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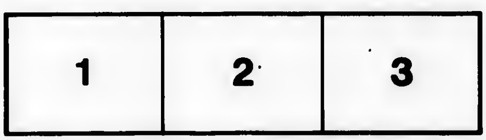

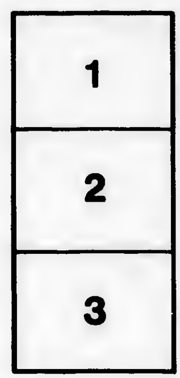

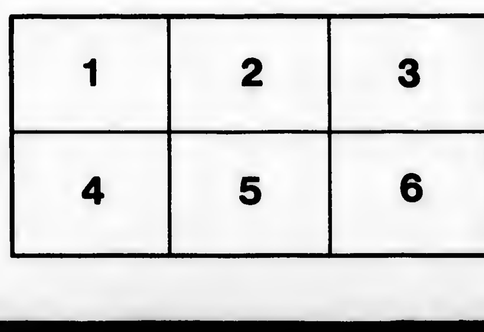

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GEOLOGICAL SURVEY OF CANADA.

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ON THE

GODERICH SALT REGION;

BY

T. STERRY HUNT, LL.D., F.R.S.,
[illegible] AND MINERALOGIST.

7

ADDRESSED TO

SIR WILLIAM E. LOGAN, F.R.S.,
LATE DIRECTOR OF THE GEOLOGICAL SURVEY.

From the General Report of the Geological Survey of the Dominion of Canada for 1867-69.

MONTREAL:
DAWSON BROS.
1870.

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GEOLOGICAL SURVEY OF CANADA.

ALFRED R. C. SELWYN, DIRECTOR.

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PRINTED BY JOHN LOVELL, MONTREAL.

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SIR WILLIAM E. LOGAN, F.R.S., F.G.S.,
DIRECTOR OF THE GEOLOGICAL SURVEY.

MONTREAL, May 1, 1869.

In the Report which I had the honor to submit to you in 1866, there will be found, on pages 263–272, an account of the salt deposit then recently discovered by boring, at a depth of 1,000 feet from the surface, near the town of Goderich, in Ontario. As regards its geological position, it was there shewn from the results of the boring that the Onondaga formation attains in that region a thickness of about 1,000 feet, of which the lower 200 feet consist of reddish and bluish shales, including beds of gypsum, and near the base a layer of rock salt, which in the Goderich well was said to have a thickness of about forty feet, including some layers of blue clay. From this depth there was obtained, by pumping, a saturated brine, my analysis of which was given. Attention was in this Report called both to the strength and the remarkable purity of the brine, and comparative results were given to show its great superiority over the brines of Saginaw in Michigan, and of Syracuse in New York. A table showing the strengths of brines of different specific gravities, and the number of gallons required for a bushel of salt, was also given in this connection. It is deemed advisable, however, to give with the present Report a more extended table of the same kind, which is reprinted from Professor Alex. Winchell's Report on the Geology of Michigan, published in 1861.

Since the publication of my Report, the well then described, which belongs to the Goderich Company, has been constantly pumped, and large quantities of salt have been manufactured from the brine. Encouraged by the success of this well, several other borings have been sunk in the immediate vicinity, and are yielding brines like the first one. The record of all these wells is essentially the same as that of the first. The presence of a stratum of rock-salt has been established by the grains of salt brought up by the sand-pump from the borings. In the course of 1867 Mr. Ransford sunk a well at Clinton, thirteen miles to the south-east of Goderich, on the line of the Buffalo and Lake Huron railway, and was rewarded by the discovery of the salt-bearing stratum, offering, it is said, a thickness of sixteen feet of rock-salt. The depth of this well is 1180 feet, and the greater thickness of rock overlying the salt at Clinton is due to the south-eastward dip of the strata; from which it results that the summit of the Onondaga formation, which appears at the surface at Goderich, is at Clinton covered by about 200 feet of the Corniferous limestone. This overlying formation occupies, to the north of Goderich, a broad triangular area extending north-eastward nearly forty miles, and bounded to the north-east and north-west by the out-crop of the underlying Onondaga formation.

Clinton.

Kincardine.

Upon this latter, at Kincardine, thirty miles north-east of Goderich, another well was sunk last year, and showed the existence of the salt-bearing stratum at a depth of about 900 feet. The record of the boring furnished me was as follows:—

	Ft.	*In.*
Sand and gravel	91	6
Limestone and hard strata	508	6
Red shale	23	0
Blue shale with a red band	117	0
Limestone	30	0
Blue and red shale, partly very soft	125	4
Rock salt	13	8
	909	0

By comparing the above result with that obtained in the first well at Goderich, it will be seen that while the amount of shaly strata from the base of the limestone to the bottom of the salt was only 205 feet at Goderich, it attains at Kincardine a thickness of 309 feet; in which, however, are ncluded thirty feet of a rock described as limestone, but which may perhaps be gypsum, masses of which were encountered in the shales in boring at Goderich. Of the 775 feet of limestone belonging to the formation at Goderich only 508½ remain at Kincardine, the upper portion being removed by erosion. It is not, however, certain that the original thickness of the Onondaga, or Salina formation as it is sometimes called, was precisely the same here as at Goderich, and thus the amount which has been removed by erosion may be somewhat greater or less than would at first appear. In like manner, the thickness of the same formation at Clinton may differ somewhat from that at Goderich, so that the overlying portion of Corniferous limestone at that place may be greater or less than 200 feet, according as the volume of the Salina formation is less or greater than at Goderich. Careful examinations of future borings would enable us to determine these important points, and for this end samples of the material extracted at intervals of fifteen or twenty feet, should be carefully preserved.

The base of the Onondaga formation comes to the surface at the mouth of the Saugeen river. Here, at Southampton, an ill-advised attempt was **Southampton.** last year made in search of salt by boring. According to the record furnished me, the solid rock was only reached at a depth of 230 feet,* after which 350 feet of white and gray limestone had been penetrated up to August 22, 1868. The subsequent record is incomplete, but beneath the limestones were encountered several hundred feet of red shales, and the boring was finally abandoned at a depth of 1,251 feet from the surface. Another well also was sunk last year at Port Elgin, five miles below South- **Port Elgin.** ampton, on the coast, and the boring in November last, had attained a depth of 890 feet, and was still going on in the red shales. In this connection may be noticed a well which was sunk in 1867, at the village of Waterloo, about eighty miles to the south-east of Port Elgin, but in the **Waterloo.** same geological position, that is to say near the base of the Onondaga

*The account of this portion of the boring is as follows:—

Gravel and sand, with trunks of trees at the base	23½	Feet.
Hard-pan and boulders	36	
Blue clay	5	
Coarse sand and gravel	16	
Hard-pan and boulders	4½	
Soft marly beds	50	
Blue clay with boulders	67	
Hard-pan and boulders, with gravel	28	
		230

formation, and was abandoned at the depth of 1,120 feet. The record of the boring was as follows :—

Superficial clays and gravels*		130	Feet.
Limestone	40		
Gypsum	17	77	
Shale	20		
Limestone, gray and white		340	
Blue shale		114	
Red shale		459	
			1120

Bitter waters.

At this depth the well was abandoned ; bitter saline waters were met with at depths of 800 and 900 feet, and were probably similar to the bitter water found at St. Catherines at the same geological horizon. In the Report for 1866, on pages 271, 272, the waters of this class are noticed, and their unfitness for the manufacture of salt pointed out. The 77 feet of limestone, gypsum and shale in the Waterloo section belong to the base of the Onondaga, or salt-bearing series, beneath which no valuable brines have yet been found. The 340 feet of limestone underlying the shale, represent the Guelph, Niagara and Clinton formations, and the red and blue shales beneath these belong to the Medina formation. By referring to the account of a boring at Barton, near Hamilton, it will be seen that these shales have there a total thickness of about 600 feet. (Report for 1866, page 251).

Onondaga and lower rocks.

It will be noticed that the Onondaga formation, as shewn in the borings of Goderich and its vicinity, consists of several hundred feet of limestone, chiefly magnesian, underlaid by two or three hundred feet of red and blue shales, which carry rock-salt at their base. These are succeeded, in descending order, by the magnesian limestones of the Guelph, Niagara and Clinton formations, which rest upon the red shales of the Medina, as seen in the Southampton and Waterloo borings. We have the following succession in going downwards :

1. Limestones of the Onondaga or Salina formation.
2. Red and blue shales of the same.
3. Limestones of the Guelph and Niagara formations.
4. Red and blue shales of the Medina formation.

Mistakes in boring.

On account of the resemblances in color between the upper and lower couples of the above series mistakes may easily occur, as at Southampton, where the strata of 3 and 4 were supposed to be those of 1 and 2. Such errors, which have caused the expenditure of considerable sums of money at Southampton, Port Elgin and Waterloo, would be avoided by a careful

*For a notice of the superficial deposits of this region, see the *Geology of Canada*, page 897.

study of the distribution of the various geological formations of this region, as described in the *Geology of Canada*. The accuracy with which the limits of the various formations throughout this region were traced out by Mr. Alex. Murray, has received repeated confirmation in the course of the various explorations for oil and salt which have been made within the past few years.

Extent of salt basin.

As regards the possible extent of the salt-bearing area now under consideration, I take the liberty of quoting the following passage from my Report for 1866, page 271:—

"With regard to the probabilities of obtaining salt wells by other borings in this region, it is to be remarked that the thickness of the deposit of salt traversed in the Goderich well may warrant us in expecting that its area may be considerable; though whether its greatest extent will be inland, or beneath the waters of the lake, can only be known by experiment. It has already been explained that salt deposits have been formed in basins, whose limits were determined by the geographical surface at the time; and it is worthy of remark that both here and in New York the salt deposits are connected with a thickening of the Onondaga formation, which, in its thinner intermediate portion, is apparently almost destitute of salt; a fact suggesting former geographical depressions, in which the two salt-bearing portions of the formation may have been deposited. Although it would be unsafe to predict that this development of salt at the base of the Onondaga formation is so widely extended, its thickness at Tilsonburg, St. Mary's, London and Enniskillen, is such that it seems probable that farther borings in these localities, where deep wells have already been sunk, may reach saliferous strata capable of yielding valuable brines."

