing appearance of copper, man 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 there were three main stages in the development of the usage of copper. 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 from, 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 copper in this region, and perhaps in the whole world. They lived as early as 7000 years B.P. and 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

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

*Before present

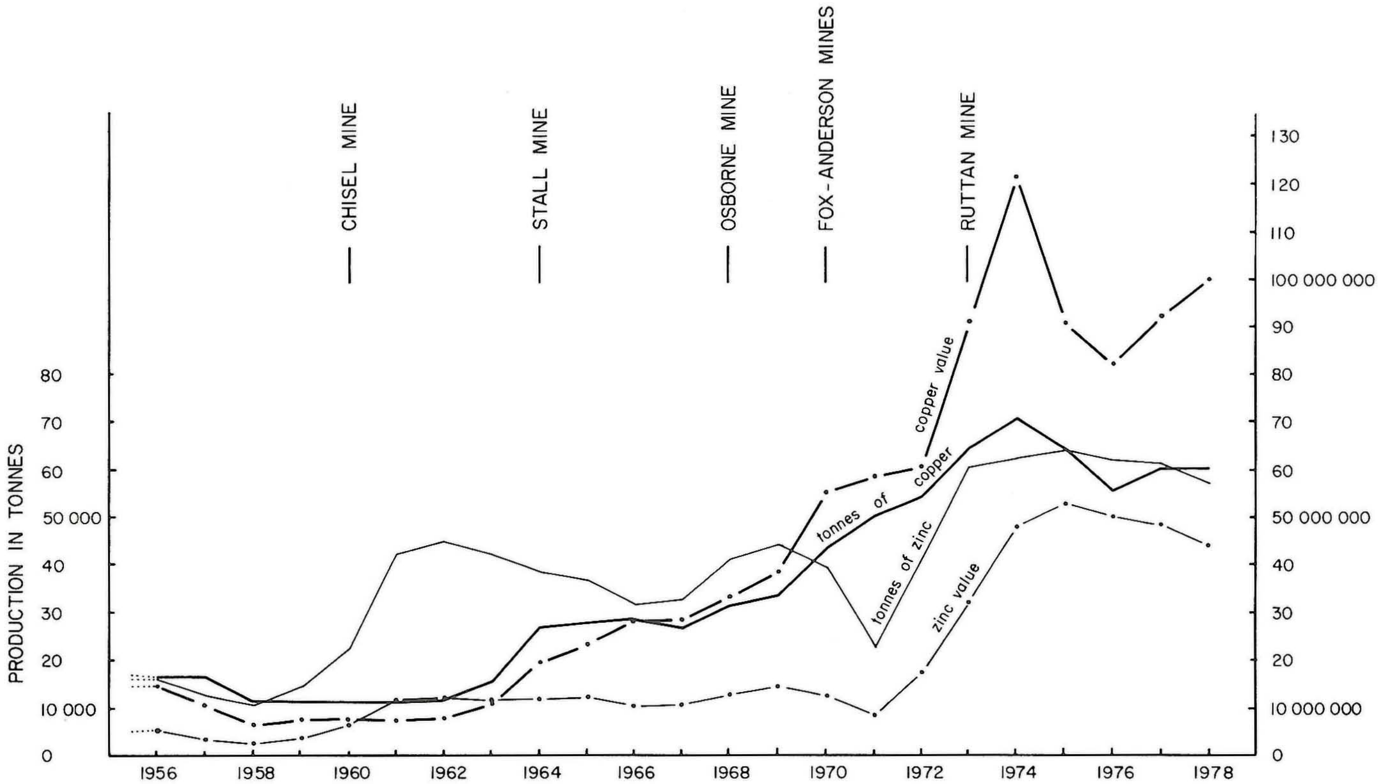

Figure 3. Manitoba copper and zinc production — 1956-1978. Data obtained from Statistics Canada, Department of Energy, Mines and Resources, Ottawa.

