THE

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

THE SECOND ANNUAL REPORT.

FOR THE YEAR 1873.

[SECOND EDITION.]

By N. H. WINCHELL, State Geologist,
AND
S. F. PECKHAM, State Chemist.

SUBMITTED TO THE PRESIDENT OF THE UNIVERSITY,
DECEMBER 31, 1873.

MINNEAPOLIS:
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[NOTE—This edition is identical with the original, excepting the correction of typographical errors. As this report was published originally only as a part of the regents' report, it has the paging of that report.—N. H. W.]

ADDRESS.

To the president of the University:

I have the honor to offer the accompanying report on the progress of the geological and natural history survey of the state, for the year 1873. The last Legislature increased the means provided for the prosecution of the survey, by doubling the cash appropriation, making it two thousand dollars annually, and transferred to the board of regents the state lands known as "*salt spring lands*," the proceeds of which they are required to expend exclusively in the prosecution of this work. At the same time the board of regents of the University were required to direct the immediate survey of the peat deposits of the state, and to cause an investigation and report on the salt springs.

While these special investigations have been carried on as far and as thoroughly as possible, the progress of the general survey has also been pushed as far as the means and time would permit.

In general, the field of observations has been, during the season of 1873, in the southwestern part of the state. The valley of the Minnesota, and those of some of its tributaries, have been subjected to a reconnoissance which has served to answer many questions that were important to answer before entering on the detailed county work, and in that manner has also served to prolong, though not yet to complete, the preliminary survey that occupied the short season of 1872. The results of this reconnoissance, both scientific and economical, will be found stated in the proper places in the accompanying report.

The counties of Cottonwood, Jackson and Nobles have been subjected to thorough inspection for peat. Incidental examinations have also been made on peat deposits in the

counties of Dakota, Hennepin, Ramsey, Le Sueur, Nicollet, Faribault and Stearns. Prof. S. F. Peckham, the chemist of the survey, has made the analysis of thirteen specimens. Before his appointment six specimens were also submitted to Dr. P. B. Rose, of Ann Arbor, Michigan, for analysis. The reports of these gentlemen will also be found in the accompanying report, supplemented by remarks on the methods of working peat, and its value as a fuel for general use, and by sundry practical conclusions on the peats of Minnesota.

The question of the existence of Carboniferous coal in Minnesota, has also occupied considerable time during the past season. The frequent statements, positively put forth in the public prints, of the finding of considerable quantities of good coal in the southern and southwestern part of the state, together with the published opinion of Mr. H. H. Eames, reporting to the Legislature in 1866, to the effect that the Carboniferous rocks of the state of Iowa are prolonged northward into Minnesota, and there furnish the "coal" of the Cottonwood and Redwood valleys, induced the attempt to determine, as far as possible, the source of the float coal found, and the real age of the rocks explored for coal in that portion of the state. This question was believed to be paramount to all others bearing on the fuel supply, and although its solution is not entirely accomplished, yet enough has been ascertained to warrant certain practical and important conclusions. The facts on which these conclusions are based, will be found stated in different parts of the following report, and need not be repeated here.

1st. The rocks that have been explored for coal, on the Cottonwood and Redwood rivers, belong to the Cretaceous system, and do not promise to be productive of coal in valuable quantities.

2d. The coal there taken out is of an inferior grade, though varying from cannel coal to charcoal.

3d. As the rocks of the Cretaceous period are believed to have existed throughout the most of the state, the only probable exception being in the southeastern portion, including half a dozen counties, such coal is likely to occur at a great many places.

4th. The "float" coal which has so often attracted the attention of the people, is derived, so far as yet known, from the disruption of the Cretaceous rocks by the glaciers of the ice period. It is scattered through the drift, and

is met with in wells and other excavations, and may be often picked up along the beds of streams.

5th. The only part of the state where good coal-bearing strata of the Carboniferous age may occur, comprises the counties of Mower, Freeborn and Faribault. As these counties are heavily covered with drift, the question can be settled definitely only by drilling or shafting to the rock. Should Carboniferous rocks be met in Faribault county, there would also be some reason for exploring for the same in the southeastern portion of Blue Earth county.

In regard to the investigation of the salt springs, nothing further has been done than to ascertain their history, and the present condition of the United States land grant. It has been found that the original grant covered 46,080 acres. Of this the state was unable to avail itself of 11,520 acres, that amount being situated outside of the area surveyed by the U. S. government. The springs, however, lying outside of the surveyed portions of the state, were carefully located by metes and bounds, and at the order of governor Sibley the request was entered at the Land Department at Washington that the lands appertaining to each spring so located, also those lying within the surveyed portions, claimed by the State under the act of Congress admitting the State into the Union, be withheld from sale and occupancy. They have not been so withheld, and those lands have not been certified to the State. This fact reduced the original available grant to 34,560 acres. It has been further reduced by the occupancy by settlers, 6,752 acres. About 1,600 acres were also previously covered by the terms of the act granting swamp lands to the State. The remainder, 26,435 acres, have been certified to the State. The Belle Plaine salt company were granted 7,643 acres of the certified salt spring lands, on complying with the acts of the Legislature. The rest of the certified lands, amounting to 18,771 acres, are now available for the prosecution of the survey. The uncertified portion of the original grant, aggregating 19,872 acres, inasmuch as the whole was properly selected and located within the terms of the "enabling act," should be the subject of a memorial to Congress, as suggested by auditor McIlrath, in his report for 1871. It is believed that the U. S. government would gladly make up, by an additional grant, the deficiency that has resulted in great loss to the State, through the neglect or inadvertence of its own officers.

The traveling expenses have been materially reduced

during the past season by the courtesy of the officers of the following railroads, who have granted me continuous passes over their roads, viz: the St. Paul and Sioux City, and Sioux City and St. Paul; the Southern Minnesota; the Northern Pacific, and the St. Paul and Pacific.

Dr. I. A. Lapham, director of the geological survey of Wisconsin, has furnished a catalogue of the plants of Minnesota, made up from various sources, including his own observations, and known to be growing in the state at the date of 1865. The reputation of Dr. Lapham for scientific accuracy, not only increases the value of this gift, but makes it highly desirable that its publication be not delayed. Although not strictly of a geological character, yet it comes within the scope of the survey and is herewith presented.

A great many individuals have aided in the prosecution of the survey during the past season. Of these, I can name Prof. Ira Moore, of St. Cloud, who has also donated to the university museum a number of interesting fossils and minerals from various localities; W. Z. Haight, of Delevan, who has taken great interest in the peat investigations, and has furnished much information on the manufacture of peat in Faribault county; Gov. Stephen Miller, of Windom; I. J. Rochussen, of St. Paul; Park Worden, of Minnesota Falls; Henry Hill and A. J. Luce, of Granite Falls, and Capt. H. H. Herrick, of DeGraff, Dak. Ter. I am also under many obligations to the citizens of Cottonwood, Nobles and Jackson counties, for assistance in making the peat survey in those counties.

In the examination of the Minnesota valley I was accompanied as far as to Mankato, and thence up the Blue Earth to Wells, by Mr. P. P. Furber, a student in the university. From Mankato to the head of Big Stone lake, Mr. C. E. Chatfield, also a student in the university was my only companion. The assistance of these young men contributed greatly to the thoroughness and success of the exploration of that valley. We depended on the scattered inhabitants for sustenance, and traveled with a single horse and light, covered wagon. At night we usually slept in our tent, camping near some farmer of whom we obtained meals.

Very respectfully,

N. H. WINCHELL.

THE UNIVERSITY OF MINNESOTA,
Minneapolis, Dec. 31, 1873.

I.

THE BELLE PLAINE SALT WELL.

(a) *General section of the well.*

The report on the Belle Plaine salt well, which was printed by order of the senate, in Jan. 1872 [Ex. Docs. of Minn. for 1872, vol. I. p. 44] covered only that part of the drill above 210 feet, and pertained only to the drift materials, or to the deposits overlying the Silurian rocks. There are some reasons for believing a portion of the loose materials passed through in that distance belong to the Cretaceous. It is known that some portions of that formation consist of loose materials, and they may be mistaken for drift, especially in a region where the soft rocks of that age are not known to exist, by workmen who are not exact observers, but are prone to classify the rocks they happen to encounter according to their visible characters and the ease with which they are penetrated. The occurrence of occasional vegetable fragments is further evidence of the preglacial age of those materials. Since that report was made the well has been sunk to the depth of 710 feet.

The section of the well is thus described by Mr. P. M. Barker, who superintended the work:

Surface and drift	216 feet
Potsdam sandrock	16 "
Ochreous shale	10 "
Soapstone, variegated and mottled	40 "
Semi-igneous formation	108 "
Red shale or marl	6 "
Igneous formation	314 "
Total depth of well	710 "

(b) *Notes and letter of A. Winchell.*

In July, 1872, samples of the preserved drillings from depths from 242 feet to 411 feet were forwarded to Prof. A. Winchell, for examination. His notes and accompanying letter to Gov. Austin are as follows:

At depth of 242 ft.—Highly magnesian clays—purple and speckled with white—mostly without siliceous grains. Generally no conclusive evidence for deciding whether drift or in place. On the whole, I think the fragments are from a formation in place. One of them contains a few quartzose grains, and has a decidedly metamorphic look. All the specimens resemble softened porphyries.

368 ft.—A mass of granules or chips, similar to above, but more uniformly red, and less unctuous. All crush under the knife and exhibit a streak lighter than the mineral—sometimes grayish.

380 ft.—Fragments still more like (242-282) but less unctuous. A broken crystal of calcite.

385 ft.—Fragment (nearly a cubic inch) of a rock, composed apparently of reddish clay and a white mineral, like magnesia or kaolin intimately mixed. The white mineral tending in places to veins. The aspect is decidedly that of a rock in place.

390 ft.—Fragments like (380) but with more calcite, and one slightly polished fragment of glassy quartzite.

398 ft.—Almost identical with (390). From the same depth, however, is a lump of adhesive clay, which is evidently produced by grinding up rock like (242-282).

400 ft.—Essentially like (242-282).

405 ft.—Essentially the same—with one fragment of quartz.

409 ft.—Same.

411 ft.—Same.

There is, in addition, a parcel of fragments from some depth not indicated. Their general character is like that of (242-282). It is easy to see that one of them is a brecciated rock composed of fragments of argillaceous character and quite soft. One is unequally cemented by a deposit of calcite.

From an examination of the specimens and the study of everything that has been written which could bear upon the question, I am led to think the rocks now being bored through, belong to the sub-Silurian series—probably equivalent to the quartzite and pipestone outcropping about New Ulm and in Pipestone county, Minnesota. (White, Io. Rep. I, pp. 169, 170; Shumard: Owen's Rep. p. 491.)

LETTER TO GOV. AUSTIN.

Ann Arbor, Mich., 12 Aug., 1872.

Gov. Horace Austin, St. Paul, Minn.,

SIR: Yours of the 24th of July was found awaiting me

on my return from the east, though the case of specimens did not arrive until August 5th, when I was prostrated by an obstinate fever, which has continued for a week. Improving such opportunities as I have had, I have made a pretty thorough physical examination of the specimens and reviewed all that has been published on the question of their identification and their relations to the geology of Belle Plaine, and I would respectfully report as follows:

1. Neither your note nor the accompanying one from Mr. Hooper intimates whether the materials passed through below 200 feet are wholly of the kind sent, or whether these fragments and masses were found mixed with much clay and sand, and even hard pebbles.

I infer, however, from an inspection of the specimens, that they are samples of rocky strata found in place.

At the same time, their uniform softness for 200 feet is very remarkable, and would suggest that the drill is passing through strata which are highly tilted.

2. Mr. Hooper informed me, last year, that at 202 feet shelly rock had been reached, which, at 210 feet, became solid sandstone and constituted a bed-rock. I inferred that this was the Potsdam sandstone, and still think that whatever there was of it, belonged to that formation. Between 210 and 242 feet, I have no information; and it appears that the sandstone, [a lower sandstone than that at St. Paul,] was completely pierced in that interval or less. The old well was, therefore, very near the bottom, or perhaps quite at the bottom of the sandstone. The ancient valley of the Minnesota river, which probably once discharged the waters of a much wider hydrographic basin, was eroded completely to the sub-Silurian rocks.

3. These sub-Silurian rocks are very remarkable. All the samples are agillo-magnesian, mostly fine-grained, unctuous, sometimes lined and frequently speckled with a white mineral like magnesia or kaolin. They present almost no grains of quartz, but sometimes enclose crystals and seams of calcite. The color is reddish and purplish. Viewed without a test for hardness, they look like vitreous porphyry. I am led to think they represent the formation known to outcrop at New Ulm and in Pipestone county. These clays, in fact, are substantially the catlinite or "pipestone" so well known in that county.

4. If these conclusions are correct, there is no hope, either of salt or a well of fresh water, by boring deeper, and not another dollar ought to be expended in this hope.

5. It will be noted that my recommendation in my former report suggested the propriety of boring *only to the bottom of the Potsdam sandstone.* As there intimated, there are certainly many regions in Minnesota, where a well bored to the bottom of this formation, would prove to be artesian. Belle Plaine, as I feared, does not prove to be favorably located. Places situated for borings. at public expense, ought to be intelligently selected, without any regard to the interests of localities, and the State ought not to be committed to unwise expenditures by the precipitate and ill-advised enterprise of smart business places.

Lest this remark, however, should be thought to apply too severely to Belle Plaine, I ought to add that considerable reason existed for boring at that place--though by no means as good reason as many supposed. The fault committed here as in so many other cases, was an attempt to proceed independently of geological knowledge in the beginning, and to call for scientific aid, not so much to guide an important enterprise, as to help it out of difficulty.

Very respectfully,

A. WINCHELL.

(c) *Notes and report of N. H. Winchell.*

In February, 1873, the writer had occasion to further examine this well, under verbal instructions from Gov. Austin. Samples preserved by the owners from below the depth of 411 feet, were found to have the following external characters. The memorandum is here given, as well as the report subsequently made to Gov. Austin, in order to preserve to science the record of the drill, and to complete the history of the exploration:

At 420 ft.—Ferruginous quartzite, with a considerable admixture of light-colored, softer, apparently talcose fragments. The quartzite is hard, and very impure. The talcose fragments are either nearly white or speckled with rusty and black spots. There are also in the drillings pieces of calcite, a soft, greenish substance that may be silicate of iron, and occasional fragments of translucent quartz, either white or slightly tinted with yellow or with green.

At 430 ft.—A mixture of dark brown or reddish silicates, strongly ferruginous, with slight traces of mica and some pieces of calcite. Some of it appears conglomeritic, or tufaceous. It is slightly unctuous in the fingers, and some of it is real iron ore. The light-colored pieces of the last (420 feet) are rarely seen. There are in it occasionally greenish pieces of quartz. It is evidently a metamorphosed sedimentary rock.

At 440 ft.—A ferruginous, unctuous shale, with very little grit. It sometimes is spotted with a white substance about as hard as talc, which has a greasy feel. This white substance seems to be the same as mentioned in the foregoing. It is sometimes minutely disseminated among the ferruginous portions. When then rubbed in the fingers, a rusty or irony stain covers the whole. Some of this is plainly siliceous and micaceous.

At 450 ft.—About the same as at 430 ft. but darker colored and less firm in the fingers. It is plainly micaceous.

At 460 ft.—Dark greenish-brown, micaceous silicates; hard and compact. Not evidently unctuous. No feldspar is discernible.

At 470 ft.—A talcose, furruginous shale, of a reddish-brown color, with occasional pieces of greenish silicates. In this lot there are also several pieces of evident flesh-colored feldspar.

At 480 ft.—A mixture of ferruginous silicates with some mica and talc and calcite; with occasional pieces also of the soft, greenish substance mentioned at 420 feet. The last is softer than calcite. The general color of the whole is dark red or brown.

At 490 ft.—The same as at 480 feet.

At 500 ft.—The same as at 480 feet.

At 510 ft.—The same as at 480 feet, but more friable, apparently, as the sample is in the form of sand. There are also in this lot several large fragments of ferruginous shale, which have a greasy feel, probably broken from the overlying beds by the bucket and brought up with the drillings.

At 520 ft.—A very dark, ferruginous mixture of the various silicates, including the light green soft substance, resembling silicate of iron. This last also resembles talc, and is as soft.

At 530 ft.—A red arenaceous shale, with some talc and calcite, and also fragments of flesh-colored feldspar.

At 540 ft.—The same as at 530 feet.

At 550 ft.—Fragments of dark red, coarse shale, like the last, and of a darker slightly greenish shale, that appears as if originally amygdaloidal, the cavities having been subsequently filled by the soft green substance mentioned at 520 ft. This latter mass is sometimes closely mixed with small geodes with rusty exterior.

At 570 ft.—A dark brown shale, like the dark shale in the last, closely mingled with the soft, greenish (silicate of iron?)

At 580 ft.—The same as at 570 feet.

At 590 ft.—The same as at 570 feet, but showing a little more red, and also evident pieces of calcite.

At 600 ft.—The same as at 590 feet, but with increasing quantities of the greenish, soft substance.

At 614 to 620 ft.—A mixture of the various silicates with considerable iron, the quartzitic characters being much more evident than at 570 feet. It is also firmer—hardly a shale.

At 620 ft.—The same as the last.

The well is said to be 710 feet in depth, and the opinion is prevalent that there was no change from 620 feet to that depth. As there are no preserved samples below 620 feet, it is also probable that there was no marked change in the rock. If that be correct, it gives a thickness of 292 feet of rock, which may all be classed as a siliceous unctuous shale, highly ferruginous, and sometimes amygdaloidal, va-

rying to a micaceous quartzite. It seems to be a metamorphosed sedimentary rock, lying below both the St. Croix sandstone and the Potsdam sandstone.

On the basis of these notes was made the following report:

REPORT TO GOVERNOR AUSTIN.

THE UNIVERSITY OF MINNESOTA,
ST. ANTHONY, MINN.,
8th Feb. 1873.

Gov. Horace Austin, St. Paul, Minn.:

According to verbal instructions from you, given on the 6th instant, I proceeded yesterday to Belle Plaine, for the purpose of making examination of the premises and the preserved samples of the drillings from the well sunk at that place, for testing the rocks for brine. The object of my visit was to ascertain the propriety of further expenditure by the State at that point, either for the purpose of proving the rock further for brine, or for purely scientific results.

I did not enter into a careful examination of the derrick and machinery, but suppose them to be, as represented, in perfect order, and ready for operation at any time. The springs that are said to be briny are situated near the drilled well. I obtained a sample of the water for analysis. To the taste it does not show brine, but a careful examination may prove it to hold a small amount of salt.* These springs issue from the base of the drift bluffs that enclose the river valley, and, according to all the information I could gather, are dependent altogether on the surface deposits for their supply. The owners of the well also say they have met no indications of brine in the well since they struck the rock, but that at varying depths in the drift materials, the water pumped out showed more or less saline property. The drift materials are said to have proved to be there 216 feet in thickness.

The preserved drillings which I examined pertain to that part of the well below 420 feet, and I can report only on that portion of the well. They extend moreover only to the depth of 620 feet. The well is said to be 710 feet deep. Without entering into details as to the character of those drillings, a matter that will find place in my next annual

*See the report of Prof. Peckham.

report, I may say that they consist in general of a siliceous, apparently talcose, shale, varying to a micaceous quartzite. It seems the whole thickness covered by the drillings I saw, is taken up with a metamorphosed sedimentary rock that lies below the St. Croix sandstone, and also probably below the Potsdam sandstone. Hence the bottom of the well is in the Huronian slates and schists, but has not yet struck the granite. In this statement it is presumed that the interval unrepresented by drillings (from 620 feet to 710 feet) is filled up, according to the opinion of the owners, by the same general class of rocks. I have no hesitation in saying that *in the rocks of that age there is almost a certainty that no salt would be obtained, and that no lower formation would offer better inducement to sink the well deeper.*

The only other reason for sinking the well deeper is on purely scientific grounds, viz. : to ascertain the character of the rock below the present bottom of the well.

In respect to this I wish to say :

First.—The well is not located where the most light could be thrown on the geology of the state by such an exploration. There are vast districts where even the nature of the outcropping rock at the surface is unknown, to say nothing of those that succeed it in descending order. The geology of the vicinity of Belle Plaine is pretty well made out, especially in the light of the developments of this well.

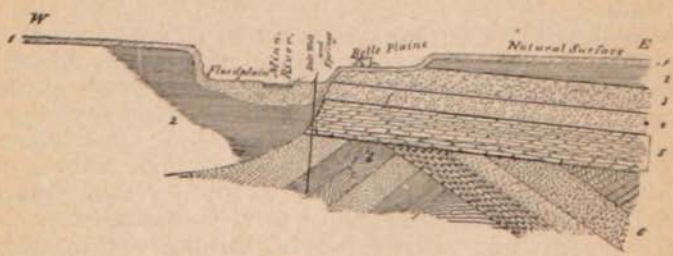
Second.—The rocks that would succeed that in which the drill stopped would be best examined where they are abundantly exposed at the surface. They belong to the class of "granitic and metamorphic" rocks, colored on my preliminary geological map of the state, and our knowledge of them is at present so limited, that before their natural outcrops are examined carefully, it is not certain that we should derive satisfactory and useful information of their nature, by sinking a drilled well through them, or into them. They are the rocks, moreover, that are least likely to need such exploration, on account of their being extensively tilted and broken by early volcanic forces so as to expose their thickness and contents to the inspection of the geologist.

Third.—It cannot be denied that the science of geology might be considerably advanced by sinking this well deeper-presuming all the time that careful records be kept and samples be submitted to a geologist for examination. It is

at the same time certain that no important question, involving the geology of the state, is pending on what might be developed.

The question may arise--if there is salt in the water at Belle Plaine, what is its source, and can it be made useful? If there be salt in the spring water there, it must issue from some part of the drift. It may be derived at first from some of the underlying formations, as the St. Croix sandstone, or the Lower Magnesian limestone, or it may come from the Cretaceous, which lies in many places unconformably on all the older rocks, but is generally deeply covered by drift. In either of these cases it would be best and soonest developed by drilling at some point east of Belle Plaine, say fifteen miles, as the rocks dip in that direction. The annexed diagram illustrates the situation of the well drilled, in respect to the rocks, and shows the positions of the formations and their dip. None of these formations, however, are known to contain brine in this country, if we except doubtfully the Cretaceous, while yet it is theoretically true that any sedimentary formation, if porous, may hold brine, if so shaped that it has not drained out.

DIAGRAM OF THE GEOLOGICAL RELATIONS OF THE BELLE PLAINE SALT WELL.



No. 1.—Drift. No. 3.—Low, Magnesian. No. 5.—Potsdam sandstone.
No. 2.—Cretaceous. No. 4.—St. Croix sandstone. No. 6.—Metamorphic and granitic.

In conclusion, I am at present of the opinion that if there be salt in the springs at Belle Plaine, it is derived from the Cretaceous rocks, but manifests itself in the drift at the base of the river bluffs, because the surface drainage is in that direction, there being a slow but constant loss of brine by that means. This subject ought to have early attention.

I wish to call your attention to the necessity of combining the records and minutes made prior to the depth of 420 feet, with those I have made on the drillings below 420 feet, so that the whole be preserved to science. The owners think those samples were forwarded by you to Ann Arbor, Michigan, and that a letter from my brother to you has has some mention of them.*

Very respectfully,

N. H. WINCHELL.

THE UNIVERSITY OF MINNESOTA,
February 16, 1874.

Prof. N. H. Winchell:

MY DEAR SIR:—In answer to your enquiry in reference to the progress of the analysis of the Belle Plaine water, I have to report, that while the work is not yet completed, enough has been done to show that it contains only a small proportion of chlorides of any kind, and also to justify the statement that the brine belongs to the class of "bitter brines," containing more sulphates than chlorides, and a larger proportion of alkaline earths (lime and magnesia) than alkalies (soda and potash.) I have found nothing as yet in my examination of this mineral water to justify the expectation that it can be made of any commercial value as a source of common salt.

Very truly yours,

S. F. PECKHAM,

Chemist of the geological survey of Minnesota

*This letter has already been given—See p. 80.

II.

PEAT.

(a) *Need of fuel—Objects of the peat survey.*

The absence of wood and coal from a large part of the settled portions of the state, and the consequent high price of fuel for domestic use, induced the last Legislature to insert a clause in the "act to aid the Geological and Natural History Survey," requiring the immediate survey of the peat deposits of the state, a report on the same to be made to the Legislature as soon as practicable. In that way it was hoped that a good fuel might be obtained, practicable for all the common uses of the settler; and that a great many of the hardships of the first settlers of the prairies of the state would thus be relieved. While this law was not intended to work a suspension of the other geological investigations required by the general law creating the survey, its immediate and practical importance has nevertheless controlled the course taken in the routes of exploration, and absorbed much of the time throughout the whole season.

Allied to the subject of peat is that of coal. It was deemed best that the two should be prosecuted together, especially as the locality of the rumored coal exposures coincided with that of the greatest need for fuel, and again with that in which peat was supposed to exist. The southwestern quarter of the state, including the Minnesota valley and those of some of its tributaries, have occupied the principal part of the season. In addition to these explorations, the counties of Cottonwood, Jackson and Nobles have been pretty thoroughly surveyed for peat. The northeastern portion of Jackson and the northwestern portion of Cottonwood should be further examined. The question of the occurrence of coal, and its origin and nature, is mentioned under the head of "The Economical Geology of the Minnesota Valley."

(b) *The varieties of peat.*

In order to a perfect understanding of that which follows, it will be well to mention the different varieties of peat, briefly describing the nature and habitat of each, and the terms by which they will be designated. The different products of a vegetable nature that have attracted attention under the general term *peat*, and have served to some extent for fuel in the state, may be classified as follows:

1. Slough peat.
2. Side-hill peat.
3. Turf-peat.
4. Turf.

Only to the first two of these is the term "peat" properly applied, yet among the common people they are all frequently embraced under that term.

1. *Slough peat*, is that which is found in low ground, occupying the lowest spots in old drainage courses which are now either entirely destitute of currents of running water, or are only filled in the wet seasons of the year, or occurring in the depressions among the drift hills or knolls, the slow drainage from which prevents the accumulating water from standing for too great a length of time above the usual level. In southwestern Minnesota such peat must be so situated also that the slough which holds it never becomes dry, else the prairie fires will certainly consume it. Hence, the necessity of constant springs of water to supply the slough in the dry months of the year. This again implies that the surface of the country must be rolling, at least that some bluffs of drift gravel must lie adjacent to the slough to give origin to springs of water. These springs are very often invisible. Their existence may be known, however, by the standing of the water of the slough at the same level, even in the dryest seasons. In case such peat lies in an old drainage course which shows no great flow of water in the dry season, the low spots containing it are still supplied with water enough to preserve the peat, by the slow, invisible, underground drainage pertaining to the valley. These correspond to the German *Wiesenmoore*.

The primary and essential ingredient that goes to form this kind of peat is a fine moss that grows over the surface of the bog, among the coarse stalks of other vegetation, such as grasses or rushes, making a handsome green surface. At a distance this moss cannot generally be seen. It is hid by the coarser vegetation. Besides this moss, the

roots and decaying stems of the grasses and other aquatic plants that may grow in the slough, also aid in the peaty accumulation. This moss is *Shagnum palustre*,* and the aquatic plants that accompany and hide it are bulrush (*Scirpus*), scourish rush (*Equisetum*), a short "blue-joint" grass, and occasionally the cat-tail (*Typha latifolia*), and species of *Polygonum*, and some others.

There is, besides the typical moss peat of the sloughs, a pulpy deposit in the bottoms of many small lakes and ponds derived from the coarse grasses and sedges that grow about their margins, which consists principally of vegetable matter, and if treated properly will make a useful fuel. It is in the form of a fine silt, and is usually too limited in quantity, and too impure in quality to be very valuable. It is apt to be most abundant on the leeward side of the lake, where the prevailing winds have driven it, and the waves have beaten and broken it. This corresponds to the *Schlammtorf* of Holland.

2. *Side-hill peat.*—This is formed on the side of a gentle declivity where springs of water furnish the necessary constant moisture. It is apt to accompany those springs that lie in belts, marking the outcropping upper edges of shale beds or other impervious rock. It is composed of the same materials as slough peat, but is more liable to be impure, from the sand and dust that are carried upon it by the high winds of the plains. Such peat may accumulate to the depth of six or eight feet. It is far less common in southwestern Minnesota than slough peat. It requires also a rolling surface that may give rise to unfailing springs. Many springy side hills that in a moister climate would become peat-bearing, dry up in summer to such an extent, in southwestern Minnesota, that no aquatic plants can survive, and no peat can be formed on them.

3. *Turf-peat.*—This is formed of the roots and fallen stalks and blades of the rank grasses and sedges that grow in the shallow sloughs, or about their margins, in situations moist enough to resist the prairie fires. It is found sometimes on a side hill or in a narrow ravine or inclined slough through which there is a slow seepage of water. It is always more impure than the foregoing varieties, and becomes mixed with sand and black mud below the depth of 12 or 18 inches, so as to render it unfit for use. It is always fibrous and conveniently handled. Owing to its being so

*This is the common term. Dr. C. A. White has, however, given the name *Hypnum aduncum* to the peat moss of Iowa.

hard as to support the weight of a man, or often of a team, in the dry months of the year, its accessibility and the ease of taking it out by simple means, it is probably the most useful variety of peat to the farmers of southwestern Minnesota. It is also the most common. In very dry seasons the fires get into this turf-peat and consume vast quantities, burning for several weeks, or even till mid-winter. It is invariably found about the margins of the little depressions in the general prairie which contain water in the spring of the year, but become nearly or quite dry in the summer. The peat itself is annually submerged for several weeks in the spring. It lies on a hard and impervious drift clay, which is generally very fine, and blackened to the depth of a foot or more by the charred vegetation of many generations.