In confirmation of the first portion of the above extract, we can now point to the existence of salt at Clinton, thirteen miles to the S. E., and at Kincardine, thirty miles N. N. E. of Goderich. These two stations are forty miles apart, and a line connecting them would pass about seven miles to the east of Goderich. It is, therefore, extremely probable that the whole region between Clinton and Kincardine will be found underlaid by salt, and may belong to a single basin, whose extent yet remains to be ascertained.

The success of the borings at Goderich and in its vicinity has, as we have seen, led to the sinking of wells for brine below the salt-bearing horizon. At the same time, other trials have been made in the hope of reaching it, by boring through rocks overlying those of the Goderich region. For the information of inquirers, it may therefore be well to recall briefly some of the facts with regard to the nature and thickness of these rocks, of which the details are given in my Report for 1866. It will there be seen that the most recent rocky strata in south-western Ontario are the

Portage formation. greenish sandstones of the Portage formation. These pass downwards into hard black slates (the so-called Genessee slates) which, in their turn, rest upon the soft gray strata of the Hamilton formation. This series of sandstones and hard shales, which appears at the surface at Kettle Point in Bosanquet, and also in Warwick, is generally concealed by the clays of the region; but from the records of numerous borings, chiefly made in search of petroleum, we have been enabled to determine its thickness in many places. Thus, in a boring at Corunna, on the St. Clair river, near Sarnia, it measures 213 feet; in two borings in Camden, 146 and 200; in Sombra, 100; in Alvinstone, eighty feet; in Warwick, and near Wyoming station, about fifty; a little north of Bothwell, about eighty; and further south, towards the shore of Lake Erie, about sixty feet in thickness. It will be understood that this varying thickness is due to the erosion along the anticlinals, before the deposition of the clays, so that in many parts of the region only the lower portions of the black slates remain, while in other places they are entirely wanting.

Hamilton formation. The hard strata just described are conformably underlaid by those of the Hamilton formation, which in some parts of New York attains a thickness of 1,000 feet, but is reduced to 200 feet in the western part of the state. It consists, in Ontario, chiefly of soft gray marls, called soapstone by the well-borers, but includes at its base a few feet of black beds, probably representing the Marcellus shale. It contains, moreover, in some parts, beds of from two to five feet of solid gray limestone, holding silicified fossils, and in one instance impregnated with petroleum; characters which, but for the nature of the organic remains, and for the associated marls, would lead to the conclusion that the underlying Corniferous limestone had been reached. The thickness of the Hamilton formation varies in different parts of the region under consideration. From the record of numerous wells in the south-western portion it appears that the entire thickness of soft strata between the Corniferous limestone below and the black shale above, varies from 275 to 230 feet, while along the shore of Lake Erie it is not more than 200 feet. Further north, in Bosanquet, beneath the black shale, 350 feet of gray shale were traversed in boring, without reaching the hard rock beneath; while in the adjacent township of Warwick, in a similar boring, the underlying limestone was reached 396 feet from the base of the black shales. It thus appears that the Hamilton shale (including the insignificant representative of the Marcellus shale at its base) augments in volume from 200 feet on Lake Erie to about 400 feet near to Lake Huron.

Corniferous formation. The Hamilton formation, as just defined, rests directly upon the solid non-magnesian limestones of the Corniferous formation. The thickness of this formation in western New York is about ninety feet, and in southeastern Michigan is said to be not more than sixty, although it increases in going northward, and attains 275 feet at Mackinac. In the townships of Woodhouse and Townsend its thickness has been found to be 160 feet; but for a great portion of the region in Ontario underlaid by this formation, it is so much concealed that it is not easy to determine its thickness. If we may conclude from the boring at Clinton, it would seem to be in that locality not far from 200 feet. In the numerous borings which have been sunk through this limestone, there is met with nothing distinctive to mark the separation between it and the limestone beds which form the upper part of the Onondaga or Salina formation, and consist of dolomite, alternating with beds of a pure limestone like that of the Corniferous formation. The saliferous and gypsiferous soft magnesian marls, which form the lower part of the Onondaga formation are, however, at once recognized by the borers, and lead to important conclusions regarding this formation in Ontario.

Tilsonburg. At Tilsonburg, a boring showed the existence of the Corniferous limestone directly beneath about forty feet of clay, while in another boring, about two miles to the south-west, it was overlaid by a few feet of soft shales, probably marking the base of the Hamilton formation. The first boring at Tilsonburgh, as mentioned in the report for 1866, was carried to a depth of 854 feet in the solid rock. Numerous specimens of the borings from the first 196 feet, were of pure non-magnesian limestones, but below that depth similar limestones alternated with dolomite. The marls which occur at the base of the Onondaga formation were not met with in this boring, though the water from 854 feet was said to be strongly saline. I was informed by the proprietors, Messrs. Hebbard & Avery, that the well furnished, by pumping, a brine marking from 35° to 50° of the salometer, but I was not able to get any of the water, and the well was soon after abandoned, although the presence of so strong a brine would seem to show the proximity of a saliferous stratum.

London. In a boring at London, where the presence of the base of the Hamilton was marked by about twenty feet of gray shales, including a band of black pyroschist, overlying the Corniferous, 600 feet of hard rock were passed through before reaching soft magnesian marls, which were penetrated to the depth of seventy-five feet. Specimens of the borings from this well, and from another near by, carried 300 feet from the top of the Corniferous, show that pure limestones are interstratified with the dolomites to a depth of 400 feet. At Tilsonburg a pure limestone was met with at 524 feet from the top.

St. Mary's. Enniskillen. At St. Mary's, 700 feet, and at Oil Springs in Enniskillen, 595 feet of limestone and dolomite were penetrated, without encountering shales; while in another well, near the last, soft shaly strata were met with at about 600 feet from the top of the Corniferous limestone, there overlaid by the Hamilton shales. It thus appears that the united thickness of the Corniferous formation and the solid limestones and dolomites which compose the upper part of the Onondaga formation, is about 600 feet in London and Enniskillen, and farther eastward, in Tilsonburg and St. Mary's, considerably greater; exceeding by an unknown amount, in these localities, 854 and 700 feet.

Thickness of Corniferous. As the few observations which we as yet possess of the thickness of the Corniferous limestone in this region, do not warrant us in assigning to it a thickness of over 200 feet, it is evident that at London and in Enniskillen the hard strata which form the upper portion of the Onondaga formation, and have at Goderich a thickness of not less than 775 feet, are greatly reduced in thickness, since the volume of the two united is only 600 feet. **Thickness of Onondaga.** To the south-eastward, however, the augmented thickness of the Onondaga would appear, from the results of the borings at St. Mary's and Tilsonburg, to be maintained. The thickness of this formation is, however, known to be very variable; while at the Niagara river it is reduced to 300 feet, and is apparently destitute of salt, it augments to the eastward, in central New York, where it again attains a volume of from 700 to 1000 feet, being equal to that observed at Goderich, and becomes once more salt-bearing. The increased thickness of the formation, in these two regions, connected with accumulations of salt at its base, would seem to point to ancient basins or geographical depressions in the surface of the underlying formation, in which were deposited these thicker portions.

Most of the details here given with regard to the thickness and character of the rocks of this region are condensed from the observations collected in my Report for 1866, pp. 241-250. They are embodied in a paper by me entitled *Notes on the Geology of South-western Ontario*, and published in the *American Journal of Science* for November, 1868; parts of which have been reprinted, with some few changes, in the last three pages.

Syracuse salt region. It is a curious fact that the numerous and productive salt wells of Syracuse, New York, although occurring upon the outcrop of the Onondaga formation, do not penetrate into it, but are sunk in a deposit of stratified sand and gravel, which fills up a valley of erosion on the shores of Onondaga Lake. The limits of this valley are nearly four miles from north to south, by two miles from east to west. The shales belonging to the base of the formation crop out to the northward, and are found in the various borings beneath the ancient gravel deposit, which is itself covered by thirty or forty feet of a more recent deposit of loam or sand. The bottom of the basin is very irregular, the shales being met with at depths of from 90 to 180 feet in some parts, and at 382 feet in the middle of the valley. According to Mr. Geddes, the greatest depth of this ancient basin is not less than 414 feet below the surface-level of Onondaga Lake, and 50 feet below the sea level.—(Trans. N. Y. State Agricultural Society, 1859.)

Beds of the ancient gravel are occasionally found converted into a hard concrete, the cementing material of which, in some cases at least, is crystalline laminated gypsum. The wells are bored in this gravel to various depths up to 350 feet; brine is met with at about 100 feet, but the brines of the deeper wells are stronger, and less liable to variations in quality with the season of the year.

Salt wells.

The report of the superintendent of the Onondaga salt springs, for 1868, contains some interesting details of wells sunk in this region during the preceding year. One of these, at a distance of two or three hundred yards from the wells which supply with brine the Liverpool district, was found to be outside of the gravel basin, the green shales of the Onondaga formation having been encountered at a depth of 82 feet, beneath which the strata, to a depth of 715 feet from the surface, consisted of green, red and gray shales, with a few beds of bituminous limestone, and a little gypsum, green shales forming the base. Fresh water was met with at 116 feet, and salt water first appeared at 164 feet. Analysis of the saline waters, from 291 and 540 feet, are given by Dr. Goessmann. That from the latter depth contained in 100 parts, chlorid of sodium, 4.5478; chlorid of calcium, 5.8658; chlorid of magnesium, 2.0237; sulphate of lime, 0.1070=12.5433. The water from the higher level contained nearly the same proportions of elements, but was less strong. The water from a well 148 feet deep in the shales, four miles farther west, was very similar in composition to that of which the analysis has just been given, and the same is true of two wells sunk in 1867 at Canastota, about twenty miles to the eastward of Syracuse.

Canastota.