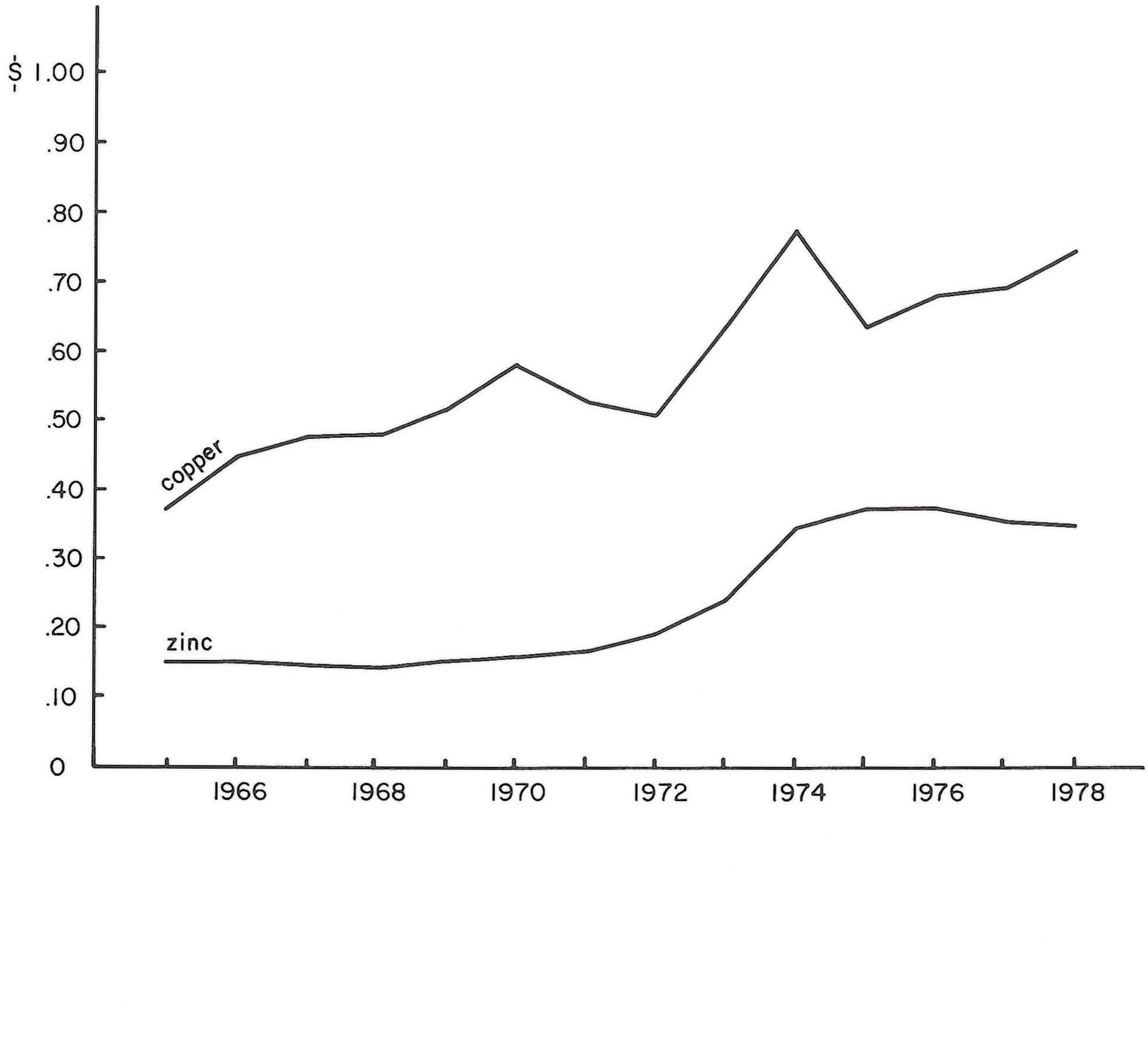

Figure 4. Average yearly price per pound of copper and zinc from 1965 to 1978.
Data obtained from Statistics Canada, Department of Energy, Mines and Resources, Ottawa.

most of their copper for tools and weapons, rarely for ornaments.

Copper artifacts, as old as 4000 years B.P., believed to belong to a different Indian group were discovered in 1978 around Caribou Lake in southeastern Manitoba*.

Probably due to the abundance of native copper, North American Indians never had the desire to discover other sources of the metal. Smelting and casting were unknown. The native copper was shaped into the intended form by cold-hammering and annealing-pounding, 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. Zinc metal was eventually separated in the latter part of the 17th century.

