

Mines Branch Information Circular IC-157

SALT, AND THE CANADIAN SALT INDUSTRY

by

R. K. Collings*

ABSTRACT

This report outlines the origin of the three major types of salt deposits occurring in the world, namely brine deposits, bedded rock salt deposits, and salt domes. Methods currently used to recover salt from these deposits are described in some detail. Sections on the properties and uses of salt, in particular its use for ice control and in soil stabilization, are included.

Canadian salt occurrences are listed and developments within the Canadian industry from 1886, the year of the first recorded production, to the present are outlined. Current Canadian operations are described and detailed statistics of production, trade, and consumption for the period 1950 to 1963 are listed. A short section on world production of salt, with production statistics of the main producing countries for 1962, is included.

Finally, several of the more recent developments relating to salt processing are noted, and two techniques for upgrading salt, namely the thermal adhesive method and electronic sorting, are described.

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Direction des mines

Circulaire d'information IC 157

LE SEL ET L'INDUSTRIE CANADIENNE DU SEL

par

R. K. Collings*

RÉSUMÉ

Ce rapport traite de l'origine des trois principaux types de gisements de sel qui existent dans le monde, savoir les nappes de saumure, les gisements stratifiés de sel gemme et les dômes de sel. Les méthodes en usage pour extraire le sel de ces gisements y sont décrites en détail. Des sections sont consacrées à l'étude des propriétés et des usages du sel, tout particulièrement pour la fonte de la glace et la stabilisation des sols.

L'auteur énumère les gisements de sel au Canada et passe en revue les développements qui se sont succédé au sein de cette industrie canadienne depuis 1886, qui marque le début de la production chez nous, jusqu'à nos jours. L'auteur décrit les opérations qui se déroulent présentement dans cette industrie canadienne et fournit une statistique détaillée sur la production, le commerce et la consommation de cette denrée pour la période 1950-1963. On y trouve également une section qui traite de la production mondiale du sel et où figure la statistique de la production des principaux pays producteurs pour l'année 1962.

Enfin, l'auteur passe en revue les derniers perfectionnements dans le traitement du sel et, notamment, les deux techniques en usage à l'heure actuelle pour purifier le sel, savoir la méthode adhésive thermique et le triage par l'électronique.

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REVIEW 49

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Canada

Collings, R.K.

**SALT
1960**

PRELIMINARY

**MINERAL RESOURCES DIVISION
DEPARTMENT OF MINES AND TECHNICAL SURVEYS
OTTAWA**

1961

1961

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1961

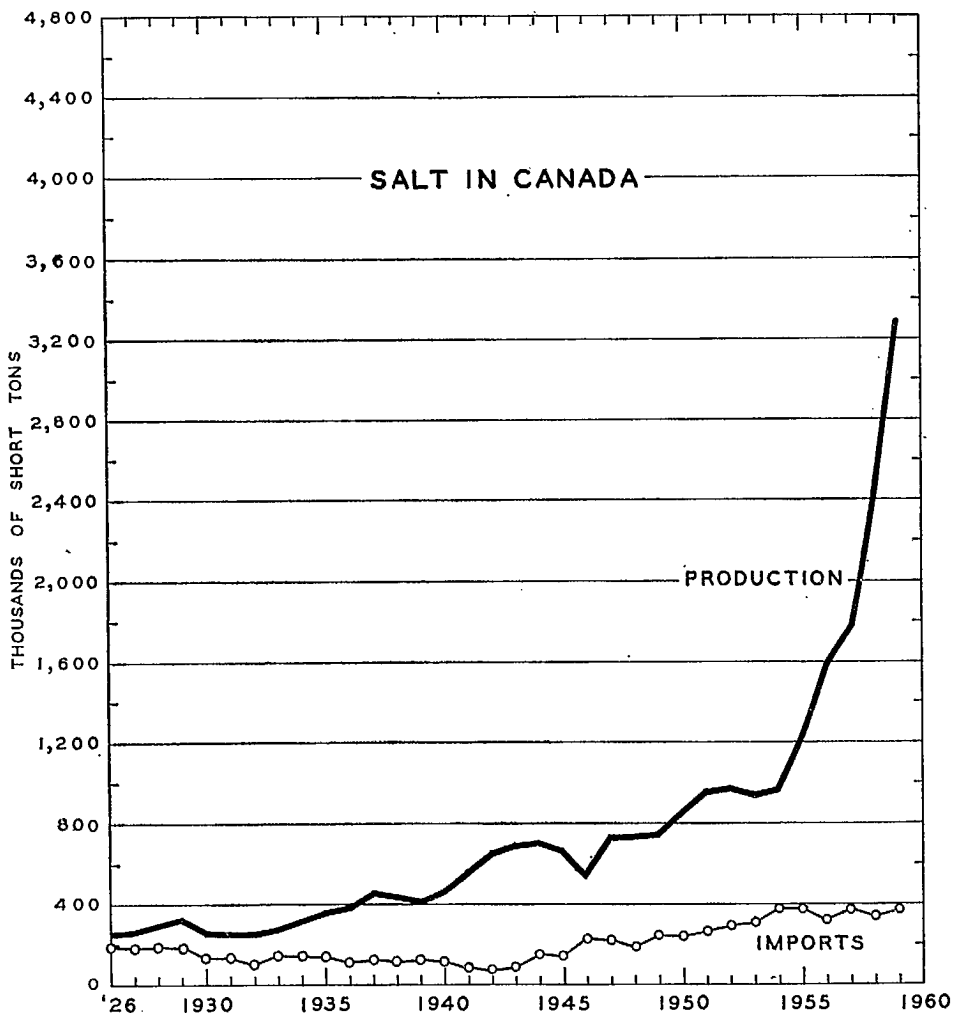
1961

SALT 1960

R. K. Collings*

Salt is recovered from underground deposits in Canada by mining at three locations—Pugwash, Nova Scotia, and Goderich and Ojibway, Ontario—and by brining followed by evaporation at nine locations—Nappan, Nova Scotia; Goderich, Sarnia, Sandwich, Watford, and Amherstburg, Ontario; Neepawa, Manitoba; Unity, Saskatchewan; and Lindbergh, Alberta.

Salt brine for use in the manufacture of chemicals is produced from underground salt beds at Amherstburg, Sandwich, and Sarnia, Ontario, and at Duvernay, Alberta.



SOURCE: D. B. S.

MINERAL RESOURCES DIVISION, DEPT. M. T. S.
R. A.

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Salt

The salt production of 1960, at 3,206,164 short tons, was 2.5 per cent below that of the previous year. Its value, \$18,644,203, was, however, 3.4 per cent higher. About 47 per cent of the 1960 output was in the form of brine for direct use by the chemical industry. Mined rock salt represented 40 per cent of the total; and the remaining 13 per cent consisted of fine evaporated salt and salt recovered in chemical operations.

Imports dropped from 369,967 short tons in 1959 to 191,940 short tons in 1960. This decrease occurred largely because Sifto Salt Limited, having established its own rock-salt-mining operation at Goderich, Ontario, reduced its imports.

The value of salt exports, \$3,461,366, was 25.4 per cent less than in 1959. Most of the salt exported was in the form of brine for use by chemical plants in the United States.

Salt—Production and Trade

	1960*		1959	
	Short Tons	\$	Short Tons	\$
Production (shipments)				
By type:				
Fine vacuum salt.....	419,354		459,857	8,918,231
Mined rock salt.....	1,279,405		1,221,999	7,512,695
Salt recovered in chemical operations.....	14,410		17,210	63,675
Salt content of brines used and shipped.....	1,492,995		1,590,910	1,539,921
Total.....	3,206,164	18,644,203	3,289,976	18,034,522
By province:				
Ontario.....	2,892,819	13,411,687	3,036,230	13,228,977
Nova Scotia.....	169,400	2,335,090	120,225	1,897,708
Alberta.....	72,513	1,102,426	61,198	1,092,331
Saskatchewan.....	50,000	1,240,000	48,776	1,189,675
Manitoba.....	21,432	555,000	23,547	625,831
Total.....	3,206,164	18,644,203	3,289,976	18,034,522
Imports (by type)				
Table:				
United States.....	705	52,898	175	62,743
United Kingdom.....	46	3,079	—	—
Total.....	751	55,977	175	62,743
For fisheries:				
Spain.....	35,312	137,494	26,607	117,504
Bahamas.....	24,827	100,261	32,029	120,824
Jamaica.....	4,297	15,561	5,032	17,572
United States.....	500	4,679	—	—
St. Pierre.....	142	2,553	40	764
United Kingdom.....	22	688	33	966
Portugal.....	—	—	48	449
Total.....	65,100	261,236	63,789	258,079
Other, in bulk:				
Mexico.....	74,837	89,571	82,240	97,227
United States.....	41,082	231,287	205,778	911,064
French Africa.....	—	—	3,360	9,265
Total.....	115,919	320,858	291,378	1,017,556

Salt—Production and Trade—Continued

	1960*		1959	
	Short Tons	\$	Short Tons	\$
Other, in bags, barrels, and other covering:				
United States.....	9,833	196,560	13,198	211,818
United Kingdom.....	337	6,346	1,427	27,416
Total.....	10,170	202,906	14,625	239,234
Total imports.....	191,940	840,977	369,967	1,577,612
Exports				
United States.....		3,398,350	1,273,923	4,630,149
United Kingdom.....		55,815	—	—
Bermuda.....		6,933	131	6,440
Other countries.....		268	23	2,933
Total.....		3,461,366	1,274,077	4,639,522

Source: Dominion Bureau of Statistics.

* All 1960 figures are subject to revision.

Salt—Production and Trade, 1950-60

(short tons)

	Production ¹	Imports	Exports
1950.....	858,896	238,239	4,100
1951.....	964,525	258,822	4,561
1952.....	971,903	288,125	2,844
1953.....	954,928	307,333	2,354
1954.....	969,887	370,412	1,199
1955.....	1,244,761	365,255	146,472
1956.....	1,590,804	319,124	333,935
1957.....	1,771,559	367,483	457,888
1958.....	2,375,192	340,887	906,707 ²
1959.....	3,289,976	369,967	1,274,077 ³
1960*.....	3,206,164	191,940	

Source: Dominion Bureau of Statistics.

¹ Producers' shipments.² This figure has been adjusted to include the salt content of brine, estimated at 500,000 tons, exported to the United States during 1958.³ Not available.

* Subject to revision.

World Production, 1959

('000 short tons)

United States.....	25,163
China.....	14,330
Russia.....	7,200
United Kingdom.....	5,533
West Germany.....	4,022
France.....	3,943
India.....	3,503
Canada.....	3,290
Other countries.....	21,916
Total.....	88,900

Source: U.S. Bureau of Mines, Mineral Trade Notes, September 1960.

PRODUCERS***Ontario**

Ontario accounted for more than 90 per cent of Canada's salt production in 1960. The entire output was from salt beds 800 to 1,800 feet below the surface in the area between Amherstburg and Goderich, in the southwestern part of the province.

Fine salt, obtained by vacuum-pan evaporation of brine from local wells, is produced by The Canadian Salt Company Limited, at Sandwich, and by Sifto Salt Limited, a subsidiary of Dominion Tar & Chemical Company Limited, at Goderich and Sarnia. The Canadian Salt Company Limited also operates a fusion plant at Sandwich. Fine salt from the evaporator plant is fused, cooled, crushed, and sized to produce a coarse salt.

Coarse rock salt is produced at Ojibway, near Windsor, by The Canadian Rock Salt Company Limited, a subsidiary of The Canadian Salt Company Limited, and at Goderich, by Sifto Salt Limited. The salt bed mined at Ojibway is at 980 feet; that mined at Goderich is at 1,760 feet.

Brine from company-owned wells is used by Dow Chemical of Canada, Limited, to produce caustic soda, chlorine, and related chemicals at Sarnia. At Amherstburg, Brunner Mond Canada, Limited, produces industrial salt, soda ash, calcium chloride, and other chemicals, using brine from local wells.

Canadian Brine Limited, a subsidiary of The Canadian Salt Company Limited, supplies brine from wells at Sandwich to a chemical plant in Detroit. The brine is pumped to Detroit through pipelines running under the Detroit River.

At Watford, Warwick Salt and Chemicals Limited produces a coarse evaporated salt for use in agriculture, ice control, water-softening, and salting hides.

Nova Scotia

Fine salt is produced by Sifto Salt Limited at a plant at Nappan, near Amherst. Brine for this operation is obtained from salt beds 1,100 to 1,800 feet below the surface.

Malagash Salt Company Limited, a subsidiary of The Canadian Salt Company Limited, operates a rock-salt mine at Pugwash. The salt, obtained from a bed at 630 feet, is crushed and screened to give a coarse product for use in ice and dust control on highways, in fisheries, and by the chemical and agricultural industries.

Prairie Provinces

Fine salt, obtained by vacuum-pan evaporation of brine from salt beds 1,000 to 3,500 feet below the surface, is produced by The Canadian Salt Company Limited at Neepawa, Manitoba, and Lindbergh, Alberta, and by Sifto Salt Limited at Unity, Saskatchewan. Part of the Lindbergh output is fused, crushed, and screened to give a coarse salt for various uses.

Western Chemicals Limited, of Calgary, Alberta, uses brine obtained from salt beds 3,600 feet below the surface to produce caustic soda, chlorine, and hydrochloric acid at its chemical plant near Duvernay, Alberta.

