

NATURAL GAS IN MINNESOTA.

A HISTORY OF FACTS, AND A STATEMENT OF GEOLOGICAL PRINCIPLES.

The great discoveries of gas in Pennsylvania and more recently in Ohio and Indiana, and in other places in the United States, have had their natural effect in Minnesota. They have caused a feverish and sometimes an expressed feeling of unrest, and of curiosity to know what would be the result in case a careful probing of the earth's crust were undertaken. They have caused a re-examination of old records, and a restatement of all the nearly forgotten incidents which occurred years ago which could be interpreted as indications of natural gas at numerous places in the state. They have sharpened the observation of all well-drillers and others who in any way could be considered to be in situations such as might reveal evidences of escaping gas. The human eye-sight, the sense of smell, the love of lucre, the knowledge of geology, the ignorance of all geologists, have received a sudden and very general popular increment. These have had their influence on our Legislature. This is all very natural and not at all blameworthy. The demand for public expenditure in search for the hidden resources of the state, when the commonwealth in general is interested in the enterprise, is a demand that should be heeded by legislators. It is one of the distinguishing marks of American civilization that the people are willing to tax themselves for the promotion of public improvements and for scientific research. The people in general are more intimately acquainted with as well as more profoundly interested in the prosecution of scientific research, and the economic results of such research, than in other civilized countries.

This general impulse toward economic geology in Minnesota resulted in the passage of the following law by the Legislature of 1887.

AN ACT TO EXTEND THE WORK OF THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF THE STATE.

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. It shall be the duty of the state geologist to make practical and actual tests by drilling or digging or other excavations in the earth such as he shall deem best suited to accomplish the purpose of this act for the discovery of any of the hidden mineral resources of the state, such as iron, copper, silver, gold, coal, gas, coal oil, common salt or any other valuable material that he may deem likely to exist in any of the rock strata of this state.

SECTION 2. In determining the localities at which such testing and exploring shall be done he shall be guided by such geological facts as he may possess or obtain, which may indicate the existence of any of the substances which it is the purpose of this act to discover. He shall also be guided by the proportionate amount of money that the owner or owners of the land on which such explorations may be proposed shall contribute to pay the cost of such exploration.

SECTION 3. It shall be the duty of the state geologist to report at once to the board of regents all discoveries either of economic or scientific interest to the state that may be made by such testing and exploration. Each report shall be published by the board of regents in the same manner as now provided for the publication of the annual reports of the geological and natural history survey of the state, and shall be paid for out of the same fund. *Provided*, that any important mineral discoveries or other scientific contribution to the geological and natural history survey that the said state geologist may deem necessary for immediate publication, shall not be suppressed until the regular report of the board of regents, but shall be issued from time to time under the direction of said state geologist.

SECTION 4. That the sum of five thousand (5,000) dollars for the year A. D. one thousand eight hundred and eighty-seven (1887) and the sum of five thousand (5,000) dollars for the year A. D. one thousand eight hundred and eighty-eight (1888) is hereby appropriated out of any moneys not otherwise appropriated for the purpose of defraying the expenses of said tests. The investigations provided for in this act shall not be conducted in the interest of any mining company or corporation.

SECTION 5. This act shall take effect and be in force from and after its passage.

Approved March 8th, 1887.

In pursuance of the requirements of this law some investigations have been made, and it is the intention of the writer herewith to make report thereon so far as they have appertained to search for natural gas.

FACTS KNOWN PRIOR TO THE PASSAGE OF THE ABOVE LAW.

It will be a natural introduction to what follows relating to the investigations that have been carried on, to recall some of the considerations, and mention some of the facts which seemed to invite the expenditure of money in search of natural gas.

1. From time to time reports have been published of the sudden outburst of gas of some sort from excavations made by railroads or by private parties, either in digging common wells or in sinking drilled holes into the rocky strata.

In the making of a well near Big Stone lake the workmen of the Chicago, Milwaukee and St. Paul Railroad met with curious manifestations. There were slight explosions, accompanied by strong odors of some gas. The substance excavated at the bottom of the well was a dark damp clay. Finally a more severe and nearly a disastrous explosion, which threw the workmen violently back and against the side of the excavation, alarmed them so that the work ceased. In this case Supt. C. H. Pryor sent a quantity of the dark clay to the writer, reporting the circumstances and asking a solution of the trouble. The clay proved to be some of the carbonaceous shale of the Benton (probably) of the Cretaceous, and there seems to be little room for doubt that the gas originated in the lignitic beds of the Cretaceous.

In Traverse county, in Arthur, a large flow of gas was encountered at 180 feet depth, said to be below the till sheet of the drift. It rushed out with such force as "to throw out a heavy iron bolt inserted in the pipe." This was on the land of James H. Flood. This flow of gas continued but a short time, and gradually diminished, and finally ceased. This account is taken from the newspaper reports. The quality of the gas was not ascertained, so far as known.

Similar facts were reported by Mr. Francis Bossard from near Waseca. Two wells on his farm gave abundant evidences of gas escaping from the earth. They are about 65 feet deep, and at the mouth of the well the gas took fire from a lighted match and burned with a blue flame extending 8 or 10 feet in the air. When burning there was a noise which could be heard, as alleged, a mile and a half, and the earth trembled "as if by heavy thunder." Water from these wells has a bluish color, and when left to stand shows an oily scum on its surface. This is in a region supposed to be likely to have the Cretaceous rocks underlying the drift.

Mr. August Peterson reported signs of gas at the mouth of the Cannon river in Goodhue county. This was in the sinking of a drill for the purpose of artesian water. "At the depth of 85 feet there was an upheaval of sand and gravel, marked and forcible; filling the pipe to the height of twenty feet with sand, packing it so tightly that we had to drill it out. After cleaning it out there was another upheaval, sending the gravel and sand thirty feet, and so it kept on. We worked a month on twenty-five feet. Whenever we got within 8 or 10 feet of the bottom of the pipe, up the gravel would come. At 115 feet we got the pipe clean, I think. The last cleaning out, however, showed a considerable yellow sand which looked as though coated with mustard; the very last, however, being a brown or blackish and oily substance which on being poured out separated from the water, a smoke or steam rising from it. Then we sent the drill down again, fully believing we were to the rock. The drill, weighing 1,500 pounds, was sent up about 15 feet in the pipe, and the sand the whole length of the drill, which is 28 feet, and shut the drill in solid, requiring several hours of work to loosen it. The parties working becoming both discouraged and angry, the thermometer ranging in the thirties (minus—N. H. W.), in extremity they procured a pile-driver and bent the pipe, so we left the place."

Making another trial at 100 feet from this place, toward the main river bluff, Mr. Peterson obtained a fine flowing well of pure water without any trouble, at the depth of 350 feet.

Besides the above statements there were rumors of the discovery of gas in several other places in the state, which could hardly be said to have authentic foundation. Some were at Hastings, at St. Paul, at Minneapolis, at points between Fort Snelling and Minneapolis, in Chisago county and at Stillwater.

2. About the same time some "experts" from the great gas regions of Pennsylvania, said to be perfectly familiar with the manner of occurrence of gas, and its geological relations to the rocks in which it is found, who could see the "first sandstone" and imagined they could see the "second sandstone" but a few hundred feet deeper, along the valley of the Mississippi in the vicinity of Minneapolis, lighted the flame of popular confidence in the certainty of gas in Minnesota in paying quantities, by confident predictions of "immense spouters," in case a suitable test should be made under their direction. At the same time that they increased the general clamor for some costly test, they increased the general distrust of all geologists and geological evidence by

saying that the geologists know nothing about where gas can be found, quoting the experience at Findlay, O., as evidence of it, and affirming that gas issues everywhere when it is properly sought for.

3. In addition to these facts are some published facts of observation, found in the geological reports of the state. In volume one of the final report, page 384, are given the particulars of an exploration for coal at Freeborn, in Freeborn county, in which gas was met with in the process of sinking a shaft. On page 388 it is stated that some of the common wells in the western part of Freeborn county are injuriously affected by the prevalence of carbureted hydrogen gas. On page 488 is a record of carbonic acid gas in a well in Manyaska, in Martin county. On page 552 Thomas Kennedy's well is described. In it are found the remains of wood, such as logs, bark and leaves of trees, and a dangerous gas gathers rendering the water poor and unfit for use. On page 629 is mentioned the well of J. P. Edwards, situated in Prior, Big Stone county, and that of Samuel Varco, both of which met with gas. The statement is made that at the depth of about 100 feet wells in that neighborhood generally encounter gas, with water, coming from a dark-colored sand.

4. Other facts of a similar nature were in the possession of the survey, derived from various counties, some from Stearns, some from Nicollet and others from Hennepin and from Blue Earth, though still unpublished.

THE INTERPRETATION THAT HAD BEEN MADE OF THESE FACTS.

By the state geologist all these signs of gas had been ascribed either to vegetable deposits in the drift or to the Cretaceous. It is now better known than before the recent great developments in Ohio and other central states which have led geologists and others to scrutinize closely all sources of illuminating gas, that a limited amount of gas, undistinguishable from that which issues from the bed-rocks, is found sometimes, in the drift. This seems to be due to the decay of vegetation embraced between the deposits of the two ice-epochs, generally; but may be produced by the burial of vegetation under the operation of much more limited agencies, such as by the flood-stage of rivers or the high tide waters along the sinking sea-coast, or the lacustrine spreading of waters in low grounds toward the close of the last glacial epoch.