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; in fact, part of it extends into that Province.

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

The Flin Flon deposit was systematically drilled 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 km 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 km to Sturgeon Landing in winter, and then in summer was barged, 200 km 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 km 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 greatest 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, 49 years later, is still continuing from deeper parts of the same deposit up to 1100 m 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 well established when Sherritt Gordon Mines, Limited brought the Sherridon mine, 70 km northeast of Flin Flon, into production. Except for a temporary closure between 1932 and 1935 due to a low copper price of 5½¢ per lb, the Sherridon mine operated continuously until 1951 when its orebodies were exhausted.

Between 1948 and 1955 a few small mines such as Cuprus, Schist Lake, North Star, and Don Jon were opened up by Hudson Bay Mining and Smelting Co., Limited in the Flin Flon area. In 1960 this company brought Chisel Lake, the first 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 three new mines have been opened in the Flin Flon area by Hudson Bay Mining and Smelting Co., Limited, the White Lake mine in 1972, the Centennial mine in 1977 and the Westarm mine in 1978 (Table 2).

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*Prof. J. Steinbring, Univ. of Winnipeg, personal communication.

For more information on mining in our Province, the reader is referred to the educational pamphlet "Mining in Manitoba" by R. Zahalan (in prep.)

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. 1978 TONNES			Ore Reserves TONNES			Production in 1978[1] 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.	Flin Flon	1	1930		57 504 690[2]	2.26	4.30	851 025[3]	2.50	2.5	543 002[2]	1.67	2.28
Sherridon	Sherritt Gordon	70 km NE of Flin Flon	2	1931	1932	7 737 936	2.37	2.00[4]						
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		3 955 501	0.64	11.47	2 287 998[3]	0.34	10.7	212 675	0.75	11.26
Rod	Stall Lake Mines Ltd.	Snow Lake area	3	1962	1964	22 675[5]	5.00	4.5	610 085[6]	5.38	2.28			
Stall Lake	H.B.M.&S.	Snow Lake area	3	1964		2 735 266	4.33	0.61	3 563 240[3]	4.43	0.5	260 966	4.65	0.28
Osborne Lake	H.B.M.&S.	Snow Lake area	3	1968		2 148 430	3.41	1.69	1 048 492[3]	3.27	1.3	224 475	2.53	1.65
Fox	Sherritt Gordon	40 km SW of Lynn Lake	4	1970		7 275 047	1.96	1.74	5 744 031[1]	1.79	2.22	874 348	1.31	1.79
Anderson Lake	H.B.M.&S.	Snow Lake area	3	1970		1 391 716	3.39	—	1 756 768[3]	3.76	0.1	21 201	3.18	0.10

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. 1978 TONNES			Ore Reserves TONNES			Production in 1978[1] 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[1]	2.36	4.0			
White Lake	H.B.M.&S.	Flin Flon area	1	1972		563 207	2.07	4.58	182 579[3]	1.88	5.1	118 179	1.92	4.99
Ghost Lake	H.B.M.&S.	Snow Lake	3	1972		287 172	1.69	10.80	274 730[3]	1.08	6.4	4 149	0.36	6.39
Ruttan	Sherritt Gordon	90 km SE of Lynn Lake	6	1973		14 748 993	1.08	1.84	26 095 297[1]	1.79	1.20	2 306 501	1.17	1.57
Centennial	H.B.M.&S.	Flin Flon area	1	1977		392 380	1.46	2.32	1 492 741[3]	1.65	2.6	185 657	1.42	2.30
Westarm	H.B.M.&S.	Flin Flon area	1	1978		183 545	3.52	1.64	1 155 699[3]	4.04	1.8	108 728	3.57	1.78

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

[1]Data obtained from Companies Annual Reports — Ore reserves as of December 31, 1978

[2]Includes the Saskatchewan portion of the Flin Flon Deposit

[3]Ore reserves as of January 1, 1978 (Cranstone, 1979)

[4]Estimated

[5]No. 1 ore zone — Depleted

[6]No. 2 ore zone — Under the terms of an agreement with Stall Lake Mines Ltd. H.B.M.&S. will bring this deposit into production in 1982

Today, 11 copper-zinc mines operate in Manitoba and the Spruce Point deposit, 40 km southwest of Snow Lake, is being developed for production by Hudson Bay Mining and Smelting Co., Limited.

