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DEPARTMENT OF MINES

GYPSUM IN ONTARIO

By

G. R. GUILLET

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GYPSUM IN ONTARIO

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ACKNOWLEDGMENTS

The author wishes to express his thanks to the personnel of the three operating gypsum companies: Canadian Gypsum Company Limited, Domtar Construction Materials Limited, and Western Gypsum Products Limited. Their willingness in providing access to their respective mines and plants, and in making available much information for this report, is greatly appreciated.

The author is indebted to B.V. Sanford of the Geological Survey of Canada for much information on Salina stratigraphy and the distribution of gypsum. Special thanks are also due to Bob Moore and George Cheena for their guidance to the gypsum deposits of the Moose River area; to T.E. Rowbottom and G.R. Hunt of Domtar Construction Materials Limited; and to V.A. McMurray of Moosonee Gypsum and Exploration Company Limited. The reports of R.K. Collings (1959) and D.F. Hewitt (1962) were freely consulted.

GLOSSARY

Explanatory Notes for Rock Descriptions

The rock descriptions given in this report adhere to the following classifications:

Crystallinity Classification

Coarse Crystalline	Over 5 millimetres.
Medium Crystalline	1-5 millimetres.
Fine Crystalline	0.2-1 millimetres.
Aphanitic	Under 0.2 millimetres; not detectable with the naked eye.
Microcrystalline	0.05-0.2 millimetres; aphanitic with crystals detectable under 10X hand lens (= lithographic).
Cryptocrystalline	Under 0.05 millimetres; individual crystals only detectable under microscopic examination (= lithographic).

Grain-Size Classification (Wentworth Classification For Clastic Fragments)

Boulder	Over 256 millimetres (or 10 1/8 ins.).
Cobble	64-256 millimetres (2½ - 10 1/8 ins.).
Pebble	4-64 millimetres (3/8 - 2½ ins.).
Granule	2-4 millimetres (3/16 - 3/8 ins.).
Very Coarse-Grained	1-2 millimetres.
Coarse-Grained	0.5-1 millimetres.
Medium-Grained	0.25-0.5 millimetres.
Fine-Grained	0.125-0.25 millimetres.
Very Fine-Grained	0.0625-0.125 millimetres.
Silt	0.004-0.0625 millimetres (settles rapidly in water).

Bedding Classification

Massive-Bedded	Beds over 36 inches thick.
Thick-Bedded	12-36 inches.
Medium-Bedded	4-12 inches.
Thin-Bedded	2-4 inches.
Very Thin-Bedded	½-2 inches.
Platy	1/16 - ½ inch.
Fissile	Less than 1/16 inch.

For the purposes of this report selenite is considered to be crystalline gypsum coarser than 1/8-inch (approximately 3 millimetres).

ANALYTICAL CALCULATIONS

In the testing of gypsum samples, a chemical analysis should include the following constituents:

- Free water
- Combined water
- Carbon dioxide, CO_2
- Silicon dioxide (SiO_2) and insoluble matter
- Iron and aluminum oxides, Fe_2O_3 and Al_2O_3
- Lime, CaO
- Magnesium oxide, MgO
- Sulphur trioxide, SO_3
- Sodium chloride, NaCl

Specification A82.20-1954, of the Canadian Standards Association, sets forth an approved method for calculating the molecular or mineral equivalents of the chemical analysis of gypsum plaster. The following procedures are adapted from this method. Steps (11)-(13) have been added by the author to apply specifically to the analysis of raw gypsum.

(1) Multiply the percentage of MgO by 2.0912 to find the percentage of $MgCO_3$.

(2) Multiply the percentage of MgO by 1.0914 to find the percentage of CO_2 as $MgCO_3$.

(3) Deduct CO_2 as $MgCO_3$ from the CO_2 determined.

(4) Multiply the CO_2 remaining by 2.2742 to find percentage of $CaCO_3$.

(5) Multiply the percentage of $CaCO_3$ by 0.56031 to find the percentage of CaO as $CaCO_3$.

(6) From the total percentage of CaO, deduct the percentage of CaO as $CaCO_3$. The remainder may be called "available CaO".

(7) The "available CaO" should bear to the SO_3 a ratio of 0.6991 to 1. Determine which (if either) is in excess.

(8) If the CaO is in excess, multiply the SO_3 by 0.6991, and subtract the result from the "available CaO". The remainder is reported as "excess CaO".

(9) If the SO_3 is in excess, multiply the "available CaO" by 1.4304 and subtract the result from the SO_3. The remainder is reported as "excess SO_3".

(10) Add together the "available CaO", and the SO_3, and subtract the "excess CaO" or "excess SO_3". The remainder is $CaSO_4$.

(11) Multiply the percentage of combined water by 4.7785 to find the percentage of gypsum ($CaSO_4 \cdot 2H_2O$).

(12) Multiply the percentage of gypsum by 0.7907 to find the percentage of $CaSO_4$ as gypsum.

(13) Deduct $CaSO_4$ as gypsum from the total $CaSO_4$ determined in (10), and report the difference, if any, as percent anhydrite ($CaSO_4$).

GYPSUM IN ONTARIO

By G.R. Guillet [1]

1 INTRODUCTION

Gypsum is a soft, light-coloured, mineral that has formed by precipitation from concentrated sea waters in lagoons and embayments along former ocean margins. In its pure form gypsum is white, but it may be grey, light brown, or pink due to impurities. It is commonly interlayered with thin laminae or beds of dolomite and shale.

Commercial gypsum deposits are usually massive and fine-crystalline. Alabaster is a compact massive variety suitable for art-sculpturing. Selenite is the transparent or translucent coarse-crystalline form of gypsum. Satin spar is a fine silky fibrous variety found in veins and joints, cross-oriented with respect to the walls. Impure earthy mixtures of gypsum, sand, and clay are referred to as gypsite.

Gypsum is the hydrous form of calcium sulphate, and has the chemical formula $CaSO_4.2H_2O$. The two molecules of water in its crystal structure are largely responsible for its commercial value. Three-quarters of this water can be driven off by heating at a low temperature. The $CaSO_4.\frac{1}{2}H_2O$ that remains is known as plaster of paris; when re-mixed with water it quickly sets to a hard rock-like mass. Anhydrite, $CaSO_4$, with which gypsum is frequently associated, has limited commercial value.

Gypsum plaster is largely consumed by the building industry in the form of plaster, lath, or wallboard in home construction.

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Raw gypsum is added in small amounts in the manufacture of Portland cement, to control the setting time of the cement. Of considerable importance historically, raw ground gypsum, known as land plaster, still finds some application as a soil conditioner.

Gypsum is widespread in the Salina Formation of Silurian age in south-central Ontario. It is also found in Devonian rocks of the James Bay Lowland, southwest of Moosonee.

The Salina Formation outcrops in a narrow belt parallel to and west of the Niagara escarpment, where it forms part of a southwesterly-dipping monocline of Paleozoic rocks. In the vicinity of its outcrop the formation is 300-400 feet thick. Gypsum occurs in a number of thin lenticular beds interbedded with dolomite and dolomitic shale. At depths greater than 200-300 feet anhydrite may predominate in some beds, but statistically gypsum is the most common form of calcium sulphate to depths of at least 1,000 feet. Further down dip in southwestern Ontario the Salina Formation may attain a thickness of 1,500 feet. Here, at depths from 1,500 to 2,700 feet gypsum is scarce, but beds of anhydrite are associated with great thicknesses of salt (Hewitt 1962).

In the James Bay Lowland gypsum outcrops along an arch of Devonian rocks extending north-westerly for 40 miles from the Precambrian escarpment south of Moosonee. The gypsum-limestone sequence, known as the Middle Abitibi River Formation, is 150-300 feet thick. Fine to medium-crystalline white gypsum is found in outcrops up to 25 feet high along some of the river banks, and drilling has proved the continuation of the gypsum to depths of 100 feet.

Gypsum is mined underground by room-and-pillar methods at two locations in the Salina Formation of south-central Ontario. Canadian Gypsum Company Limited mines a 4-foot bed at a depth of 90 feet near Hagersville. At Caledonia, 8 miles north of Hagersville, Domtar Construction Materials Limited mines an 8-foot bed at a depth of 75 feet. Both companies have calcining and wallboard-fabricating plants at the mine sites. In 1963 Western Gypsum Products Limited opened a plaster and wallboard plant at Clarkson, west of Toronto.

EVALUATION OF GYPSUM DEPOSITS

Gypsum deposits can be evaluated by normal economic and laboratory studies. The low unit value of gypsum does not permit an elaborate mining method or a distant haul to market. An open-pit operation within 100 miles of the principal market area would be ideal. Development of the high-quality Moose River area gypsum deposits is hampered by their remoteness from the southern Ontario market. Production from the gypsum deposits of south-central Ontario is hampered by the thin lenticular character of the beds and the necessity of underground mining.

Colour is perhaps the most important single property of gypsum. White gypsum can be used for all manufactured goods, whereas dark gypsum is suitable mainly for wallboard and cement. Particular note should be taken of soft shale, especially red shale, because of the discolouration it can cause to an otherwise white gypsum.

Texture is also an important consideration. A massive fine- or medium-grained "sugary" texture permits easy grinding. Selenite is difficult to grind because of its excellent platy cleavage; selenite fragments are thin, tabular, and flexible. Satin spar is almost as difficult to grind because of its fibrous habit.

Anhydrite is classed as an impurity because, without water in its molecular structure, it cannot be calcined to a plaster; gypsum containing more than 8 percent anhydrite does not make a good plaster. Salts, such as NaCl and various potassium salts, are deleterious and should be avoided. Calcium and magnesium carbonates can be tolerated in amounts up to 15-20 percent, and there is some evidence that wallboards made from such plasters have superior strength.

Sampling of gypsum beds is best done by channeling from top to bottom using a core drill or by hand-chipping. Because of the softness of the gypsum the writer found that the taking of samples was greatly facilitated by the use of a light axe; in this way a sample could be cut from the gypsum face or outcrop, where otherwise the rock simply absorbed the shock of the hammer.

Gypsum samples should be analysed chemically for free H_2O, combined H_2O, CO_2, SiO_2 and insoluble matter, Fe_2O_3 and Al_2O_3, CaO, MgO, SO_3, and NaCl. Specification A82.20-1954 of the Canadian Standards Association gives details of the chemical method, and outlines the accepted method for calculating the percentages of the principal minerals. Although the specification refers particularly to gypsum plaster (calcined gypsum) it can be applied to raw gypsum with slight modification. Some of the calculations commonly used are reproduced in the Glossary at the front of this report.

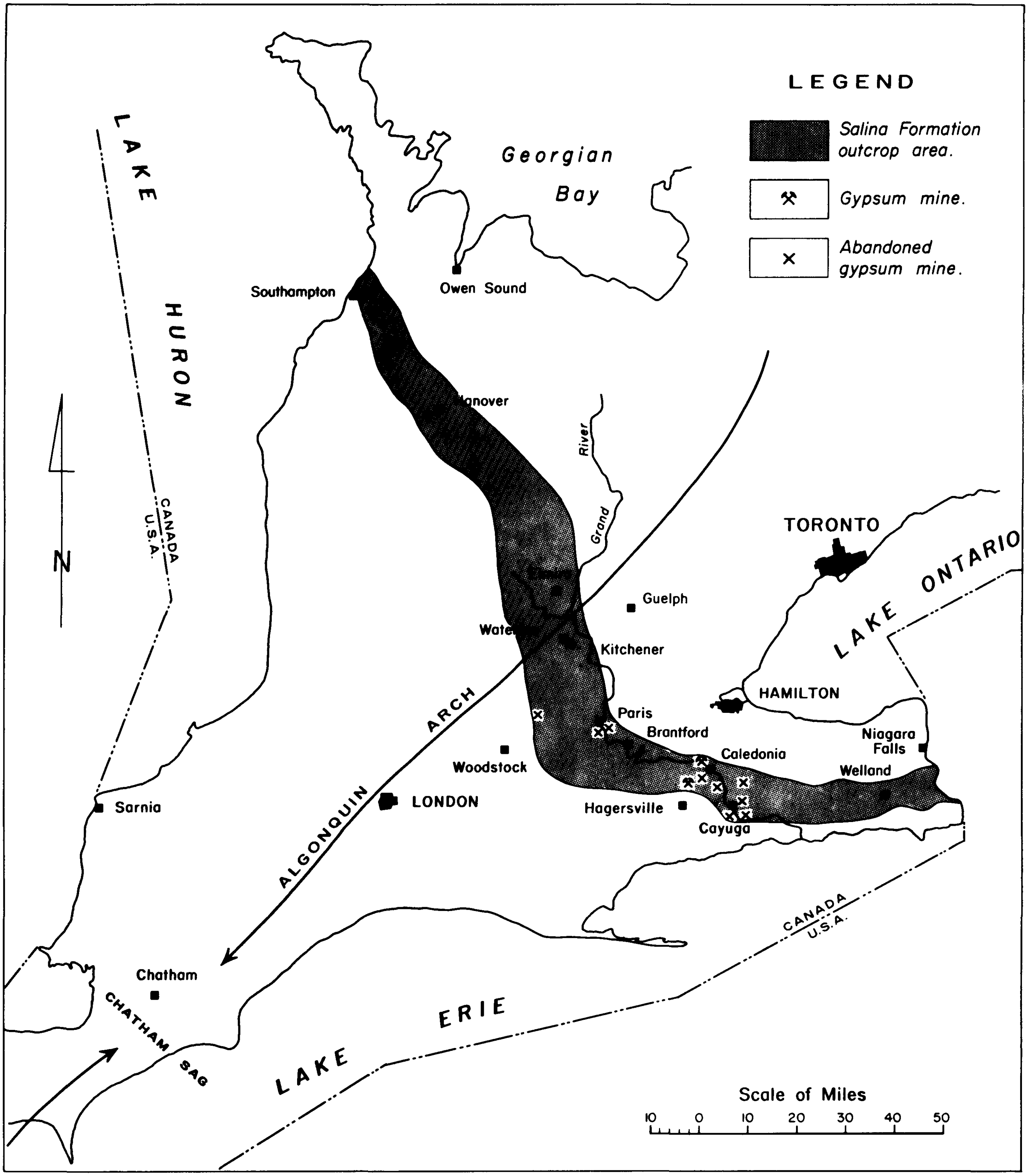


Figure I — The Salina outcrop belt in Ontario.

II GYPSUM IN SOUTH-CENTRAL ONTARIO

Gypsum occurs in thin beds in the Salina Formation of Silurian age. In Ontario the Salina Formation outcrops in a belt 10-35 miles wide that extends through south-central Ontario from the Niagara River to Lake Huron (Figure 1). The formation is present in the subsurface throughout southwestern Ontario, where it is noted for its great thicknesses of salt (Hewitt 1962). Salt is absent in the vicinity of the Salina outcrop belt, but lenticular beds of gypsum and anhydrite are present. In general the proportion of anhydrite to gypsum increases with depth, and below a depth of 200-300 feet beds in which anhydrite is predominant may be found. However, in a study of rock cuttings from oil and gas-well borings it was noted that gypsum is the most common form of calcium sulphate to depths of at least 1,000 feet.

All gypsum production in Ontario has come from mines near the Grand River, between Paris and Cayuga, in Brant and Haldimand counties. In recent years only two mines have been active, one at Caledonia, the other near Hagersville, but Cole (1915, p. 76) lists 14 locations from which gypsum has been produced.

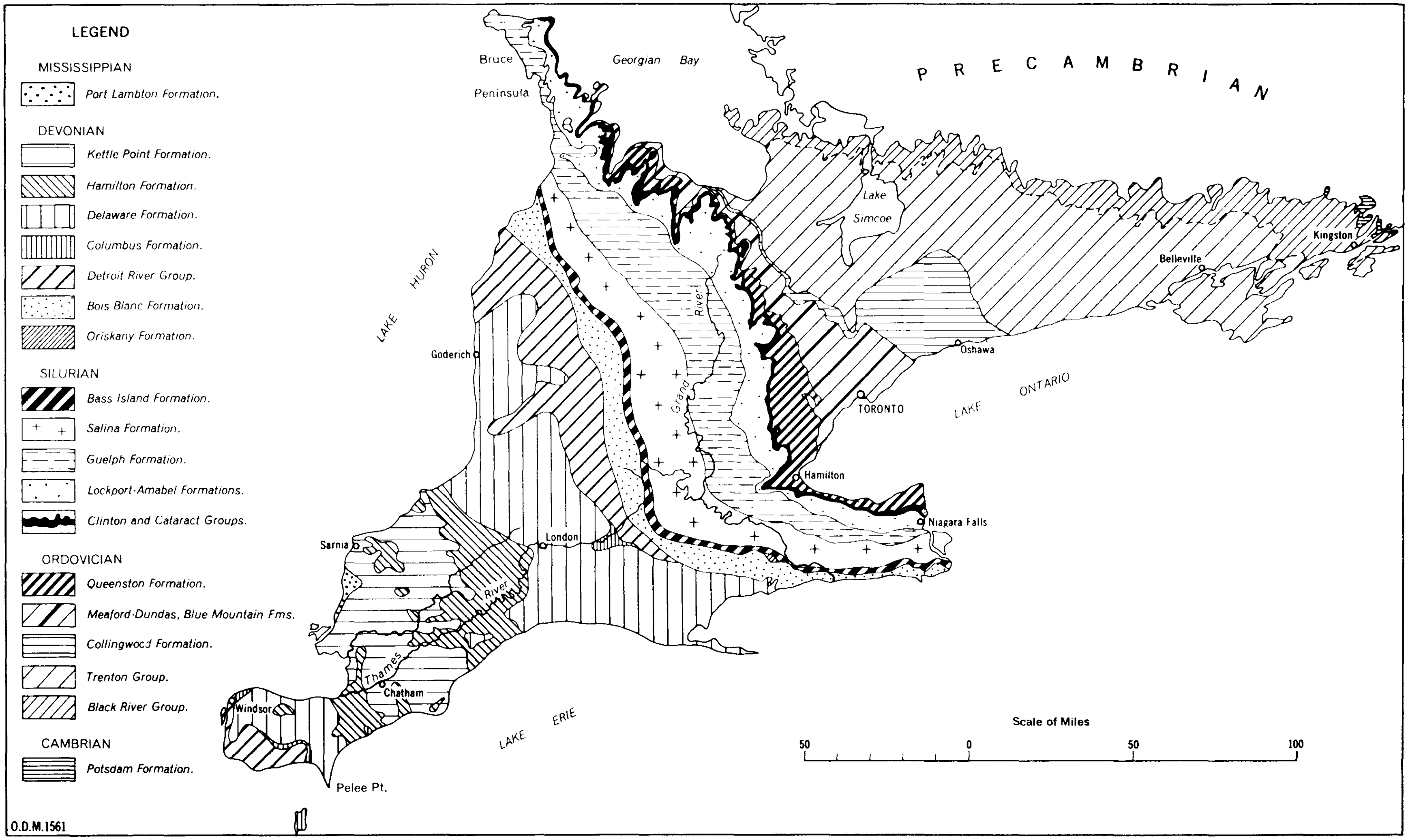


Figure 2 - Regional geology of southwestern Ontario
(after Geological Survey of Canada)

SALINA FORMATION

The geology of south-central Ontario is shown in Figure 2. The regional dip of the strata is about 30 feet per mile to the southwest. In early Salina time the Guelph-Lockport dolomite formed the rim of the Michigan and Appalachian basins (Figure 3). According to Briggs (1958, p. 46) the Michigan basin was connected with the Arctic seaway through a shallow gap near Georgian Bay. The Appalachian basin was connected to the Michigan basin through the Chatham sag in the Cincinnati-Algonquin arch. The gypsum deposits of Ontario and New York were deposited on the inner flank of the sill of Guelph-Lockport rocks that enclosed these basins on the east side.

Lithology

Figure 4 is a generalized columnar section for southwestern Ontario. The evaporites, salt and anhydrite, are extensively developed in the Salina Formation in this area. Near its outcrop belt the Salina Formation is thinner, salt is practically absent, and the anhydrite is largely altered to gypsum. The Salina Formation is described by Roliff (1949, pp. 159-61) as follows:

"The Salina formation lies between the Guelph-Lockport dolomites below, and the Bass Island series above, and consists of thin-bedded, fine-grained, gray, buff, and brown dolomites

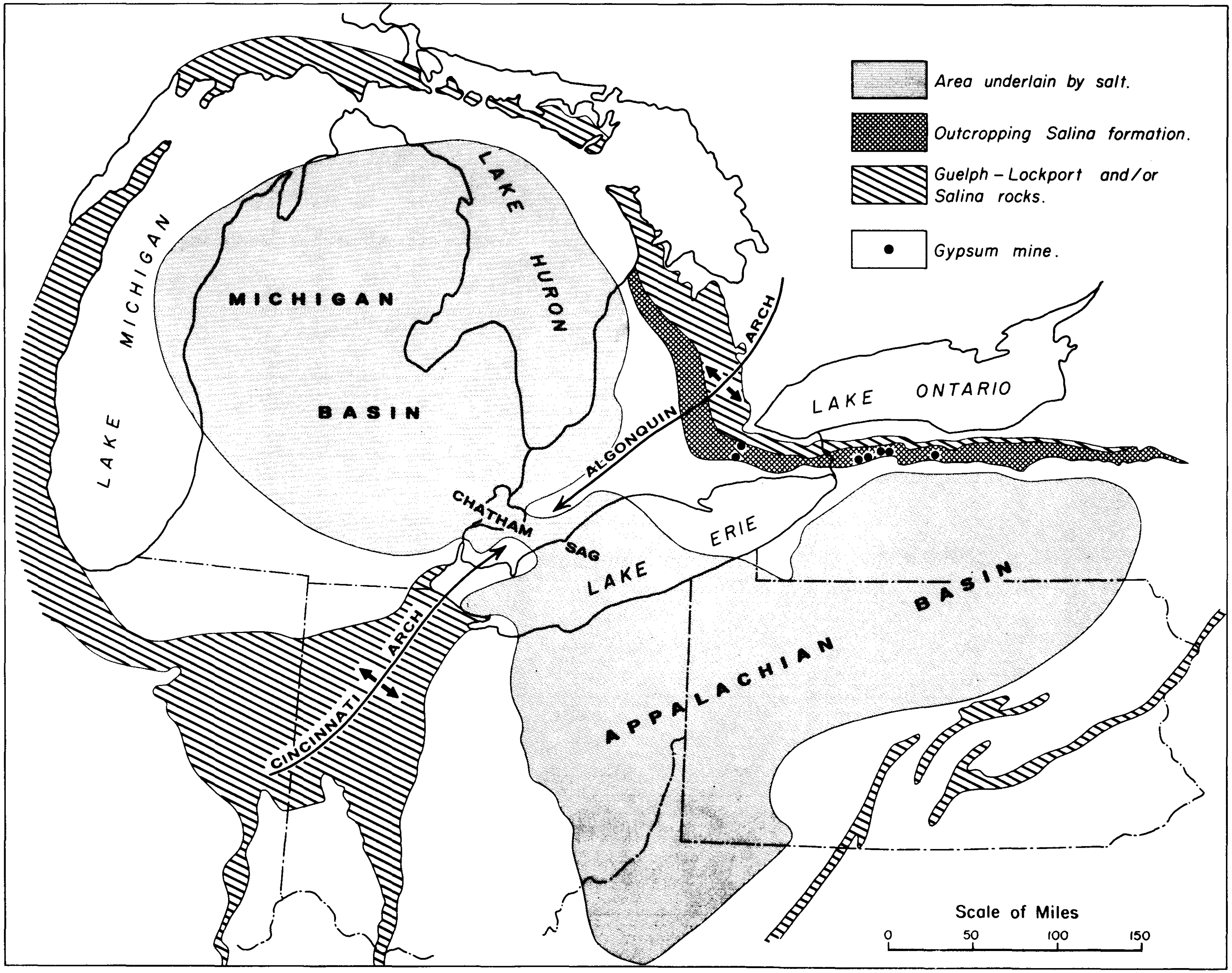


Figure 3 — The major evaporite basins in northeastern United States and Ontario.
After Roliff (1949), and Alling and Briggs (1961), with modification.