4. *Turf.*—This is the common sod of the prairie. It passes into the last. It is made of the prairie grass roots, and those of other vegetation that may grow there. In dry sloughs, that furnish a fine growth of hay annually, it is sometimes fit for fuel, but it rarely becomes thick enough to make it of much use for that purpose. It always contains considerable sand and clay.

(c) *The quality of Minnesota peats.*

There is nothing in Minnesota, so far as yet discovered, that answers to the extensive *moors* or *heathers* of the moist climates of Ireland, Holland and North Germany. They occur on the northeast coast of North America, in Labrador, Newfoundland and Anticosti, where the summers are not so excessively warm, and where frequent fogs give the atmosphere that state of moisture which the peat mosses require. Along the low lands on the south coast of Anticosti "a continuous plain covered with peat extends for upward of eighty miles with an average breadth of two miles; thus giving a superficies of more than a hundred and sixty square miles."* It has a thickness of three to ten feet. In the wooded portions of the state the peat deposits are likely to be made up of more or less coarse vegetation, such as deciduous leaves, and the stems and roots of various ericaceous plants. In the extensive peat deposits of the old world the vegetable fiber is entirely destroyed below a depth of ten or fifteen feet, and the peat has a compact, earthy texture, and a black or brown color.

*Geology of Canada, 1863.

The peat deposits of Minnesota are, so far as known, too shallow to exhibit this perfect decomposition, and hence, they are generally distinctly fibrous from top to bottom. In the lower portions of the deep peat bogs of Ireland the per cent. of ash is much greater than near the surface, reaching sometimes as high as nineteen per cent. those portions near the surface, which contain the vegetable matter but little altered, affording but one and a half per cent. Thus, while the density of peat, and hence its usefulness for domestic fuel, are enhanced by the greater depth, its combustibility and its purity are diminished. The superficial layers have nearly the same composition as wood. The foreign substances, that constitute the ash of the lower portions, are lime silica, iron and clay. The lime is derived from the small shells that often inhabit the bog, and which sometimes are so abundant as to have caused, by their accumulation, a bed of shell-marl at the bottom of the lake before the growth of the peat mosses filled it. Such shell-marl beds often occur at the bottom of peat bogs. Silica may have entered the growing peat by being blown on in the form of sand, or washed in by freshet rains from the adjoining hills. Iron is found in nearly all water in its natural state. As a carbonate it may be carried in solution by spring water issuing from ferriferous gravel or sand. On exposure to the air it is converted to a hydrated peroxyd, which is precipitated as a red film on all substances. If long continued it would thus form a bog ore, or brown hæmatite. It would descend by its specific gravity to the bottom of the peat bog. The clay that makes a part of the ash of peat is a composite substance. Its chief ingredient is alumina. It may also be carried into the bog by small streams so as to mingle with other impurities in the greatest proportion at the bottom. By reference to the accompanying chemical analyses, performed by Dr. P. B. Rose, of Ann Arbor, Mich., and by Prof. S. F. Peckham, chemist of the survey, it will be seen that a great diversity exists in the qualities of the samples of peat from Minnesota, but that they compare favorably with peats analyzed from Iowa, Connecticut, or even the famous Irish peat.

(d) *Peat analyses by Dr. Rose.*

Of the peats analyzed by Dr. Rose, the samples numbered 1 and 2 were procured and furnished the survey by Dr. C. D. Williams, of St. Paul. No. 3 was furnished from

the manufactory by W. Z. Haight. No. 4 was obtained by the survey, and is named in the section describing it, "peaty, lake sediment," No. 5 is properly not a peat, but a turf-peat, as defined on page 90. No. 6 is a fair sample of raw peat, from Wells, in Faribault county, obtained by the survey. The corresponding serial numbers in the records of the survey, run from 5 to 10 inclusive.

Prof. N. H. Winchell, state geologist of Minnesota, St. Anthony Falls, Minn.

DEAR SIR:—The six samples of peat furnished me by express, and marked as follows:—

No. 1—Schmidt's land, St. Paul—taken out eight feet below the surface;
No. 2—Schmidt's land, St. Paul—two feet below the surface;
No. 3—Manufactured peat, from Wells;
No. 4—Lake Emily, near St. Peter;
No. 5—Empire City;
No. 6—From Wells, not manufactured;—

have each been submitted to an analysis, with the following results: 100 parts of the air-dry peat contain—

	Hygroscopic water.	Ash.	Organic matter.
Peat No. 1 (Serial No. 5)	13.75	12.73	73.52
Peat No. 2 (Serial No. 6)	12.65	21.67	65.68
Peat No. 3 (Serial No. 7)	14.00	18.17	67 83
Peat No. 4 (Serial No. 8)	9.83	67.17	23.00
Peat No. 5 (Serial No. 9)	8.83	77.35	13.82
Peat No. 6 (Serial No. 10)	15.95	18.17	65.88

The ash or inorganic matter, varying greatly in quantity, was still further subjected to analysis, with the subjoined result:—

Peat ash.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Silica	49.09	65.39	58.31	88.95	59.37	61.32
Potassa	.63	.57	.41	.12	.14	.55
Soda	.37	.31	.18	.11	.08	.23
Lime	13.87	10.60	14.18	1.43	18.10	12.44
Magnesia	3.01	2.24	2.90	.82	1.41	2.43
Iron and alumina	14.92	6.31	10.21	7.04	6.58	9.71
Sulphuric acid	8.23	8.34	2.11	.12	.14	2.37
Carbonic acid	10.27	5.97	11.63	1.82	14.12	10.69
Phosphoric acid	Trace.	Trace.	.....	.....	.....	.....
Chlorine	.....	.....	Trace.	.....	.....	Trace.
	100.39	99.73	99.70	100.70	99.94	99.96

The following is the elementary analysis of the organic matter :—

	Per 100 of the organic matter.			Per 100 of the original air-dry peat.		
	Carbon.	Hydrogen.	Oxygen & nitrogen.	Carbon.	Hydrogen.	Oxygen & nitrogen.
Peat No. 1.....	53.06	6.19	40.75	39.03	4.56	29.93
Peat No. 2.....	52.22	6.11	41.67	34.30	4.01	27.37
Peat No. 3.....	52.02	6.68	41.30	35.30	4.54	27.99
Peat No. 4.....	48.66	9.73	41.61	11.19	2.24	9.57
Peat No. 5.....	46.58	10.51	42.91	6.44	1.45	5.93
Peat No. 6.....	51.94	6.17	41.89	34.22	4.06	27.60

The composition of the above samples of peat compared with that of *hard wood* is as follows ;

	Carbon.	Hydrogen	Oxygen and nitrogen.	Ash.	Water.
Wood.....	39.6	4.8	34.8	0.8	20.0
Peat No. 1.....	39.03	4.56	29.93	12.73	13.75
Peat No. 2.....	34.30	4.01	27.37	21.67	12.65
Peat No. 3.....	35.30	4.54	27.99	18.17	14.00
Peat No. 4.....	11.19	2.24	9.57	67.17	9.83
Peat No. 5.....	6.44	1.45	5.93	77.35	8.83
Peat No. 6.....	34.22	4.06	27.60	18.17	15.95

The heating power of each of the six samples of peat, as compared with an equal weight of air-dry oak wood, is based on the amount of oxygen required for complete combustion, or by the number of pounds of water raised from 32° to 212° F.

100 lbs. of air-dry peat No. 1 = 104.2 lbs. of oak wood.
100 lbs. of air-dry peat No. 2 = 94.7 lbs. of oak wood.
100 lbs. of air-dry peat No. 3 = 98.1 lbs. of oak wood.
100 lbs. of air-dry peat No. 4 = 34.4 lbs. of oak wood.
100 lbs. of air-dry peat No. 5 = 16.9 lbs. of oak wood.
100 lbs. of air-dry peat No. 6 = 89.6 lbs. of oak wood.

All of which is most respectfully submitted,

P. B. ROSE,

Asst. in chemistry, University of Michigan.

Chemical laboratory, University of Mich., Nov. 22, 1873.

(e) *Peat analyses by Prof. Peckham.*

Prof. N. H. Winchell, state geologist of Minnesota:

MY DEAR SIR —The following is a report of the chemical investigations conducted in accordance with your suggestions for the geological survey of Minnesota:

I desire to state that when I assumed the duties of chemist to the geological survey last August, I found absolutely nothing in the University laboratory in preparation for special investigations of the nature of those I was about to undertake. The room in which I have worked had to be fitted up. Much of the apparatus used had to be procured from New York. All my solutions of reagents had to be prepared, as well as many of the reagents themselves. In fact I began at the beginning and fitted up my laboratory before doing any of the work at hand. I have also discharged at the same time the duties of a full professorship in the University, and have consequently only been able to give the work of the survey the second place.

No. 1. *Tripoli.*—You have placed in my hands for examination a specimen of tripoli, or very fine grained, friable sandstone, of which 25.15 per cent. was found to be soluble in boiling concentrated hydrocholic acid. The remaining 74.85 per cent. consisted of microscopic, apparently angular fragments of white quartz. The soluble portion consisted chiefly of ferric oxide ($Fe_2 O_3$) and a smaller portion of the carbonates of lime and magnesia, of which quantitative determinations were not made.

"*A*," *clippings of native copper.*—A specimen which I have marked A, of which I have made the following record: A letter was handed me addressed to Prof. Winchell by R. S. Russell, of Pleasant Grove, Olmsted Co., Minn., containing an enclosure of minute fragments or clippings of what appeared to be native copper. "Found on the south bank of Root river in the neighborhood of green shale * * imbedded in loose rock found on the surface."

Completely soluble in dilute nitric acid. Evaporated to dryness the residue was completely soluble in water and contained nothing but nitrate of copper.

Mineral Water.—A pint of mineral water not labeled. It appeared not to have been filtered. The results of as complete a qualitative analysis as the small quanity would admit of, are as follows:

The water contained a brown, flocculent deposit and crys-

talline scales. It was neutral to litmus, tumeric and lead papers, showing the absence of free acids, alkalies and sulphuretted hydrogen. It was also odorless, with a bitter saline taste.

Three hundred and ninety-three cubic centimeters were evaporated to dryness. A portion of the residue dissolved in water contained potassium, sodium, chlorine, sulphuric acid and a trace of phosphoric acid. The residue insoluble in water dissolved in hydrochloric acid with escape of carbonic acid, and the solution contained chlorides of lime and magnesia.

The results indicate that the water held in solution:

Carbonate of lime.

Carbonate of magnesia.

Chloride of sodium and potassium.

Sulphate of sodium and potassium.

Phosphates, a trace.

A little organic matter was not dissolved in hydrochloric acid.

This water will be further examined.

No. 29.—A specimen supposed to be carbonate of magnesia, was found to be a light-colored friable clay, containing a large proportion of sand; will be still further examined.

Nos. 30 *and* 31.—Two specimens of siliceous limestone, containing small, rounded grains of a soft, light-green mineral, were to be examined for carbonate of copper. Dilute hydrochloric acid dissolved the lime with disengagement of carbonic acid. The hydrochloric acid solution was colorless and contained lime, iron, magnesia and a trace of manganese, with carbonic and silicic acids, but no copper. The insoluble portion consisted of grains of quartz sand, and the green mineral which contained iron, alumina, magnesia and soda, with silicic acid. This green mineral has the appearance of being green slate, in water-worn grains. The species can only be accurately determined by a quantitative analysis. They will be still further examined.

Peats numbered 16 *to* 28 *inclusive.*—Thirteen specimens of peat were examined with reference to hygroscopic water, organic matter and ash. They were all treated exactly alike. An average sample of each of the specimens was finely pulverized and thoroughly mixed Of this one gramme was carefully weighed in a one-ounce platinum crucible. The covered crucible containing the assay was then placed in an air bath, and heated to 212-220 degs. Fahr., until it

ceased to lose weight. The loss was estimated as hygroscopic water. The cover was then removed, the crucible inclined and heated to dull redness, finally to bright redness, until the combustible matter was entirely consumed. The loss was estimated as organic matter and the residue as ash. The following results were obtained:

No.	Hygroscopic water.	Organic matter.	Ash.
16	12.72	68.52	18.76
17	13.04	48.64	38.32
18	10.99	44.56	44.45
19	20.64	53.60	25.76
20	16.75	47.03	36.28
21	11.93	33.48	54.59
22	13.58	53.28	33.14
23	11.03	41.67	47.30
24	10.225	64.475	25.30
25	10.80	16.33	72.87
26	8.69	31.90	59.41
27	9.85	42.63	47.52
28	29.44	58.17	12.39

These peats will be still further examined.

An absolutely accurate comparison of these peats with oak wood cannot be made without a determination of the carbon and hydrogen present in each; but in order to furnish a tolerably correct basis of comparison, the average amount of carbon and hydrogen as compared with the total amount of organic matter, was estimated in the six specimens examined by Dr. Rose. It was found to be 58.4 per cent. The proportion contained in oak wood being made the standard of comparison or 100 per cent., all of the peats examined by Dr. Rose and myself, were found to possess the following values, 100 pounds of the air-dry substance being taken in each case:

100	lbs.	Oak wood =	100.0 lbs.	100 lbs.		No. 19 =	70.5 lbs.
"	"	Serial No. 5=	99.0 "	"	"	" 20 =	61.7 "
"	"	" " 6=	86.0 "	"	"	" 21 =	44.0 "
"	"	" " 7=	89.3 "	"	"	" 22 =	70.1 "
"	"	" " 8=	30.2 "	"	"	" 23 =	54.8 "
"	"	" " 9=	18.1 "	"	"	" 24 =	84.9 "
"	"	" " 10=	86.7 "	"	"	" 25 =	21.4 "
"	"	" " 16=	90.2 "	"	"	" 26 =	42.0 "
"	"	" " 17=	64.0 "	"	"	" 27 =	56.1 "
"	"	" " 18=	58.6 "	"	"	" 28 =	76.5 "

No. 28 was one of the first examined, and was not probably sufficiently dried, as the amount of water is very large, 29.44 per cent. The ash is only 12.39 per cent., however, which is very low. This peat is no doubt very nearly as valuable as number 16, when properly dried.

The value of these peats, as compared with each other, is as follows:

1	Ser. No. 5	7	Ser. No. 28	13	Ser. No. 27
2	" 16	8	" 19	14	" 23
3	" 7	9	" 22	15	" 21
4	" 10	10	" 17	16	" 26
5	" 6	11	" 20	17	" 8
6	" 24	12	" 18	18	" 25
				19	" 9

All of which is respectfully submitted.

S. F. PECKHAM,

Chemist to the geological survey of Minnesota.

St. Anthony Falls, Dec. 23, 1873.

Of the foregoing samples analyzed by Prof. Peckham,

No. 1 was obtained at Stillwater, Washington county.

"A" was from Pleasant Grove, Olmsted county.

"Mineral water" was from the reputed salt springs at Belle Plaine, Scott county. Other samples have been since obtained and will receive analysis.

No. 29 was from the sandstone near the Red Jacket mills, in Blue Earth county, apparently consisting of magnesia or magnesia and lime. (See description of that locality, page 96.)

Nos. 30 and 31 were from the St. Lawrence limestone, the former from St. Lawrence, Scott county; the latter from Judson, in Blue Earth county.

No. 16 was a peat from St. Cloud, 18 inches below the surface.

No. 17 was a peat from Lura, in Faribault county, 18 inches below the surface; land of W. Z. Haight. Bog A.

No. 18 was from the same bog as No. 17, 3 feet below the surface.

No. 19 was a peat from the same place, Bog B, 18 in. below the surface.

No. 20 was from the same bog as No. 19, 3 feet below the surface.

No. 21 was a turf-peat, owned by John Haggard, sec. 4, T. 101, R. 39.

No. 22 was from K. K. Peck's land, near Windom, 2 feet below the surface.

No. 23 was from K. K. Peck's land, near Windom, 3 feet below the surface.

No. 24 was a peat from land of Rev. Edward Savage, near Windom, 18 inches below the surface.

No. 25 was a turf-peat from S. O. Taggart's land, sec. 24, T. 105, R. 35.

No. 26 was a peat from land of A. A. Soule, Mountain Lake, 2 feet below the surface

No. 27 was peat from land of St. Paul & Sioux City railroad, sec. 13, T. 106, R. 37, 2 feet below the surface.

No. 28 was a peat from land of F. G. Taylor, Brooklyn, Hennepin Co.

(f) *Where peat exists in Minnesota.*

The method adopted for testing for peat is very simple. A common augur, of about one and a half inch bore, is supplied with a jointed rod eight or ten feet in length. The handle and all of the joints are removable, and can be transported in one package. The thread of the auger will bring out the material passed through, from any desired depth, the samples being preserved if necessary. This will answer for most cases. If the peat prove too pulpy or too wet to be brought out on the thread of the auger, other means must be adopted. When it is too fibrous and loose to be penetrated by the auger, the desired sample can be taken out by the hand, as the loose and fibrous parts are always near the surface. The best way to illustrate the contents of a peat marsh, is to take out and dry a full section from the surface to the bottom, cutting the fiber with the slane, and exposing the variations in composition and color without disarranging their superposition.

The following notes on the observed location of peat deposits do not embrace a much larger class of observations, made during the summer on localities where peat does not exist, but where it was supposed by the owners to exist in abundance

1. At a point about half a mile east of Empire City, in Dakota county, the augur was sunk in the land of Albert Whittier. This is within the valley of the Vermilion river, and revealed the following section.

No. 1.—Turf peat, about	1 ft.
No. 2.—Black, sticky, heavy mud	3 ft.
No. 3—Sand, with some gravel, penetrated	1 ft.

This character of surface prevails, judging from outward appearances, over an area of many acres in this part of the valley, passing also on to the land of Mr. Gray, further east.

2. Sec. 22. T. 114, R. 19, Dakota county. Owner's name unknown. Agents, Claggett & Crosby, Farmington.

No. 1.—Wet turf-peat	1 ft.
No. 2.—Fine, black mud	2 ft.
No. 3.—Green, sandy clay	1 ft.
No. 4.—Sand, of a greenish cast	2 ft. 4 in.
No. 5.—The same, indefinitely.	

3. About sec. 22, T. 114, R. 19, Dakota county.

No. 1.—Black turf-peat, loose and fibrous..... ..... 1 ft.
No. 2.—Fine, black mud..... 6 in.
No. 3.—Sand and gravel..... 6 in.
No. 4.—The same indefinitely.

4. In the same bog; near an outcrop of the St. Peter, N. W. from Empire City.

No. 1.—Black turf, fibrous..... ..... 1 ft.
No. 2.—Sand; the same indefinitely..... 1 ft.

5. In the same bog; owned here by James Murphy.

No. 1.—Black, impure turfy peat..... 1 ft.
No. 2.—Yellowish-green, sandy clay..... 1 ft.

This burned over more or less for some distance in various directions a few years ago, passing also on to the land of others. This whole slough is termed "meadow" by the owners, and furnishes annual crops of hay. In the dry months teams can be driven over it in most places. It is in the valley of the Vermilion, the greatest part lying on the north side of the river.

6. Land of James Murphy, sec. 15, T. 114, R. 19.

No. 1.—Turf-mold, or Turf-peat and hard enough for teams to pass over, little fibrous, burned over a few years ago..... 1 ft. 6 in.
No. 2.—Yellowish-green clay [see Dr. Roses analyses] 6 in.

7. Near the center of the same bog, E. of Murphy's.

No. 2—Black turf-peat, wet..... 6 in.
No. 2.—Clay and mud of brownish-ash color, with streaks of green..... 1 ft.

8. Land of Caleb Adams, same slough. One mile northwest of Empire City.

No. 1.—Fibrous turf-peat..... .....1 ft. 6 in.
No. 2.—Sand. indefinitely.

This peat has as good (or better) appearance as any yet seen on this marsh.

9. Land of D. S. Pilcher, two and a half miles east of Farmington, sec. 27, T. 114, R. 19. A branch of the Vermilion valley, coming in from the southwest, consists now of a long, wide slough, having the surface characteristics of the valley of the Vermilion.

No. 1.—Black muck, somewhat fibrous on the top, becoming clayey and sandy, but passing into stiff, brown clay in 18 in..... 1 ft.

Tested no further.

Mr. Pitcher says this surface turf burned, in 1863, from July to December, making many "hog-wallows."

10. Kasota, LeSueur County. This marsh is crossed by the Sioux City R. R. This point is on the east side of the R. R., six rods from the drift bluff.

No. 1.—Pretty good peat ..... 8 in.
No. 2.—Black, sandy clay..... 2 ft.

The whole depth drilled showed frequent shells.

11. In the same marsh, on the west side of the R. R., fifteen rods from the drift bank.

No. 1.—Roots and stems of grass, with some peaty, vegetable decomposition..... 8 in.
No. 2.—Black, peaty mud, with a few fragments of shells and some sand..... 1 ft. 4 in.
No. 3.—Black or brown mud, with sand and fragments of shells..... 4 ft.

12. Head of lake Emily, in LeSueur county, near St. Peter. Land of M. French.

No. 1.—Roots and soft, fibrous lake sediment..... 1 ft.
No. 2.—Peaty lake sediment, with little or no sand..... 1 ft. 6 in.
[See Dr. Rose's analyses.]
No. 3.—Peaty mud, with a little sand..... 1 ft.
No. 4.—Black, lake mud, sandy.....2 ft.

13. Wells, Faribault Co., land of Clark W. Thompson.

No. 1.—Watery, fibrous peat..... 4 ft.
No. 2.—Peaty mud, with shells and some sand..... 6 in.
No. 3.—Brownish mud and clay..... 6 in.

14. Wells, Faribault Co., land of Clark W. Thompson. Same slough as the last.

No. 1.—Good peat, showing some sand grains..... 6 ft.
No. 2.—Peaty mud and clay. [See Dr. Rose's analyses].... 6 in. to 1 ft

15. Wells, Faribault Co., same slough.

No. 1.—Peat of good quality..... 5 ft.
No. 2.—Peaty mud..... 6 in.

16. There is a peat deposit of 80 or 100 acres near Lura, in Faribault county, sec. 30, T. 104, R. 25. Land of H. F. Quinby and J. Robinson. Said to be four feet deep.

17. Peat is manufactured near Fairmount, in Martin county, by Mr. A. L. Ward.

18. Near Lura station, in Faribault county, peat exists in considerable quantities, on land of W. Z. Haight. [See Prof. Peckham's analyses.]

19. Sec. 24, T. 105, R. 35; Cottonwood county. Land of S. O. Taggart. In a dry slough, covering many acres, the surface consists of a turf-peat, to the depth of about a foot, passing into black mud and sand. The very top is fibrous and even spongy.

20. Land of S. O. Taggart, 5 miles east of Windom. In a narrow spring ravine, where water stands or slowly runs throughout the year, and near its head, a thickness of a foot or more of turf-peat may be taken out over a space of a few rods square. It is thicker and better near the head of the ravine than at any other point, owing to the more constant protection of the grass and roots from the prairie fires.

21. Other similar peaty ravines occur on land of Miss Ellen Imus, near that of Mr. Taggart.

22. A mile and a half northeast of Cannon City, Rice county. Land of Wm. Dunn. A shaking bog of peat is said to occur on S. E. 1-4 sec. 11, T. 110, R. 20.

23. Mountain lake, Cottonwood Co. Near Mountain Lake station, on land of A. A. Soule, a coarse turf-peat covers the surface of a dry slough to the depth of ten to eighteen inches. Near a spring along side of this slough which is tributary to Mountain lake the surface quakes, and the peat is thickest.

24. Around Mountain lake the land is low, and is flooded in the wet season. This low land contains considerable peat for some distance out toward the lake. The surface shakes under the tread. It is covered in the summer with a tall grass, which much resembles the wild rice, yet the softest places, where the peat occurs purest, are furnished with a short grass. Peat here is two or more feet thick. The land examined is owned by A. A. Soule.

[See Prof. Peckham's analyses.]

25. Sec. 13, T. 106, R. 37, Amo, Cottonwood Co. A slough that shakes is in the valley that forms the prolongation of the Des Moines valley northwestward above the great bend a few miles above Windom, and has a spongy

peat about two feet in thickness, with black mud below. It covers six or ten acres.

26. In the same prolongation of the Des Moines valley, on K. K. Peck's land, two miles above the bend of the Des Moines, is a thickness of two or three feet of peat. This valley seems to hold about two feet of peat along a considerable area through the middle, and would supply a great quantity. It is not of a superior quality, but might be very useful to the settlers.

27. Sec. 2, T. 105, R. 38, Cottonwood Co., Government land. Side-hill peat occurs on a gentle slope over the space of a few rods, having a thickness of a foot and a half or two feet. Such peatty patches appear also on the opposite side of the main valley, arising from the issuing of springs that keep the surface moist, while the lower land in the same slough is dry and hard. This peat is not free from sand. It also smells strongly of sulphuretted hydrogen.

28. NE ¼ sec. 28, T. 105, R. 36, Cottonwood Co. Land of A. J. Hall. In a turfed ravine, where water stands or slowly oozes through the turf, sloping gently toward the Des Moines river, a turf peat may be taken out to the depth of a foot or twenty inches. The belt containing peat is from ten to twenty feet wide, and similar in its situation to that of Mr. S. O. Taggart, but more extensive. It shakes under the feet for three or four feet about, but a horse can walk safely over it in most places in the dry season. Indeed, it is mown for hay every year. An irony scum lies on the ground and on the grass stalks. The peat itself is a turf, but contains shells and some grit.

Another similar ravine is on the same claim. Numerous others might be located along the ravines that cross the Des Moines bluffs.

29. SW. ¼ sec. 4, T. 104, R. 36. Delafield, Jackson county. Land of Rev. Edward Savage. A good moss peat occurs here in a slough, having an average thickness of two feet, over an area of ten acres or more. The slough is confined between bluffs that appear to be entirely composed of drift, and has a feeble drainage into a small lake (String lakes). The surface is mostly covered with a short (blue joint?) grass, but also with chair-bottom rushes. Some patches also of *Typha latifolia* are seen. No horse tail rush appears. In passing over the surface of this marsh it quakes five or six feet around, and the auger hole is immediately filled with water to the top. Below eighteen inches (even sparingly in ten or twelve inches) shells begin to be rather

common, and the auger next brings up a black mud with many shells. The most of this peat is made up of the peat moss, though at a depth of a foot or eighteen inches it contains grass roots and other fiber.

30. NE. ¼ sec. 30, T. 105, R. 36. Land of Arthur Johnson. Turf-peat occurs in a ravine, twenty feet over, where fuel can be taken out.

31. Land of Geo. C. Bush, sec. 6, T. 105, R. 37, holds a peatty turf, in a dry slough near the mouth of a ravine, in considerable abundance. Sandy below.

32. T. 105, R. 38, Southbrook, Cottonwood county. Peat exists, according to Mr. John Crapsey, three miles north of Talcott lake.

33. Land of the St. Paul & Sioux City and Sioux City & St. Paul R. R., sec. 31, T. 105, R, 37, Jackson county. A thin deposit of about six inches of peat covers about half an acre, mostly under water. This is the only peat that can be found in the vicinity of Heron lake.

34. Land of F. G. Taylor, Brooklyn, Hennepin county, seven miles north of Minneapolis, furnishes a fine quality of peat. [See analyses of Prof. Peckham.]

35. Land of B. S. Langdon, sec. 4, T. 102, R. 41, Nobles county. Here a turf-peat occurs, about 14 inches in thickness, lying on a side-hill or gentle slope, having a springy character when trod on. It is underlain by a black mud, which has been mistaken for non-fibrous peat. Of the turf several cords (perhaps a hundred) have been taken off, preparatory to excavating the rich (?) peat below, when it was discovered that it would not burn, but when placed in the fire turned out hard and heavy like burned clay. The turf itself will make a fuel that will compare well with any turf-peat discovered.

36. Peat, eight or ten inches thick, exists on the railroad land, sec. 27, T. 101, R. 40, Nobles county, of a turfy character, but good quality. It lies over an acre or two, but may be taken out probably in other places along the different creeks that unite here.

37. At Bigelow, in Nobles county, there is a considerable thickness, perhaps two feet, of half-carbonized, pulpy, vegetable silt, lying entirely below the water of a lake, made up of decaying sedges and grasses and their roots. It is torn in pieces by the waves in the lake and gathers about the shores and under the bog-turf, driven most abundantly to the side that faces the prevailing winds. It is often intermixed with fine mud and shells, especially near the

bottom. It will probably furnish, if dry, a combustible material that would answer well for fuel, if it should prove obtainable in sufficient quantities, and especially if it were to be pressed and molded. It has not the necessary origin nor nature to be styled peat.

38. John Haggard takes out turf in a low patch on sec. 4, T. 101, R. 39, Nobles county. It occurs partly on state swamp land, partly on railroad land, and partly on the claim of Charles Peterson. It is in nature and position similar to the turf on B. S. Langdon's land, northwest of Worthington. Mr. Haggard takes it out with a spade, about a foot in depth, in large blocks. Then drawing it to the house he cuts it into convenient smaller blocks, and spreads and piles it for drying. After drying about four or six weeks it is fit for burning. It burns quickly but leaves considerable ash. (See the report of Prof. S. F. Peckham.)

39. On the S. E. ¼ sec. 27, T. 102, R. 34, Jackson county, Mr. W. V. King correctly describes a peat marsh.

40. Peat occurs of good quality just west of the limits of St. Cloud, in Stearns county, about a foot and a half thick, underlain by a bed of shell marl, which, before the introduction of the Shakopee lime, was considerably burned for quick lime. [See Prof. Peckham's analyses.]

41. Peat occurs within the corporate limits of St. Paul, having, according to Dr. C. D. Williams, a depth of eight feet. It lies on the land of Mr. Schmidt. [See analyses of Dr. Rose.]