Uses

The great increase in the production of copper during recent decades is a striking testimony to the ever increasing demands for the metal from all quarters. 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; hence its use in automobile radiators, heating or cooling apparatus, cooking vessels, hot water heaters and wherever heat conductivity is important.

Malleability and Ductility — Copper can be rolled into flat sheets less than 0.050 mm in thickness or drawn into wire having a uniform thickness of only 0.025 mm; one half kilogram of copper is sufficient for the production of over 100 km 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. This quality provides another reason for the use of copper in 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 5500 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 in the spraying of vines. 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 but does not seriously affect 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 strong as high-grade steel. The latter alloy has an exceptional resistance to fatigue with rapidly varying load stresses, and is therefore, 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 does not have such a lustrous pedigree as copper. It has however 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 chemical additives in the making of paints, rubber and pharmaceuticals.

Galvanized iron or steel is iron or steel that has been dipped into molten zinc thereby receiving a protective coating of 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. Two thirds of the zinc used in die casts in the United States (the major importer of Canadian zinc) is consumed by the automobile industry.

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.

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 (Fyfe, 1974). The grades of the copper-zinc ores mined in Manitoba in 1978 ranged from 4.65% Cu and 0.28% Zn at the Stall Lake Mine to 1.17% Cu and 1.57% Zn at the Ruttan Mine and 0.75% Cu and 11.26% Zn at the Chisel Lake Mine. A natural phenomenon is therefore 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 (Sangster, 1972). 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. Analogous 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 have been 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 including burial under thick piles of volcanic lavas and sediments, folding, faulting, metamorphism and deep erosion, took place over a period of millions of years and brought the sulphide deposits to their present situation.

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 occur in basic intrusive rocks, where copper is generally subordinate to nickel. Nickel-copper deposits of this type have been mined at Lynn Lake (Pinsent, 1977), in the Bird River area in southeastern Manitoba (Theyer, 1977) 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.

Sedimentary Deposits — Copper showings associated with rocks of sedimentary origin have been found and studied in recent years at Kadeniuk Lake, 50 km south of Lynn Lake (Baldwin, 1976). Although little is known about this type of deposit in Manitoba, the above findings are interesting and do merit further investigation.

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 (Elbers, 1976, Baldwin, 1977). 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 so far in Manitoba by private companies and the Government have been limited.

EXPLORATION FOR COPPER-ZINC DEPOSITS

The massive sulphide deposits in Manitoba occur in a wide variety of shapes but generally as flattened lenses or groups of lenses, concordant with the local stratigraphy. 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 a length extending up to several hundred metres.