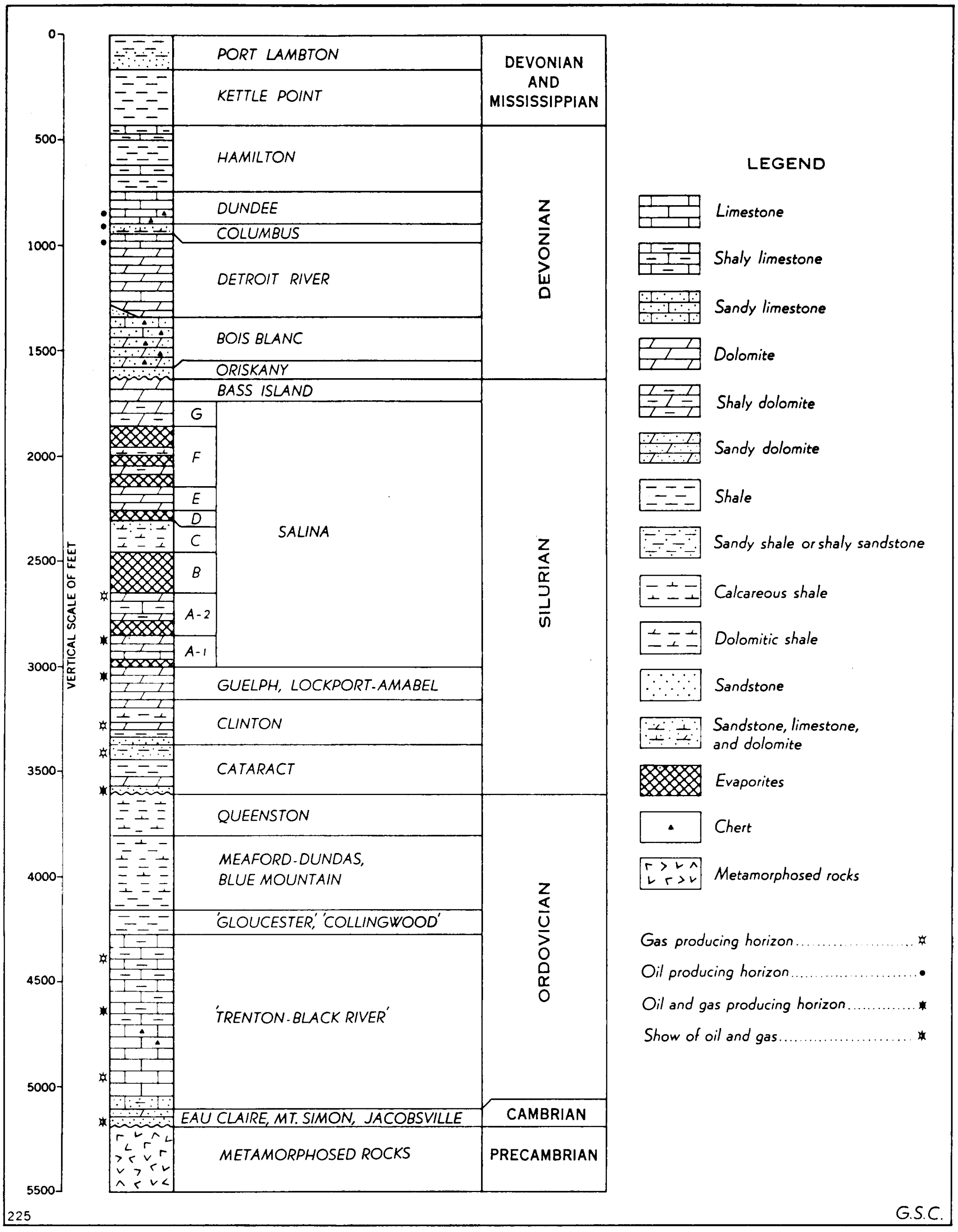


Figure 4 - Generalized geological columnar section for southwestern Ontario (after Geological Survey of Canada)

and limestones, shaly dolomites and limestones, dolomitic and calcareous shales, beds of gypsum and anhydrite, and in many places, beds of salt. There is practically no pure shale in the entire succession, and the dolomitic shale may, perhaps, be more accurately defined as an argillo-calcareous mud rock, the nearest approach to true shale being some thin zones of gray and greenish gray and reddish argillaceous rock in some wells in the southwestern part of the province, and in wells and outcrops in the Walkerton-Kincardine area. In general, the succession consists of alternating gray dolomitic shale or argillo-calcareous mud rock, and intervals of brown-colored fine-grained to dense dolomite, rarely with dark bituminous streaks, and commonly with thick beds of salt, particularly in the area west of London. Small quantities of white anhydrite and gypsum are present throughout practically the entire formation, although perhaps more prevalent in the gray shaly intervals."

Contacts

"It is difficult to fix definite and sharp demarcation between the Salina and the Guelph-Lockport below. In general, the base of the Salina is placed where there is a marked increase in size of grain to sugary-textured dolomites, from the dense shaly dolomites that lie below the lowest anhydrite bed of the Salina. Its relation to the Guelph-Lockport in general appears to be conformable, but locally at least, there is definite evidence of erosion at the end of Guelph-Lockport time. The top boundary of the Salina is placed just above the highest shaly dolomite containing anhydrite or gypsum. ..... in Haldimand and Welland counties, where the Akron-Bertie formations (regarded as equivalent to the Bass Island) crop out, these latter contain shaly strata near the base, and this similarity between basal Bass Island or Akron-Bertie beds and the uppermost Salina, makes the contact uncertain in the samples of many wells in this area."

Thickness

Grieve (1955, p. 12) describes the thickness of the Salina Formation as follows:

"The Salina formation increases in thickness in a northwesterly direction from as thin as 350 feet east of London, where no salt is present, to nearly 1,500 feet near Sarnia, where the aggregate thickness of the salt beds is approximately 700 feet."

Near the Salina outcrop belt, which marks the rim of the Michigan basin in Ontario, the Salina Formation is its thinnest. All units of the Salina Formation, except those of predominantly salt, are continuous, with little lithological change, from the centre of the basin onto the rim. The total thickness of the Salina Formation near its outcrop belt is remarkably constant. The range of thickness indicated by a typical borehole in each township is as follows:

SALINA FORMATION - RANGE OF THICKNESS

County	Thickness Min. (feet)	Thickness Max. (feet)
Welland	375	390
Haldimand	317	337
Norfolk	316	397
Oxford	370	510
Perth	415	589
Bruce	532	910

The thickness gradually increases westward down the dip of the formation. In the western portions of Perth and Bruce counties, the increased thickness marks the appearance of salt in the geological column.

Subdivision of the Salina Formation

Studies in Michigan have led to a subdivision of the Salina Formation into seven lithological units, designated A to G in ascending order (Landes 1945). This subdivision is illustrated for southwestern Ontario and the Niagara peninsula in Figure 5.

In the area adjacent to the Salina outcrop belt -- the area of most interest for gypsum -- the Salina Formation is much thinner, due principally to the disappearance of salt

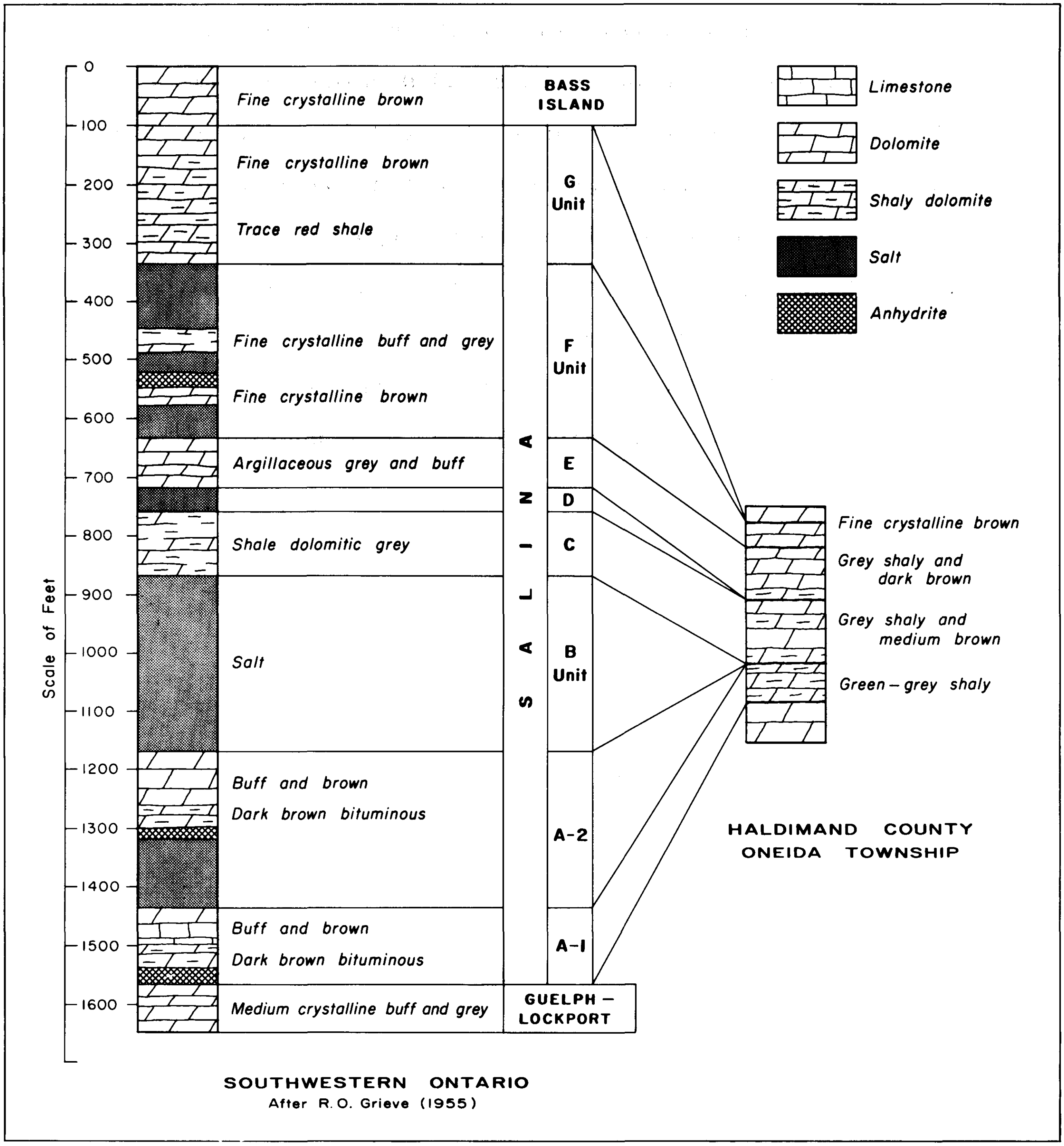


Figure 5 — Subdivision of the Salina Formation.

but also to a gradual thinning of the dolomitic beds eastward. All Salina units, except units B and D which are almost entirely salt, are represented, but units A-2 and G are often thin or absent immediately adjacent to the Salina outcrop belt. Figure 6 illustrates Salina subdivisions for typical columnar sections in each township along and adjacent to the Salina outcrop belt. The subdivisions were made by B.V. Sanford (personal communication) of the Geological Survey of Canada. Lithological descriptions for the subdivisions are given in the accompanying table.

SUBDIVISIONS OF THE SALINA AND ADJACENT FORMATIONS

Formation	Unit	Description
Bass Island		Fine crystalline medium and light brown dolomite.
Upper Salina	G	Fine crystalline grey-brown dolomite.
	F	Fine crystalline medium brown dolomite with minor interlayers of grey dolomite.
	E	Medium crystalline grey shaly dolomite; dense fine crystalline medium brown dolomite; gypsum and anhydrite.
	C	Dense fine crystalline medium brown dolomite interlayered with fine crystalline medium grey shaly dolomite; gypsum and anhydrite scarce.
Lower Salina	A-2	Fine crystalline dark grey to black shaly dolomite with minor dark brown dolomite; gypsum and anhydrite.
	A-1	Fine crystalline green-grey shaly dolomite interlayered with minor dense fine crystalline medium brown dolomite; gypsum and anhydrite common. Gypsum in upper 20-30 feet is pink.
Guelph-Lockport	C	Medium crystalline dark brown dolomite and green-grey shaly dolomite; gypsum and anhydrite.
	B	Medium crystalline buff, brown, and grey dolomite.
	A	Medium crystalline dark brown dolomite.

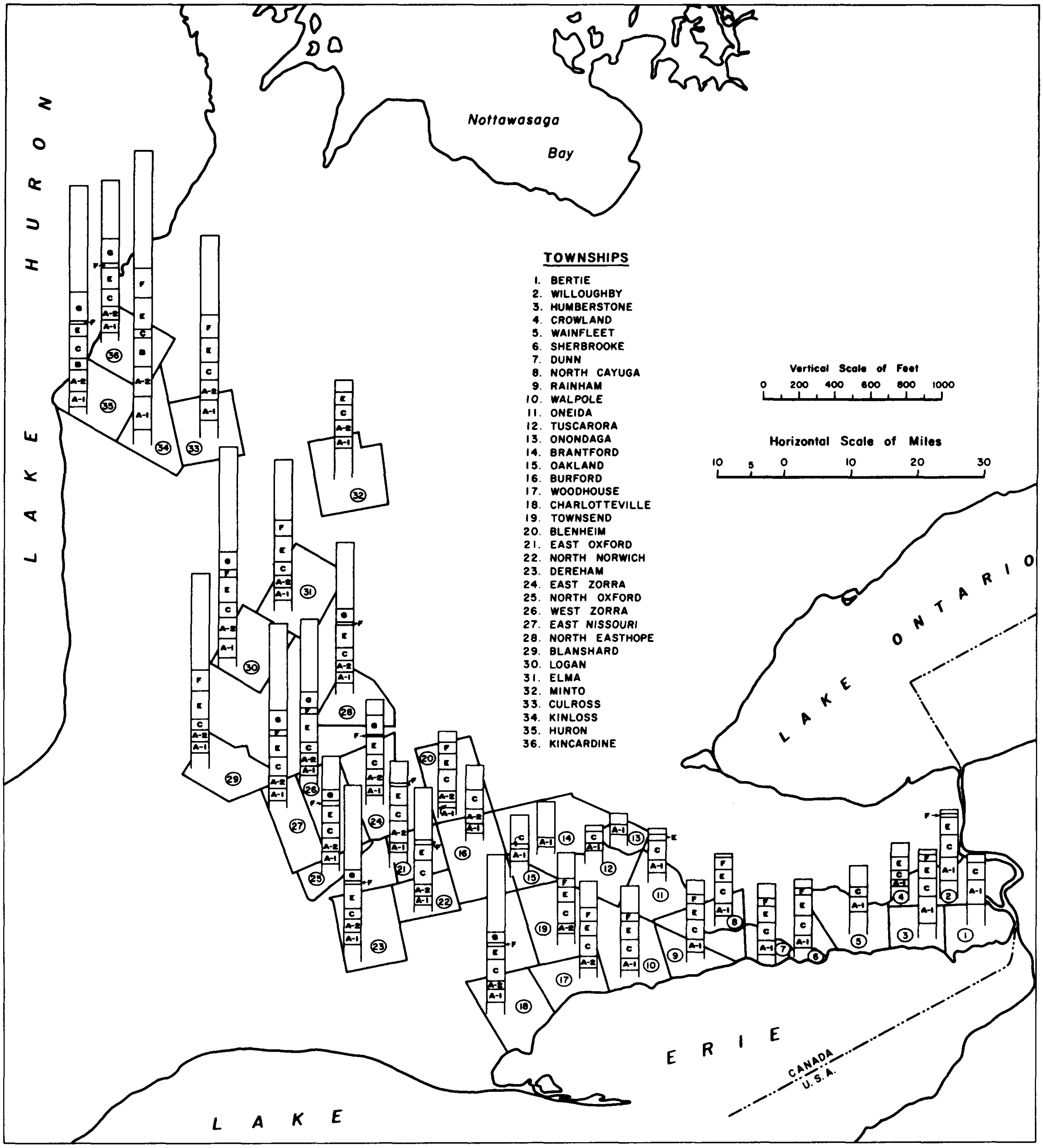


Figure 6 — Columnar sections showing subdivisions of the Salina Formation along or near its outcrop belt.

GYPSUM-ANHYDRITE, DEPOSITION AND DISTRIBUTION

The Evaporite Cycle

Because of the lithological similarities of evaporite deposits throughout the world and throughout geologic time, many of the physical and chemical conditions controlling their deposition are now fairly well understood. A great deal has been written on the subject of evaporite deposition, among which some of the more recent are papers by Briggs (1958), Douglas and Goodman (1957), Morris and Dickey (1957), Scruton (1953), and Sloss (1953).

It is generally agreed that a basin or lagoon with a restricted connection to the open sea is a necessary physical requirement for the deposition of salt and gypsum. The Michigan and Appalachian basins were apparently suitable structures in Salina time. Sea water of normal salinity is permitted to enter the basin. Provided there is no substantial outlet, evaporation increases its salinity. The denser more-saline waters sink, inhibiting their outward flow across the shallow rock sill or reef that separates the basin from the sea. As the salinity of the basin water increases, precipitation of the evaporites begins according to their order of solubility. According to Scruton (1953, p.2498) "When high concentrations are developed a strong horizontal salinity gradient exists which produces lateral segregation of different salts during precipitation." Anhydrite (or gypsum) is less soluble than salt and so is

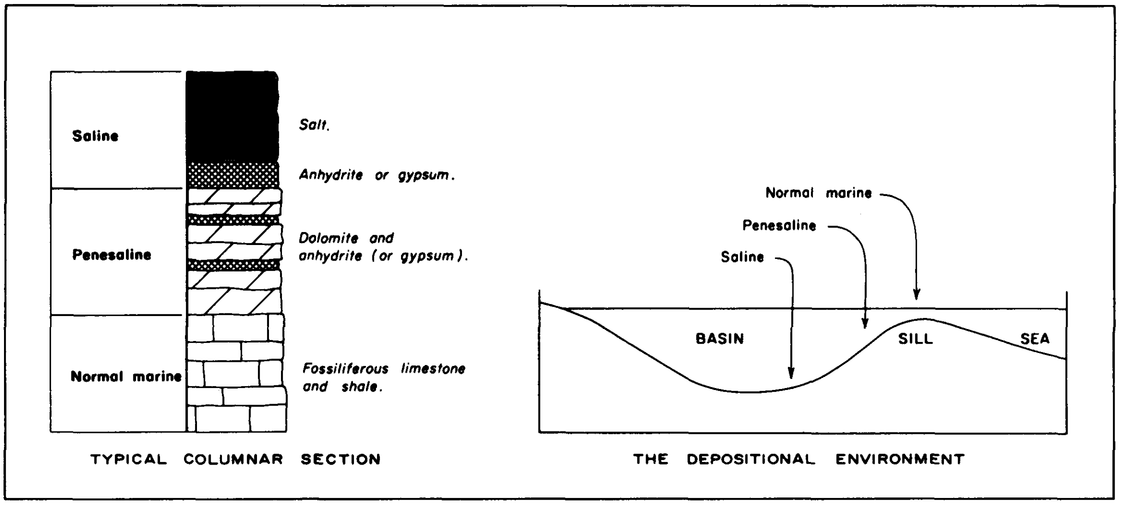


Figure 7 — The evaporite cycle. Modified from L. L. Sloss (1953).

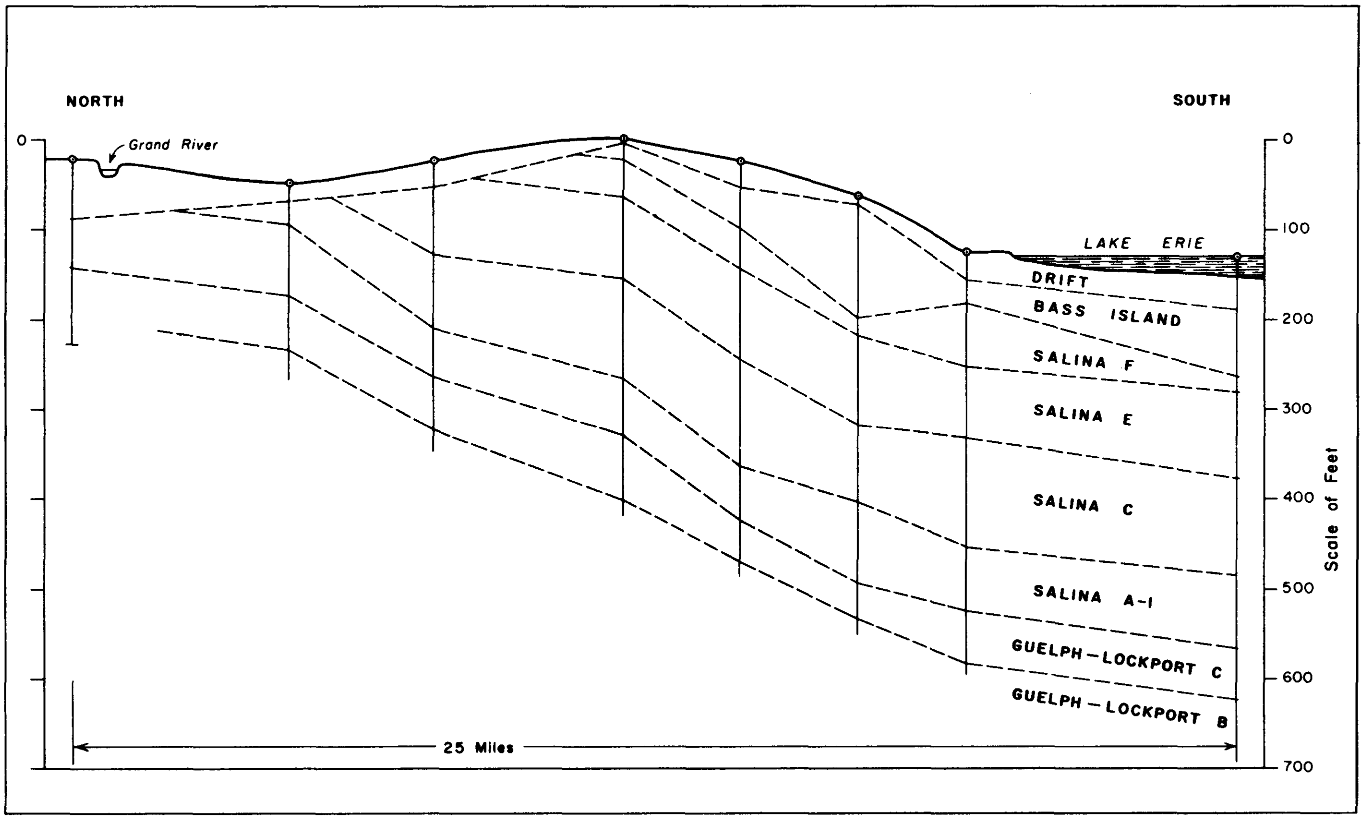


Figure 8 — North-south section; Oneida, North Cayuga, and Rainham townships, Haldimand county.

deposited first. Hence, deposition of anhydrite and gypsum will favour the less-saline waters of the basin margin. The normal evaporite cycle will follow the pattern indicated in Figure 7.

A description of salt in the Salina Formation of southwestern Ontario is the subject of a study by Hewitt (1962). According to B.V. Sanford (personal communication) salt was formerly more widespread in southwestern Ontario, extending for some distance east of London in gradually thinning beds. Most of this salt has been removed by leaching, but its former existence is marked by thin residues of clastic quartz and carbonate grains and by collapse breccias in the associated shale and carbonate rocks. However, there is little evidence that salt was ever deposited near the Salina outcrop belt.

Conditions governing the deposition of $CaSO_4$ have been studied by Posnjak (1940, pp. 247-272). He demonstrates that anhydrite rather than gypsum will precipitate above 42°C. regardless of the NaCl concentration of the brine. If sea water has an NaCl concentration of 4.8 times normal at 30°C., then anhydrite will be deposited instead of gypsum.

DISTRIBUTION OF GYPSUM AND ANHYDRITE

A study of rock particles recovered from the drilling of oil and gas wells is a useful way of tracing gypsum distribution. Of the many thousands of borings made for oil and gas in southwestern Ontario, more than 4,600 are represented by samples of the rock cuttings preserved at the Geological Survey of Canada. Individual samples commonly represent sections 5-10 feet in length. A catalogue of holes has been prepared by B.V. Sanford (1964); it includes all borings for which sample cuttings are available to June 1963. The collections are available for study at 601 Booth Street, Ottawa.

