REPORT

OF A

GEOLOGICAL SURVEY

OF THE

VICINITY OF BELLE PLAINE,

SCOTT COUNTY, MINN.

PRINTED BY ORDER OF THE SENATE.

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J. B. CHANEY,
STATE PRINTER.

COMMUNICATION FROM THE GOVERNOR.

STATE OF MINNESOTA,
EXECUTIVE DEPARTMENT,
ST. PAUL, January 23d, 1872.

Hon. W. H. Yale,
President of the Senate.

SIR:—On the 28th day of February, 1870, a law was passed by the legislature and approved by the governor entitled "An Act to aid in the development of Salt Springs at Belle Plaine," which donated six sections of the State salt lands to said company, on certain conditions. [See chapter 114, page 421 of the special laws of 1870.] These conditions were afterward complied with by the company, and the lands conveyed to the company by the State, as required by the terms of the law.

On the 6th day of March, 1871, "An Act to further aid the Belle Plaine Salt Company in the development of Salt Springs at Belle Plaine" was passed. [Chapter 129, special laws of 1871, page 365.] This act contained a proviso that there shall be a geological survey of the springs and adjacent neighborhood, and that the provisions of the law giving further aid shall not be operative unless the report of the geologist shall be favorable.

Prof. A. Winchell, State Geologist of the State of Michigan, was designated by the Governor to make such survey and report the results thereof to him. Prof. Winchell accepted the appointment, made the survey in June last, and filed his report with me on the 17th of that month. As the survey and report were made pursuant to an act of the legislature, and as the report contains the recommendations and conclusions of the geologist, touching matters of public policy, I deem it my duty to lay it before the legislature, for their consideration, and have the honor to enclose the same herewith.

Should the legislature be of opinion that, notwithstanding the report, the probabilities of a successful termination of the enterprise are sufficient to justify its further prosecution at the expense of the State, with that object in view, or if, on the other hand, it should be thought, though such probabilities should be excluded, yet that work should be prosecuted with reference to other possible results, and in the interest of science, then further legislation might be required.

Very respectfully,

Your obedient servant,

HORACE AUSTIN, Governor.

REPORT.

Sir:—In pursuance of an appointment from Governor Austin, dated St. Paul, March 30, 1871, I have made such geological survey in Minnesota, and especially in Scott county as seemed requisite to enable me to form an opinion ot the prospect of obtaining brine at Belle Plaine, or in its vicinity, of sufficient strength to sustain the manufacture of salt.

For the information of your company, I proceed to state the facts and general principles which have guided me to a conclusion.

Common salt and its solution, brine, being a product of chemical reactions in the primeval ocean, and not, to any considerable extent, the result of recent causes, its original home was the ocean; and as a geological product, its place is amongst the other sediments and precipitates of the sea, which make up the body of stratified rocks. Without pausing to explain the circumstances under which we believe the saline particles have become mingled with mechanical sediments in the progress of rock-making, it may be interesting to know that all formations since the beginning of Palæozoic Time, and not unlikely from an earlier period, are liable to be found saliferous.

That a formation originally saliferous may have remained such to the present day, it must always have preserved, since solidification, such an attitude that fresh waters have not been able to filter through it and wash out its salinity. That is, the formation must always have preserved a dishlike configuration. It must be stated, however, that in cases where the mother-rock of the brine is underlaid immediately by a porous formation, as sandstone, the latter generally becomes saturated with the leachings of the salt rock above, and serves as a reservoir to be tapped in the search for supplies of brine. The mother-rock of brines is apt to be argillaceous and gypsiferous as well as saliferous; and unless beds of sandstone be interstratified, it is useless to expect great supplies of brine, however strong, in this formation. The storehouse of its brines is below.

Natural brines of workable strength and quantity have also accumulated in beds of superficial gravel and sand, in situations where such deposits have received the leachings of a salt formation. This is the situation of the brines of Onondaga county, New York, and the vast deposits along the eastern flanks of the Sierra Nevadas.

The principal brines of the United States have been obtained from the following formations, beginning with the lowest:

Salina Group.—This contains rock-salt at Goodrich, Ontario, and Alpena, Michigan. Brine accumulates in its porous strata, and supplies wells at St. Clair, Mt. Clemens and Port Austin, Michigan. Its leachings saturate gravel beds which supply the extensive works of Onondaga county, New York.

Marshall Group.—This supplies the numerous wells along the Saginaw Valley in Michigan. It is simply a receptacle of brines filtered from the overlying formation known as the "Michigan Salt Group," and found in no other portion of the United States.