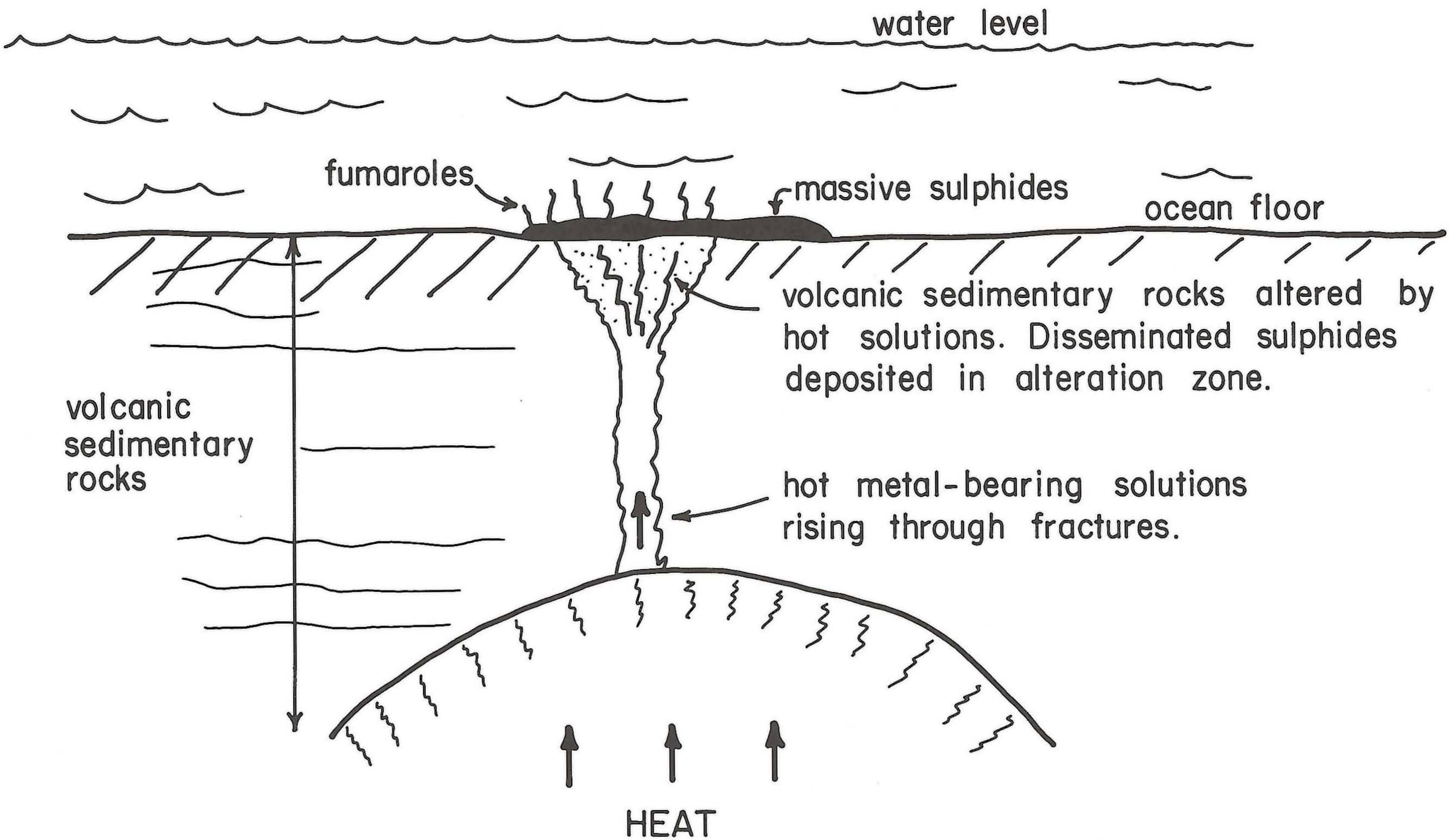

Figure 5. Simplified diagram showing formation of a volcanogenic massive sulphide deposit by metal-bearing fumaroles.