The author examined cuttings from all the borings made in the Salina outcrop belt and the adjacent area to the west down the dip of the formation to a depth of 800-1,000 feet. The greatest number of borings are in the counties bordering Lake Erie. Borings in the counties to the north are widely scattered and few in number. The number of borings examined in each of the counties along or adjacent to the Salina outcrop belt from south to north is indicated below. Holes drilled offshore in Lake Erie were not examined.

Number of Boreholes for which Sample Cuttings are available

County	Number of Borings Examined
Welland	39
Haldimand	175
Norfolk	229
Brant	53
Oxford	129
Waterloo	8
Perth	19
Wellington	2
Bruce	18
	672

Gypsum is present in minor amounts in the A-1 and E units of the Salina Formation in practically all borings examined. It is also sometimes present in the C unit of the Salina Formation, and occasionally also in the top unit of the Guelph-Lockport Formation. Typically it is dispersed through these units in amounts of less than 10 percent, but local concentrations of gypsum fragments may indicate the presence of significant gypsum seams. A list of the sections in which gypsum comprises more than 10 percent of the rock fragments will be found in Appendix I of this report.

The occurrence of gypsum in the top unit of the Guelph-Lockport Formation may be of secondary origin, the result of leaching and migration of Salina gypsum. However, B.V. Sanford of the Geological Survey of Canada suggests (personal communication) that it may represent primary deposition from lagoonal waters in late Guelph time.

The colour of the gypsum is normally white or pale shades of buff and grey. It contrasts well with the dark brown and green-grey dolomites, and is therefore easy to identify in the drillhole cuttings. Pink gypsum in the amount of 10-15 percent is a fairly constant feature of the upper 30 feet of the A-1 unit. Anhydrite can usually be recognized by its denser texture and translucent blue-grey colour.

There is no well-defined transition point at which anhydrite is replaced by gypsum. In a general way it is probably true that the proportion of anhydrite to gypsum increases with depth, but down to the maximum depths examined (1,300 feet) gypsum is predominant. Although the intimate association of the two minerals is an established fact, one or the other is always greatly predominant at any given point in any one bed; in a gypsum bed the proportion of anhydrite seldom exceeds 10 percent, and visa versa. However, any one bed may be predominantly gypsum at one point but change over a short distance laterally to become predominantly anhydrite. The study of drill cuttings indicates a typical sequence of four to six gypsum or anhydrite beds distributed through the Salina geological column. It is common for an anhydrite bed to be succeeded at depth by one or more gypsum beds. Beds composed predominantly of anhydrite occur at depths as shallow as 225 feet.

In addition to the notes that follow, L.H. Cole (1913, pp. 59-62) gives some information on the occurrence and distribution of gypsum beds in Brant and Haldimand counties, based on drilling during or before 1911. W.S. Dyer (1925, pp. 45-48) also gives an account of gypsum occurrences, principally for the Brant-Haldimand area.

Welland County

The Salina Formation is the bedrock for much of the southern part of Welland county. An examination of oil and gas-well cuttings in Bertie, Humberstone, and Wainfleet townships indicates some concentration of gypsum at depths of 120-150 feet and 230-270 feet. In lot 4, concession III NR, Bertie township, gypsum comprises 35 percent of the rock cuttings for the section 140-150 feet. In lot 31, concession III, Wainfleet township gypsum comprises about 30 percent in both of the sections 160-180 feet and 220-230 feet.

Haldimand County

The Salina Formation is the bedrock for the north half of Haldimand county. To the south the Salina rocks are overlain by the Bass Island dolomite and the Bois Blanc limestone. Most of the gypsum produced in Ontario has come from the townships of Seneca, Oneida, and North Cayuga, in the northwest part of the county.

Borings for oil and gas are especially numerous in Walpole and Rainham townships, and gypsum is common in many of the Salina sections. In Rainham township, concentrations of gypsum are noted at three horizons: - the top one at a depth of about 160 feet in the north part of the township, deepening to 190 feet in the south; the middle one at 190 feet in the north, 230 feet in the south; the third varying from 350 feet to 380 feet from north to south. Anhydrite is common in the middle horizon near the centre of the township. In lot 2, concession VI, Rainham township, fragments of massive white gypsum comprise 40 percent of the rock cuttings representing the section 198-211 feet. The same bed occurs on lot 9, concession VI, where massive white gypsum comprises 20 percent of the section 180-190 feet.

In Walpole township there appear to be at least five horizons where gypsum is concentrated. From top to bottom they are at depths of: - 115 feet in the north part of the township, deepening to 210 feet in the south; 180 feet in the north, 240 feet in the south; 270-290 feet restricted to the southern part of the township (Anhydrite is common in this seam); 260 feet in the north, 320 feet in the south; 360 feet in the north, 400 feet in the south.

Although small concentrations of gypsum fragments were present in the cuttings from most of the borings made between Caledonia and Hagersville on the west side of Oneida township, gypsum was not present in the amounts that might have been expected considering the mining activity in the area. Three main gypsum horizons were noted: - the first at a depth of 60 feet in the northwest part of the township, deepening to 100 feet in the southwest; the second ranging in depth from 130 feet in the northwest to 180 feet in the south; the third at a depth of 170-200 feet.

Gypsum was not common in drillhole cuttings from the eastern part of the county. Only one horizon of significant gypsum concentration was noted. In Seneca township and near the north boundary of North Cayuga township a small concentration of gypsum was noted at depths varying from 60 to 110 feet. In the southern part of North Cayuga township it is 160-180 feet deep, and near the Lake Erie shore in South Cayuga, Dunn, and Sherbrooke townships it varies from 190 to 230 feet deep. Significant amounts of gypsum are scarce in drillhole cuttings from Moulton and Canborough townships.

Brant County

Drilling information is scarce for all of Brant county except in the northwest corner of Burford township. Much of the drilling along the Grand River in Onondaga and Tuscarora townships is old, and the cuttings have not been saved. During the early years of gypsum mining in Ontario a number of small mines were opened in outcropping gypsum seams in the banks of the Grand River.

The Salina Formation is the bedrock for most of Brant county, and the northern parts of the townships of Onondaga, Brantford, and South Dumfries are north of the lower Salina contact. In the southern part of Brantford township several local concentrations of gypsum are present in the zone between

225 feet and 275 feet. Rock cuttings from the drilling in the northwest corner of Burford township show small gypsum concentrations at depths of 225-250 feet, 275-290 feet, 360-375 feet, and 430-450 feet. A single hole in Oakland township indicated several small gypsum concentrations at a depth of 200-230 feet. Only a few holes in Onondaga township showed minor concentrations of gypsum; these are in the zone 115-130 feet. However, the sample representing the section 63-73 feet in lot 17, concession III WFC, was estimated to be 90 percent gypsum. Of the several holes available for study from Tuscarora township, one near the Grand River showed some concentration of gypsum at a depth of 80-100 feet. Near the centre of Tuscarora township gypsum is slightly concentrated between 200 feet and 220 feet.

Norfolk County

Norfolk county lies almost completely south of the Salina outcrop belt. Borings for oil and gas have been extensive, but sample cuttings were examined for only those in the north half of the county where depths to the Salina Formation are not excessive. Gypsum is seldom absent from the cuttings, and anhydrite is locally common in the deeper sections.

In Charlotteville township at least four sections in which gypsum is slightly concentrated are found at depths of 500-600 feet. Anhydrite may predominate in some of the lower sections. In lot 18, concession V, massive white gypsum comprises 60 percent of the section 533-547 feet. In Middleton township small concentrations of gypsum were noted at several depths in the zone 500-800 feet. Anhydrite was predominant in some sections. Drilling information is largely confined to the southern half of Townsend township. Sections showing slight concentration of gypsum are present at 180-190 feet, 240-260 feet, 280-300 feet, 310-340 feet, 400-420 feet, and 470-490 feet. Anhydrite may occur in any section below 240 feet, but it normally does not predominate. Drilling in Windham township is also largely confined to the south half. Several small concentrations of gypsum occur in the zone 390-470 feet, and others are occasionally found to depths of 800 feet. Anhydrite sometimes predominates below 420 feet. In lot 9, concession IX, Windham township massive white gypsum comprises 50 percent of the section 245-260 feet. In Woodhouse township slight gypsum concentrations are noted at 230-245 feet, 270-290 feet, 300-320 feet, and 405-425 feet. Anhydrite occasionally predominates below 300 feet.

Oxford County

Only Blenheim township lies within the Salina outcrop belt; in the western part of Oxford county the depth to the first gypsum bed exceeds 500 feet. Borings for gas and oil throughout the county are widely scattered and few in number.

Information obtained from a study of the cuttings from the only three holes available in the southern half of Blandford township indicates some concentration of gypsum at depths of 200-210 feet, 385-405 feet, and 530-540 feet. Drilling in Blenheim township is confined to the southwest corner; some concentration of gypsum is noted at 230-240 feet, 270-290 feet, 300-320 feet, and 330-345 feet. In the southwest corner of Dereham township slight concentration of gypsum is noted at 580-600 feet, 620-650 feet, 740-780 feet, and 880-885 feet. Anhydrite is sometimes common in the lower two sections. In the north part of East Nissouri township the main gypsum concentrations evident in the three holes examined are at 540-550 feet and 610-640 feet. A single hole in the northeast part of North Norwich township indicates some concentration of gypsum at depths of 190-200 feet, 220-240 feet, and 485-495 feet. In South Norwich township gypsum concentrations are noted at 370-390 feet, 410-430 feet, 560-580 feet, and 620-640 feet. Anhydrite sometimes predominates below a depth of 600 feet. Several inconsistent gypsum concentrations are noted in the zone 330-610 feet in North Oxford township. In West Oxford township some concentration of gypsum occurs at depths of 410-430 feet, 470-490 feet, and 560-580 feet. White massive gypsum comprises 30 percent of the section 477-491 feet on lot 12,concession I,West Oxford township. Little information is available for East and West Zorra townships. One hole in East Zorra indicates slight concentration of gypsum at 368-375 feet and 411-419 feet. A single hole in West Zorra indicates small gypsum concentrations at 568-598 feet, 638-644 feet, and 680-688 feet. Anhydrite is locally common in the bottom section.

Northward Continuation of the Gypsum Beds

In the northern counties, along or adjacent to the Salina outcrop belt, drilling information is very scarce. In Waterloo county no significant concentration of gypsum was noted in the few holes available for study; these were principally in the vicinity of Kitchener and in Wilmot township. However, Waterloo county is largely underlain by Salina rocks, and the negative results from the few holes available should not discourage exploration for gypsum particularly in the western half of the county.

Perth county lies west of, and adjacent to, the Salina outcrop belt. The few widely scattered borings available for study indicate that local concentrations of gypsum occur throughout the county, but that depths become excessive in the western part. In Blanshard township several small concentrations of gypsum were noted below 600 feet; anhydrite is predominant at 800 feet. Two holes near the centre of North Easthope township have slight concentrations of gypsum at depths of 435-440 feet, 520-525 feet, and 660-675 feet.

In Elma township a single hole in the south-central part indicates some concentration of gypsum at 570-580 feet, 645-650 feet, and 815-820 feet. Several concentrations of gypsum were also noted in Logan township between the depths of 700 and 1,300 feet.

The west part of Wellington county is underlain by Salina rocks but there are no test borings available for study.

A number of widely scattered holes in Bruce county indicate the continuation of gypsum to the shore of Lake Huron. At Kincardine the section 920-930 feet is 40 percent gypsum and 940-950 feet is 60 percent gypsum.

CHARACTERISTICS OF THE GYPSUM BEDS

Gypsum beds in the Grand River area are thin and discontinuous. Miller (1904, p. 52) describes them as follows, and points out an interesting topographic feature that may have guided early, near-surface, mining.

"The beds of gypsum are never continuous for long distances, but appear as detached lenticular or dome-like masses; the strata above them being arched over and often broken, while those below constitute an even undisturbed floor. The gypsum is interstratified with the dolomite, and often separated by beds of it. The layers of gypsum may sometimes extend for a quarter of a mile, but they have always been found, on working, to be lenticular in form, and to gradually thin out, until the strata above and below the masses come in contact. This peculiar structure gives rise to mounds on the surface, which are regarded by the inhabitants as indicative of the presence of gypsum beneath."

The gypsum is fine-grained, sugary-textured, structurally massive, and white to light brown or grey in colour. It is intimately interlayered with fine-crystalline brown dolomite, or greenish-grey shaly dolomite, which may occur in distinct beds or in thin discontinuous wavy laminae. Layers of pure gypsum range from paper-thin laminae to layers up to several inches in thickness; the thicker ones commonly consist of massive botryoidal swellings that are veined and outlined by paper-thin dolomite laminae. These colloform gypsum structures appear to be secondary in origin; they may have developed by the volume increase attendant with the conversion of anhydrite to gypsum.

A typical gypsum bed is composed of alternating layers of gypsum and shale or dolomite; where gypsum comprises at least three-quarters of the section the bed may be of economic interest. The bed is rarely sharply defined; rather it grades into dolomite or shaly dolomite by a progressive increase in the number or thickness of these impure layers. Detailed descriptions of the gypsum beds at Caledonia and Hagersville are given in a later section, under descriptions of the two companies presently engaged in mining at these locations.

III GYPSUM IN THE MOOSE RIVER BASIN

The most striking occurrences of gypsum in Ontario are the river-bank outcrops of massive white gypsum found along the Moose and Cheepash rivers 40 miles southwest of Moosonee. These occurrences were first mentioned by Robert Bell (1877, p. 321). Detailed descriptions of the Moose River outcrops, and an area known as Gypsum Mountain, are given by J.M. Bell (1904, pp. 156-9). An excellent report on the mineral resources of the Moose River basin by W.S. Dyer contains a general description of the several gypsum outcrop areas (Dyer 1929, pp. 39-44). There has been no commercial production of gypsum from these deposits.

GEOLOGY OF THE JAMES BAY LOWLAND

The area drained by the Moose River and its tributaries the Missinaibi, Mattagami, Abitibi, French, and Cheepash rivers, lies in the southeast corner of the Paleozoic basin that forms the James Bay lowland. Outcropping areas of the Paleozoic rocks overlap, and are progressively younger, from northwest to southeast. They appear to be truncated against Precambrian rocks that form an escarpment-like rim along the southeast side of the basin. The escarpment has been inferred as a fault plane at least over part of its length (Martison 1953, p. 52).

The geology of the James Bay lowland is described by Martison (1953); Figure 9 shows the bedrock geology as shown

FIG.9 — GEOLOGY OF THE JAMES BAY LOWLAND

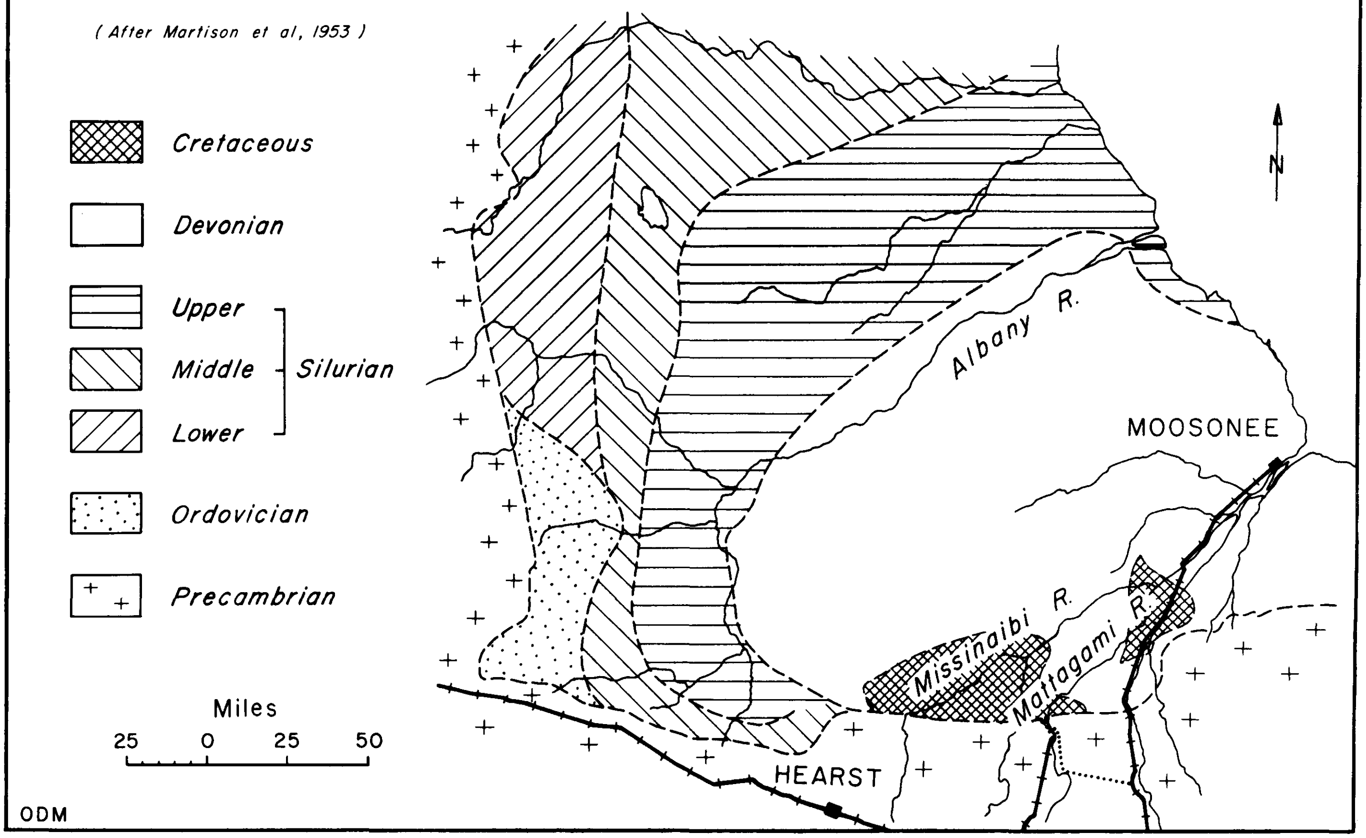
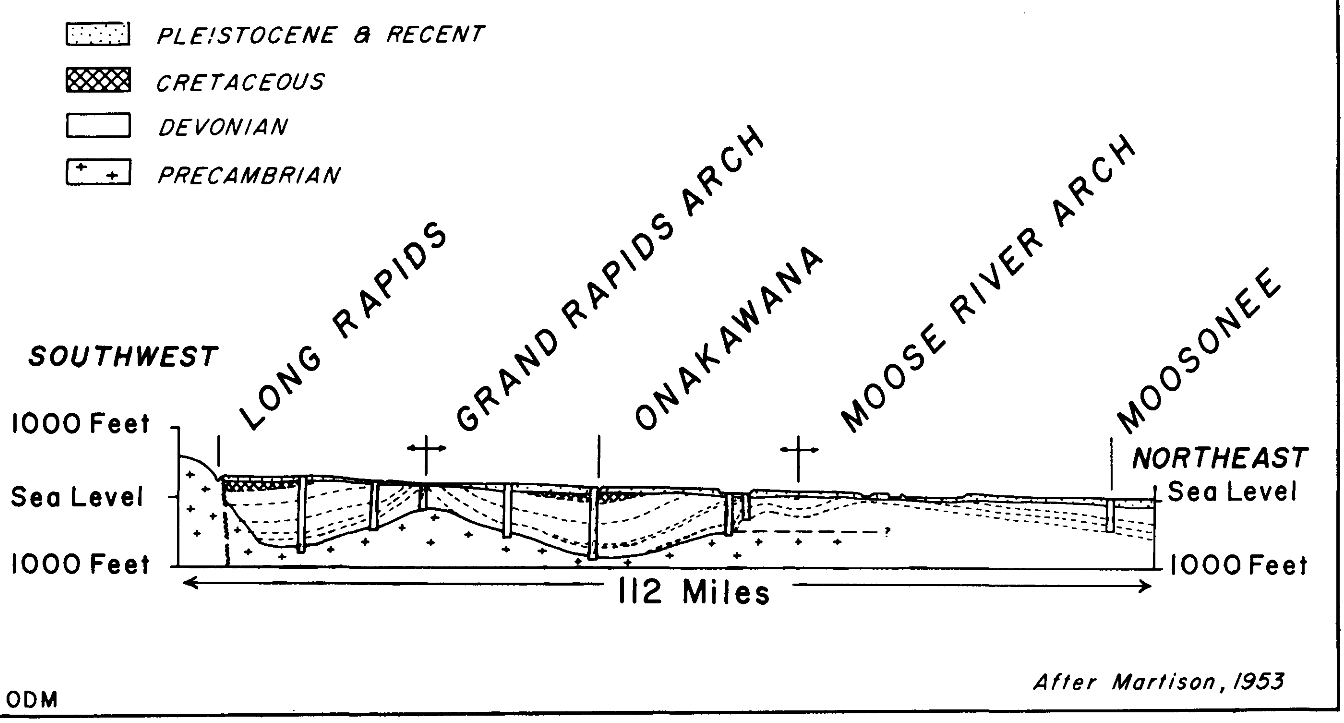


Fig. 10 — Northeast — Southwest Structure Section — MOOSE RIVER BASIN



on map no. 1952-3 which accompanies Martison's report. A generalized structure section along the line of the Moose River is shown in Figure 10. Gentle arching of the sedimentary sequence has been caused by buried Precambrian ridges at Grand Rapids on the Mattagami River and in the vicinity of Moose River Crossing. These northwesterly-trending anticlines are marked by low-angle dips in an otherwise flat-lying sedimentary sequence.

The Paleozoic rocks of the James Bay lowland include limestones, shales, and sandstones of Ordovician, Silurian, and Devonian age. In the Moose River basin several thin remnants of Mesozoic rock rest without angular unconformity on Devonian shales. The Mesozoic rocks, believed to be Lower Cretaceous in age, consist of lenticular beds of kaolin-bearing quartz sand, fireclay, and lignite. Severe glacial gouging during the Pleistocene, followed by marine inundation, has left a thick mantle of till, clay, and gravel. The retreating waters of James Bay have left a poorly-drained, muskeg-covered coastal plain, on which bedrock is practically restricted to the banks of the major rivers. Small lamprophyre dikes of post-Middle Devonian age (Martison 1953, p. 52) are widely scattered east of the Moose River.

In 1949-50 the Ontario Department of Mines drilled three holes to investigate the sedimentary sequence in the James Bay lowland. One hole drilled at Campbell Lake, between the Mattagami and Missinaibi Rivers, 10 miles north of the granite escarpment, reached the Precambrian basement at a depth of 1,025 feet. A hole at Puskwuche Point on the James Bay shore, 35 miles north of Moosonee, reached Precambrian rocks at 1,529 feet. The third hole was drilled at Jaab Lake, 100 miles west of the James Bay shore and 75 miles north of the granite rim; it was abandoned in Silurian rocks at a depth of 1,810 feet. A generalized columnar section based principally on the logs of these holes is illustrated in Figure 11. Detailed logs are given by N. Hogg, J. Satterly, and A.E. Wilson (Martison 1953, pp. 115-40).

Abitibi River Formation

Although gypsum occurs at intervals throughout much of the Paleozoic sequence of the James Bay lowland (see Figure 11), the occurrences of most interest belong to the Abitibi River Formation of Middle Devonian age. The Abitibi River Formation comprises upper, middle, and lower members. Gypsum of the middle member outcrops along the Moose River arch in the banks of the Cheepash, Moose, and French Rivers, and in an outcropping above the muskeg known as Gypsum Mountain.