Carboniferous Conglomerate.—This is the reservoir of brines supplying most of the wells in West Virginia, Ohio, Indiana and Illinois. It also supplies some of the shallow wells in the Saginaw valley, Michigan. The source of the brine is believed to be the coal measures overlying.

Mesozoic Formations are known to be highly saliferous in Kansas and Nebraska and other parts of the West; and probably the salt of northwestern Minnesota is derived from these sources. The great salt deposits of Nevada are of Mesozoic age—as also those of central Europe and Great Britain.

The problem to be resolved in reference to Belle Plaine was, threefold, 1st, whether the age of the rocks approximates to that of any of the known saliferous formations of the United States; 2d, whether the altitude of the strata is such as to have retained their primitive saliferous constituents; 3d, whether the situation is such that the filtering of a saliferous formation could have accumulated in beds of sand and gravel resting on the surface of the rocks.

With the view of determining the geological age of the underlying and neighboring strata, I made geological examinations of various points along the valley of the Minnesota river.

At Kasota, 30 miles from Belle Plaine, is quarried a highly magnesian limestone of a reddish creamy color, which outcrops at an elevation of about a hundred feet above the river. At Ottawa, 16 miles from Belle Plaine, up the river, is quarried a similar stone, a little more tinged with red, which outcrops at an elevation of 75 feet above the river. I did not visit these two localities, but saw abundant examples of the rocks. The latter locality, morever, has been described by Dr. Shumard.

A sample of the stone from Ottawa, crushed and treated with dilute sulphuric acid, effervesces with great briskness, and leaves an undissolved residue amounting to but an insignificant percentage. It is not, therefore, a sandstone, though its granular character gives it a somewhat arenaceous aspect, and the rock is sometimes regarded as a sandstone. This aspect and the buffish color are common to magnesian rocks. In fact, the presence of magnesia is readily proven in this case, by the distinct flavor of Epsom Salts detected in the solution. Chemical analysis shows that the usual composition of this formation, in Minnesota, is essentially one proportion of carbonate of lime to one of carbonate of magnesia. Dr. Shumard has given us the following analysis of a sample of the rock from "White Rock bluff," which I judge to be the Ottawa outcrop (Owen, Geology of Minnesota, &c., p. 484, Note):

Carbonate of lime	58.65
Carbonate of magnesia	29.15
Insoluble matter	7.25
Alumina oxyd of iron and manganese	1.55
Water	2.65
Loss	0.75
	100.00

At Keystone, four miles above Belle Plaine, at an elevation of 60 or 70 feet above the river is an outcrop of magnesian limestone similar to that at St. Lawrence, of which more particular mention will be made. A slight outcrop of the same occurs one and a half miles below Belle Plaine, on the land of William Hinman. At St. Lawrence, which is about four miles below Belle Plaine, and at an elevation of about forty feet above the river, occurs the following series of strata, enumerating from above downward and designating the lowest visible stratum as "A":

F. Magnesian limestone, speckled and mottled with green, and having numerous greenish partings. Greatly shattered—2 feet.

E. Magnesian limestone, buffish, thick-bedded, vesicular. Contains crystals of brown spar. Quarried for building—4 feet.

D. Magnesian limestone, reddish-tinged, hard, fine, crystalline—2 feet.

C. Magnesian limestone, irregularly bedded, buffish, containing green specks—probably of silicate of iron—and fucoidal casts—4 feet.

B. Arenaceous greenish shale, with partings of light clay—8 inches.

A. Buffish, magnesian limestone in thin layers. Thickness unknown.

From these observations, it appears certain that the first bench above the bottom lands of the Minnesota Valley, between Kasota and St. Lawrence, is underlaid by the "Lower

Magnesian Limestone" of Owen, which is probably the equivalent of the "Calciferous Sandrock" of New York. It appears, further, that in the distance of 34 miles, it dips down the river at such a rate as to be about 60 feet nearer the water at St. Lawrence than at Kasota—supposing, as is probable, that nearly the same part of the formation outcrops at each locality.

Passing from St. Lawrence northeastward down the valley to Brentwood, we pass a region known as Sand Prairie, characterized by an upland, rolling surface, and a poor, sandy soil, without tree or shrub. It is apparently a deposit of detritus arising from the abundant disintegration of some neighboring sandstone.

Turning southward, up Sand creek, we find the sandstone which has probably been the origin of these sands. By examination in the beer-vaults at Jordan, and along the various outcrops higher up the stratum, we find a section somewhat as follows:

F. Sandrock, buffish, quite ferruginous, thick bedded. Seen at the mill—6 feet.

E. Sandrock, ferruginous, thin and irregularly bedded, friable and disintegrating, with many ferruginous seams, crusts and concretions. In the quarry, 3 feet.