As to the Cretaceous origin of some of this gas, there was abundant reason to suspect that the lignites and lignitic beds of that age might be the source of this gas in those instances where the beds of the Cretaceous were known to exist in the neighborhood. In the Cretaceous all the conditions necessary for the production and retention in reservoirs below the surface of considerable quantities of illuminating gas are found to coexist not only in Minnesota but throughout a large extent of territory in Dakota. The lowermost layers of the Dakota group in Minnesota seem to consist, in some places, of lignitic clays and lignite beds, though in others the bottom of this group is sandstones and conglomeritic sandstones. Overlying this is an impervious sheet of clays and carbonaceous shales, dark, plastic, often finely laminated, belonging to the Benton group. These beds would not only themselves be likely to be a source of illuminating gas, but would serve as a tight canopy to retain any that might be generated by the vegetable remains in the underlying Dakota group.

From the greater portion of the state where these signs of gas were known the Trenton formation is wanting, and from the whole of the state the rocks of the Carboniferous age are wanting. In the light of the great developments in Ohio and Indiana of gas from the Trenton, attention was at once attracted to the Trenton formation in Minnesota, and the known and supposed extension of those strata under the surface of the state was closely outlined and carefully considered. The conclusion was reached that the Trenton limestone might be the source of gas in Minnesota, and that in those areas where it was reasonably supposed to lie below the surface, as in Freeborn and Mower counties, at the depth of several hundred feet, it might embrace the natural conditions which it manifests where it is gas-bearing in other places, and it might have a sufficiently close covering in the form of the green and blue shales of the Cambrian [Cincinnati group] to retain such gas within its own porous substance. This consideration was rendered the more reasonable, and more in keeping with the conditions delineated by Prof. E. Orton concerning the Trenton as a gas-bearing rock, by the known fact that the upper part of the Trenton (the Galena) is, in southern Minnesota, and in northeastern Iowa, a porous magnesian limestone. Hence it seemed possible that all the gas known to escape from the surface of the ground, or from wells in that area, might emanate primarily from the Trenton, though

known only as coming immediately from the Cretaceous or from the drift. It was also remembered that at Findlay the real source of the gas which escapes at the surface through crevices in the Niagara limestone and in the drift, is in the Trenton limestone at a depth of 1,648 feet below the surface.

FACTS THAT HAVE TRANSPIRED SINCE THE PASSAGE OF THE LAW, RELATIVE TO THE EXISTENCE OF NATURAL GAS IN MINNESOTA.

When the law was passed, and for some time before, parties had been engaged in drilling test wells at several places. One was at Faribault, and from this well was reported with particularity, and positiveness, the discovery of coal, marble, and the "conglomerate rock," in which last were said to be evidences of gas. Fair samples of anthracite coal were shown to all who desired to examine it, which were averred to have come from the bottom of this well. Other wells were being sunk at St. Paul, and in South St. Paul, and another at the State Fair Grounds, intermediate between St. Paul and Minneapolis. Gas was reported to have been found issuing from several places at St. Paul and particularly from the St. Peter sandstone near Fort Snelling, on the east side of the Mississippi. Considerable quantities of inflammable gas were exhibited and burned in public places by parties interested in some of these wells, said to have been obtained within a few miles of the Capitol building. At Hastings gas was discovered, as claimed, along the bluffs of the river, and a company was to be organized to bring it into economic recognition and use. At Freeborn, in Freeborn county, the old gas-supply was re-examined. Three drilled wells were sunk to the depth at which gas was found, and gas-pipes were inserted in them with gas-burners at the upper ends. From these the gas was seen to issue, and on applying a lighted match would burn with considerable heat and light. At Duluth a company began to drill for gas, another began at Stillwater and still another at Moorhead and another at Mankato. One was begun also in North St. Paul. The fever spread throughout the state. It is probable that but few counties can be named in which there has not been more or less agitation and some proposals by capitalists to bore for gas—the last being at Minneapolis, where it is reported a gentleman who is familiar with the Pennsylvania gas region, is sure he can see the "first and sec-

and sandstones," and the correct geological relations that indicate the surety of getting a large flow if a proper test should be made.

WHAT HAS BEEN DONE BY THE SURVEY TO DISCOVER THE
POSSIBLE GAS-RESERVOIRS IN MINNESOTA.

Although the terms of the law making it the duty of the state geologist to undertake a search for economic products are very broad, it was plain that the first expenditure should be for the discovery of gas. There are other economic interests that justly claimed a representation in any such public expenditure, and specially the iron resources of the state, both so far as known and developed, and particularly the unexplored iron regions of northeastern Minnesota which may be said simply to have been discovered, not explored.

Accordingly negotiations were entered into with the St. Paul Heat and Power Company, of St. Paul, who had been sinking a deep well near the State Fair Grounds between Minneapolis and St. Paul, and at other points, in search for gas, for the purchase of one of their deep-well outfits, including steam engine and all appliances and tubing for a deep well two thousand feet deep, six inches in diameter. This also included the derrick which had been erected on the grounds. This was transported to Freeborn county and was put to use in drilling a six-inch well at Freeborn, in that county, in order to ascertain, if possible, the origin of the natural gas that escapes there and is burned at the upper ends of the pipes. The machinery is still there, and is engaged in the same undertaking, under the charge, and at the cost of the Minnesota Natural Gas, Oil and Fuel Company, at Albert Lea.

The operations at Freeborn.

It will be best to rehearse the facts which led to the selection of this point in the state at which to make the first trial for natural gas.

In the third annual report of the survey (for 1874) the first report on Freeborn county was given, and includes the following account of

“Explorations for coal.

“In common with many other places in southern Minnesota, Freeborn township, in the northwestern corner of this county, has furnished, from the drift, pieces of Cretaceous lignite that resemble coal. Those have in a number of instances incited ardent expectations of coal, and led to the outlay of money in explorations. Such pieces are taken out in digging wells. The opinion seems to grow, in a community where such fragments are found, that coal of the Carboniferous age exists in the rocks below. In sinking a drill for an artesian well, at Freeborn village, very general attention was directed to the reported occurrence of this coal in a regular bed in connection with a ‘slate rock.’ This locality was carefully examined, and all the information was gathered, bearing on the subject, that could be found. The record of the first well drilled is given below as reported by the gentleman who did the work:

1. Soil and subsoil, clay.....	15 feet.
2. Blue clay.....	35 feet.
3. “Conglomerated rock” (hard to drill).....	2 inches.
4. Sand, with water.....	5 feet.
5. Fine clay, tough, hard to drill, with gravel and limestone pebbles.....	60 feet.
6. Sand, with water.....	4 inches.
7. “Slate rock” } probably Cretaceous.	7 feet.
8. “Coal”..... }	5 ft. 4 in.
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Total depth.....	122 feet.

“This indication of coal induced the drilling of another well, situated 100 feet distant, toward the N. E. In this the record was as follows, given by the same authority:

1. Soil and subsoil, clay.....	15 feet.
2. Blue clay.....	33 feet.
3. “Conglomerated rock”.....	2 inches.
4. Sand with water and pieces of coal.....	12 inches.
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Total depth.....	60 ft. 2 in.”

Further exploration was made in the sinking of a shaft in the same vicinity, but at the depth of 35 feet the work was so impeded by the influx of water, and the workmen being without adequate knowledge and means for removing it, it had to be abandoned.

At still another point, about three-fourths of a mile north of this place, a shaft was sunk to the depth of 57 feet, the strata having been tested first by a drill-hole to that depth. In this drill-hole gas was first met with in noticeable quantity. It rose above the top of the pipe, and being ignited it flamed up eight or ten feet with a roaring sound. The shaft was so near the drill-hole that it drew off the gas gradually, as supposed, allowing the intermixture of so much air that rapid burning was prevented. The exploration here being given up it was resumed at the former place, where another shaft was begun. But water

entered the shaft so copiously that the work had to stop at 106 feet. The water here was impregnated with the same gas as that which rose in the drill at three-fourths of a mile further north. Such water was also found in the well at the hotel at Freeborn. A test was made with sugar of lead for sulphureted hydrogen, but as it failed the gas was presumed to be carbureted hydrogen.

Again in 1880 this search for coal was resumed by Mr. E. B. Clark, who caused a shaft to be sunk 144 feet,* with the following result:

Soil.....	2 feet.
Yellow till	14 feet.
Softer blue till.....	29 feet.
Sand.....	1 foot.
Gray till, harder than the yellow till.....	47 feet.
Sand.....	1 foot.
Gray till.....	2 feet.
Quicksand.....	44 feet.