The greatest thickness of Abitibi River rocks was intersected in the Jaab Lake drillhole (Hogg, Satterly, and Wilson 1953, p. 124) between 273 and 975 feet. The 702-foot section is reproduced below:

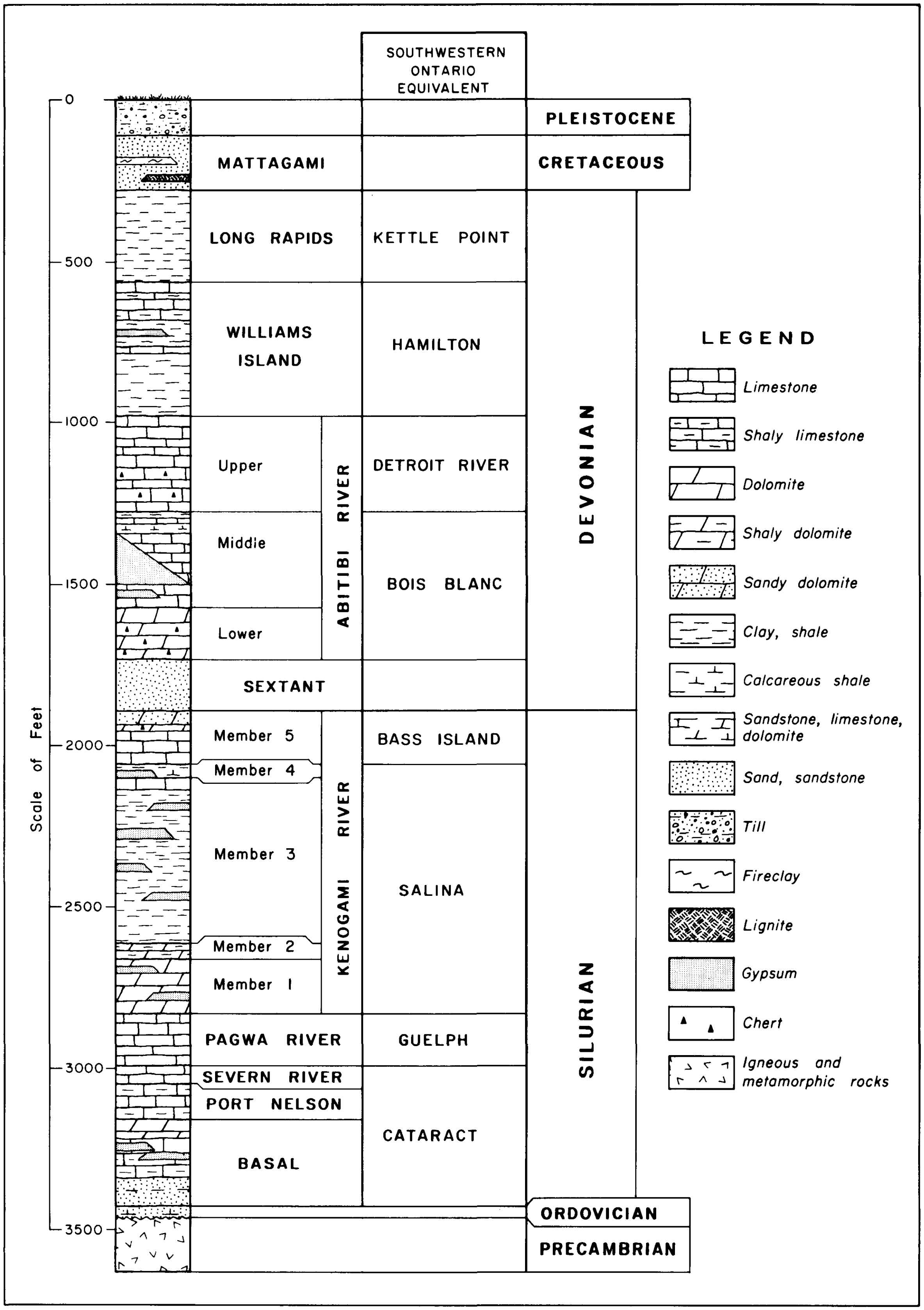


Figure 11 — Generalized columnar geological section for the James Bay Lowland.

Abitibi River Formation

		Thickness (feet)
Upper member	Pale-brown, fine-grained limestone	46
	Thinly-bedded, dark-brown limestone	46
	Pale-brown crinoidal limestone	35
	Buff limestone	175
Middle member	Grey and buff limestone	225
	Grey limestone with chert	14
Lower member	Argillaceous limestone	2
	Grey dolomite with chert	154
	Brown limestone	5

The Abitibi River Formation is overlain by interbedded limestone and soft clay-shale of the Williams Island Formation. The contact is clearly marked by the change in lithology and increased fossil content of the upper Abitibi River member. In the northern part of the Moose River basin the lower member appears to be absent and the middle member rests directly on green and red conglomerate and sandstone of the Sextant Formation. Most of the clastic fragments that comprise the Sextant rocks were derived from the Precambrian basement on which the Sextant lies. The lower member of the Abitibi River Formation occurs west of the Moose River basin where it overlies member 5 of the Silurian Kenogami River Formation. The contact is an erosion surface, and the sudden occurrence of black bituminous streaks is diagnostic for the upper buff and grey Kenogami River limestones (Hogg, Satterly, and Wilson 1953, p. 137).

Upper Member

The upper member of the Abitibi River Formation outcrops along the lower reaches of the Kwataboahegan and French rivers in the northern part of the Moose River basin. Outcrops are also found at Grand Rapids on the Mattagami River, and at Coral, Sextant, and Long rapids on the Abitibi River. At Grand Rapids the upper member is exposed in 50-foot banks for a distance of 2 miles on both sides of the river. An analysis for a 40-foot section at Coral Rapids is given by W.S. Dyer (1929, p. 68) as follows:

$CaCO_3$	95.46
$MgCO_3$	1.09
Fe_2O_3 and Al_2O_3	1.85
Insoluble	2.42
	100.82

The upper member consists predominantly of thin to very thin bedded, fine-grained, buff-weathering, brown, fossiliferous limestone. Corals and crinoids are especially common, but stromatoporoids, bryozoans, brachiopods, and trilobites also occur; reef structures are sometimes developed. Minor amounts of gypsum, shale, and sandstone may be interbedded with the limestone. The member is correlated with the Detroit River Formation of southwestern Ontario; Detroit River rocks are the source of more than 80 percent of the high-calcium limestone produced in the province (Hewitt 1960, p. 6).

Middle Member

The middle member, referred to by Dyer (1929, p. 19) as the Moose River Formation, is exposed on the upper branches of the French River near the Precambrian contact, and at Coral, Sextant, and Long rapids on the Abitibi River. These outcrops consist of thin-bedded grey and buff limestone and limestone breccia. Outcrops of massive gypsum and gypsum-limestone breccia are found along the Moose River arch in the banks of the Cheepash, Moose and French rivers, and at Gypsum Mountain (Figure 12).

Where gypsum is not in abundance the middle member of the Abitibi River Formation is commonly a thin-bedded aphanitic, mottled grey and buff, argillaceous limestone. In some cases it exhibits a fine colour lamination, and occasionally it contains bituminous streaks. Chert is sometimes common and pyrite is occasionally present. Unlike the gypsum areas, fossils are fairly common. Corals and stromatoporoids sometimes form reef structures; brachiopods, bryozoa, and trilobites are relatively rare. In some areas the limestone is interbedded with grey calcareous sandstone. Locally the limestone has been brecciated.

Along the Moose River arch, massive white gypsum comprises about 50 percent of the middle member, and fossils are notably scarce. The gypsum is white or occasionally light grey or amber, fine to coarsely crystalline, massively structured or coarsely banded and sugary textured. Clear or amber selenite, recrystallized along fractures or limy laminae, sometimes also occurring in coarse stellate spots, may comprise 10 percent or more of some sections. Paper-thin laminae, and rare coarse clots of brown cryptocrystalline limestone, comprise less than 5 percent of many sections of the massive gypsum, but become more common

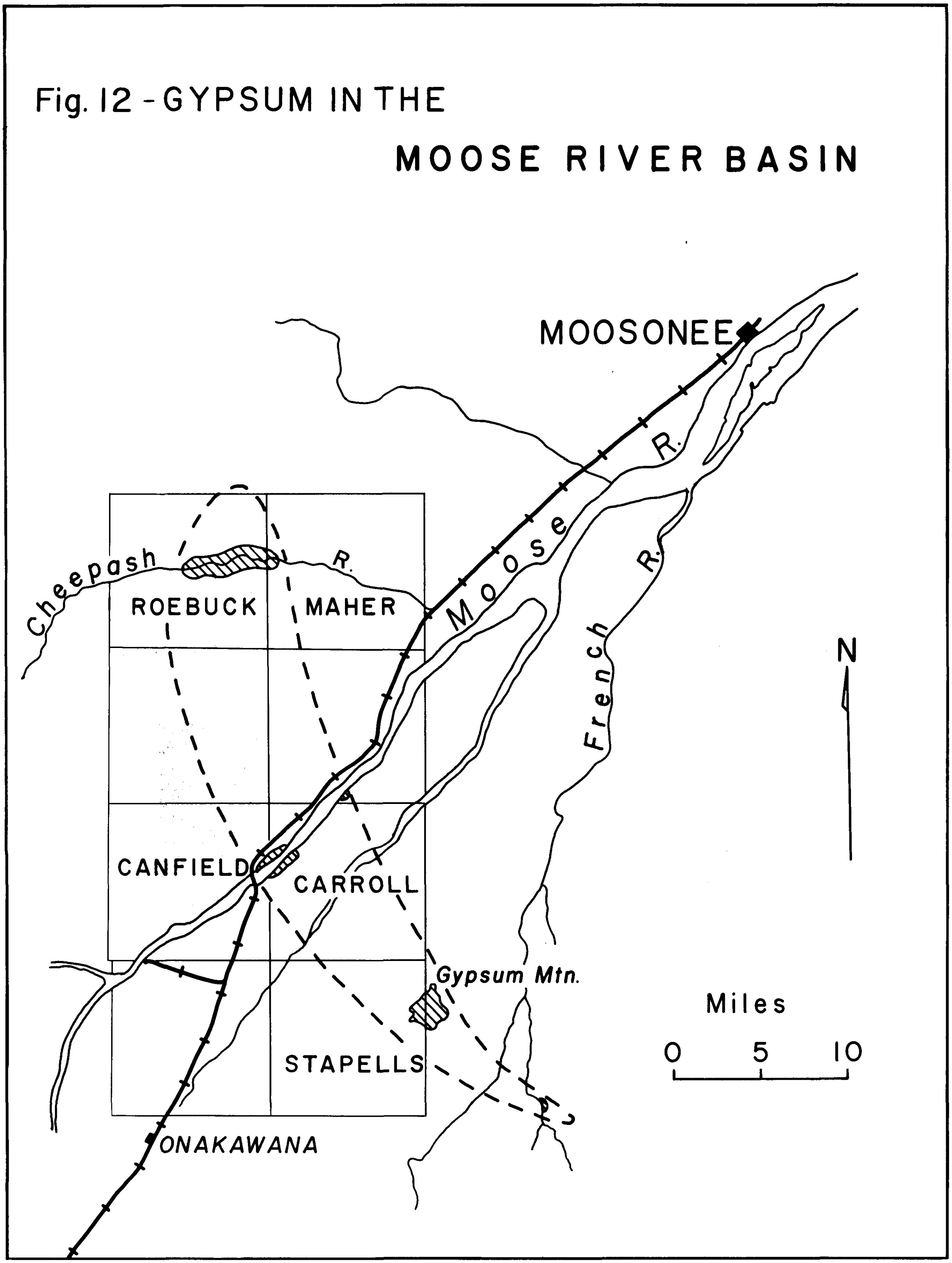


Fig. 12 - GYPSUM IN THE
MOOSE RIVER BASIN
MOOSONEE
Moose R.
French R.
Cheepash R.
ROEBUCK
MAHER
CANFIELD
CARROLL
STAPELLS
Gypsum Mtn.
ONAKAWANA
N
Miles
0
5
10

Massive white and amber gypsum at Moose River Crossing.

Massive white gypsum on the Cheepash River.

in banded sections. Gypsum predominates through a vertical range of about 100 feet, becoming more selenitic with depth. It becomes increasingly mixed near the base with a fine-grained aggregate of clastic gypsum and carbonate grains veined by secondary, cross-oriented, white or amber selenite. A similar fine aggregate is the matrix for a gypsum-selenite-limestone breccia which overlies massive and banded gypsum on the banks of the Moose River.

Thin or very-thin bedded buff weathering, brown, aphanitic limestone or limestone breccia containing occasional crinoid discs and pyrite nodules, is rarely observed overlying massive or banded gypsum on the Moose and Cheepash rivers. This limestone which probably belongs to the upper member of the Abitibi River Formation, rests on an irregular gypsum surface, the grosser irregularities being filled by a fine-grained grey clastic aggregate of gypsum and limestone with or without large breccia fragments.

Gypsum of the middle member is further described under individual occurrences in a later section.

Lower Member

Exposures belonging to the lower member of the Abitibi River Formation are restricted to the Albany River near Fort Albany and in an area 125 miles above the river mouth. The member is present in the subsurface throughout much of the Lowland but appears to be absent in parts of the Moose River basin.

Typically the member is a very light buff or brown, sometimes argillaceous, fine-grained limestone. In some cases the limestone is interbedded with grey cherty dolomite, grey shale, or red and green sandstone. Bituminous streaks and rusty pyrite spots are sparsely present. Corals are common; trilobites, brachiopods, bryozoa, cephalopods, and crinoids are occasionally found.

GYPSUM DEPOSITION AND DISTRIBUTION

Significant gypsum occurrences are restricted to outcrops along the Moose River arch in Roebuck, Canfield, Carroll, and Stapells townships, and in the unsurveyed area extending a short distance east of Stapells township. Principal outcrop areas are located on the Cheepash River, the Moose River, a slightly elevated area known as Gypsum Mountain, and on the Wakwayowkastic River, the central branch of the French River (Figure 12).

It is probable that the maximum development of gypsum is along the Moose River arch, and that the axis of the arch approximates the long dimension of the basin of calcium sulphate deposition. Only minor thicknesses of gypsum were intersected in a hole drilled to the Precambrian floor (Dyer and Gerrie 1953, pp. 87-95) at Onakawana, 20 miles southwest of the Moose River gypsum outcrops. No gypsum is reported in the log of a hole drilled through the middle member of the Abitibi River Formation at Moose Factory, 40 miles northeast of the Moose River outcrops (Satterly 1953, pp. 141-144). Gypsum was not reported in middle Abitibi River rocks intersected in the Campbell Lake and Jaab Lake drillholes (Hogg, Satterly, and Wilson 1953, pp. 115-130) respectively 55 miles southwest and 75 miles northwest of the Moose River outcrops.

Although remnants of anhydrite are scarce it is probable that the calcium sulphate was largely deposited in the anhydrous form. The coarse colloform structure almost certainly represents disordered swelling deformations resulting from the gypsification of anhydrite.

The basin of deposition, although small in areal extent, appears to have been stable for a considerable time, judging by the thickness of gypsum. The purity of the deposits further suggests that conditions during deposition were nearly ideal: the floor of the basin sank at a uniform rate; the basin waters were replenished by sea water contaminated with a minimum of silt; and the dense sodium chloride brine was returned to the open sea by some such means as King's (1947, p. 473) theory of reflux. The gypsum basin was likely a shallow lagoon on the edge of the Middle Devonian sea.

Gypsum on the Cheepash River

Outcrops of gypsum are numerous over a distance of 5½ miles on the Cheepash River; exposures are first encountered 10 miles above the Ontario Northland Railway bridge. Although the river is normally shallow it can be ascended to the gypsum

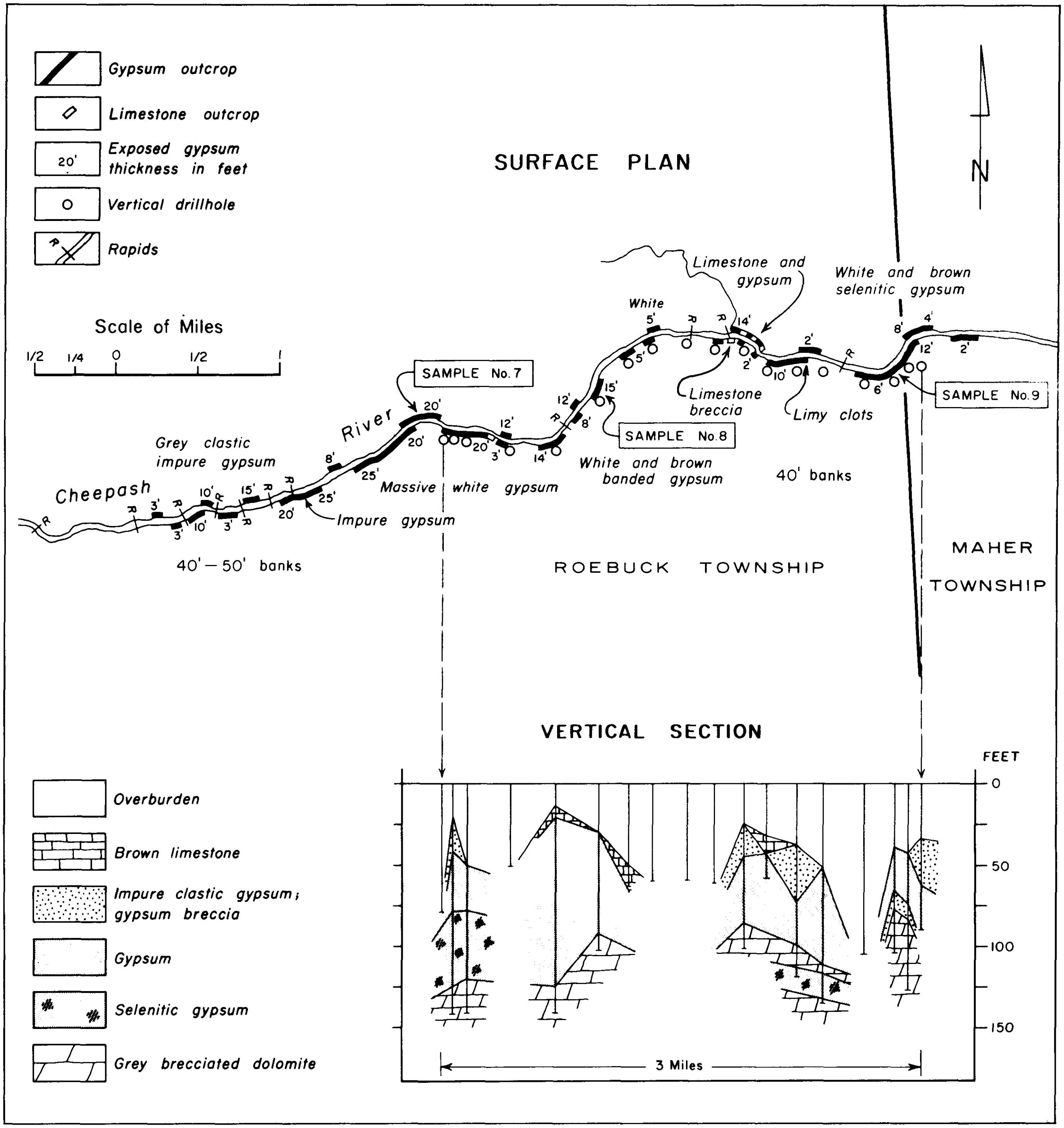


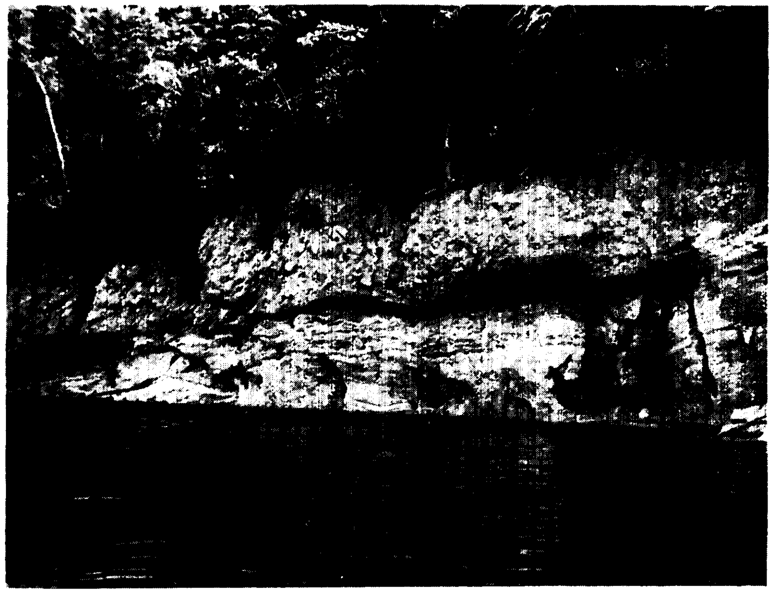
Figure 13 — Gypsum occurrences on the Cheepash River.

area by canoe in less than a day.

Figure 13 is an outcrop map along the Cheepash River. Outcrops of gypsum start in Maher township, half a mile east of the boundary of Roebuck township, and continue for 5 miles on both sides of the river in Roebuck township. The bed of the Cheepash River has been cut 40-50 feet down from the level of the muskeg plain. Smooth, rounded or undercut, waterworn outcrops of gypsum extend to a maximum of 25 feet above the river level, and are topped by silty clay till or recent river silts. Deep pools in front of many gypsum outcrops have obviously been formed by solution of the gypsum in the river bed; they prove the continuation of the gypsum 10-20 feet below river level.

The gypsum in many places is of high purity. Analyses of three vertical channel samples are shown in the accompanying table. Sample locations are indicated on the surface plan (Figure 13). For the most part the gypsum is massive, medium-grained, and white, but brown or amber-coloured selenitic gypsum may be present interspersed throughout the white gypsum. Both clear and amber selenite are locally common and may comprise 25 percent of some exposures. The typical colloform structures of the massive gypsum are 2-4 inches in diameter, and are delineated by thin brown limestone laminae.

The top 1-2 feet of some gypsum exposures is a rather impure, fine-grained, grey clastic aggregate of gypsum and minor carbonate, sometimes containing coarse breccia fragments of gypsum and limestone. Coarse clots of brown limestone,



Banded gypsum overlain by breccia on the Moose River.

Natural bridge of gypsum at Gypsum Mountain.

sometimes forming chains of limestone fragments, are occasionally present in massive white gypsum. Limestone outcrops are scarce, but the abundance of angular limestone fragments along the river banks suggests its probable occurrence between the gypsum outcrops. Limestone and limestone breccia is present in low outcrops 1 mile west of the Maher-Roebuck boundary.

In the autumn of 1963 the Moosonee Gypsum and Exploration Company drilled 18 holes over a 3-mile distance along the south bank of the Cheepash River. A generalized geological section along the line of these holes is shown in Figure 13. The drilling proved the existence of a thin discontinuous capping of brown limestone. The presence of occasional fossils suggests that the limestone belongs to the upper member of the Abitibi River Formation. An unexpected feature indicated by the drilling is the extremely scalloped bedrock surface; holes collared within a few hundred feet of outcrop encountered 50-100 feet of overburden in some places.

The drilling proved the continuation of gypsum to a depth of 125 feet. The best continuous intersections were made near the centre of the outcrop area, where 70-85 feet of high purity gypsum was encountered in several adjacent holes. Coarse selenitic gypsum shows a general increase with depth, the proportion of selenite crystals larger than $\frac{1}{4}$-inch exceeding 50 percent in some sections. There is also a tendency for increased amber-colouration at depth.

CHEMICAL ANALYSES - CHEEPASH RIVER[1]

	Sample No. 7	Sample No. 8	Sample No. 9
Free H_2O	0.19	0.22	0.18
Combined H_2O	19.77	19.93	20.20
CO_2	1.71	1.37	0.22
SiO_2 & insoluble	0.36	0.44	0.81
Fe_2O_3 & Al_2O_3	0.16	0.08	0.10
CaO	33.04	32.82	32.88
MgO	0.93	0.69	0.51
SO_3	44.26	44.17	45.20
NaCl	0.1	0.2	0.1
Total	100.52	99.92	100.20

Theoretical Calculations

	Gypsum percent	Anhydrite percent	$CaCO_3$ percent	$MgCO_3$ percent
Sample No. 7	94.46	1.39	1.57	1.94
Sample No. 8	95.22	0.24	1.41	1.44
Sample No. 9	96.51	0.49	--	1.07

Sample Description

Sample No. 7 - 10-foot vertical channel sample of white gypsum from west part of gypsum area.

Sample No. 8 - 8-foot vertical channel sample of brown and white gypsum from central part of gypsum area.