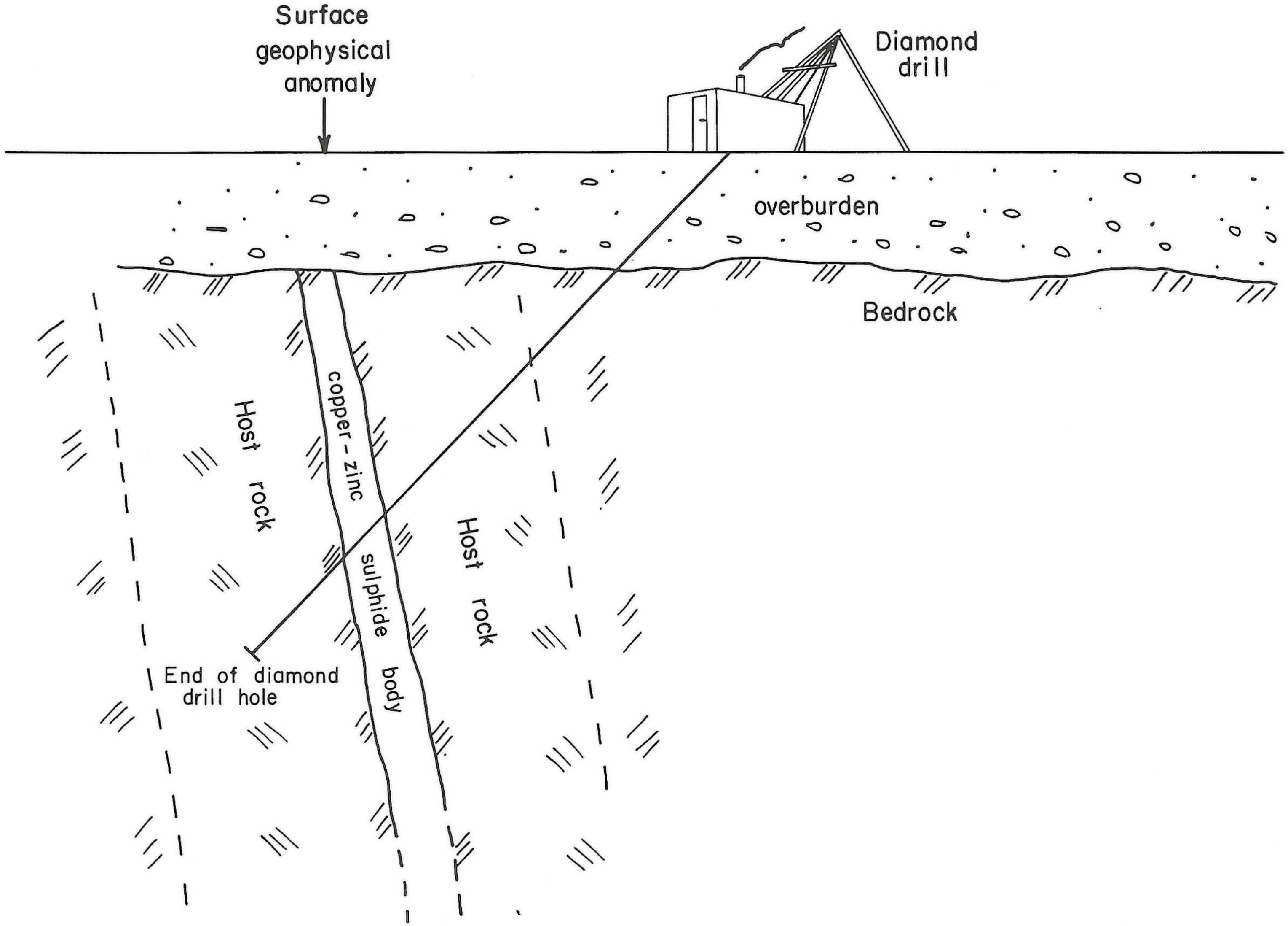

Figure 6. Diamond drill hole testing of a geophysical anomaly caused by a sulphide body.

The majority of sulphide deposits, however, do not outcrop because they are either covered by overburden (sand, gravel, clay, top soil) or 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.

By 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 conductive geological features such as uneconomic iron sulphides, graphite, fault zones and water seams in overburden 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 (Boldy, 1977). Drilling costs, currently running at approximately $65/metre, form the most expensive component of an exploration program. The average cost of finding a mine has been estimated at between 20 and 30 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.

The 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 any production starts.

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. This is the case with most Manitoba copper-zinc deposits and in fact, except for the Ruttan open pit still in operation (Plate 2), 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 and dumped into the main ore pass. The ore collected at the bottom of the shaft is sent through a primary crusher. It is then hoisted to surface where it goes through a secondary crushing operation before entering the concentrator.

Milling

The ore extracted from a mine contains only a few parts of copper and/or zinc per hundred parts of waste. It has to 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 gangue by the froth flotation process. Organic compounds are added to the water slurry causing differences in surface chemical properties of the fine particles. Some of these are entirely wetted 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 the 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 new 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.

Copper Smelting

The copper concentrate is blended with silica sand and melted in a furnace at a temperature above 1000°C. Two products are obtained. The heavier

Plate 2. Ruttan open pit. (Published with the permission of Sherritt Gordon Mines Limited)

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, tellurium are recovered. The zinc-bearing slag is processed and sent to the zinc refinery at Flin Flon for recovery of the metal.

Zinc Refining

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 (Plate 1). It processes all the copper and zinc concentrates from the Flin Flon-Snow Lake mines and part of the concentrates from the Fox and Ruttan mines of Sherritt Gordon Mines Limited. The rest of the Fox and Ruttan concentrates, and the copper concentrates produced in Thompson as a by-product of the nickel mines are shipped for further treatment outside of Manitoba.