In one of these, after penetrating through about 300 feet of red and blue clays, a cemented gravel was met with, followed by loose gravel and sand to a depth of not less than 648 feet, where a hard rock was encountered, and the boring discontinued. The water from these wells was a strong but bitter brine containing in 100 parts, sulphate of lime, 0.0058; chlorid of calcium, 4.8200; chlorid of magnesium, 0.9281; chlorid of sodium, 15.2288, and carbonate of iron 0.0150. For this analysis and description of the well I am indebted to Dr. C. A. Goessmann. Here, then, as at Syracuse, the brine occurs in a deep excavation in the Onondaga formation. The shales of this region, as long since pointed out by Eaton, show, in many parts, peculiar hopper-shaped markings, which are recognized as the casts of crystals of chlorid of sodium, and hence it was conjectured that the source of the brines was to be found in these strata; although it was not impossible that they might be derived from more

Source of brines.

recent deposits of rock-salt occupying the remarkable gravel-filled basins which are shown to exist at Syracuse and Canastota. The discovery, in Ontario, of rock-salt in solid masses interstratified with the base of the Onondaga formation, leaves, however, but little doubt of the correctness of the views long maintained by the New York geologists, that the source of the brine is to be found in this formation. Borings like those of Goderich will probably one day show the existence in the vicinity of Syracuse of similar beds of rock-salt, which now yield to the action of infiltrating waters the brines that accumulate in the gravel beds occupying the reservoirs just described. These also receive the bitter waters which are derived from the shales of the same formation, and contaminate the brines of Syracuse; although they do not mingle to any injurious extent with the water from the borings of Goderich and its vicinity.

Port Austin, Michigan.

In this connection it may be mentioned that brine has been obtained at Port Austin, Huron County, Michigan, on the opposite side of the lake and a little north of west from Goderich. The surface rock of this region is a sandstone of the Chemung formation, beneath which, at a depth of 1198 feet from the surface, there was extracted a brine of which a specimen furnished to Dr. Goessmann marked 88° of the salometer, and gave for 100 parts, chlorid of sodium, 17.6161; chlorid of calcium, 3.1274; chlorid of magnesium, 1.5675, and sulphate of lime 0.0129 = 22.3239. The thicknesses of the different formations across this western region, from New York to Michigan, are well known to be very variable, and it is impossible, with our present data, to say at what depth the Onondaga formation should be found at Port Austin; but the occurrence there of a brine at 1198 feet would indicate either a considerable diminution in the volume of the strata between the base of the Onondaga and the Chemung, or the existence of a saliferous horizon in the Devonian strata, and consequently intermediate between the Onondaga formation and the Michigan salt group, which is situated at the base of the Carboniferous limestone in that State. In the vicinity of Lake Huron, in Ontario, the Onondaga has a thickness of 1,000 feet, the Corniferous probably about 200, the Hamilton very nearly 400, while the Portage group is represented, both near Sarnia and in the adjoining state of Michigan, by more than 200 feet, making thus 1800 feet from the base of the Onondaga to the summit of the Portage formation. (Report for 1866, p. 241-250.) The above facts with regard to salt in Michigan and New York, are worthy of being put on record, as they may be found to have, in more ways than one, an important bearing on our own salt deposits. Some are private communications of C. A. Goessmann, Ph. D., now professor of chemistry at Amherst, Mass., but for several years chemist to the Onondaga Salt Company. His published papers on the Onondaga brines in the *American Journal of Science* for 1866, [2] XLII.,

Goessman's researches.

211, 308. have also been consulted, and various pamphlets and reports by him will be frequently cited in the course of this Report. I take this occasion to express my deep sense of the value of his important contributions to the chemistry of salt-making in New York, and of the courtesy with which he has aided me in my inquiries into the salt manufacture at Syracuse. He has also visited the Goderich region and submitted the brine to analysis.

ANALYSES OF THE BRINES OF GODERICH AND ITS VICINITY.

In the Report for 1866, a first analysis was given of the brine extracted from the well of the Goderich Company, the first one bored at Goderich, **Goderich Co.'s well.** and at that time not yet pumped in a continuous or regular manner. Since that time the well has furnished an uninterrupted supply of salt water, and has yielded, for the greater part of the time, 100 bushels of salt daily. It becomes therefore an interesting inquiry whether, during this period of more than two years, the composition of the brine has undergone any change, and to this end we may compare four analyses made from brines taken at the dates given below, the analysis II. being by Dr. Goessmann, the others by myself:—

I. August 19, 1866; cited from Report for 1866, page 269.
II. April 1867; from a Report by Dr. Goessmann.
III. February 1868; brine sent me by the proprietors of the well.
IV. November 5, 1868; brine collected by me at the well.

Analyses.

	I.	II.	III.	IV.
Chlorid of sodium......	259.000	241.433	undet.	236.410
" " calcium....	.432	.216	.182	.190
" " magnesium.	.254	.336	.288	.410
Sulphate of lime......	1.882	5.433	.5679	4.858
	269.568	247.418	....	241.868
Specific gravity.	1.205	1.195	1.192	1.187
Degrees of the salometer.	100°	95°	94°	92°

The cause of these variations is to be found in the fact that the sources **Causes of variation.** of saline matters in these brines are three-fold: 1st. The solution of nearly pure rock-salt; 2nd. The solution of beds of gypsum or sulphate of lime, which lie in the shales above the salt; and 3rd. The intermixture of bitter waters, containing large proportions of chlorids of calcium and magnesium. Such waters occur in the strata both above and below the salt deposit, and become mingled with the fresh waters which flow in to supply the void caused by pumping. The composition of these bitter waters is very variable; in some the chlorid of calcium and in others the chlorid of magnesium predominates. The waters of this class are noticed in connection with salt-making in the report just cited, page 271, and analyses are given on pages 272, 273 and 276. The analysis of a similar water from Syracuse is given in the present report on page 219. The quantity of bitter salts in the Goderich brines, however, is insignificant when compared with those of most other salt-producing regions. It is to be noticed that at the time of the first analysis, the well was not regularly pumped, and that the brine, though saturated, contained less gypsum and more chlorid of calcium than it has since yielded; while the chlorid of magnesium has somewhat increased in quantity. The density of the brine is subject to some little variation, but is said in the Goderich Company's well rarely to fall below 92°, and after a repose of a few hours to rise considerably above it. Of the other wells which have been sunk at Goderich, four were being pumped at the time of my last visit, in November, 1868, and from these I took specimens of brine. It was not considered necessary to analyse these brines from adjacent wells of the same depth, but their specific gravity at 62° F. was determined, and is here given, with the corresponding degree of the salometer:—

Goderich Company's well,	density	1.187	equal	92°	salometer.
Dominion well,	"	1.175	"	87°	"
Huron well,	"	1.176	"	87°	"
Ontario well,	"	1.160	"	81°	"
Victoria well,	"	1.160	"	81°	"

The brines of Clinton and Kincardine shew a strength and purity comparable to those of Goderich. Of the following analyses, V is that of the brine from the Clinton well, collected by me on the 6th November, 1868, and VI is that from Kincardine, sent to me by the proprietor a few days later, the well not having been in operation at the time of my visit to the district:—

	V.	VI.
Chlorid of sodium	204.070	241.350
" " calcium	.470	.840
" " magnesium	.184	.230
Sulphate of lime	5.583	3.264
	210.307	245.484
Specific gravity	1.157	1.191
Salometer	80°	94°

MANUFACTURE OF SALT AT GODERICH AND CLINTON.

Of the wells above mentioned, that of the Goderich Company has been regularly worked since October, 1866, and the manufacture of salt was commenced at the four others named above, the Dominion, Huron, Ontario, and Victoria wells, during the summer months of 1868. In November last, the boring of three others was nearly or quite completed. Two of these, called the Prince and Maitland wells, are, like that of the Goderich Company, on the north side of the Maitland River, while a third, the Tecumseh well, is on the south side, near the others mentioned above. The number of kettles used, and the daily produce of the wells then in operation was, in November, 1868, stated to be as follows:—

Goderich.

Salt works.

Goderich Co,	104 kettles.	yielding	100	barrels of salt.
Dominion,	60 "	"	55	"
Huron,	120 "	"	110	"
Ontario,	60 "	"	55	"
Victoria,	60 "	"	55	"
	404 kettles	"	375 barrels.	

The Goderich Company and Huron wells have two blocks of kettles each, the others but one, the block of kettles consisting of two parallel rows of from twenty-six to thirty cast-iron kettles each. The arrangement is copied from the works of the Onondaga Company, at Syracuse, New York, where the number of kettles in a block varies from fifty to sixty. The capacity of the kettles used at Goderich varies from 120 to 140 gallons, the larger ones being placed towards the front, and exposed to the greater heat, from which, however, they are partially protected by arches constructed under the first nine or ten kettles. At Syracuse, in some of the blocks, the rear kettles have a capacity of not more than 100 gallons. The cost of a block of sixty kettles at Goderich is said to be $1,500, to which is to be added for the construction of the furnace, $1,600, making a total of $3,100.

Salt boiling.

The fuel hitherto used at Goderich has been chiefly wood, which costs there $2.50 the cord. Bituminous coal, which has been tried there to a small extent, is shipped from Cleveland, and delivered at Goderich, as I was informed, for $3.80 the ton. The amount of salt to be obtained by the use of a cord of wood, at Goderich, was variously estimated by the different salt-makers. The figures furnished me by Mr. Samuel Platt, which seem to be the result of careful observations at the Goderich Company's works, give a consumption of sixteen cords of hard-wood for one hundred barrels, of five bushels each, of salt. Of this amount of wood one and a-half cords are consumed for the engine employed in pumping the brine, leaving fourteen and a half cords for the evaporation, which gives about 34½ bushels to the cord of wood. The estimates at two other wells, given me by persons worthy of confidence, corresponded respectively to 35⅓ and 36 bushels to the cord, and we may therefore, I think, assume 35 bushels of salt, of 56 pounds each, to be the average result for the cord of hard-wood employed at Goderich.

Fuel; coal and wood.