Sample No. 9 - 10-foot vertical channel sample of white gypsum from east part of gypsum area.

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[1] Analyses by Laboratory Branch, Ontario Department of Mines, 1964.

Gypsum on the Moose River

The first mention of gypsum in the Moose River basin referred to outcrops on the Moose River in Canfield and Carroll townships. Although these occurrences were mentioned by a number of early explorers, the most detailed descriptions were given by J.M. Bell (1904, pp. 156-158). The exposures occur in both river banks on the downstream side of the railroad bridge at Moose River Crossing, 142 miles north of Cochrane.

The most accessible gypsum outcrops are in the north bank, commencing 200 yards east of the railway bridge and continuing downstream for 2½ miles. Outcrops in the south bank start opposite the east end of Murray Island and continue downstream for 2 miles. A second outcropping of gypsum, ½ mile in length, occurs in the south bank opposite Wait Island 7 miles below the bridge. These locations are shown in Figure 14.

Gypsum on the Moose River, although generally less attractive in outcrop than occurrences on the Cheepash River, is of good quality. Analyses of the three vertical channel samples indicated on Figure 14 are given in the accompanying table. Typically the exposures consist from top to bottom of 3-15 feet of gypsum breccia, 3-6 feet of banded brown selenite and white gypsum, and massive white gypsum continuing below water level. The banks on the south side of the river are 35-45 feet high to the level of the muskeg plain, silty

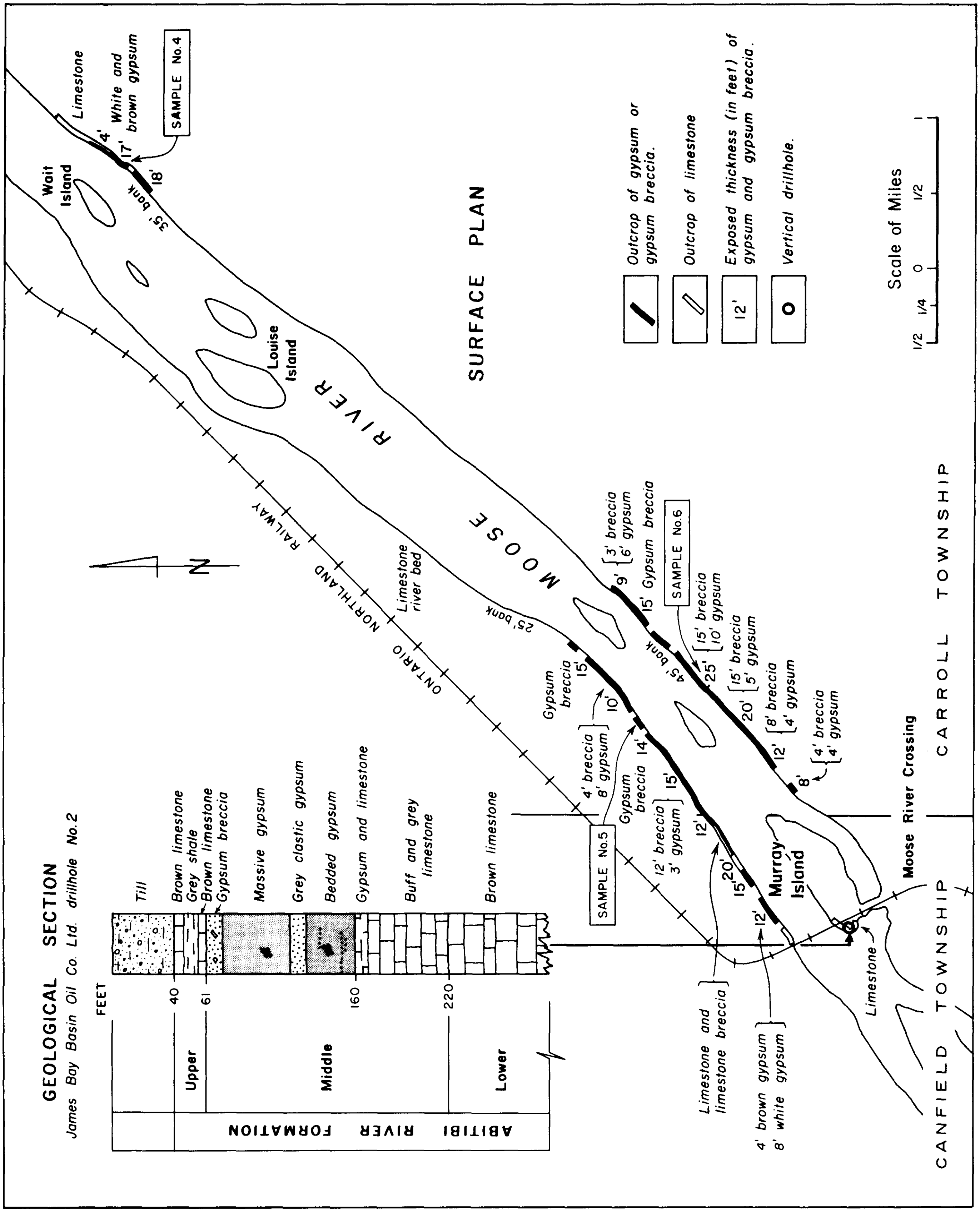

Figure 14 — Gypsum occurrences on the Moose River.

clay till overlying the gypsum sequence. The banks on the north side have been terraced by river erosion and average 25 feet high; stratified river sands overly the gypsum sequence. The river is usually deep adjacent to gypsum outcrops. Thin-bedded, fine-grained, brown limestone is seen to overlie gypsum or gypsum breccia in several places near the extremities of the outcrop area; it also forms a smooth pavement for the river bed over a wide area. Gypsum breccia is a conspicuous feature of the Moose River occurrences. Angular blocks of gypsum, selenite, and limestone, up to 10 feet or more in size but averaging perhaps 1 foot, are loosely cemented in a fine-grained, grey, clastic aggregate of gypsum and carbonate. The variety of structures and colours in the gypsum and selenite fragments is nowhere observed in the underlying gypsum beds. It is presumed that a considerable thickness of upper gypsum beds was brecciated during an erosion interval that preceded the deposition of Upper Abitibi River limestone.

Gypsum breccia rests on a smooth undulating surface of wavy-banded brown selenite and white gypsum. Coarse resinuous brown gypsum and selenite usually comprise more than 50 percent of the banded zone; medium-grained white gypsum, and traces of limy material, make up the remainder. Where distinct the bands are commonly 2-4 inches thick. Banding appears to be a secondary feature as it is conformable with the overlying breccia contact.

The banded zone passes rather abruptly downwards into a more massive fine- to medium-grained white zone having the typical

Crenulated gypsum beds grading into limestone.

Gypsum overlain by thin-bedded limestone on the Moose River.

coarse colloform structure. Individual colloform masses are delineated by thin limy lenticles, along which the recrystallization of brown selenite has normally occurred. Carbonate impurities are usually less than 5 percent, but associated brown selenite may constitute 30 percent of the zone in some places.

In 1923 W. Tees Curran secured patents on 12 claims staked along the river banks. Nine claims, S.5306 to S.5314 inclusive, completely cover the gypsum outcrops on the north side of the river. Three claims, T.19449 to T.19451, are on the south shore near the middle of the upstream outcrop area. According to Lanning (1926, p. 1173) four holes were drilled in the gypsum to depths of 25 to 47 feet.

In 1929 the James Bay Basin Oil Company Limited drilled 3 holes on Murray, Mike, and Grey Goose Islands, upstream from the gypsum outcrops (Martison et al 1953, pp. 153-154). The Mike Island hole, 2 miles upstream from the railway bridge, encountered gypsum interbedded with shale and limestone through a vertical range of 200 feet starting at a depth of 239 feet. The Murray Island hole, collared at the railway bridge, intersected nearly 100 feet of gypsum; the log of this hole is illustrated in Figure 14. The gypsum sequence is remarkably similar in thickness and lithology to that intersected on the Cheepash River.

In 1955 Atlas Gypsum Corporation Limited was formed to evaluate 14 unpatented claims located on the north side of the river between the Curran claims and the Ontario Northland Railway track. Some line-cutting and survey work were carried out but the claims were allowed to lapse.

CHEMICAL ANALYSES - MOOSE RIVER[1]

	Sample No. 4	Sample No. 5	Sample No. 6
Free H_2O	0.06	0.23	0.14
Combined H_2O	20.31	19.99	19.99
CO_2	0.20	0.48	0.72
SiO_2 & insoluble	0.44	0.40	0.48
Fe_2O_3 & Al_2O_3	0.08	0.04	0.02
CaO	32.84	33.22	33.10
MgO	0.35	0.70	0.72
SO_3	45.96	45.24	45.44
NaCl	0.2	0.2	0.1
Total	100.44	100.50	100.71

Theoretical Calculations

	Gypsum percent	Anhydrite percent	$CaCO_3$ percent	$MgCO_3$ percent
Sample No. 4	97.04	1.36	--	0.73
Sample No. 5	95.51	1.35	--	1.46
Sample No. 6	95.51	1.69	--	1.51

Sample Description

Sample No. 4 - 13-foot vertical channel sample from southeast shore opposite Wait Island.

Sample No. 5 - 8-foot vertical channel sample from northwest shore.

Sample No. 6 - 8-foot vertical channel sample from southeast shore.

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1 Analyses by Laboratory Branch, Ontario Department of Mines, 1964.

Gypsum Mountain

A low outcropping of gypsum known as Gypsum Mountain lies on the east boundary of Stapells township midway between the Abitibi and French rivers and 12 miles southeast of Moose River Crossing. Although the maximum relief probably does not exceed 25 feet above the level of the muskeg, the improved drainage in the area has encouraged a substantial growth of timber, which from a distance, presents a mountain-like aspect relative to the unending muskeg that surrounds it. The area of outcrop is less than 3 square miles, but a karst topography, represented by scattered sinkholes in the muskeg, and frost-lifted gypsum boulders, extends for several miles to the northwest and southeast.

The occurrence was discovered by Alexander Niven in 1898 while surveying the Algoma-Nipissing boundary. It is difficult of access except by helicopter, and suitable landing sites are scarce even for these. The area is one of great natural beauty because of the numerous gypsum arches which have been formed by solution along several watercourses that transect the occurrence. J.M. Bell (1904, p. 158) describes it as follows:

"The surface of the land within the limits of the gypsum is exceedingly rough and uneven, and the topography is often strange and fantastic. The rugosity increases towards the middle, where the deep holes and intervening elevations present a labyrinth of wonderful natural bridges, snow-white pillars, majestic columns and deep narrow caverns. Here and there the larger holes are basins filled with water of sparkling transparency from which threads of water flow to feed a fairly large creek that winds through a maze of caves and tunnels to the east of the [Stapells township] boundary line. These clear-watered natural reservoirs, with their surrounding cliffs and floors of shining white gypsum and with the high Banksian pines above, reflected in the marvellously clear water, give a scene of exquisite beauty."

The area of outcrop is shown on Figure 15. The occurrence was briefly examined near its centre where banks of gypsum 20 feet high are common. Here the gypsum is uniform, massive, white, and fine- to medium-grained; it has a friable sugary texture composed of interlocking gypsum laths. Weathered surfaces are scaly and grey to buff in colour. Impurities consist of rare thin lenses of brown limestone and wavy, paper-thin, grey-black laminae. In some places selenite is associated with the dark impurities but its proportion rarely exceeds 5 percent of the mass. The high purity of the gypsum is indicated by the accompanying analyses, based on two vertical channel samples. Beds of limestone or gypsum breccia were not observed.

Gypsum Mountain represents the point of maximum elevation of the gypsum above sea level. It is therefore perhaps the most attractive gypsum area for minimum overburden cover, but as with the other gypsum outcrop areas its surface is undoubtedly very irregular.

CHEMICAL ANALYSES - GYPSUM MOUNTAIN [1]

	Sample No. 1	Sample No. 2
Free H_2O	0.23	0.11
Combined H_2O	19.53	18.43
CO_2	0.97	4.12
SiO_2 & insoluble	0.48	0.90
Fe_2O_3 & Al_2O_3	0.08	0.28
CaO	33.56	32.98
MgO	0.71	2.42
SO_3	43.98	41.58
NaCl	0.4	0.4
Total	99.94	101.22

Theoretical Calculations

	Gypsum percent	Anhydrite percent	$CaCO_3$ percent	$MgCO_3$ percent
Sample No. 1	93.31	0.95	0.45	1.48
Sample No. 2	88.05	1.02	3.37	5.06

Sample Description

Sample No. 1 - Channel sample of top 7 feet of a 16-foot gypsum bank.

Sample No. 2 - Channel sample of middle 6-foot section in an 18-foot bank.

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[1] Analyses by Laboratory Branch, Ontario Department of Mines, 1964.

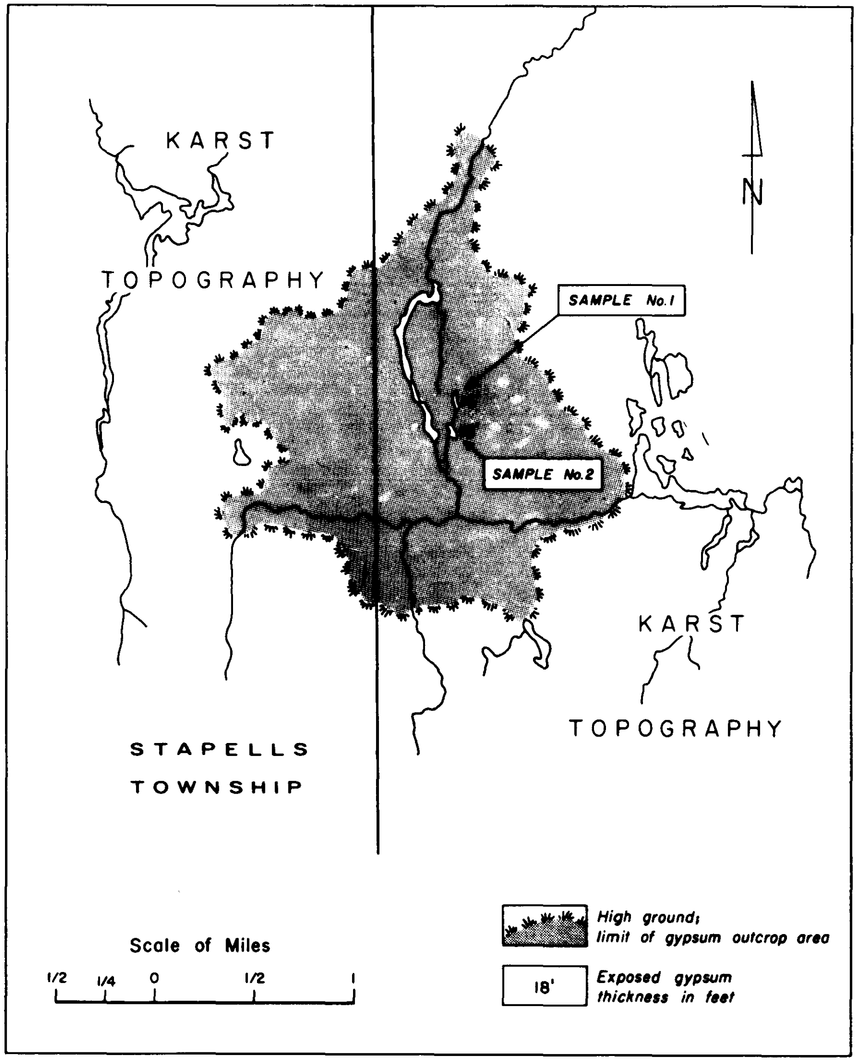

Figure 15 — Gypsum Mountain.

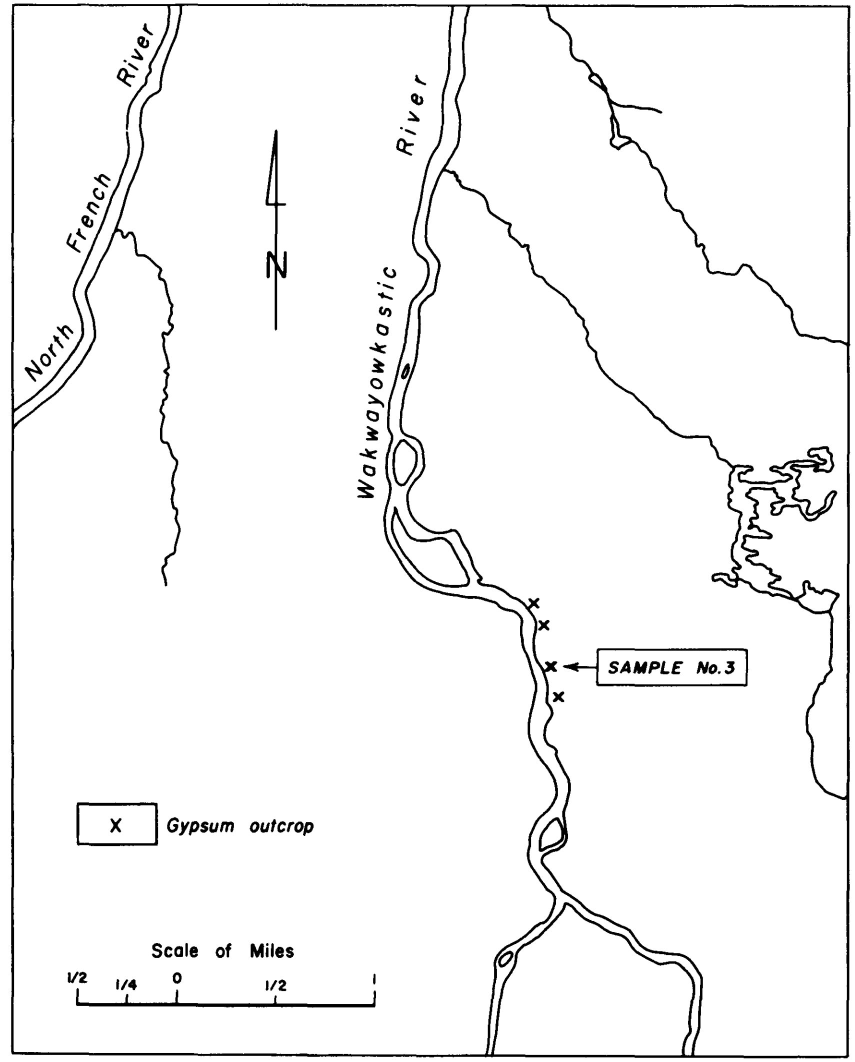

Figure 16 — Gypsum occurrences on the central branch of French River.

Gypsum on the French River

Several low outcrops of gypsum occur over a distance of $\frac{1}{2}$-mile on the central branch of the French River. This branch of the French River is called the Wakwayowkastic River. The gypsum occurrence is 20 miles southeast of Moose River Crossing.

Figure 16 shows the locations of the gypsum outcrops. They are restricted to the east bank and form low smooth exposures having a maximum thickness of 8 feet above river level. A chip sample taken at scattered points over one outcrop gave the accompanying analysis. The quality of the gypsum is high; it is uniformly fine-grained, white, and massive. Impurities consist of rare brown and black limy laminae and traces of rusty sulphide stain. Minor amounts of clear grey selenite are disseminated through the massive gypsum in stellate recrystallized spots. No limestone or gypsum breccia was observed.

CHEMICAL ANALYSIS - FRENCH RIVER[1]

Free H_2O	0.10
Combined H_2O	20.01
CO_2	0.39
SiO_2 & insoluble	0.94
Fe_2O_3 & Al_2O_3	0.08
CaO	32.66
MgO	0.59
SO_3	45.30
NaCl	0.2
Total	100.27

Theoretical Calculations

Gypsum percent	Anhydrite percent	$CaCO_3$ percent	$MgCO_3$ percent
95.60	1.38	--	1.23

Sample Description

Chip sample; chips of gypsum taken at random over a small outcrop area on the east bank of the Wakwayowkastic River.

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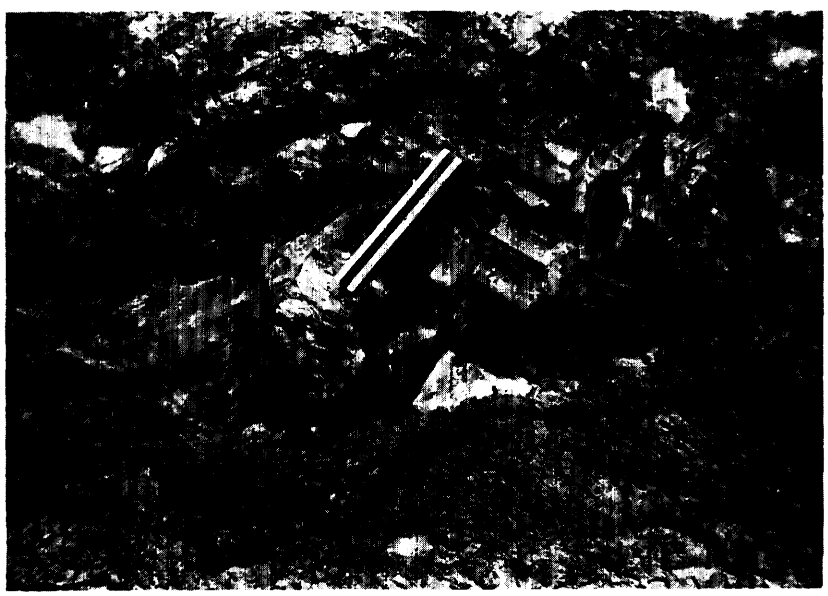
[1] Analysis by Laboratory Branch, Ontario Department of Mines, 1964.

Areas of Karst Topography

Karst topography, a physiographic feature developed in a region of easily soluble bedrock, is common in parts of the gypsum belt. It is characterized by depressions of various sizes formed by subsidence of the land surface into solution cavities in the gypsum. The process is a continuing one, and recently formed sinkholes are marked by torn muskeg walls. Frost-lifted boulders of white gypsum are an occasional associate of the karst terrains, and are especially conspicuous from the air. The development of karst features between the principal outcrop areas almost certainly proves the continuation of gypsum throughout the entire belt.

A karst topography is particularly in evidence between Gypsum Mountain and Moose River Crossing. The sinkholes are generally widely separated, but only near the Abitibi River do they appear to be entirely lacking; nor have gypsum outcrops been reported in the banks of this river. Karst features are also common southeast of Gypsum Mountain, but they do not extend as far as the north branch of the French River. Between Moose River Crossing and the gypsum outcrops on the Cheepash River karst features are only found within about a mile of the outcrop areas themselves. A helicopter reconnaissance of Salt Brook, which lies midway between the Moose and Cheepash outcrop areas, did not reveal gypsum outcrop or karst features; the brook has not cut deeply below muskeg level.

Gypsum-limestone breccia.

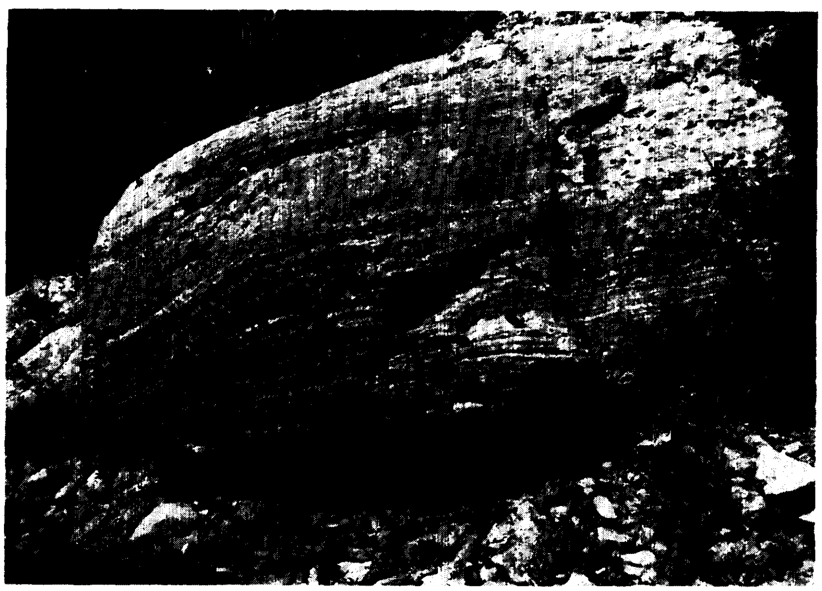


Coarse colourless selenite in breccia.