* See map.

OTHER OCCURRENCES

Salt beds occur at depth on the west coast of Cape Breton Island; under Hillsborough Bay, Prince Edward Island; and in the area south of Moncton, New Brunswick.

Beds of salt varying from a few feet to several hundred feet in thickness underlie large sections of the Prairie Provinces. The beds occur in a huge southwesterly-dipping basin that extends from northeastern Alberta southeasterly through central Saskatchewan and thence into southwestern Manitoba. These beds vary from less than 400 feet below the surface in northern Alberta to 6,000 feet or more in southern Saskatchewan.

USES AND TECHNOLOGY

Salt is important chiefly as a raw material for the chemical industry, which uses salt brine for the production of sodium hydroxide, chlorine, and hydrochloric acid. These, in turn, are employed in the manufacture of soda ash and a variety of other chemicals.

Fine salt, produced by the vacuum-pan evaporation of brine, is used in food- and leather-processing, the salting and curing of meats and fish, textile-dyeing, and chemical manufacture, for dairy purposes, and in cattle and stock feed.

Salt is also used as a soil stabilizer, a glazing agent in the manufacture of sewer pipes and drain tile, and a drilling-mud ingredient when drilling is done through underground salt seams.

The coarser grades of salt are generally preferred for fish-curing, ice and dust control on highways, dairy and food purposes, the regeneration of calcium and magnesium zeolites in water softeners, refrigeration, meat-packing, and the curing and tanning of hides and skins.

The coarser grades of salt are usually obtained by mining, crushing, and screening rock salt. The four standard sizes produced are:

No. 2	$-\frac{3}{8} + \frac{1}{2}$ inch
No. 1	$-\frac{1}{2} + \frac{1}{4}$ inch
C.C.	$-\frac{1}{4} + \frac{1}{8}$ inch
F.C.	$-\frac{1}{8}$ inch

One of the major problems encountered in rock-salt-mining is the excessive production of fines (i.e. minus $\frac{1}{8}$ inch material), which, although useful as a source of salt for chemical purposes, have limited commercial application. These fines are formed into briquettes or are pressed between rolls to form a thin ribbon of salt. They are then crushed and screened to give salt of the coarser, more useful varieties.

Fine salt from evaporator plants is also pressed to form blocks or briquettes, which in turn are crushed and screened to produce the coarse variety. Coarse salt may also be obtained from fine by fusion, the salt being melted at about 1,500°F in large furnaces similar to those employed by the glass industry. The molten salt is discharged into conveyor-mounted metal briquette moulds, where it quickly hardens. The briquettes are then crushed and screened to the desired sizes.

Mined rock salt, although sometimes of high purity, usually contains such mineral impurities as gypsum, limestone, and dolomite, the removal of which is generally difficult. Great promise for their removal, however, is shown by a 'thermo-adhesive' beneficiation method recently developed by International Salt Company, of Cleveland, Ohio. The separation technique is based on the fact

Salt

that pure salt crystals transmit infrared rays of a certain wave length, whereas the gangue minerals (gypsum, limestone, and dolomite) absorb the rays and hence become heated. If salt containing the gangue minerals is subjected to infrared rays before being discharged to a conveyor belt coated with a heat-sensitive polystyrene resin, the heat-absorbing gangue minerals will adhere to the belt. Thus the salt crystals are discharged at the end of the conveyor, while the gangue minerals travel around the end roller and are removed from the underside of the conveyor belt by a scraper.

*Available Data on Consumption of Salt
in Specified Canadian Industries, 1958¹
(short tons)*

Chemical products (dry salt and salt content of brine).....	991,448
Slaughtering and meat-packing.....	50,311
Pulp and paper mills.....	44,122
Food preparation.....	36,309
Fish-processing.....	21,494
Stock and poultry feed.....	25,764
Leather tanneries.....	7,053
Soaps and cleaning preparations.....	2,095
Dyeing and finishing textiles.....	1,701
Breweries.....	887
Artificial ice.....	285
Other industries ²	628,000 ^(e)

Source: Dominion Bureau of Statistics.

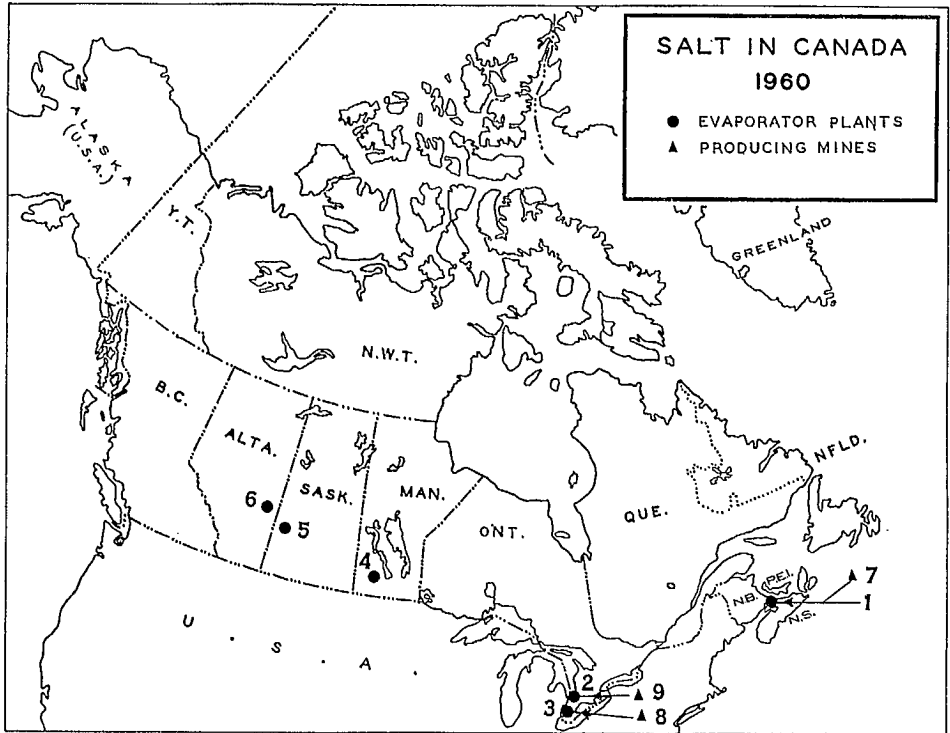
¹ Latest year for which all data are available.

² Apparent consumption (1958) less the amount used by specified industries. Includes coarse rock salt for winter maintenance of roads and railways, refrigeration, chemical use, etc., as well as fine salt.

(e) Estimated.

TARIFFS

	British Preferential	Most Favored Nation	General
Canada			
Fishery salt.....	free	free	free
Bulk salt.....	“	3¢ per 100 lb	5¢ per 100 lb
Salt in bags, barrels, etc.....	“	3.5¢ per 100 lb	7.5¢ per 100 lb
Table salt.....	5%	10%	15%
United States			
Bulk salt.....			1.7¢ per 100 lb
Salt in bags, barrels, etc.....			3.5¢ per 100 lb



MINERAL RESOURCES DIVISION, DEPT. M.T.S.

Evaporator Plants

- | | |
|--|--|
| 1. Sifto Salt Limited (Nappan) ✓
<i>(1961)</i> | 4. Canadian Salt Company Limited, ✓
The (Neepawa) |
| 2. Sifto Salt Limited (Goderich and Sarnia) ✓
Warwick Salt and Chemicals Limited
(Watford) | 5. Sifto Salt Limited (Unity) ✓
<i>(1961)</i> |
| 3. Canadian Salt Company Limited, ✓
The (Sandwich)
Brunner Mond Canada, Limited ✓
(Amherstburg) | 6. Canadian Salt Company Limited, ✓
The (Lindbergh) |

Producing Mines

- | | |
|--|---|
| 7. Malaga Salt Company Limited (Pugwash) ✓
<i>Mine</i> | 9. Sifto Salt Limited (Goderich) ✓
<i>(1961)</i> |
| 8. Canadian Rock Salt Company Limited, ✓
The (Ojibway) | |

Brine

1. The Canadian Brine Company (Sandwich) ✓

April 1961

In addition an evaporator plant for production of fine salt utilizing waste fines from Pugwash mine is being constructed at Pugwash.

Canadian Sult

N.C. Hobson - VP. & G.M.

Sitte Sult

W.R. Spence Vice-President

INTRODUCTION

Common salt, chemically known as sodium chloride, is an indispensable mineral and one of the most useful known to man. It occurs in relative abundance in many of the countries of the world in buried deposits, from which it may be recovered by underground or solution mining, and in saline lakes, from which it may be recovered by solar evaporation. The oceans of the world, averaging $3\frac{1}{2}$ per cent sodium chloride, constitute an enormous reserve of this mineral. Recovery of ocean or sea salt is practised in many countries where climatic conditions are favourable.

Sodium chloride is a basic raw material for the manufacture of numerous chemicals, notably soda ash, caustic soda, and chlorine. Large quantities of salt are used in food processing, where it acts not only as a preservative but also adds a pleasant flavour. Common salt is very useful as a soil stabilizer, particularly for rural roads. In northern climates it is used extensively to control ice conditions on highways and city streets, much to the chagrin of the corrosion-conscious motoring public.

World production of salt currently is in excess of 100 million tons annually. Although Canada in 1962 contributed less than 4 per cent of this total and ranked only eighth as a world producer, salt production nevertheless forms a very important part of the non-metallic mineral segment of the Canadian mineral industry. Canadian salt production in 1963, at 3,734,517* short tons valued at \$22,599,336*, was exceeded in tonnage only by gypsum and in value only by asbestos and perhaps potash; excluding metals, fuels, and structural materials.

Ontario is Canada's chief salt producer, annually accounting for over 85 per cent of the total production. Other producing provinces are Nova Scotia, Alberta, Saskatchewan and Manitoba, in that order. Most of Canada's production is in the form of rock salt from its three mines at Ojibway and Goderich, Ontario, and Pugwash, Nova Scotia. Substantial tonnages of salt are produced and used as brine by the chemical industry. The remainder of the Canadian production is largely fine evaporated salt for use by the food industry and in numerous miscellaneous processes. Canada's per capita consumption of salt in 1963 was in the order of 250 pounds.

ORIGIN OF THE THREE MAIN TYPES OF SALT DEPOSITS

Salt, in solution, occurs in the oceans of the world, in springs and lakes and in underground deposits, and, in solid form, as rock salt in underground bedded deposits and domes. Mineral compounds frequently associated with salt are calcium, magnesium and sodium sulphates; calcium, potassium and magnesium chlorides; and calcium and magnesium carbonates.

*Preliminary, subject to change.

Brine Deposits

The oceans of the world contain vast quantities of salt in solution. The average salinity of ocean water is $3\frac{1}{2}$ per cent, although salinity varies from place to place and with depth. Conservative estimates place the amount of salt contained in ocean waters at $4\frac{1}{2}$ million cubic miles.

Surface brine deposits such as the Dead Sea of Israel and Great Salt Lake in Utah are remnants of larger deposits of brine which either were cut off from ancient seas or which may originally have been fresh water that gradually had become saline as a result of leaching of associated or nearby salt strata, or by the addition of saline water from other sources.

Underground brine deposits are usually considered to be of secondary origin, having been formed by the leaching action of waters on salt-bearing sediments or rock salt deposits. These brine deposits may occur at or near the host salt beds or they may be at a considerable distance, having been transported by underground waters or having been forced to a higher elevation by the static pressure exerted by surrounding and overlying sediments.

Bedded Rock Salt Deposits

Most rock salt deposits are believed to have had their primary origin in the oceans of the world. Many millions of years ago, large portions of the present land surface of the world were covered by ocean waters. Salt and other evaporite minerals were deposited in marine or semi-marine basins where circulation between the open sea and basin was restricted by dynamic or static barriers. Thick layers of salt were built up during long periods of arid climate when the rate of surface evaporation exceeds rainfall and terrestrial run-off. The weight of these salt layers resulted in the continued downwarping of the underlying sediments, thus making room for more salt until salt beds measuring hundreds of feet in thickness gradually were accumulated. The remaining water in these connate bays or basins gradually evaporated, leaving huge salt deposits which subsequently were covered and compacted by alluvial deposition.

Salt Domes

Salt domes are large cylindrical bodies that have been thrust up from buried deposits of rock salt through overlying layers of sediments by static pressure.

Many salt domes have been penetrated during exploratory drilling for oil in Germany, Russia, Roumania; in the Persian Gulf region; and in the Gulf Coast district of the United States, where several hundred salt domes are known. The Gulf Coast domes occur both off-shore and in Texas, Louisiana; Mississippi, and Alabama. In Canada, salt domes are believed to exist on a few of the Arctic Islands.

A single salt dome may measure several miles across and be up to 5 or 6 miles deep, but most are much smaller. Salt domes characteristically

are flat across the top and generally are capped by several hundred feet of anhydrite. The overlying anhydrite cap probably was the result of concentration of the anhydrite in the original salt as a result of ground water leaching of the latter mineral. The anhydrite usually grades upward into gypsum which undoubtedly has been formed by hydration of the upper portion of the anhydrite. Above the gypsum, or anhydrite if there is no gypsum, there usually is a calcite cap rock. The calcite apparently has been formed by the action of carbonate water on gypsum.

METHODS OF RECOVERY

Salt is recovered for use by several methods: solar evaporation of sea water or brine from lakes; vacuum-pan or open-pan evaporation of naturally occurring brine or brine produced by solution of rock salt deposits; and underground mining of rock salt deposits.