At Syracuse, where wood is also used to a considerable extent, the yield of salt is from 37 to 38 bushels to the cord of wood, and the ton of coal gives about the same amount, so that in round numbers the production of a pound of salt there, requires the combustion of a pound of coal ($37 \times 56 = 2072$ lbs.) The cost of coal delivered to the salt-makers at Syracuse was, in 1868, $8.50 American currency. The wood used there by some of the manufacturers is cut from lands in the vicinity. From these figures, which I received at Syracuse from what I consider undoubted authority, it would seem that the salt-makers of Goderich will not be gainers by the attempt to substitute imported coal for the wood of their own neighborhood, since, while the cord of wood is equal in salt-producing power to a ton of coal, its cost in round numbers, is, at present prices, only two-thirds as much.

Syracuse and Goderich brines.

The brines of Syracuse mark from 59° to 65° of the salometer, while those of Goderich, as seen above, give from 81° to 90° and even 95°. A pure brine of 60° contains 15.6 per cent. of salt, and 38.9 gallons of it are required to yield a bushel of salt; while a brine of 90° holds 23.4 per cent., and yields a bushel of salt for 24.5 gallons. Hence it appears that, in round numbers, the Goderich brines contain about one-half more salt than those of Syracuse, or are fifty per cent. richer. So that, as remarked by Dr. Goessmann, we should expect fifty-two bushels as the yield at Goderich for the cord of wood, being an increase of nearly 50 per cent. on that now obtained.

This great discrepancy between what might be expected, and the results actually obtained at Goderich, is easily explained, and is found in the fact that the system of evaporation pursued at Syracuse, and adopted at Goderich, is one not suited to the strong brines of the latter region. On this point Dr. Goessmann remarks that the only difficulty with which the salt-makers of Goderich have now to contend "is the rapid incrustation of the kettles, a trouble due to the strong concentration of their brine, in connection with their peculiar system of manufacture." Under these circumstances, the salt separates in considerable amount in very fine grains, and a hard incrustation forms on the bottom and sides of the kettles, which soon becomes several inches in thickness. This not only causes a considerable waste of salt, since these crusts are not fit for market, but, what is of much greater importance, prevents the economical application of the fuel; besides which, the necessity of a frequent removal of the crust of salt generally keeps one of each row of kettles out of service. The crust may be removed either by mechanical means, or by dissolving it out with fresh water, a process which involves the loss of time, fuel and salt. With weaker brines, on the contrary, like those of Syracuse, the fresh supplies of brine added to the emptied kettles suffice to dissolve any exist-

Incrusted boilers.

ing crust, and the difficulties which cause such a serious loss at Goderich are not felt.

Goessmann's opinion.

Dr. Goessmann proceeds, in describing the manufacture at Goderich:— "The salt is, after separation from the pickle, (mother-liquor) as might have been expected from a brine like that of Goderich, of a superior color, of a hard fine grain, resembling the best brands of home and foreign manufacture, and this success is attained without any but the ordinary care required for the manufacture of common fine salt. It will be noticed that the sole objection which may be raised against the Goderich brine, is merely incidental, for the brine is too strong to be worked to its full advantage by the system of manufacture at present pursued. Evaporation by more moderate heat, for instance, on the European plan of large pans, or evaporation by solar heat in wooden vats, on the Onondaga plan, would, no doubt, prove more successful. Each of these methods would produce, with less trouble, not only a very good marketable article of its kind, but secure what is most important, the full percentage of salt, which might be expected, comparing its concentration with the brines of Onondaga, to be a difference of 50 per cent."

Evaporation in pans.

Clinton.

The above extracts are from a printed Report by Dr. Goessmann, dated January, 1868, on the salt resources of Goderich. Since that time the system of evaporation in pans has been tried at Clinton, and the results fully justify the recommendation by Dr. Goessmann. The Stapleton salt-work here erected by Mr. Ransford, has two pans, each twenty-one feet wide by forty feet long, and fifteen inches deep. Under the front pan three wood fires are kept up; the brine in this is maintained in rapid ebullition, while the waste heat passes under the second pan, in which a slower evaporation goes on, producing a coarse flaky salt. The daily production of these two pans was, I was informed, equal to fifty barrels of fine salt from the front pan and twenty barrels of coarser salt from the rear one, equal to seventy barrels, and the consumption of wood for this production was seven cords, being at the rate of fifty bushels of salt for the cord of wood. Although the brine was said to mark generally 85°, the specimen taken by me, whose analysis is given on page 221, was not above 80°; the result thus shows most satisfactorily the greater economy of fuel to be attained by the use of pans, and the utilization of the waste heat, as practised at Clinton. The crust which forms on the first pan is removed once a week, and is found in that interval of time to be from one and a quarter to one and a half inches in thickness. But very little crust is deposited in the rear pan, except at the end nearest the fire. In Cheshire, in England, where brines as concentrated as those of Goderich are evaporated, pans similar in dimensions to those at Clinton are made use of; while single pans, having a breadth of twenty by a length of forty feet, and a depth of two feet, are also employed, in which the evaporation is carried at temperatures as low as 150° Fahrenheit, for the production of coarse salt.

Platt's system.

Mr. Samuel Platt, under whose superintendence the first salt was made at the Goderich Company's well, has patented an evaporating pan, to which the heat is applied by the means of steam heated to a pressure of thirty pounds. In this way it is expected to effect an important saving of fuel, and obtain other advantages. I have not yet learned the result of experiments in progress for the purpose of testing the merits of this system. Several other proposed improvements in evaporators have recently been made the subject of patents in Canada.

Purity of the brines.

Attention was called, in the Report for 1866, to the great purity of the Goderich brines, of which Dr. Goessmann subsequently writes, in his report already cited: "The present brine of Goderich is not only one of the most concentrated known, but also one of the purest, if not the purest, at present turned to practical use for the manufacture of salt;" and he proceeds to

Earthy chlorids.

remark that the proportion of obnoxious deliquescent chlorids (of calcium and magnesium) is from one-fourth to one-fifth of that found in the brines of Syracuse. It will be seen by referring to the table of analyses, given on page 221, that the proportion has not increased after more than two years pumping of the well first sunk; the only change being that the amount of gypsum has augmented. The earthy chlorids, just mentioned, being much more soluble than the salt, do not separate, but remain behind in the mother liquor, which should, from time to time, be emptied from the evaporating vessels. From a neglect of this it would otherwise happen that the salt would, after a time, be rendered impure from the adhering

Mother liquors.

mother-liquors, and be reduced to the condition of salt manufactured from inferior brines like those of Saginaw; the impurity of which consists in these same earthy chlorids, which it becomes necessary to remove by a special process. The precaution of throwing out the mother-liquors from time to time, has not been attended to at Goderich; and when it is found necessary to empty a kettle for the purpose of removing the crust, it has been the practice to transfer the brine into an adjoining kettle. The effect of this is shown by the following comparative results for 100 parts of brine; A being the recent brine, marking 94°, whose analysis is given at III. on page 221, and B, a saturated brine, marking 100°, taken from one of the boiling kettles at the same time:—

	A.	B.
Chlorid of calcium	·182	·688
" " magnesium	·283	1·185
Sulphate of lime	5·679	4·908

The diminution in the amount of sulphate of lime is due to the fact that both heat and the presence of earthy chlorids diminish its solubility.

These latter salts are present in a four-fold proportion in the evaporated brine, showing clearly the accumulation of these which takes place when the common salt is removed, and the necessity of throwing out the old liquors from time to time.

In the brines of Saginaw, the chlorid of magnesium, which is more obnoxious than the calcium salt, is got rid of by the addition of a small portion of quick-lime, as described in the Report of 1866, page 265. On page 267 of that report will be found analyses of brines from other regions, that of Syracuse included, which, as we have seen, contains from three to four times as much of these bitter earthy chlorids as our own brines. These are decomposed by an ingenious process, which consists in washing the pre- Purifying salt. viously drained salt in a pure saturated brine, to which has been previously added a sufficient proportion of carbonate of soda to decompose the earthy chlorids present in the salt, the proportion being determined by the results Factory-filled salt. of analysis. The salt purified by this operation is drained, and partially dried in bins, after which the drying is completed in hot-air chambers, or in revolving cylinders heated to 250°—300° F., and the salt finally screened and ground. This process yields the so-called "Factory-filled Salt" of Syracuse, greatly estimated for dairy use, of which about 700,000 bushels are manufactured yearly.

ON THE MANUFACTURE OF SOLAR SALT.

We have already referred to the advantages offered by Goderich for the manufacture of solar salt, and now propose to give a brief account of the system pursued for making it at Syracuse, New York, based upon published reports, and upon my own observations in 1868. The conditions in which the brine is met with in a gravel-filled basin of small extent on the shores of Onondaga lake, near to Syracuse, have already been Syracuse salt works. described. The salt-producing area, known as the Salt Springs reservation, is divided into four manufacturing districts, known as the 1st, or Syracuse, the 2nd, or Salina, the 3rd, or Liverpool, and the 4th, or Geddes district. The wells in the Liverpool district became valueless and were abandoned in 1866, and the brine now required for the works at Liverpool is raised from the wells in the Salina district, and conveyed by a line of bored logs of nine inches calibre, to a reservoir seventy-five feet long, fifty-three feet wide, and eight feet deep. The large reciprocating pumps hitherto used are now being replaced by small rotary brass pumps, one of which, costing $300 American currency, is said to be sufficient for the most abundant well.

The various salt-makers in these four districts, were in 1860, united into Onondaga Salt Co. an incorporated company, known as the Salt Company of Onondaga. By this union of their interests under one head they have been enabled to secure great advantages. Among these have been the appointing of agents in the principal markets of the country, the establishment of a general direction ensuring uniformity in the quality of the salt and the mode of preparing it for market, and finally the employing of a scientific chemist to direct the works, and, by careful studies, to suggest improved methods of manufacture.

Annual production.