D. Sandrock, irregularly whitish or ferruginous, heavy-bedded, obliquely and beautifully banded with iron streaks and laminæ. In quarry, 12 feet.

C. Sandrock, buffish, similar to D, but thinner bedded. In the quarry, 8 feet.

B. Sandrock, hard and ferruginous above, soft, friable and buffish-red, below. Falls of Sand Creek, 10 feet.

A. Sandrock, whitish, compact. In the beer vaults, 12 feet seen.

This sandrock formation, notwithstanding its considerable elevation above the magnesian limestone at St. Lawrence, I am induced to regard as the Potsdam sandstone, whose stratigraphical position is *beneath* the magnesian limestone.

At Dooleyville, 4 miles north-east of Jordan, is an outcrop over several acres, of a buffish and reddish, coarse, silicious sandrock, dipping about 2 degrees toward the south east. Some portions are quite hard, and even vitreous, while the lower portions rapidly disintegrate into a clean silicious sand, of rounded transparent grains, *beautifully adapted to the manufacture of clear glass.* The impurities would not probably exceed one-tenth of one per cent. This sandrock should not be confounded with that at St. Paul.

This ridge strikes in the direction of the Little Rapids of the Minnesota river at Carver City, which owe their existence to the unyielding strata, dipping there with the descent of the stream. This conclusion supposes a considerable swell in the stratification, to bring the rocks at the rapids to the altitude of the sandstones at Jordan.

The thickness of the sandstone at Dooleyville is about 24 feet to which must be added, below, about 10 feet, exposed in the neighboring railroad cut.

At Nagel's limekiln, on the Louisville Prairie, about one mile south of Merriam Station, we find another outcrop of limestone in a bluff facing west, and re-appearing in an outlier a quarter of a mile nearer the river. The rock is very irregularly stratified, and varies much in hardness and color. The prevailing colors are finkish and buffish. Some of the layers are sandy, others magnesian, others ochrey and ferruginous, others purely calcareous. Some portions are quite resicular and abound in small crystals of brown spar. Thirty-six feet are exposed in the quarry, and below this, a well has been sunk 38 feet in the limestone, making a total of 74 feet. Below the limestone the well extended 24 feet in sandstone, which was at first hard, like that of Dooleyville, and below, resembled the Jordan sandstone.

At Shakopee, the same formation exhibits an exposure of 20 feet, and is here also manufactured into lime. The lime at these localities is of a slaty color, but is said to be of good quality. White lime is sometimes manufactured from the selected purely calcareous layers.

As this limestone seems to hold a place next above the Jordan sandstone, and also considerably resembles the St. Lawrence limestones, I am led to regard it as the Lower

Magnesian Limestone of Owen, though the top of the bluff at Nagel's limekiln is probably 70 feet higher than the quarry at St. Lawrence, ten miles distant in a straight line, up the river.

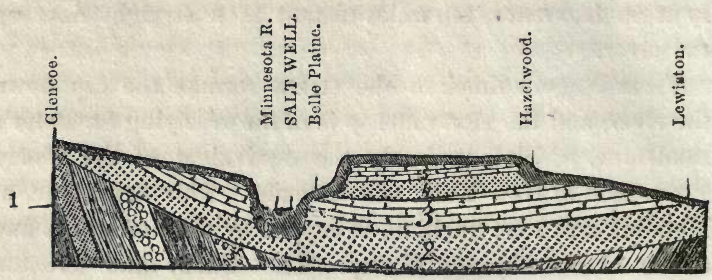
From Nagel's limekiln the strata resume the dip down the river, and the next outcrop is of the overlying St. Peter's sandstone, which is probably the equivalent of the Chazy Formation of New York and Canada. This sandstone, at Mendota and Fort Snelling, is capped by the limestones and shales of the Trenton Group. The Chazy and Trenton formations bound the gorge of the Mississippi River to St. Paul and to the Falls of St. Anthony. Just above the falls, the limestones thin out in the bed of the river, but continue to appear, for a few miles, along the banks and at the higher levels. The Chazy sandstone disappears nearly at the same time, and the magnesian limestone comes to the surface.

From the foregoing statement of facts it appears that the region from St. Paul to Kesotah, and we may add, to Mankato, is underlaid by rocks occupying the lowest position in the Palæozoic series, and beneath the lowest zone of brine-producing strata known in the United States. This, however, is not decisive against the existence of brine in these strata.

It also appears that in a direction parallel with the axis of the Minnesota valley, the strata present a slightly concave conformation, which is essential for the accumulation of brine.