Solar Evaporation

This method of producing salt is uneconomic in northern climates and is practised only in certain coastal areas and where the climate and terrain are suitable. A suitable climate is one that is characterized by a high rate of evaporation and a low rainfall; for example, that of southern California. A suitable terrain for the construction of salt flats or fields is a level, low-lying coastal area consisting of relatively impervious clay sediments.

Solar evaporation is today carried on in the United States, Mexico, Central and South America, the Caribbean area, southern Europe, the Middle East, Asia, Africa, Australia, and New Zealand, and on some of the Pacific Islands. Solar evaporation is not practised in Canada. In 1962, solar evaporation accounted for perhaps 30 per cent of the total world production of over 100 million tons of salt.

At the start of operations, embankments are constructed to separate the salt fields from the sea and to form a chain of shallow ponds which constitute the evaporation system. This system consists of two main parts: a first and more extensive part, called the concentrating area, in which sea water is concentrated by solar evaporation to the point at which it just becomes saturated with sodium chloride, and where the less soluble minerals such as calcium sulphate and magnesium carbonate are precipitated; and a second, and much smaller part, called the crystallizing area, where further evaporation results in the deposition of crystalline sodium chloride. The process of crystallization is continued until most of the sodium chloride is precipitated, which is just about at the point where most of the remaining solutes, principally magnesium and potassium salts, begin to separate. The residue liquor, or bittern, which contains the unwanted solutes, is run to waste. The sodium chloride, which is deposited as a crystalline crust in the crystallizing area, is removed by mechanical scrapers, crushed to the desired size, dried, screened, and packaged for shipment. At some locations

it is washed with pure brine, following crushing, to remove residual impurities.

Vacuum- and Open-pan Evaporation

Brine used in vacuum-pan and open-pan evaporation may be natural brine, formed by solution of deposits of rock salt by underground waters, or artificial brine formed by pumping water down a "well" to the salt horizon.

Salt "wells", usually drilled by churn drill, are 8 to 10 inches in diameter and generally contain two concentric pipes - an 8 to 10 inch casing pipe lining the hole down to the salt horizon, and a smaller, 3 to 4 inch pipe extending to the bottom of the salt horizon. Fresh water is pumped down to the salt through the opening between the two pipes. Upon reaching the salt it forms brine which, being heavier, sinks to the bottom and is forced up the inner pipe. In some cases the fresh water is pumped down the centre pipe and the brine brought up the annular space between the two pipes. The water may also be pumped down one well and brine recovered through a nearby well.

The brine is stored in large tanks, where gypsum and other impurities are precipitated by the addition of chemicals. It is then concentrated to produce a fine, pure salt by one of several methods, the most common of which is the vacuum-pan evaporator method.

Vacuum-pan evaporators are large cylindrical steel vessels that measure 50 to 75 feet in height and up to 20 feet or more in diameter. They usually are grouped in a two-, three-, or four-pan series to form a double, triple, or quadruple "effect". Live steam is fed to the first evaporator, whereas the second, third and fourth evaporators are fed by exhaust steam from the previous evaporator. Figure 1 is a schematic diagram of a triple-effect system.

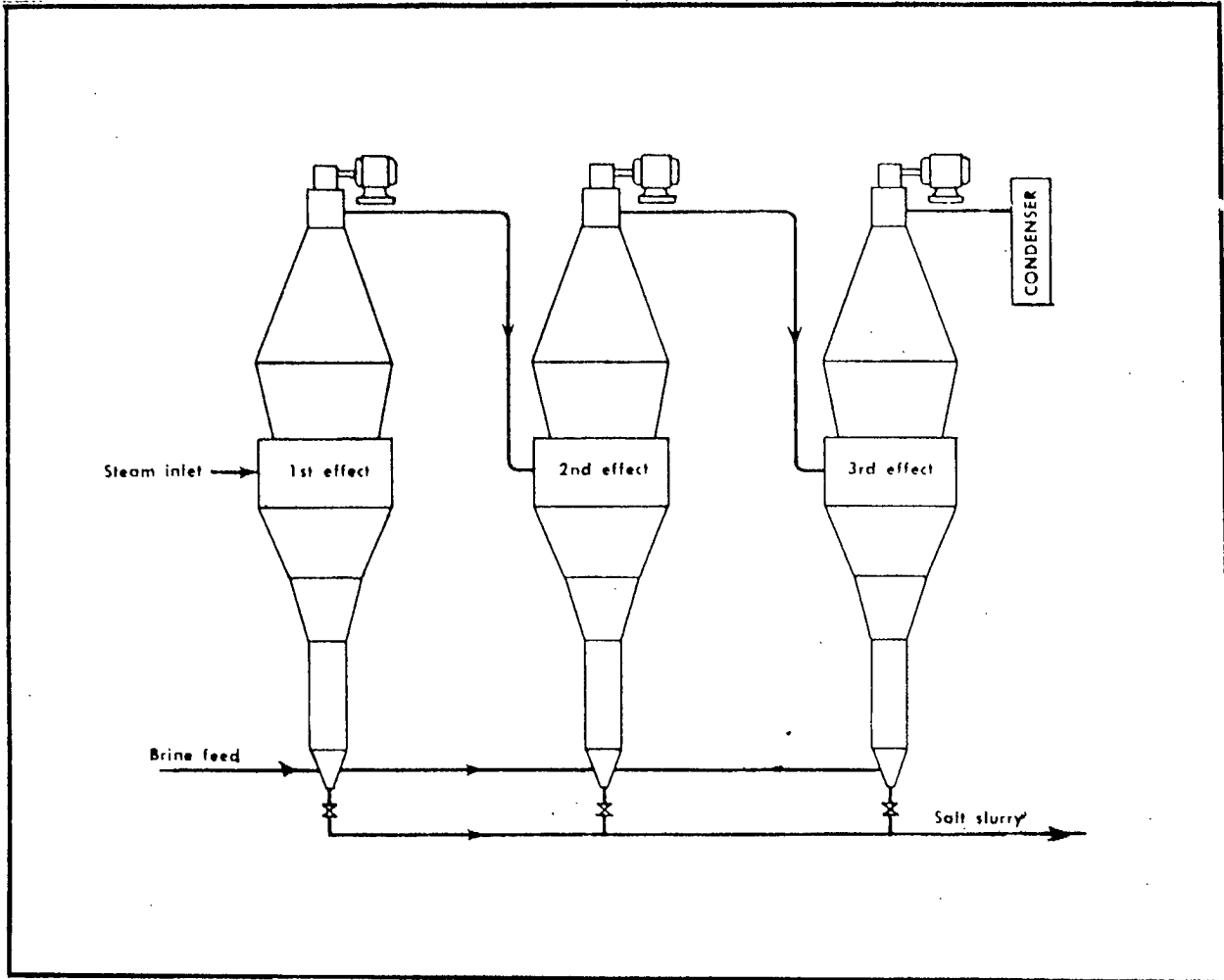


Figure 1 - Triple-Effect Vacuum-Pan System.

The steam chamber is an integral part of each pan. This chamber, located near the mid-point of the evaporator, consists of a series of relatively short copper tubes arranged vertically around a centre well and secured at the top and bottom by tube sheets. Low-pressure steam, circulating around these tubes, transfers its heat to the brine, which is circulated through the tubes by an impeller located in the central well. The air in the upper portion of the evaporator is partially evacuated by vacuum pump. This results in a marked lowering of the boiling point of the brine. As the water evaporates, the salt crystallizes and falls to the lower section, or leg, of the evaporator, where it is removed as a slurry. The slurry is washed and filtered on a top feed, rotary filter. Hot air, forced into the filter, removes most of the moisture from the salt. It may then be further dried by rotary dryer or heated screw conveyor, prior to screening.

Other evaporation methods, such as the open-pan or grainer system and the Alberger process, are used for the production of special types of salt in the United States and certain other countries, but not in Canada.

The open grainer system has been used in Canada but gradually has been replaced by vacuum pan evaporation.

The grainer method of producing salt consists of the evaporation of brine in shallow open trays or pans that may measure from 100 to 150 feet or more in length by 10 to 15 feet or more in width by about 2 feet in depth. The required heat for evaporation is usually derived from steam from an external boiler. This steam circulates through pipes arranged parallel to the length of the pan and just slightly below the brine surface. No boiling takes place in a grainer, but evaporation of the water at the surface causes flake-like crystals of salt to form. These crystals gradually increase in size and sink to the bottom of the pan, whereupon they are carried to the discharge end of the pan by conveyor rakes. The salt crystal-cake is dried, screened, and packaged.

In the Alberger system, brine is heated by heat exchangers and live steam injection to a temperature of about 290°F. The hot brine is treated in gravelers, which are large cylindrical tanks containing a bed of stones, to remove calcium sulphate. The calcium sulphate, being less soluble at higher temperatures, precipitates on the stones and is thus largely removed. The temperature of the brine is reduced by flash cooling which causes some salt to form. This salt with the remaining brine is fed to large circular grainer pans where surface evaporation results in further salt precipitation. The salt slurry is removed from a well in the grainer and centrifuged or filtered to produce a dry salt which contains both cubic grains from the flashers and flake-like grains from the grainers.

Rock Salt Mining

The third method of obtaining salt, namely underground mining of seams of rock salt, is coming into greater prominence. This is especially true in Canada.

Access to the salt deposit usually is by means of a vertical shaft that extends to the salt horizon. The salt seam, which may vary from a few feet to several hundreds of feet in thickness, is exploited by the room-and-pillar system of mining. Room and pillar sizes are determined by the depth below surface and thickness of the seam being mined. Rooms commonly are 50 to 60 feet square, while pillars may be 50 feet or more square. Mining heights vary from as little as 8 or 10 feet to 50 feet or more, depending on conditions.

A crawler-mounted undercutter, which in many respects resembles a lumberman's chain saw, is employed to undercut the face to a depth of about 10 feet. The undercut is 6 inches in width and extends across the bottom of the face. It serves two purposes: it provides room for expansion of the salt when blasted, thus reducing the amount of explosives required; and it provides a smooth, even floor which facilitates loading and removal of the broken salt. The salt face above the undercut is drilled by jumbo-mounted, electric, rotary-type drills to a depth of about 10 feet. These drills are equipped with auger-type drill rods with removable tungsten-carbide

bits. The holes, which are evenly spaced across the full width and depth of face, are lightly loaded with low-strength dynamite or fuel-oil-coated ammonium nitrate prills and blasted. The blast reduces most of the salt to easily manageable sizes. The average break per pound of power is about 2 tons.

Trackless mining is employed throughout most mines. Front-end and gathering-arm loaders or shovels are used to fill rubber-tired shuttle cars that carry the salt to the crushing station where it is reduced, usually by a single-roll crusher, to about -6 inches. In some instances the salt is reduced to its final size underground by a secondary crusher. However, at some mines it is elevated to the surface following primary crushing. On surface it is reduced and screened to four standard sizes:

No. 2	-5/8 +1/2 in.
No. 1	-1/2 +1/4 in.
CC (coarse crushed)	-1/4 +1/8 in.
FC (fine crushed)	-1/8 in.

Rock salt mining has the following advantages, as compared with evaporation methods, for the production of salt -

1. Rock salt generally can be produced at a lower cost.
2. A wider range of sizes is possible.
3. Production rate is high.

The chief disadvantage is that the purity of the salt produced, being largely governed by the purity of the deposit, in most instances is less than that of salt produced by evaporation methods. The purity of rock salt, depending on the deposit and degree of beneficiation, may vary from 96 to 98 or perhaps even approach 99 per cent sodium chloride. Evaporated salt, on the other hand, generally contains in excess of 99.5 per cent sodium chloride.

PROPERTIES OF SALT

Common salt is a chemical compound composed of 60.7 per cent sodium and 39.3 per cent chlorine by weight. It is represented by the chemical symbol NaCl and is known mineralogically as halite.

Halite crystallizes in the cubic system and frequently exhibits highly developed, cubic cleavage, splitting easily along planes parallel to the crystal faces. It has a vitreous lustre, is transparent to translucent, has a hardness of 2.5 on the Mohs scale of hardness and a density, when pure, of 2.16 at 50°F. Halite is readily soluble in water, the solubility increasing slightly with increased temperature. A saturated solution at 32°F contains 26.3 per cent sodium chloride by weight while at 225°F, the boiling point of saturated brine, the brine contains only 28.4 per cent salt. Halite decrepitates strongly upon heating and boils at about 1470°F. It usually is quite brittle but will flow under certain conditions without the development of cracks or loss of transparency.

Salt is never found in an absolutely pure state in nature because most deposits, having been formed by the evaporation of sea water, contain other salts and evaporite minerals. Although commonly colourless to white, salt may be faintly yellow, red, blue, purple, or other colour because of minor impurities.

USES OF SALT

General

Salt, aptly termed "the substance of 14,000 uses", is an essential raw material in many chemical manufacturing processes. It is used, in solution, in the production of soda ash, caustic soda and chlorine which, in turn, are used in a wide variety of processes, including the manufacture of pulp and paper, glass, synthetic fabrics, explosives, soaps, liquid detergents and bleaches, insecticides and weed eradicators, and also in the manufacture of chemicals such as sodium bicarbonate and hydrochloric acid.