42. At Red Wing, Goodhue county, good peat has been taken out and experiments in manufacture made on the farm of Capt. O. Eames. This peat lies in the bottoms, between the shore and next range of river bluffs. The experiments were made under the direction of the *Davidson steamboat company*, by Capt. Isaac Webb, of Stillwater.

43. At East Minneapolis, Mr. W. W. Wales and Dr. M. D. Stoneman took out about 25 cords of peat in 1865. The average thickness is about eight feet, and the peat, although light and fibrous at the top, was heavy and solid below, becoming brown or nearly black. Digging and drying cost 80 cents per cord. It was consumed in common stoves, leaving a heavy ash. In cost it would not compete with pine wood from the saw mills.

(g) *The working of peat.*

The great porosity and consequent bulk of peat make it exceedingly desirable that, before it is used for fuel, it should be compressed, both for the purpose of removing the contained moisture, and of getting an intenser heat. The brown, fibrous peats are also liable to crumble on being handled, and will not bear transportion, unless rendered more tenacious and dense by some process of manufacture.

To accomplish this, various methods have been invented. The "turf" that is extensively burned by the peasantry in Ireland, France and Germany, is simply taken from the bog and dried in the sun. When first taken from the bog its weight consists of from 70 to 90 per cent. of water. When ready for use it still holds from 20 to 35 per cent. That which has been stacked from six to twelve months still retains from 18 to 20 per cent,, and after being kept in a dry house for two years, from 10 to 15 per cent. of water. Its heating effect then is about equal to that of an equal weight of pine wood. Peat may be condensed and prepared by machinery so as to weigh more than hard wood. It may be made nearly as solid and tenacious as coal, its specific gravity being nearly that of bituminous coal. In this form it may be subjected to a strong blast, rendering it useful in ordinary grates and furnaces.

It is intended to describe briefly some of the methods of manufacturing peat in America. Many of the facts herein stated are obtained from *Leavitt's peat journal* of March, 1867; others from Prof. Johnson's "*Peat and its uses.*"

"In this country comparatively little has been done; and until quite recently, no machinery whatever, especially constructed and adapted for the production of solid fuel from peat, has been put in practical operation. The impression has seemed to prevail that the material is to be treated like clay, and that brick machines might be readily made to work the desired results; but the idea is erroneous. Numerous brick machines have been tried, some of them very ingeniously and perfectly constructed, and which have been demonstrated to be also perfect in their operation upon clay; but have proved an entire failure when peat was substituted instead. It is true, however, that with two or three of these machines peat has been compressed into compact blocks having the appearance of great solidity *when moist;* but so soon as the moisture is evaporated, as it will inevitably be in time, the mass is found to be porous and light.

"Quite a number of *presses*, some of them exceedingly ingenious in device and construction, and powerful in their operation and supposed to be so arranged as to press the water out of the mass, and leave the material compact and nearly or quite dry, have been built and tested, with failure of success as a uniform result; and although the records and reports of such cases, both in Europe and this country, are sufficiently extensive to explode the idea that any profitable results can be obtained by pressure alone, there are, nevertheless, those who are still persistent in their efforts to accomplish it by such means, and are now devising new methods of applying powerful pressure, which, were they to consider but for a moment the nature of the material in its crude state, would be seen at once to be clearly of no avail. The famous Beater press, which, within a few years, has acquired great notoriety, and is now probably the most powerful press in use for hay, straw, cotton, tobacco, &c., has been tried several times in New York and Massachusetts, by parties sanguine of success, but with only the same results as with other presses."

Ashcroft and Betteley's process.—"Under the patents of Ashcroft and Betteley operations were commenced in Massachusetts in 1864. Their process, as claimed, provides for separating the fibrous from the thoroughly decomposed portions of the peat, by combing; in doing which the mass is reduced to a pulp, which is then conveyed into high tanks where it is proposed to allow it to remain until by its own weight and pressure it shall have become sufficiently dense to be formed into blocks, when, by opening a small gate near the bottom of the tank, it is presumed that the pressure of the superincumbent mass will force it out in a continuous sheet, of uniform size, as regulated by the orifice, which may then be cut in blocks and laid away to dry."

Roberts' process.—The machinery set up at Pekin, New York, in 1865, is the invention of Mr. M. S. Roberts. The following description of it is from the *Buffalo Express*, of November 17, 1865: "In outward form the machine was like a small frame house on wheels, supposing the smoke-stack to be a chimney. The engine and boiler are of a locomotive style, the engine being of thirteen horse power. The principal features of the machine are a revolving elevator and a conveyor. The elevator is seventy-five feet long, and runs from the top of the machine to the ground where the peat is dug up, placed on the elevator, carried to the top of the machine, and dropped into a revolving wheel that

cuts it up, separates from it all the coarse particles, bits of sticks, stones, etc., and throws them to one side. The peat is next dropped into a box below, where water is passed in sufficient to bring it to the consistency of mortar. By means of a slide under the control of the engineer, it is next sent to the rear of the machine, where the conveyor, one hundred feet long, takes it and carries it to within two rods of the end; at which point the peat begins to drop through to the ground to the depth of about four or five inches. When sufficient has passed through to cover the ground to the end of the conveyor—two rods—the conveyor is swung round about two feet, and the same process gone through as fast as the ground under the elevator, for the distance of two rods in length, and two feet in width, gets covered, the elevator being moved. After the eighteen rods are covered, the machine is moved two rods ahead, enabling it to again spread a semi-circular space of some thirty-two feet in width by eighteen rods in length. The same power which drives the engine moves the machine. It is estimated by Mr. Roberts that by the use of this machine from twenty to thirty tons of peat can be turned out in a day." Four men are required to run it.

In this process it is to be observed that the method requires the addition of a very considerable quantity of water, before the peat can be treated; whereas a great desideratum has ever been to discover some process by which the large amount of water the peat already contains in its natural state may be discharged.

Hodges' process.—Mr. James Hodges, of Montreal, after considering the many difficulties in the way of manufacturing peat successfully, conceived the idea of a manufactory complete, which might be made to float about in the bog, excavating, pulping, manufacturing and spreading out the pulped peat to dry, until some seventy per cent. was evaporated, or it was fit for carriage to the store or to market. After three years' experience, he arrived at the conclusion that it may be effected in the following manner:

"An extensive, undrained bog, from eight to twelve feet in depth—or if deeper the better—have been selected, the first process is to trace out at some distance from the margin, a contour level line of say several miles in extent. Along this line, a space of some nineteen feet in width must be cleared and the live moss or turf entirely removed; by the side of this a space of ninety feet in width is to be cleared and drained to receive the pulped peat.

"At one end of the contour line before mentioned, a barge or scow, eighty feet long, sixteen feet beam and six feet deep, must be constructed, and launched into a hole in the bog dug to receive her. The barge or scow is to contain all the machinery necessary for the complete manufacture of the peat.

"At one end of the scow is placed a pair of large screw augers, eleven feet in diameter, which, being provided with proper shafting and gearing, are made to revolve by means of a steam engine placed on the rear of the vessel. These augers, or screw excavators, bore out the peat in precisely the same manner that a common auger bores itself into wood; and, the scow being made to move onward as the boring proceeds, it follows that a channel nineteen feet wide, of from four to six feet deep is formed, in which the scow, with her burden of machinery, floats, the water from the adjacent peat draining into and filling the canal as fast as it is made, the usual speed of the scow being some fifteen feet per hour.

"A competent engineer should determine and lay out the canal level, as well as arrange its water supply, upon which depends in a great measure the successful working of the whole.

"The peat, when bored out or excavated by the screws, is delivered into the barge, and conveyed by means of an elevator to a hopper, into which it is tumbled. It then passes through machinery which removes all sticks and roots, and, eventually destroying the fiber, reduces the peat to a homogeneous mass of soft pulp, like well tempered mortar.

"This pulp then passes into a long spout or distributor, which, extending at right angles over the side of the scow, spreads out the pulp on the leveled moss by the side of the canal in a thin slab nine inches in thickness and ninety feet in width.

"After the slab or pulp has been deposited for a couple of days, or in hot weather for a shorter period, it begins to consolidate, and shows symptoms of cracking. Immediately any cracks make their appearance, it must be marked out by drawing a frame-work carrying curved knives placed six inches apart across it. A few days more harden the pulp so that by the aid of boards a man can walk on it, and mark it longitudinally with cuts eighteen inches apart.

"In about a fortnight, the shrinkage of the pulp-slab causes the cuts made in it to open, and the whole presents

the appearance of an immense floor covered with bricks eighteen inches long by six inches wide. As soon as the bricks are sufficiently hard to bear handling, they are separated and "footed;" that is, stood up on the ends, five in a stook, with one across the top, in which position they remain until dry enough to be removed to the store or to the market.

"In the manufacture of peat fuel considerable experience is required, and unless attention is paid to matters of detail, apparently of little importance, serious loss may be the result.

"In forming, or uncovering the canal track, nothing more is required than that the turf, or live moss, about six inches in thickness, together with the roots of all trees upon the surface of the bog, should be removed; and as upon all undrained bogs the roots of such stunted trees as grow there are all on the surface, this operation is easily accomplished.

"In the preparation of the pulp-beds great care is required, and a surface should be obtained as level and even as possible. The roots of all trees must be removed, and this is more readily accomplished with the trees themselves, by which means considerable labor is saved, one man pulling them down on one side, while another with an ax cuts the lateral roots at some distance from the stem, leaving the smaller portions behind. The long grass, shrubs and rank mosses are cut down with a short scythe, and used in filling up any irregularities in the surface. Drains from nine to twelve inches deep should also be cut and covered over with the spare turf taken from the canal track. The soil from the drains may also be used in leveling and filling up inequalities in the pulp-bed. In some places, where the growth of shrubs has been very rank and coarse, the turf upon the whole surface of the pulp-beds has been cut into strips and inverted; but it is better to cut drains, and leave the turf in its natural position. The soft pulp, when poured upon it in a semi-fluid state, advances lava like, pressing down any small branches of shrubs and the long grasses which may be standing in the way of its onward progress.

"The pulp should not be deposited nearer than five feet of the canal, and upon this space may be placed any surplus moss or turf from the uncovering of the canal track, which will not only keep the pulp in place, but also form a road and towing path for the canal. At the rear, or ninety feet

from this bank, a double thickness of turf is all that is necessary to complete the pulp-beds.

"The canal track and pulp-beds being prepared, and the scow with its machinery in position, nothing more is required than to set it in motion, giving the necessary feed, say one and a half inches for each revolution of the screw excavators, which may be increased to three inches if necessary. As the screws revolve, they cut off continuous slices of the peat, which, by the assistance of a couple of men, are delivered, through the rear of the shield the screws work in, into a well in the bow of the scow. These men also remove any large masses of extraneous material, such as pieces of wood, roots of trees, etc., which may work in. It is sometimes required, when working in peat which is very full of roots, to have a man placed in front to remove them as they are brought up by the knives of the screws—roots as much as a man can lift being occasionally excavated.

"After the peat is delivered into the well, it is carried by means of an elevator, and tumbled into a hopper, from which it passes through the stick and fiber catcher, the pulping and distributing trough, without any assistance whatever; it being only necessary to see that the stick catcher is kept clear, and, occasionally, when the pulp is too dry, to turn on a pump until it is reduced to a proper consistency.

"The leveling of the pulp should be done as evenly and smoothly as possible. A few days' experience will enable any intelligent man to accomplish this; and upon its being well done depends, in some measure, the quality of skin upon the peat—so essential, not only in shedding the rain and preventing cracking from the sun, but also in giving a permanent toughness to the bricks.

"The crew of the scow, all told, will number six, including the master who keeps the knives of the screw excavators clean, and sees that all is going on right; two men at the screw excavators, one engine man, one man leveling the pulp, and one man to tend the stick-catcher and pulping-spout.

"The marking of the pulp-beds into transverse cuts, at six inch intervals, is proceeded with as soon as the pulp begins to set, or becomes so tough that when the incisions or cuts are made in it by the knives, they do not re-unite. The operation is performed by two men, one on each side of the pulp-bed, who by means of a rope pull a frame-work of wood, carrying curved knives to and fro across the bed. A

little practice enables them to perform the work with great accuracy. The longitudinal cuts, eighteen inches apart, are made as soon as the pulp is sufficiently hard to bear the weight of a man upon a plank laid on its surface. It is performed by pushing a circular plate of iron, which, cutting like a circular saw, severs the peat to the very bottom. In making these last cuts, care should be taken that they go quite through the peat, so that surface water from rain may freely pass off through the drains in the pulp-beds into the canal.

"Upon the state of the weather depends the time when the next operation should be performed; but if the pulp-slab, when first spread out, is not more than nine inches in thickness, which it should never exceed, then a fortnight will be ample time to harden the bricks for footing.

"The footing is done by gangs of men and boys, one man and three boys working together; the man, using a suitable tool, separates the bricks, which the boys foot, or place in groups or stooks of five; four stand on their ends inclining to each other, with their tops touching, the fifth being balanced horizontally upon them. A man and three boys will foot four thousand bricks in a day.

"After the bricks have been exposed to the weather for a few days, they should be refooted or turned, two boys handling four thousand as a day's work.

"Nothing now remains to be done but to wheel the bricks, when sufficiently dry, into barges, and convey them to the store."

Mr. Hodges plan of operation is rather extensive, not to say immense, yet wherever the necessary area and supply of peat can be found, there can be no doubt but his method would prove as profitable as any other, and perhaps more so. It has been put into successful operation in Canada, and has furnished a fuel that, used on the Grand Trunk railway, produced the most promising results.

Elsbery's process.—This was invented by Dr. Louis Elsberg, of New York city, in 1864, and his experimental machinery was erected at Belleville, N. J. It is based on the principle of the *Exter process*, an invention made in Bavaria, in 1856. In the latter method the bog is laid dry by drains, and the bushes and grass turf removed down to good peat. A gang of three plows is then propelled by a portable steam engine over the surface tearing up the peat to the depth of about an inch. It is then pulverized where it lies by a harrow, drawn by oxen. After several turnings

by an instrument like our cultivator, in order to expose it to the air and sun, it is gathered by scrapers and loaded in wagons, and conveyed to the press or magazine, where it is further pulverized by passing it through a series of toothed rollers. It then enters a very complicated drying oven, where by a series of spiral rollers it is moved over successive shelves or floors, the interior of the oven being heated partly by steam and partly by hot air. The floors consist of steam-chambers, made of iron, and the hot air made to circulate over the peat at a temperature of 120° to 140° Fah. The fine peat is thence conveyed to the press which forms it into bricks of suitable size for locomotives. It has a specific gravity of 1.14, and forms an excellent fuel. One cubic foot of this pressed peat weighs 72 pounds. The process of Elsberg varies from this in having a cylindrical pug-mill in which the peat, air-dried as in Exter's process, is further broken, and at the same time subjected to a current of steam admitted through a pipe and jacket surrounding the cylinder. The steam peat is then condensed by presses similar to those of the Exter method, fed directly from the mill. In this way the complicated drying-oven of Exter is dispensed with. Samples of peat prepared by this method have, according to Prof. Johnson, a specific gravity of 1.2 to 1.3.

Leavitt's process.—Mr. T. H. Leavitt, of Boston, Mass., in 1865, invented the following machinery and method of manufacturing peat: "The machinery consists of a strong tank or cistern, three feet in diameter, and six feet high, supported upon a stout framework about four feet above the floor of a suitable building, which should be near the bog, and is best constructed on a side-hill so that easy access can be had to the lower story on one side from the base of the hill, and to the second story on the other side. The top of this tank is open, and even with the floor of the second story. Within the tank, and firmly fixed to its sides, are numerous projections of a variety of forms, adapted to the treatment of the material in its several stages as it progresses through the mill, which is divided into three apartments; through the center of the tank revolves an upright shaft to which are affixed knives and arms varying in form and structure to correspond with the stationary projections in each apartment; below the tank is a receiver, or hopper; and under this is a moulding or forming machine, two feet in width and twelve feet long, of like simple construction, which receives the condensed material from the hopper and delivers it in blocks of any desired form and size. The whole

is adapted to be driven by a small steam engine and requires about six and ten horse-power respectively for the two sizes of machines as at present constructed, of the capacity of fifty and one hundred tons each of crude peat, per day of ten hours.

"The crude material is brought from the bog in ordinary horse-carts, or on small cars running over a cheaply constructed tram-way, to the mouth of the mill, in the floor of the second story of the building, where it is dumped or shoveled into the mill in any convenient quantity; but the arrangement is such that only a given amount is admitted, and under treatment at one time, so that all parts have a uniform and regular supply. The treatment is such that the original organization of the peat is entirely destroyed; in the second stage, the air, of which a large amount is contained in its cells, is ejected; advantage is taken of some of the natural properties of the material, and the mass is condensed in the moist state in the lower part of the mill, from whence it is delivered into the hopper of the moulding machine, and is discharged in a continuous line of moulds (which are fed into the rear part of the machine by a boy), at the rate of fifty to one hundred tons per day of ten hours. The work of removing the blocks to the spreading ground is easily accomplished; and they are exposed in the open air for drying, in much the same manner as bricks are exposed in a brick-yard.

"The amount of water contained in well drained peat is ordinarily from 65 to 75 per cent., varying according to the character of the material and the drainage of the meadow; so that the weight of dry, hard fuel from the product of a day's operations, is from 12 to 17 tons, or 25 to 35 tons, from the two sizes of machines respectively.

"The water remaining in the blocks as they come from the mill can be got rid of only by evaporation, which goes on very rapidly after this method of treatment; and the fuel is, at the expiration of about six to ten days, sometimes in four or five, in condition to be housed or transported to market."

The Rae process.—This invention, patented May 22, 1866, was made by Dr. Julio H. Rae, of Syracuse, N. Y. It is thus described in a circular issued by the owners: "The peat is delivered into a top of a cylinder placed in a vertical position, in which is a revolving shaft, to which are permanently fastened, near its top, two or more arms, which are set at an angle with the axis of the shaft, their

office being to draw down the peat from the top of the cylinder and feed it along into that part of the cylinder where it will be subjected to the action of the revolving knives or cutters, which are found on the under side of the blades projecting from the shaft, and placed at an angle with the axis of the shaft. The number of blades can be varied, and also the number of cutters on the blades. In a cylinder of about four feet in length about seven such blades can be used advantageously. They are arranged around the shaft in spiral order, and are so inclined that the front edge of each blade is higher than the rear edge, whereby they are made to give a downward impulse to the peat as they revolve. Below the lowest blade is a propeller, consisting of a series of blades, each bent so as to form a section of a screw, but the blades are fastened to the shaft in the same plane. The office of the propeller is to seize the peat and press it downward through an opening in the bottom of the cylinder into a chamber, wherein are placed conveyors that convey and force the peat into condensing and discharging tubes that project through the sides of the chamber. The condensing tubes and the conveyors are placed in a horizontal position, the ends of the conveyors reaching a little way within the tubes, but they can be arranged in any other desired position. The inner ends of the tubes are cylindrical and the tubes gradually decrease in diameter for about one-half their length, so as to resemble the frustum of a cone. From or near the point of their greatest contraction, the tubes assume a shape nearly semi-cylindrical, retaining that shape to their outer ends, and gradually increasing again in diameter. The rounded upper side of the tubes at their discharge end, gives a corresponding rounded form to the peat that is forced through them, but any other form may be adopted. The peat is received from the ends of the discharging tubes on the ground or upon a traveling belt or platform, and may be cut up immediately into proper lengths, convenient to be handled in drying.

"There are four sizes of these machines, viz.:

"No. 1, requiring about one horse-power, designed for farmers, is capable of turning out per day what, when properly dried, will make from four to six tons of merchantable fuel.

"No. 2 is double the capacity of No. 1, requiring about two horse power.

"No. 3 is a combination of Nos. 1 and 2, nearly double their capacity, requiring from four to six horse power.

"No. 4 is more than double the capacity of No. 3, requiring from eight to twelve horse power, and capable of turning out per day enough peat to make, when cured, forty tons of merchantable fuel."

These machines were run, a few years ago, by the *Minnesota peat company*, of St. Paul, and the *Minnesota packet company*. In simplicity of construction, and in power and capacity, these mills seem to excel. They also have a very great advantage over Leavitt's and all others employing moulds for giving shape to the condensed peat. The use of the moulds is cumbersome and expensive.

The Aubin process.—This method was inaugurated at Meriden, Conn., in 1870. It covers different patents, designed for economizing labor, obtained in 1868 and 1869. The following description is from the circular issued by the agent in New York, in 1870: "If the manufacture of the fuel is to be carried on upon a limited scale, of say five tons, or thirty to fifty tons per day, hand labor, with the ordinary long-handled shovel, is probably the simplest and cheapest way to get the peat *up* from the deposit: it is then thrown into wheelbarrows, and if the distance is not too great, can be dumped directly into the mouth of the elevator. When peat to be dug is at a sufficient distance from the machine to justify or necessitate the use of cars, then a set of double portable rails can be employed. When the swamp cannot possibly be drained, the use of scows or wire tramways may be resorted to. For large operations, to supply railroads or manufacturing districts, a steam digger, on a scow, or on tracks, will be, of course, cheaper than hand labor.

"The peat, once dug and conveyed from the pit, falls into a large hopper, from which a screw elevator, especially devised for peat, propels it up to the slicing and cleaning apparatus, placed above the grinding and puddling cylinder. When the bog cannot be drained, the peat taken from it contains, of course, too large a proportion of water for thorough and economical working; in such case the elevator is furnished with a *wringer*, which can be operated or not, at will, and arranged to separate the surplus water as the material passes through it. The peat, in a fit condition to work up well, being elevated in a continuous and evenly-fed supply, falls into the *slicer and cleaner*. This portion of the apparatus is composed of a series of rapidly revolving cutters, which owing to their peculiar form and position, slice the peat and separate from it all hard or foreign substances.

From the slicer and cleaner the peat, *still better fitted* for grinding, falls into the *grinding and pulverizing* machine. This is a cylinder three feet in diameter by six feet long, and made of boiler-plate iron. The cylinder itself is stationary, but within is a large revolving iron drum, eighteen inches in diameter. To this are bolted in two spiral rows, forty-four cast iron knives, all nine inches long, but of three slightly varying shapes, and three sizes, increasing toward the mouth of the cylinder. These knives are named, according to size, *cutters*, *grinders* and *puddlers*, and remind one very much of the three kinds of teeth, incisors, canines and molars. They are between one and three inches in thickness and have each several square corners, but no sharp edges. Attached to the inside of the cylinder, under the drum, is a corresponding fixed series of twenty-two nearly crescent-shaped iron knives. Between these and the revolving knives the peat is carried along, cut, ground and perfectly "pulped," and falls, finally, into a sluggish stream, through a spout a foot or more square, into a large wooden moulding hopper. Along one side of the cylinder is the "stone pocket," a long, spacious iron trough, placed horizontally. It has an exterior cover for removing its contents, and communicates with the interior of the cylinder, to which it is attached in such a position that the revolving knives necessarily throw any stone or other hard substance into the pocket, instead of crushing it against the fixed knives. This contrivance is simple and effective. Under the moulding hopper is a series of rollers set in a long, stout frame, about four feet high and three feet wide, called the *conveyor*. One man puts a shallow wooden box or mould into a trough of water. Another submerges and removes it and lays it on a little branch of the conveyor. Here a wooden *pusher* strikes it a blow and sends it on the main conveyor; another drives it into the narrow space under the moulding hopper, where the weight of the peat and the hopper's peculiar shape fill it, before another blow from the same pusher forces a second mould under the hopper and expels the first. Other moulds rapidly follow, moving the first slowly along till a third pusher thrusts it upon a little side-shelf, from which two men easily set it down with eleven of its fellows, in three piles of four each, upon a wooden four-wheeled car.

"The drying field is a large, smooth meadow, crossed by two main tracks, running 1,500 feet in a straight line from the machine, and intersected at right angles by cross-tracks, 150 feet apart, and running 300 feet each way from the

main tracks, with turn-tables at the junctions. These tracks are three feet wide, and laid with iron rails near the machine, and wooden rails where the wear is less. There is a short switch-track, built so that three cars, instead of two, can be run up to the conveyor at once, though only one can be loaded at a time.

"The pulverized peat is so tenaciously adhesive that the moulds used are of a novel construction, to meet this difficulty. They are four and a half feet long by two feet wide, and five inches deep. The corners are secured with iron clamps, and an extra strip is nailed at each end to serve as a handle. The bottom is removable, and across it are fastened, at equal distances, ten pine strips, about two and a half inches high and an inch wide at the base, but beveled off on each side to one-third that thickness at the top. These moulds cost about $2.50 each, and about 500 of them are in use.

"Each car is propelled by two men. Four men unload it. Two seize a mould, one at each end, walk briskly away with it to the place where it is to be dumped, tip it wrong side up, jerk off the side frame, and drop it on the grass, pick the bottom off the sticky mass of "pulp," toss it into the frame, catch up the empty mould again, and trot back to the car. This process is repeated with the other moulds. When first emptied, the wet, black peat is just dense enough to keep its shape; but in the warm season it hardens so fast that within forty-eight hours it will resist the severest storm, and then resume the drying process when the weather clears, at the point where the rain interrupted it. Strange as it may seem, this peat fuel absorbs much less water than wood does, and hence can be dried on the bare earth, under the open sky. It does not even adhere to the grass, which, however, is soon worn away.

"As it dries the peat shrinks to about half its first thickness, changes color from black to brown, and cracks along the grooves, so that when it is half dry, boys can easily 'hack' it—*i. e.*, break each mould into about twenty pieces, and pile it in two or three small, loose heaps. In two weeks or a month, according to the weather, the peat is dry enough to be gathered by men or boys, in baskets, barrows or carts, and stored in covered wooden sheds, with wide cracks between the sideboards to admit air, and the ends left open.

"The capacity of the three foot cylinder per day, at thirty revolutions regularly fed, is seventy-five tons of dry fuel.

Whatever be the number of revolutions, the moulding machine adapts itself to the demand.

"The cost of machinery, including *engine, boilers*, and entire equipment, is dependent on the amount of fuel it is required to be produced by the operator; being for small works, intended for horse power—say five tons per day—about $200; for a product of 250 tons per day, about $20,000—an engine of eighty horse power being required to drive the latter."

Haight's process.—This is the invention of Mr. W. Z. Haight, of Delavan, Faribault county, Minnesota. It has been successfully operated at Fairmont, in Martin county, and at Wells, in Faribault county. At the latter place it was taken for locomotives by the Southern Minnesota railroad. The works at this place have been thus described by the Wells *Atlas*:

"A bold bank is selected, in order to secure a good drying yard close to the bog, on which the engine and machinery is located, where a frame is erected 12x16 feet and eight feet high, from the top of which a wooden car track, supported by a light trestle work, descends to the surface of the bog, a distance of 150 feet, with a fall of 25 feet. From that point the track is made in sections of 14 feet each, which are portable, thrown down on the surface of the bog, and with the use of a few curved sections, the track can be shifted in any direction so as to excavate the entire bog that is in reach. This track can be extended many hundred feet out across the surface of the bog, if desired, giving access to several acres. On this track one car plies, which is loaded by three men who stand by the edge of the excavation, (water being lowered about six inches from the surface to insure dry feet). The sod is cut up into chunks, with sharp, diamond pointed, spade like tools, from two to four feet deep, according to depth of the peat, and left submerged in the water until the car is at the proper place, when the chunks are pitched from the water into the car, with common four-tined forks, and when the regular amount, about two tons, is loaded into the car, it is hauled by the power of the engine up the incline, over the large platform under which the mill is situated, and by a simple contrivance the car is made to dump its load, also to unship the windlass from the power that hauled it up, being no trouble to the feeder, who at will starts the car back, which, in going down the inclined plane gains momentum that carries it out hundreds of feet along the level track. Meanwhile the men in the bog do the necessary work, cut-

ting chunks for another load, so there is no time lost in the absence of the car. The feeder, who stands on the platform, then feeds the turfy mass into the mill, which is an ingeniously constructed machine, though simple, very durable, so arranged with knives cutting through grates, pickers, conveyors, etc., that it will treat the most fibrous mass or sod peat that can be produced and reduce it to a pulp or jelly at once, and that too without clogging or winding in the machine. Owing to its perfectness it renders it unnecessary to strip off the top sod from the bog, all that is necessary being to mow off the grass or other vegetation, if there is any growing thereon, thereby saving considerable expense in labor, also a good part of the fuel, when ground up with the lower or more decomposed peat. By the conveyers, the peat, as fast as pulped, is forced through a pipe into a vat with dump bottom, which holds one cart load. Here the cartman receives it by driving his cart under and dumping a load into it from the vat, adjusts the vat botton, drives to the spreading ground, dumps his load from the cart and returns, during which time another load has accumulated in the vat. The pulp is dumped on a smooth plat of ground, where a man with a common shovel spreads it into beds four inches thick, nine feet wide, and as long as necessary, setting up boards at the sides to keep it from spreading, who is followed by another man with a tool similar to a rolling colter for a plow, fixed on a long handle, who cuts the bed of soft peat into blocks 8x13 inches, which commence to solidify at once by the ejection of the water, and in one or two days, by the use of a light tool made expressly for the purpose, these blocks are tipped up on edge or corners promiscuously, so the sun and wind can have a better chance at them. In two days more they are piled in open ricks, in which posture they remain on an average, two weeks, when they are housed to finish drying.