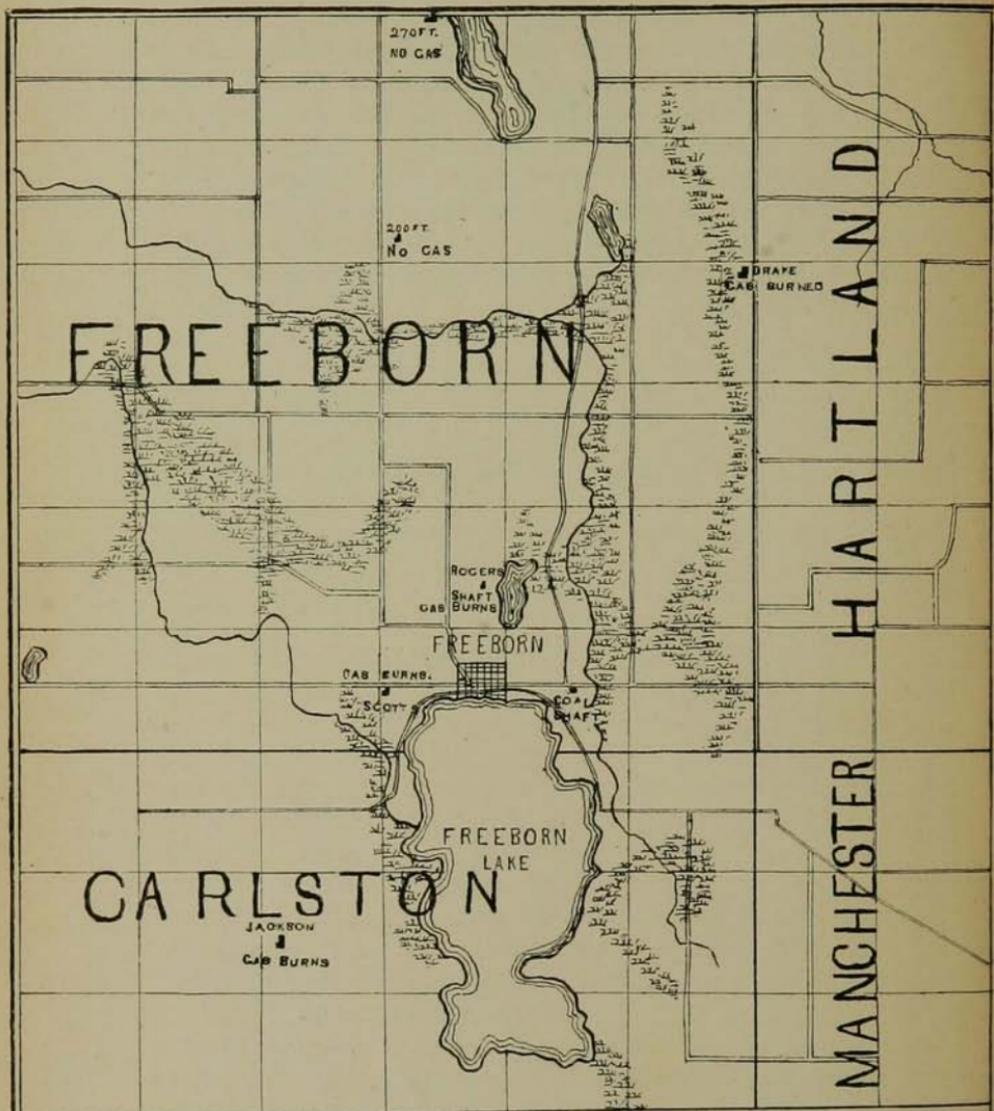
Total depth reported..... 130 feet.

At the depth of 124 feet from the surface Mr. Clark reported a stratum of slate two inches thick, "underlain by six inches of soil." The bottom of this exploration was said to have been *drilled* four feet in "slate." By the term slate in all these wells the workmen designate the slaty gray shale which appears in many places in the drift in Minnesota and is derived from the Cretaceous. When it is more than usually abundant it indicates the near proximity of the beds from which it is derived, and in some instances it has been found on excavation, or is in outcrop in the neighborhood along some stream or ravine. The county reports that have been published contain numerous proofs of the nature and origin of this "slate."

A visit was made to the locality before work was begun, and further information was obtained respecting the extent of these evidences of gas. By the aid of some of the citizens of Albert Lea, who had become informed of the former indications and their significance, several new trials had been made, and the flow of gas had been restored and had been conducted to burners which were regulated by thumb-stops.

The small map accompanying shows a section of that part of Freeborn county which embraces the area of natural burning gas. On returning from this visit the following letter was written:

*Vol. 1, final report, p. 385.



MAP OF THE VICINITY OF FREEBORN MINN.

To Show the Region of Natural Gas

By W.H. Winehell.

MINNEAPOLIS, MINN., June, 16, 1888.

To the Minnesota Gas, Oil and Fuel Company, Albert Lea, Minn.,

GENTLEMEN: At your request I give herewith a brief statement of the results of the examination I made of the gas wells at Freeborn last week.

There was a party of fifteen or more, and they all witnessed the exhibition of gas-burning from the tops of two inch pipes sunk into the earth about seventy-five feet. That there could be no deception as to the genuineness of this, and the origin of the gas as claimed, the sand pump was sunk into each one and gravel and clay were brought from the bottom. The pumping was also intended to relieve the gas from obstructions caused by water and gravel which get into the pipe and choke the flow of gas. Four such wells are in existence in the immediate vicinity of Freeborn, and afford gas intermittently, the stoppage being caused probably, as represented, by obstructions that now interfere with the current of gas, and choke up the bottom of the pipe. I am credibly informed also that indications of gas have been met with in numerous other instances in the sinking of wells in the neighborhood of Freeborn, and I know, of my own observation, that, now nearly fifteen years ago, when I first surveyed Freeborn county, such exhibition of gas was witnessed in the sinking of a shaft for explorations for "coal," and that it permeated the water of some wells and rendered the water unfit for general use.

The current of gas coming from one of these wells burned with considerable roaring, when allowed to escape in full force, issuing from a series of gas-jets arranged about a central disk, and, when regulated by the stop-cock, it becomes luminous, and burned with the regularity of any gas-supply.

The country round about is an open, ordinary prairie, like that seen in much of the southern and western part of the state, there being no rock exposure in any direction for many miles round. The evenly spread drift has an unknown thickness, and the surface drainage, while finally reaching the streams that flow into the Minnesota river, yet is so sluggish that numerous marshes are caused on the level prairie, and some shallow lakes of considerable size. These wells are on the west side of the morainic tract which passes through the county and which constitutes actually the highest water-divide, but they are not much lower than that divide.

In the absence of reliable data for determining the character

and age of the underlying rock at Freeborn, I can only give you hypothetical explanations of the source of this gas, and must defer till some new facts are ascertained, all positive statements. The general geology of that part of the state will permit the existence of either one or two of those formations that supply gas, at Freeborn, viz. : the Cretaceous, or the Trenton. The Cretaceous is known in some places in the western states and territories to contain not only lignite, and possibly to furnish petroleum, but also to give origin to natural gas, and it has been my opinion that the gas at Freeborn issued primarily from the rocks of that age. The "coal" that was sought by shafting at Freeborn in 1873 and 1874 was Cretaceous lignite, and the reports that were given me of the materials passed through, while evidently so described and modified as to fit the true Carboniferous rocks of Iowa, yet were, so far as I could see, indicative of the Cretaceous only. The deepest was about 128 feet, and at the bottom was said to be "coal."

I think the Trenton formation may exist below Freeborn. Indeed it is very likely to be found, in case of drilling a deep well at a depth not to exceed one thousand feet, and possibly not 500 feet. This formation is well known in Indiana, in Illinois and Ohio as the source of great quantities of natural gas, and it may be the source of that at Freeborn. Even if gas issue now from the Cretaceous, it may come primarily from the Trenton. At Findlay, Ohio, it rose from the Trenton through several hundred feet of strata, and at the surface escaped for thirty years from the Niagara limestone. It was only a deep well that penetrated the Trenton that revealed its real origin. So here, in case of drilling at Freeborn, the drill ought not to cease till the Trenton be reached, even if gas in considerable amount should issue before reaching it.

In conclusion: I am satisfied, both from the facts above stated, and from the analysis made by Prof. Dodge,* that the gas that issues at Freeborn is natural rock gas; that the geology of that part of the state, so far as it is known, is favorable for the existence of the Cretaceous and the Trenton formations in that part of Freeborn county; that either of these may be the source of

* Two samples were submitted to Prof. Dodge. These were obtained and transported under unfavorable conditions, and there is no doubt that the gas became mixed with common air before they reached him. He reported in one sample common air 47.37 per cent, and marsh gas or light carbureted hydrogen, 51.98 per cent. In the other sample he reported common air 24.59 per cent, and marsh gas or light carbureted hydrogen, 74.58 per cent. In each case there was less than one per cent of carbonic acid gas.

this gas; that the imperfect developments which you have prosecuted are ample to show the probability of a great gas reservoir that can be reached by a deep drill; and that all the indications warrant me in saying that you should by all means prosecute the investigation to its final result, and that too as soon and as rapidly as is consistent with due economy.

In view of the importance of this investigation to the State at large, I shall take pleasure in allowing the use of the deep well machinery belonging to the State, in such a test; and under the law of the appropriation made by the last Legislature, will allow such further aid as I consistently can to have the exploration made thorough and complete.

Respectfully,
N. H. WINCHELL,
State Geologist.

Accordingly the drilling machinery was removed from St. Paul to Freeborn and a well was begun which has reached the depth of 535 feet, giving the following record. The drillings are deposited at the university.

The record of the Freeborn gas well.

	Depth.
1. Yellowish-blue pebbly clay.....	20 feet.
2. Slightly darker pebbly clay.....	30 feet.
3. The same.....	40 feet.
4. The same.....	50 feet.
5. The same.....	60 feet.
6. The same.....	70 feet.
7. Gravel and sand, bearing gas.....	74 feet.
8. Same as No. 3, pebbly clay.....	80 feet.
9. Same as No. 3, pebbly clay.....	90 feet.
10. Same as No. 3, pebbly clay.....	100 feet.
11. Same as No. 3, pebbly clay.....	110 feet.
12. Same as No. 3, pebbly clay.....	120 feet.
13. Drift gravel and sand, with fragments of lignite.....	130 feet.
14. Drift gravel and sand, with many fragments of gray limestone...	140 feet.
15. Fine quicksand.....	145 feet.
16. Magnesian buff porous limestone, resembling Galena, mixed with drift pebbles.....	150 feet.
17. Magnesian limestone drillings, but mingled with some siliceous drift pebbles derived evidently from above. The rock fragments are small and apparently also argillaceous.....	160 feet.
18. Gray limestone, compact, apparently Trenton, also mingled with some drift.....	190 feet.

(No samples at 170 and 180 feet.)