CHARACTERISTICS OF THE GYPSUM BEDS

Gypsum in the Moose River basin has attracted attention because of its high purity. Outcropping sections are commonly white and massive, showing little or no interbedding with limestone or dolomite. Such gradation with limestone, however, did apparently occur towards the end of the deposition cycle, but an erosion interval removed these upper beds. Remnants of limestone, interbedded limestone and gypsum, and variously coloured gypsum and selenite, are preserved as angular fragments in a fine clastic groundmass of gypsum and carbonate that overlies the massive gypsum beds. Many of the fragments are lithological types not now represented in the gypsum sequence. They commonly range to 2 feet in size, and rarely are more than 10 feet. Features of bedding and grain gradation are occasionally seen in the fine grey matrix. The matrix consists mainly of subangular gypsum grains, but very fine carbonate grains are present in amounts of 10-25 percent disseminated through the gypsum or concentrated as bedding-plane laminae. Thicknesses of breccia up to 15 feet are exposed in the banks of the Moose River, and drillhole intersections indicate as much as 37 feet in some places on the Cheepash River; but its distribution is erratic and in some places it is entirely lacking. Brief erosion intervals in the gypsum deposition sequence are represented by thin beds of the grey clastic gypsum-carbonate matrix, with or without breccia fragments.

Stellate selenite "eyes" in massive gypsum.



Selenite "eyes" in banded gypsum.

Underlying the gypsum-limestone breccia is a banded zone, 3-6 feet thick, of brown and white gypsum. The zone consists of about equal parts of medium- to coarse-grained, resinous brown or orange-coloured gypsum, and fine-grained, feathery, white gypsum. Much of the brown gypsum is selenitic, in crystals to 1 inch. The coarser grain size and brown colouration is associated with fine-grained rhombic carbonate grains disseminated through the gypsum crystals in amounts of 5-10 percent. The banding is coarse, wavy, and discontinuous; it traces an undulating pattern parallel to the breccia contact. The zone appears to be a contact feature, and does not occur where breccia is absent. It is best exposed in the banks of the Moose River.

Beneath the banded zone are the massive white gypsum beds that are so strikingly exposed in many of the outcrops throughout the gypsum belt. In many places these beds are of high purity, averaging more than 95 percent gypsum through vertical sections up to 60 feet thick. The gypsum is a fine-grained snow-white, rather friable aggregate of interlocking lath-shaped grains. The structure is normally massive consisting of a compact assemblage of colloform swellings that are generally attributed to the increase in volume attendant with the conversion of anhydrite to gypsum. The individual swellings are 2-6 inches in diameter; they are rudely delineated by discontinuous trains of very fine carbonate grains that form brown, paper-thin, laminae. In some cases these laminae are stained black by carbonaceous material. Where laminae are sufficiently common the structure may assume a coarse horizontal banding. Thin beds of brown aphanitic limestone, only rarely deposited in the gypsum sequence, have been broken and dislocated by crumpling of the beds during the crystallization of gypsum. The limestone fragments occur as unoriented clots or discontinuous chains sparsely disseminated through the gypsum beds.

Selenite is a major constituent of the gypsum beds. It may occur in crystals up to 1 inch in length, disseminated through massive fine-grained gypsum in unoriented "spots" or stellate groups. More commonly it is developed by recrystallization along limy laminae and fracture planes. As a fracture - filling it is frequently cross-oriented. Coarsely crystalline patches, composed of an aggregate of individual crystals to 6 inches in length, are occasionally present in impure sections of the gypsum beds. Selenite crystals are clear or translucent, colourless or resinous brown; intensity of the brown colour varies with the abundance of very fine carbonate grains scattered through the crystals. Selenite is rarely absent, and in many places it constitutes 5-25 percent of the gypsum beds. The proportion of selenite tends to increase with depth, and in a number of drillholes on the Cheepash River selenite was seen to predominate in the lower half of the gypsum sequence. A common association at the base of the sequence is a 10-20 foot section of coarse ($\frac{1}{4}$-1 inch) recrystallized amber selenite overlying brecciated cream-coloured dolomite. Both the massive selenite bed and the dolomite are veined by cross-oriented white selenite filling fractures 1/8 - 1/2 inches thick.

IV OTHER GYPSUM OCCURRENCES

Stormont County, Cornwall Township

A 4-5-foot bed of black laminated gypsum occurs in Beekmantown dolomite at a depth of 190 feet in the vicinity of Cornwall. Thin gypsum beds are interlayered with dolomite for 5 feet both above and below the main gypsum bed. The occurrence was proved to be continuous over a wide area in drilling performed by the Ontario Hydro during 1954 in the Long Sault dam site area and in the vicinity of the Barnhart Island powerhouse.

V THE GYPSUM INDUSTRY IN ONTARIO

USES

The value of gypsum in industry is principally due to the combined water in its molecular structure. Three quarters of this water is readily removed by moderate heating; the resulting material when ground and re-mixed with sufficient water can be shaped as desired, and, after a few minutes setting time, it becomes a compact mass of moderate hardness. In this way it is used extensively as a plaster, particularly in the construction industry. Gypsum is also used in the raw state as an additive to Portland cement, and in various minor roles. Collings (1959, pp. 4-5) gives the following outline for gypsum uses:

"Vast amounts of calcined gypsum are used by the building construction industry. The calcined gypsum, or plaster of paris, mixed with water, hydrate of lime, and aggregate (sand, expanded perlite, vermiculite, etc.) is applied over wood, metal, or gypsum lath to form a wall finish in buildings. Calcined gypsum is the main constituent of gypsum board, lath and tile, and of most types of industrial plasters. Gypsum board, lath and sheathing are all formed by introducing a slurry, consisting of plaster of paris, water, foam, accelerator, etc., between two sheets of absorbent paper where it sets to produce a firm, strong wallboard. Gypsum lath is used in buildings as a base for plaster, whereas gypsum board and sheathing generally are used, without plaster, for sheeting walls and ceilings.

High-purity calcined gypsum is used in dentistry to form plaster casts for plate work, and by the medical profession for surgical casts to support fractures. Finely-ground calcined gypsum is used by the glass industry as a bedding plaster to support large sheets of plate glass during polishing operations. Calcined gypsum also is used as a molding plaster by the foundry and ceramic industries, for casting machine parts and ceramic pieces.

Crude uncalcined gypsum is used to control the set of Portland cement. The gypsum, which seldom exceeds 5 percent of the total weight of cement, is interground with the calcined cement clinker. Crude gypsum, reduced to 40 mesh or finer, is used as a filler in paint and paper. It also is used, to a limited extent, as a substitute for salt cake in glass manufacture. Powdered gypsum is used as a soil conditioner to offset the effect of black alkali, to restore impervious or dispersed soils, and as a fertilizer for peanuts and other leguminous crops.

Gypsum and anhydrite (anhydrous calcium sulphate) are potential sources of sulphur compounds. In Europe, gypsum or anhydrite is calcined at high temperatures with coke, silica, and clay to produce sulphur dioxide, sulphur trioxide, and by-product cement. The two gases are then converted into sulphuric acid. To date, gypsum and anhydrite are considered uneconomic sources of sulphur and sulphur dioxide in Canada; however, research into methods of utilizing gypsum and anhydrite might result in the eventual development of a chemical industry based on these minerals".

PRODUCTION AND CONSUMPTION

The accompanying table (Kuster and Mallory 1963, p. 5) shows the breakdown for uses of gypsum in the United States in 1962. No similar statistics are available for Canada. Since World War II the trend has been towards an increased use of gypsum wallboard. Production of gypsum lath and building plasters, and the use of gypsum in cement and minor industrial roles, is not showing important growth trends.

GYPSUM PRODUCTS SOLD OR USED IN THE UNITED STATES, 1962

USE	QUANTITY (short tons)	VALUE (dollars)
Uncalcined:		
Portland-cement retarder	2,765,000	12,365,000
Agricultural gypsum	1,241,000	4,222,000
Other uses (fillers etc.)	43,000	510,000
	4,049,000	17,097,000
Calcined:		
Industrial:		
Plate-glass and terra-cotta plasters	43,000	714,000
Pottery plasters	48,000	1,073,000
Dental and orthopedic plasters	13,000	487,000
Industrial molding, art, and casting plasters	85,000	1,806,000
Other industrial uses	80,000	2,665,000
	269,000	6,745,000
Building:		
Plasters:		
Base-coat	1,026,000	18,294,000
Sanded and premixed perlite	504,000	12,247,000
Mixing plants	1,000	16,000
Gaging and molding	119,000	2,521,000
Prepared finishes	10,000	869,000
Roof-deck	344,000	5,186,000
Keene's cement	35,000	924,000
Other	16,000	997,000
	2,055,000	41,054,000
Prefabricated products	7,711,000	327,404,000
		368,458,000
Grand total		392,300,000

In 1962, production from the two mines at Caledonia and Hagersville totalled 435,140 tons. The bulk of this production was calcined at the companies' own plants located at the mine sites, but about one-quarter of it was sold in uncalcined lump to cement companies.

GYPSUM PRODUCTION IN ONTARIO, 1875-1962

Year	Tons	Value	Year	Tons	Value
1875	120	$180	1911	20,335	$ 32,535
1878	489	675	1912	31,331	50,246
1879	579	720	1913	40,581	92,627
1880	875	1,240	1914	74,300	221,175
			1915	81,172	200,422
1881	657	1,040	1916	36,668	116,185
1882	1,249	1,946	1917	48,943	130,138
1883	462	837	1918	38,214	151,564
1884	688	1,254	1919	59,899	278,111
1885	525	787	1920	74,707	404,162
1886	5,826	12,000			
1887	8,560	11,715	1921	84,790	433,053
1888	6,700	10,200	1922	110,227	621,668
1889	7,382	13,128	1923	99,958	542,317
1890	6,200	8,075	1924	88,121	467,097
			1925	82,020	491,833
1891	3,850	8,775	1926	89,987	496,059
1892	3,978	25,980	1927	83,998	500,688
1893	2,958	19,243	1928	85,811	553,271
1894	4,695	32,457	1929	100,347	832,689
1895	3,817	20,566	1930	94,946	776,069
1896	4,200	20,750			
1897	3,200	18,881	1931	53,358	374,469
1898	2,970	17,255	1932	35,655	186,176
1899	1,861	16,512	1933	24,460	112,319
1900	1,861	18,050	1934	33,234	141,389
			1935	38,247	164,807
1901	2,305	15,662	1936	40,191	182,783
1902	3,834	19,149	1937	53,780	233,895
1903	4,740	21,988	1938	57,503	242,470
1904	7,802	29,024	1939	59,440	260,793
1905	4,206	27,951	1940	75,271	313,512
1906	4,711	25,095			
1907	10,186	19,652	1941	90,599	276,459
1908	10,389	20,778	1942	82,795	304,170
1909	11,488	23,604	1943	92,448	335,637
1910	10,043	17,825	1944	90,288	348,873

Gypsum Production in Ontario, 1875-1962 (cont.)

Year	Tons	Value	Year	Tons	Value
1945	92,174	$385,516	1954	357,432	$822,094
1946	122,527	490,980	1955	366,416	808,424
1947	155,249	671,548	1956	366,956	840,829
1948	182,303	770,004	1957	379,621	853,199
1949	203,187	871,467	1958	425,733	1,059,590
1950	199,314	875,217	1959	412,100	1,017,340
1951	262,581	672,276	1960	355,603	871,408
1952	278,992	1,060,429	1961	425,287	991,944
1953	334,495	899,630	1962	435,140	1,007,818

PRESENT PRODUCERS

DOMTAR CONSTRUCTION MATERIALS LIMITED

Domtar Construction Materials Limited operates a mine and plant for the recovery and processing of gypsum on the north bank of the Grand River ½-mile north of the town of Caledonia.

Development, operation, and geology at the Caledonia mine are briefly described by G.R. Hunt (1957, pp.123, 124). Much of the following description is also taken from various unpublished papers prepared by Mr. Hunt. The early history and development of the No. 1 Mine are described by G.E. Cole (1925, pp. 12-15).

History of Development

The Caledonia mine was opened by the Alabastine Company of Paris in 1905. It was subsequently operated under the names: Ontario Gypsum Company; Canada Gypsum and Alabastine Limited; Gypsum, Lime and Alabastine, Canada Limited. In 1961 the company's name was changed to Domtar Construction Materials Limited, consistent with a unification of all companies associated with the former Dominion Tar and Chemical Company Limited.

The No. 1 Mine was operated continuously from 1905 to 1953 and produced more than 4 million tons of gypsum. The 8-foot gypsum seam was located at a depth of 75 feet and was worked from a 5- by 6-foot inclined shaft 750 feet in length.

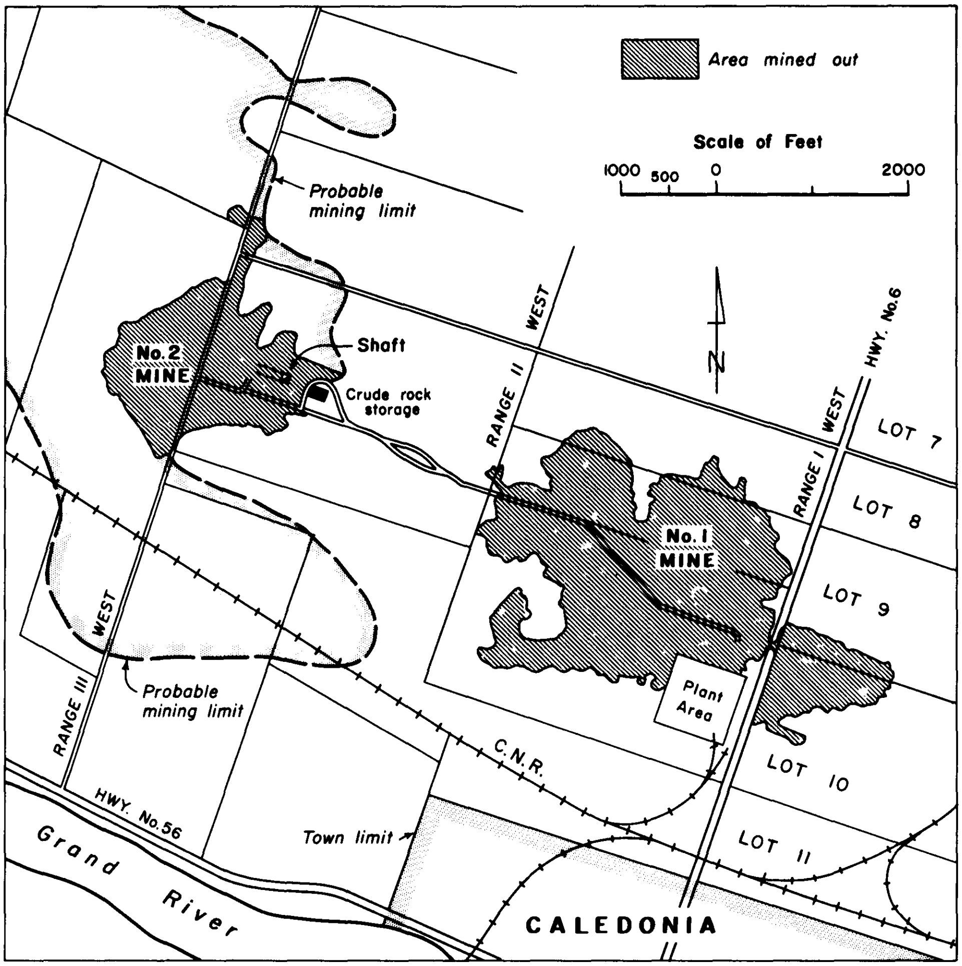


Figure 17 — Domtar Construction Materials Limited; plan of workings.

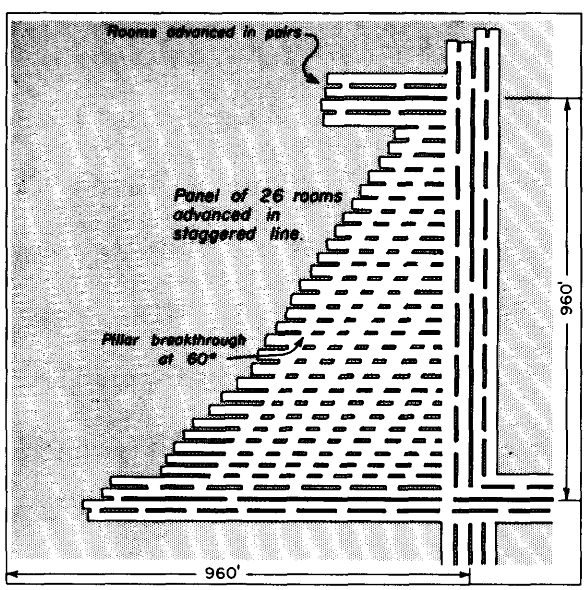


Figure 18 — Plan view of a 26-room panel at the Caledonia Mine.

The No. 2 Mine was opened in 1952; it is serviced by an inclined shaft, 13½ by 10 feet in section, sunk with a westerly heading on a 28 percent grade. The 8¼-foot gypsum seam lies at a vertical depth of 75 feet and is overlain by 0-18 feet of gypsiferous dolomite and 50-60 feet of dense yellow and blue clay.

Mining Method

The method of mining the almost flat-lying gypsum seam is illustrated in Figure 18; it is described by G.R. Hunt (personal communication) as follows:

"The room and pillar method of mining is used. About 20 percent of the gypsum seam is left undisturbed in the form of pillars to support the mine backs. A mine face unit is simply the kept-in-line faces of a number of equally spaced parallel rooms of uniform width. A face unit may consist of as many as thirty rooms. In the Caledonia mine the rooms are 20 to 22 feet in width at 32-foot centres. The long-wall pillars that would normally develop between rooms are further cut by 18-foot wide parallel crosscuts on 55-foot centres running at 60 degrees to the strike of the main rooms. At Caledonia the mine rooms are called "pockets", and the main development heading, off which the rooms or pockets turn at right angles, are locally called "leads". Mine faces are driven either in a westerly or northerly direction where possible in order to ensure face drainage."

Trackless mining is employed throughout the mine. Self-propelled, rubber-tired, drill jumbos are positioned for drilling 10-foot holes across the full face width of 22 feet with one relocation. Blasting is done electrically using 30 percent Forcite and Belite A explosives. A face-round blast gives 100 tons of broken rock for 156 lineal feet of rock drilling. The broken rock is loaded by electrically-powered, crawler-mounted, Joy 11 B U machines, loading into Joy 60 E 12 rubber-tired, diesel-electric shuttle cars. The 9-ton shuttle car load is discharged to a two-stage crushing sequence, comprising a jaw and a cone crusher located in the main conveyor way, and the minus 2-inch rock is conveyed to surface by belt. A TD6 Traxcavator is used for general clean-up around the mine face and haulageways and for general road maintenance. Ventilation is provided by means of a vertical shaft from surface, equipped with a 100,000 c.f.m. fan.

The roof of the mine is self-supporting, and timbering or roof-bolting is used only in the wider areas of the main haulageways or where the thickness of solid rock above the roof is insufficient. The mine roof consists of 6-18 feet of dolomite overlain by clay. Mining is discontinued in areas where the overhead thickness of dolomite is less than 6 feet.

The Gypsum Seam

Although gypsum is present in significant amounts through

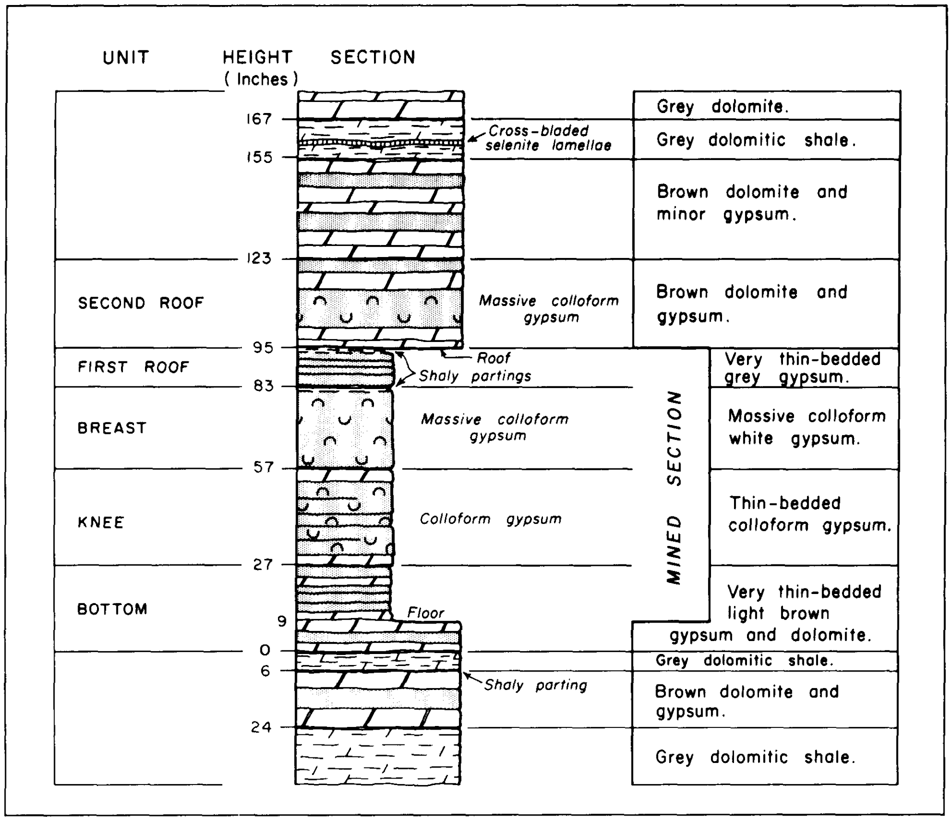


Figure 19 — The main gypsum seam; Domtar Construction Materials Limited, Caledonia.

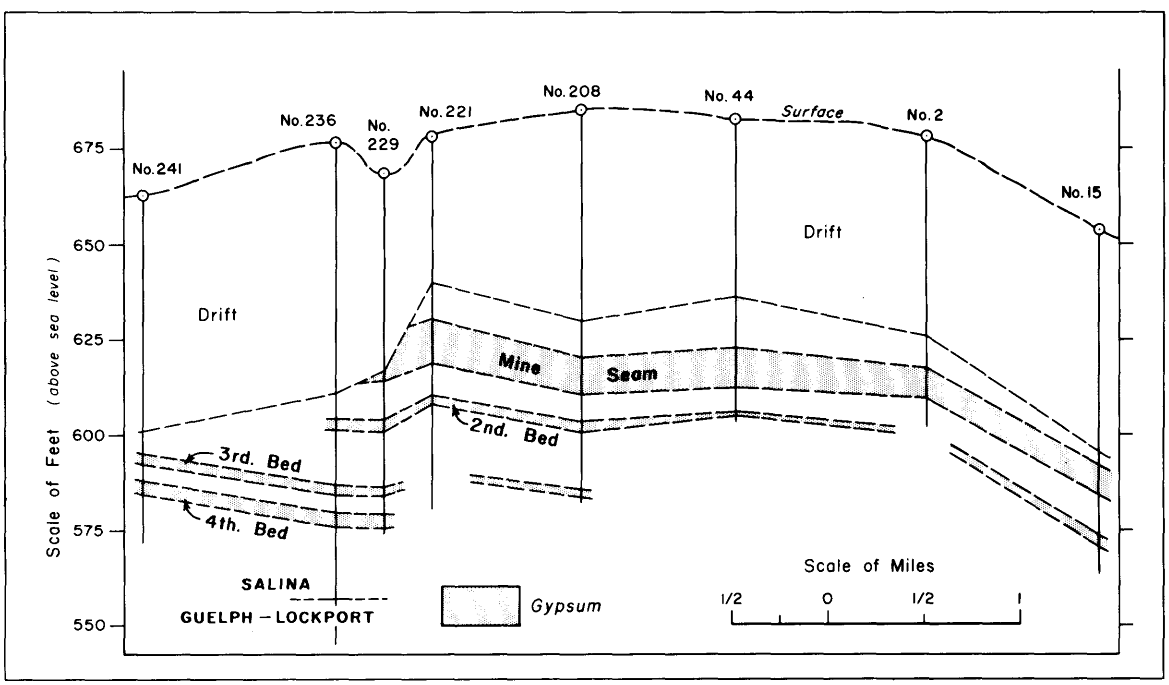


Figure 20 — Gypsum seams on the property of Domtar Construction Materials Limited.

a vertical section of about 15 feet, the portion mined varies in thickness from 7 to 9 feet. The mined section consists of four units designated from bottom to top as the "Bottom", "Knee", "Breast", and "First Roof." The section is illustrated and described in Figure 19. Although the thickness of individual units varies from place to place, their lithological characteristics are remarkably persistent throughout the mine area.