These works pay to the state a tax of one cent per bushel, besides a rental, which is, however, insignificant, since it appears that the whole sum paid by the Company to the state in 1867, for rents and penalties, was only $102 ; the duty amounting for the same time to $75,956.06, being for 7,595,565 bushels of fifty-six pounds each, the amount inspected in 1867. Of this amount, 2,271,892 bushels were made by solar evaporation and 5,323,673 bushels by boiling. Of the solar salt, 308,266 bushels were ground, and of the fine or boiled salt, 188,866 ; of which 41,929 bushels, prepared in the Geddes district, are described as table-salt.

I am not able to give the entire number of blocks of kettles in the establishments of the Company ; but it is stated in their report for 1867, that the average daily produce of salt for each block during the year was equal to nearly 261 bushels, while the average from the seven blocks of kettles at Goderich, from the figures given on page 223, was 268 bushels.

The cost of making solar salt in the Onondaga region is estimated to be a little less than that of boiled salt.

Solar-salt making.

The process of making solar salt at Syracuse is divided into three stages: First, the settling of the brine, as it is called ; second, its concentration, or what is called pickle-making ; and third, the making of salt from the pickle. The brine after being raised, is stored in reservoirs, from which it is led through bored logs to the deep-rooms or settling-rooms, as they are termed, where it is exposed to the air in large tanks, which are deeper than those used in the subsequent stages. There the brine absorbs a portion of oxygen from the air, by which means the carbonate of protoxyd of iron, which is dissolved in the recent brine, is converted into insoluble peroxyd of iron. This separates in a hydrated form, as an insoluble yellowish mud, which accumulates in the bottom of the tanks, and the brine becomes clear and colorless. This first stage is not required for our Goderich brines, which are free from any trace of iron.

Settling-rooms.

The process of evaporation, of course, begins in the settling room, but is continued in what are variously called lime-rooms, gypsum-rooms, or plaster-rooms, from the fact that the sulphate of lime or gypsum, (which is the same substance as uncalcined plaster of Paris) is here deposited in a hydrated state, and in the form of crystals, which in time nearly cover the bottoms of the vats. As the brine approaches saturation, flakes of gypsum are seen

Lime-rooms.

Gypsum.

floating on the surface of the liquid, and at length the appearance of crystals of salt shows that the second stage of the process is accomplished, and that the saturated brine, known as salt-pickle, is ready for the third stage. This is then at once removed, and is ready for the salt-rooms, in which the deposition of the salt goes on.

Salt-rooms.

By salt-rooms are meant areas occupied by the evaporating vats or covers, as they are called, which are provided with moveable roofs, that can be drawn over the covers in rainy weather, but withdrawn at other times, so as to expose the brine to the action of the wind and sun. The covers are rectangular in shape, and all of the same size, being sixteen by eighteen feet, and six inches deep. They are raised on wooden supports two or three feet from the ground, and are arranged in sets or strings, each from four to six inches above the other, so that the liquid can be made to flow from the higher to the lower by opening small gates. The whole number in use at Syracuse in 1867 was 41,718; of these, in round numbers, two-fifths belong to the settling and gypsum-rooms, while three-fifths, or about 25,000, are salt-covers. The average yield for each cover at the Salt Company's works was, in 1867, $54\frac{3}{8}$ bushels; while for the salt-covers, which are fed with saturated brine, it would, if we take their number to be 25,000, equal more than 90 bushels to the cover, for the season. With the purer and more concentrated brines of Goderich the settling tanks are unnecessary, and the time required in the gypsum-rooms to bring the brine to the condition of saturated pickle would be very much abridged, so that a much less proportion of the covers would be required for the gypsum-rooms, and the average production of salt to the whole number of covers, very greatly increased.

Salt-covers.

Conditions for working.

One of the conditions required for the production of a good large-grained solar salt, which is most esteemed in the markets, is that the bottom of the covers in the salt-rooms should be as smooth as possible; rough surfaces favoring the deposition of numerous small crystals. It is also necessary to have the salt-covers supplied with a sufficient supply of good pickle, so that the salt already deposited may always be covered. An exposure of the salt uncovered to the air favors the formation of new small crystals, and the addition of an unfinished or not sufficiently concentrated pickle produces the same effect, inasmuch as it brings an excess of sulphate of lime into the salt-room; and the increased separation of gypsum will also cause the production of a larger proportion of fine grains of salt. It is also of great importance that the waste pickle, from which the greater part of its salt has crystallized, should be removed from time to time, as its presence not only impairs the quality, but diminishes the quantity of the salt deposited.

A correct understanding of the chemical relations of the various con-

Chemistry of brines.

stituents of brines is so important to the manufacturer of salt that it is well to enter into some details on the subject, and to embody the result of a very careful and valuable series of experiments carried on by Dr. Goessmann at Syracuse, and published by him in a report to the Onondaga Company in 1864. In the Report of the Geological Survey for 1853–56, pages 404–419, I have described in detail the manufacture of salt by the evaporation of sea-water, and the chemical reactions which come into play in the process.* The composition of sea-water differs in some important particulars from that of brines like those of Syracuse and Goderich, and especially in the presence of a large amount of sulphates, so that the evaporated brine or salt-pickle from sea-water contains no chlorid of calcium and only a trace of gypsum, but besides a large proportion of chlorid of magnesium, a considerable amount of sulphate of magnesia.

Their composition.

The compounds found in native brines, like those of Goderich and Syracuse, are as follows: 1st, chlorid of sodium or common salt; 2nd, chlorid of calcium; 3rd, chlorid of magnesium; and 4th, sulphate of calcium or sulphate of lime. In addition to these, small portions of carbonate of iron are often present; this substance is separated at an early stage of the process, as already explained, in the form of hydrated peroxyd of iron, and unless carefully removed in the settling-tanks gives a reddish tint to the salt. This objectionable impurity is, however, entirely absent from the brines of Goderich and its vicinity. In addition to the substances already mentioned, the brines contain small portions of chlorid of potassium and of bromid of magnesium. These, however, have no perceptible influence on the manufacture of salt. The chlorids of calcium and magnesium, being compounds of what are sometimes called the earthy metals, are frequently spoken of as earthy chlorids, a term which, for convenience, will sometimes be made use of in discussing the relations of the various elements of brine to water and to each other.

Earthy chlorids.

Solubility of salt.

A saturated brine prepared with pure water and pure salt (chlorid of sodium) has a specific gravity about 1.205 at 60° Fahrenheit, (Liebig) and contains 26.423 per cent. of salt. The presence of earthy chlorids, however, diminishes the solubility of salt in water, so that a saturated brine containing these chlorids is less rich in salt than if it were pure. Another point to be considered in this connection, is that as these chlorids are much more soluble in water than the salt, the latter crystallizes out first, leaving them behind in the pickle, where they accumulate; the salt which separates retaining only so much of the earthy chlorids as is present in the pickle which moistens it. At length, after the separation of the greater part of the salt, either by boiling or by solar evaporation, the proportion of these

* See also the American Journal of Science for 1858, vol xxv. page 361.

chlorids becomes so great that they predominate in the pickle or mother-liquor, which becomes what is called bittern by the makers of salt from sea-water. It has a sharp and bitter taste from the presence of the chlorids of calcium and magnesium, and as these compounds have a great attraction for water, and even absorb it from moist air, when in concentrated solutions, it follows that the pickle from which the greater part of the salt has been separated no longer loses water by exposure to the air at ordinary temperatures, and although very dense, and marking a high degree on the salometer, holds but a small proportion of salt. **Mother-liquor.**

Sulphate of lime. The sulphate of lime presents curious relations both to water and to the other compounds present in natural brines. 100.00 parts of pure water, at ordinary temperatures, dissolve about .25 parts of the sulphate of lime, but it is somewhat less soluble in water at the boiling point, and at higher temperatures becomes almost insoluble ; a property which causes it to be deposited in high-pressure boilers in which sea-water and other waters holding this sulphate in solution, are exposed to temperatures much above 212° F. Sulphate of lime is much more soluble in a strong solution of salt than in pure water, while on the other hand the earthy chlorids diminish its solubility. Thus 100.00 parts of pure saturated brine are capable of holding in solution from .50 to .60 parts of sulphate of lime while in the bittern or pickle in which there has accumulated a large amount of earthy chlorids, the sulphate becomes nearly insoluble. Its solubility in brine, as in pure water, is also diminished by heat, so that a brine brought to saturation by boiling, deposits more of its sulphate of lime than if concentrated by evaporation at the ordinary temperature. These points are exemplified by the following series of analyses made by Dr. Goessmann with the especial object of throwing light upon the manufacture of solar salt at Syracuse. **Goessmann's experiments.**

I. Brine from one of the wells at Syracuse, having a specific gravity of 1.1225, which corresponds to 65° of the salometer at 70° F.

II. Pickle or saturated brine obtained by concentrating I by solar heat until it was ready to deposit salt. It then had a specific gravity of 1.2062, equal to 100° of the salometer at 70° F.

II A. An artificial brine, almost identical with the last, and prepared for certain experiments to be mentioned farther on.

III. Pickle "from the *first cover* of a string of salt-vats numbering from thirty to thirty-four covers. The latter were partitioned into two sub-divisions. The one towards the head of the string was from five to six inches higher than the one towards its termination."

IV. Pickle "from the *last cover* of the same string," the whole having been filled with new pickle for the season's work. The liquid flows from III down to IV, so that the latter represents a pickle which has parted with a considerable portion of its salt.

V. Pickle from the last cover or string of a similar series, at the middle of the summer season, when evaporation had proceeded so far that the pickle was low and the salt partly bare.

A comparison of the results given under II, III, IV, and V, will show that in these pickles, the proportion of sulphate of lime diminishes as that of the earthy chlorids increases.