"The cost, the past season, of running this establishment, at a capacity of 60 tons of wet or 15 tons of dry peat per day, (equal at least, when properly prepared and well seasoned, to 15 cords of good wood,) is as follows:

Superintendent	$2 50
Engineer per day	2 75
Three men in bog to load car	6 00
Man to spread pulped peat into beds	1 50
Boy to turn up blocks	1 00
Two boys to rick up blocks	2 00
Man to feed peat into mill	1 50
Boy to drive cart	1 00

Man to cut peat into blocks	1 50
Cart horse	1 00
One ton peat at cost price for engine	1 72
For oil, and wear and tear on engine	1 00
Add 22 cts. per ton for housing 15 tons, one day's product	3 30
Total	$26 77

"All the peat is being sold at $4.00 a ton, except that to the Railroad Co., at which price the yield per day would be $60.00. Subtract from that the amount of expenses, $26.77, leaves $33.23—a handsome profit. The price of peat per ton should be estimated equal to that of good wood per cord, sawed and split for stove fuel, and unsawed for steam powers.

"The cost of an establishment, excepting engine and drying sheds, capable of manufacturing 100 tons of wet peat, or 25 tons when dry, per day,—mill $400. Frame, trestle-work, car track, car, dump cart, etc., about $300.

"This is the cheapest mode of utilizing the peat, both as to the matter of machinery and labor, that we have any account of, and as it has been practically proven a success at this place, we see no reason, if the same plan be followed, why it should not be equally successful elsewhere."

It must be admitted, however, that although great progress has been made in this country in the construction of machinery for the manufacture of peat, a great deal of labor and capital have been consumed to no purpose. Many of the companies that, with hundreds of thousands of capital each, sprang into existence a few years ago when a feverish excitement spread over the country in reference to peat, have entirely disappeared, and nothing remains to witness their folly but the idle and rusty machinery they "invented" or purchased, and the almost forgotten titles to thousands of bogs, which they eagerly bought. This phase of the peat enterprise is not, however, the just criterion by which to judge of it. It is only an index of a deep seated want. The unmatured developments of the first peat agitators in this country were enough to start into a flame the desire of the people for relief from the high prices of wood and coal. The result was a wide-spread speculation. From this there has been a corresponding reaction. This however does not in the least affect the real value of peat as a fuel, nor detract from the credit of the inventions that have been made. Sober-minded men, consumers of large quantities of fuel, have in some instances, and in various parts of the country, steadily and persistently followed up the matter. Here and

there a railroad, an iron-furnace, a manufacturing establishment or a family has continued to produce and use peat fuel until it has won much of its lost favor, and is now in actual demand by consumers of the heaviest class, who are ready to purchase largely and at highly renumerative prices. This demand however is one that will not be met by anything less than a constant and steady supply, equal to its requirements. It calls for the best machinery, equipped with the best facilities and aids, and backed by large capital. The following extract is from a letter to the writer from T. H. Leavitt, of Boston, dated Dec. 3, 1873:

"The most active and really practical operations in peat and its utilization of which I have present knowledge are in the lake Superior iron regions of Michigan.

"In October last I made a trip there and at Ishpeming, near Marquette, witnessed the successful use of peat fuel for the smelting of the ores of that region. Operations more or less experimental have been quietly prosecuted there during the last four years. A furnace of moderate capacity, especially adapted for smelting with peat, has recently been constructed and was put in operation about ten days before I was there, and was then in most perfect operation, and was considered a decided success as regards economy, ease of management, quality and quantity of metal produced, &c.

"The fuel was very poorly made, (lacking the density which might easily be given it, weighing 35 lbs. per bushel, whereas it might probably be made to weigh 40, 45 to 50 lbs. at no greater cost,) and in many things they lacked experience, but all appeared enthusiastic of their success. They commenced with charcoal and ten per cent. peat, gradually increasing until at the time I was there they were using upwards of 70 per cent. of peat, and were only waiting permission from the agent to use *all* peat, which the furnace men assured me they were convinced would be not only successfully done, but be actually better than to use any mixture of charcoal. The metal produced was regarded as fully equal in quality and perhaps superior to the very best grade ever produced in that region.

"Considering the immense quantities of peat in that region and the success attained with a fuel so poorly manufactured, I can but feel that for that region and its iron interests the peat fuel enterprise has yet a prominent and very important place to fill.

"The cost of producing the fuel there is stated to be $3 per ton."

(h) *The value of peat for fuel.*

It is not intended here to attempt the details of experiments and comparisons with the view of demonstrating the usefulness of peat as a fuel for domestic and metallurgical purposes. That has already been abundantly attested by the approval of railroad engineers, who have used it, and are still using it, both in this country and in Europe, and of owners of furnaces and manufacturing establishments, as well as by the testimony of chemists and government commissioners that have reported on its working, in France, in Germany and in America. The following tabulated comparisons are given for the purpose of placing within reach of those within the state interested in this subject, reliable means of estimating the cost of peat, and its heating capacity, compared with other kinds of fuel. These are the results of careful and long continued experimentation:

(1) *Weight for weight.*

The following comparisons are given by Gysser, on certain woods and charcoals in Germany, the basis being equal weights of each.*

Beech wood, split, air-dried	1.00
Peat, condensed by Weber and Gysser's method, air-dried with 25 per cent. of moisture	1.00
Peat, condensed by Weber and Gysser's method, hot-dried, with ten per cent. moisture	1.48
Peat charcoal, from condensed peat	1.73
The same peat, simply cut and air-dried	.80
Beech charcoal	1.90
Summer-oak wood	1.18
Birch wood	.95
White pine wood	.72
Alder	.65
Linden	.65
Red pine	.61
Poplar	.50

"The general results of the investigations hitherto made on all the common kinds of fuel, are given in the subjoined statement. The comparisons are made in units of heat, and refer to equal weights of the materials experimented with." [*Peat and its uses*, p. 102.]

*See Prof. Johnson's "Peat and its uses," p. 97.

Air-dry wood		2,800	
Air-dry peat	2,500		3,000
Perfectly dry wood		3,600	
Perfectly dry peat	3,000		4,000
Air-dry lignite, or brown coal	3,300		4,200
Perfectly dry lignite, or brown coal	4,000		5,000
Bituminous coal	3,800		7,000
Anthracite coal		7,500	
Wood charcoal	6,300		7,500
Coke	6,500		7,600

(2) *Bulk for bulk.*

One of the greatest obstacles to the general use of peat for fuel consists in its bulkiness. Uncondensed peat, air-dried, will occupy two and a half times the amount of storage room that anthracite coal will, the weights being equal. As it is also of lower heating capacity, requiring two and a quarter tons of peat to equal one of anthracite, the bulk required for the peat would be equal to five and five-eighths times that of coal. By condensation peat is greatly improved in heating capacity and in convenience in handling. Johnson gives the following as the composition and density of the best condensed peat, compared with that of hard wood and anthracite.

In 100 parts.	Carbon.	Hydrogen.	Oxygen and nitrogen.	Ash.	Water.	Specific gravity.
Wood	39.6	4.8	34.8	0.8	20.0	0.75
Condensed peat	47.2	4.9	22.9	5.0	20.0	1.20
Anthracite	91.3	2.9	2.8	3.0	....	1.40

The heating power of peat, of the different qualities, taken from different depths, compared with pine wood, are thus given by Prof. Johnson, after Karmarsch, equal bulks being taken instead of equal weights:

100 cu. ft. of turfy peat, on the average,	=	33	cu. ft. of pine wood in sticks.				
" fibrous	"	"	= 90	"	"	"	
" earthy	"	"	=145	"	"	"	
" pitchy	"	"	=184	"	"	"	

The following also shows the relative heating effect and weights of an English cord of oak wood (taken at 100 as the standard) and of several European air-dried peats, bulk for bulk, quoted from Brix by Prof. Johnson:

	Weight per cord.	Heating effect.
Oak wood	4,150 lbs.	100.
Peat from Linum, 1st quality, dense and pitchy	3,400 "	70.
" " 2nd quality, fibrous	2,900 "	55.
" " 3rd quality, turfy	2,270 "	53.
Peat from Buechsenfeld, 1st quality, hard and pitchy	3,400 "	74.
Peat from Buechsenfeld, 2d quality	2,730 "	64.

(i) *What has been done in peat.*

A few years ago the question of manufacturing peat was put to a practical test by the *Minnesota peat company*, located at St. Paul. The Rae machinery was used. The work was continued long enough to show that it was not profitable at the current prices of wood, and was suspended. A similar attempt was made at Red Wing, about the same time, and with the same result. The process used there is not known. In southern Minnesota Mr. W. Z. Haight has prosecuted the manufacture more successfully, and is now engaged in erecting the necessary buildings and apparatus for working peat by his process the coming season, at Lura station, in Faribault county. He produced, at a cost of two dollars per ton, a good fuel at Wells, in the summer of 1871, with his machinery, which was well suited for use in locomotives. The stoppage of his work there was not due to a failure to produce a good fuel, nor to its being too costly, but, he says, to a lack of demand sufficiently large to warrant extensive operations. His method is described in a preceding section. Except the preparation of small amounts in St. Paul, by Dr. C. D. Williams, for experimentation, the foregoing are believed to be the only attempts that have ever been made in the state of Minnesota, to produce from the peat deposits of the state a fuel for general consumption by any process of manufacture.

(j) *Raw or manufactured peat.*

Some experiments have been made by Dr. C. D. Williams on a fuel made by a saturation of turf-peat with the residuum, or "shale oil," that is a product of the petroleum refineries of Pennsylvania. These trials demonstrate that a good fuel may thus be formed. The combustible material in the turf itself is not so much as in true peat. The analyses of Prof. Peckham show the greater per cent. of ash in excess of that of peat. This shale oil has a carbonaceous composition, not yet certainly ascertained, consisting very largely of carbon and hydrogen, both of which are combustible. The adding of the shale oil to the turf not only increases by so much the combustible material in a given bulk, but improves the quality of the fuel. By this means some of the poor peats may be made serviceable, at a cheaper rate, perhaps, than by the process of manufacture. The following facts in reference to the cost of this shale oil

delivered at Worthington, in Nobles county, are on the authority of Dr. Williams. The residuum can be had for removing it from the vats:

Cost of barrel containing 43 to 45 gallons	$1 50
Cost of filling and drayage to cars, per barrel	50
Charges Pittsburgh, Fort Wayne & Chicago R. R. to Chicago	1 00
Charges West Wisconsin R. R. to St. Paul	1 00
Charges St. Paul & Sioux City R. R. to Worthington	1 00
Add for profits to dealer	1 00
Cost at Worthington per barrel	$6 00

(k) *Practical conclusions on peat.*

1. There is not so much real peat in the state of Minnesota as has been supposed. There is a great abundance of turf, made up of grass roots, containing a large per cent. of ash, not properly called peat, that will furnish, in any exigency, a fuel that will keep a family from suffering. This, however, is not thought the object of the survey to investigate, nor to locate, as it exists, as is often stated in the public press, on almost every square mile.

2. While a good fuel, almost equal to the Iowa coal, can be produced by the manufacture of peat by a process of condensation and evaporation, it is far from certain that it will not cost as much, or more than wood or coal at the present prices.

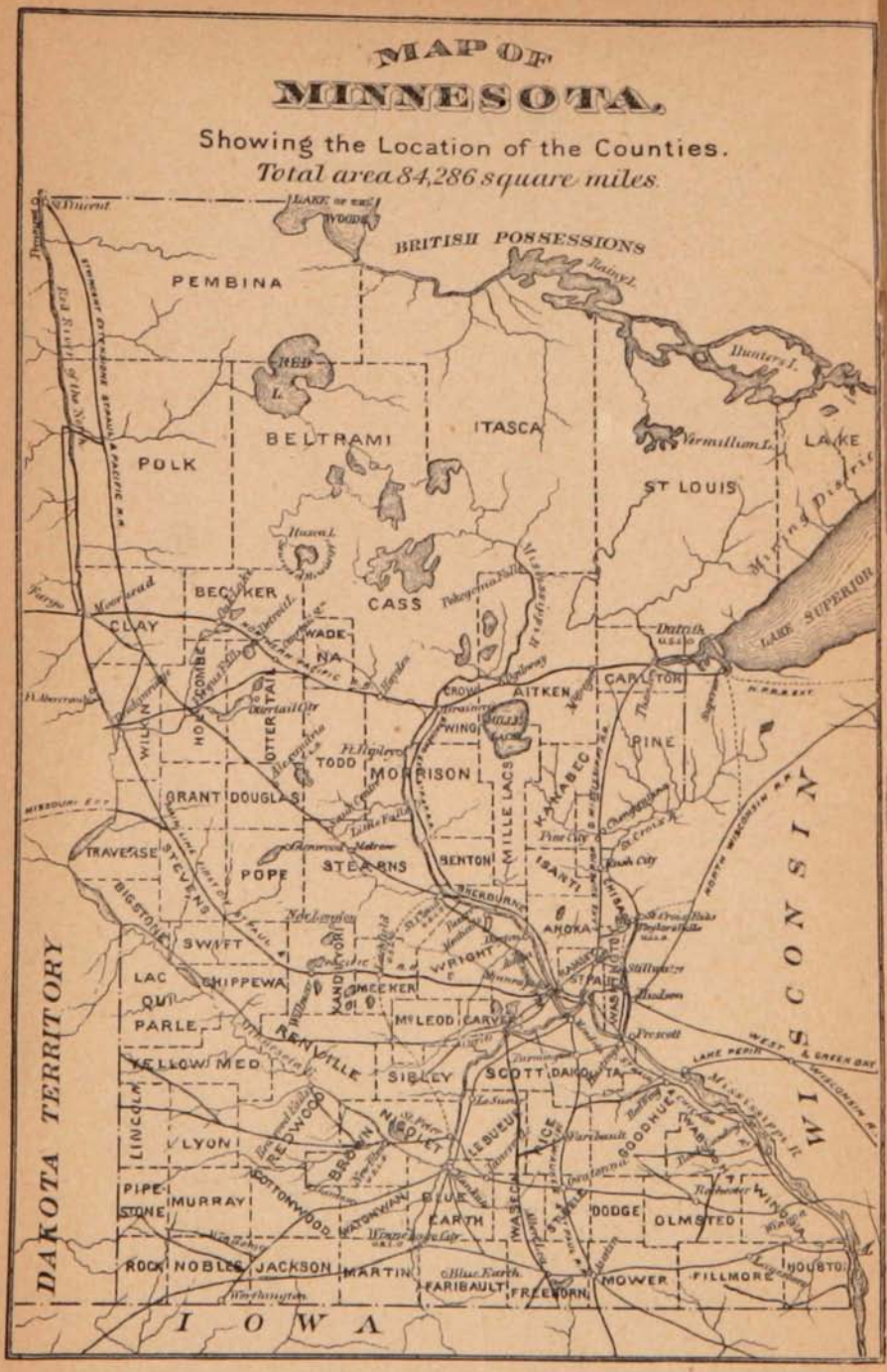
3. If in any part of the northwest peat can be made useful as a fuel by manufacture, it is the woodless and coalless region of southern and western Minnesota.

4. Cautious experimentation should be carried on by those interested in the subject, with the view to test the comparative cost of peat, wood and coal, at the prices current in different localities.

5. The farmers, and others who need fuel, but do not have means to produce a condensed peat, can take out in mid-summer a winter's supply, from the turf peat found on many farms in the prairie region, but they will generally not find it possible to utilize the real peat deposits without some method of manufacture. They will be too apt to crumble, and thus make a slow, smoldering fire.

6. There is no known instance of the existence of peat, in Minnesota along river valleys, on the bottom lands, where the surface is subject, at the present time, to inundation by spring freshets.

7. There are old river channels, or valleys of excavation,


MAP OF
MINNESOTA.
Showing the Location of the Counties.
Total area 84,286 square miles.
BRITISH POSSESSIONS
PEMBINA
RED L.
BELTRAMI
ITASCA
POLK
ST LOUIS
LAKE
CASS
BECKER
CLAY
WADENA
CROW WING
AITKEN
CARLTON
PINE
LAKE SUPERIOR
MORRISON
TODD
GRANT
DOUGLAS
TRAVERSE
STEVENS
POPE
STEARNS
BENTON
MILLE LACS
KANABEC
ISANTI
ANOKA
SWIFT
LAC QUI PARLE
CHIPPEWA
MCLEOD
CARVER
SCOTT
DAKOTA
RENVILLE
SIBLEY
YELLOW MED
LINCOLN
LYON
REDWOOD
BROWN
NICOLLET
LE SUEUR
RICE
GOODHUE
WABASHA
WINONA
PIPESTONE
MURRAY
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON
DAKOTA TERRITORY
WISCONSIN
IOWA

both in the drift and between rocky bluffs, that no longer exist as rivers, which contain considerable deposits of peat.

8. There are depressions in the rolling drift surface, in some localities, which, fed by invisible springs, maintain a nearly uniform stage of water throughout the year, and may hold peat of the best quality.

9. But a small portion of the state has been examined. In that a much smaller amount of peat was found than had been anticipated. Other portions, and especially the central southern counties, are believed to promise more peat than the counties examined. According to Dr. C. A. White, state geologist of Iowa, a peat bearing belt enters Minnesota from the south, bounded, in general, by the Des Moines on the west, and the Cedar on the east.

10. Large quantities of peat are believed to exist in the northern part of the state, many of the cranberry marshes being peat bogs of great purity.

11. The value of peat as a common fuel having been demonstrated, and its existence in sufficient quantities within the state having been ascertained, it becomes a legitimate expedient for the State to stimulate the invention of successful methods of utilizing it by offering rewards.

III.

THE GEOLOGY OF THE MINNESOTA VALLEY.

(a) PRELIMINARY CONSIDERATIONS.

In the fall and winter of 1766 Jonathan Carver explored the valley of the Minnesota, but aside from the mention of the rapids near Shakopee, he has given no information of the geology of the valley, although he claims to have ascended it a distance of two hundred miles above Mendota.

The expedition of Maj. S. H. Long was undertaken in 1823, by order of John C. Calhoun, secretary of war. The

able historiographer to the expedition was Wm. H. Keating, who also served as geologist. He was appointed from the University of Pennsylvania, where he occupied the chair of mineralogy and chemistry. This party ascended in canoes a distance of 130 miles, when they abandoned them for the land, following the valley to Big Stone lake, thence descending the Red River valley to lake Winnipeg. The observations of Prof. Keating on the geology of the Minnesota valley, are the earliest, with the exception of the doubtful accounts of Le Sueur, of the copper mines on the Blue Earth, that we have any knowledge of, although an old map accompanying the *Recueill de voyages*, published in Amsterdam in 1720, shows a "coal mine" located some distance up the Minnesota. They were made with that haste which a traveling geologist always finds unavoidable when he is acting simply as an accompaniment to an expedition, instead of its guide and commander. No time could be spared to indulge the geologist in making such detailed observations as would enable him to state emphatically the bearings of isolated facts, which he picked up, on each other, or to generalize with any certainty. He could simply act as a gatherer of facts. His success lay in the exactness and fullness of his observations. Prof. Keating's geological observations may be summarized in the following descending section :

1. The bluff at Fort Snelling, made up of (a) slaty or splintery limestone, 8 feet; (b) blue limestone, useful for building, 15-20 feet; (c) sandstone, 60 feet; (d) earthy argillaceous limestone 10 feet; (d) crystalline and conglomeritic limestone, 4 feet; (e) a limestone of finer grain and more earthy texture than the last in which the river is excavated at the fort. Keating is the only geologist that has ever reported limestone *in situ* below the sandstone (c) at Fort Snelling. Six miles below the small Indian village Weakaote, he notes the occurrence of the Little Rapids, caused by a sandstone in horizontal stratification "in every respect similar to that found at Fort St. Anthony." The same sandstone is again mentioned as occurring near Kasota, having horizontal ledges of rock overlying it, supposed to be the same as seen at Fort Snelling. The banks of the Redwood river, near its mouth, are said to be made up of "a fine white sandstone."
2. "Primitive rock" was first seen *in situ*, several miles above Patterson's rapids, which are a few miles above the mouth of the Redwood river, and was examined very carefully and described in detail. He remarks in general : "It seemed as if four simple minerals, quartz, feldspar, mica and amphibole, had united here to produce almost all the varieties of combination which can arise from the association of two or more of these minerals." Owing to its confused and various composition, he compares it to that seen at a subsequent period of the expedition, between lake Winnipeg and the lake of the Woods. He regards all that section of country between Patterson's rapids and the upper Mississippi, and thence

to Fort Alexander, at the mouth of Winnipeg river, as underlain by granite and sienitic granite. These rocks are again mentioned at a point five leagues above Lac qui Parle, at the mouth of Spirit Mountain creek.

In the fall of 1835, G. W. Featherstonhaugh's ascent of of the Minnesota occured. His geological observations were very meagre. He took the pains to ascend the Blue Earth a short distance in search of the copper mine of Le Sueur. Keating did not visit it, passing it with the simple remark that he believed the substance obtained by Le Sueur to be a phosphate of iron, judging simply by its color. Mr. Featherstonhaugh says: "The Mahkatoh appears to form about half the volume of the St. Peter's, and is a very rapid stream. The Sissitons we had met, told us it forked eleven times, and that the branches abounded in rapids and shallow places. About twelve, we came to a fork or branch coming in on our right, about forty-five yards broad, and we turned into it, having a well wooded bluff on the right bank about ninety feet high. The stream had very little current, owing to the main branch, which we had just left, rushing down with great velocity and making back-water here. We had not proceeded three-quarters of a mile when we reached the place which the Sissitons had described to us as being that to which the Indians resorted for their pigment. This was a bluff about 150 feet high on the left bank, and from the slope being very much trodden and worn away, I saw at once that it was a locality which for some purpose or other had been frequented from a very remote period. We accordingly stopped there, and I told the men to make a fire and warm themselves, whilst I examined the place.

"As soon as I had reached that part of the bluff whence the pigment had been taken, Le Sueur's story lost all credit with me, for I instantly saw that it was nothing but a continuation of the seam which divided the limestone from the sandstone, and which I have before spoken of at the Myah Skah,* as containing a silicate of iron of bluish-green color. The concurrent account of all the Indians we had spoken with, that this was the place the aborigines had always resorted to to procure their pigment, and the total silence of everybody since Le Sueur's visit, respecting any deposit of copper ore in this or any other part of the country, convinced me that the story of his copper mines was a fabulous

*Myah Skah is "white rock bluff," supposed to be the bluff at Ottawa, in Le Sueur county.

one, most probably intended to raise himself in importance with the French government of that day. Charlevoix having stated that the mine was only a league and three-quarters from the mouth of the Terre Bleu, made it certain that I was now at that locality, and the seam of colored earth gave the key to the rest. Le Sueur's account of the mine being at the foot of a mountain ten leagues long, was as idle as the assertion that he had obtained 30,000 pounds of copper ore in twenty-two days, for there is nothing like a mountain in the neighborhood. The bluff, to be sure, rises to the height of about 150 feet from the river; but when you have ascended it you find yourself at the top of a level prairie, so that what might to an inexperienced traveler appear to be a mountainous height, is nothing but the summit of the gorge which the river has cut out." [*Canoe Voyage up the Minnay Sotor, Vol. 1 p.* 303.]

With the exception of an occasional mention of granite in place, and a very brief notice of the red quartzite near the mouth of the Waraju river, the foregoing is the only geological note of importance recorded by Mr. Featherstonhaugh on the valley of the Minnesota.

In the survey of Wisconsin, Iowa and Minnesota by Dr. D. D. Owen, the examination of this river was committed to Dr. B. F. Shumard. Dr. Shumard and his party ascended the valley in canoes as far as the Redwood river, where he was attacked with pleurisy, and was compelled to abandon the further prosecution of the survey. This was in June, 1848. His report exhibits the first attempt ever made to parallelize the rocks of the valley with those of the rest of the state, and determine their geological age, and their equivalents in other states, by reference to a standard of comparison. That standard was a nomenclature adopted by the chief of the survey, based on the New York survey, as follows, with its equivalents:

No. 1. *Formation 3, C.* Corralline and Pentamerus beds of the Upper Magnesian limestone. (The Niagara group of New York.)
No. 2. *Formation 3, B.* Lead-bearing beds of the Upper Magnesian limestone. (The Utica Slate and Hudson River group.)
No. 3. *Formation 3, A.* Shell-bed. (The Trenton and Black River limestone of New York.)
No. 4. *Formation 2, C.* Upper, white saccharoid sandstone, or St. Peter sandstone.
No. 5. *Formation 2, A. and B.* Low. Magnesian limestone. (The Calciferous sandrock of New York.)
No 6. *Formation 1.* Lower, light-colored quartzose sandstone. (The Potsdam sandstone of New York.)
No. 7. *Red, argillaceous and ferruginous sandstones.* (Supposed to be a downward extension of the Potsdam sandstone.)

Of these Dr. Shumard recognized Nos. 3 and 4 at the mouth of the river, in the Fort Snelling bluff. At Shakopee, and thence to the Little Rapids, he notes No. 5. The sandstone at the last place he regards as belonging to a formation several hundred feet below the white sandstone of No. 4, probably to No. 6. At "white rock bluff," situated on the right bank of the river, about six miles below Traverse des Sioux, he regards the exposed section to consist of No. 6, capped with No. 5, about fifty feet of the former and fifteen of the latter. The same formations are exposed, at intervals, to the mouth of the Blue Earth river, where the section is said to be similar to that of *white rock bluff*. Ascending the Blue Earth river six or eight miles and observing the same geological horizon as far as he went, he notes, subsequently, two or three exposures of No. 6 before reaching the mouth of the Waraju river, one being two miles below the mouth of that stream. The red quartzite at the mouth of the Waraju he regards as the lower beds of No. 6, more or less altered by metamorphism where they abut upon the igneous rocks. He also notes conglomerate and granite outcrops about a mile in a straight line above the mouth of the Waraju. He mentions granite at La Petite Roche, twenty-five miles above the mouth of the Waraju, and at frequent other points before reaching the Redwood. He describes an interesting exposure two or three miles below the mouth of this river.

There will be further occasion to refer to Dr. Shumard's report, since, although in the main corroborated by the observations of the past season, additional facts have been gathered which necessitate some change in his parallelisms.

(b) THE TRENTON LIMESTONE AND SHALES.

After leaving the immediate vicinity of the mouth of the river, this formation is not seen again throughout its course, consequently no new facts can be given respecting its characters or extent, except those noted in Dakota county.

The quarry of Daniel F. Aiken is a mile and a half northwest of Farmington, on sec. 24 T. 114, R. 20. The beds show a considerable disturbance, and a portion of the usual building-stone, belonging to No. 4 of the section below, appears to be wanting from that cause. Yet Mr. Aiken is positive that no greater thickness of No. 4 exists there than that seen.

Section at Daniel F. Aiken's quarry, near Farmington, Dakota Co.

No. 1.	Shattered, loose beds of limestone	5 feet.
No. 2.	Shale	6 "
No. 3.	Stone, which crumbles to shale	2 "
No. 4.	The Minneapolis quarry stone	4 "
	Total	17 feet.

In traveling south on the Sioux City railroad, from Fort Snelling, the form of the brow of the bluffs of the Minnesota valley, appear to lose the Trenton on the east side of the river several miles sooner than on the west side. On the east side the limestone extends about three and a half or four miles above the fort. On the west side it seems to continue in the bluffs, though hid from sight, for a distance of six or eight miles.

(c) THE ST. PETER SANDSTONE.

This, like the Trenton overlying, also disappears from view soon after leaving Fort Snelling. Owing to its destructible nature, it is very rarely seen except when protected by the Trenton. Yet at one other point has it been discovered in the Minnesota valley. A very interesting observation was made at the Asylum quarry, at St. Peter, in Nicollet county. The stone there wrought is the first below the St. Peter sandstone, the Shakopee limestone, the uppermost member of the Lower Magnesian. In the top of the quarry, where the workmen had stripped off the loose drift materials, about two feet of a white, friable sandstone were seen, with a thin strip of green shale about midway in it. This lay, in place, over the limestone, and afforded the only recorded observation ever made on the very base of the St. Peter sandstone. It seems to maintain its strictly arenaceous character, or very nearly so, to its very contact with the limestone. This observation confirmed the belief, derived from the examination of the valley to that point, that the St. Peter and the Kasota quarries were in the same horizon as the Shakopee quarries, and that they all occur within the first thirty feet below the St. Peter sandstone.

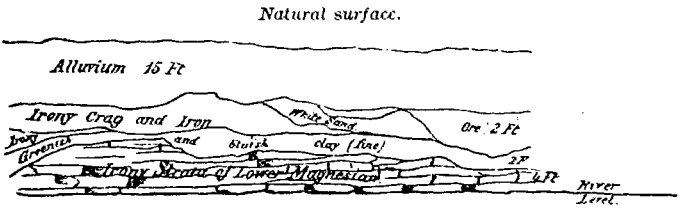
A friable, white sandstone, believed to be the St. Peter, was again observed, about two miles above the mouth of the Maple river, in the banks of which it affords a number of exposures. Those examined were in the northeastern part

of Rapidan township, in Blue Earth county, (T. 107, R. 27, secs. 11, 12 and 13). It is here underlain by about two feet of a greenish-blue clay, and is associated with concretionary and irregular sheets of brown hematite. In the banks of the Maple, where the Shakopee limestone is exposed and somewhat quarried, there are occasional missing places in the beds of that formation. If by the action of the river the section is kept clear, so as to remove the drift, this bed of clay can be seen lying with distorted and dishing strata in these intervals The strata are sometimes not preserved, but the masses appear as if thrust into the excavation in the Shakopee limestone, and are very sandy. In other cases the clay seems to have been shaped in layers conformable to the surface of the Lower Magnesian, but unconformable with its bedding. At one place the following section can be made out:

Section in Rapidan, Blue Earth Co.

No. 1.	Alluvium	15 feet.
No. 2.	Irony crag and impure iron ore	2 "
No. 3.	Greenish bedded clay	2 "
No. 4.	Strata of Shakopee limestone, more or less stained and encrusted with iron	4 "
	Total	23 feet.