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; i.e. a minimal number of trees is allowed to be cut and garbage is 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 for more pleasant living conditions. New mining structures may be built 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 and in some cases for other filling jobs such as the construction of road beds. Liquid waste from various plants is purified to such a degree as not to affect the water life in surrounding bodies of water. A new flue system, including a 250 m smoke stack (Plate I) was

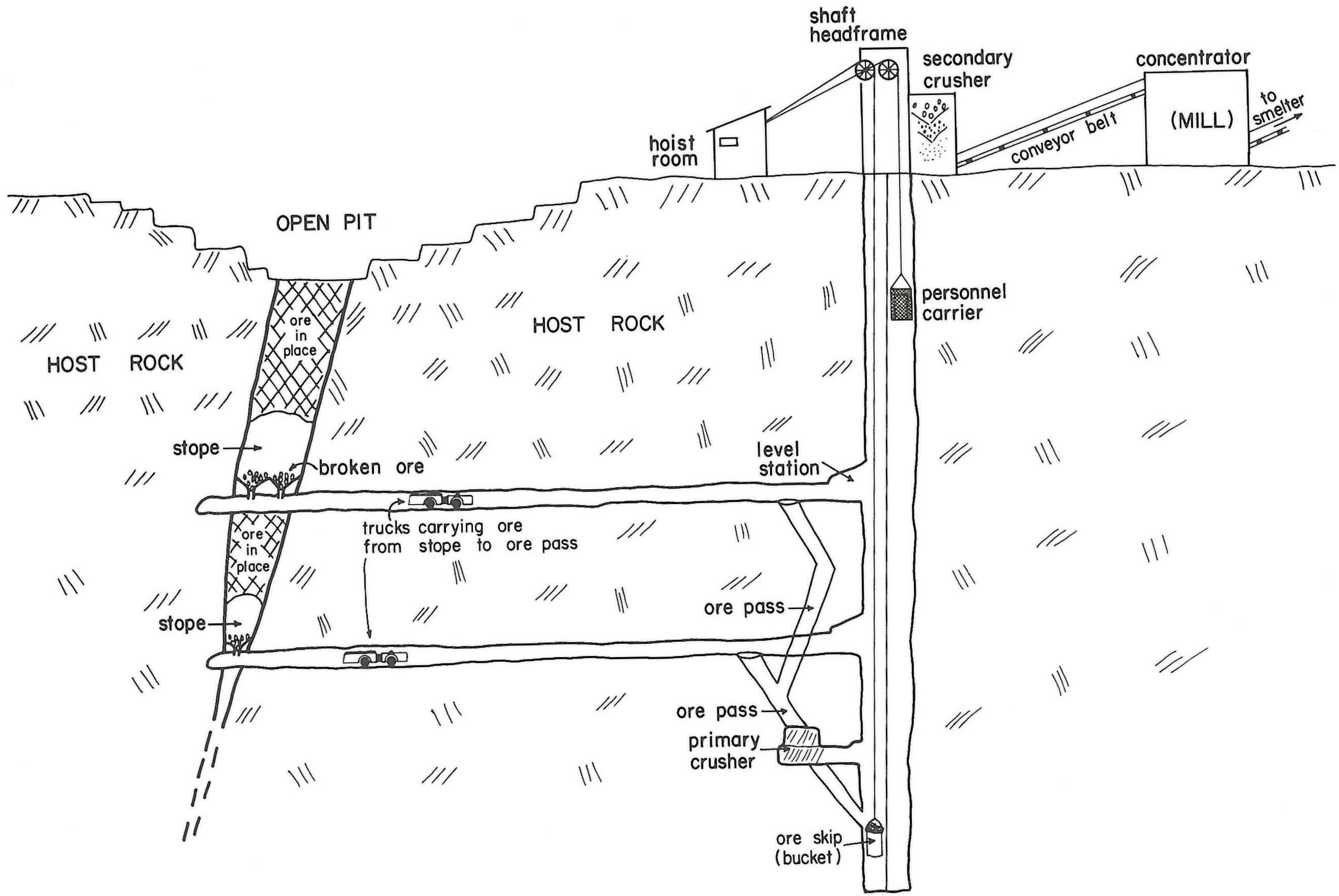

Figure 7. Simplified section of a typical mine.

completed by Hudson Bay Mining and Smelting Co., Limited in 1974 to alleviate the effects of the fumes from the smelting and roasting plant in the Flin Flon area.