19.	Same as the last, but with slight signs of drift.....	200 feet.
20.	Same as the last, but containing broken pebbles of drift material, evidently from above.....	210 feet.
21.	Coarse drift pebbles, some of the larger ones of limestone like No. 16. The pebbles are of greenstone, granite, and quartz- yte.....	220 feet.
22.	Dolomitic, but mixed with grains of pure quartz, very fine- grained, buffish-gray, having a rapid effervescence.....	230 feet.
23.	The same, but the limestone is nearly white, and compact, some chert fragments are visible.....	240 feet.
24.	Gray aluminous limestone.....	250 feet.
25.	Gray limestone.....	260 feet.
26.	Gray limestone.....	270 feet.
27.	Gray limestone.....	280 feet.
28.	Gray limestone.....	290 feet.
29.	Gray limestone.....	300 feet.
30.	Gray limestone, finely crystalline.....	310 feet.
31.	Gray limestone, with siliceous grains.....	320 feet.
32.	Gray limestone.....	330 feet.
33.	Gray limestone.....	340 feet.
34.	Gray limestone.....	350 feet.
35.	Gray shale, with quick effervescence.....	360 feet.
36.	Gray limestone.....	370 feet.
37.	Bluish gray shale; slight effervescence.....	380 feet.
38.	Bluish gray shale; pebbly.	390 feet.
39.	Fine bluish shale.....	400 feet.
40.	Coarser shale, containing pebbles of limestone and various crys- talline rocks	410 feet.
41.	Fine homogeneous gray shale.....	420 feet.
42.	A mixture of blue and gray shale and limestone containing peb- bles and Trenton fossils. Here was said to be a good show of oil; but it was only temporary, and no trace of it could be found at a subsequent visit.....	430 feet.
43.	Same as the last, the oil signs ceased	440 feet.
44.	Fine blue-gray shale, containing grains of silica.....	450 feet.
45.	Blue shale.....	460 feet.
46.	White sandstone, evidently the St. Peter sandstone. Here a green oily appearance is reported to have been conspicuous for a time but was soon lost.....	470 feet.
47.	White sandstone	480 feet.
48.	White sandstone	490 feet.
49.	White sandstone	500 feet.
50.	Green shale, dark, 5 feet thick. The well is cased to this green shale—i. e., the inner casing, 5½ inches in diameter	510 feet.
51.	White sandstone	515 feet.
52.	White, fine sand. The superintendent here declares that he is sure that a flow of gas was met, and that it is necessary to shut off the water to develop it.....	535 feet.

Subsequent to the above the drillings were not so frequently preserved. Mr. H. G. Day sent samples which afforded the following further record.

53. At a depth of 710 feet samples show a fine-grained magnesian limestone. The letter (Jan. 7, '89) accompanying this states that "the drill is now down 700 feet, and while it is not yet below what you designate St. Peter sandstone, the formation has materially changed in the last 50 feet. The rock at intervals of 5 to 15 feet is intensely hard, the thickness of the hard rock being at times an inch or two, and again several feet. Under each hard substance, is a cavity or very soft porous rock or sand, and when the drill went through into these cavities, in each case very strong coal oil or gas odor came to the surface. The sand bucket was impregnated with the odor so strongly that it filled the derrick room." If this change in the rock had been going on for 50 feet, the bottom of the St. Peter was at a depth of 650 feet, or 180 feet below the point above recorded at which it was first recognized. Sixty feet of the Shakopee limestone; at 710 feet.
54. The next sample sent in is a white saccharoidal, rounded, sandstone, with the record: "21 feet of this at a depth of 840 feet." There is hence an interval of 109 feet unknown..... 840 feet.
55. Slowly effervescing magnesian limestone, with the note: "Ten feet of this at a depth of 880 feet, underlying and overlying sandstone." 880 feet.
56. Mottled green and reddish shale, with the note: "A thin stratum of the green shale overlying 18 feet of red shale. Green shale struck at 900 feet." This green shale is undoubtedly within the St. Lawrence horizon (the "Mendota beds" of Wisconsin), and that allows the interval from 650 feet to 900 feet for Shakopee limestone, the Richmond sandstone, the main body of the Lower Magnesian and the Jordan sandstone. This interval, amounting to 250 feet, can not be subdivided accurately because of the lack of record. This shale, with varying amounts of magnesian limestone, continues to the bottom of the well, at 950 feet 900 feet.
57. Drillings made up of green shale and magnesian limestone, mostly the latter. Taken at depth of..... 920 feet.
58. Drillings mainly of fine-grained, nearly white, magnesian limestone, but evidently also siliceous, but with some fragments of purplish shale. The accompanying note is: "About 20 feet of this." Taken at..... 930 feet.
59. Much like the last, but more siliceous; effervesces generally, but leaves a large insoluble residue. This is probably from some of the layers of the St. Lawrence and can not be further defined. Has some greenish shale. 950 feet.

By a condensation of the record the following appears to be the geological position of this well:

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1. Drift.....	150 feet.
2. Galena limestone	10 feet.
3. Trenton limestone and shales.....	310 feet.
4. St. Peter sandstone.....	180 feet.
5. Lower Magnesian (with its parts, Shakopee, Richmond and main body of limestone), and Jordan sandstone.....	250 feet.
6. In the St. Lawrence limestone (with the accompanying shales): pierced.....	50 feet.
Total.....	<hr/> 950 feet.

Under date of Dec. 5, the investigation was still going on. Mr. H. G. Day, who has been active in promoting this enterprise, says: "We found oil of the pea-green color (petroleum) in small quantities in the Trenton. At a depth of 534 feet Mr. Bowland (the superintendent) claims he found a vein of gas of about the character of that in the exhibition wells, but water was coexistent and it could not well be cased off; so he bored further, and at a depth of 565 feet he claims to have found the strongest vein of gas yet encountered there. It certainly gave the gas odor, and filled the atmosphere with its fumes for several rods about. Every bucket that came up brought the odor, but as the well was nearly full of water, it was impossible to fully test it. We have been at work lately trying to case off the water from this vein, but have so far failed, although we have cased down with seed-bags and closed the hole tight around the casing at the bottom three times. The water vein was lower and we could not clear the well of water. While waiting for some elevators to lift and lower the casing we are now boring deeper. If we find nothing important before the elevators come we shall then make further efforts to case off the water just above the lower gas vein, and we intend to persevere in that purpose. If we fail, or if the gas does not show itself, as all believe it will do, we are determined to go deeper, perhaps 2,000 or 3,000 feet, and we very much desire to use your machinery therefor. Our 'backers' want to make a thorough investigation, and seem willing to stand the expense."

Mr. Day also says, under date of Dec. 13, '88; "We have been using every effort during the past two or three weeks to shut off the water in our well at the gas indications, 465 feet, and have had the help of three experts, men as capable as any to be had.

But it is impossible, we at last found, as the water and gas indications are coexistent. These men agree that there are almost certain evidences of gas, such as would be considered sure in the gas regions of the east. We are boring deeper, and want to go down 2,000 feet if necessary. We want to make the test thorough, and all concerned will not be satisfied otherwise."

This being the situation at Freeborn at the present time, the search not being concluded, it will be next in order to rehearse the facts connected with some other wells in the same county.

Other wells in Freeborn county.

In the immediate vicinity of Freeborn several common wells have been found to develop, at the depth of something less than 100 feet, the same signs of burning gas as Mr. Scott's near the village. Of these the farthest northeast is in the northeast quarter of sec. 13, Freeborn, and the farthest southwest is in the western part of sec. 9, Carlston, separated from each other about seven miles. Several others intermediate between these extremes are so situated, including that at Scott's where the above test was made, that the direction of greatest evidence of gas seems to run in a narrow belt extending about N. E. and S. W. In general, about Freeborn, common wells pass through first about 70 feet of blue till, then a dark clay about 3 feet, sand about six inches, giving the gas flow, and then blue clay ("till") extending down to the rock, which is struck at about 150 feet. The rock is struck at 150 feet at Hartland. At a mile and a half south from Hartland, four miles east of Freeborn a well penetrated to a depth of 226 feet, which included 40 feet in rock, with no sign of gas. The rock was found to be a white magnesian limestone like that in the deep well at Albert Lea. Toward the west and northwest, in Freeborn county, from the point at which the above test was made for gas nothing is known as to the existence of gas at any depth, as no wells sufficiently deep have been dug.

In Bath township, Mr. Michael Whalan, N. W. $\frac{1}{4}$, S. W. $\frac{1}{4}$ sec. 33, T. 104, 21, and Mr. Hans Nelson in N. E. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 4, T. 103, 21, Bancroft, found, at the depth of 190 feet, a gray sand of medium grain in the drillings from which were found fragments of charcoal and black, lignitic cellular woody material which resembles that found in the lignitic beds of the Cretaceous

20.	Mus. Reg. No. 6211.	Same as the last, from.....	237 feet
21.	" " " 6212.	Same as last, from.....	240 feet
22.	" " " 6213.	Mainly a homogeneous, buff, magnesian limestone, with some quartz sand, from.....	241 feet
23.	Mus. Reg. No. 6214.	The drillings consist, mainly of the same, light-buff magnesian limestone, but contain also numerous pieces of a dark earthy shale, not inflammable nor combustible, from.....	243 feet
24.	Mus. Reg. No. 6215.	Reddish-buff magnesian limestone, with some fragments of opaque white silica and some rounded sand, from.....	248 feet
25.	Mus. Reg. No. 6216.	Same as the last, from.....	250 feet
26.	" " " 6217.	The same without silica and sand, from.....	254 feet
27.	" " " 6218.	Reddish-buff, compact, magnesian limestone, from.....	258 feet
28.	" " " 6219.	The same, from.....	260 feet
29.	" " " 6220.	Reddish-buff, compact, magnesian limestone, mottled with gray, from.....	265 feet
30.	Mus. Reg. No. 6221.	The same, without gray mottlings, but with some chert and some sand, from.....	270 feet
31.	Mus. Reg. No. 6222.	Light-gray to buff, crystalline magnesian limestone, with rare beads from crinoid filaments, from.....	275 feet
32.	Mus. Reg. No. 6223.	Buff magnesian limestone, from.....	285 feet
33.	" " " 6224.	Light-buff magnesian limestone, some of the drillings being unwashed, and then, dried, resembling a light-gray shale, from.....	295 feet
35.	Mus. Reg. No. 6225.	Vesicular, buff, magnesian-limestone, resembling the upper part of the Niagara limestone, from.....	300 feet

There is but little to serve as a guide in assigning these limestone strata to their geological horizon. There is, in the Albert Lea well, a thickness of about 186 feet of limestone which does not vary very much lithologically, extending from 114 feet to 300 feet. It is shaly in some places, and also arenaceous. These characters would not preclude the Galena limestone, which is thought to be the most probable rock in that geographical area. If, however, the Devonian limestones extend as far north as Albert Lea, these beds could all be assigned to that age, as far as their lithology is concerned, except Nos. 33 and 34, which have a greater resemblance to the Niagara. This would bring the Devonian upon the upper Silurian, as supposed in the deep well at Austin.* The shale extending from 155 to 220 feet, a thickness of 65 feet, would, in that case, represent the Austin rock, and the mixed and arenaceous beds extending from 220 feet to 240 feet would parallelize with the conglomerate of the Austin well. There would be then 45 feet of magnesian limestone in the Albert Lea well, below the conglomerate horizon before the lithology of the Niagara is recognizable. This would fall into the upper part of No. 8 of the Austin well.