In the direction at right angles with the valley a similar conformation exists, and we know that from the mouth of the Warajn river, northward, the Huronian rocks (next beneath the Palæozoic) occupy the surface when not concealed by drift, and the streams also descend from that direction to the Minnesota; while on the east, the Potsdam sandstone, after passing beneath the Lower Silurian and Upper Silurian strata, comes to the surface again in the valley of the Mississippi river.

The following section presents a general view of the geological structure from Glencoe through Belle Plaine and Hazelwood to the Cannon river:



1. Huronian System—[The dips of the strata are hypothetical.]

2. Potsdam Sandstone—Believed to be considerably eroded in the valley of the river.

3. Calciferous Formation—(Lower Magnesian Limestone.)

4. Chazy Formation—(St. Peter's Sandstone.)

5. Trenton Limestone and Shales.

6. Drift Materials, represented as covering the whole surface and partially filling the ancient excavation of the Minnesota river. The two upper terraces at Belle Plaine are believed to be shaped by the underlying formations, though deeply buried in drift.

The basin structure, as far as shown in this section, is sufficient for the accumulation of brine, and it might be looked for in the vicinity of Belle Plaine, were there not a lower depression of this basin further southward, extending into Iowa and Missouri. The shaly strata of the Trenton group which overlie the central portion of the section, are likely to be somewhat saliferous, and the brine, in such case, would find its way to the Potsdam sandstone, and flow toward the lowest depression of that formation. But the nearest places of outcrop of the formation are in Sibley, Carver and Nicollet counties; and I cannot doubt that surface waters have saturated that sandstone for many miles to the southeast of the Minnesota valley. The search for brine in this sandstone would therefore be rewarded only with fresh water. That water, in places lower than the outcrop of the formation—as along the valley of the Minnesota river—ought to rise to the surface. The experiment of boring into it would probably result, therefore, as at Chicago, in a copious Artesian well.

The foregoing statements show, 1st, *That the situation at Belle Plaine is geologically lower than any known brine-producing formation of North America;* and 2d, *That even if the shales of the Trenton group should prove to be a saliferous formation the product is likely to accumulate uderneath a region far to the south.* It must be added that no accumulation is probable, even toward the south, since the southern border of the basin is so depressed that fluids have probably found a free circulation through it, and most of its saline constituents have been carried away.

It remains to consider whether the situation is such as to justify the expectation that the superficial sands and gravel of the river-bottom at Belle Plaine, or its vicinity, have become saturated with brine of sufficient strength to justify the attempt to manufacture salt.

The superficial materials represented by number 6, in the diagram before referred to, have accumulated in the valley of the river at Belle Plaine to a depth of 210 feet. They consist mostly of sand and gravel. These facts are apparent from the following statement of materials passed through in boring the existing well.

At depth of FEET.	Intervening thickness. FEET.	
0	9	Soil and gravel.
9	9	Clay and gravel.
18	18	Sand and gravel.
36	54	Quicksand.
90	1	Coarse sand.
91	6	Clay. At 93 feet, a piece of grapevine with bark.
97	38	Sand, varying from quicksand to coarse sand. At 114 feet, sand filled the pipe 12 feet; at 125 feet, it filled 5 feet.
135	45	Gravel, quicksand, and coarse sand. At 144 feet the pipe filled 10 feet. At 168 feet another piece of grapevine.
180	7	Blue Clay.
187	13	Rock fragments.
200	2	Gravel. Brine stood 18° by salometer.
202	8	Shelly rock.
210		Bed-rock—said to be a sand stone—probably Potsdam sandstone (see diagram.)

Here is a favorable bed of materials to serve as a reservoir for any brines which might escape from the outcrops of any of the contiguous strata; and some surface indications of brine have long been known; but, in boring into these deposits no brine seems to have been reached of sufficient strength for practical purposes. This may be either because the supplying formation is insufficiently saliferous, or because the gravel beds are not underlaid by an impervious floor of clay, capable of arresting the downward escape of the brine.

Should this well be properly pumped, the strength of the brine would probably be somewhat increased. It would be desirable to pump it from the bottom, and also at the depth of 180 feet, immediately above the seven feet bed of clay—the hole below being, in the meantime, temporarily stopped. It is my opinion that if the strength could be increased to 50° or even to 45°, the salt manufacture might be established. The remoteness of this part of Minnesota from the principal sources of supply of salt, and the cheapness of fuel, would render available a very much weaker quality of brine than could be employed in a region as far east as Chicago. I feel it my duty to state, however, that *I do not consider this expectation very encouraginy. The increase of strength produced by pumping would not probably be sufficient.*