These parts are arranged, relatively to each other, according to the annexed diagram:



The white sand which here is supposed to belong to the St. Peter, but which may belong to the Cretaceous, is in some way associated with this iron ore. It seems to lie in patches, sometimes just below the iron, and in other places where the iron is wanting. It seems to lie above the clay or shale (No. 3 of the section), its position being the same as that seen at St. Peter.

At other places, a little above the point of the foregoing section, the iron and sand are found irregularly mingled,

the iron occuring in the form of concretionary sheets, at least in sheets that enclose cavities. As much as four feet of this sand can here be made out, but the clay layer cannot be seen.

At a point a few rods further up, this white sand can be seen in a bluff on the left bank of the river (probably on sec. 13,) rising 40 or 50 feet, its exact upward limit being hid by the drift. At the bottom of this bluff the Shakopee limestone is exposed in the form of a rounded, water-worn buttress, rising in a solid mass about twelve feet above the river. About this bare rock, which exposes not more than a square rod of surface, or 200 square feet, are fallen pieces of the iron ore mentioned. The rock itself seems coated with thin layers of irony stone, which yet appear calcareous. No clay or shale, the equivalent of No. 3, of the last section, can be seen. Overlying this iron and mingled with it, is a deposit of white sand, rising, as already stated, about fifty feet. This sand is so incoherent that one cannot ascend it. It slides like drift sand, yet is perfectly homogeneous *as sand*, without any resemblance to any drift sand. It is purely white. It is mainly massive; yet irregular lines of sedimentation can be seen in it. Also variously arranged in it are little, thin deposits of shale which probably were green till faded and oxydized. These are sometimes an inch thick, but usually not more than one-fourth of an inch. They are in detached, lenticular patches, and not now plastic, but soapy. No fossils can be seen. It seems to lie *unconformably on the Lower Magnesian*, separated only by a thin bed of greenish-blue shale. (Compare *Geological survey of Missouri*, 1855–71, *p.* 142.)

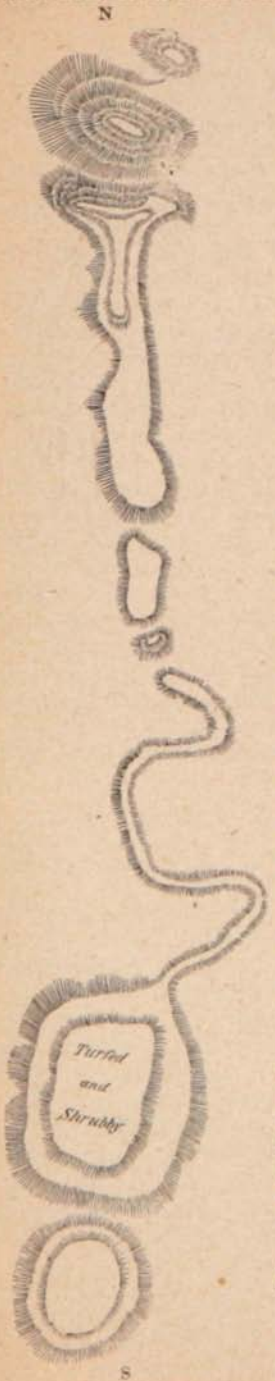
At a point a little further along, this sand is more presistent, and shows horizontal bedding, by reason of the manner of its falling down from the bluff. Beds 3-8 inches.

In the banks of the Watonwan, at Garden City, in Blue Earth county, are further exposures of the St. Peter, at least of the sandstone already mentioned in Rapidan on the Le Sueur. It is here associated with more or less clay, crag, and iron and lime cement. A heavy deposit of drift crag may be seen on E. T. Norton's place, and also on Elder A. Case's land, on the right bank, opposite Mr. Norton's. Under the crag is clean white sand. A little farther up in the bluff is red and blue clay, belonging, undoubtedly, to the Cretaceous. This crag is sometimes made up of this white sand cemented, with little gravel, and seems then to be derived mainly from the St. Peter, more or less disturbed by drift

forces. It lies on Mr. Case's land, in a continuous layer along the bluff, and projects like a bed of rock, the incoherency of the underlying white sand causing it to crumble out. This is also shown on the north side of Mr. Case's land, along the bluff where the current of the river has kept the surface fresh. This sandstone is again exposed in the banks of the river about two miles above Garden City.

Further examination of the St. Peter was made in Dakota county. An outlier of the St. Peter, situated in Sec. 11, T. 144, R. 19 W., is known as *lone rock*, owing to its rising in the midst of a prairie and forming a very conspicuous object for a great many miles in all directions. From its summit, which is about a hundred feet higher than the surrounding prairie, can be seen toward the east, the crests of several other outliers of the same stone within a mile or two, one of which is known as *chimney rock*, while still further east the eye looks upon the bluffs of the opposite side of the Mississippi. Toward the south the valley of the Vermilion spreads out in a broad basin. Farmington village is situated to the southwest, and the spacious grain elevator of the station of Rosemount is a conspicuous object toward the northwest. The country immediately surrounding is a treeless prairie, for the most part a level. In the midst of this flat these knobs of the St. Peter rise, forming knolls on which, when sufficiently turfed, two or three species of oak, and a variety of shrubs, maintain a stunted growth. In the rocky knoll named *lone rock* there is a marked dip of the

Lone Rock, Sec. 11, T. 144, R. 19, Dakota Co.

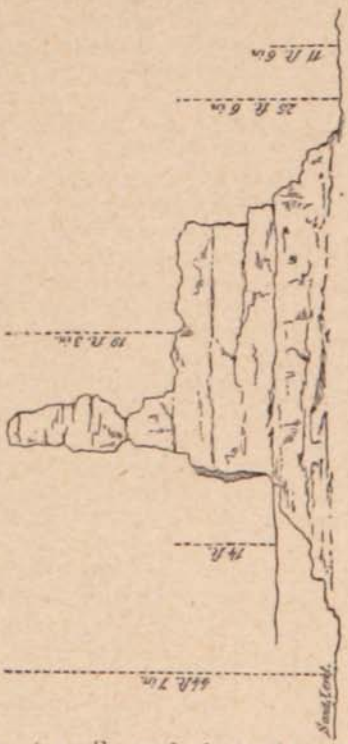


strata, 5 to 10 degrees, near the north end, toward the south; besides irregularities of sedimentation that greatly resemble dip. The rock rises in the form of an interrupted ridge, running north and south, and extends about twenty-five rods. The height from the surface of water standing in a little excavation on the northern flank of the bluff, to the base of the bare rock is 12 feet 4 inches, measured by Mr. Furber, by Locke's level; from the lowest rock seen to the top of the rock is 40 feet 11 inches, by the same. There are indications on the top of the rock that the formation did not extend much higher. The grains are coarser, and the lining cement is more abundant. The weather has also caused it near the top to show thin beds of one half to one and a half inches. The rock is about 20 feet wide at the northern end, but tapers to two or three feet; then swells out in a sort of zigzag ridge, and after one or two interruptions, disappears under turf on which grow shrubby oaks. The southern extremity is rocky again like the northern. The dip mentioned only shows at the northern extremity of the ridge. In the valleys about, the drift prevails, and boulders may be seen. The adjoining diagram shows the form and winding contour of the ridge.

Another of these outliners is known as Castle Rock. It is situated in sec. 32, T. 113, N., R. 19 W., Dakota county. The following diagrams show the elevation and aspect of this rock from the west, south and southeast :*

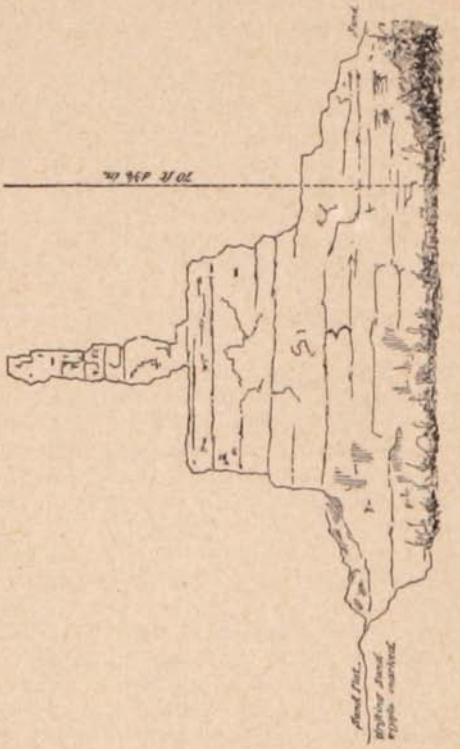
*Featherstonhaugh gives a wood-cut of *castle rock*, drawn by a "traveler" who had visited it. He locates it near the sources of Le Grand Gres river, supposed to be Sand creek.

View of castle rock from the west.



View of castle rock from the south.

View of castle rock from the south-east



There is another exposure of the St. Peter on sec. 22, T. 114 N., R. 19 W., about a mile and a half west of Empire City, in Dakota county, within the river bluffs of the Vermilion, and on the north side of the immense slough that lies on that side of the river. It is somewhat quarried for foundation stone. The beds exposed are under about two feet of drift, and about twelve feet above the level of the slough. They lie horizontal. This indicates that the whole valley of the Vermilion, at that point, where it is said to have its greatest width, is wrought in that sandstone.

(d) THE SHAKOPEE LIMESTONE.

This limestone belongs to the great Lower Magnesian formation and is the uppermost member of it. In ascending the Minnesota valley its first outcrop is seen at Shakopee, in

Scott county, where it is wrought for quicklime. It is again exposed at Louisville, in the same county, five miles above Shakopee. A short distance above Louisville it recedes from the river, and the underlying sandstone, seen at Jordan, comes to the surface with a gentle dip to the N. or N. N. E., forming the "little rapids" in the river, and affording a useful building-stone at the quarries at Jordan. In turn this sandstone, by the same dip, is driven back from the immediate valley, and a lower limestone is seen, as at St. Lawrence, having different physical characters, yet belonging to the great Lower Magnesian.

At Ottawa and Kasota, as also at St. Peter, the Shakopee limestone has returned. It thence continues in the valley of the Minnesota, sharing its banks with the underlying Jordan sandstone, to Mankato, where a fine exposure of the beds of both may be seen. As the river there changes its direction it soon passes away from the area of the Shakopee limestone, although there are several fine outcrops on the Blue Earth, and on its tributaries the LeSueur, the Cobb and the Maple, as far south as the township of Rapidan. It is also exposed on the Watonwan, at Garden City, and gives rise, as at other places in the same township, to valuable mill sites.

This, in general, is the course of the Shakopee limestone. It has formerly been supposed to represent the whole of the Lower Magnesian, or For. 2 of Dr. Owen. Its thickness is about 70 feet. The underlying sandstone is about 50 feet thick. The thickness of the next member of the Lower Magnesian has not yet been made out. It is visible at St. Lawrence, in Scott county, and at Judson, in Blue Earth county. This, it will be observed, is not in keeping with the age given the Jordan sandstone by Dr. B. F. Shumard. He referred the sandstone at *little rapids*, and that underlying the limestone at Mankato, to For. 1, of Dr. Owen's series, which he made the equivalent of the Potsdam, of New York. The Lower Magnesian, however, in the bluffs of the Mississippi, at Winona, and at other points, is over two hundred feet thick. In approaching St. Paul its thickness grows no less. It would be a singular phenomenon, to say the least, if at Shakopee, less than forty miles from Hastings where it has its full development, it should have become reduced to less than seventy-five feet. The existence of a heavy, calcareous formation below the Jordan sandstone, demonstrated by the observations of the past season, as detailed in the following pages, proves beyond all question

that the Jordan sandstone has been erroneously referred to the Potsdam age. The Shakopee limestone also maintains a distinct horizon in passing to the east. It was seen, in the season of 1872, at Quincy, in Olmsted county, and was mentioned in the report of progress for that year (page 82).

This assignment of the Jordan sandstone to the great Lower Magnesian formation is, on the other hand, in harmony with the reports of the Missouri geologists who describe that formation as made up of a series of alternating, yet constant, calcareous and arenaceous members. To what extent the lower part of the Lower Magnesian may be thus subdivided, and whether it corresponds to any extent with the Missouri subdivisions, it is not now possible to say.

Section at Shakopee, in Scott county.

No. 1. Can hardly be separated from the rest, but seems more shattered and thinner bedded. It also contains some chert. It is crystalline and porous, with no regularity of bedding..... 6-8 feet

No. 2. An irregular layer of sandstone, or of very sandy limestone, used for building-stone, making some good faces; beds about 8 inches..... 2 feet

No. 3. Rather heavier beds of hard gray limestone, of a magnesian texture and feel. These beds are sometimes cracked and checked in all directions, and pass into fine-grained patches, and then thicken again. These thin beds are not infrequently wavy or contorted within the mass. Purgatories are also common in the face of the bluff through all the parts..... 10-12 ft.

Section at Louisville, Scott county.

The quarry of Mr. G. Baptiste Contre shows a much disturbed and shattered condition of the layers, with frequent green stains as if of carbonate of copper. No constant general section of the bedding can be given, but the lower eight or ten feet are of a reddish color and in heavier beds. This quarry shows very evidently the effect of volcanic upheaval or disturbance. In general it bears a close resemblance to the stone seen at Shakopee. Twenty feet, more or less, can be seen. The quarry is in a bluff or terrace, facing the river, yet is separated from the river by another terrace of the same height, made of the same layers of rock, facing away from the river. This latter rises as an island, about 30 feet above the river bottom.

The same rock is more or less exposed in the road from Shakopee, for a mile, before reaching Louisville. At Shakopee—and the same is true most of the way to Louisville—

this limestone is the cause of a distinct terrace, which rises about 20 feet above the bottoms. On the surface of this terrace a great many boulders of northern origin, often remarkably large, are strewn, the close proximity of the rock preventing them from disappearing in the thin alluvium. As the direction of the river seems not to coincide with the direction of the strike of the limestone, it soon passes on to the belt of the sandstone seen in the *little rapids*, and at Jordon, the transition from the former stone to the latter being indicated by a change in the character of the river bluffs, and the terrace already mentioned. A short distance below the mouth of Sand creek the limestone affords an exposure in the right bank of the river, while the creek itself is on the sandstone. The sandstone there is the only rock visible in the river, as far as to St. Lawrence, which is in T. 114, R. 24, Scott county. The limestone there exposed lies below the sandstone, and will be described in another place. With the exception of a slight exposure a mile or two below Belle Plaine, and another near Blakeley, the rock is not seen again on the east side until reaching *white rock bluff*, at Ottawa. On the west side about a mile below the Jessenland church (sec. 13, T. 113, R. 26) there is a low outcrop of the lower limestone in the river bottoms.

At Ottawa, in Le Sueur county, the Shakopee stone has fully returned, and affords a very fine outcrop, rising, with the underlying sandstone, to the hight of about 70 feet above the river, and causing as at Shakopee a broad terrace, on which the village stands.

Sections at Ottawa, Le Sueur county. (a) Quarry of John P. Rinshed.

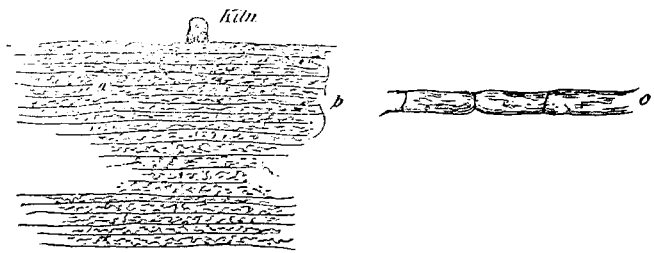
No. 1.	Fawn-colored, arenaceous limestone in even beds that correspond in undulations with the upper surface of No. 3	4 ft.
No. 2.	Sandstone with a calcareous cement; of a lighter color. and corresponding in undulations with the surface of No. 3	2 ft.?
No. 3.	Magnesian limestone, very much like the Shakopee stone, holding green clayey deposits; in lenticular and irregular beds; the surface, freshly uncovered by the removal of the beds of No. 2, has much the appearance of being weathered, rising and falling at gradual angles and causing the overlying members to have corresponding undulations. Not well seen here. Said to be	8 ft.
	Total	14 ft.

Other quarries showing nearly the same composition of layers as Rinshed's, are owned by Levi Case and Charles Schwartz.

(*b.*) *At Rinshed's lime-kiln.*

Nearer the river, at Rinshed's kiln, the underlying sandstone can be seen. In this section there is exhibited either a fault or an instance of unconformability in the bedding. The relation of the sandstone to the limestone may be best exhibited by the following diagram:

Diagram showing the relation of the limestone to the sandstone, at Ottawa, Le Sueur county.



Explanation.

a.' Horizontal layers of white crumbling sandstone showing oblique sedimentation; sedimentation undisturbed, seen 25 feet.
b. Interval of ten feet hid by debris.
c. One bed of fawn-colored limestone, almost free from sand; lies below the stone of Rinshed's quarry, 2 feet.

About ten rods below this kiln, near another old kiln built by excavating in the sandstone along the bluff, the following section may be seen:

(*c*) *Ten rods below Rinshed's lime-kiln.*

No. 1. Lime-stone, fawn-colored, in undulating beds; beds two or three inches or as thick as one or two feet, apparently disturbed..... 15 feet.
No. 2. Sandstone, as at Rinshed's kiln, undisturbed, seen... 25 feet.

Just back from the bluff where the last section was taken, is the opening that furnishes stone for the kiln. The limestone here appears like that at the bluff.

The whole of these exposures make up, in general, one irregular stratum of limestone, with sandy patches and layers occurring indiscriminately, and should not be divided generally into different members. The sandstone underlying, however, has an uneven upper surface, due perhaps, to the violence of the latest sedimentation, instead of upheaval,

before the disposition of the limestone. There is no other way except that of supposing a fault, or an instance of unconformability within the Lower Magnesian, to account for the position of the heavy bed of limestone exposed so far below the top of the sandstone at Rinshed's kiln.

A little more than a quarter of a mile below Rinshed's kiln, a little ravine crosses the beds, showing the upper portion of the sandstone, as follows:

(d) *Section in the sandstone at Ottawa.*

No. 1.	Red, hard sandstone, in one heavy bed, exactly like that in the cut on the Sioux City R. R. near Louisville	1 foot.
No. 2.	White sandrock, like that in the railroad cut near Louisville, seen	2–3 feet.

The observations made at Ottawa throw much light on the relation of the limestone there with that at Shakopee, thus—

Shakopee limestone=Ottawa limestone.
Louisville kilns....=Ottawa kilns.
Jordan sandstone...=Ottawa sandstone.

At St. Peter the quarry near the asylum exposes the uppermost layers of the Shakopee limestone. Owing to the work going on in the finishing of the asylum building, a fine opportunity is here afforded for seeing these beds in their best estate. The beds are here very regular, differing very much from the thin and confused bedding at Shakopee, and in the deep openings they seem to be all very heavy. Indeed, in the face of the quarry the bedding can hardly be discovered. It seems almost massive. Yet on quarrying the stone it parts along certain horizontal planes that must be bedding planes. Some faces show five feet. Other beds are two, and three, and four feet. The upper four feet are checked into beds of two to four inches by the weather. It is rather darker, when first quarried, than the Kasota stone, but has the same general cast of color. It seems sometimes to have a brownish tinge. The amount seen here is about twenty-five feet.

In the banks of the river at St. Peter, the sandstone, corresponding to that already described at Ottawa, can be seen, forming perpendicular or overhanging bluffs fifteen feet or more in hight.

On the terrace formed at St. Peter by these rocks, other

quarries have been opened by Albert Knight, and by others, but none exhibit the characters of the formation so fully as that at the asylum.

Across the river from St. Peter, and about a mile toward Kasota, is another exposure of the limestone, in a bluff along the roadside. It seems here to be more shattered and irregular, and like the Shakopee stone. Lime burned near here cannot be distinguished from the Shakopee lime. About eighteen feet are seen, the lower part being in good heavy beds. The upper surface is waterworn, and in the openings the Cretaceous has been deposited.

Geo. C. Clapp's lime kiln and quarry are five miles below Makato, on sec. 17, township of Kasota, within the main drift bluffs of the Minnesota, but on the terrace formed by the Shakopee limestone, and about a mile from the river. His quarry, located near his kiln, exposes a fine gray limestone, about two feet thick, sometimes less or more graduating into the Shakopee stone which underlies. It is very firm, little porous, and contains *Orthis*, at least, and affords the finest and purest limestone hitherto seen in the Shakopee stone. It must be regarded as the upper portion of the Shakopee. This fine, compact texture, and gray color, are not continuous in the same horizon, in other places the harsh magnesian grain and arenaceous quality existing in the same beds. Running along the river for several miles, sometimes touching the river and sometimes exposed back of islands that show the same, this limestone forms a bluff of solid beds. Although there is usually a heavy talus covering the foot of this bluff, yet at several points the identity of this horizon with that at St. Peter, and hence with that at Shakopee, is fully established by the exposure of the underlying sandstone. It is seen at a point about two miles below Mr. Clapp's farm. This bluff shows a good stone, as at St. Peter and Kasota, but is not much quarried. Perhaps it is more arenaceous in patches. It is blotched with whiter spots, and with soft chert.

Another fine exposure of this geological horizon is visible about a mile and three-quarters below Mankato, on the same side of the river. The place here referred to is that sometimes known as *hurricane bend*, although the point so named by steamboat captains is said to be about four miles further down the river. The section here exposed is the same as at Clapp's, and also the same as at Makato, but here there is an observed thickness of sandstone amounting to forty-five feet, somewhat hid by debris. This equiv-

alency is unmistakable, since the bluff can be traced nearly all the way to Clapp's, and since between here and Mankato, besides the continuance of the same surface features—the wide, stony prairie formed by the terrace, the uniform altitude of the terrace, and its striking similarity to the terraces at St. Peter, Kasota, Ottawa and Shakopee—the actual continuity of the formation can almost be traced out by exposures of the rock.

In the report of progress for 1872, the section at Maxfield's quarry at Mankato was given (p. 83) covering 61 feet of the Shakopee limestone. The further examination of this locality, and of the river bluffs for several miles below, during the season of 1873, makes it desirable to unite the sections observed in one general section, as follows:

Section at Mankato, in Blue Earth county.

No. 1.	Porous magnesian limestone, not used	4–6 ft.
No. 2.	Coarse, friable sandstone	2–4 ft.
No. 3.	Magnesian limestone burned for lime	2 ft.
No. 4.	Calciferous sandstone, in heavy beds, of various grain and texture, sometimes mottled, quarried for building	30 ft.
No. 5.	Upper shale bed, arenaceous and mottled with red	2–3 ft.
No. 6.	Calciferous sandstone, generally used as a cut-stone, compact and even grained	4 ft.
No. 7.	Rough and irregular magnesian limestone, somewhat arenaceous, but unfit for cutting	10 ft.
No. 8.	Lower shale bed; very much the same as the upper	2 ft.
No. 9.	One heavy bed, generally good for cut-stone	3 ft.
No. 10.	Irregular and sandy bed; more or less cavernous and porous, its lower three or four inches in thin chips, fine grained, and stained with iron	3 ft.
No. 11.	Jordan sandstone, seen about	45 ft.
	Total of the Shakopee limestone, about	65 ft.

From Mankato toward the mouth of the Blue Earth river, the Shakopee limestone is seen at frequent places, forming precipitous mural faces, capping the underlying sandstone; the two united making bluffs that rise from seventy-five to a hundred feet. These exposures are mostly on the right bank, but there are also elevated islands in the river, or at least elevated portions in the area of the bottom land, that present similar perpendicular rocky bluffs on one or more sides. These exposures extend somewhat beyond the mouth of the Blue Earth. The Blue Earth has cut its passage through this rim of rock, at the point of its debouchure upon the Minnesota bottom land, and on its right bank, at the place of the crossing of the St. Paul and Sioux City R. R., a series of interesting observations were made. Before

reaching this point, however, in following the highway from Mankato to South Bend, but on the east side of the bridge over the Blue Earth, the Shakopee limestone is exposed in a recent excavation by the side of the road, in the removal of the Cretaceous clay, which is seen there to overlie it unconformably. The limestone here shows the effects of long exposure to the weather, and the action of water in the form of waves, probably those of the Cretaceous ocean, prior to the deposition of the clay. A much better example of the same effects may be seen a little further south, just before the crossing of the Blue Earth by the Sioux City R. R., where the grade is cut into the rock for several rods before reaching the river. The old Silurian surface is here very much weathered, and coated with iron peroxide, the nooks and openings, and all sheltered places being filled with the fine, plastic but bedded greenish clays of the Cretaceous age; the drift gravels and sand overlying both. These phenomena are alluded to again and more fully discussed under the head of the Cretaceous.

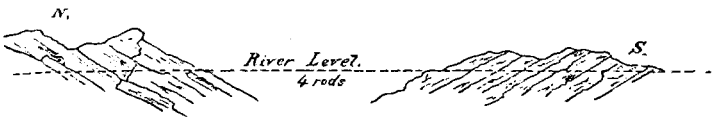
Passing from the mouth of the Blue Earth south, towards the Red Jacket flouring mills, occasional exposures of the Shakopee stone are met with along the highway and in the railroad cuts (Minn. and Northwestern R. R.), for about three miles. The Red Jacket mills are on the Le Sueur river, four miles south of Mankato.

On the Maple, near its union with the Le Sueur, in sections 11, 12 and 13, township of Rapidan (107, 27,), Blue Earth county, quarries that are feebly run, are owned by Barney Simmons, Samuel Michael, and by Messrs. Averill, Culver. Wood and Allgrain. These quarries reach about two miles above the mouth of the Maple, and are in the same horizon as the Mankato quarries. The stone occurs in horizontal, heavy beds, along the low banks of the river, exposing 25 or 30 feet. Some mention has been made of the Shakopee stone at this place in describing the sandstone there seen to overlie it, and supposed to be the St. Peter. (See p. 133).

The Shakopee limestone is exposed at Garden City, in Blue Earth county, in the banks of the Watonwan river. Mr. S. M. Folsom owns a slight exposure which is somewhat worked, situated in the low bank of the river, near the water. At the mill dam, just above the highway bridge, it may be seen, exposed in a rough and very irregular outcrop, in the midst of the river, forming a rocky island. It here

presents large cavities, and sometimes a breccia. The beds are thick, and lie in a short synclinal, as illustrated below.

Synclinal in the Shakopee limestone, at Garden City, in Blue Earth county.



This synclinal is not believed to be anything that affects the general dip of the formation, but an illustration of the irregularity that it sometimes presents in its bedding. A similar phenomenon was noted in respect to this limestone, at Ottawa, in LeSueur county. It is a structure very common in the Waterlime, of the Upper Silurian, seen in northwestern Ohio.

This exposure of the Shakopee limestone has very much the general character seen at Shakopee. In the roughened upper surface the usual gasteropod, seen also last year at Rochester, in Olmsted county, was seen at Garden City, (*Euomphalus.*)

(e) THE JORDAN SANDSTONE.

This name is here applied to that member of the Lower Magnesian which immediately underlies the Shakopee limestone. As has already been stated, it has been referred by Dr. B. F. Shumard to the Potsdam sandstone or formation 1, of Dr. Owen's series. The observations of the past season have disclosed the fact that it is only about fifty feet in thickness, and is underlain by another great limestone formation which, while it differs considerably from the Shakopee stone, is still a magnesian limestone, and belongs to the same great series.

This stone is first seen in ascending the Minnesota valley, so far as at present known, at the "little rapids," near the city of Carver, in Carver county. It here causes a fall of about seven feet, divided between two separate rapids. The lower rapid has a fall of about four feet. The upper is about half a mile further up. The stone is thick bedded and coarse-grained. A few rods above the upper rapid it is exposed in the right bank, showing about six feet in nearly horizontal beds. This sandstone was penetrated in sinking

a well at Louisville, after passing through the Shakopee limestone, the thickness of over twenty feet. Passing along the public road from Louisville to Jordan, the strike of the sandstone can be seen by outcrops, in the form of stony islands, in the river bottoms, and by exposures near Dooleyville. Where the public road crosses "Van Oser's"* creek, a short distance above Dooleyville, it has a dip of 10 or 15 degrees toward the W. N. W. About twenty-five feet can here be made out in passing along the stream from a short distance above the road to the crossing of the St. Paul and Sioux City R. R. It is in heavy beds and is coarse-grained. It is full of seams and checks, presenting some appearance of dip in different directions. Some of the seams, or lines of apparent bedding, run nearly perpendicular, but they do not have a constancy that shows dip. The operation of the stream is such as to bring out the bedding, by the wearing away of the softer layers, so as to indicate dip in the direction already stated.

Near the railroad bridge over Van Oser's creek, and in the public road, this sandstone is conglomeritic and broken. It shows the effect of heat. The bedding is disturbed and even fractured, the openings having been again filled with coarser materials and some pebbles. Some parts of it are highly ferruginous, so as to make an impure iron ore which is black. These characters, however, are confined to a very small area, not being seen over more than three or four square yards, making a mound-like prominence that rises two or three feet above the level of the rest of the bedding, which is bare for some rods about.

About a mile above the crossing of Van Oser's creek, the St. Paul and Sioux City R. R. cuts through sandstone which may be somewhat below the beds last mentioned. The upper part of this may be regarded as belonging in the section at the creek. This cut is composed of the following parts:

No. 1.	Hard (yet within friable) sandstone, in one bed, of a reddish color, which resembles the color of the Shakopee stone near the bottom of the section at Louisville.....	3 ft.
No. 2.	Fine, incoherent, white sandrock, massive; seen five feet, may amount to.....	10 ft.

Directly east of this cut, across the public road, No. 1 above, which is supposed to be the same as the sandstone seen in Van Oser's creek, outcrops so as to show 15 or 20

* This is corrupted from Van Osterhaus.

feet. It causes a considerable knoll, where huge blocks four or five feet thick are checked loose by the weather and removed from the general mass. This is a favorable place for quarrying.