More recently several other wells have been drilled at Albert Lea, and some have obtained an artesian flow of water. Incomplete records of some of these wells have been obtained.

The "Greene-Dommick company" well is three blocks west

*The record of the Austin deep well is given in the 14th annual report, p. 16.

of the city park. It had 92 ft. 4 in. to the rock, the drift consisting of sand followed by 50 feet of blue clay, four feet of gravel, and a hardpan, which last lay on the rock. The first rock was a buff magnesian limestone of fine grain, effervescing freely, resembling the Onondaga portion of the Devonian limestones as described in Ohio, and also in the report on Fillmore county.* This had a thickness of 20 feet. This was followed by a shale three feet in thickness, and the shale by 40 feet of bluish, very fine-grained sandrock resembling the Austin rock, so-called, but effervescing freely, and disintegrating, leaving an impalpable residue. Below this the workmen reported a "crevice" 15 inches in perpendicular thickness, from which were shown some pebbles and fragments of white granular quartzite and one of a dark gray, arenaceous quartzite. Under this was a porous, nearly white, fossiliferous limestone which is easily referable to the Niagara such as that described in the southern part of Fillmore county** and on the Mississippi river further southeast. This extends, with some variation to compacter texture, and the intermixture of some rounded grains of white quartz, to at least the thickness of 20 feet below the crevice, at which point the record is broken, and nothing further is known till at the depth of 212 feet when the drillings show a compact saccharoidal limestone which had been pierced six inches. It may fairly be presumed, since no drillings were shown, that no change worthy of note took place in this unknown interval, and that the Niagara extended downward to the last — which itself also seems to belong to the Niagara.

At Albert Lea a mucky deposit is found in some wells at about thirty-eight or forty feet below the surface. This is associated with quicksand, and contains leaves and sticks. It renders useless some of the common wells. Other wells in the vicinity of Albert Lea yield a gas which on being examined by Prof. Dodge was found to be carbonic dioxide. When this was first discovered it was supposed to be burning gas of the same quality as that at Freeborn, but it would not ignite.

DEEP WELLS IN OTHER PARTS OF THE STATE.

The exploration at Mankato. Prompted by the prevalent idea that gas must exist in many unknown reservoirs in the crust of the earth, capriciously formed and distributed in a manner

* Final report, Vol. I, p. 303.

** Final report, Vol. I, p. 302.

wholly unknown and inexplicable by geology, some parties at Mankato organized a company and sought the services of the diviner's-rod. A gentleman by the name of Booker was paid \$250 for "locating" the gas veins at Mankato. This "witch," whose services are well known in Ohio where he has been extensively advertised by his bombastic circulars, passed over the ground, and, as reported, was taken with jerks and shakings so violently in certain places over which he passed that he could not endure the current. He was obliged to stand on one foot, placing the other against his knee to break the electric flow. He predicted that a gas flow equal to that at Van Wert, Ohio, would be obtained by drilling at the point he designated, which was near Minneopa falls, about where the company desired to drill.

Here a well was drilled to the depth of 1,000 feet, giving artesian water, and reputed to have brine at the bottom, with the following imperfect record, which is ambiguous in some of its parts:

Record of the deep well at Minneopa falls, near Mankato.

- | | | |
|----|--|-----------|
| 1. | "Loose soil, sand and gravel," about..... | 100 feet. |
| 2. | "Blue slate," probably a shale of the "Mendota" horizon,
about..... | 10 feet. |
| 3. | "White sandstone," about..... | 35 feet. |
| 4. | "Red stone, clay-like," about | 20 feet. |
| 5. | "Bluish slate, white when dry," about | 100 feet. |
| 6. | "Pink sand," about | 10 feet. |
| 7. | "More white sand," about..... | 100 feet. |

Then comes the quartzite, which was struck at 585 feet.

[No samples of these strata above the quartzite were seen by the writer, but the description is such as was given by the gentleman (Fox) who was last in charge of the well. This record seems defective, since among the drillings preserved, of which samples are deposited at the University, is a magnesian limestone at the depth of 117 feet, and other samples as detailed below.]

- | | | |
|----|---|----------|
| 8. | Magnesian limestone, some of it being pinkish and easily effervescing, and other parts being specked with greensand, like that seen at the quarries at Judson,* a few miles northwest from this place. Said to be the first rock struck—117 feet below the surface. The pipe is driven down to this. Thickness..... | unknown. |
| 9. | Whatever the succession of parts above, there is a substantial accord in all the evidence that a red quartzite and pebbly conglomerate was struck at 585 feet. Prof. Bechdolt is of the | |

* Final report, Vol. I, p. 425.

opinion that the whole of this was conglomeritic. This is the New Ulm rock, the "Baraboo quartzite," the Huronian quartzite of Wisconsin, the Wausaugoning quartzite of Pigeon point, the Pewabic quartzite of the Giants' range, the Pokegama quartzite of the upper Mississippi, the Thessalon quartzite of the original Huronian in Canada, the Potsdam quartzite of the Adirondack region, the "granular quartz" of the Green mountains, and the "red sandrock" of the Champlain valley, and probably the Braintree quartzite of Massachusetts. There is a remarkably uniform lithology and constancy of general stratigraphic relations that attend this great quartzite from Minnesota to New England. In New England it has given fossils that fix it in the primordial zone, and the same have been found in it at Pipestone in Minnesota, about..... 200 feet.

10. Below this quartzite and conglomerate was found a grayish hard rock which in the drillings is fine and nearly black. These drillings contain magnetite in considerable amount, which when examined for titanium show the rock is not titanitic, and hence that the stratum is probably not the equivalent of the gabbro of northeastern Minnesota, as it was first suspected of being. It is on the other hand likely some part of the dark slates of the Animike which often contain non-titanitic magnetite.* Under the microscope this proves to be a highly quartzose fragmental rock, about..... 60 feet.
11. Associated intimately with this, and not distinguished from it by the drillers, is a light reddish soft rock, the drillings of both sorts appearing in the same collection, and both being said to have been "first below the quartzite." This reddish rock soils the fingers, but some of it is harder and will not crush easily. Parts of it are kaolinic, even white, and it also contains some crystals of calcite which show rapid effervescence. A few of the grains put into hydrochloric acid soon form a jelly, showing the probable presence of some zeolitic mineral, perhaps laumontite. The general aspect of this soft red rock, which also contains some fragments of hard red felsyte, is the same as that of the "ash-bed conglomerates," and laumontitic amygdaloids of the Cupriferous of the northern part of the state.
12. Below this the drill entered a compact red felsyte, the drillings from which, while showing some of the soft red rock described above, also become sub-granular and phanero-crystalline, the separated minerals being apparently orthoclase and a greenish foliated mineral like some chlorite. In this the work stopped at the depth of one thousand feet.†

* Compare the sixteenth annual report.

† Subsequently the official record of this well was furnished by Mr. S. R. Patterson, of Hartford City, Ind. But this is confirmed by no samples of the drillings. It fills up some of the gaps of the other record, and confirms the depth reported for the red quartzite, here

The record of this well seems to indicate that the Cupriferous formation lies below not only the Potsdam quartzite, or some portion of it, but also below some portion of the Animike, at least below some beds which are identifiable with the magnetic, fine quartzites of the Animike. This brings up various important stratigraphic problems which have been studied in the northern part of the state, but their consideration cannot be entered on here.

The deep well at Stillwater. The well at Stillwater was drilled, not with direct reference to seeking burning-gas, but, while the prevalent agitation on that subject probably prompted the undertaking, several citizens united in an effort to ascertain thoroughly the nature of the rocks that might lie below the city to the depth of two or three thousand feet. The well is 5 5-8 inches in diameter. It is situated on block 21, of the original town, about 40 rods west from the City Hall. In the following record the figures show the bottom of the respective strata, but the samples are from the top of the same, having been collected when the several changes first took place. The pipe rests on the stratum represented by the sample got at 701 feet. The hole is dry, nearly, below this pipe, except that by seepage a small quantity of brine enters the well. After stopping eight days there was found in the bottom about eight feet of such brine. This is on the authority of Mr. John McKusick. Some of this was preserved and on being examined by Mr. Sidener at the University laboratory was found to embrace some bromine, this test being made to ascertain its alliance with natural rather than artificial salt water.

styled "conglomerated granite." The red slate of this record (No. 11) is the same as No. 11 of the record above. But No. 12, the "dark blue granite," is the same as No. 10, the actual order of succession being more likely that of this record.

1. Soil.....	10 feet.
2. Quicksand and gravel.....	78 feet.
3. Soft sandstone	28 feet.
4. Red rock.....	10 feet.
5. Sandstone.....	100 feet.
6. Slate.....	100 feet.
7. Sand rock.....	100 feet.
8. Green slate.....	70 feet..
9. Soft sand or water rock.....	84 feet.
10. Conglomerated granite.....	150 feet.
11. Red slate.....	100 feet.
12. Dark blue granite.....	75 feet.
13. Red slate.....	25 feet.
14. Red granite.....	70-95 feet..