	I.	II.	II A.
Sulphate of lime	0.5772	0.4110	0.4090
Chlorid of calcium	0.1533	0.2487	0.2687
Chlorid of magnesium	0.1444	0.2343	0.2578
Chlorid of potassium	0.0119	0.0194	0.0194
Bromid of magnesium	0.0024	0.0039	.....
Carbonate of iron	0.0044	.....	.....
Chlorid of sodium	15.5317	25.7339	25.6906
Water	83.5747	73.3488	73.3545
	100.0000	100.0000	100.0000

	III.	IV.	V.
Sulphate of lime	0.3188	0.1146	0.0264
Chlorid of calcium	0.4223	2.6959	10.4690
Chlorid of magnesium	0.6005	2.7513	10.5020
Chlorid of potassium	0.0194	0.8177	3.3769
Bromid of magnesium	0.0331	0.1160	0.4485
Chlorid of sodium	25.0462	20.1066	8.7441
Water	.....	.....	.....
	100.0000	100.0000	100.0000

In this connection Dr. Goessmann gives the following analyses, in which VI shows the proportion which the sulphate of lime and the earthy chlorids bear to the salt in the fresh pickle, II; and VII the average composition of the solar salt made from this pickle at Syracuse. These results show that only about one-eighth of the earthy chlorids present in the fresh pickle are retained by the salt, the remainder accumulating in the mother-liquor, except a small portion, which is supposed to pass through the pores of the wood.

	VI.	VII.
Sulphate of lime	1.5400	1.3378
Chlorid of calcium	0.9335	0.0932
Chlorid of magnesium	0.8817	0.1200
Chlorid of sodium	96.6448	98.4490
	100.0000	100.0000

The composition of the old and half-exhausted pickles is shown in the analysis IV, and at a still later stage in V. The evils resulting from this accumulation of chlorids are many: first, the salt removed from these

Effects of earthy chlorids.

is impregnated with a very impure pickle, which not only adheres to the crystals, but fills small cavities in them; the presence of these earthy chlorids being unfavorable to the production of solid crystals free from cavities. These adhering solutions of earthy chlorids never dry completely at ordinary temperatures, and keep the salt constantly moist, and very easily affected by damp weather. Again, these impurities affect the quantity as well as the quality of the salt produced, by retarding the process of evaporation. Under any circumstances the force of affinity causes such saline solutions as these to evaporate less rapidly than pure water, at ordinary temperatures. Thus it was found by Dr. Goessmann, on exposing equal volumes to evaporation under the same conditions, that while pure water lost 60 per cent. of its volume, a recent brine, marking 65° of the salometer, (analysis I) lost but 45 per cent., a fresh pickle 43.66, and an old partly exhausted pickle only 30.05 per cent. of its volume. Were the last to evaporate as rapidly as fresh pickle, it would yield a less quantity of salt, since, as appears from the analysis already given, it contains less salt for the same volume; but in fact, its evaporation is much retarded by the affinity of the earthy chlorids for water. This becomes so manifest that, after a certain stage of concentration, evaporation ceases altogether at ordinary temperatures. It is well known to chemists that these chlorids, if evaporated to dryness by artificial heat, will, on exposure at ordinary temperatures, absorb moisture from the air, and redissolve, or deliquesce, as it is termed. A similar process takes place with the concentrated bitterns, which at the temperature of the air lose water in dry weather, and absorb it again in moist weather. This process, and the effect of the purity of the pickle upon the quantity of salt produced, is shewn by the following experiments of Dr. Goessmann:—An artificial pickle, closely resembling the fresh pickle II, and having the composition represented under II A, having been prepared, five glass basins were arranged, and placed in a position exposed to air and light, but sheltered from rain. Of these vessels, 1 was filled with the pickle II A; 2, with equal parts of II A and III; 3, with equal parts of II A and IV; and 4, with equal parts of II A and V; while 5 was supplied only with the impure pickle V. It was found that during the whole season the 600 volumes of this last, taken for the experiment, were never reduced below 320, a bulk which was subsequently augmented to 340 volumes when the damp weather of autumn came on. After an exposure during the whole salt-making season, the salt from each basin was collected and carefully weighed, with the following results, the produce of the fresh pickle being taken at 100:—

Rates of evaporation.

Goessmann's experiments.

1.	gave of salt........................	100·00	parts.
2.	" " "	99·72	"
3.	" " "	95·35	"
4.	" " "	81·[illegible]3	"
5.	" " "	[illegible]	"

From the sparing solubility of salt in a bittern like V, it results that if fresh pickle be mixed with it, the mixture can no longer hold the whole of the salt in solution, but deposits a considerable portion of it in fine grains. All of these considerations shew that the accumulation of the impure liquors in the salt-covers is to be carefully avoided, and that they should be thrown away before they reach such a stage of concentration and impurity as to retard the efficient working of the process and reduce the yield of salt. Such a result is shewn in the experiments 3 and 4, where the falling off in the production is seen to be five and nineteen per centum.

Dense pickles.

These impure pickles have a specific gravity considerably greater than that of pure saturated brines. Thus, according to Dr. Goessmann, the pickle V, which contains less than nine per cent. of salt, marks 32° on Beaumé's scale, which corresponds to a specific gravity of about 1.278, and would equal 123° of the ordinary salometer, were the scale of this instrument to be extended; while a pure saturated brine, of 100° of the salometer, corresponds very nearly to 25° of Beaumé's areometer. Dr. Goessmann recommends this latter instrument to be used for testing the old liquors, and states that a pickle marking 30° Beaumé (equal to a specific gravity of 1.256) is to be rejected, as no longer fit for the purpose of making solar salt.

Bromine.

It will be seen from the analyses already given that the small amounts of chlorid of potassium and bromid of magnesium which these brines contain, accumulate in the old pickle, and might, perhaps, in some cases be turned to account as sources of potash and of bromine. Though this is not attempted at Syracuse, bromine is manufactured from the bitterns of salt-springs in western Pennsylvania and in Germany, and potash salts are extracted from the bittern of sea-water on the shores of the Mediterranean. The brines of Goderich are fortunately so pure that these foreign elements are present in too small amount to be of significance, although traces of both potash and bromine are found in them.

Brines compared.

As we have seen that the earthy chlorids are the most objectionable impurities in natural brines, it will be well to compare our own with those of Syracuse and of Saginaw. The following table shews the proportion of the two chlorids united, and also that of the sulphate of lime, calculated for 100.00 (one hundred parts) of the solid matters of the different brines; the difference between the sum of these and 100.00, being in each case pure salt.

Goderich.

		Earthy chlorids.	*Sulphate of lime.*
1.	Goderich Co's. well, Aug. 1866	·26	·69
2.	" " Apr. 1867	·22	2·19
3.	" " Nov. 1868	25	2·00
4.	Clinton " " "	·31	2·65
5.	Kincardine " " "	·44	1·33

6.	Syracuse brine, analysis I, page 232,.......... .	1·42	3.51	Syracuse.
7.	" saturated salt pickle,................	1·81	1.54	
8.	Saginaw brine (analysis by Douglas),..........	16·63	.53	Saginaw
9.	" " (" Dubois),...............	17·42	2.20	
10.	" " (" Chilton),.............	22·89	.45	
11.	" " (" Webb),...............	8·04	undetermined.	

The amount of sulphate of lime in the Goderich brine in August, 1866, before the well was pumped, was very small, though it has since increased. The smaller proportion contained in the Saginaw brines is due to the large amount of earthy chlorids present, which, as we have said, diminish the solubility of sulphate of lime. The proportion of earthy chlorids in the Goderich brines is seen to be but a small fraction of that contained in those of Syracuse; yet in the manufacture of solar salt these chlorids will slowly accumulate, and so require, though to a less degree, the same precautions as at Syracuse for getting rid of them from time to time. The following recommendations for the improvement of the solar salt at that place, copied from the Report of Dr. Goessmann already noticed, which was published in 1864, are therefore worthy of notice. Alluding to the different stages of the process, as described on page 228, which are carried on in three separate systems of vats, known as settling-rooms or deep-rooms, gypsum- or lime-rooms and salt-rooms, he observes :—

" The successful working of these rooms, as a general rule, is best aided by building them in distinct systems, corresponding with the number of processes intended; the succeeding set of rooms always from four to six inches lower than the preceding ones, and every system with a perfectly even bottom, but a distinctly slanting position towards their termination. Such a construction not only favors a desirable independent management of each system of rooms, but admits of a more successful drawing-off of brine or pickle. * * * * * The degree in which the bottom of every system of vats has to incline, is best regulated by the respective lengths of the strings; the longer the string of vats the less may be the rate of inclination. The latter ought to be such as to enable the workmen to draw from every one of these divisions, whenever required, that portion of the saline solution which has reached the desired point for which it was retained there. The flow itself, on the other hand, ought to be sufficiently slow to prevent the stirring up, and thus the carrying along of sedimentary matter to the succeeding division. The latter purpose can be much aided by a proper distribution of gates for discharging the brine from the upper to the lower section. Several small gates properly located are always preferable to one large one; the additional trouble caused by being compelled to open at every new charge or discharge, several gates instead of one, is more than compensated by the decided advantage gained in being enabled to draw or run off the old pickle uniformly, and thus more effectu- Plan of solar salt works.

ally, towards the termination of the lower rooms. The changes to which the brine is subjected while still in the first two systems of vats—the settling and the gypsum-rooms—manifest themselves, as we have observed, uniformly throughout the whole mass; and the vats being always filled with a saline solution of the same or similar original composition, and terminating also each time with a certain uniform state of the solution, in the form of a saturated pickle, do not exactly require separate divisions within their systems of vats. Nothing remains to be said here in regard to their construction, but that they ought to present a sufficient area of surface for evaporation, to enable the manufacturer to feed his salt-rooms whenever it may be required; this being requisite in order to produce a superior article of salt. It may be a very difficult question to ascertain the exact relative proportion between the surfaces of evaporation in the settling and gypsum rooms on the one hand, and the salt-rooms on the other; yet to find something near to it is one of the most important questions. A satisfactory decision of that question can only be obtained by adopting a method for working the salt-rooms to the best advantage, a method which tends to protect free evaporation in the salt-rooms from retarding influences—influences which are undeniable, yet uncertain in force."