At Jordan, three and a half miles above this place, this sandstone affords its typical outcrop. It occurs in Sand creek, about a half mile above the village. Quarries here are owned by John Volk, and by Wosanick and Loniacheck. The general section obtainable from the various outcrops along this creek has been described.*

Section at Jordan, Scott county.

No. 1.	Sandrock, buffish, quite ferruginous, thick-bedded, seen at the mill	6 feet.
No. 2.	Sandrock, ferruginous, thin and irregularly bedded, friable and disentegrating, with many ferruginous seams, crusts and concretions. In quarry	3 feet.
No. 3.	Sandrock, irregularly whitish or ferruginous, heavy-bedded, obliquely and beautifully banded with iron streaks and laminae. In quarry	12 feet.
No. 4.	Sandrock, buffish, similar to No. 3, but thinner bedded. In the quarry	8 feet.
No. 5.	Sandrock, hard and ferruginous above, soft, friable and buffish red below. Falls of Sand creek	10 feet.
No. 6.	Sandrock, whitish, compact. In the beer vaults, seen	12 feet.

In the bed of the creek, near the breweries, this stone seems somewhat calcareous. It is of a reddish color and slightly porous, while the quarried stone shows generally a white color, except where irony water has rusted the interlaminations, presenting then a streaked section of rust and white. The bedding in the creek is also thinner. Although the foregoing section makes up a thickness of 51 feet for this sandstone as exposed at this place, the observations of the survey do not warrant the assignment of that aggregate thickness to the outcrops there. Some of the localities named being regarded as on the same geological horizon. The general uniformity of characters makes it difficult to judge how much of the bedding at one place may be included in the outcrop at another; but twenty-five or thirty feet would probably cover the thickness exposed.

The next known exposure of this stone is at Ottawa, where it underlies a considerable thickness of the Shakopee limestone. The geology of this place has been given in treating of the Shakopee limestone. The interesting ob-

Report of a geological survey of the vicinity of Belle Plaine, Scott Co., Minn. By Alexander Winchell. In this report the name of *Jordan sandstone* was first applied to this stone, although still regarded as of the Potsdam age.

servation was there made of a local unconformability in the limestone, with the Jordan sandstone. (See p. 141).

From Ottawa to Mankato, this sandstone may be seen at nearly all places where the Shakopee limestone is exposed. It is apt to be somewhat covered by debris, as it lies at the base of the continuous bluffs that these two formations cause throughout that part of the Minnesota valley.

Near the Red Jacket mills, four miles south of Mankato, on the Le Sueur, is an outcrop of sandstone, which is doubtfully referred to the Jordan. It is in the right bank, just above the mill dam. It forms a perpendicular bluff rising from the water about 20 feet, underlying a heavy deposit of drift which rises nearly two hundred feet higher. In the sandstone are soft, apparently magnesio-calcareous pieces, about an inch in diameter, usually flattened, or pointed, or edged, which if dry, crumble to powder in the fingers, revealing little or no grit, but which when wet, are sticky and plastic. These pieces resemble somewhat the thin deposits of shale seen in the sandstone that has been referred to the St. Peter a few miles higher up on the Le Sueur. (See the Report of Prof. Peckham for an analysis of these pieces of shale). This fact in connection with the existence of irony crag in the overlying drift bluff, make the resemblances of this outcrop to the above outcrops supposed to be St. Peter, and to those at Garden City, rather greater than to the Jordan. The geographical and topographical relations of this outcrop, however, cause it to appear very strongly to belong to the Jordan. (See p. 133).

At Cappels mill, on the Watonwan, two and a half miles below Garden City, a sandstone is exposed, and somewhat worked. Its stratigraphical relations are not certain, but it probably belongs to the Jordan.

Three miles below is the Rapidan mill. The same sandstone is exposed at this mill and at several places between these mills.

At Minneopa falls, sec. 21, T. 108, R. 27, the cascade is caused by the Jordan sandstone. The perpendicular fall of the water is about 30 feet, but 45 feet of the sandstone can be made out. Before reaching the point where the water leaps over, the steam works its way through a perpendicular thickness of 15 feet of sandstone beds. It then comes in contact with a harder portion of the sandstone, which has a thickness of about six feet. This resists the water longer than the under lying layers, and maintains a projecting shelf. The mist that rises keeps the walls wet, and the freezing of

winter crumbles away the soft sandstone, so as to form about the pool where the water strikes, a walled amphitheatre rising about 40 feet on each side. This glen is more or less shaded with elms, cedars, birches, butternuts and oaks. It is prolonged in the form of a rough and shaded gorge, worn in the solid rock, of about the same depth, down to the point of issue of the stream upon the Minnesota bottoms, the distance of about half a mile. The gorge below the fall is darkened by the dense foliage, the stream in its course being much of the time hid from sight but for a few rods. This gorge is crossed, about a quarter of a mile below the falls, by the St. Paul and Sioux City R. R. At the foot of the falls a little lake of water is confined by the upheaved pebbles in front of the cascade. The gravel of the surrounding beach is hard enough to admit of a passage on all sides. There are also several narrow paths along the walls of the amphitheatre, where the fallen fragments are sufficienty turfed and overgrown to permit a passage up or down the stream. An elm tree which is nearly three feet in diameter grows near the foot of the cascade, and on the right bank. Its annual rings of growth would indicate at least some part of the time elapsed since the retreat of the fall from the place where it stands. Within six feet of it the perpendicular sandstone wall rises to the height of over forty feet. The stream is subject to great fluctuations of volume, sometimes becoming quite dry. In passing down the Minneopa gorge to its union with the Minnesota river, the bluffs become more and more wooded, the stone only showing alternately in patches on opposite sides, and no lower view of the Jordan sandstone can be had, at least none than can be proved to be lower. Before reaching the Minnesota, however, a continuous bog is encountered, running along both sides of the creek, about ten or fifteen feet above the creek. This either indicates a change in the formation, bringing in a shale or clay (perhaps a limestone), or that the muddy alluvium of the Minnesota bottoms has been carried back up the Minneopa so as to shed the water of the bluffs. This bog is about on a level of the Minnesota flood plain, and the channel of the creek is cut in alluvium that cannot be distinguished from that of the Minnesota bottoms.

Seven or eight miles above Mankato, or one and a half above the wind mill, along the road to New Ulm, is another exposure of the Jordan sandstone, with features very much like those at Minneopa. A little creek, which is dry in

summer time, exposes first about two feet of coarse sandstone in its bed. Following the creek down a few rods, there is a perpendicular fall of about fourteen feet, which in time of high water must make a handsome cascade, similar to the Minneopa waterfall. The immediate cause of the fall is the occurrence of a layer of about a foot with a harder or more enduring cement, underlain by crumbling sandstone. Over the sandstone rises the drift, about fifty or seventy-five feet, mainly made up of hardpan (glacier drift), the top of which, however, is composed of fine sand in oblique stratification. The alternation of layers here is a follows:

No. 1.	Closely cemented sandstone, projecting beyond the next	5 inches
No. 2.	Coarse, white sand, in water worn grains, crumbling out easily	6 inches
No. 3.	Same as No. 1	6 inches
No. 4.	Same as No. 2	1 foot
No. 5.	Brink of falls. Same as No. 1	1 foot
No. 6.	Same as No. 2, seen	30 feet

This horizon is undoubtedly the same as that at Minneopa falls. The appearance of the gorge below the falls, and the occurrence of a cemented part giving rise to the perpendicular fall of the water, are very much the same. The beds lie here, as there, nearly horizontal. The grains of sand are, perhaps, somewhat coarser here than at Minneopa.

This sandstone can be seen in the bluffs on the opposite side of the Minnesota river, surmounted by a great thickness of drift. The bluffs are mainly wooded, but some smooth buttresses and slopes, wrought apparently in the drift, and covered with grass, yet reveal the stone, large slabs and blocks from which lie on the hillside.

(f) THE ST. LAWRENCE LIMESTONE.

At St. Lawrence, which is about four miles northeast of Belle Plaine, in Scott county, a still lower member of the Lower Magnesian is exposed, presenting somewhat different lithological characters. It is harder than the Shakopee limestone, evenly bedded, quartzose and specked with green. These green specks have somewhat the appearance of coming from metamorphism, yet they are caused by little rounded masses, which, if harder, would seem to have been water-worn and deposited with the sedimentation. They are, however, rather soft, cutting like talc. They exactly fill the cavities in which they lie. In some small portions they almost make up the bulk of the rock, which then has a

green compact appearance, as if hornblendic. While the rock is evidently calcareous and magnesian in some parts, and almost destitute of these green specks, it is also siliceous and sharply crystalline. On analysis the little green specks have been found by Prof. Peckham to consist of lime, iron, magnesia and a trace of manganese. See p. 96, "Nos. 30 and 31."

The section here exposed is as follows:

Section at St. Lawrence, Scott county.

No. 1.	Beds two to four inches, with shaly partings and green specks	3 ft.
No. 2.	Beds fourteen to eighteen inches, hard, siliceous, occasionally porous from crystallization, specked with green, showing crystals of brown spar—a good building stone	4 ft.
No. 3.	Somewhat ferruginous, hard and crystalline, less porous than No. 2	2 ft.
No. 4.	Beds irregular, specked with green, and showing green surfaces	4 ft.
No. 5.	Band of greenish shale, sandy	6 in.
No. 6.	Beds two to four inches: magnesian limestone; seen about	1 ft.
	Total	14½ ft.

Quarries here are owned by Mr. Hewitt and Mr. Beason.

At Judson, on the right bank of the Minnesota, in Blue Earth county, is the only other known exposure of the St. Lawrence limestone in the valley of the Minnesota. It here occurs on both sides of the river, and is used for building stone. It was in traveling along the highway from Mankato to this place that the most indubitable evidence of the position of this limestone was obtained. Mention has already been made of the occurrence of the Jordan sandstone at Minneopa falls, and at a little waterfall by the side of the road, some miles above (see p. 150). In passing northwestwardly the observer crosses nearly at right angles the direction of strike of the successive formations in that part of the state. Soon after leaving the little unnamed waterfall, above mentioned, and within three-quarters of a mile, an outcrop occurs of a reddish, arenaceous limestone, very unlike the St. Lawrence stone, but similar to the outcrop in Jessenland township, in Sibley county, which will be further noticed as a possibly separate member of the Lower Silurian (see p. 155).

Within that distance, or a little before reaching that waterfall, the road begins to pass down from a high, and rather

rolling, drift plateau, on to a lower plateau or terrace, overstrewn with boulders, like the terraces at Ottawa, Kasota and Shakopee, which skirts the valley for several miles, and indicates, as there, the advent of a hard, and resisting rocky foundation, into which the boulders cannot disappear. The surface of this lower plateau is mainly alluvial, the boulders lying in it, but not covered from sight. This red limestone occurs in the surface of that lower plateau. At a half mile further the character of the rock which lies so near the surface is disclosed in a little opening by the roadside, apparently made for getting stone for use, but abandoned on account of the loose and shaly character of the beds struck. These shaly and thin beds, united perhaps with the red beds seen before, may have given rise to the boggy bench already mentioned as occurring near the base of the Jordan sandstone in the banks of the Minneopa gorge, since the are so situated as to be very near the line of separation of that sandstone from the St. Lawrence limestone. Near this little opening are two culverts that are constructed of stone, quarried of course near, like the St. Lawrence stone. Passing along this lower plateau about a mile, to Judson, the general surface features remain about the same. At Judson quarries, in the St. Lawrence stone, are owned by John Goodwin, and by Mrs. Wolf. On the opposite side of the river, at Hebron, the same stone is wrought by Wm. Phillips, Wm. H. Thurston and J. H. Dunham.

This is, lithologically, exactly the St. Lawrence stone, and has a dip of two or three degrees to the southeast. Supposing that to express the average dip from Judson to the last exposure of the Jordan sandstone, there would be room for a thickness of thirty or forty feet of beds the character of which is not known. In that interval must fall the reddish outcrop three-quarters of a mile northeast of the little unnamed waterfall, and probably the Jessenland outcrop, in Sibley county. Mr. Goodwin's quarry, near the ferry, shows eight feet of bedding, but lies twenty-five feet above the river. The beds are four to eight inches, although the uppermost three or four feet of the quarry are very much weathered and in thinner beds. The bedding planes are usually entirely covered with a green coating, and the body of the whole is specked thickly, and sometimes largely made up of green particles.

The other quarry of Mr. Goodwin, and that of Mrs. Wolf, both situated a little further up the river, are similar in characters and position to that already described. It is mainly

a limestone, and very durable, of a flesh color, varying to buff, striped, specked and blotched with green. The sides of the bedding are almost altogether green.

Allusion has already been made to a reddish stone closely associated with St. Lawrence limestone, the geological horizon of which it is difficult to state. The first exposure observed of this occurs three miles above Blakeley, and on the west side of the river, in Jessenland township. It is in the river bottoms, N. E. ¼, sec. 12, T. 113, R. 26, owned by Mr. D. Doheny, who has opened a little quarry. It is a red, metamorphic limestone, nodular, concretionary, and filled with checks and planes of separation, the thickest beds being not more than four inches, the most of them less than two, and more or less contorted. It has greenish surfaces, and isolated pockets of fine, apparently copper stained materials, but very sparsely disseminated. It is almost a worthless stone for any use except macadamizing, owing to the ease with which the beds are fractured transversely. It is rough and irregular. It is fine-grained generally, rarely porous, and cryptocrystalline. When weathered it shows an arenaceous composition. It is seen in surface exposure over several square rods, the thin red chips covering the ground. About six feet of bedding may be seen. The position of this limestone is supposed to be somewhat above that seen at St. Lawrence, and below the Jordon sandstone. It perhaps has not characters sufficiently defined and constant to be separable from the St. Lawrence. Indeed there are some good reasons for supposing it may be the uppermost portion of that limestone considerably charged with iron, and changed in outward appearance by the waters of the valley.

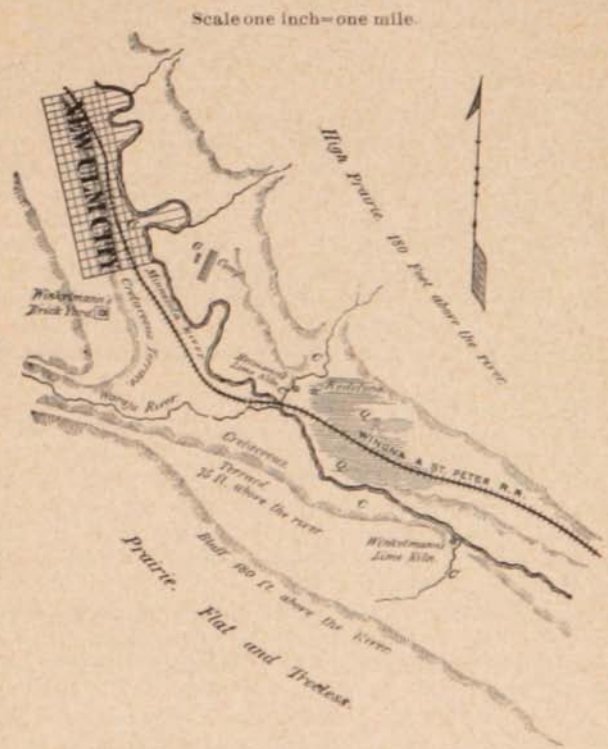
(g) THE ST. CROIX SANDSTONE.

In the report of progress for 1872, this name was provisionally applied to the light-colored sandstones exposed largely on the upper Mississippi and on the St. Croix rivers, lying immediately below the Lower Magnesian. During the season of 1873 no observations on this series of sandstone have been made, and no new light can be added to the question of the age of those beds, except what may be found in connection with the description of the outcrop of red quartzite at the mouth of the Waraju river, near New Ulm.

(h) THE POTSDAM SANDSTONE.

This name is here applied to the red sandstones that lie below the light colored sandstones of the upper Mississippi valley, and to their supposed equivalents in the southwestern part of the state. The principal observations on this sandstone made during the season of 1873, were upon the outcrop near New Ulm. The annexed map of this locality will give a correct idea of the position of this outcrop in respect to the outcrops of conglomerate and granite which occur a short distance further up the river. A careful observation on the dip of the quartzite, south of the railroad cut, corrected for variation of the needle, gave 27° N. 10° E. A similar observation on the conglomerate gave a dip of 18° toward the E. S. E. The granite outcrop is located on the authority of Dr. B. F. Shumard, who says: "The granite is a hundred yards removed from the conglomerate, with its line of elevation running nearly parallel with the latter. Flesh-colored feldspar makes nearly two-thirds of the granite." This outcrop of granite was not noticed by the survey in examining this locality.

Map of the vicinity of New Ulm and Redstone, showing the position and dip of the conglomerate and quartzite



Explanation.

c. Cretaceous outcrop; beds horizontal.
g. Granite outcrop.
cong. Conglomerate outcrop; dip 18° E.S.E.
q. Red quartzite outcrop; dip 27° N. 10° E.

The dip of the quartzite varies in degree. It is greatest near the river, and is least near the northern extremity of the exposure. Indeed, near the northern extremity the surface has a slope which is apparently due to dip, in the opposite direction. A section north and south through the quartzite would show dip changing somewhat as illustrated by the following diagram, sketched on the spot:

Dip of the quartzite at Redstone.

At the northern extremity of the exposure the surface of the rock shows a coarser grain, becoming almost conglomeritic. No true conglomerate can be here seen, but there are grains of white quartz as large as a mustard seed disseminated through it. The relation of this coarser portion to the rest of the quartzite is such as to cause it to *overlie* the most of the quartzite, but its actual superposition cannot been seen. In some of the thin bedding near the lowest part exposed, mica scales are visible on the planes of the bedding. When fresh they are black, but if weathered they are of a golden yellow color.

In many places there are evidences of a higher stage of the Minnesota at some earlier time. These consist of furrows and water-worn surfaces. There are some pot-holes, worn usually so as to have their elongated dimension in the direction of the river, their shape being generally oval. One of the largest noticed was 20 inches long and 15 inches wide. Its depth was 24 inches. These water-marks rise 120 or 125 feet above the river.

On the north side of the river, nearly opposite New Ulm, is an outcrop of coarse jaspery conglomerate, the pebbles in which are occasionally a foot in diameter and waterworn. There are also white quartzite pebbles. Ten feet may be seen, in an irregularly descending strike nearly north and south. The strike of this conglomerate outcrop is conspicuous in the woodless prairie, or terraced slope from the prairie. It rises from the very river bottoms and enters the bluff diagonally at a hight of perhaps 50 feet above the river. The talus hides the underlying stone. The strike faces up the river.

The quartzite outcrop at New Ulm was described in general the report of progress for 1872 (p. 75). The degree of dip and the thickness of the bedding exposed were, however, over estimated. There may be 250 feet of stratification exposed, and the hight of the rock does not exceed 125 feet above the river.

The following is Dr. E. Emmons' description of the "sandstone of Potsdam," taken from his report on the sec-

ond geological district of the state of New York, printed by the Legislature, in January, 1838.

"I shall not enter upon its geological relations, any further than to state, that in Potsdam, and other towns in which it appears, it uniformly rests on the primary strata; and in no part of the country is there any rock which interposes itself between it and the primary, so that it appears here as the oldest repesentative of the transition series. The identification of this rock with the sandstones along the southern border of lake Ontario, will be a matter of some difficulty. It is geologically below the transition limestone, and never in the northern district alternates with it, but always holds the relation of an inferior rock. So much is known of its position, but still some doubt remains as to its general relation, and to its name and place in the series of rocks. Some call it the old red sandstone; others regard it as equivalent to the new, or saliferous rock of Eaton.

* * * * * * *

"This rock is a true sandstone, of a red, yellowish-red, gray and grayish-white colors. It is made up of grains of sand, and held together without a cement. Intermixed with the siliceous grains are finer particles of yellowish feldspar, which do not essentially change the character of the sandstone, but they show the probable source from which the materials forming it were originally derived, viz., some of the varieties of granite. Unlike, however, most of the sandstones, it is destitute of scales of mica. The coloring matter of the rock is evidently oxide of iron, but unequally diffused through it, giving it intensity or deepness of color in proportion to its quantity. In some places it is almost wanting, which makes it, when pulverized, a good material for glass. The grains and particles in its composition are generally angular, but where it takes the character of a conglomerate, as it does in the inferior layers, they are frequently rounded. The thicker strata exhibit an obscurely striped appearance, owing to the prevalence of certain colors in the different layers."

Quartzite similar to that described at Redstone was again seen in the southern part of sec. 7, T. 106, R. 36, on land belonging to the St. Paul & Sioux City R. R. It presents here a small surface exposure, in a ravine, without exhibiting any distinct bedding. Its surface is glaciated in a direction, corrected for variation, S. 34° E.

At another point, perhaps in the edge of the next section west (12), is a larger exposure of this quartzite. The

dip is 4° or 5° N. 10° W. The stone is very hard, but banded with light and red beds, evident on the planed surface and on the fractured side. This point shows glaciation S. 30° E. (corrected for variation). There are other smaller exposures further west a short distance. They occur frequently on the hillsides, where the drainage has washed off the light drift which contains a few boulders.

At still another point, in the same section, the glaciation is very evident. There is here a trench, traceable across the whole extent of the exposure, a distance of several rods, which does not perceptibly vary in direction. It is a foot across, and two inches deep, and its direction, corrected for variation, is S. 32° E.

There is an extensive and important ridge of this quartzite not yet visited, about in the northern part of T. 108, ranges 35, 34 and 33, situated between the Big and Little Waraju rivers.

Mr. I. J. Rochussen is authority for the location and further items of other outcrops of this red quartzite. It may be seen, according to his description, on the edge of the valley of Rock river, in Rock county, three miles north of Luverne. It consists of a ridge three miles long, running N.E. and S.W., so far as known, its average height being 25 or 30 feet. The beds lie nearly horizontal or show a very slight dip, and are from one to four feet in thickness, and rather easily quarried. Also on the road to Sioux Falls, 15 miles west of Luverne, and two and three miles west and northwest of a settlement known as Valley Springs, are a number of outcrops, one large, isolated piece being known as *lone rock*. It is quarried at one point, and there shows conglomerate. At Sioux Falls, 15 miles further west, in Dakota, the same rock forms the fall, and lies in heavy layers nearly horizontal. The aggregate fall is 120 feet.

(i) THE GRANITES OF THE VALLEY.

The following account of the granites of the Minnesota valley will consist of a location of outcrops, and a description of their physical, outward characters. No attempt will be made to classify them, or to refer them to any horizon of rocks exposed in the northern part of the state. There has not yet been sufficient time to engage in mineralogical or chemical comparisons with the northern granites. There is no hesitation in saying that they are a southwestward exten-

sion of those northern granites, and that their parallelisms probably exist and that they can be referred to their proper places, when a sufficiently detailed examination of the state shall have been made.

With the exception of the small exposure of flesh-colored granite near New Ulm, mentioned by Dr. B. F. Shumard, the first outcrop of rock of this kind occurs in ascending the valley at "La Framboise place," where it rises seventy-five or a hundred feet above the level of the river. This is at Little Rock creek, about four miles below fort Ridgely. The exposure has long been known among the French traders as La Petite Roche. It is one of a series of exposures in the same vicinity, extending along the river bottoms, mainly on the north side, for a mile or two. In general this rock is granite. It rises in low knolls, perhaps 50 feet above the flood plain, visible from the "state road" that skirts along the foot of the bald drift bluffs on the north side of the river. Its outward appearance is that of a reddish granite, made up of the ternary granite compound, the separate grains of which are not coarse, the largest ones being the feldspar. The quartz is milky, or often amethystine; the mica is rather scarce for typical granite, and the feldspar is red or flesh-colored. The red color greatly predominates, giving a reddish tinge to the whole stone, wherever the weathered surface is kept free from lichens, or where the interior is freshly exposed by cuts for quarrying. The drift bluffs are not at all affected in contour or direction by these granite knolls, although the river itself winds about in the lowest channel accessible. No regular dip is distinguishable. The granite shows an abundance of seams and divisional planes, in various directions, that make it presumptuous to say which way the original bedding may have lain. The only circumstance that indicates the direction of dip is the occurrence of the most abrupt faces, in numerous places, on that side toward the river, the opposite slopes being more gradual, descending gently toward the north, as if the horizon of bedding sloped in that direction at an angle of 35° or 40°.

On close inspection of this granite with a pocket-glass, there seems to be much uncertainty about the color of the feldspar. The reddish color is most prevalent outside of the feldspar crystals, or only on their surfaces, as if the stain arose from rustiness and weathering, and had permeated the loosened granular mass by being in solution in water. There is a powdery, at least a gritty and sandy cement,

which fills the interstices within the mass and between the grains of quartz and the crystals of feldspar, that seems to be generally redder than the distinct quartz or feldspar portions. Yet that loose and more finely pulverized part seems to be made up entirely of quartz, appearing, on close examination, to have the light color and distinct fracture of glassy quartz, the red color vanishing from sight. The color seems to be located very largely in the cement, as in the red quartzite at New Ulm, suggesting the query whether this may not be more highly metamorphic sandstone. In a deep fracture, however, the red color is much less observable, being replaced by a gray, the feldspar grains becoming more evident, and the whole rock appears much like the St. Cloud granite.

Above fort Ridgely, by following the only passable road, a number of granite outcrops were not seen. At a point two miles below the Lower Agency, T. 112, R. 34, sec. 10, Mr. Wm. H. Post lives on the bottoms, near the mouth of a little creek coming in from the north. From him the following statements of granite in the bottoms above fort Ridgely were derived. It outcrops much more frequently on the south side than on the north side of the river. Throughout the whole distance to the fort (10 miles) occasional mounds of bare granite rise up in the bottom land. But these exposures are often quite small and at some distance from the river. At Marshner's carding factory, seven miles above the fort, are a number of granite knobs, in the vicinity of a lake situated in the bottoms. Half a mile further up is another exposure, but more or less connected, by smaller exposures, with that at Marshner's. The next principal outcrop between fort Ridgely and Mr. Post's, is on the south side of the river, and is visible from his house. It shows a conspicuous bared spot, with some timber, rising in one place nearly as high as the enclosing bluffs, but not effecting the general level of the prairie, unless it be in causing, as has been observed in one or two other places, a knobby or rolling tendency in the prairie surface, with gravel and boulders strewn over the surface of the knolls. One very prominent rock rises nearly forty feet above the general level, cone-like, and can be ascended only on one side. It bears a few cedars.

At Mr. Post's, granite outcrops occur at two places in the bottoms. These rise but a few feet above the general level. This granite has a strong resemblance to that at La Framboise's. It contains but little mica, and the feldspar is flesh-colored. The color here penetrates the feldspar crys-

tals. In some places, however, the mica is more abundant, and the feldspar is less red.

Birch Coolie creek joins the Minnesota in sec. 5, T. 112, R. 34. The sides of this ravine, a short distance above its mouth, are in granite, which is more or less decomposed. It seems to have a dip S., SE., and SW. The only place where real granite can be seen is about 30 rods above the mill dam of Mr. Eldridge. It here rises 20 or 30 feet above the creek. In other places the creek runs over it, making rapids and falls, some of which Mr. Eldridge has improved for his mill power.

A substance was met with here for the first time which was afterwards seen at a number of places. Its origin seems to be dependent on the granite. Its association with the granite is so close that it seems to be a result of a change in the granite itself. It lies first under the drift, or under the Cretaceous rocks, where they overlie the granite, and passes by slow changes into the granite. It has some of the characters of steatite, and some of those of kaolin. In some places it seems to be a true kaolin. It is known by the people as "Castile soap." It cuts like soap, has a blue color when fresh, or kept wet, but a faded and yellowish ash color when weathered, and when long and perfectly weathered, is white and glistening. The boys cut it into the shapes of pipes and various toys. It appears like the pipestone, though less heavy and less hard, and has a very different color. It is said to harden by heating. This substance, which may, at least provisionally, be denominated a *kaolin*, seems to be the result of the action of water on the underlying granite. Since it prevails in the Cretaceous areas, and is always present, so far as known, whenever the Cretaceous deposits have preserved it from disruption by the Glacial period, it may be attributed to the action of the Cretaceous ocean. In some places it is gritty, and in others it may be completely pulverized in the fingers. A great abundance of this material exists in the banks of the Birch Coolie, within a short distance of its mouth.

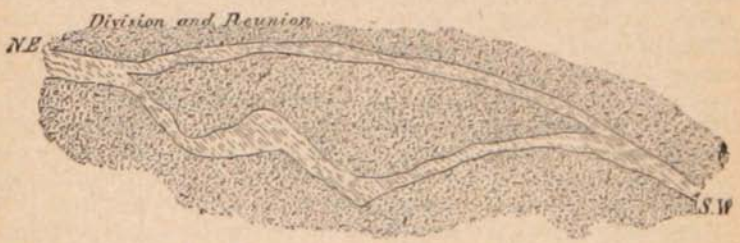
In the bed of the creek, above the mill-dam, several veins are seen crossing the smoothed surface of the rock. In low water these can be closely inspected, and their composition and structure ascertained. The following sketches illustrate some of their interesting features.

The structure of granite veins at Birch Coolie.