Record of the Stillwater well.

	Taken at
1. Rusted, coarse quartz sand, rounded.....	18 feet.
2. Gray siliceous shale, or "slate.".....	103 feet.
3. White sand, with some yellowish shale.....	142 feet.
4. Fine white sand, giving first water.....	162 feet.
5. Green shale.....	203 feet.
6. Fine white sand, with globules of pyrites.....	215 feet.
7. Green shale or sand, mingled with some white sand.....	271 feet
8. White sand with some specks of green sand; water in large volume.....	302 feet.
9. Mainly white sand, having a grayish aspect.....	312 feet.
10. Quartz sand, with some gray grains, all rounded.....	322 feet.
11. Rounded white sand, with some gray grains and some pyrites...	349 feet.
12. Gray shale, slightly greenish.....	380 feet.
13. Whitish sand, but specked with pink, gray and some yellowish quartz, and occasionally a red orthoclase fragment.....	450 feet.
14. White sand, rounded.....	460 feet.
15. A greenish-whitish, compact, kaolinic shale or clay, with a con- siderable amount of rounded quartz sand, the last probably mixed in the clay by the drilling process.....	540 feet.
16. Coarse, yellowish-white quartz sand, almost pebbly.....	630 feet.
17. The same. Here the water all ran out.....	680 feet.
18. Red slate, or shale, with white kaolinic grains.....	701 feet.
19. White sand (quartz) mingled with reddish grains and with red shale pieces.....	706 feet.
20. Red clay (shale), unwashed, hardened in drying.....	717 feet.
21. Dark-red or brown feldspathic sandstone.....	796 feet.
22. Dark-red or brown feldspathic sandrock.....	892 feet.
23. Somewhat darker, otherwise the same as the last.....	923 feet.
24. Same as the last.....	952 feet.
25. Same as the last.....	2250 feet.

At the time this depth was reached (Dec. 6, 1888), there was a temporary suspension of work, but it was resumed again subsequently, the record being reported at 2,570 feet to be still the same as at 2,250 feet. This gradually became more kaolinic-feldspathic and trappose, also amygdaloidal and calcitic, and at 3,300 feet was succeeded by diabase and a succession of beds characteristic of the Keweenaw to 3,400 feet.

This red, or brownish rock (No. 25), is quite a different rock from the red kaolinic rock described in the Minneopa well, and lies much higher in the strata. This is the Fond du Lac and Ashland brown sandstones, well known as a building material, with the interstratified shales, a section of which on the St. Louis river has been taken with care and published in the tenth report of the survey.* There seems to be in this well an alternating graduation

* Tenth report p. 30. The full thickness is not represented in this section.

from the light-colored sandstones to this feldspathic and reddish formation, indicating a chronological downward order unbroken by any important omission of strata, or unconformity. This agrees with observations in other places, and in some other wells; and if the "ash-bed" reddish rock described in the Minneopa well be correctly placed in the strata above the Animike, or within the Animike, there must be between this "red rock" and that of the Minneopa well, not only the red quartzite but also the gabbro horizon. The gabbro sheet, therefore, if it extended to Stillwater, would be the first of the crystalline rocks that might be expected in further prosecution of that well. Below that would come, in regular order, the New Ulm quartzite; then the Animike black slates with their magnetite and felsyte.*

The deep well at Moorhead. All information respecting this well was obtained through the courtesy of Mr. Sam. Partridge, of Moorhead. He has furnished a complete set of the drillings, and some notes that were made as the work progressed, by Mr. Andrew Holes. These notes are included at proper places, in the following record, which is made up from the drillings sent. The contract was executed by Gray Brothers, of Jamestown, Dakota. The well is located at centre of 7th street, north of Front street. Contractors began with a 14 in. hole, for 100 feet. Water was struck at 120 feet, which rose to near the top. Owing to losing the drill at about 174 feet in quicksand, and being unable to raise it, the contractors commenced at another point about 30 feet north of the first hole. A boulder was struck at 150 feet, and another at 170 feet, in gravel; broken by blasting.

	Thickness.	Depth of Well.
1. Black soil.....	2 feet.	2 feet.
2. Yellow loam, or clay.....	3 feet.	5 feet.
3. Yellow clay — lacustrine or alluvial; brick clay.....	50 feet.	55 feet.
4. Very fine, lacustrine blue clay, with occasionally a pebble.....	55 feet.	110 feet.
5. Drift gravel, with some clay, blue	5 feet.	115 feet.
6. Drift gravel, much limestone.....	10 feet.	125 feet.
7. Coarse drift gravel, much limestone.....	10 feet.	135 feet.
8. Drift gravel and sand, somewhat clayey; blue.....	10 feet.	145 feet.
9. Sandy and gravelly clay, blue.....	10 feet.	155 feet.
10. Sandy clay, blue.....	10 feet.	165 feet.

* At a depth of 3,500 feet (May, 1889) the drillings indicate that the drill has entered gabbro, though of rather finer grain than most of that which appears in the hills of the Mesabi range, north and east of Duluth.

11. Sandy clay, blue.....	20 feet.	185 feet.
12. Gravelly and sandy clay, blue; with flakes of metallic iron, probably from the drill.....	10 feet.	195 feet.
13. Boulder; hard gray gneiss, mostly feldspar and quartz, fine-grained, the sparse mica being silvery and like hydromica, evidently a metamorphic rock, striped with sedimentary variations, some of the feldspar pinkish; broken by dynamite	5 feet.	200 feet.
14. Boulder; quartzose, gray, evidently fragmental, very hard, in a talcose or sericitic matrix, and with veins of the same.....	20 feet.	220 feet.
15. Bluish, sandy clay	20 feet.	240 feet.
16. Bluish, sandy clay.....	60 feet.	300 feet.
17. Quicksand.....	45 feet.	345 feet.
18. Quicksand, with some clay.....	15 feet.	360 feet.
19. Green shale or clay; the drillings contain some grit; evidently the commencement of the green granitoid rock	15 feet.?	375 feet.
20. No drillings sent.....	15 feet.	390 feet.
21. Soft, reddish, feldspathic chlorite-granite, or gneiss..	10 feet.	400 feet.
22. No drillings sent.....	40 feet.	440 feet.
23. Soft, reddish, feldspathic chlorite-granite, or gneiss ..	35 feet.	475 feet.
24. Soft, reddish, feldspathic chlorite-granite, or gneiss...	125 feet.	600 feet.
25. Soft, reddish, feldspathic chlorite-granite, or gneiss...	35 feet.	635 feet.
[NOTE.—The rock from 375 feet to 635 feet is said to vary from "blue" (green?) to red, or brown, and <i>vice versa</i> , every 20 or 30 feet, indicating a gneissoid rock.		
26. Same as the last.....	110 feet.	745 feet.
27. The same, but varying toward the rock like the boulder described above at the depth of 200 feet.....	20 feet.	765 feet.
28. Same as the last, but more green from chlorite.....	35 feet.	800 feet.
29. Same as the last.....	100 feet.	900 feet.
30. The same.....	100 feet.	1000 feet.
31. The same; but the drillings present a different aspect, and are so fine that only with difficulty can the ingredients be made out. The feldspar and quartz are not perfectly differentiated	10 feet.	1010 feet.
32. The same as the last, but coarser. It is evident from this that the rock is an imperfectly crystalline granitoid rock, the outlines of the quartz and feldspar not being defined, but blending together, as if a finely granular felsyte, with some cloudings due to impurities. The impurities cannot be easily defined mineralogically, as they also fade out in the mass, but are perhaps micaceous or chloritic	40 feet.	1050 feet.
33. The same, but darker colored; the feldspathic ingredient is frequently pink.....	15 feet.	1065 feet.
34. The same; fine drillings	25 feet.	1090 feet.
35. The same; fine drillings.....	30 feet.	1120 feet.

36. Soft, greenish, but finely red-mottled, flaky felyte(?); texture and grain like the last. This is so fissile and so dark colored that it has a very different aspect from the last. The partings are glistening as if slickensided and chloritic. It is associated with some of the eruptives, but its characters do not identify it certainly with any known horizon... 75 feet. 1195 feet.
37. The same, with some calcite and some white feldspar(?)..... 10 feet. 1205 feet.

The Moorhead well shows that there the drift rests on crystalline rocks of a peculiar gneissoid kind.

[Note. As the Moorhead well is being drilled at public cost, the writer deemed it proper to remonstrate against further expense, and communicated at once with the mayor through Mr. Sam. Partridge. In a few days the *Moorhead News* contained the following, giving correctly the recommendation written to the mayor:

Mr. Sam. Partridge this morning received a communication dated May 8, from Prof. N. H. Winchell, state geologist, addressed within to the mayor of Moorhead, stating that he had just examined the samples of drillings taken from the Moorhead artesian well which were sent to him a short time ago, and expressing regret that he had not before been able to obtain samples, "because," said he, "I could at once have told you that there was no earthly use of your going to further expense on the well. You ought to have stopped when the drill struck the rock at the depth of 390 feet, the rock being granitic and of that sort which forbids any hope of obtaining artesian water or other product of value."

Soon thereafter further drillings were sent by Mr. Partridge, and by other gentlemen, asking re-examination, on the ground that, "having gone so far it was heart-rending to give it up now." The lower drillings did not afford any reason to change the opinion before reported.

Still the drill was continued, and the newspapers of Fargo (*Argus*) spurred it on with such comments as follows:

Mayor Hansen, of Moorhead, says they intend to continue sinking the artesian well, in spite of professor Winchell's prognostications. And in this the whole Red River valley says — "good for Hansen." There is no geological or other prescience that can guess dead sure on Red River valley matters. Success is what is wanted, and Hansen shows true grit.