Fine salt produced by brine evaporation, in addition to its use by the chemical industry, is consumed in large quantities in seasoning and preserving foods, in curing meats and fish, in cattle and stock feed, in leather processing, in textile dyeing, and for dairy and other purposes.

The coarser varieties of salt, produced from rock salt or by the compaction or fusion of the finer varieties of salt, are preferred for ice control on highways and railways, for refrigeration, for meat packing, for curing and tanning hides and skins, and for the regeneration of calcium and magnesium zeolites in water softeners. A coarser variety of salt cake also is obtained by solar evaporation of sea water and by the evaporation of brine in open grainers. Salt produced by open-pan evaporation of brine or by the fusion of fine salt, although very pure, is expensive to manufacture and is used only where purity is essential, as in the curing of fish or in the dairy industry.

Salt is also used as a soil stabilizer, as a glazing agent in the manufacture of sewer pipe and drain tile, and as an ingredient in some drilling muds.

Ice Control

The largest single use of salt in Canada, apart from its use by the chemical industry, is its application in the control of ice and snow conditions on municipal streets and highways. Salt placed in contact with ice lowers the melting temperature and results in the formation of brine. Although, within the temperature range in which salt is effective, it is possible to melt all the ice on a road surface with salt, this is both costly and unnecessary. The action of salt in removing ice depends primarily on the salt grains penetrating to the pavement before being completely dissolved. The salt brine formed by solution spreads in all directions, undercutting the ice, and effectively destroys the ice-pavement bond. Vehicle traffic completes

the job by breaking up the honeycombed ice. Thus only a relatively small portion, perhaps 10 to 20 per cent, of the total ice is actually melted.

Fine salt is not suitable for ice removal because it dissolves very rapidly without marked penetration. The resulting brine forms a slippery coating on the ice surface which, in many instances, is more dangerous than the ice itself. Rock salt ranging between 1/4 and 1/16 inch is preferred, although in colder weather and with thicker layers of ice, coarser varieties, up to 1/2 inch, are sometimes used. Application rates vary. The Salt Institute of Chicago, in its publication entitled Technical Analysis of Salt for Ice and Snow Removal, recommends the use of 250 pounds of salt per lane mile at temperatures above 20°F, and 400 pounds per mile when the temperature is below 20°F, for rural roads. The rate recommended for urban and municipal areas is 800 pounds per lane mile.

The melting capacity of salt drops off rapidly at temperatures below 30°F. For example, a report by the Highway Research Board of the United States notes that one pound of salt will melt 46.3 pounds of ice at 30°F, 14.4 pounds at 25°F, 8.6 pounds at 20°F, 6.3 pounds at 15°F, and 4.9 pounds at 10°F. Melting action stops at -6°F, the eutectic temperature of pure salt in water. However, it should be remembered that daytime pavement temperatures, because of absorbed heat from the sun and from vehicular traffic, usually are considerably higher than air temperatures.

Soil Stabilization

Salt also is used as a soil stabilizer, being particularly applicable for stabilizing clay, sand and gravel aggregate used in the base of primary roads and the surface of secondary roads. Salt-stabilized secondary roads retain moisture during dry periods, thus do not become as dusty, and shed rainfall during wet periods and thus do not become as muddy and rutted. Frost damage is effectively reduced because the salt results in a marked lowering of the freezing point. The finer grades of salt generally are used in most road-stabilizing programmes. Rate of application varies but is in the order of 4 to 6 tons of salt per mile of road per inch of compacted depth. The salt is thoroughly mixed with the road materials prior to compaction.

Common salt also is used, frequently in conjunction with calcium chloride in a 50:50 mixture, for dust control on secondary roads.

CANADIAN SALT OCCURRENCES

General

Substantial salt deposits are known in six of the ten provinces of Canada, namely Nova Scotia, New Brunswick, Ontario, Manitoba, Saskatchewan and Alberta. Salt recovery operations currently are conducted in each of these provinces with the exception of New Brunswick. Brine springs, usually indicative of salt deposits, have been found in two of the remaining provinces, Newfoundland and British Columbia, and in Prince Edward Island a rock salt

deposit of undetermined size was encountered at a depth of over 14,000 feet under Hillsborough Bay, on the southern side of the Island. (Figures 2, 3 and 4)

The brine springs of Newfoundland, derived from Carboniferous rocks, occur in the southwestern section of the Island along the eastern shore of St. George's Bay, whereas those in British Columbia occur near Kwinitza, on the north bank of the Skeena river about 30 miles east of Prince Rupert; at Nanaimo, on Vancouver Island; and on Saltspring Island.

Salt deposits have been penetrated during oil-well drilling operations in the Norman Wells and lower Mackenzie basin areas of the District of Mackenzie, Northwest Territories. Bed thicknesses in the order of 100 to 250 feet were encountered at depths ranging from 2000 to 5000 feet. However, little is known of the areal extent of these deposits. Evaporite formations also have been encountered at depth north of Great Slave Lake. Several of the Arctic Islands, notably Axel Heiberg and Ellef Ringnes, contain piercement structures which may be underlain by salt.

Nova Scotia (Figure 2)

Brine springs and salt seepages occur throughout the whole of the northern part of Nova Scotia: in Cumberland, Pictou, Antigonish, Hants and Colchester Counties on the mainland, and in Victoria and Inverness Counties on Cape Breton Island. Underground rock salt formations measuring up to 1500 feet in total thickness occur at depths of 85 to 3500 feet below the surface at Malagash, Pugwash and at Nappan, Cumberland County. These salt deposits, of Mississippian age, occur in the Windsor formation. Other deposits have been discovered at depth at Mabou and Port Hood, Inverness County. At Mabou, an 86-foot salt-bearing zone was intersected at a depth of 2260 feet and, at Port Hood, salt beds interbedded with anhydrite and shale were noted in the interval between 6090 and 6625 feet. Salt currently is recovered at Pugwash by mining, and at Nappan by brining.

New Brunswick (Figure 2)

Although minor amounts of salt were produced in New Brunswick prior to 1900 by evaporation of brine from salt springs, the presence of rock salt was not definitely established until the early 1920's when salt was penetrated during oil-well drilling operations in the Weldon-Dorchester area. Subsequent drilling revealed the presence of two distinct salt deposits in this area, the Weldon-Gautreau and the Dorchester.

The Weldon-Gautreau salt deposit underlies a $7\frac{1}{2}$ square mile area immediately north of Hillsborough. Total salt thickness varies from 200 feet to 1500 feet, while depth below surface varies from 700 feet to 2000 feet. The Dorchester salt deposit, believed to be plug-like in character, is north and slightly west of Dorchester. The salt beds occasionally are interbedded with gypsum, clay, and other impurities. However, narrow seams of high-purity salt occur at intervals within the total salt section.

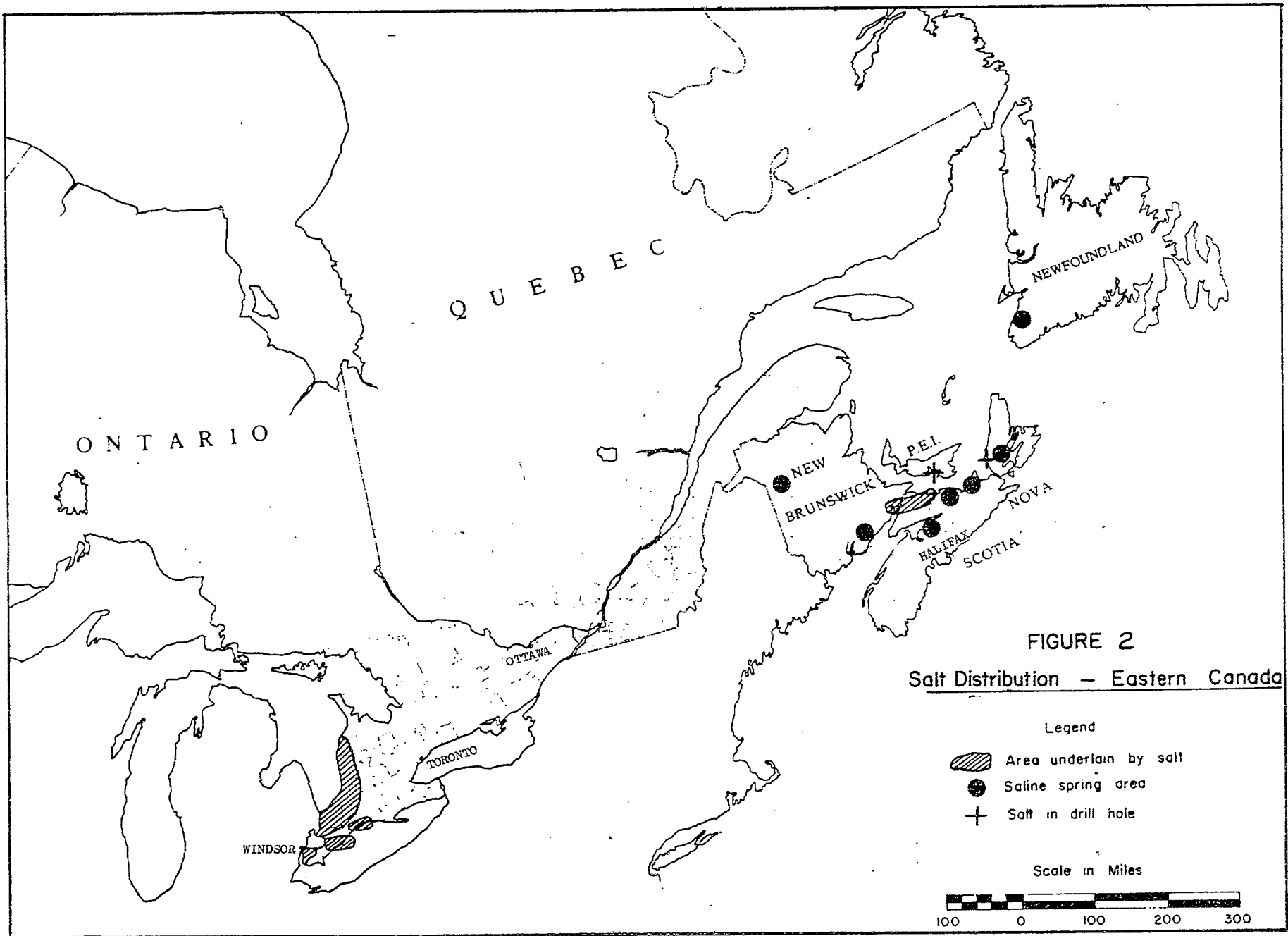



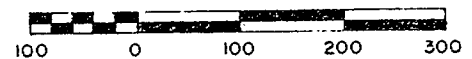


FIGURE 2
Salt Distribution - Eastern Canada

Legend

-  Area underlain by salt
-  Saline spring area
-  Salt in drill hole

Scale in Miles



Brine springs and seepages are known in the Sussex area. These and gravity survey results indicate that the section east of Sussex is probably underlain by salt, although no rock salt deposits have yet been discovered in this area. Brine springs also have been noted at other locations, including Plaster Rock, in northwestern New Brunswick, and at several places in the southeastern quarter of the province.

Ontario (Figure 3)

Salt in Ontario is confined to the southwestern portion of the province west of a line passing through Wingham and London. This salt, of Silurian age, belongs to the Salina group and is associated with anhydrite and shaly dolomite. The salt is bedded and occurs in an upper horizon, which is 900 to 1600 feet below the surface, and a lower horizon, occurring at 2700 feet.

The upper salt horizon underlies the Windsor area and that portion of Ontario lying north of Chatham, west of London, and south of Kincardine. Maximum salt thicknesses are in the order of 400 feet at Windsor, 200 feet at Chatham, 600 feet at Sarnia, and 300 feet at Goderich.

The lower salt horizon extends from Wallaceburg northward to Kincardine and is generally west of Seaforth and Strathroy. This horizon has a maximum salt thickness of about 140 feet, in the Sarnia area.

Salt brining operations currently are conducted at Goderich, Sarnia, Windsor, and Amherstburg. The salt deposits at Goderich and Ojibway are being developed by underground mining. A large deposit of high-purity rock salt was intersected at a depth of 1700 feet near Strathroy, west of London, by Midrim Mining Company during drilling operations in 1956. However, no development work has yet been undertaken.

The Prairie Provinces (Figure 4)

The salt deposits of the three Prairie Provinces--Manitoba, Saskatchewan, and Alberta--are considered collectively, since these deposits are closely associated.

The salt deposits underlying the Prairie Provinces occur in the Middle Devonian formation, which is subdivided into two groups: the upper, Manitoba group and the lower, Elk Point group. The Prairie Evaporite formation, containing the major salt deposits, forms part of the Elk Point group. This formation contains three major salt horizons in Alberta which range up to 1000 feet or more in total thickness. However, in Saskatchewan, the Prairie Evaporite formation contains only one major salt horizon, which has a total thickness of about 600 feet. This formation is also present in Manitoba, where it underlies a narrow 30-mile strip of land along the Manitoba-Saskatchewan border extending northward from the International Border to about latitude 52°.