As there are different methods employed for expressing the strength of brines, it may be useful to add here that the salometer expresses percentages or hundredths of complete saturation. One hundred degrees expresses complete saturation; 50°, half saturation; 25°, one-fourth saturation, and so on. "Percentage of salt" in brine is a very different thing. "Eighteen per cent. salt" means that in 100 pounds of brine, 18 pounds are salt. Saturated brine contains about 25 per cent. of salt, and this percentage is equivalent to 100° on the salometer. Beaume's Hydrometer is a salometer graduated to 26° instead of 100°. The strength of brine is also expressed by its specific gravity, which is its weight compared with an equal bulk of pure water. Thus, if a certain volume of water weighs one pound, the same volume of saturated brine will weigh 1.2 pounds. Still another method is to give the number of grains of salt in one wine pint of brine; or lastly, to state the number of gallons of brine required to produce a bushel of salt weighing 56 pounds.

Natural brines always contain some impurities, and the salometer is affected by these in the same way as by common salt. Hence some deduction must be made from the indicated strength, depending on the proportion of impurities in the brine. The impurities can be determined only by chemical analysis.

Below is an abridged table showing the equivalencies of the various methods of expressing the strength of brines:

Equivalent Expressions for Strength of Brines.

Salometer.	Beaume's Hydrometer.	Specific Gravity	Per centage of Salt.	Grains to 1 pint.	Gallons to 1 bushel.
0	0	1.000	0	0	Infinite
10	2.60	1.017	2.57	191	256
18	4.68	1.032	4.63	348	140
20	5.20	1.035	5.14	388	126
30	7.80	1.054	7.71	592	82.3
40	10.40	1.073	10.28	804	60.6
50	13.00	1.093	12.85	1,024	47.6
60	15.60	1 114	15.42	1,252	38.9
70	18.20	1.136	17.99	1,489	32.7
80	20.80	1.158	20.56	1,736	28.1
90	23.40	1.182	23.13	1,992	24.5
100	26.00	1.205	25.70	2,259	21.6

The nominal strength of the brines employed in the Saginaw salines is about 80°, but they contain a large percentage of chloride of calcium. The mean strength of the Onondaga brines, in 1862, was 61°. It is supposed the first Onondaga brine employed in the manufacture of salt did not possess a strength above 40° or 45°.

The prices of wood per cord in Onondaga county, have been as follows: In 1849, $2.00; in 1856, $5.50; in 1857, $4.50; in 1860, $3.50; in 1861, $3.25; in 1864, $3.50. Anthracite coal became extensively used in 1857, costing about $3.50 per ton, and reducing the cost of salt two or three cents per bushel. One ton of coal, at Syracuse, makes about fifty bushels of salt. The following table shows the relative value of different classes of fuels for purposes of evaporation:

	Equal W't.	Equal B'lk.
Maryland Bituminous........	1,000	1,000
Pennsylvania Anthracites.....	977	986
Pennsylvania Bituminous coals	951	938
Virginia Highly Bituminous coals......................	850	757
Foreign Bituminous coals.....	801	741
White Oak..................	700	610
Red-Heart Hickory..........	700	592
White Ash..................	690	551
Black Walnut...............	615	486
Hard Maple.................	530	460
White Pine.................	362	298

Although I am unable, for reasons already stated, to report favorably in reference to the prospect of obtaining brine at Belle Plaine, I entertain a decided conviction that it would be judicious to make a further expenditure at that place.

1. The present well should be pumped in the manner already indicated. There is a chance of obtaining, by this means, a brine of sufficient strength to evaporate either by artificial or solar heat.

2. The present well ought to be continued down to the bottom of the Potsdam sand stone. I cannot learn that any deep boring has been made in Minnesota. My observations in Michigan for fifteen years past teach me the importance of such explorations. The results are of public utility. Even if possessing no *positive* value, mere negative results are valuable, as indicating in what formations, and under what circumstances to expect nothing. Negative results, systematically and reliably attained, may save many random ventures and expenditures hereafter. But in this case I think there is good reason to anticipate an Artesian overflow of fresh water. The possibility of copious Artesian wells along the valley of the Minnesota may lay the foundation of important business enterprises now unanticipated. It would demonstrate the probability of Artesian wells in analagous situations throughout the southeastern portion of the State. It is a public, more than a private interest, which is concerned in exploring this sand stone; and it would be good public policy if the State would provide for the expense. This locality is the proper one for the experiment, since by far the most expensive portion of the undertaking has now been completed, in sinking a substantial six-inch pipe through the boulder drift two hundred feet, to the surface of the friable sand rock.

Very respectfully submitted,

ALEXANDER WINCHELL.

Ann Arbor, Mich., June 17, 1871.