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 ceased. The copper and zinc ore reserves published in 1979 were estimated to be sufficient to keep the existing mines in operation for about 10 years under favourable economic conditions. To extend this projected life and to maintain a healthy mining industry in the province, new deposits will have to be discovered and developed.

The 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 some potential for copper and zinc deposits.

In the last ten years over 50 million dollars 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. Table 3 shows the deposits found during the same period.

New regions have been and are being explored all the time, but with new ideas and improved exploration techniques, it is still the traditional areas which attract the major interest (Table 4). One of the latest discoveries, by Granges Exploration Aktiebolag in 1976, was in fact on Embury Lake, only 7 km away from the original Flin Flon mine. In 1979, a renewed interest was shown in the Sherridon area, partly because of similarities noticed between rock types of this area and rock types around the giant Broken Hill deposit in Australia, one of the largest lead-zinc deposits in the world.

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.

TABLE 3: IMPORTANT COPPER-ZINC DEPOSITS FOUND FROM 1969 TO 1979

Name of Deposit	Company (Abbrev.)	Area	Locality on Figure 1	Tonnage Reported TONNES	%Cu	%Zn	Year of Discovery	Status
Ruttan	Sherritt Gordon	Ruttan Lake	6	see Table 2			1969	in production
Reed Lake	H.B.M.&S.	Reed Lake	7	1 035 794	2.18	—	1969	undeveloped
Centennial	H.B.M.&S.	Baker's Narrows	1	see Table 2			1970	in production
Barrington Lake	H.B.M.&S.	Barrington Lake	8	136 050(*)	2.5	—	1972	undeveloped
Westarm	H.B.M.&S.	Schist Lake	1	see Table 2			1973	in production
Spruce Point	Freeport Can. Expl.	Reed Lake	7	907 000	2.00	4.00	1973	under development by H.B.M.&S.
Farewell Lake	M.M.R.	SE of Reed Lake	9	256 681	2.03	—	1974	undeveloped
Lost Lake	H.B.M.&S.	Snow Lake	3	224 301	1.45	4.9	1974	in production through Ghost Lake Mine
Trout Lake	Granges Expl.	Embury Lake	1	3 174 500	2.60	4.30	1975	undeveloped
Frances Lake West	M.M.R. — Granges	Lynn Lake	10	90 700(*)	0.58	4.7	1976	undeveloped
Sylvia	M.M.R.	SE of Reed Lake	9	3 900 100	0.97	1.50	1977	undeveloped

H.B.M.&S. = Hudson Bay Mining & Smelting Co., Limited
M.M.R. = Manitoba Mineral Resources Ltd.
(*) = Department estimates from published information

TABLE 4: IMPORTANT COPPER-ZINC DEPOSITS FOUND BEFORE 1969 AND UNDEVELOPED AS OF DECEMBER 31, 1979

Name of Deposit	Holder in 1979 (Abbrev.)	Area	Locality on Figure 1	Tonnage Reported TONNES	%Cu	%Zn		Date of Discovery
Copper-Man	Hartland Mines	S of Wekusko L.	11	154 190	3.13	4.71	"A" zone	1928
				67 118	1.49	3.91	"B" zone	
Bob Lake	Sherritt Gordon Mines	Sherridon	2	2 158 660	1.33	1.18		1941
Hyers Island	W.B. Dunlop	Oxford Lake	12	317 450	2.5	—		1943
Sherlynn	Sherlynn Mines Ltd.	Lynn Lake	10	165 074	2.63	1.21		1947
"FL" Group	Granges Expl.	Lynn Lake Eldon Lake	10	453 500	0.9	2.2		1947
"Z"	Sherritt Gordon Mines	Lynn Lake	10	138 771	1.11	2.49		1947
Vamp Lake	Hudvam Mines Ltd.	Vamp Lake	13	363 888	1.5	1.7		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 Ltd.	Sourdough Bay	1	1 360 500	1.3	—		1967

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

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