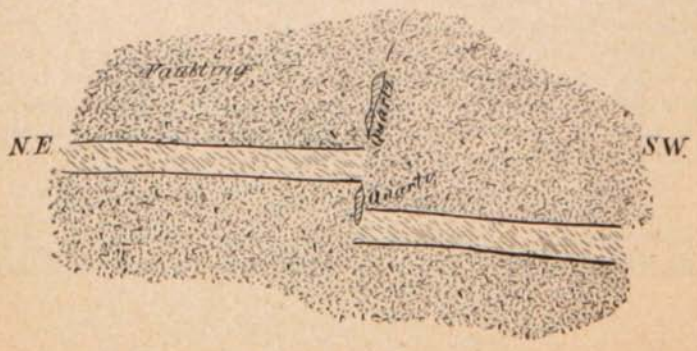
The vein, a part of which is illustrated by figures below, is in granite, and is made up of granite. The constituent

parts, however, in the vein, are much finer, than in the body of the enclosing rock, and show a deeper tinge of red color. Its direction is S.W., and it is four inches wide. It is visible along the creek 250 feet, and it is crossed by numerous other veins that are mainly quartzitic and narrow. The structure of the main vein is somewhat schistose, and seems to be harder, judging from its forming a ridge that stands above the general surface of the rock one or two inches. Tne laminæ of the schistose vein run usually at some angle across the direction of the vein, but in one place, where is a slight change in the direction of the vein, they nearly correspond with it. Their usual direction is nearer N. and S. This main vein is faulted in several places, and is divided so as to enclose an irregular oblong area at one point. The fault here sketched is accompanied by a very little quartzitic deposit, but there is no constant vein of quartz crossing the main vein, though there is a small indistinct seam that curves off to the south on the east side. The laminæ in the two separated ends of the vein exhibit a curving in opposite directions, as if they had been somewhat elastic or plastic, and by being wrenched apart, had bent toward each other.

Division and reunion of vein at Birch Coolie.

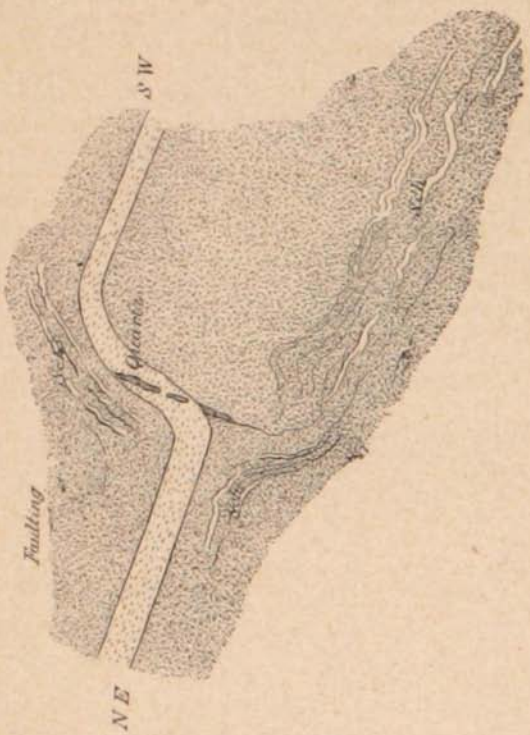


Faulting in vein at Birch Coolie.



The following diagrams represent some of the effects of disturbance in changing the direction and structure of veins. The curvature represented in the first below, is a part of the same vein as described above. It is accompanied by a change in the arrangement of the minerals in the granite, producing a curving, schistose lamination.

Faulting in vein.

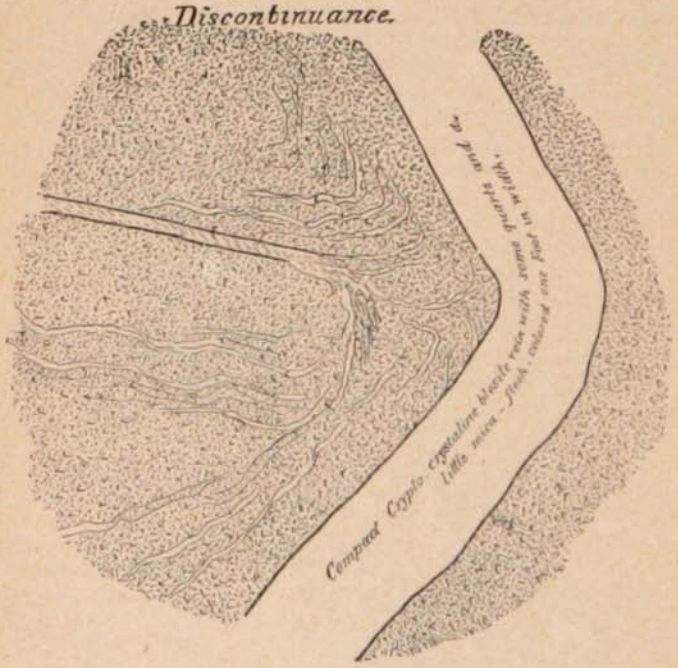


Sch—*Schistose granite.*

In the second, the same vein is intercepted by a vein that has the outward aspect of orthoclase felsite, which seems to be of earlier date, inasmuch as the former is discontinued on reaching the latter. The discontinuance of the smaller vein seems to have been the cause of a certain ramifying schistose structure in the vicinity of the point of contact of the two veins. The felsite vein is one foot wide, and has a

flesh color, with probably considerable quartz crystallized with it. It also shows some mica. It faults another vein, and hence is of later date than it.

Discontinuance of vein in granite at Birch Coolie.



[For "Compact, Crypto-crystalline blesite," read Compact, crypto-crystalline felsite.]

Granite of the same composition and outward appearance as that below fort Ridgely outcrops on both sides of the Minnesota, at the mouth of Crow creek, sec. 35, T. 113, R. 35. It is here also superficially decomposed to the depth of several feet, forming a substance resembling kaolin, already mentioned as occurring at Birch Coolie. The usual points of exposure of this kaolin are in the banks of the little ravines that enter the Minnesota river. It is generally overlain by deposits of Cretaceous age, comprising clay, lignitic shale, sandstone or limestone. When the water carries this kaolin out on to the bottoms, and there spreads it over the surface, it becomes dry after the subsidence of the water, and then appears as a nearly white, exceedingly unctuous, glittering scum covering the ground. In this con-

dition it shows minute flakes and sheets, that appear like exfoliations of talc.

At the mouth of the Redwood river, on both sides of the Minnesota, granite outcrops give rise to many rocky hills and knolls. The Redwood river, for some distance before reaching the Minnesota bottoms, is channeled through granite rock. This, together with the excavated Cretaceous rocks overlying, and the drift deposits, gives the river a very deep gorge through which it flows at a rapid rate, sometimes plunging over precipitous or perpendicular rocky descents, presenting a series of waterfalls, rapids, and quiet, deep pools of confined water, which are rarely excelled for picturesque beauty. The river falls about 100 feet in half a mile.

The granite, through which the river is cañoned, is usually the typical ternary compound, but shows variations. It is sometimes slaty or schistose. Just below the flouring mill of Messrs. E. Birum and Brothers, the rock on the left side is cut by divisional planes into oblique cuboidal blocks, and is called, in the absence of better, a "building stone," from the ease with which it could be quarried. It is also schistose, made up largely of quartz grains which are coarse, mingled with fine, glittering flakes that may be talc or mica. The greenish color of the whole stone, on fresh fracture, gives the rock a talcose character, although there are also occasional black scales that are plainly micaceous. The most frequent divisional planes here, causing the slaty or schistose structure, run about NE. and SW., and slope at an angle of about 25 degrees below the horizon, toward the SE. This rock might be denominated a schistose and talcose quartzite.

At Redwood Falls the granite is overlain by the kaolin, which has been mentioned, presenting, in connection with this substance, a very interesting series of exposures, and suggesting very interesting questions both economical and scientific. About a mile below the village, on the left bank of the river, is a conspicuous white bluff,* composed of white kaolin clay. Near the top of this bluff, where the rains wash it, it is silvery white, and that color is spread over much of the lower portions, though the mass of the lower part is more stained with iron, having also a dull greenish tinge. The white glossy coating which appears like the result of washings by rains, is spread over the perpendicular sides. On breaking off this glossy coating, which is sometimes half an inch thick, the mass appears indistinctly

*This is probably that seen by Keating, and pronounced "white sandstone."

bedded horizontally, but contains hard lumps and irony deposits. Further down, the iron becomes more frequent, and gritty particles like quartz impede the edge of a knife. The bedding also is lost, and the closest inspection reveals no bedding. Yet there is, even then, a sloaping striation or arrangement of lines visible in some places on the fresh surface, that corresponds in direction with the direction of the principal cleavage plane of the talcose and quartzitic slate already described. In other places this arrangement is not seen, but the mass crumbles out in angular pieces which are superficially stained with iron. The profile of the bluff here presents a singular isolated knob or buttress that rises boldly from the very river, connected with the main bank by a narrow edge along which a man cannot walk with safety. On either side of this bold promontory are retreating angles in the bluff along which a descent can be made. A careful inspection of these ravines and of the adjoining bluffs affords indubitable proof that this material, white and impalpable as it is, results from a change in the underlying granitic rocks.

Just above this point, is another exposure. It here supplies what is locally known as the "paint rock," from an enterprise started several years ago in manufacture of mineral paint from this material. The decomposed granite here has very much the same appearance as the kaolin, already described, at Birch Coolie, but contains more quartz, and is more stained with iron. It has a greenish color, but within might be blue. It passes upward into the greenish, and then white, kaolin clay already described, but it stands out in a crumbling, rusty buttress, exposed to the weather, and has quartzitic veins and concretions, iron-coated, and often an impure iron ore in considerable quantities. It shows silvery or shining talcose flakes, the same as seen in the so-called building rock, a short distance below the mill of Birum brothers.

A short distance above this, nearly opposite Redwood Falls, is situated the rock which was quarried for the manufacture of paint. This has in every respect the same character and composition as that last described. It consists of a perpendicular bluff or point, standing out from a lower talus that rises about 75 feet above the river, to the hight of 75 feet more. On the top of this is the drift-clay hardpan, covered by four or five feet of sand and gravel, the whole bluff being about 150 feet above the river. This bold bluff, or promontory, stands between re-entrant angles, its face fall-

ing down sheer thirty or forty feet. There is here visible an irregular slaty or cleavage structure in the rock, that at a distance has the appearance of dip toward the S. E. 30°. This also contains quartz veins and deposits, accompanied by iron, in some places too abundantly to allow of being cut with a knife, though very much of it can be easily shaped with a knife. It shows "slickensides," or surfaces that seem to have been rubbed violently against each other, causing a scratched and smoothed appearance, even within the body of the bluff. These surfaces are concave or curving, like putty hardened after being pressed through a crevice.

Between Beaver Falls and Vicksburg the granitic rocks appear almost constantly in sight, rising in mounds or bald irregular slopes, along the river bottoms, reaching occasionally as high as the river bluffs. For some distance above Beaver Falls, a ridge of granitic rock, running along within the bluffs, divides the channel into two parts, both of which are sometimes occupied by water, no such rock, nor any other, being visible in the bluffs themselves.

At eight miles above Beaver Falls such rock occurs in great force in the river bottoms, giving the appearance of a village, at a distance, partly hid by the scant foliage. Here it occupies the whole valley, spurs running in either direction into the river bluffs.

At Vicksburg the river bottoms are crowded with granite mounds and hills, some of them holding large blocks of hornblende schist that lie *in situ*, the transition from granite to schist being very abrupt.

After passing Patterson's rapids (T. 114, 37), the next important granite exposure noted was at Minnesota Falls, situated in the north part of town 115, range 39, although small mounds of granite occur for three miles below. Here the river bottoms are occupied by a schistose granite, which splits up conveniently for foundation stone. The change in the character of the rock is evident in the generally turfed condition of the mounds. The rock is here intersected by veins of quartz and trap dykes, the latter being traceable across the valley for half a mile, running N. E. and S. W. This trap is heavy and dark green, with some shining faces on the hornblende, when freshly broken. In higher levels, and apparently overlying this bedded schistose granite, is a compact hard-weathering granite. It is of a gray or greenish-gray color much resembling the St. Cloud granite. The rock at Minnesota Falls differs very noticeably from any

observed in the river valley at lower points. It is bedded, and has a strong dip towards the S. E.

At a point, a short distance from the river, up a little ravine, that joins the Minnesota, opposite Austin and Worden's flouring mill at Minnesota Falls, the mineral already described as kaolin, or "paint rock," may be seen. This decomposing granite here holds quartz veins and deposits; which being coated with a lustrous black mineral, or holding it in sheltered angles or cavities, has attracted the attention of the settlers, who have regarded it as possibly an ore of silver or of copper. This mineral has a dark, brown powder. When in the form of films or sheets, or larger globules, it parts with a specular cleavage. In some places a considerable iron rust is seen in this quartz, and in others drusy or peppery crystals, as if of the same composition, are scattered over the surface, making it appear specked under the glass. These fine crystals make a lighter powder. Prof. Peckham pronounces this mineral to be hematite iron ore. It is specular.

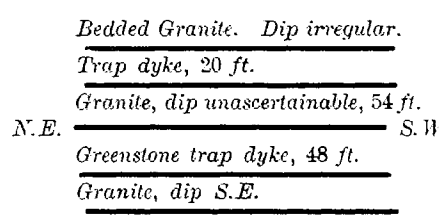
The valley all the way between Minnesota Falls and Granite Falls is about two miles wide, and presents a singular billowy prospect, of granitic knobs, rising and falling on all sides, the river worming its way among them and having frequent rapids and water-falls, useful for mill privileges. At Granite Falls, as at Minnesota Falls, and all the way between, the rock in the valley is a schistose granite, almost a mica schist; but it varies to a hard gray granite that resembles that at St. Cloud both in color and composition. This, however, forms but a small part, the greater portion being schistose or laminated. It also varies to a red granite, i. e. one in which there are evident flesh-colored crystals of feldspar. These two variations do not seem to lie with any as certainable fixed relation of superposition to the schistose or bedded granite, but rise in knobs and irregular masses higher in the valley than that. They are not wooded, nor turfed, the schistose granite which more easily decomposes being generally turfed.

The most marked peculiarity of the granite at this place is its constant dip toward the S. E. This has been observed at several other points before reaching Granite Falls, but some uncertainty has generally existed in regard to the true character of the lamination seen, and it has not been spoken of as dip. Although the usual direction of inclination is toward the S. E., it varies, at Granite Falls, from S. E. to N. E. It amounts to 25 degrees, but sometimes reaches 40 degrees. At one place at Granite Falls the rock dips to

the north for some distance. The red and gray colors are variously mingled, without any apparent law of association or alternation. Although the patches of more massive and typical granite are suitable for a fine building material, they still show the same dip toward the S. E., and are distinctly bedded throughout. These hard knobs rise from ten to twenty feet above the general level of the other granite, and show various effects of running water.

The trap dykes, the direction of which is shown by the adjoined diagram, occur in the river bottoms, about a mile above Granite Falls.

Trap dykes at Granite Falls.



There are sudden changes in the rock from real granite to hornblendic schist. These occur irregularly. A change like this gives rise to the waterfall near the flouring mill of Hon. Henry Hill, the fall being due to the greater resistance of the harder rock. The trap dykes above mentioned also cause rapids and waterfalls where they cross the river.

Between Granite Falls and Montevideo, at the mouth of the Chippewa river, the granite occasionally appears in the river bottoms. It was noticed at a point six miles below Montevideo, on the north side. The bedding, supposed to be due to original sedimentation, still dips to the east. It appears sometimes to stand nearly vertical. At this place occurs a belt or bed of hornblendic schist.

At two miles below Montevideo, is a conspicuous outcrop of compact hard granite, of a red color, lying mainly on the north side of the river, in the bottoms. This has the same dip, viz., 30 or 35 degrees to the southeast. The beds here regarded as representing dip, and at other points mentioned, should be further described. They are in thickness ½ to 2 or three inches, or they seem sometimes to be a foot or two. When weathered they appear thinner, and the granite then sometimes presents a slaty structure, the edges standing out sharply at the angle of dip. At Minnesota Falls

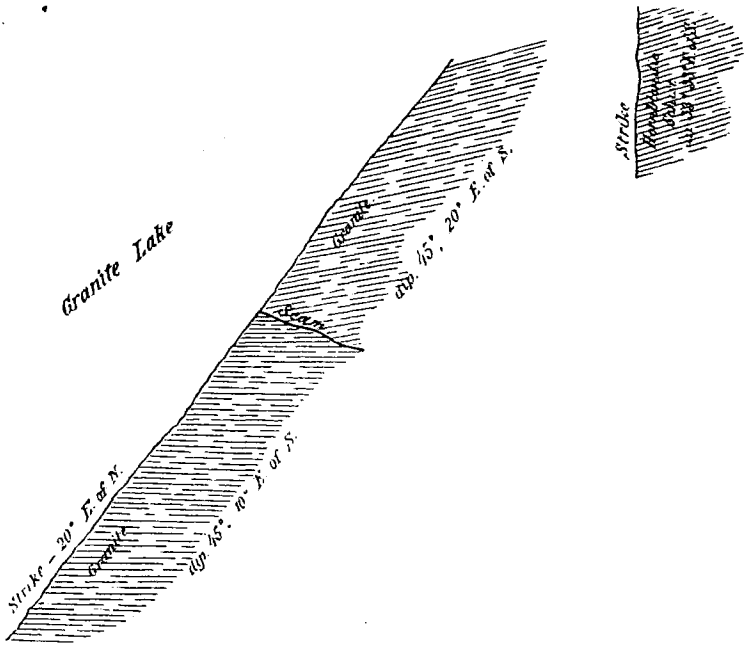
and from there to Granite Falls, these beds are so micaceous as to make what has been termed a schistose granite, the whole mass becoming easily disrupted by frost and water, and then turfed over. But at this place the beds are closely compacted, and the whole is almost massive. The thickness of the bedding can easily be seen, however, in the occasional thin sheets that part from the knobs, or in the striations that mark the faces of the water worn, bald knobs. Although these knobs rise at irregular intervals, and are variously situated with reference to each other, having sloughs between them, yet they are arranged somewhat in succession in one direction, making rows or almost somewhat continuous ridges, running parallel in the direction of the strike, N.E. and S.W., which of themselves indicate a system of bedding. On a weathered cross-section of the bedding, the marks of striation or sedimentation often show a wavy arrangement, or distorted parallelism, and sometimes they vanish and widen alternately. The dip measured in one place is here 58°, 10° east of south. At another point very near the last, it is 85° in the same direction. This granite has the color and apparent composition of that seen below fort Ridgely.

This granite shows occasionally a knob of hornblendic schist, rising among the granite mounds, having very much the form, dip and bedding of the granite.

There is also occasionally a mound or dyke of trap, or greenstone, split into shapeless blocks under the weather, the planes of division running in various directions. These have no bedding, nor dip, but are very heavy, and uniformly of a dark green color. They do not disturb the uniformity of dip in the granite.

The following diagram will exhibit some of the features of the granite as exposed two miles below Montevideo:

Granite two miles below Montevideo, Chippewa Co.



The change in the direction of dip in the granite here sketched is rather less sudden than here represented. The seam, or joint, marking the point of contact of the beds dipping in different directions, is very much covered with turf, and the manner of union cannot be ascertained definitely, but on the face of the bluff (strike) there is no apparent disturbance or irregularity.

A belt or wedge-shaped, lenticular mass of hornblendic schist occurs in the granite here described, on the land of Mrs. E. A. Hull, having a more easterly dip, and running N. W. and S. E. It is 20 rods long, and from 20 ft. to 6 rods wide. Its dimensions and form cannot be fully and exactly seen. It appears in low knobs much like the granite, and the intervals of non-exposure are grassy.

Mr. L. R. Moyer, county surveyor of Chippewa county, reports granite on the prairie, three miles east of Montevideo, and in the Minnesota bottoms, a mile above Montevideo.

Near the lower end of Lac-qui-parle lake, granite appears on both sides of the lake. It is usually inaccessible from

the prevalence of water; but in the dry months of the year it can be reached on the north side without any trouble, except from tall grass and bushes. There are three or four small bare spots on the south shore that can be seen, and three or four others that rise up in the midst of the lake. Two of these spots of bare rock also occur on the north side, near the foot of the lake. This rock, so far as can be seen on the north side, shows very much the same composition as further down the river. It contains quartz, mica and flesh-colored feldspar, with patches and veins of quartz, some of which are mingled with porphyritic feldspar. The exposed surfaces are annually submerged, or nearly so, and do not exhibit very plainly such markings as indicate sedimentation or dip. There seems to be an indistinct arrangement of the mica scales, so as to give the rock a schistose structure, but this, although generally running N. E. and S. W., does not have that direction invariably, and does not at all represent the lamination or bedding seen below and already described. In only one small area can there be seen what looks like the same bedding, and there it is but six inches in thickness, the beds being one or two or three inches, with a dip of 75° toward the S. E. Jointing planes divide the whole mass into blocks and rhombs, four or five or six feet in thickness. There is considerable low land about the lake, much of which is flooded at the wet season of the year, but it is stony and bushy, and has the appearance of rock in a great many places near the surface. Such appearances are seen the whole length of the lake, and especially on the north side. About three miles above the foot of the lake, rock can be seen on the south side at two points, rising plainly above the general level of the bottoms, and ascending in the slope from the prairie. Such exposures continue to near the head of the little lake in T. 120, R. 44, where granite appears in several places on the south side of the river.

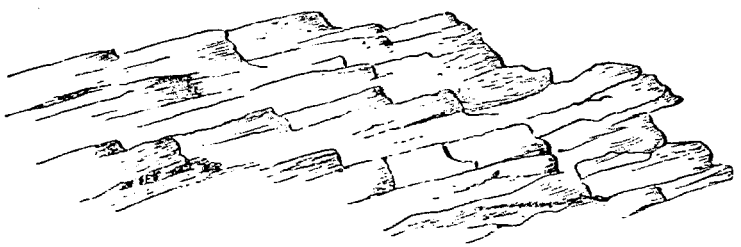
Further up the river, near where it enters T. 120, R. 44, may be seen a large exposure of coarse granite. The crystals of feldspar are large and flesh-colored, or red. Yet the granite also varies to a lighter color, in which the feldspar is nearly white. It shows, in the latter case, a perpendicular jointing, the planes being one or two or three inches apart. The whole exposure consists of bare, massive, rounded knobs, cut into angular rhomboidal blocks, by jointing planes, but in no place showing the dip seen lower down the Minnesota river.

Granite also outcrops about three-quarters of a mile above Mr. F. Frankhouse's, on the south side of the river, two miles above the last.

Red granite also appears about a mile further up, in the river bottoms, near Mr. W. Movius' house, presenting an irregular exterior, showing no dip, although there are here also conspicuous jointing planes. This is about three-fourths of a mile above the mouth of the Yellow Banks creek. Opposite Mr. Movius', on the south side, in the bottoms, may be seen another similar granite mound.

At three miles below the foot of Big Stone lake, there is a tumultuous outcrop of red granite, extending to the lake, on both sides of the river. This shows planed and striated surfaces on a grand scale. These marks have a N.W. and S.E. direction (corrected for variation), or that, in general, of the Minnesota valley. The whole rock, including the upper surfaces and the sides of the mounds, is planed off. The best exhibition of these markings is seen on the northwestern slopes, in which direction there is a system of jointing planes, dividing the granite into blocks that have at first sight a strong semblance of dip, the masses breaking off more nearly at right angles on the southeast side. This is a coarse, red granite, with large crystals of feldspar. The following diagram illustrates the effect of the jointing in the rock, acted upon by glacial forces from the northwest.

Jointing and glaciation at Big Stone lake.



Above the foot of Big Stone lake there is no known outcrop of granite throughout its extent. Cretaceous rocks constitute the only outcrops. These are seen sometimes in the little creeks that enter it, and are outlined as terraces on its banks.

The examiners of the land of the Winona and St. Peter R. R. report granite *in situ*, on the prairie, T. 113, R. 43, sec. 17, and T. 113, R. 39, sec. 29.

Further examination of the granitic belt was made at Sauk Rapids and St. Cloud, for the purpose of comparison with the granites of the Minnesota valley, and with a view to some parallelization; but as that region will undergo a more detailed survey, and no results were obtained bearing on the subject of the relative age of the rocks at that place and the granite of the Minnesota valley, those observations are reserved for future comparisons.

(j) THE CRETACEOUS.

In the progress of the season's work, the first point at which these rocks were seen was in Dakota county. At Empire City, where the highway crosses the Vermilion, sec. 24, T. 114, R. 19, the river is handsomely terraced. The valley between the lowest benches that rise on each side is from one to two miles wide. The first terrace is very conspicuous in the treeless landscape, and consists superficially of coarse drift. Its crest is gently rounded off. It is occupied with fine farms. The same is true of the land lying along its base, which might be called the flood plain of the river. Yet it is probable the river never floods the greater part of it. Some of this plain is wet and grassy, making fine meadow land, and other parts of it are plowed for wheat. The first terrace seems sometimes broken, about midway, into two terraces, the constancy of which could not, however, be discovered. It is subject to numerous re-entrant bends and other sinuosities, the points intervening being stony and only fit for pasturage. The pebbles are generally quartzitic, and lie very thick on the surface. They are rounded as by water. The hight of this terrace above the river, measured by Mr. Furber by Locke's level, was found to be 81 ft. 3 in. Above this terrace there is a further ascent to the level of the general prairie. What part the St. Peter sandstone, which forms *lone rock* a short distance north, and shows an outcrop in the valley a short distance up the river, plays in the formation of this terraced slope to the Vermilion, cannot be certainly ascertained, but it probably is very small. The Cretaceous clays and shales, with their associated loose sandstones, however, are perfectly adapted to the formation of terraces along streams, as has been, and will be further mentioned in describing the Minnesota valley, and they are believed to be the sole cause of these terraces. If the reader wishes to investigate this subject further, he is referred to those chapters and para-

graphs that describe the terraces of the Minnesota, and discuss the drift and its phenomena. This assignment of these terraces to the agency of the stratified deposits of the Cretaceous does not rest on bare opinion. The Cretaceous clay was seen in outcrop near the bridge over the Vermilion near Empire City. The destructible nature of these beds causes them to be covered by loose materials, which, after the lapse of time, spread over the entire surface, and superficially appear to compose the whole substructure. The beds themselves are thus only outlined in the form of terraces.

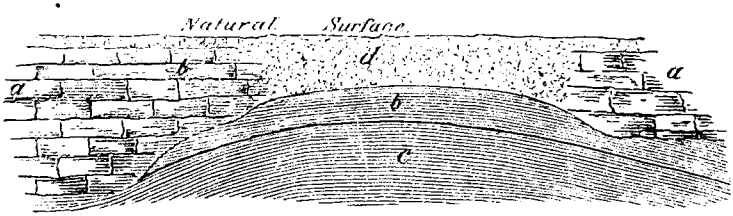
In ascending the Minnesota valley the first point at which the Cretaceous was indentified, so far as it can be without the aid of fossils, is at the Asylum farm, near St. Peter, in Nicollet county. It lies here in the water-worn openings of the Shakopee limestone. It is a white, or greenish-white deposit, holding much sand. It has a great many flinty fragments, and some siliceous limestone lumps. The latter are rounded, but the former are angular. The lumps are porous, crystalline, hard, and gray or white. No fossils can be seen, and no stratification. It seems rather to have been *jammed* into the openings in the Shakopee stone. A similar exposure, presenting the same characters, occurs across the river from St. Peter, and about a mile toward Kasota, in a bluff by the side of the road.

A heavy bed of white sand, which has been described as probably belonging to the St. Peter sandstone (p. 134), occurs on the Blue Earth and its tributaries. It is associated with an impure iron ore, and with light green shale, but its exact relation to them has not been ascertained. It may belong to the Cretaceous.

At Mankato, in Blue Earth county, a series of very interesting observations was made on the Cretaceous, throwing some light on the history of that period of submergence which brought the most of Minnesota below the ocean. Where the road to South Bend crosses the Blue Earth, on the east side of the bridge, is a cut in greenish clay, by the side of the road. This deposit of clay lies in a nook alongside the bluff of Lower Silurian, and doubtless was protected from destruction in the glacial period by that bluff. It is covered with drift, and at one place occupies a cleft in the Silurian rock, running nearly to the surface of the ground at the top of the bluff. Its position here, and as represented in the following sketch, is very deceptive. It appears very much as if in place in the Shakopee stone, but the beds of

that stone hold as low a place, horizontally, a little further to the left, as this clay. The bluff of Lower Silurian can be seen to disappear behind the clay, in some places the clay being removed so as to show the bluff at lower points than at others. There is every indication that this deposit is of small extent.

The Cretaceous at Mankato.



Explanation.

a. Shakopee Limestone.
b. Bedded, greenish clay, weathering white, but little sandy.
c. Sandy, bedded greenish clay.
d. Drift, mostly coarse fragments of Shakopee Limestone.

Passing along the right bank of the Blue Earth river from the highway to the railroad bridge, we come to a cut in the Shakopee stone. This is in the same horizon as that just described, and shows more fully the manner of superposition of the Cretaceous on the Silurian rocks. This cut is perhaps 70 feet above the river, the bank of which is composed entirely of rock, the lower portion of which is the Jordan Sandstone, and the upper, the Shakopee limestone, the latter comprising about 20 feet. In general this railroad cut shows a mixture of Cretaceous clay with the Lower Silurian, the top of the whole being thinly and irregularly covered over and chinked up with coarse drift. The Lower Silurian is more or less broken and tilted, at least the bedding seems to have been cut out into huge blocks by divisional planes, which, either by weathering or water-wearing, were widened, the blocks themselves being subsequently thrown to some extent from their horizontality, tipping in all directions. The opened cracks and seams were then filled with the Cretaceous clay, which is deposited between these loosened masses, and sometimes even to the depth of twenty feet below the general surface of the top of the rock. The clay sometimes occupies nooks and rounded angles, sometimes sheltered *below* heavy masses of the Silurian beds.