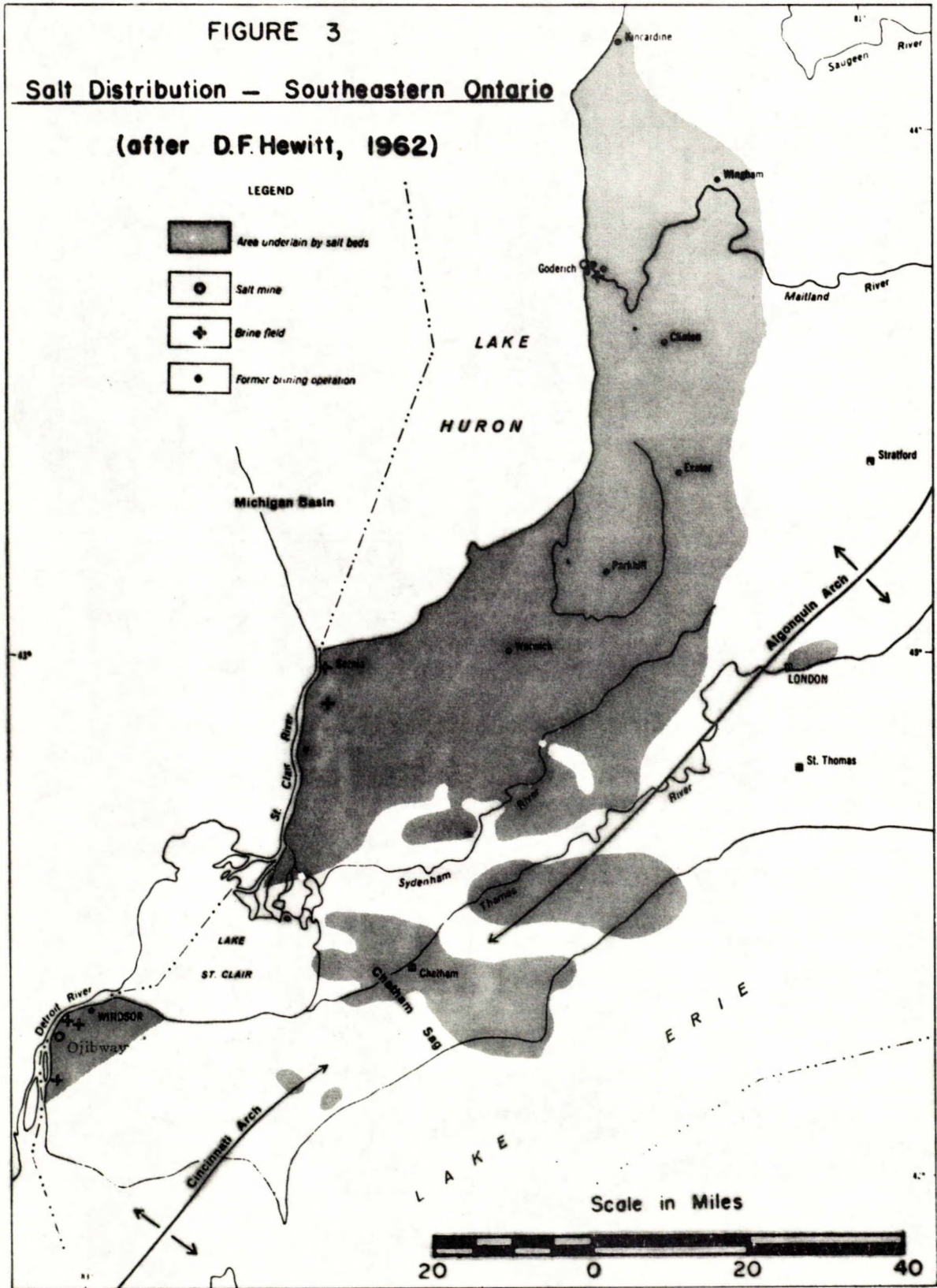
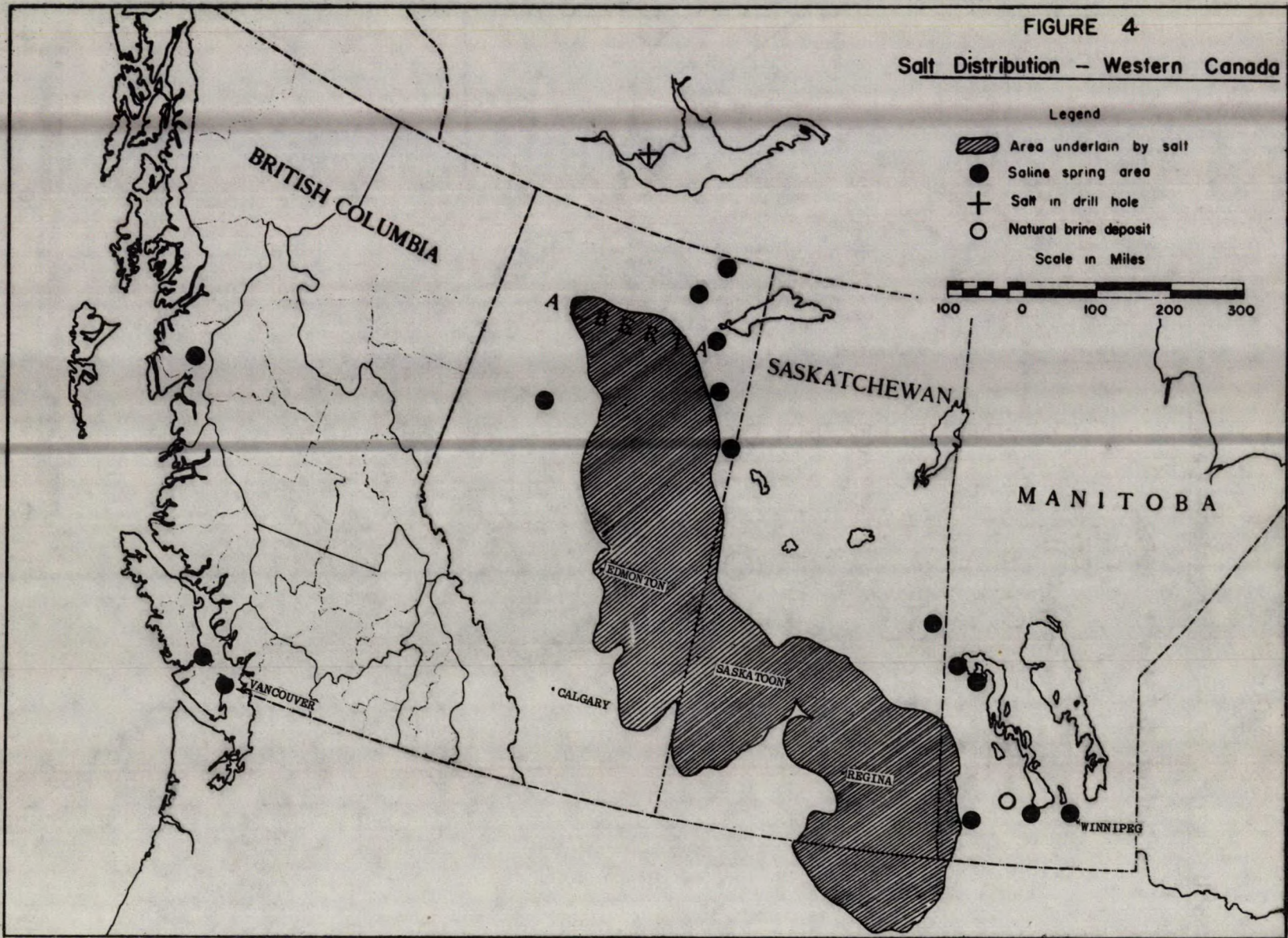


FIGURE 4

Salt Distribution - Western Canada



Two other salt formations overlies the Prairie Evaporite formation in Saskatchewan: the Hubbard Evaporite, which is up to 60 feet thick, and the Davidson Evaporite, which overlies the Hubbard and has a maximum thickness of about 200 feet.

The top of the Prairie Evaporite formation occurs at depths of from 700 feet in the McMurray-Waterways district of Alberta, to 3000 feet or more in eastern Alberta, central Saskatchewan, and southwestern Manitoba and to 6000 feet or more in southern Saskatchewan and southeastern Alberta. Salt from this formation currently is recovered by brining and used in the manufacture of fine evaporated salt at Unity, Saskatchewan, and Lindbergh, Alberta, and for the manufacture of chlorine and caustic soda at Duvernay, Alberta.

In Manitoba, brine springs occur in the area to the west of Lake Winnipegosis and brine deposits have been found at depths of over 1000 feet in the Winnipeg and Portage La Prairie areas. At Neepawa, north of Brandon, salt is presently obtained from brine deposits that are 1400 feet below the surface.

THE CANADIAN SALT INDUSTRY

Early History

The Canadian salt industry had its beginning in the early nineteenth century when brine from springs in Nova Scotia, Manitoba, Saskatchewan and Alberta was evaporated to produce salt for local consumption. However, the production of salt on a commercial basis was not instituted until the year 1866. In that year, a rock salt deposit was located at a depth of 964 feet at Goderich, Ontario, during oil-well drilling operations, and a small evaporation plant was erected to process brine formed with this salt. The discovery of other salt deposits in southwestern Ontario closely followed the Goderich discovery, and evaporating plants soon were erected at Clinton, Seaforth, Sarnia, Goderich, and Windsor. The largest of these plants, erected at Windsor in 1893, became inadequate and was replaced by a newer and much larger plant in 1928. Today only three evaporator plants are operated in southwestern Ontario. These are at Windsor, Sarnia and Goderich, respectively. Ontario has two rock salt mines, one at Ojibway and the other at Goderich. The Ojibway mine, the older of the two, began salt mining operations in 1955. The Goderich mine was officially opened in November, 1959.

Nova Scotia became Canada's first producer of rock salt in 1919 following the discovery, in 1917, of salt at a depth of 85 feet at Malagash, Cumberland county. In 1930 salt was discovered at Nappan, near Amherst, at a depth of 920 feet; however, construction of a processing plant was delayed until 1946 and production of salt by the evaporation of brine commenced at Nappan in 1947. A second rock salt mine, under development for five years, was officially opened at Pugwash in November, 1959. The Pugwash salt deposit, discovered in 1953, is up to 500 feet in total thickness. The salt bed currently mined is at a depth of 630 feet. Mining operations at Malagash were suspended in 1959 when the Pugwash deposit was brought into production.

Salt was discovered at a depth of 650 feet in the McMurray district of northern Alberta in 1907; however, only small quantities of salt were produced in this area until 1925. In that year a plant was erected at McMurray and large-scale production of salt was commenced. Operations at the McMurray plant were suspended in 1927 because of the high cost of transporting processed salt to consumers in the Edmonton area. In 1936 a salt plant was erected at Waterways (near McMurray). This plant continued to produce salt until 1950, when competition from a plant, built at Lindbergh in 1948, forced it to close. The Lindbergh plant, which is still in operation, produces fine salt by the evaporation of an artificial brine formed from salt deposits that are 3600 feet below the surface in that area.

Salt was produced as early as 1820 from brine springs located west of Lake Winnipegosis in western Manitoba. However, only small amounts of salt were produced in this province until 1932. In that year a plant was erected at Neepawa, north of Brandon, to produce salt from natural brine deposits located 1400 feet below the surface. This plant is in operation today.

Small quantities of salt were produced at Senlac and Simpson, in central Saskatchewan, during the early part of the twentieth century; today, however, only one plant, located at Unity, is operated. This plant, erected in 1948, produces salt from an artificial brine formed from salt deposits located at depths of over 3000 feet.

The year 1911 marked the first production of salt for chemical purposes in Canada. In that year a plant was erected at Sandwich, Ontario, for the manufacture of caustic soda and bleaching powder. This plant was later expanded to include the production of chlorine and hydrochloric acid. Salt for this operation was obtained by brining underground salt deposits. Since 1911 many salt-based chemical plants have been established at various locations in Canada; however, only three plants--a soda ash plant at Amherstburg, Ontario, and caustic-chlorine plants at Sarnia, Ontario, and Duvernay, Alberta--use salt from company-operated brine wells. Most of the remaining caustic-chlorine plants are in Quebec and Ontario and use rock salt from Canada's three mines. Salt for use in caustic soda-chlorine production in Vancouver is imported from the United States.

Current Operators

There are only two major producers of salt in Canada at present--The Canadian Salt Company Limited, and the Sifto Salt Division of Domtar Chemicals Limited, a subsidiary of Dominion Tar and Chemical Company Limited. Both companies have head offices in Montreal. Minor amounts of salt are produced by Brunner Mond Canada, Limited, at Amherstburg, Ontario.

The Canadian Salt Company Limited operates brine wells and evaporator plants at Sandwich, Ontario; Neepawa, Manitoba; and Lindbergh, Alberta. This company also operates two salt-fusion plants, one at Lindbergh and the other at Sandwich. These plants use salt from the evaporator plants at each of the respective locations. Brine for export to Solvay Process

Division's chemical plant at Detroit, Michigan, is obtained from wells at Sandwich, Ontario, operated by the Canadian Brine Company, a subsidiary of The Canadian Salt Company Limited. The saturated brine is pumped to Detroit through pipe lines running under the Detroit River. The Canadian Salt Company Limited operates two rock salt mines through a subsidiary, The Canadian Rock Salt Company Limited. One mine is at Ojibway, Ontario, where an 18-foot section of salt is mined at a depth of 980 feet; the other is at Pugwash, Nova Scotia, where a 20-foot section is mined at 630 feet. The Pugwash operation was recently expanded by the addition of a vacuum-pan evaporation plant which produces high-purity fine salt using brine formed by solution of rock salt fines.