In relation to the foregoing extract, it is to be observed that the preparatory stage, which requires two sets of rooms at Syracuse, on account of iron in the brine, may, in the absence of this impurity, be effected in a single set of rooms, in which the brine shall be brought to the point of saturation and a portion of gypsum deposited. The stronger the brine also the smaller need be the area of the gypsum-rooms as compared with the salt-rooms, so that the comparative area of the former at Goderich may be very much reduced, as noticed on page 229. The influences alluded to as retarding free evaporation in the salt-rooms are those of the earthy chlorids, which, as already shown in page 231, have—when in considerable quantities—a powerful effect in this way. Hence, the necessity of getting rid of these, from time to time, by drawing off and rejecting the old pickle before it becomes so impure as to become prejudicial. The means of determining this point has already been shown on page 234.

Gypsum-rooms.

As already remarked above, the settling and gypsum-rooms, in which the evaporation is carried only to the point of saturation, do not require sub-divisions in their systems of vats or covers; but for the salt-rooms this is very desirable, and Dr. Goessmann recommends the following arrangement:—

Salt-rooms.

"The vats are to be built in sub-divisions, with a perfectly even bottom, but slightly inclined towards the termination of the string. The first subdivision, next to the gypsum-rooms, ought to have the largest number of covers, the one following a less number, and the third, if the last, only one cover to every ten or twelve covers preceding in the whole string; for instance the first division may have twenty covers, the second ten, and the third only three covers. These various divisions ought to be connected with each other by two or, better, three small gates, and the gates between the second and third divisions should be larger than those between the gypsum-rooms and the salt-rooms. These sub-divisions facilitate a proper division and economy of the salt pickle."

Salt-covers, Syracuse.

The vats or covers used at Syracuse have, as already mentioned, a uniform size of sixteen by eighteen feet, and while settling-vats are generally deeper, those of the gypsum and salt-rooms have a depth of six inches, four inches of which is filled with brine or pickle. This, in the salt-covers, is replaced, as it evaporates, by fresh supplies of pickle, a process which is repeated as often as the salt itself appears above the level of the pickle, and continued until a sufficient amount of salt has been formed for removal. The gathering of the solar salt usually takes place twice or three times during a season. The natural consequence of this system of working is that in proportion as salt is obtained from the pickle the soluble chlorids accumulate in the remaining portion. This accumulation would sooner or later be felt throughout the whole string of vats used for salt-making, particularly if they were built on one level, and supplied with new pickle without certain precautions. Such conditions could not but interfere most seriously with the quality and quantity of the salt. Hence, as Dr. Goessmann emphatically says, the whole system of constructing and supplying the salt-vats during the season should be arranged so as keep the new pickle as much as possible separate from that which is old and partially exhausted.

Mode of working.

It is with this object in view that he recommends the arrangement of a string of salt-covers in three successive sub-divisions, numbering, respectively, twenty, ten and three. With such a system "the supply of new pickle ought to be managed with the following precautions: First, draw as much of the remaining old pickle as possible from the second into the third division, then from the first into the second, and, finally, open the gates between the gypsum-room and the first salt-room, which is thus supplied with fresh pickle. Aim always at the most successful separation of the remaining old pickle before supplying the new. The last or lowest cover will thus, in the course of the season, receive almost all the inferior old pickle left from the previous charges of the string. The pickle thus accumulating there will be more or less highly charged with the chlorids of calcium and magnesium, and a few weeks trial in the next season will soon indicate the point where salt-making profitably ceases." As already remarked, this impure or worthless pickle is much denser than saturated brine, and its value diminishes with the increased specific gravity, so that

Dr. Goessmann informs us that a brine marking 30° of Baume's areometer is worthless for salt-making purposes.

The site selected for solar salt-works should be on well-drained land, free from stagnant waters; the vats should never rest upon the earth, and should turn their open front towards the prevailing currents of air.

Gypsum.

As regards the sulphate of lime, the only foreign material present in any notable quantity in the brines of the Goderich region, it is to be remarked that it separates with the salt, during the process of solar evaporation, in the hydrated form, as small needle-shaped crystals of gypsum, which fill up, more or less, the cavities in imperfectly developed crystals of salt, adhere to the outside of these, or are mixed, in a loose state, with the bulk of the salt. This latter condition "enables the careful manufacturer to separate a considerable portion of the gypsum by subjecting the salt to a careful washing before harvesting it. An accumulation of a certain excess of sulphate of lime within the salt-vats, towards the close of the season, is almost unavoidable, and it is, for this important reason, very advisable to return the small-sized crystals of solar salt—for instance, the scrapings of the salt-vats—at the end of the salt-making season, to the gypsum-rooms. This precaution will not only secure an additional return of a superior quality of salt, afterwards, but will leave the excess of sulphate of lime where it properly belongs;" the yet unsaturated brine of the gypsum-room dissolving the salt, but leaving the gypsum behind. "To start the solar salt-making anew from time to time—for instance, every spring and fall before closing up the works,—is, on account of many advantages, very advisable."

The average amount of sulphate of lime in the solar salt of Syracuse, as calculated from the analysis of a good recently prepared pickle, need never exceed 1·5 per cent., which amount is considerably less than some of the best and most valued foreign coarse salts contain. The smaller quantity of sulphate of lime actually observed in the solar salt from the first gathering of the season, as well as in the coarser grained portion of the second crop, (from 1·315 to 1·316 per cent.) and the more or less increased proportion of it in the finer portion of the various crops, particularly in the last crop of the season, confirm the above statements. Its uniform distribution throughout the whole of every crop, remains, therefore, the sole object of the manufacturer. Sulphate of lime is generally not considered as interfering with the effects expected from good solar salt, yet being a matter foreign to salt, and apparently not directly promoting its specific action, a reduction of its proportion in salt should be sought, if for no other reason, for that of improving the appearance of the product. The means of effecting this has already been pointed out in the preceding paragraph. The proportion of sulphate of lime to 100 parts of the solid matters of the

Goderich and Syracuse brines.

Goderich brine is shown by the table on pages 234-35 to be considerably less than in the more dilute brines of Syracuse; but the former, during concentration to the condition of a pickle such as is required for solar salt, deposits a considerable portion of the sulphate, so that in the pickle it amounts only to 1·54 per cent.; while the Goderich brine, brought to the same condition, holds, on account of its greater purity from the noxious earthy chlorids, an amount of sulphate equal to about 2·0 per cent., or nearly as much as a pure saturated solution of salt. From this it will be seen that, while free, to a remarkable extent, from the chlorids of calcium and magnesium, whose presence is so prejudicial, the Goderich brines contain of the sulphate of lime a somewhat larger proportion than the Onondaga salt. This compound, as already remarked, is however no way injurious to the quality of the salt; in fact, the best Ashton and Turk's Island salt contain rather more sulphate of lime than that of Syracuse. It is, as already remarked, the earthy chlorids which not only injure the grain of the salt, render it liable to get moist in a damp atmosphere, but prove injurious to the flavor of butter, to which they impart a bitter taste. The presence of these in the ordinary salt of Syracuse having been recognized as impairing its value for the uses of the dairy, the treatment of the boiled, and in some cases of the solar salt by a small portion of carbonate soda, as described on page 227, has been resorted to, producing what is known by the trade-mark of *factory-filled salt*, and, being entirely free from the earthy chlorids, is peculiarly fit for the salting of butter. It is said that while for any other purposes than for the preservation of butter the presence of small quantities of earthy chlorids is of little or no importance, a very small proportion of them suffices to impair the delicate flavor of butter. As our brines contain on an average only one-fifth or one-sixth as much of these objectionable compounds as those of Syracuse, it follows that with the same care in making the salt, either by boiling or by solar evaporation, a salt would be obtained a holding much less proportion of these chlorids than the ordinary salt of Syracuse, and scarcely requiring the subsequent chemical process which is there applied for their removal.

Factory-filled salt.

ADVANTAGES OF THE GODERICH REGION FOR SALT-MAKING.

The finding of salt at Goderich attracted, early in 1867, the attention of the Onondaga Company, and Dr. Goessmann, who was sent to examine and report upon the new discovery, visited the region for that purpose in June, and again in December 1867; his object being to verify the truth of the statement made in my Report, published in the spring of 1867, that the brine of Goderich was the strongest and the purest known, and also to determine what were the facilities offered by that region for the manufacture of salt. In his Report thereon, addressed to the Onondaga Company, and dated January 1868, Dr. Goessmann thus sums up the result of his examination as to these two points:—

"The present brine of Goderich is not only one of the most concentrated known, but also one of the purest, if not the purest, at present turned to the manufacture of salt." After referring to the discovery of salt at Clinton, Dr. Goessmann proceeds: "Goderich possesses, in a high degree, all necessary additional resources and facilities for the manufacture of salt and its transportation to all the important commercial points in the western lakes, and is, therefore, the most formidable competitor which the salt-works of the state of New York have ever yet had to contend with." In confirmation of the statements made by me in preceding pages, I make the following citations from the Report in question, premising that they carry the greatest weight, from the known scientific accuracy of Dr. Goessmann, and from the fact that he has, as chemist to the Onondaga Company, devoted himself for years to the study of the salt-manufacture:—

It has been shown by the analyses on page 221 that on pumping the Goderich Company's well the density of the brine fell from 100° to 95°, while the amount of sulphate of lime increased. These changes were already apparent when, in April, 1867, Dr. Goessmann received samples of the brine and of the boiled salt for examination. His analysis of the former has already been given on page 221, II. He proceeds to remark: "The two samples of brine tested by Dr. Hunt and myself differ in strength by about 1.75 per cent. of salt. The difference in regard to the percentage of gypsum, which effects but little the relative commercial value, may find a satisfactory explanation, etc. * * * The proportion of gypsum obtained by myself is still somewhat less than that contained in the Onondaga brines. Comparing the results of both analyses in regard to the percentage of chlorid of sodium contained in the Goderich brine with that known to be in the average of the brines of Onondaga, (about 16 per cent.) we notice that the Goderich brine in either case exceeds the former by about 50 per cent. of salt, or more; while the proportion of obnoxious deliquescent chlorids contained in the Goderich brine amounts to only one-fourth or one-fifth of that found in the brines of Onondaga."

Analysis of Goderich salt.