When the Findlay, Ohio, people were first boring for gas, the state geologist delivered a lecture there in which he said it was useless to bore in such a formation, as they would never find gas. But they kept right on and struck a gas

well — before the state geologist got away from town. And now Findlay has the biggest gas display in the world. With all due respect to Mr. Winchell, state geologist of Minnesota, why not let Moorhead do the same?

A second letter from Mr. Partridge, accompanied by drillings down to 1,425 feet, states that a remarkable change occurred after the last drillings before were sent, viz.: *A bed of quick-sand had been found near the bottom of the well, from which water quickly rose to near the top of the ground*, and that the interested parties felt greatly encouraged to proceed.

On examining the samples from this lower depth, they are found to be as follows, when thoroughly washed:

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|-----|---|-----------|------------|
| 38. | Mainly water-worn sand, but embracing also films of iron rust, scales of slag from some furnace, or fire-box where coal was burned, angular bright pieces of soft coal which burns readily in a flame, and some seeds which look fresh enough to sprout. These have been planted in order to ascertain, if possible, what sort of angiospermous vegetation lived at the age of the Moorhead granite and has so singularly preserved not only its form but its farinaceous store of food so long. There are also in this some granite drillings. This sample was sent in the condition of a hardened clayey lump, but on washing away the finer parts these ingredients appear. It is probably from this that rose the supply of water which came to near the surface,— though it is a reasonable query as to how it was distinguished from that which was struck at 120 feet and which rose then to near the top..... | 15 feet. | 1265 feet. |
| 39. | Mixed granitic rock; some rounded material, including pebbles of weathered limestone that effervesce in hydrochloric acid; also scales of iron matter from some clinkers from coal burnt in a furnace or other fire-box..... | 15 feet. | 1280 feet. |
| 40. | The drillings are mainly of a light-colored but chloritic granite, quite rusty with scales of iron from the drill, and others from some other source as remarkable as those mentioned above..... | 45 feet. | 1325 feet. |
| 41. | Drillings mostly of white feldspar and quartz, but also with evident, fresh chlorite-films..... | 100 feet. | 1425 feet. |

It is scarcely necessary to comment on these drillings. They demonstrate, to any geologist, not only the position of the bottom of the well, and the futility of further expense, but also the probably intentional tampering with the record, by which it was hoped the enterprise would be pushed further.

According to the latest accounts the mayor of Moorhead is still drilling in this granite. May 26, 1889.]

The Duluth deep well.

The drillings of this well, as furnished by Messrs. Gridley, Mishler and others, were procured and sent to the survey by Wm. F. Phelps, Esq., secretary of the Duluth chamber of commerce. They are well washed and carefully preserved in glass bottles and numbered so as to show the different depths from which they came. After the well had been sunk about 231 feet the enterprise changed hands. Previous to 231 feet no record was kept, nor drillings preserved. The well is located at Short Line Park, near Duluth, which is a short distance west of the head of lake Superior, but within the general valley of the St. Louis river. The mineral water met with in this well was analyzed by Prof. Dodge, of the university of Minnesota, and the result of the analysis is given below. It seems to be very similar to the brine met with in the Stillwater and Hastings wells.

Record.	Thickness.	Depth of Well.
1. Earth	100 feet.	100 feet.
2. Rock (?) no drillings preserved.....	131 feet.	231 feet.
3. Brownish-red, finely granular, homogeneous, with little free silica, apparently of the copper series.....	12 feet.	243 feet.
4. Gray epidotic, finely granular gabbro.....	33 feet.	276 feet.
5. No drillings.....	104 feet.	280 feet.
6. The same as No. 4.....	37 feet.	417 feet.
7. The same as No. 4.....	31 feet.	448 feet.
8. Apparently the same, but finer-grained, approaching diabase.....	15 feet.	463 feet.
9. Essentially quartzose, but the drillings contain also evidently feldspathic (labradoritic) fragments; the grains vary from limpid quartz to gray or pink or purplish; some of the larger are composed of grit, the included grains being rounded.....	5 feet.	468 feet.
10. The same as the last, pyritiferous, a quartz conglomerate.....	5 feet.	473 feet.
11. Drillings gray, pulverulent; rock very fine-grained, aphanitic, apparently soft.....	17 feet.	490 feet.
12. Drillings brown, with green grains of epidote (?) white grains of calcite and quartz and red grains of orthoclastic material. The needle does not pick out grains that are plainly of magnetite, but scales of rusted metallic iron, derived from the drill. This iron is found also in all the foregoing. The rock is not typical gabbro, but represents one of its modifications. It is rather fine-grained.....	16 feet.	506 feet.

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|---|-----------|------------|
| 13. This rock is essentially a brown felsyte perhaps a conglomerate, some parts being finely granitic in grain. It is also apparently fragmental, and also resembles some of the coarser, pseud-amygdaloidal beds of the Cupriferous seen along the lake Superior shore further east..... | 2 feet. | 508 feet. |
| 14. Evidently a conglomerate that contains principally brown felsyte; also brown shale, and white and gray quartz and granular quartzite. The shale is perhaps the matrix, and has mainly disappeared in the process of drilling and washing the drillings. It is slightly pyritiferous, and epidotic..... | 3 feet. | 511 feet. |
| 15. Pink and gray, quartzose conglomerate, and granular quartzite, pyritiferous..... | 2 feet. | 513 feet. |
| 16. The drillings are principally granular white or limpid quartz in small, angular grains. The cement seems to have been of the same material in finer grains..... | 1 foot. | 514 feet. |
| 17. Same as the last, evidently a white, granular quartzite..... | 2 feet. | 516 feet. |
| 18. The same, but showing gray also..... | 4 feet. | 520 feet. |
| 19. The same, but more gray, also pink..... | 4 feet. | 524 feet. |
| 20. The same..... | 4 feet. | 528 feet. |
| 21. Drillings dark-gray, pulverulent; similar to No. 11 above..... | 2 feet. | 530 feet. |
| 22. Trap-rock, epidotic diabase, some fragments brown; drillings fine, generally of a gray color..... | 24 feet. | 554 feet. |
| 23. Gray, diabasic traprock, epidotic and apparently amygdaloidal..... | 20 feet. | 574 feet. |
| 24. The same; some fragments being brownish..... | 16 feet. | 590 feet. |
| 25. Drillings very fine, but apparently the same as the last..... | 8 feet. | 598 feet. |
| 26. Brown-gray diabasic rock, rather coarse-grained..... | 15 feet. | 613 feet. |
| 27. Drillings are of two sorts, (a) brown granito-felsitic, and (b) gray, fine-grained and traplike; some of the latter appearing to be porous or amygdaloidal or fragmental..... | 6 feet. | 619 feet. |
| 28. "Black slate" or argillyte, aphanitic and purplish-gray, occasionally embracing fragments of coarser grit-rock as well as of light-grain softer slate or schist. This black slate has a slaty cleavage, but it can not be determined whether coincident with a sedimentary bedding or not, although it appears to be independent of such a structure; evidently the Thompson slate formation..... | 61 feet. | 680 feet. |
| 29. The same as the last; with some drillings of white vein-quartz..... | 200 feet. | 880 feet. |
| 30. The same, but having a greenish tinge apparent, and being some softer..... | 200 feet. | 1080 feet. |

31. No drillings.....	90 feet.	1170 feet.
32. The same as No. 28.....	5 feet.	1175 feet.
33. The same as No. 30.....	60 feet.	1235 feet.
34. Essentially the same rock, but apparently not so slaty, with vein quartz.....	105 feet.	1340 feet.
35. The same, rather light gray.....	30 feet.	1370 feet.
36. Gray slate, slightly pyritiferous; evident slaty cleavage.....	5 feet.	1375 feet.
37. The same as the last.....	25 feet.	1400 feet.
38. Drillings are of two kinds, (1) dark gray slate (?) like the last, and (2) a lighter rock, apparently hydro-micaceous slate.....	35 feet.	1435 feet.
39. Drillings very fine and of a light yellowish color. Thorough washing leaves a residue of fine quartz grains mainly; but this does not indicate the general character of the rock, as the matrix of these grains is evidently lost by the washing. These grains are mainly white, sometimes glassy, but of various shapes and sizes. They can not be said to be waterworn, and are themselves minutely granular when magnified about 40 diameters. Mingled sparsely with the white and glassy grains are also a few that are purplish, or gray, and also some of a loose, hypermicaceous schist. The general yellow-rusty color is caused probably by the oxidation of iron scales derived from the drill. These scales pervade all these drillings.....	2 feet.	1437 feet.
40. The same as the last.....	8 feet.	1445 feet.
41. The same as the last. In this can be seen, under the microscope, some fragments of a rock that appears to be a kaolinic itacolomyte, and it is not unlikely that they are from the rock that furnishes these quartzose washings.....	3 feet.	1448 feet.
42. The same as the last, but also contains some drillings like the next.....	2 feet.	1450 feet.
43. Gray compact, very fine-grained, crypto-crystalline or fragmental, diabasic (?) rock.....	2 feet.	1452 feet.
44. Same as the last, but also contains some gray slate..	2 feet.	1454 feet.
45. Same as No. 43.....	1 foot.	1455 feet.
46. The same fine-grained gray rock predominates; under the microscope it appears to consist of fine glittering grains resembling quartz.....	1 foot.	1456 feet.
47. Same as the last, but more evidently a fragmental gray quartzyte.....	1 foot.	1457 feet.
48. The same, but somewhat lighter-colored.....	10 feet.	1467 feet.
49. Same as the last.....	10 feet.	1477 feet.
50. Gray quartz ^y te, very fine, same as No. 46.....	10 feet.	1487 feet.
51. The same.....	8 feet.	1495 feet.

52. The same, but some grains are apparently from a somewhat cleavable rock, though not argillitic..... 5 feet. 1500 feet.
53. The same gray rock, evidently slaty and finer-grained..... 7½ feet. 1507½ feet.