The Sifto Salt Division of Domtar Chemicals Limited operates brine wells and evaporator plants at Sarnia and Goderich, Ontario, at Nappan, Nova Scotia, and at Unity, Saskatchewan, as well as a rock salt mine at Goderich. At Goderich, a 45-foot salt section is being mined at 1760 feet. The company's vacuum-pan evaporator plant at Goderich has recently been reconstructed on a site adjacent to the site of the older plant. High-purity coarse salt is produced at the company's Unity, Saskatchewan, plant by the salt fusion process.

Brine for use by the chemical industry is produced at a number of locations in Canada. In Ontario, Brunner Mound Canada, Limited operates brine wells near Amherstburg for the production of soda ash, calcium chloride, and related chemicals, and Dow Chemical of Canada Limited produces caustic soda, chlorine and other chemicals at Sarnia using brine from salt beds underlying the plant. Western Chemicals Limited, Calgary, Alberta, produces caustic soda, chlorine, and hydrochloric acid at its chemical plant at Duvernay, Alberta, using brine from company-owned wells.

Warwick Salt and Chemicals, until very recently, operated Canada's only remaining open grainer salt plant at Warwick, Ontario. Although this plant is still operative there has been no production during the past few years.

Production, Trade, and Consumption

Canada's salt production showed a gradual rise from 62,359 short tons in 1886, the earliest year of recorded production, to 969,887 short tons in 1954. The salt produced during this interval chiefly consisted of evaporated salt and salt in brine form for use by the chemical industry. Less than 10 per cent of the 1954 production was rock salt. However, the opening of the Ojibway rock salt mine in 1955, the Goderich and Pugwash mines in 1959, and the initiation of brine export to the United States in 1958, resulted in a dramatic increase, with production passing the 1 million ton mark in 1955, the 2 million ton mark in 1958, and the 3 million ton mark in 1959. Preliminary statistics show that 3,734,517 short tons of salt, valued at \$22,599,336, were produced in Canada in 1963. Today, production of rock salt, and salt in brine form for use by the chemical industry, far outranks evaporated salt production. In 1963, rock salt represented 48 per cent of the total output, salt in brine and chemical salt 39 per cent, and

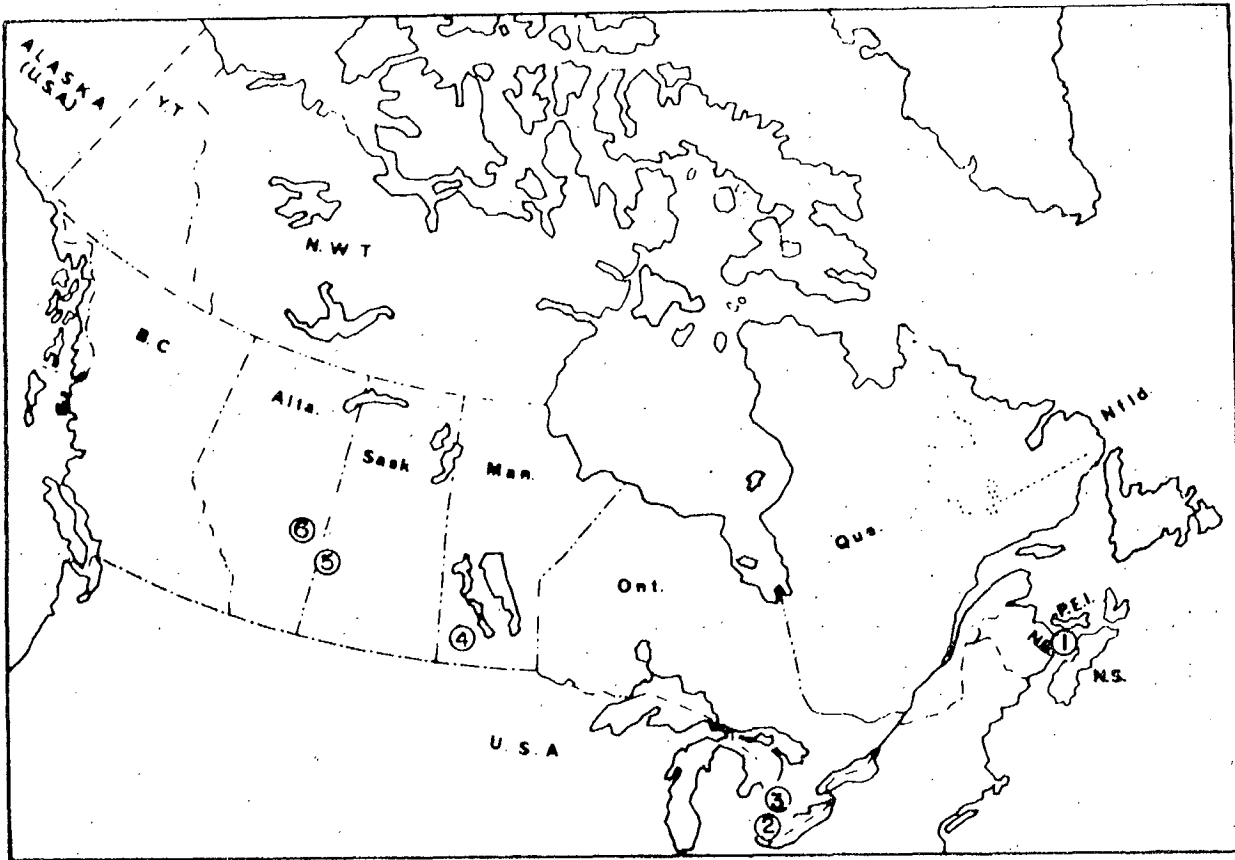


Figure 5 - Canadian Salt Operations, 1963.

EVAPORATOR PLANTS

1. Domtar Chemicals Limited, Sifto Salt Division, Nappan, N.S.
1. The Canadian Rock Salt Company Limited, Pugwash, N.S.
2. The Canadian Salt Company Limited, Sandwich, Ont.
2. Brunner Mond Canada, Limited, Amherstburg, Ont.
2. Domtar Chemicals Limited, Sifto Salt Division, Sarnia, Ont.
3. Domtar Chemicals Limited, Sifto Salt Division, Goderich, Ont.
4. The Canadian Salt Company Limited, Neepawa, Man.
5. Domtar Chemicals Limited, Sifto Salt Division, Unity, Sask.
6. The Canadian Salt Company Limited, Lindbergh, Alta.

FUSION PLANTS

2. The Canadian Salt Company Limited, Sandwich, Ont.
5. Domtar Chemicals Limited, Sifto Salt Division, Unity, Sask.
6. The Canadian Salt Company Limited, Lindbergh, Alta.

MINES

1. The Canadian Rock Salt Company Limited, Pugwash, N.S.
2. The Canadian Rock Salt Company Limited, Ojibway, Ont.
3. Domtar Chemicals Limited, Sifto Salt Division, Goderich, Ont.

fine evaporated salt 13 per cent of the total production.

Ontario, Canada's chief producing province, accounted for over 86 per cent of the total Canadian production of salt in 1963. Nova Scotia was the second largest producer, followed by Alberta, Saskatchewan, and Manitoba.

Only minor amounts of salt were exported from Canada prior to 1955; however, since that year exports have increased markedly. During the period 1955 to 1957, rock salt from the Ojibway mine in Ontario was the chief export. Export of salt in brine form, again from Ontario, was begun in 1958 and, in 1959, rock salt from the Goderich mine was added as an export item. Most of Canada's salt exports go to the United States. Indeed, in 1963 exports to that country represented 95 per cent of the total value of salt exported. Value of exports for that year was \$3,701,356. Recently there has been a trend towards increased export of salt from Nova Scotia, in particular to the West Indies, Central America, and points as far distant as New Zealand.

Canada at all times has had to import substantial quantities of salt to meet the needs of the Atlantic and Pacific coast fishing industry, the west coast chemical industry, and, until quite recently, the rock salt requirements of southern Ontario and Quebec. In 1954, imports reached a peak of 370,412 short tons. Since that year, and particularly since 1959, imports have declined, being partially replaced by rock salt from Canada's three producing mines. Imports in 1963 amounted to 332,581 short tons, valued at \$1,581,906.

The apparent consumption of salt in Canada exceeded production prior to 1956, being 200,000 to 300,000 short tons greater than production during the 10-year period preceding that year. However, although showing a steady increase as a result of increased use by the chemical industry and in ice and dust control on highways, consumption since 1956 has been well below production. In spite of this, Canada will continue to import salt for use by the fishing industry and, in particular, for the chemical industry of British Columbia. Per capita consumption of salt in Canada was in the order of 250 pounds in 1963.

The following graphs (Figures 6-8) and statistical tables (Tables 1-6) relate to Canadian production, trade and consumption of salt. Detailed statistics for 1962 and 1963 are included in Table 4. Source of the statistical information, in all cases, was the Dominion Bureau of Statistics, Ottawa.