"A sample of boiled salt from the Goderich works gave as follows:—

Chlorid of sodium	97.0309
Chlorid of calcium	.0072
Chlorid of magnesium	.0313
Sulphate of lime	1.4306
Moisture	1.5000
	100.0000

"This sample of salt, in a dried state, would contain not less than 98.5 per cent. of chlorid of sodium or pure salt. It ranks, consequently foremost among the common fine salt (boiled) in the market. In the percentage of the deliquescent chlorids of calcium and magnesium, which are considered the most obnoxious component parts of brine or salt, it compares most favorably with the best foreign and domestic salt. In fact the composition of the Goderich brine is such as to warrant, *à priori*, with but little care, a superior salt, common, fine and coarse. The commercial value of the brine of Goderich, in consequence of its superior purity as compared with the brine of Onondaga, is, judging from the previous statements, quite obvious. The Michigan (Saginaw) and Ohio River brines, I need scarcely add, have still less chance to compete on anything like equal terms."

"The salt," he adds, further on, "is, after separation from the pickle, as might have been expected from a brine like the Goderich, of a superior color, and of a hard and fine grain, resembling the best brands of home and foreign manufacture, and this result is attained without any but the ordinary care required for the manufacture of common fine salt. It will be noticed that the sole objection which may be urged against the Goderich brine is merely incidental, for the brine is too strong to be worked to its full advantage by the system of manufacture at present pursued."

Cost of making.

The low price at which English salt is imported makes it probable that the product of the Goderich region can scarcely compete with it in that part of the Dominion to the east of Lake Ontario, while the wells already sunk are probably more than sufficient to supply the remaining portion of the country. From these considerations it would seem that the only chance for a further development of the salt resources of the Goderich region is be found in the United States market. The present duty on salt entering that country amounts, however, to twenty-four cents in gold on 100 pounds of packed salt, and eighteen cents on 100 pounds of loose salt, making it, upon the barrel of 280 pounds, $\$0.67\frac{2}{10}$. By a proper system of evaporation, either by solar heat, or by a more economical use of fuel, as has been already pointed out, Dr. Goessmann conceives that the net cost of the barrel of fine salt, the barrel included (which costs 30c.), should not exceed \$0.70, while the freight from Goderich to Chicago would cost 10c.; to this he adds for storage, landing, selling, etc., at Chicago, $\$0.21\frac{1}{2}$, making the cost of a barrel of fine salt from Goderich, delivered at Chicago, $\$1.68\frac{1}{2}$. This, at the price ruling in January, 1868, would leave a small margin for profit, which might be increased if the salt were shipped loose, and thus entered at a reduced duty. For this traffic the position of Goderich, on the lake, and at the terminus of a railway, offers very great advantages; and, but for the duty against which it has to contend, it seems probable that the salt region of Goderich, stretching, apparently, to Clinton on the one side and to Kincardine on the other, might, from the greater purity and strength of its brines, command the market of the north-western United States.

Table giving a comparison of different expressions

Degrees; Salometer.	Degrees; Baumé.	Specific gravity.	Per cent. of Salt.	Grains of Salt in one pint.	Gallons for a bushel of Salt.
0	0	1.000	0	0	Infinite.
1	.26	1.002	0.26	19	2509
2	.52	1.003	0.51	38	1297
3	.78	1.005	0.77	56	863
4	1.04	1.007	1.03	75	647
5	1.30	1.009	1.28	94	516
6	1.56	1.010	1.54	114	430
7	1.82	1.012	1.80	133	368
8	2.08	1.014	2.06	152	321
9	2.34	1.016	2.31	171	285
10	2.60	1.017	2.57	191	256
11	2.86	1.019	2.83	210	232
12	3.12	1.021	3.08	229	213
13	3.38	1.023	3.34	249	196
14	3.64	1.025	3.60	269	182
15	3.90	1.026	3.85	288	169
16	4.16	1.028	4.11	308	158
17	4.42	1.030	4.37	328	149
18	4.68	1.032	4.63	348	140
19	4.94	1.034	4.88	368	133
20	5.20	1.035	5.14	388	126
21	5.46	1.037	5.40	408	120
22	5.72	1.039	5.65	428	114
23	5.98	1.041	5.91	448	109
24	6.24	1.043	6.17	469	104
25	6.50	1.045	6.42	489	99.7
26	6.76	1.046	6.68	510	95.7
27	7.02	1.048	6.94	530	92.0
28	7.28	1.050	7.20	551	89.5
29	7.54	1.052	7.45	572	85.3
30	7.80	1.054	7.71	592	82.3
31	8.06	1.056	7.97	613	79.5
32	8.32	1.058	8.22	634	76.9
33	8.58	1.059	8.48	655	74.5
34	8.84	1.061	8.74	676	72.1
35	9.10	1.063	8.99	697	69.9
36	9.36	1.065	9.25	719	67.9
37	9.62	1.067	9.51	740	65.9
38	9.88	1.069	9.77	761	64.1
39	10.14	1.071	10.02	783	62.3
40	10.40	1.073	10.28	804	60.6
41	10.66	1.075	10.54	826	59.1
42	10.92	1.077	10.79	848	57.6
43	11.18	1.079	11.05	869	56.1
44	11.44	1.081	11.31	891	54.7
45	11.70	1.083	11.56	913	53.4
46	11.96	1.085	11.82	935	52.2
47	12.22	1.087	11.08	957	50.9
48	12.48	1.089	12.34	979	49.8
49	12.74	1.091	12.59	1002	48.7
50	13.00	1.093	12.85	1024	47.6

for the strength of Brine from zero to saturation.

Degrees; Salometer.	Degrees; Baumé.	Specific gravity.	Per cent. of Salt.	Grains of Salt in one pint.	Gallons for a bushel of Salt.
51	13.26	1.095	13.11	1047	46.6
52	13.52	1.097	13.36	1070	45.6
53	13.78	1.100	13.62	1092	44.7
54	14.04	1.102	13.88	1115	43.8
55	14.30	1.104	14.13	1137	42.9
56	14.56	1.106	14.39	1160	42.0
57	14.82	1.108	14.65	1183	41.2
58	15.08	1.110	14.91	1206	40.4
59	15.34	1.112	15.16	1229	39.7
60	15.60	1.114	15.42	1252	38.9
61	15.86	1.116	15.68	1276	38.2
62	16.12	1.118	15.93	1299	37.5
63	16.38	1.121	16.19	1322	36.9
64	16.64	1.123	16.45	1346	36.2
65	16.90	1.125	16.70	1370	35.6
66	17.16	1.127	16.96	1393	35.0
67	17.42	1.129	17.22	1417	34.4
68	17.68	1.131	17.48	1441	33.9
69	17.94	1.133	17.73	1465	33.3
70	18.20	1.136	17.99	1489	32.7
71	18.46	1.138	18.25	1513	32.2
72	18.72	1.140	18.50	1538	31.7
73	18.98	1.142	18.76	1562	31.2
74	19.24	1.144	19.02	1587	30.7
75	19.50	1.147	19.27	1611	30.3
76	19.76	1.149	19.53	1636	29.8
77	20.02	1.151	19.79	1661	29.4
78	20.28	1.154	20.05	1686	28.9
79	20.54	1.156	20.30	1710	28.5
80	20.80	1.158	20.56	1736	28.1
81	21.06	1.160	20.82	1761	27.7
82	21.32	1.163	21.07	1786	27.3
83	21.58	1.165	21.33	1811	26.9
84	21.84	1.167	21.59	1837	26.5
85	22.10	1.170	21.84	1862	26.2
86	22.36	1.172	22.10	1888	25.8
87	22.62	1.175	22.36	1914	25.5
88	22.88	1.177	22.62	1940	25.1
89	23.14	1.179	22.87	1966	24.8
90	23.40	1.182	23.13	1992	24.5
91	23.66	1.184	23.39	2018	24.2
92	23.92	1.186	23.64	2045	23.8
93	24.18	1.189	23.90	2072	23.5
94	24.44	1.191	24.16	2098	23.2
95	24.70	1.194	24.41	2124	23.0
96	24.96	1.196	24.67	2151	22.7
97	25.22	1.198	24.93	2178	22.4
98	25.48	1.201	25.19	2205	22.1
99	25.74	1.203	25.44	2232	21.8
100	26.00	1.205	25.70	2259	21.6
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Explanation of table. The preceding table is extracted from Professor Alexander Winchell's Report on the geology of Michigan, published in 1861. An abstract of it was given in my Report for 1866, but it has been thought advisable to re-print it at length as a guide to our salt-manufacturers. Pure water dissolves at ordinary temperature a little over one-third its weight of salt, or from thirty-five to thirty-six hundredths. The amount varies somewhat with the temperature, and the results of different experiments are moreover not perfectly accordant, but from the most accurate observations it appears that 100 parts by weight of pure saturated brine, at temperatures from 32° to 70° F., contain from 26·3 to 26·7 parts of salt. Some earlier determinations however, gave but 25·7 parts, and upon this figure the table was calculated.

The specific gravity of a saturated brine at 60° F. is 1·205, pure water being 1,000. The salometer employed in many salt-works for fixing the value of brines is an areometer with an arbitrary scale divided into 100 parts. The density of pure water on this scale is represented by 0°, and that of saturated brine by 100°; each degree of the salometer, therefore, corresponds very nearly to one-quarter of one per cent of salt. The areometer or hydrometer of Baumé has also an arbitrary scale, but it is an instrument in common use and may conveniently replace the salometer. In the following table the true specific gravity, with the corresponding degrees of the salometer, and of the hydrometer of Baumé are given in the first three columns. The succeeding columns give the percentage of salt in a pure brine for each degree of the salometer, the number of grains of salt to the wine pint of 36·625 cubic inches, and the number of gallons of such brine required to yield a bushel of salt, weighing 56 pounds. These latter numbers are based upon the supposition that a saturated brine contains only 25·7 per cent of salt, but if we take into account the effect of the small quantities of earthy chlorids and other impurities which ordinary brines contain, they will be found not only sufficiently accurate for all purposes but nearer the truth than if based upon the composition of a perfectly pure brines.

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