Summary of the Duluth well.

It appears from the above record that the Duluth well passed through 131 feet of drift materials. It encountered the fragmental rocks of the Cupriferos and found 112 ft. of characteristic strata. It then entered gabbro at 243 ft. which was found to be 220 feet in thickness, extending to 463 feet. Then came a hard red and purplish quartzite. This is interbedded with imperfectly characterized gabbro, with conglomerates consisting largely of brown felsyte pebbles, and with soft, indeterminable rock the drillings of which are very fine or pulverulent, of a dark gray color; the thickness of all the layers (67 ft.) carrying the well down to 530 feet. At the depth of 530 ft. the well entered trap-rock. As this is below the foregoing gabbro it introduces a new element in the stratigraphy of the Cupriferos, the gabbro having been regarded as the lowest of the Cupriferos. This trap, with its associated amygdaloidal beds, some known felsytes (some of them granitic), and fragmental tuffs, continued to the depth of 619 feet, a thickness of 89 feet, when the black slates of the Animike were struck. These slates, with the gray quartzites, and occasional diabasic rocks connected with them, have continued thence to the bottom of the well at 1507½ feet. In this formation, at the depth of 1225 feet the operators report the discovery of the mineral water referred to below. But it is quite likely that it was in the drill-hole all the time after passing the Cupriferos formation. Such water was found in the Stillwater well and also in that at Hastings in the Cupriferos, but the mineral contents of that at Duluth are not only more varied but also in far greater amount. Following is the analyses of both. The report of the Duluth analysis was furnished with the drillings, and that from Hastings was analyzed in 1881 at the request of Prof. C. W. Hall.

Analysis of water from the Duluth deep well.

An analysis of water taken from the gas well at Short Line Park, near Duluth, made by professor James A. Dodge, of the State University of Minnesota, at the request of Dr. D. A. Strickler, of Duluth, Minn.

	Part per million.	Grains per gallon, U.S.
Siliceous matter.....	200.9	11.718
Carbonate of iron.....	44.6	2.601
Sulphate of magnesia.....	2.0	.117
Chloride of magnesium.....	503.0	29.340
Chloride of calcium.....	16,847.0	982.685
Chloride of sodium.....	15,070.0	879.046
Chloride of potassium.....	500.0	29.165
Bromide of sodium.....	430.0	25.069
Lithium salts.....	traces.	traces.
Total mineral matter.....	33,597.5	1,959.741
Free ammonia.....		.93
Albuminoid ammonia.....		.40

Analysis of the water from the flowing well at Hastings, reported by Prof. Dodge.

The following gives the character of the solid residue from the water. Compare Vol. II, of the final report (Dakota county) for an account of this well:

	Grains per gallon.
Silica.....	.62
Carb. lime.....	9.29
" iron.....	.17
Sulph. mag.....	5.84
Chl. mag.....	1.82
Chl. potass.....	1.15
Chl. sod.....	26.15
Total solid matter.....	45.04

The deep well at Faribault. The record of this well could not be obtained. No drillings were preserved. It was reported to be 520 feet in depth, "with signs of gas and anthracite coal."

The deep well near the State Fair grounds, between St. Paul and Minneapolis, in which also the "expert" from Pennsylvania predicted and subsequently "discovered" burning gas, is said to be 500 feet deep. Of this well the record could not be obtained.

The well in North St. Paul, in like manner can not be reported, since the record is unknown.

The deep well in South St Paul, drilled by the same parties as the last two, under the instigation and advice of the Pennsylvania "expert," will also go to posterity with no record except as a monument to the infatuation which can be inspired by the positive assertions of a wanton adventurer in the minds of men ignorant of geology but eager for wealth.

In the matter of the drilling of these four wells last mentioned,

all of which have now been abandoned, the advice of the writer was sought, and he unhesitatingly recommended that no money be spent in a search for gas. This opinion was based on the geological structure of this part of the state and the known geological relations of the gas-flowing wells of other states.

CONCLUSIONS.

The experience which has resulted from the efforts to find natural burning-gas in Minnesota, as above detailed, gives rise to some reflections and conclusions which it will be well to gather into a final statement.

1. There is a body of geological truth that to the geologist is as inflexible as any natural law, and as sure as any deduction from observed facts. This truth is accepted by all geologists, without exception. When any economic research or any scientific question is presented for solution it must first be compared with these known laws of geology. If it violates none of them the geologist gives his answer accordingly, for these truths are not fluctuating. His answer must be in accord with the facts, and the evidence so far as it exists. If the problem involves elements which lie beyond the scope of the facts in hand, or which are not covered by any established law of the science, his answer must necessarily be *that he does not know*. He may, however, go beyond a statement of ignorance. He may collate the evidence favorable or unfavorable bearing on a hypothetical answer.

2. It is in the realm of this uncertainty that lie most of the problems that the geologist has to answer; and it is here that he sometimes makes the mistake of giving a conclusive answer when he should give a conditional one. A similar mistake is made by some scholastics and so-called philosophers in estimating the value of geological evidence in general. This error is due to a confounding of geological science with geological hypothesis. There is no limit to geological hypothesis, and any bungler or itinerant "expert" may indulge in it; but there is a distinct boundary to the body of truth known as geological science. Sometimes the popular estimate is based on the shifting arena of hypothesis, and geology is charged with being a mass of speculation and contradiction, liable to vary from year to year. The practical geologist, in answering economic problems, has to discriminate rigidly between science and hypothesis, and to adhere unflinchingly to the guidance of science.

3. If under the guidance of science, the geologist states that

neither the Trenton limestone nor the Coal Measures can be found by drilling in a region where the surface rock is the St. Peter sandstone or the Shakopee limestone, he is justified by one of the laws of his science. If further he be asked if there be gas beneath the St. Peter sandstone, his "body of truth" does not give an infallible guide and will not answer positively. It will only answer conditionally. The geologist here can only appeal to such evidence as exists, and can answer, after weighing it *pro* and *con*, by a statement of probability on the side of the preponderance of evidence.

4. It requires but a brief examination of the reports that have been published of the geology of the state to learn that the great formations that furnish gas in the United States are almost wholly wanting in Minnesota; the Trenton only being found in such situation as to give a reason for exploration.

5. The results of all wells that have been sunk in the state, with a primary or remote idea of discovering gas, have confirmed this statement, and have coincided, except in minor matters of detail, with the conclusions that have been expressed and with the published geological maps and reports of the survey.

6. The facts stated in the reports, therefore, may be considered as belonging to the "body of truth" of the science, and can be relied on for future guidance so far as they bear on this economic question.

7. The drilled well at Freeborn has passed through the Trenton limestone, and hence through the lowest known formation that supplies burning gas; and if gas exists, as asserted by the superintendent, in the St. Peter sandstone that lies below the Trenton and is now only repressed by the surrounding and overlying volume of water, it will be, if demonstrated by the efforts that are now being made, a great discovery in the geological environments of the gas problem. It may, hence, become as important as the original discovery of gas in the Trenton limestone at Findlay, and thus add another formation to the list of gas producers.

7. This, however, will require an actual demonstration to be admitted into the "body of truth" of geological science, since the science at present, so far as it has any evidence, pronounces with a strong preponderance of weight against it.

8. So far as the science affords any evidence in favor of gas below the Trenton limestone in Minnesota, it may be summed up about as follows, applying it to the region of Freeborn: There is, perhaps, one chance in ten that the formation which is known

in the northern part of the state as *Animike slates and quartzites*, underlies the county of Freeborn at the depth of about 3,000 feet. In case it were found at that depth there might be, perhaps, one chance in one hundred that it would contain some gas, and one in a thousand that it would afford enough for economic purposes.

THE ACTUALITY AND POSSIBLE SOURCE OF THE GAS AT FREEBORN.

The fact still remains that natural burning-gas is found at Freeborn. It rises from a sandy layer in the drift, about seventy-five feet below the surface, and burns freely and even violently when gathered in pipes and ignited. As the drill passed through no Cretaceous strata their presence in the vicinity is rendered more questionable, but still not negatived. As the drill penetrated no vegetable deposit known elsewhere as the "forest bed" its presence is also more questionable. But both these are liable to produce gas, the latter in smaller quantities than the former, and either may exist in the neighborhood and might be struck in case of a drill at some short distance in any direction from the site of the present well. Indeed there is no source for this gas, so far as the writer is aware, except the Cretaceous, or the "forest bed," and he is inclined to refer it as heretofore to the Cretaceous.

The "forest bed" is known to exist in Freeborn county, as well as in Mower, and to extend irregularly and indefinitely southward into northern Iowa. It seems to furnish carbonic acid gas in some wells at Albert Lea, and has been the cause of some trouble in search for good water for domestic use. But it is not invariably the case that carbonic acid is produced by this bed of vegetation. Prof. Orton states that in Ohio a light carburetted hydrogen is struck in the drift deposits much more frequently than carbonic acid.*

On the other hand a well in Vernon, Blue Earth county, which gives a voluminous discharge of carbonic acid gas, owned by C. B. Frazer, is said to have a record which indicates that the gas originates in the Cretaceous. This well passed through a clay, or shale which is apparently of Cretaceous character and age, and at about 115 feet entered sand. The future must determine the source of the gas that escapes at Freeborn, for the evidence seems almost evenly divided between the Cretaceous and the "forest bed."

*Report of the Geological Survey of Ohio, Vol. 41, p. 773.

The latest discovery. According to the *Freeborn County Standard* of June 6th, published at Albert Lea, a new discovery of gas has been made on Sec. 30, Riceland, about six miles northeast from Albert Lea. The gas here escapes from a well bored to the depth of sixty-three feet, and burns with considerable violence, and in quantity sufficient to operate a ten-horse power engine. The characteristics of this well are identical with those of the shallow wells at Freeborn, and they add further probability to the hypothesis that the gas reservoirs of the region are confined to the drift.