FIGURE 6

Canadian Production of Salt

1886-1963

Thousands of Short Tons

4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0

1886 90 1900 10 20 30 40 50 60

Year

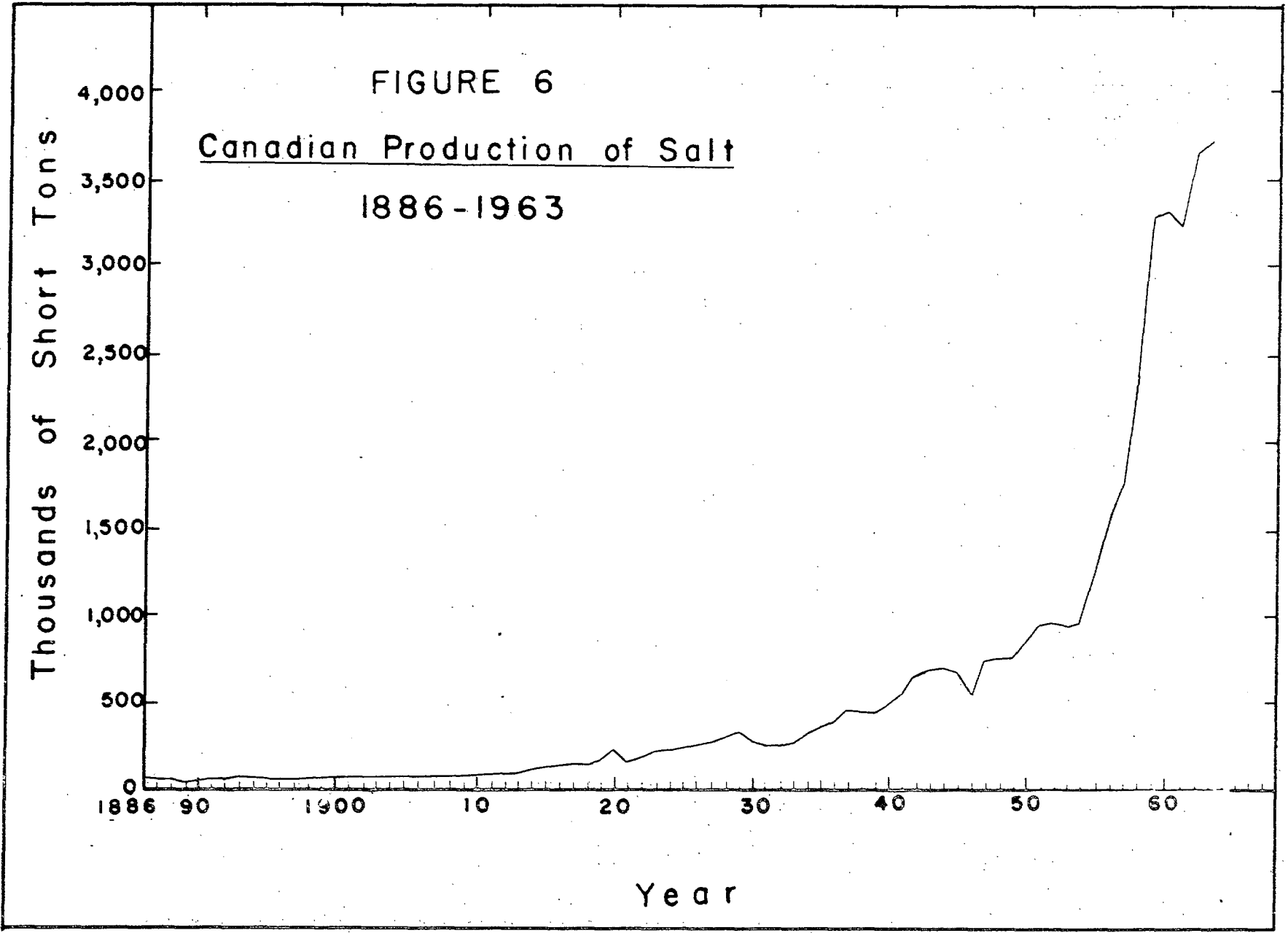


FIGURE 7

Canadian Production of Salt

By Types

1950-1963

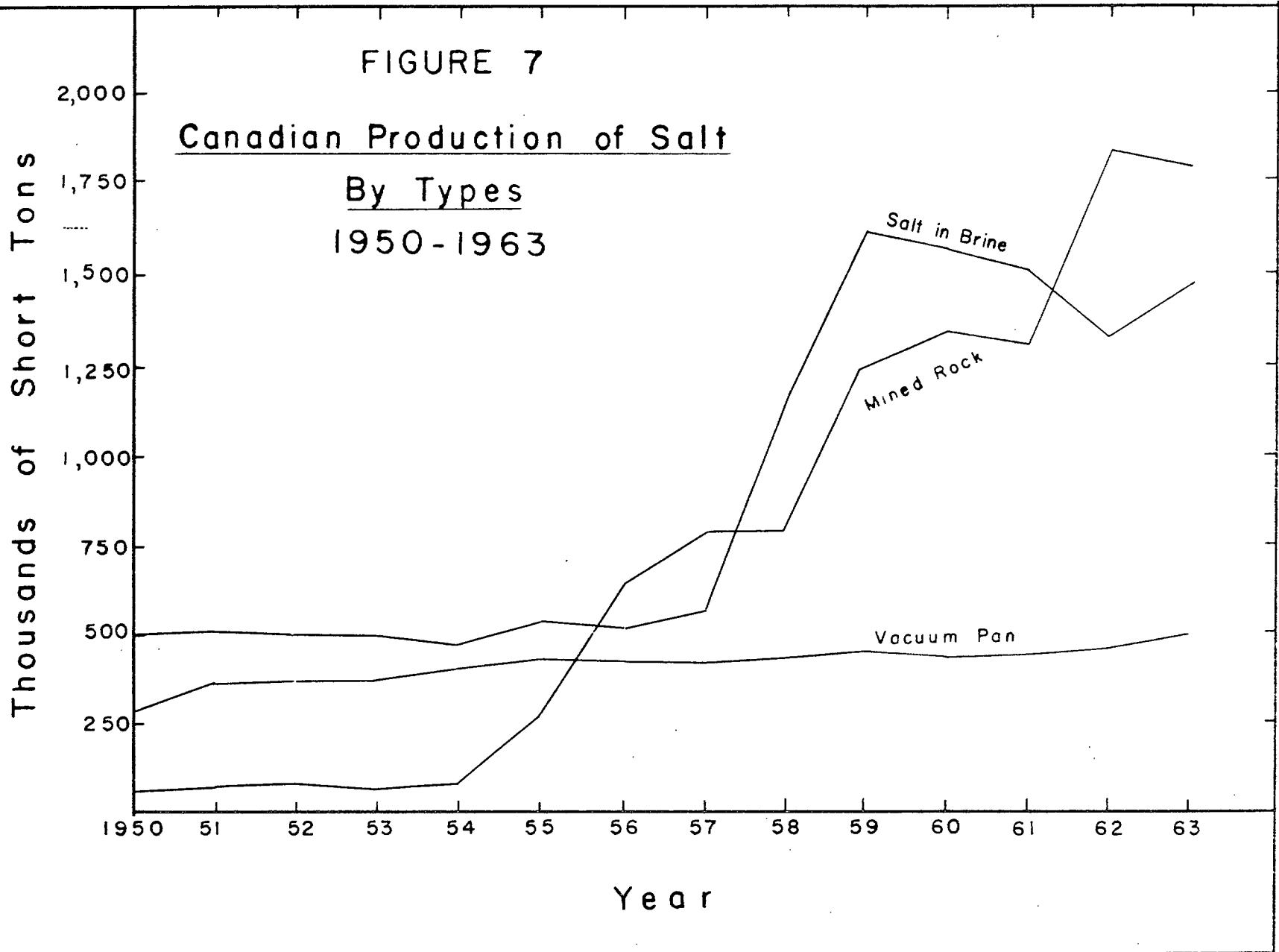


FIGURE 8

Canadian Production, Trade,
and
Apparent Consumption of Salt
1950-1963

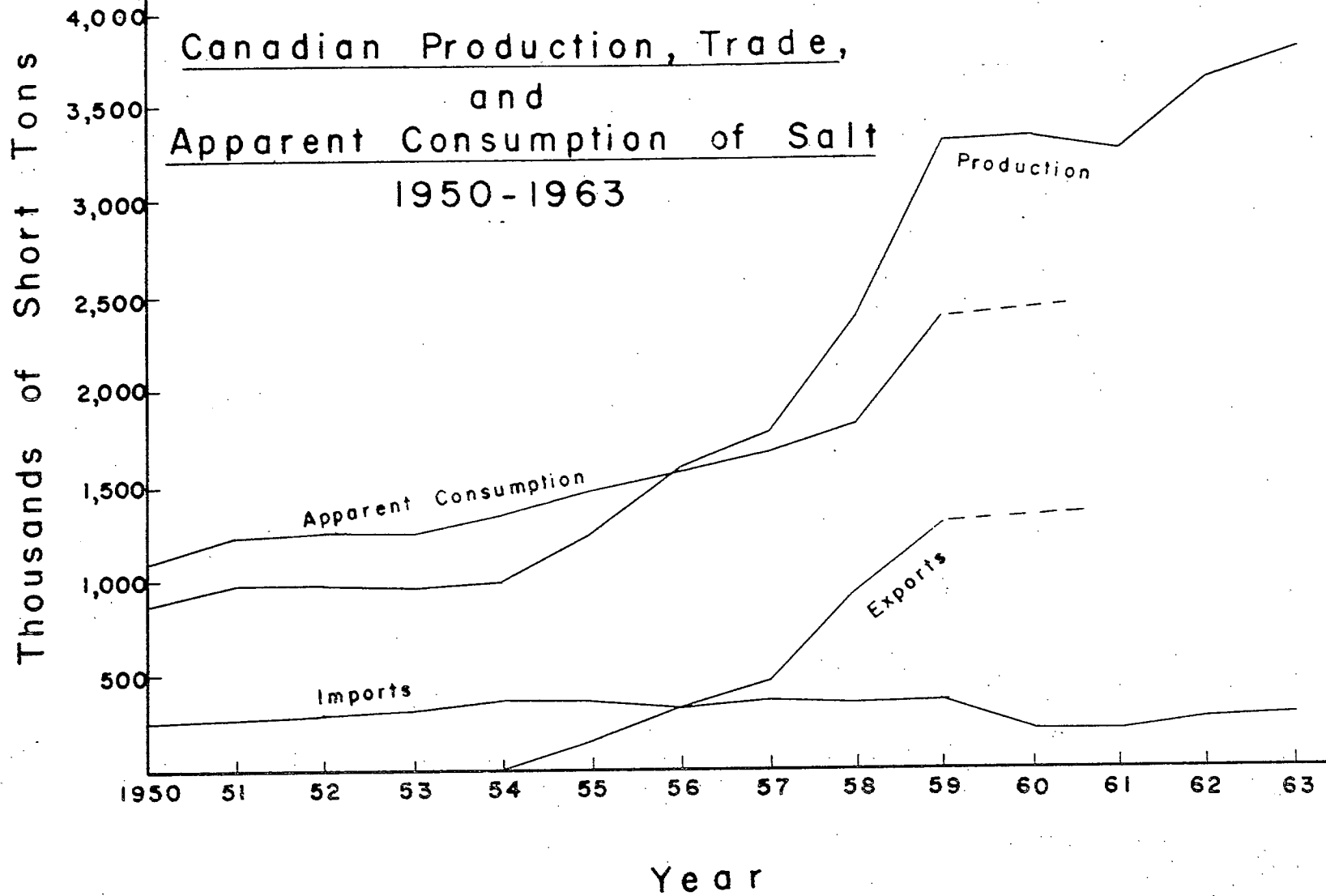


TABLE 1
Canadian Producers' Shipments of Salt, 1950 to 1963
 (Short tons)

By Province						
Year	N. S.	Ont.	Man.	Sask.	Alta.	Total
1950	101,930	696,582	16,592	18,186	25,606	858,896
1951	127,252	772,585	16,778	28,192	19,718	964,525
1952	138,845	757,025	18,113	33,540	24,380	971,903
1953	127,819	749,046	18,078	35,100	24,885	954,928
1954	150,589	733,066	17,809	37,227	31,196	969,887
1955	144,862	998,789	18,954	40,748	41,408	1,244,761
1956	132,539	1,347,729	21,068	42,814	46,654	1,590,804
1957	122,763	1,538,805	19,372	43,684	46,935	1,771,559
1958	125,872	2,126,483	20,560	46,511	55,766	2,375,192
1959	120,225	3,036,230	23,547	48,776	61,198	3,289,976
1960	163,901	3,007,599	21,925	49,064	72,431	3,314,920
1961	225,875	2,861,705	23,103	51,964	83,880	3,246,527
1962 (1)	312,519	3,155,589	25,010	54,931	90,729	3,638,778
1963	339,500	3,225,000	23,500	52,917	93,600	3,734,517

By Type					
Year	Mined Rock	Fine Vacuum (2)	Grainer	Chemical (3)	Total
1950	57,068	290,538	9,869	501,421	858,896
1951	74,812	373,094	7,784	508,835	964,525
1952	82,881	377,349	6,995	504,678	971,903
1953	70,510	375,928	4,934	503,556	954,928
1954	81,006	414,799	1,750	472,332	969,887
1955	267,984	430,327	1,142	545,308	1,244,761
1956	640,027	428,956	32	521,789	1,590,804
1957	786,975	422,977		561,607	1,771,559
1958	787,032	438,394		1,149,766	2,375,192
1959	1,221,999	459,857		1,608,120	3,289,976
1960	1,322,856	433,538		1,558,526	3,314,920
1961	1,294,988	446,712		1,504,827	3,246,527
1962 (1)	1,845,393	463,093		1,330,292	3,638,778
1963	1,776,510	488,101		1,469,906	3,734,517

(1) Preliminary, subject to change.

(2) Includes table, dairy, pressed block, as well as dry salt used by the chemical industry.

(3) Salt content of brine used by chemical industry mostly, but also includes some dry salt.

TABLE 2
Canadian Salt Imports, 1950 to 1963
 (Short tons)

By Type					
Year	Table (2)	Fishery	Bulk, n.o.p.	Bags and Barrels n.o.p.	Total
1950	-	57,580	157,753	22,906	238,239
1951	19	59,080	181,067	18,656	258,822
1952	32	69,549	183,641	34,903	288,125
1953	24	60,121	210,826	36,362	307,333
1954	24	58,745	270,802	40,841	370,412
1955	39	49,621	279,578	36,017	365,255
1956	45	58,985	242,133	17,961	319,124
1957	97	80,178	269,681	17,527	367,483
1958	41	56,977	267,424	16,445	340,887
1959	175	63,789	291,378	14,625	369,967
1960	751	65,100	115,919	10,170	191,940
1961	1,373	60,515	126,485	10,992	199,365
1962 (1)	1,188	47,672	185,961	11,015	245,836
1963	-	66,835	254,598	11,148	332,581

(1) Preliminary, subject to change.

(2) Imports of table salt not available as a separate class after 1962.
 n.o.p. - not otherwise provided for.

TABLE 3
Canadian Production, Imports, Exports and Apparent
 Consumption of Salt, 1950 to 1963
 (Short tons unless noted otherwise)

Year	Producers' Shipments	Imports	Exports (2)	Apparent Consumption (3)
1950	858,896	238,239	4,100	1,093,035
1951	964,525	258,822	4,561	1,218,786
1952	971,903	288,125	2,844	1,257,184
1953	954,928	307,333	2,354	1,259,907
1954	969,887	370,412	1,198	1,339,101
1955	1,244,761	365,255	146,472	1,463,544
1956	1,590,804	319,124	333,935	1,575,993
1957	1,771,559	367,483	457,888	1,681,154
1958	2,375,192	340,887	906,707	1,809,372
1959	3,289,976	369,967	1,274,077	2,385,866
1960	3,314,920	191,940	3,461,366	-
1961	3,246,527	199,365	2,829,138	-
1962 (1)	3,638,778	245,836	3,987,668	-
1963	3,734,517	332,581	3,701,356	-

(1) Preliminary, subject to change.

(2) Dollar value 1960 onward, export tonnages not available after 1959.

(3) Production plus imports less exports. Not available after 1959.

TABLE 4

Canadian Salt Production and Trade Statistics,
1962 and 1963

<u>Production (shipments)</u>	1962		1963 (1)	
	Short Tons	\$	Short Tons	\$
<u>By type</u>				
Fine vacuum salt	463,093	9,651,016	488,101	
Mine rock salt	1,845,393	10,391,050	1,776,510	
Salt recovered in chemical operations	25,926	118,606	25,395	
Salt content of brines used and shipped	1,304,366	1,766,463	1,444,511	
Total	3,638,778	21,927,135	3,734,517	22,599,336
<u>By province</u>				
Ontario	3,155,589	15,387,911	3,225,000	14,570,000
Nova Scotia	312,519	3,112,753	339,500	3,922,600
Alberta	90,729	1,454,462	93,600	1,468,900
Saskatchewan	54,931	1,337,471	52,917	2,031,536
Manitoba	25,010	634,538	23,500	606,300
Total	3,638,778	21,927,135	3,734,517	22,599,336
<u>Exports (2)</u>				
United States		3,919,662		3,510,854
New Zealand		22,461		55,121
Trinidad		986		39,311
Jamaica		11,409		37,811
British Guiana		387		21,206
Leeward and Windward Islands		6,612		10,889
British Honduras		3,052		7,066
Bermuda		5,773		5,693
Other countries		17,326		13,405
Total		3,987,668		3,701,356
<u>Imports</u>				
<u>By type</u>				
<u>Table (3)</u>				
United States	1,178	97,590		
Britain	10	175		
Total	1,188	97,765		

TABLE 4 (cont'd)

Canadian Salt Production and Trade Statistics,
1962 and 1963

<u>Imports</u>	1962		1963 (1)	
	Short Tons	\$	Short Tons	\$
By type				
<u>For Fisheries</u>				
Spain	36,376	132,264	39,970	143,800
Bahamas	3,920	20,580	18,985	128,136
Jamaica	4,521	15,346	5,578	22,090
Netherlands	40	760	90	1,817
United States	2,793	11,221	2,212	8,411
Britain	22	798	-	-
Total	47,672	180,969	66,835	304,254
<u>Other, in bulk</u>				
Mexico	100,091	123,042	99,263	119,621
United States	85,870	485,030	155,335	891,872
Total	185,961	608,072	254,598	1,011,493
<u>Other, in bags, barrels and other covering</u>				
United States	10,677	226,698	10,812	258,944
Britain	338	7,126	336	7,215
Total	11,015	233,824	11,148	266,159
Total imports	245,836	1,120,630	332,581	1,581,906
By province				
Newfoundland	32,715	121,193		
Nova Scotia	13,608	70,465		
New Brunswick	507	3,023		
Quebec	10,897	87,465		
Ontario	58,230	502,450		
Manitoba	1,379	25,915		
Saskatchewan	1,631	32,554		
Alberta	242	3,449		
British Columbia	126,627	274,116		
Total	245,836	1,120,630		

(1) Preliminary, subject to change. Production by type and provincial breakdown not available at time of writing.