The gypsum is fine-grained, sugary-textured, structurally massive, and white to light brown or grey in colour. It is interlayered with aphanitic brown dolomite and to a lesser extent, with grey dolomitic shale or shaly dolomite. Individual gypsum layers range from paper-thin laminae to beds several inches in thickness. Gypsum may be in sharp contact with the thin dolomite seams or gradational with them. In most cases the thicker and purer gypsum layers are characterized by massive colloform or botryoidal structures that deform the stratification both above and below. Massive gypsum layers are veined by paper-thin dolomite laminae and minute fractures healed by clear, colourless, selenite. A pseudoporphyritic texture, due to discreet crystals and grains of recrystallized selenite slightly coarser than the groundmass, is especially noticeable in the colloform masses.

The roof and floor sections of the mine consist mainly of brown aphanitic dolomite irregularly interlayered with gypsum. A 5-foot thickness of mixed dolomite and gypsum in

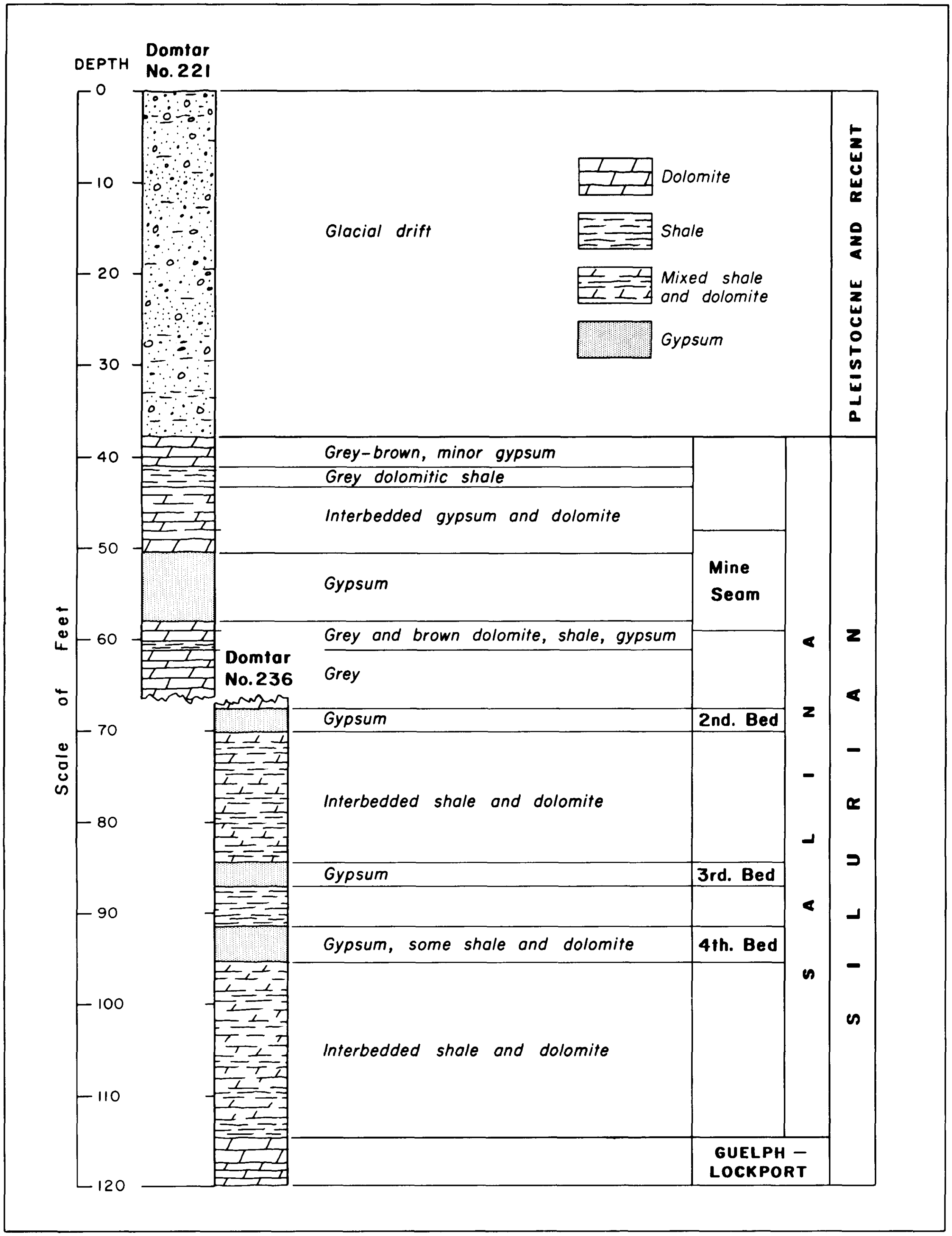


Figure 21 — Typical columnar section through the Salina Formation at Caledonia

the roof contains 20 - 55 percent gypsum. A mottled dark-grey and medium-grey dolomitic shale is present to a minor extent in beds 2-4 inches thick. The shale is poorly laminated and contains no gypsum, but occasional bedding planes or horizontal fractures are filled by fibrous and translucent selenite and epsomite (G.R. Hunt, personal communication). A 12-inch shaly horizon, 5 feet above the roof of the mine, is relatively impervious to water; it is credited with sealing the mine workings from excessive surface drainage. During mining, the gypsum breaks cleanly to a shale parting at the top of the "First Roof" unit.

Some of the gypsum seam is left in the mine floor to provide a firm level base for the trackless mining equipment. If not carefully controlled the seam will break to an irregular and gradational shale-dolomite contact 2.0-2.5 feet below the desired floor level.

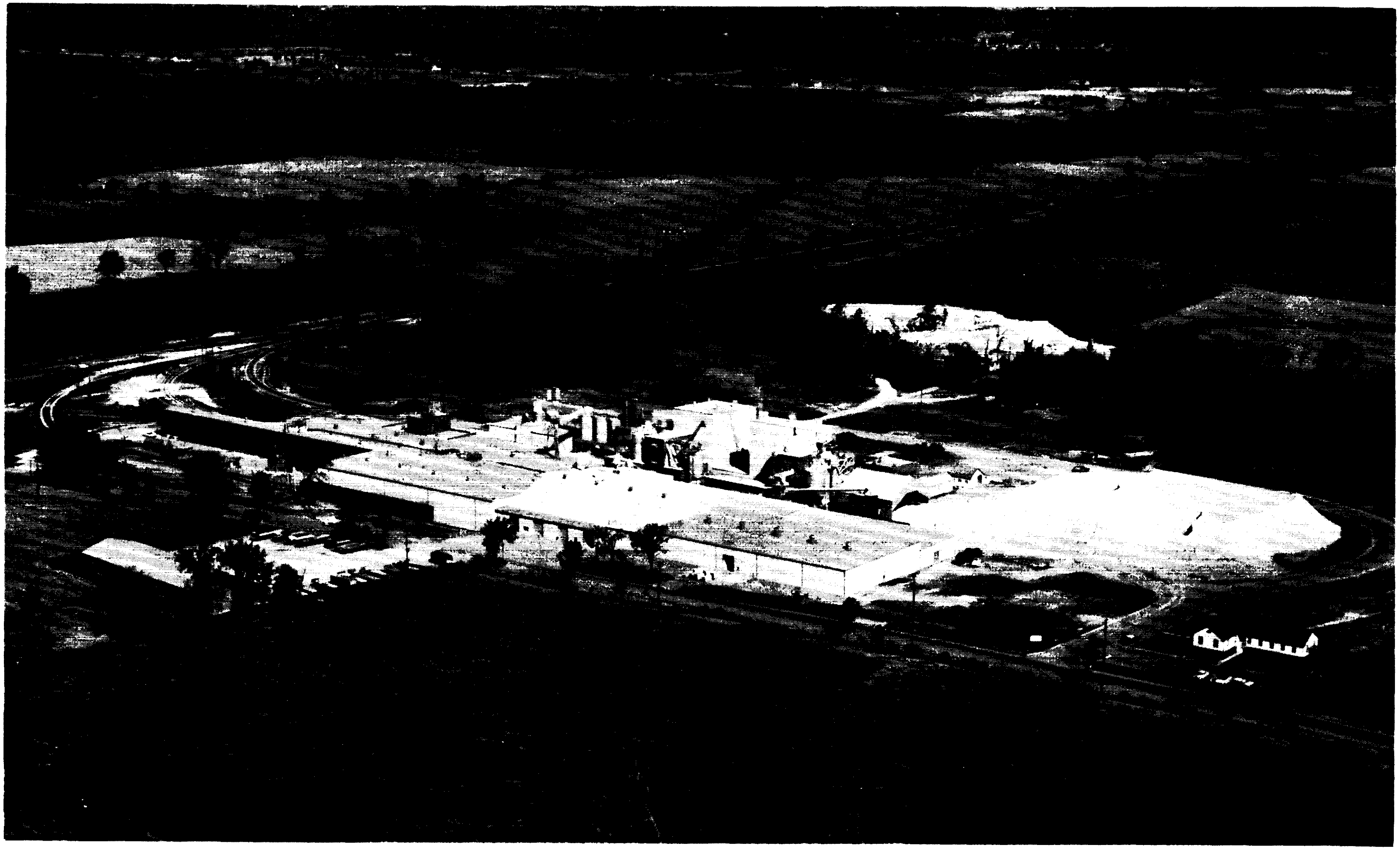
Milling and Calcining

The minus 2-inch gypsum lump is stored at the shaft-head in two 130 ton bins. It is trucked to the plant as required and elevated to a small storage bin in the milling section. Prior to further grinding, the lump gypsum is dried in a parallel-flow, oil-fired, rotary dryer equipped with a cyclone dust collector. The dried lump is elevated to two small bins which feed two Jeffrey hammermills. Hammermill discharge is elevated to two bins feeding three Raymond roller mills in closed circuit with cyclone particle collectors.

The ground gypsum is pumped pneumatically to the calcining sections where it is stored in two 200-ton steel bins. There are three calcining kettles in the original mill building, and four in a new building. The 10-foot diameter kettles operate on a batch-process, calcining 14 tons of gypsum on a $2\frac{1}{2}$-hour cycle. Four tons of water are evolved from each batch, and about 1 ton of gypsum fines are reclaimed by a precipitator in the exhaust stack. Kettles are dumped at a temperature of 315°F; calcined material is retained in hot-pits for cooling prior to transfer by drag chains and screw conveyors to storage.

Plaster of paris from the new calcining plant is delivered by screw conveyor to the wallboard plant, where the material is made into all types of board products.

Courtesy Phil Aggus & Son, Hamilton



Canadian Gypsum Company, Limited, Hagersville

CANADIAN GYPSUM COMPANY LIMITED

Canadian Gypsum Company, Limited, began exploration of the Hagersville area in 1930, and opened a plant and mine in 1931. According to company officials (personal communication) "The Salina group here is an extension of that found in western New York, where gypsum had been produced since the mid - 1800's, and the Hagersville seam corresponds stratigraphically with that mined in Genessee County, New York, in the vicinity of Oakfield; hence, the name "Oakfield seam" was given to the gypsum mined at Hagersville."

The mine and plant are located 3 miles north of Hagersville, on the west side of Highway no. 6, in concessions III and IV, Oneida township, Haldimand county. Underground development extends over an area ½-mile by 1¼ miles.

Mining Method

The "Oakfield seam", a 3-4 foot seam of white gypsum, lies at a depth of 60-100 feet in the mine area. It is mined from a vertical, 2-compartment, shaft 95 feet deep. The room and pillar method of mining is used, and panels of four rooms are driven as single units for distances of 200 feet at right angles to the main haulageways. Rooms are 24 feet wide, and crosscuts are arranged to leave pillars 12 feet by 18 feet. Drilling is done by Copco percussion drills mounted on rubber-tired Joy carriers; drillholes are $1\frac{3}{4}$ inches in diameter. Broken gypsum is recovered by 3-drum, 30 horsepower, slusher hoists equipped with 58-inch buckets. Using portable ramps the slushers load end-dump cars of 2-ton capacity. Cars are hauled by battery-powered locomotives to the shaft. The main haulageways are brushed to a height of 5 feet. A soft bed of shaly dolomite overlying the gypsum seam is supported by 36-inch roof bolts installed on a 5-foot grid. Ventilation is provided by two vertical air and escape shafts. Mining is carried on during 2 shifts each day.

A double-drum, 100 horsepower, Ingersoll Rand hoist lifts the broken gypsum to surface in a 24-inch by 36-inch single car cage. The gypsum is discharged into a single roll crusher, and delivered directly to the mill or stockpiled in the yard.

The Gypsum Seam

The Oakfield seam is overlain by 10-40 feet of brown dolomite or grey shaly dolomite, and 20-50 feet of till. The bedrock dips south at a very low angle and outcrops north of the plant. The area of outcrop forms the northern limit of the mineable zone; the southern limit is gradational because of an increasing anhydrite content with depth. The mineable zone averages 8,000 feet in width (north-south).

The average section in the vicinity of the Oakfield seam, as exposed in the mine workings, is shown in the accompanying table.

	Lithological Unit	Thickness (inches)
	Shaly dolomite	
	Gypsum	10-18
	Dolomite	24-32
Mined Section	(Shale parting	
	Shale	4-12
	Gypsum (Oakfield seam)	36-48
	Dolomite	4-8
	(Shale parting	

Gypsum in the Oakfield seam is a fine-grained, white variety, much of which occurs with a massive colloform structure superimposed on the horizontal bedding. Individual swellings in the massive colloform sections are 2-6 inches in diameter; they are outlined by thin shaly or limy laminae which amount to less than 10 percent of the seam.

A thin bed of platy, brown, shaly dolomite is gradational with the base of the Oakfield seam and is difficult to avoid in mining. Similarly, above the seam a soft, thin-bedded, grey shale is usually broken with the gypsum. The roof of the underground workings consists of a 24-30-inch thickness of fine-grained, brown, shaly dolomite which must be supported by roof bolting into an overlying, compact, gypsum bed. This gypsum seam is also of good quality, but it is not mined because of the thickness of waste rock between it and the main gypsum bed.

Milling and Calcining

Gypsum is reclaimed from stockpile, or delivered direct to the mill from the primary crusher at the shaft head. Final sizing of the plant feed is accomplished by rolls crushers and screens. Two rotary kilns are used for calcining the gypsum, and the resulting stucco is ground in either a Raymond mill or a Tube mill. A complete range of gypsum plasters and wallboards are made at the plant. The wallboard section is highly automated.

WESTERN GYPSUM PRODUCTS LIMITED

The Clarkson Plant of Western Gypsum Products Limited commenced production in 1963. The company also has plants in Winnipeg, Calgary, and Vancouver, and mines at Silver Plains, Manitoba, and Windermere, British Columbia. In 1960-61 the company carried out exploration for gypsum in the vicinity of Drumbo, 10 miles northeast of Woodstock. Western Gypsum Products Limited is a subsidiary of British Plaster Board (Holdings) Limited, of London, England.

Exploration in the Drumbo Area

A large amount of diamond drilling was carried out principally on lots 20-22, concessions VI-IX, Blenheim township, Oxford county. The holes encountered 150-200 feet of overburden, 200-250 feet of Salina rocks, and were stopped in the underlying Guelph-Lockport dolomite. A 6-7-foot gypsum seam was intersected at a depth of about 375 feet. In 1961 a 42-inch diameter vertical shaft was drilled on the west half of lot 21, concession VI, to further explore and sample the bed. Development of the property was still under consideration in 1964.

The Clarkson Plant

A modern and highly-automated milling and fabricating plant was opened on the shore of Lake Ontario at Clarkson in 1963. The plant has its own docking facilities, and up to the present time (September 1964) has been receiving both truck and boat-shipments of crude gypsum from outside sources.

Crude gypsum is stockpiled on an open concrete floor at the back of the plant, and is reclaimed as required by a subgrade hopper and conveyor. In the milling section the 6-inch feed is reduced to minus 1-inch in a hammermill and elevated to primary storage bins. Gypsum from primary storage is further ground in a vertical shaft Raymond roller mill and is air-classified to 90 percent minus 100-mesh. A hot air stream passing through the mill during grinding removes surface moisture from the gypsum particles.

Calcining is accomplished in a single kettle of 20-ton capacity. The kettle is gas-fired, and the calcining cycle is about $2\frac{1}{2}$ hours. Moisture is exhausted to the atmosphere through electrostatic precipitators. The finished plaster is dumped from the kettle to a hot pit where it is allowed to cool before it is transferred by screw conveyors and bucket elevators to the product silos.

Plaster products are mixed with additives and aggregates as required, and bagged. Wallboard and lath are manufactured in a conventional board machine, and dried in an 8-deck gas dryer. About 75 men are employed in the plant.

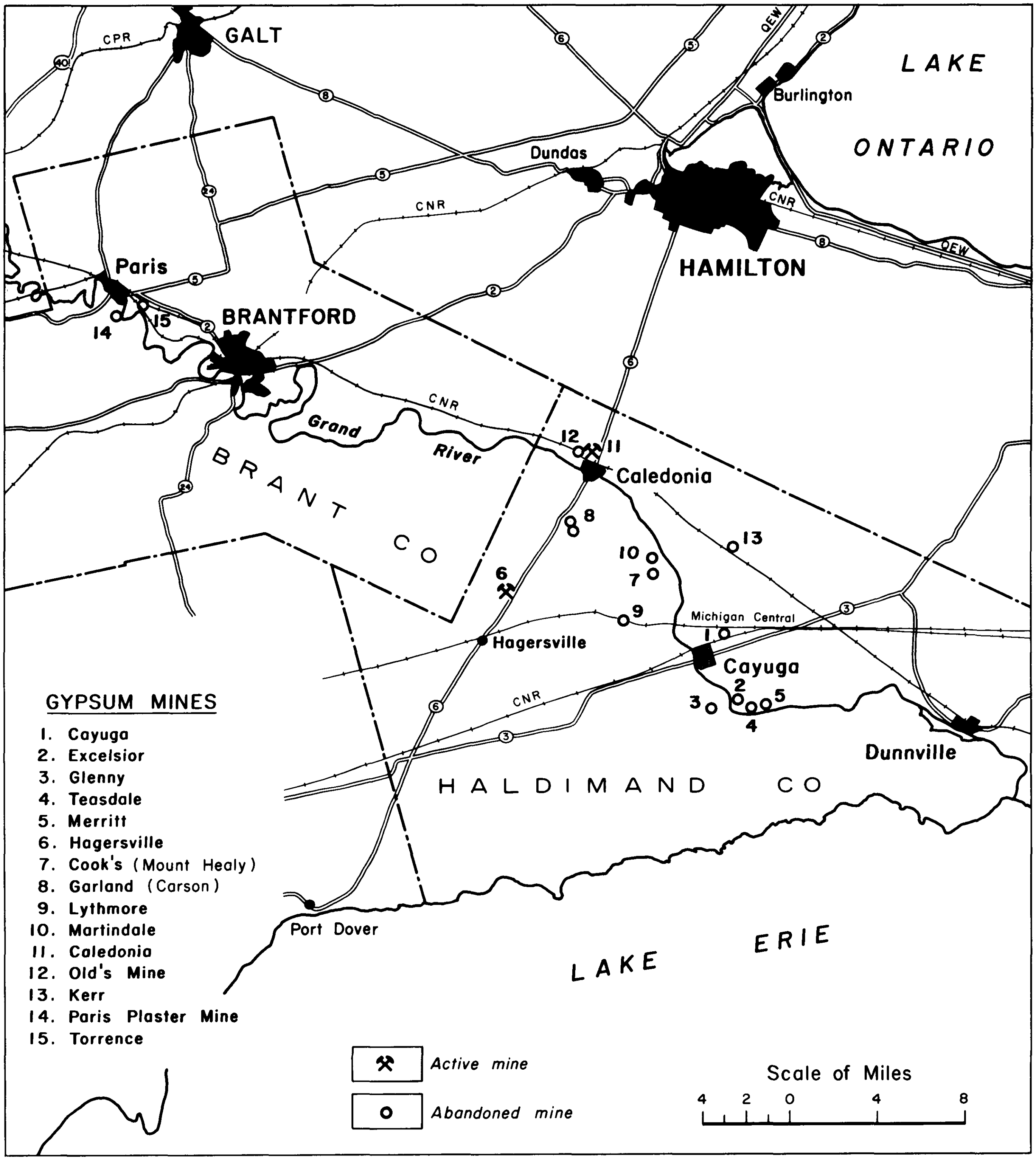


Figure 22 — Gypsum mines in Haldimand and Brant Counties.

PAST PRODUCERS

The history of gypsum mining in Ontario dates from 1822 when a small gypsum bed was opened in the bank of the Grand River about 1 mile south of Paris. Fourteen other mines have since been opened, all but two of them in Haldimand county. Most active development of the gypsum occurred in the latter half of the 18th century when many deposits were worked principally for land plaster. Since World War I only four mines have been active, two of which are still operating. L.H. Cole (1913, pp. 63-76) traces the history of these mines to 1913, and G.E. Cole (1925, pp. 5-7) summarizes their operations to 1924. Figure 22 shows the locations of the principal mines.

Cayuga Mine

The Cayuga mine was opened in 1942 and closed in 1949; it was operated by the Cayuga Gypsum Company. A 3-foot seam of white gypsum was worked from a vertical shaft located in the northwest corner of lot 25, concession IN., North Cayuga township. The gypsum seam lies at a depth of 85 feet, and is overlain by 30 feet of shale and 52 feet of clay.

Excelsior Mine

The Excelsior mine was located on the north side of the Grand River in lot 2 of the Jones Tract. It was opened by A.W. Thompson in 1875, and was worked successively by Messrs. Gill, Allan, and Brown, the Adamant Manufacturing Company, and the Alabastine Company, until 1895. A grinding mill was built on the property in 1875 and a calcining plant in 1891. The 4-foot bed of white gypsum, at a depth of 50 feet, was reached by an inclined tunnel.

Glenny Mine

The Glenny mine, located on the south side of the Grand River in lot 3 of the Jones Tract, North Cayuga township, was opened by Robert Glenny in 1874, but may have been worked on a small scale as early as 1850. It was operated by the Grand River Plaster Company from 1880 to 1892, and was re-opened by the Imperial Plaster Company in 1902. It was purchased by the Toronto Plaster Company in 1911, but appears to have been closed shortly thereafter. A grinding mill was built in 1878, and a calcining plant in 1886. The 4-foot gypsum bed, located at a depth of 42 feet, was reached by a 300-foot inclined tunnel.

Teasdale Mine

The Teasdale mine was opened by Thomas Teasdale in 1889, leased to the Alabastine Company in 1890, and closed in 1895.

The property was located on the north side of the Grand River, and included lot 1 of the Huffman Tract and lot 4 of the Jones Tract in North Cayuga township. Production from the $4\frac{1}{2}$-foot bed of white gypsum was transported to Paris, Ontario, for calcining.

Merritt Mine

The Merritt mine, located on the north side of the Grand River in lots 2 and 3 of the Huff Tract, North Cayuga township, was opened about 1850. It was operated by the Grand River Plaster Company from 1880 until it was closed in 1893. A grinding mill was built on the property in 1878, and a calcining plant in 1886. A $4\frac{1}{2}$-foot bed of white gypsum was worked from a tunnel driven from the river bank.

Cook's Mine (Mount Healy Mine)

In 1838 a grinding mill was built at York to grind gypsum from Cook's mine which was located on the south side of the Grand River in the Cook Block of the River range, Oneida township. It is uncertain when the mine was first opened, but in 1870 it was re-opened by W. Donaldson and Company and re-named the Mount Healy mine. Originally a quarry operation, it was later taken over by the Crown Gypsum Company and worked from a 500-foot inclined tunnel. The 4-foot bed of white gypsum was located at a depth of 70 feet. The mine was closed in 1919.