(2) Tonnage by country not available.

(3) Imports of table salt not available as a separate class after 1962.

TABLE 5

Available Data on Consumption of Salt
in Specified Canadian Industries, 1961(1)

(Short tons)

Chemical products (dry salt and salt content of brine).....	1,228,757
Snow and ice control	550,000(2)
Food preparation	41,270
Slaughtering and meat-packing	60,535
Pulp and paper mills	48,494
Fish-processing	17,609
Leather tanneries	7,582
Soap and cleaning preparations	2,474
Dyeing and finishing textiles	714
Breweries	772

Source: Dominion Bureau of Statistics, Ottawa.

(1)The latest year for which all data are available.

(2)Estimate by Domtar Chemicals Limited.

TABLE 6

Tariffs

	British Preferential	Most Favoured Nation	General
Canada			
Fishery salt	free	free	free
Bulk salt	free	3¢ per 100 lb	5¢ per 100 lb
Salt in bags, barrels, etc. ..	free	3.5¢ per 100 lb	7.5¢ per 100 lb
Table salt	5%	10%	15%
United States			
Bulk salt		1.7¢ per 100 lb	
Salt in bags, barrels, etc. ..		3.5¢ per 100 lb	
Salt in brine		10% ad valorem	

WORLD PRODUCTION OF SALT

Salt production is carried on in most countries of the world although there are a few exceptions, notably Finland and the Scandinavian countries. Large rock salt deposits recently have been discovered in Denmark, but these have not yet been developed.

Production in the northern parts of the Northern Hemisphere is largely from underground deposits of salt and brine, whereas in the southern portions and in the Southern Hemisphere production is largely derived from sea water by solar evaporation.

The United States is the chief world producer of salt, followed by China, Russia, the United Kingdom, and West Germany. Canada ranked eighth as a world producer in 1962, accounting for about $3\frac{1}{2}$ per cent of the estimated total world production of 100.5 million tons. Table 7 lists most of the countries currently engaged in salt production, their production, and the relative positions of the twenty top producing countries for 1962.

TABLE 7
World Production of Salt, 1962 (1)
 Thousands of Short Tons

Country	Production	Chief Producers	
		Percent of World Production	Position as World Producer
North America and West Indies		33.4	
Canada	3,639 (2)	3.6	8
Mexico	660	0.7	17
United States (including Puerto Rico)	28,807	28.6	1
Bahamas	222 (2)		
Other	272		
Total	33,600 (2)		
South America		2.6	
Argentina	640 (2)	0.6	19
Brazil	1,284	1.3	15
Columbia	337		
Peru	103 (2)		
Venezuela	154 (2)		
Other	107		
Total	2,625 (2)		
Europe		39.0	
Austria	546 (2)	.5	
Bulgaria	139 (2)		
Czechoslovakia	207 (2)		
France	4,200 (2)	4.2	7
Germany			
East	2,200 (2)	2.2	11
West	5,428 (2)	5.4	5
Greece	132 (2)		
Italy	3,004 (2)	3.0	9
Netherlands	1,391	1.4	14
Poland	2,287 (2)	2.3	10
Portugal	294 (2)		
Roumania	1,470 (2)	1.5	13
Spain	1,760 (2)	1.8	12
Switzerland	185 (2)		
U.S.S.R.	9,000 (2)	9.0	3
United Kingdom	6,704 (2)	6.7	4
Yugoslavia	185 (2)		
Other	38		
Total	39,170 (2)		

- Cont'd

TABLE 7 (cont'd)

World Production of Salt, 1962 ⁽¹⁾

Thousands of Short Tons

Country	Production	Chief Producers	
		Percent of World Production	Position as World Producer
Asia		22.6	
Burma	172		
China	13,200 (2)	13.1	2
India	4,247 (2)	4.2	6
Indonesia	335		
Iran	160		
Japan	944	0.9	16
Korea			
North	440 (2)		
Republic of	428		
Pakistan	499		
Philippines	106		
Taiwan	656	.7	18
Thailand	220 (2)		
Turkey	475		
Viet-Nam, South	213 (2)		
Yemen	132 (2)		
Other	453 (2)		
Total	22,680 (2)		
Africa		1.9	
Algeria	144 (2)		
Ethiopia (including Eritrea)	191		
South Africa, Republic of	310		
Tunisia	175 (2)		
United Arab Republic (Egypt)	570 (2)	0.6	20
Other	520 (2)		
Total	1,910 (2)		
Oceania		0.5	
Australia	550 (2)		
Other	6 (2)		
Total	556 (2)		
Estimated World Total	100,541		

(1) Source - Salt, by Robert T. MacMillan, Preprint from Bureau of Mines Mineral Yearbook, 1962, United States Department of the Interior.

(2) Estimate.

RECENT DEVELOPMENTS

There have been several developments within the salt industry during the past 10 years which are of interest. A number of these, although not necessarily related to Canadian salt operations, are presented below under the headings Salt Brining, Underground Mining, Fine Salt Compaction, and Beneficiation of Rock Salt.

Salt Brining

One of the most interesting developments with respect to salt brining has been the development of techniques for connecting two or more adjacent wells. In single-well operation, raw water is pumped down the annulus between two concentric pipes to the salt, where it forms brine which in turn is brought to the surface through the inner pipe. The disadvantages of single-well operation are:

1. Considerable time is required to develop a cavity of sufficient size to maintain adequate production of saturated brine.
2. Cave-ins, although infrequent, can cause considerable damage and might cause a particular well to be abandoned.
3. Recovery of salt is low, generally less than 30 per cent of the total salt available in the area influenced by the brining operation.

The practice of using two or more interconnected wells is becoming increasingly common because it results in rapid brine saturation and a notable increase in the **recovery** of salt from a particular area as compared with single-well operations. Adjacent wells are connected by "hydrofracturing". This process consists of pumping water into one well under enough pressure to fracture the salt formation from this well to the next. When fracture is complete, the salt-saturated water rises to the surface and is recovered. In developing a brine field, holes or wells are usually laid out in a straight line on the surface at distances of 300 to 400 feet to form a gallery. Adjacent galleries are laid out parallel to the first at intervals of about 600 feet. Unfortunately the direction of fracturing cannot always be positively controlled; hence, fractures may sometime occur between holes in different galleries rather than between adjacent holes in the same gallery.

Underground Mining

Perhaps the most significant recent development in underground mining of rock salt has been the introduction of ammonium nitrate and fuel oil (AN-FO) for blasting. Although not yet adopted in Canadian salt mines, the use of AN-FO as a primary blasting agent is increasing in the United States.

The ammonium nitrate prills are coated with fuel oil in a special mixer, using a ratio of about 6 pounds of oil per 50 pounds of prills. They are then stored in plastic bags for up to 24 hours before using. The blast holes are bottom-loaded with a primer dynamite cartridge which contains an electric, millisecond delay cap. The coated prills are then blown into the hole through a plastic tube which is supplied from a pressurized prill container. Fragmentation is reported to be excellent and fewer holes are required per face than with dynamite.

Some concern has been expressed over the danger of a premature detonation because of static-electricity build-up. This is possible under certain conditions, but investigation has shown that the build-up of static electricity is negligible if the relative humidity is 70 per cent or over, as in most salt mines. Static-electricity build-up can also be reduced by grounding all parts of the system. The use of anti-static caps and electro-static voltmeters is a further guard against premature static spark detonation.

Fine Salt Compaction

One of the major problems encountered in rock salt mining operations is the excessive production of $-1/8$ inch fines. These fines, although useful as a source of salt for chemical purposes, have limited commercial application. Increasingly larger percentages of these fines are being reprocessed by brining followed by evaporation to form fine salt, and by pressing between smooth rolls to form a thin ribbon of salt, or briquette rolls to form salt briquettes. The compacted salt is then crushed and screened to give coarser, more useful, varieties.

Fine salt from evaporator plants also is pressed to form blocks or pellets, which in turn are crushed and screened to produce coarse salt. Coarse salt may also be produced from fine salt by fusion. The salt is melted at about 1500°F in large furnaces similar to those employed by the glass industry and the molten salt is discharged into conveyor-mounted metal briquette moulds, where it quickly hardens. The salt briquettes thus formed are crushed and screened to the desired sizes.

Beneficiation of Rock Salt

Fine salt produced by vacuum-pan evaporation of brine is relatively pure. Mined rock salt, although sometimes very pure, frequently contains such mineral impurities as gypsum, limestone, dolomite, etc. These impurities frequently occur intimately mixed throughout the salt horizon. Removal of these impurities is generally difficult, although a beneficiation method recently developed by International Salt Company of Cleveland, Ohio, and referred to as the thermo-adhesive method, shows great promise as a means of separating mineral impurities from rock salt. This separation technique is dependent upon the fact that pure salt crystals transmit infrared rays of a certain wave length, whereas gangue minerals absorb them and hence become heated. If salt containing gangue minerals is subjected to infrared rays prior to being discharged onto a conveyor belt coated with a heat-sensitive polystyrene resin, the gangue minerals, because they absorb heat,

will adhere to the belt, whereas the cooler salt crystals are not affected. The salt crystals are discharged at the end of the conveyor, but the gangue minerals continue to stick to the belt as it travels around the end roller and are removed from the cooler underside of the conveyor by a scraper.

An electronic sorter for upgrading the coarser grades of salt, recently developed by K and H Equipment Limited of Bancroft, Ontario, now is available from this company. This unit is based on the fact that some minerals, such as salt, are translucent and will allow light to pass through them whereas others, such as rock gypsum, are opaque and do not transmit light. The salt containing mineral impurities is fed in a thin stream between a light source and a light-sensing device by a vibrating feeder. The translucent salt particles are not affected by the light beam and fall through. Opaque, impure grains, on the other hand, interfere with the light beam and cause an electronic device to activate valves in an ejector bar located immediately below the light source. These valves release a short jet of high-pressure air that ejects the impure particles, deflecting them over a splitter and into a waste compartment. A Kand H electronic sorter installed at the Goderich plant of Domtar Chemicals Limited is currently used to upgrade salt for use in water softeners.

SELECTED BIBLIOGRAPHY

1. L.H. Cole, "The Salt Industry of Canada", Report No. 716, Mines Branch, Ottawa (1930).
2. Dana's Manual of Mineralogy, John Wiley & Sons, Inc., New York (1946).
3. D.W. Kaufmann, "Sodium Chloride", ACS Monograph Series, Reinhold Publishing Corporation, New York (1960).
4. S.W. Mudd Series, "Industrial Minerals and Rocks", The American Institute of Mining, Metallurgical and Petroleum Engineers, New York (1960).
5. J.B. Hamilton, "Salt in New Brunswick", Mineral Resource Report No. 1, Mines Branch, Department of Lands and Mines, Fredericton, New Brunswick (1961).
6. D.F. Hewitt, "Salt in Ontario", Industrial Minerals Report No. 6, Ontario Department of Mines, Toronto (1962).
7. R.T. MacMillan, "Salt", Preprint from Bureau of Mines Mineral Yearbook, United States Department of the Interior (1962).
8. W.J. Pearson, "Salt Deposits of Canada", Symposium on Salt, The Northern Ohio Geological Society, Inc., Cleveland, Ohio (1963).
9. L.P. Bush, "Developing Ammonium Nitrate-Fuel Oil Blasting at International Salt Company", Symposium on Salt, The Northern Ohio Geological Society, Inc., Cleveland, Ohio (1963).

10. R.B. Hopler and R.J. Shiel, "Ammonium Nitrate and its Application Underground", Symposium on Salt, The Northern Ohio Geological Society, Inc., Cleveland, Ohio (1963).
11. R.K. Collings, "Salt", The Canadian Mineral Industry, Department of Mines and Technical Surveys, Ottawa (1950 to 1963).
12. Booklet, "Salt Stabilized Roads", The Canadian Salt Company Limited, Montreal, Quebec. (Not dated)
13. Booklet, "Technical Analysis of Salt for Ice and Snow Removal", The Salt Institute, Chicago, Illinois. (Not dated)