Garland Mine (Carson Mine)

N. Garland opened two mines on adjoining lots south of Caledonia. The first was opened in 1870 on property originally owned by Joseph Brown, lot 13, concessions V and VI, Oneida township. Ownership was transferred to L.J. Johnson in 1881, but it reverted to N. Garland in 1891 and was closed in 1895. Mr. Garland opened a second mine in 1886 on the west half of lot 14, concession V, Oneida township. It was purchased by William Smith in 1898. Later, both properties were taken over by the Alabastine Company and re-named the Carson mine. During the early years, gypsum from the mines was ground in a mill at Caledonia, but the Alabastine Company transported their production to a mill at Paris, Ontario.

Access to the first mine was by an inclined drift driven southwest from Mackenzie Creek. The 5-foot bed of white gypsum occurred at a depth of 52 feet. An inclined drift also gave access to the second mine, where the gypsum bed was found at a depth of 70 feet.

Lythmore Mine

The Lythmore mine was located in lot 29, concession III, Oneida township, just northwest of Lythmore station. It was opened in 1916 by the Ontario Gypsum Company, and was later operated by Gypsum, Lime, and Alabastine Canada Limited. It was closed in 1932. A 2-compartment, 6-foot by 10-foot, vertical shaft, 114 feet deep, intersected an 8-foot bed of grey gypsum at a depth of 81 feet, and 3 feet of white gypsum at 114 feet. The 8-foot bed was broken into 3-foot and 5-foot seams by a 1-foot shale bed. An air shaft $\frac{1}{4}$-mile west of the main shaft, and collared 57 feet above the latter, encountered the 8-foot bed at 139 feet. It also intersected 40 inches of white gypsum at 72 feet, and 66 inches of grey and white gypsum at 104 feet; these two seams apparently cut-off at the bedrock surface before reaching the main shaft. The two shafts were connected by a drift at the 90-foot level, driven along the 8-foot grey bed. Broken gypsum was trammed by battery locomotive on a 36-inch gauge track, and hoisted to surface in a 2-ton skip. A grinding and calcining plant on the property had been built by the Crown Gypsum Company in 1908 to process gypsum from the Martindale mine. It was expanded and used throughout the life of the Lythmore mine.

Martindale Mine

The Martindale mine was located $\frac{1}{2}$-mile below York on the south side of the Grand River; the property included lots 56 and

57 of the River range, Oneida township. The mine was opened by John Martindale in 1846 and was worked almost continuously for 50 years. In 1908 it was re-opened by the Crown Gypsum Company. By amalgamation in 1917 with the Alabastine Company, the Crown Gypsum Company became the Ontario Gypsum Company, and the mine was worked under this name until it closed in 1919. In the early years the gypsum was processed in a grinding and calcining plant at York, but after 1908 it was handled in a new plaster plant at Lythmore. The bed of white gypsum was reached by a tunnel from the river bank.

Old's Mine

In 1910 the Caledonia Gypsum Company sank an inclined exploration shaft on the farm of John Old. The property, located $\frac{3}{4}$ miles northwest of Caledonia, adjoined the Caledonia mine; it consisted of lot 10, range II west, Seneca township. Thin lenticular beds of gypsum were found at depths of 55 feet and 70 feet. When its mill was burned in 1911 the mine was closed.

Kerr Mine

Sometime prior to 1913 the Crown Gypsum Company sank an exploration shaft on the Kerr property. The property lies $4\frac{1}{2}$

miles east of York, at Cooks station on the C.N.R. Pink gypsum was encountered intermittently in the bottom 30 feet of the 80-foot shaft, but no production is recorded.

Paris Plaster Mine

A mine opened by Wm. Holmes in 1822 on the west bank of the Grand River about 1 mile below Paris was one of the earliest mining ventures in Ontario. The property included the farms of Messrs. Miller and Martin, lot 12 concession I, Brantford township, Brant county. The mine was purchased by the Alabastine Company in 1890, and was closed in 1905. A grinding mill was built in 1823, and calcining facilities were added later. The mine was worked from a tunnel driven from the base of a hill. A bed of grey gypsum, $4\frac{1}{2}$-6 feet thick was worked at a depth of 100 feet.

Torrence Mine

First prospected in 1846, a mine was later opened by Wm. Hynes and James Wright on lot 16 concession I Brantford township, Brant county. Drifting in the mine was of an exploratory and development nature only; no production is recorded.

MINING AND PROCESSING

Thick beds of gypsum located near surface lend themselves well to conventional open-pit mining. The low unit value of crude gypsum makes it necessary to have an inexpensive mining operation. Of the 70 mines operating in the United States in 1962, 54 were open-pit (Kuster and Mallory 1963, p. 1).

Gypsum in southern Ontario was formerly mined by inclined open cuts that followed the beds a short distance underground from their outcrops in the banks of the Grand River. More extensive workings were developed from inclined adits, and the gypsum was mined at shallow depths by room and pillar methods. Track haulage was common, the motive power being supplied by hand or horse.

At Hagersville and Caledonia gypsum is mined by room and pillar methods at depths of about 100 feet. Canadian Gypsum Company Limited gains access to a 4-foot gypsum seam by way of a vertical 2-compartment shaft. Rooms are driven 24 feet wide and the backs are supported by pillars 12 by 18 feet. Domtar Construction Materials Limited mines an 8-foot seam from an inclined shaft. Rooms 20-22 feet wide are driven in parallel units, each room being separated from the next by a 10-12 foot longwall pillar that is later partly removed by crosscuts. Trackless mining is employed by the Domtar company at Caledonia and the gypsum is removed from the mine by belt conveyor. At Hagersville, battery-powered locomotives haul 2-ton end-dump cars to the shaft for hoisting. The mining methods are further described in the section dealing with the individual companies.

Primary and secondary crushing is accomplished with jaw, gyratory, or impact mills that may be located in the mine, at the shaft head, or in the milling plant. Final grinding is normally by hammermills and roller mills in closed circuit with screens or cyclone-type particle collectors. Drying in rotary dryers normally precedes fine grinding.

Calcining is accomplished in "kettles" or rotary kilns. The chemistry of gypsum calcination is discussed by Bauer (1952, pp. 113-123). Kettles are batch-calciners of a type peculiar to the gypsum industry. They are vertical steel cylinders, 8-15 feet in diameter and 8-12 feet high, enclosed in a shell of brick. The kettle is normally fired by oil or gas, and the hot gases are permitted to circulate between the brick and steel shells. Kettles hold 10-20 tons of raw gypsum, ground to 100 mesh, and the charge is heated to 250-300°F. The calcining cycle normally takes 2-3 hours, during which time constant agitation of the batch is maintained by horizontal revolving paddles and the boiling turbulance caused by steam evolution. Slight subsidence in the boiling action may mark the end of the first dehydration, when the gypsum will have lost three-quarters of its water of crystallization and be largely present in the hemihydrate, or plaster form. But the end-point is not always distinct, and further dehydration will cause the formation of anhydrite and a consequent deterioration in the quality of the plaster. Kettles are discharged to hot pits, where the plaster cools prior to transfer to storage or fabricating plant. Calcining plants at Caledonia and Clarkson use kettles.

Calcination by rotary kilns uses gypsum in lump form, usually minus 2-inch. Gypsum is fed into one end of the slowly revolving kiln, where the temperature is about 250°F., and discharged at about 300°F. after a retention time of 35-40 minutes (Collings 1959, p. 19). The process is a continuous one, and the plaster is ground to 100-mesh after discharge. The calcining plant at Hagersville uses rotary kilns.

Finished plaster is mixed with additives and aggregates, as required for its various end uses, and bagged. Plaster for lath and wallboard is mixed with various additives, and extruded as a wet slurry between layers of absorbent paper in board-forming machines. Fabricating processes are well described by Collings (1959, pp. 19-21).

MARKETING

Most gypsum mines are captive, and are operated in association with their own calcining and fabricating plants.

Except for deliveries of crude gypsum to cement plants, the mine output is consumed almost entirely by the company's own plaster and wallboard plants. In the United States a few small mines are operated without calcining plants, the ground crude being sold for local cement or agricultural use.

In Ontario, the mines at Caledonia and Hagersville produce gypsum principally for their own use. Both companies deliver crude gypsum lump to Portland cement companies.

Price information is scarce for gypsum since there is little open market for the crude rock. Sales to cement plants are made by individual negotiation on long term contracts. Typical prices in the United States in 1959 (Havard 1960, p. 485) were $3.50 per ton for cement rock, and $17.25 per ton for base coat plaster, in carload lots f.o.b. producing mill. Prices for wallboard were quoted at $45-$50 per 1,000 square feet.

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APPENDIX I

Gypsum Distribution based on Oil and Gas-well Borings

The list that follows shows locations of oil and gas-well borings that intersected concentrations of gypsum or anhydrite in amounts sufficient to indicate the possibility of mineable seams. The list is based on the study of rock cuttings from 672 boreholes in the counties of Welland, Haldimand, Norfolk, Brant, Oxford, Waterloo, Perth, Wellington, and Bruce. Samples of the rock cuttings normally represent sections 5-10 feet in length arranged consecutively throughout the entire length of the hole. Although gypsum is a minor constituent of certain parts of the Salina Formation in practically all borings examined, only the sample sections containing more than 10 percent gypsum are recorded. No particular attempt was made to distinguish between gypsum and anhydrite, but where anhydrite was obvious and predominant the section is marked with an asterisk.

A list of oil and gas borings in Ontario has been prepared by B.V. Sanford (1964) of the Geological Survey of Canada. The list includes all borings to June 1963 for which sample cuttings are available. Borehole cuttings may be examined at the Geological Survey of Canada, 601 Booth Street, Ottawa.

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE (*Anhydrite predominant) (percent)
Brant	Brantford	I	7	227-235	25
				251-259	35
				267-275	25
	Burford	I	15	228-256	20
		I	18	280-295	15
				372-380	15
		I	19	263-272	15
				368-374	15
		I	19	396-404	25
		I	19	149-170	15
				234-246	15
				284-293	20
				297-309	15
				322-340	15
		I	20	280-290	25
		I	21	203-211	20
		I	22	224-241	15
				259-265	20
				427-438	50
		I	22	361-381	20
		I	22	283-294	25
				459-464	20
		I	22	345-358	20
		I	23	200-223	15
				362-370	20
				473-480	20
		II	18	260-280	30
		II	21	216-225	40
				268-272	25
				339-344	30
				377-383	35
				429-436	20
		IV	8	225-243	20
	Oakland	IV	8	200-205	25
				225-230	20
	Onondaga	II WFC	21	115-120	30
		III WFC	14	130-135	25
		III WFC	17	63-73	90
Brant	Tuscarora	III	13	200-222	30
		BF	7	82-88	25
				95-100	35
Bruce	Brant	I	35	218-222	15
	Culross	V	18	693-699	30
		VIII	5	546-562	15
				759-765	30

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE (*Anhydrite predominant) (percent)
Bruce (cont.)	Kincardine	CNR STN.		920-930	40
				940-950	60
Haldimand	N. Cayuga	I N	16	65-75	20
				170-175	15
		I N	24	50-60	15
		I N	37	235-240	15
				260-275	35
		I STR	45	100-110	20
				160-190	25
		I STR	46	90-120	15
		JONES TRACT	26	165-180	25
				200-205	15
				370-375	20
		JONES TRACT	26	170-175	30
		JONES TRACT	27	160-165	15
		JONES TRACT	27	155-165	20
	S. Cayuga	VII	15	185-190	15
	Dunn	V S	13	221-227	15
				311-325	15
	Moulton	III LES	24	230-240	20
		I C	5	173-187	25
	Oneida	III	17	135-140	15
				235-240	15
		EPR	23	180-185	20
		EPR	23	170-180	20
		WPR	10	60-70	25
				135-140	15
		WPR	10	195-200	30
		WPR	11	70-75	25
				125-155	15
				160-165	20
				195-200	20
		WPR	22	175-180	25
		WPR	23	65-70	15
				90-105	15
	Rainham	I	6	196-206	20
		I	13	170-195	15
		II	1	325-340	20
		II	2	260-270	15
		II	4	380-390	15
		III	2	190-195	20
				230-245	30*
				370-390	20

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE (*Anhydrite predominant) (percent)
Haldimand (cont.)	Rainham (cont.)	III	3	165-180	15
		III	3	190-205	20
				365-370	20
		III	3	350-360	20
		III	4	190-210	15
		III	4	225-235	15*
		IV	1	230-245	25*
		IV	11	189-217	15
		IV	13	150-155	15
				175-200	30
				205-210	15
				220-225	20
		V	4	315-325	15
				430-435	20
		V	5	250-260	15
				340-350	15
		V	8	145-160	20
				210-220	25*
		V	9	140-180	20
				205-210	25
		V	12	165-185	15
				355-360	20
		VI	2	198-211	40
		VI	3	160-190	20
		VI	4	120-140	15
		VI	6	170-180	30
				210-215	25
		VI	6	170-185	20
				215-225	15
		VI	9	180-190	20
		VII	6	175-180	20
				200-210	15
				360-375	15
		VIII	4	135-155	20
				180-195	15
		VIII	4	185-205	30
	Seneca	I SSCR	7	105-110	25
	Sherbrooke	I	12	185-195	25
		II	12	155-165	25
		II	16	190-200	20
	Walpole	I	6	210-215	15
				235-240	15
				275-285	15
		I	7	245-250	20
		I	7	235-240	20
				280-295	25*
		I	7	270-280	20*
		I	8	225-230	15

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE (*Anhydrite predominant) (percent)
Haldimand (cont.)	Walpole (cont.)			295-300	20*
		I	8	280-285	30*
		I	8	230-235	20
				260-265	20
				320-325	20*
		I	8	290-305	20*
		I	9	485-490	25
		I	20	450-455	20
		II	4	395-405	15*
		II	18	240-245	25
				370-375	15
		II	20	240-250	25
				255-265	25
				320-325	20
				340-345	25
		III	19	440-450	15
		IV	19	220-240	20
				245-250	15
				260-270	25
				320-325	15
				360-365	15
		VII	2	185-190	20
				195-200	30
				215-220	25
		VII	14	145-150	20
				210-220	15
		VIII	15	406-415	20
		X	23	290-295	25
		XIII	8	260-270	15
		XIII	9	360-370	25
		XIV	8	360-365	20
		XIV	8	125-130	15
				185-190	15
		XIV	9	100-110	25
				260-270	20
		XIV	10	170-180	20
		XIV	10	360-365	30
		XV	6	260-280	20
Norfolk	Charlotteville	I SFR	19	525-535	30
				590-600	20
		I	18	581-595	15
		III	24	490-495	35
		IV	18	507-514	40
				528-535	25
				542-549	30
				613-620	30*
		V	3	655-665	15
		V	18	533-547	60

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE(*Anhydrite predominant) (percent)
Norfolk (cont.)	Charlotteville (cont.)			589-596	20
		VI	12	543-576	25
		VI	12	550-560	25
		VII	4	563-590	15
		VII	22	565-570	25*
				715-725	20*
		IX	5	619-627	30
		IX	7	650-660	15*
				806-815	20
		IX	22	415-420	20
		XII	3	550-615	25*
		XII	4	550-560	15
				615-620	25
				695-700	25*
	Middleton	I STR	7	684-690	15*
		I STR	8	605-610	15
		I STR	8	858-876	20*
		I STR	20	863-866	20
		I STR	34	545-560	20*
				810-825	20
		I STR	35	500-520	15
		I STR	46	645-655	20
		II STR	8	622-628	20*
				652-656	20*
		II STR	18	655-660	15*
				795-800	15
				825-830	15*
		II STR	31	526-533	20
				579-598	20
				760-769	20*
		II STR	33	740-770	15
				855-860	25
		II STR	34	855-860	20
		II STR	34	715-720	20
				760-800	20*
				840-845	30
		II STR	34	800-805	20*
				820-830	20
		II STR	34	735-745	15*
		II STR	35	565-575	15
				590-600	15
				760-770	15*
		II STR	35	695-710	15
		II STR	35	740-750	20
		II STR	36	495-520	25
		III STR	22	635-645	30
		III STR	30	600-610	20
				625-640	25*
				810-820	20

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE(*Anhydrite predominant) (percent)
Norfolk (cont.)	Middleton (cont.)	IV STR	21	604-615	25
		IV STR	23	643-654	25*
		IV STR	24	615-620	25
		I NTR	32	709-716	30
		I NTR	34	527-557	30
				669-677	40
		II NTR	1	685-690	15
				705-715	15
		II NTR	1	735-740	20
		II NTR	1	770-775	50*
		II NTR	2	600-605	50*
				610-615	50*
		II NTR	6	695-700	25*
				735-740	40*
		II NTR	11	622-628	25*
		II NTR	34	443-452	25
		II NTR	35	461-470	20
				644-659	40*
		II NTR	35	510-520	20*
	Townsend	VII	18	310-320	15
				430-440	25
		IX	6	332-350	25
		IX	12	322-328	20
				412-418	15
		X	2	248-257	15
				278-285	20
				302-330	20
				548-555	15
		X	5	294-300	20
				324-336	20*
				452-464	20*
				506-519	25
		X	9	292-345	15*
				554-560	15
		X	10	285-305	15
		XI	10	280-285	20
				310-315	15
		XI	12	245-250	15
				260-275	15
		XII	7	294-300	20
				330-354	20
		XII	8	340-364	15
		XII	8	366-396	15
				523-529	15
		XII	12	232-237	15
				375-381	20*
				403-408	15
				505-512	30

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE(*Anhydrite predominant) (percent)
Norfolk (cont.)	Townsend (cont.)	XII	13	245-260	15
				340-350	25*
		XII	15	236-260	20
				380-385	15*
		XII	15	237-260	20
				400-410	15
		XII	15	180-185	20
		XIII	6	440-480	15
				480-500	15
		XIII	6	457-477	15
		XIII	6	485-495	15
		XIII	6	237-254	20*
		XIII	7	475-485	15
		XIII	7	352-362	15
		XIII	7	347-383	20
				445-454	15*
				492-502	20
		XIII	10	406-412	20*
		XIII	13	395-405	20*
		XIII	18	178-193	20
				315-320	20
				330-340	20
		XIV	3	335-340	25
		XIV	8	296-320	30
				434-440	20*
		XIV	9	300-315	30
		XIV	10	266-273	20
				292-304	25
		XIV	24	185-195	20
	Windham	VIII	9	320-340	20
				381-410	20
		IX	9	245-260	50
		XII	22	542-557	20*
		XIII	8	610-631	20
		XIII	11	380-398	20
		XIII	11	418-425	20*
		XIII	12	391-419	20
		XIII	12	389-420	15
		XIII	13	408-422	25
		XIII	13	415-435	20*
		XIV	6	598-603	25
		XIV	6	570-583	20
		XIV	7	399-409	25
				454-462	25
				493-503	35
		XIV	10	410-417	25
		XIV	10	435-442	30
		XIV	13	430-445	20
				465-471	25*
		XIV	13	468-471	25
		XIV	13	438-448	20*

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE(*Anhydrite predominant) (percent)
Norfolk (cont.)	Windham (cont.)			686-698	30
		XIV	14	509-516	25
		XIV	14	457-508	25
		XIV	14	455-462	30
		XIV	18	539-550	50
				800-806	20*
		XIV	18	550-555	25
		XIV	18	414-446	30
	Woodhouse	I	23	410-430	20
		I	24	230-245	15
		III	5	735-740	20
		III	10	310-330	20
		IV	8	455-460	25
		IV	11	335-345	20
				475-490	25
		IV	11	247-253	25
				280-286	25
				478-484	35
		IV	11	405-410	20*
				435-440	20
		IV	11	263-273	20
				303-308	25*
		V	9	280-290	20
				405-415	25
		V	9	270-275	15
				300-315	15
		V	11	230-235	20
		V	13	230-235	30
		VI	8	302-313	25
		VI	9	422-429	40
		VI	11	291-303	25
Oxford	Blandford	II	12	532-542	40
		V	3	380-406	15
		V	4	198-208	35
				396-404	25
	Blenheim	I	16	300-325	25
		I	17	245-320	15
		I	19	310-340	25
		I	19	229-242	30
				280-290	20
		I	19	229-240	25
				285-293	25
		I	19	304-310	20
				341-347	50
		I	20	325-345	15
		I	21	341-349	15
		I	21	235-245	50

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE (*Anhydrite predominant) (percent)
Oxford (cont.)	Blenheim (cont.)			265-277	25
		I	21	374-382	25
		I	24	181-188	20
	Dereham	I	18	565-580	20
				725-740	15
				860-865	25*
		II	27	525-532	25
		VIII	12	672-684	20
				732-744	40
		IX	25	719-751	15
		X	12	619-634	30
		XI	23	575-580	20
		XI	24	740-760	25
		XI	27	650-660	20
				780-785	15
		XII	21	780-785	25*
		XII	22	740-755	25*
		XII	23	620-630	15
		XII	24	535-540	15
				590-620	15
		XII	24	580-585	35
		XII	24	640-650	15
				880-885	25
		XII	25	630-640	25
		XII	25	697-705	15
		XII	26	560-570	15
				585-610	15
				670-680	20
				770-775	15
		XII	27	880-885	30
	E. Nissouri	VIII	32	740-750	15
		X	35	605-610	20
				690-700	15
		XIV	32	546-552	30
				640-646	20
	N. Norwich	II	4	191-197	20
				221-237	25
				486-494	25
		V	3	330-350	20
		VI	8	380-385	15
				655-660	15
	S. Norwich	VII	13	355-360	15
				365-370	30
				605-610	20*
		VIII	13	559-566	20
		X	8	458-464	20
				495-513	25
				640-646	15

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE (*Anhydrite predominant) (percent)
Oxford (cont.)	S. Norwich (cont.)	XI	22	618-629	15
		XI	2	385-391	20
		XI	2	558-566	15
		XI	2	412-426	20
				569-593	15
		XI	3	370-375	20
				415-435	20
				555-565	30
				695-700	15
		XI	5	582-588	25
		XI	22	413-417	20
		XI	23	389-399	25
				601-611	20
		XI	23	411-423	20
				506-512	15
				627-638	20*
	N. Oxford	II	18	330-350	30
				600-610	20
		V	5	535-540	15
				565-570	20
	W. Oxford	BF	3	426-467	30
		I	1	447-478	15
		I	3	488-498	30
				578-585	25
		I	12	477-491	30
		I	27	677-686	30
				795-804	30
		II	3	380-385	15
				405-410	30
				555-565	20
		II	4	407-432	30
		II	5	567-574	15
		II	5	550-580	15
		II	5	435-440	40
				465-470	35
				585-615	15
		II	6	415-420	20
		II	16	462-488	20
		II	24	436-442	20
				634-646	20
		III	4	405-420	15
				435-445	15
		V	13	578-594	20
	E. Zorra	XV	16	368-375	25
				411-419	30
	W. Zorra	II	28	568-598	15
				638-644	20
				680-688	20*

COUNTY	TOWNSHIP	CON.	LOT	DEPTH FROM SURFACE (feet)	GYPSUM and (or) ANHYDRITE (*Anhydrite predominant) (percent)
Perth	Blanchard	VIII	10	732-748	25
		XV	5	718-726	20
		XV	10	605-615	20
				787-802	15*
	N. Easthope	VI	28	520-525	15
		VIII	23	435-440	15
				660-675	20
	Elma	XIII	15	570-580	20
				645-650	20
				815-820	60
	Logan	I	25	696-745	20
				1090-1098	30*
				1130-1145	20
		II	29	702-706	20
				804-818	15
				862-878	25
				942-955	30
				1304-1314	30
		III	31	1180-1191	60
				1305-1315	30
		XI	11	753-765	25*
				940-948	25*
Welland	Bertie	III	4	150-155	15
				275-280	15
		III	4	130-135	15
				245-250	15
		III NR	4	140-150	35
		X NR	9	130-135	20
		XIII NR	16	70-80	25
				130-140	20
	Crowland	VII	16	124-132	15
	Humberstone	Sherkston		120-150	15
				170-180	15
		Sherkston		165-170	15
				225-230	15
	Wainfleet	I	24	130-148	15
				305-315	20
		VI	43	118-135	30
		III	31	160-180	30
				220-230	30

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