The clay is uniformly bedded, about horizontally, with some slope in accordance with the surface on which the sedimentation took place. But the most interesting and important feature is *the condition of these old Silurian surfaces.* They are rounded by the action of water, evidently waves. The cavities and porous spots are more deeply eroded, making little pits on the face of the rock; or along the lines of section of the sedimentation planes with the eroded surface. there are furrows due to the greater effect of water. The rounded surface of these huge masses of Lower Silurian is coated with a thickness of about a half inch, or an inch and a half, of iron ore, which scales off easily, and is easily broken by the hammer. While this scale of iron ore is thicker near the top and on the upper surfaces of the blocks. yet it runs down between the Cretaceous clay and the body of the rock, so as to prove its date older than the clay. The conclusions that must be drawn from this observation are about as follows:

1st. The Silurian rocks were long weathered, and washed clean, even water-worn and rounded, at this place, when they went below the Cretaceous ocean. Nothing intervenes between their iron stained surfaces and the clay.

2nd. This point seems to have been on or near the ancient shore line, where the violence of the waves was great. These rounded knobs could not have received their coating of iron if constantly submerged. The iron indicates the action of atmospheric gases on iron held in solution in water, as a bog ore formation.

3rd. The Cretaceous clay here, whatever be its place in the Cretaceous age, was deposited in a quiet ocean.

4th. This bluff, facing to the south, or south-east, like that at Mankato, indicates the approach of the Cretaceous ocean from that direction, though this may have been only a reef, or an island, just before the further submergence.

5th. There may have been, and was probably, a further deposition of clay of the Cretaceous age which was destroyed and transported by the drift period, at this place.

6th. The drift succeeded, and was not violent enough in its forces to disturb these tilted and waterworn masses of Lower Silurian limestone, so but that their old surfaces abut still unconformably against the Cretaceous clay.

7th. The Cretaceous sea must have advanced slowly over the Silurian rocks. These washed surfaces could not have been produced when the sea was retiring, else the Cretaceous sea would have washed out the clay. Further the clay lies directly in contact with these surfaces.

8th. The Cretaceous sea must have gone farther north and east so as to deeply submerge these disturbed masses, in order to have deposited such fine sediment in their crevices.

9th. While the washed surfaces indicate a shore line, or a reef, the clay proves deep submergence.

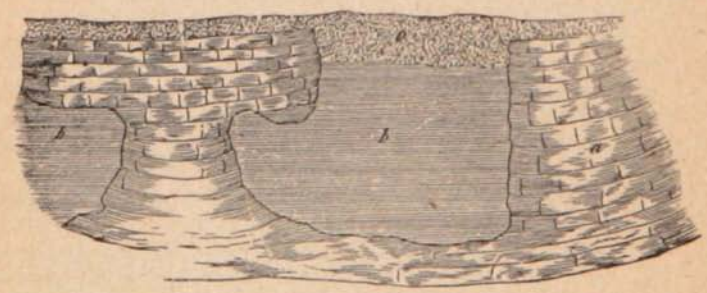
10th. The Cretaceous sea must have retired rapidly, so as to give no opportunity to wash out the clay.

11th. These washed surfaces must have been produced as the sea was advancing.

12th. While it is certain that the Cretaceous sea advanced slowly on the land, it is not certain that it retired rapidly. The clay existing there may have been protected from the retiring shore waves by superimposed beds hundreds of feet thick—such higher beds having been subsequently removed by the drift forces; but it is likely that drift forces that were able to destroy so much Cretaceous, would also so have disturbed the Silurian masses as to leave no trace of the clay, or even to have transported away the Silurian masses themselves. Hence it is probable that there was but little Cretaceous deposited over the remaining clay, and that the sea retired rapidly.

The adjoining sketches will give a better idea of the position of the Cretaceous, with respect to the Silurian.

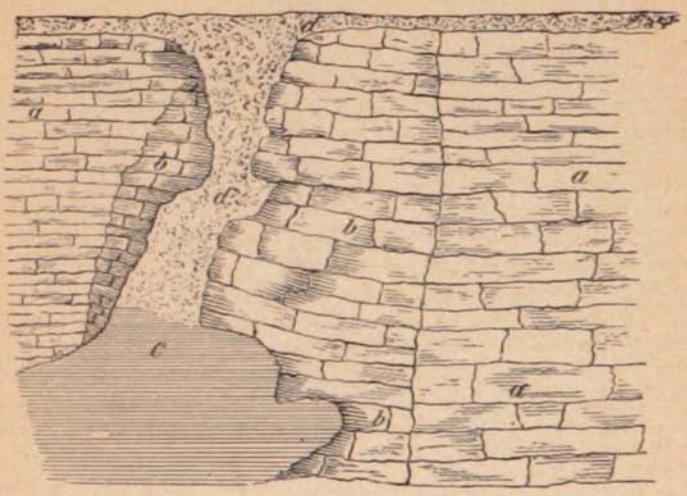
The Cretaceous on the Lower Silurian.



Explanation.

a. Weathered surface of Silurian.
b. Cretaceous clay.
c. Coarse drift.

The Cretaceous on the Silurian.



Explanation.

a. Silurian rock, cut by the grading of R. R.
b. Weathered surface of Silurian rock.
c. Cretaceous clay, greenish blue, bedded.
d. Coarse drift.

On sec. 25, T. 108, R. 29, (as nearly as can be made out), is an exposure of Cretaceous clay. The bank of the flood plain of the river is made up, almost everywhere, of sandy, more or less stratified, alluvium. But here, although having about the same hight, it is made up almost entirely of a mass of large, water-washed fragments of conglomeritic sandstone, which lie in confusion, some having fallen down into the water. They are underlain by a fine blue clay, without gravel or pebbles, belonging to the Cretaceous. Hence the sandstone or conglomerate pieces are not *in situ*, but pertain to the drift. Sometimes a layer of drift-pebbles and cobble-stones, about three inches thick, separates them from the clay. These large masses are 8 or 12 feet long, and 5 or 6 feet thick, and are scattered in talus over the Cretaceous clay, even into the river.

Dr. B. F. Shumard, in his report on the Minnesota valley, has mentioned an outcrop of *formation* 1 *capped with about* 25 *feet of gray, concretionary limestone*, about two miles below the mouth of the Waraju, and describes it as having disseminated crystals of calcareous spar. His analysis shows it to hold 90 per cent. of carbonate of lime. A

very long search was made for this exposure in the season of 1873. It could not be found—that is to say, nothing could be found pertaining to the Silurian rocks. A sandstone was seen in outcrop on sec. 16, T. 109, R. 29, on the north side of the river, in Nicollet county, quarried a little by Wm. Fritz, which proved to pertain to the Cretaceous, holding dicotyledonous leaves and branches. It consists of alternating layers of friable sand with angular shapes, but little rounded by attrition, and hard, cemented gray sandstone, which is sometimes coarse enough to be styled conglomeritic. The section here is as follows, the upper members being somewhat displaced by the washing out of the friable layers.

Section in Cretaceous sandstone. Land of Wm. Fritz, sec. 16, T. 109, R. 29, Nicollet Co.

No. 1.	Hard, gray sandstone, rusted in the weather, and checking into beds of about four inches,—sometimes one or two inches	18 in.
No. 2.	Friable white sand	10 in.
No. 3.	One course of gray sandstone, of variable thickness	1-3 ft.
No. 4.	White sand	6 in.
No. 5.	Gray sandstone, quarrying out in layers 6-10 inches thick, but in the quarry appearing massive; very hard, the cement appearing to be silica. It contains fragments of wood, charcoal and angiospermous leaves. Its under surface is undulatory, its thickness varying from	3-6 ft.
No. 6.	White, friable sand, seen	3 ft.

This whole quarry lies perhaps 35 or 40 feet above the river, and 40 or 50 rods from it. The persistency of this group of layers is evidenced along here by their forming a little terrace above the bottoms, which rises about 25 feet, and is visible for more than a mile. Pieces of this stone had been seen at lower points on the river, said to have been taken from the beds *in situ*, but it had been impossible to find those beds. One such place was at Mr. E. Rowe's, on sec. 23, T. 109, R. 29, on the south side of the river.

Four miles below New Ulm, on the south side of the river, is a bluff made up of Cretaceous, on the land of John Gruebel, as follows:

Section on sec. 2, T. 109, R. 30.

No. 1.	Black alluvium	2 ft.
	Passing below into—	
No. 2.	Clayey alluvium, of a light-brown color	4½ ft.

No. 3.	Red clay, containing some sandstone in masses: stratified	2½ ft.
No. 4.	Belt of greenish, sandy clay	1 ft.
	Passing into—	
No. 5.	Sandy clay, of a light umber color	1½ ft.
No. 6.	Bedded sandy clay, of an earth color, (same as No. 2)....	2 ft.
No. 7.	Greenish sand, the color coming from the mixture of green shale with the sand, the grains of sand being white quartz	2 in.
No. 8.	White sandstone, in one bed, or weathering into beds of two inches	1 ft.
No. 9.	Green bedded shale, or clay, with some fine sand grains, and some laminations or thick beds that are all white sand, but generally maintaining a green color, seen...	18 ft.
No.10.	Slope and talus	10 ft.

The bedding seen in the foregoing section is horizontal, and shows no fossils. Although there is no opportunity at this place to determine whether this series of shales lies above or below the sandstone at Fritz's, by an observation made in the bank of the road at the crossing of the Waraju, it is believed to overlie that sandstone, but to underlie a series of calcareous beds that appear in the right bank of the river, about a mile below the mouth of the Waraju. The colors near the top of the foregoing section exchange places a little, in following the bluff along, drift boulders and gravel occupying the place of clay, in No. 3. In some places the red, irony stain passes down lower. It is likely that the red, brown and ochery colors are due to ferriferous waters, since the deposit of the Cretaceous, and to oxygen in the air. Hence it is not certain that the drift extends through the whole of No. 3, although drift boulders are mixed with it, or replace it, in some places. When evenly bedded and free from boulders, it undoubtedly belongs to the Cretaceous, the drift stopping with No. 2. When it is replaced by boulders, the Cretaceous is only so much the more worn away, the color pervading them, or passing down to lower beds.

From the mouth of the Waraju going down the right bank of the Minnesota, a regular terrace is seen to rise several feet above the flood plain. About a mile down, this terrace shows its origin and composition, in the banks of a ravine which cuts it. (See map of this locality, page 157.) Before reaching that point, however, an outcrop of "gray concretionary limestone" is seen on the top of the terrace plateau. This limestone here is overlain by a couple of feet of water-washed limestone, gravel and cobble-stones, mixed toward the top with the usual black alluvium. The appearance of the quarried stone is like *drift* pieces, and the bed from which it is taken is intersected variously with

divisional planes, cutting the mass into irregular fragments, which, on being taken out, appear weathered. Yet there are crystal-lined cavities, some parts of it being mostly made up of calc-spar. Since the formation of the crystals, calcareous water has again deposited lime on the edges of the crystals, which, having first been of the thin (axe-shaped) variety, have now the appearance of separate but crowded cock's combs, the little, beaded accretions of lime being arranged on their edges. There is also a considerable quantity of uncrystallized lime on other surfaces. The interior of the stone is of a light gray or drab color, and when compact and free from crystals, is very fine grained. It is said to make a white, strong quicklime, of which there can be no doubt. This limestone outcrop, which shows only about 16 inches, is within a mile of the red quartzite outcrop near New Ulm, the bare bald surfaces of which are visible, from this point, on the other side of the Minnesota.

A little below the last described exposure, is Mr. Wm. Winkelmann's lime-kiln and quarry. The stone here burned is in the same horizon, and comes from the banks of a ravine that here enters the Minnesota. The limestone is much mixed, confusedly, with shale, but the following general section can be made out, in which no fossils were seen:

Section at Wm. Winkelmann's, near New Ulm, in Brown county.

No. 1.	Alluvium and boulders	2 ft.
No. 2.	Green shale, interstratified with belts and irregular nodules or masses of gray limestone	15 ft.
No. 3.	Green shale	1 ft.
No. 4.	White sand, varying to green shale	1½ ft
No. 5.	Green clay	2 ft
No. 6.	Calcareous shale, or marl, with some argillaceous matter	5 ft
No. 7.	Green shale, or clay, with blotches of red, seen	1 ft.
	Total	27½ ft.

The same kind of greenish marl is exposed up the Waraju, the immediate bluffs being somewhat wrought in it, to a point just back of New Ulm, where the bank is opened by Mr. Winkelmann for laying pipes to supply his machinery and brick-yard. The trench which he has dug passes through it just before reaching the bank of the Waraju river. The flat on which New Ulm stands seems to be made up by a terrace wrought in the Cretaceous. The surface of this flat is strewn with boulders.

Another creek joins the Minnesota nearly opposite the mouth of the Waraju, and also afords such exposures of the Cretaceous limestone as to invite the construction of lime-kilns. The sections here seen are not so favorable as that of Mr. Winkelmann, and contain more shale, some of which shows also a red color. In the shale are crystals of selenite; exposed ten feet. The kilns at this place are owned by John Heiman and Francis Baasen.

On the Waraju, about three miles from New Ulm, Mr. Christan Dauffenbach has established a manufactory of fire-brick. He obtains the material from the left bank of the river, where the Cretaceous affords the following section:

Section in Cretaceous on the Waraju river.

No. 1.	Hardpan drift, made up of clay and stones, seen about..	30 ft.
No. 2.	White sand, the age of which is uncertain, containing irony concretions and deposits. It is somewhat indistinctly stratified obliquely, like drift sand, and has some coarse grains. Its position in reference to the overlying hardpan drift, together with its thickness and purely white color, indicates its age to be Cretaceous.....	100 ft.
No. 3.	Blue clay, containing some siliceo-calcareous, irony lumps; said by Mr. Dauffenbach to hold some coal, mixed with No. 4 for making fire-brick.....	4 ft.
No. 4.	Sandy marl, probably largely aluminous, pronounced a silicate of magnesia by the chemist of the agricultural department at Washington. It is white, and when long submerged, soft and fluid-like, but when dry has to be quarried by blasting. This, mixed at the rate of two-thirds, with one-third of No. 3, makes a fine white, fire-brick—seen.....	12 ft.
	Total hight of bluff.....	146 ft.

The above section varies in short intervals. In connection with others seen at New Ulm, it shows how careful geologists must be in attributing to drift all that is found before striking the indurated rock.

Under the guidance of Mr. Dauffenbach, about half a mile further up the river, a sandstone outcrop was encountered. It rises in a bluff immediately from the water, on the opposite side of the river. In this sandstone, which here appears firm and massive, and which is probably the equivalent of No. 2, of the foregoing section, are many irony mud balls, or concretions, having a fancied resemblance to plums or bananas. They vary in shape and size. They have been gathered as fossil "fruits," and sent east as rare curiosities.

The general section of the Cretaceous at New Ulm is as follows:

No 1. Drift, gravel and boulders, with a surface-loam in some places, or largely made up of sand.....10 to 20 ft.
No. 2. Fine clay, blue, bedded, weathering white, used for pottery or brick ..... 4 to 10 ft.
No. 3. Sand or fine gravel, not cemented, readily crumbling, containing magnesian balls, or rounded lumps made up of a fine white powder—seen..... .20 to 30 ft.

The conspicuous Cretaceous terrace that occurs along the Minnesota at New Ulm, is due to this fine crumbling sand, overlain by a more tenaceous clay or shale. The varying composition of the Cretaceous makes it difficult to establish the horizontality of different outcrops, but there cannot be much doubt that No. 3 above is the equivalent of No. 2 of the section on the Waraju.

In the southwestern part of T. 110, R. 31, is another important exposure of the Cretaceous. It is in the banks of the Waraju, and consists of blue clay, and is used by the potters both at Mankato and New Ulm. That which is most highly esteemed is taken from the right bank about 40 feet above the river. It contains no gravel, nor any perceptible grit. It is owned by Silas Barnard.

A trial was made by Mr. H. B. Kaufer, potter at Mankato, of a clay outcrop on the other side of the river, about a quarter of a mile further up. Although this is about the same altitude above the river, and has outwardly the same general color and character, it is said to have proved unfit for potter's use, owing to the occurrence of small, black, hard, roughened pebbles, that can be broken only with great pressure, called "sulphur balls." These small specks weather black, and are doubtless composed of crystalline sulphuret of iron.

At Sleepy Eye, T. 110, R. 32, the Winona and St. Peter R. R. Company are sinking a well for artesian water. At the depth of 143 feet the drill had passed through the following section:

Black loam	5 or 6 feet.
Gravelly, brown clay	20 feet.
Gravelly, blue clay	115 feet.
Soft, pulpy, blue clay, that necessitated the tubing of the well	3 feet.
Total depth	143 feet.

In sinking a former drill, a pocket of coal was met in the gravelly, blue clay, at the depth of 75 or 80 feet.

The Cretaceous again occurs in the banks of Little Rock creek, near fort Ridgely, and was at one time explored there for coal.

At a point two miles below the Lower Sioux Agency, sec. 10, T. 112, R. 34, on the north side of the Minnesota, a small creek joins the river. Up this creek, about three-quarters of a mile from the river bluffs, the Cretaceous appears in its banks. A concretionary marl, or apparently limy earth, of a white color, crumbles out under the projecting turf. It appears in fragments of an inch or two, or sometimes larger, with angular outline. The surfaces of these pieces show a great number of round or oval spots, or rings, which seem to be formed by the sections of concretions inclosed in the mass. It is rather hard when dry, and nearly white. It is associated with a blue clay, the relations of which cannot here be made out.

At a point a little further up this creek appears a heavy deposit of concretionary, rusty marl, or ferro-calcareous substance, the exact composition and proper name of which it is impossible to give, before it has been chemically examined. It is in heavy beds, that fall off in large fragments, like rock. The first impression is that the bluff is composed of ferruginous conglomerate, but there is not a foreign pebble in it. Every little round mass has a thin shell which is easily broken, revealing either a cavity or a loose, dry earth. These concretions are generally not more than 1-4 or 1-2 inch in diameter; seen 18 feet. Under this is the light, concretionary clay or marl already described.

At the Lower Agency an exposure of the Cretaceous occurs in the road, seen in descending to the ferry. It consists of a sandy marl. Beds horizontal, or nearly so.

In the banks of Crow creek, which enters the Minnesota 3½ miles below Redwood Falls, the Cretaceous beds are carbonaceous, and have been considerably explored for coal, on the land of George Johnson. In 1871, Wm. H Grant, of St. Paul, entered upon a systematic examination of these layers, drifting into the side of the ravine 200 or 250 feet. This work is said to have cost about $2,000. A similar "coal mine" was opened in the banks of the Redwood, near Redwood Falls, where $5,000 are said to have been expended in a like fruitless attempt. This coal is from one of those layers in the Cretaceous that are usually known as lignites. It is earthy, passing sometimes into a good cannel coal, or into a bituminous clay. The compact cannel coal is in detached lumps, and occurs throughout a band of about

four feet in thickness. This lignitic band was followed in drifting into the bank of Crow creek, and was found to divide by interstratification with black clay, showing some leafy impressions and pieces of charcoal.

The "coal" here is said to overlie a bed of lumpy, concretionary marl, similar to that described at two miles below the Lower Agency, or two and a half miles below Birch Coolie. In some of the concretions are small shining balls of pyrites, which the workmen treasured up as gold. Over the "coal" is a blue clay, requiring a timbered roof in the tunnel. This clay is likewise Cretaceous. The underlying lumpy or concretionary white marl becomes siliceous, or even arenaceous, the concretions appearing more like chert. Some of it is also pebbly, showing the action of water currents.

The same lignitic coal occurs near Mr. Johnson's on the land of Hugh Curry, Wm. H. Cornell, E. O. King and Mr. Riker's, in the little ravines that enter the Minnesota, the exposures being kept fresh by the freshet waters. More or less exploring and drilling, besides that done by Mr. Grant, has been engaged in, in this vicinity, but never with any better success.

Near Redwood Falls, on land of Mr. Birney Flynn, is another outcrop of carbonaceous deposit in the Cretaceous. This is seen in the left bank of the Redwood river. It is in the form of a black bedded clay or shale, five or six feet thick, more or less mingled with charcoal and ashes, the whole passing below into charcoal fragments mixed with the same ash-like substance. In the latter are sometimes large pieces of fine, black, very compact coal, the same as that already spoken of at Crow creek, as cannel coal. These masses show sometimes what appears to the eye to be fine woody fiber, as if they, too, were simply charred wood. Further examination will be needed to determine their origin and nature. They constitute the only really valuable portions of the bed, the light charcoal which everywhere shows the distinct woody fiber, being generally mixed with the light ashy substance, and in a state of fine subdivision.

A short distance above Mr. Flynn's land is that of George Houghton, where the Redwood Falls coal mine was opened.

This mine consists of a drift into the bluff, forty feet, following a lignite, or charcoal bed in the Cretaceous. The bed here is seven feet think, the greater part of it being made of black, bedded shale or clay, though Mr. Flynn is authority for the statement that it showed a great deal

more of the real charcoal than any other point discovered. Some fragments that lay near the opening contained about nine parts of light charcoal to one of ash, the whole very slightly cemented, and so frail as to hardly endure transportation. In this drift were also numerous pieces of what is described by the owners both here and at Crow creek, as "stone coal." It is the same as that mentioned as probably a cannel coal, occurring at Crow creek. It is these harder lumps that are found scattered in the drift throughout the southwestern part of the state, so often mentioned in the newspapers.

Up a little creek that comes into the Yellow Medicine river from the south, near the village, is an exposure of fine stratified blue clay that weathers to a yellowish color. It has a thickness of at least ten or fifteen feet.

At a point six miles below Montevideo, on the north side of the Minnesota, there is a terrace within the main river bluffs, extending along the river for three miles at least, on which there is a wide plateau. This terrace rises 45 or 50 feet above the water, the flood plain being about 12 feet. On examining for the cause of this terrace, the only indurated rock found was in a little point that juts out toward the river about on a level with the top of the terrace: and that consists of granite, overstrewn with boulders. The terrace, however, is probably not due to underlying granite, for the surface of granite would not be so nearly level as to give the uniformity and regularity of outline here seen. It is more likely that Cretaceous rock, of a fragile and crumbling character, is concerned in giving form to this terrace, as has been seen in a number of other cases.

A mile further up the river, this bench shows a fresh section down to the water level. In general, the whole consists of fine sand, in which swallows burrow and breed. It stands, however, in nearly perpendicular walls, something like the "bluff." Yet it is not the *bluff*, because it is too fine, has no shells nor pebbles, and is stratified. It also becomes a bright blue color near the water level, and shows a sticky, clayey consistency, indicating a good material for brick. It cannot be of the same date and origin as the *bluff*, since it is an isolated instance of the occurrence of such beds along the Minnesota valley. It has very much the character of a late alluvial deposit, but rises too high to be of the same date as the flood-plain of the river. It is throughout mainly sand. The sedimentation is not always horizontal, if the individual layers be regarded separately, but it is if

taken collectively. There is a wave-like arrangement or anastomosing of layers; some are quite oblique and cross-bedded. In some parts of the upper 25 feet there is a rustiness, confined to certain thin beds, which makes them adhere in masses after falling out of the bluff, and at a distance have something of the appearance of sandrock. These, however, crush down at once under the hammer, or even in the fingers. While this deposit has very much the aspect of fine drift, its occurrence here in the form of a wide, continuous plateau, rising nearly fifty feet above the water, makes it very probable that it belongs to the Cretaceous, although it differs from any rock of that age before seen.

About half a mile, a little west of south from the stage station at the head of Big Stone lake, in Dacotah, an exposure of Cretaceous occurs in the right bank of the upper Minnesota. It shows superficially only a weathered, sliding talus of shale, which is black and somewhat slaty, but which on digging becomes moister and soft and somewhat flexible, yet parting into small chips. Over the surface of the ground, where this shale outcrops, the turf is prevented from growing, and two conspicuous objects, weathered out from the shale, are seen. 1st. Little angular crystals of pure gypsum, the largest seen weighing not over half a pound. 2d. Little angular bits of yellowish red ochre, that are hard and thin, but can be cut with a knife. There is also an occasional piece of brecciated, clayey, or at least aluminous rock, the cracks and surfaces of which are filled and coated with crystals of calc-spar. When broken by the hammer, these part along the numerous planes that on either side are lined by this calc-spar, and each fragment is entire, appearing itself a mass of calcite. It is only by several attempts that a view of the interior, on which these coatings are formed, can be obtained. The thickness of this shale bed cannot be ascertained. The angular bits of ochre are most numerous near the top, where the drift supervenes, but the gypsum crystals are scattered over the whole outcrop. The indications are that the gypsum and ochre are embraced within the shale, and become superficial by weathering. The whole may be twenty-five feet thick.

This shale bed is the cause of a terrace in the descent from the high prairie, and of numerous springs that issue below the drift, about sixty feet below the prairie level. These springs excavate narrow ravines and "gulches" in the shale, the whole being smoothly turfed over, except at

the point above described. These alternating gulches, and the intervening short pieces of the remaining terrace, make the bluff in general appear hilly, in its ascent from the bottom-land. These ravines, in the wet season of the year, are very soft, and since they appear practicable for a horse, are the cause of many misfortunes to the traveler. Many such treacherous, springy places are described as occurring along the shores of lake Travers, at some elevation above the waters of the lake. The same rolling ascent from the bottom land to the high prairie can be seen also at the head of Big Stone lake, on the Minnesota side, and it is there doubtless, due to the same cause.

General section of the Cretaceous in southwestern Minnesota.

The limited observations that have been made on the Cretaceous in Minnesota, will not warrant a conclusion on the alternation of parts described in the foregoing account of the Minnesota valley. The beds are nearly horizontal everywhere seen, a fact which makes it necessary to pass over long intervals before looking for a change in the observed horizon. While this simplifies the problem, it leaves out of the account the possible changes that may exist in the character of the sedimentation on any geological horizon, and introduces an element of uncertainty in any attempt to generalize the rocks of the Cretaceous. Future observations made in detail in the various counties crossed by the Minnesota and its tributary valleys, will throw very much light on the question of the superposition of the outcropping members that have been seen the past season. The following arrangement is altogether provisional, and is intended to express such superposition as seems to be correct, in the light of the information now at hand.

In descending order.

1. Shale holding gypsum. Big Stone lake.
2. Clay and lignite clay. Crow creek and Redwood Falls.
3. Concretionary marl. Sec. 10, T. 112, R. 34.
4. Potter's clay. New Ulm and T. 110, R. 31.
5. Dauffenbach's fire-brick section. Waraju river, (perhaps the sandstone seen near Red Jacket mills, and at Garden City, belongs here,) (p. 133).
6. Limestone and shale. Winkelmann's quarry, near the mouth of the Waraju river.
7. Sandy shale. Gruebel's section, sec. 2, T. 109, R. 30.
8. Sandstone. Fritz's quarry, sec. 16, T. 109, R. 29.

(k) *The drift, and the general topography of the valley.*

Southwestern Minnesota is characterized by extensive drift deposits. They are spread so evenly over the whole country, that to the eye of the travĕler, there are but few important variations from a dead flat. One vast plain seems to spread out on all sides. The view is only obstructed by the narrow timber belts that skirt the valleys of streams, or by the dim haze in which the horizon is itself lost to sight. There are minor irregularities of surface due to the occurrence of gravelly knolls, and to the erosion wrought in the surface by streams of water, but these do not effect materially the general flatness of the whole region.

The general composition of the drift is such as to prove its origin to have been due to glaciers. By far the largest part consists of "blue clay," the surface of which is weathered to a yellowish brown to the depth of 15 or 20 feet. This contains gravel stones and boulders, yet it is nearly, and often quite, impervious to water. There are places, especially along the immediate valleys of the principal drainage courses, in which the drift shows a very sandy and gravelly composition, the sand and gravel being deposited in oblique and vanishing layers often to the depth of over fifty feet. This character is very common along the Minnesota from Mendota to Mankato. In this case the main bluffs of the river constituting the principal, and the first, descent from the prairie level, are made up of such stratified deposits, but at a short distance from the river valley, in either direction, the typical unmodified glacier drift returns with its full development.

Besides these instances of stratified gravel and sand in the drift along the immediate river valleys, isolated knolls, or clusters of knolls, composed of the same materials, are sometimes seen rising boldly and conspicuously from the midst of the level prairie, reaching all hights up to a hundred feet or more. Such knolls are sometimes ferriferous, and the gravel is hardly cemented, making a crag, with lumps of impure bog-ore. This ore is not now properly a bog-ore, since it lies on the sides of gravel knolls, one or two hundred feet high, (as on the Maple river, near the Red Jacket mills,) but it is probably a brown hematite. It is very siliceous and not likely to be of economical value. These gravel knolls are sometimes very stony, with northern boulders. Instances of such gravelly, rolling tracts, sometimes of large extent, were noted in the reconnoissance

made the past season, as follows: A belt of gravelly knolls runs from the southeast part of Faribault county, to about the center of the same. South from Lura it may be seen across the treeless prairie, and is scantily wooded. It furnishes the only stone useful for building or for foundations, in the form of northern boulders, that can be found throughout a wide extent of country. This gravel belt rises considerably higher than the village of Wells, and probably gives source and head to the artesian overflow of water that there exists. These artesian wells are 115 feet deep, and passed through "blue clay." In about the center of T. 110, R. 32, is a gravelly ridge or succession of drift knolls, running NNW., showing boulders on the surface. The country about is flat and prairie like, covered with the hardpan, glacier drift, and these knolls are quite a relief to the eye. One can hardly resist the conviction that rock *in situ* must occur somewhere exposed in these knolls, and it is only after a lengthy examination that their true character is established. This ridge runs about a mile east of Sleepy Eye village, and the separate knolls rise 25–40 feet. They lie about on the strike of the red quartzite from New Ulm. The eastern ascent of the Coteau des Prairies enters Minnesota from the NW., in the southwestern part of Yellow Medicine county. East of this ascent about ten miles is a range of gravel hills running nearly N. and S., known at their southern extremity as the "cobble knolls," and at their northern as the "antelope hills." They are composed, as their name indicates, of drift. They have a general extension N. and S., but yet they occur in clusters. Some are quite sharp and abrupt. They rise from 125 to 200 feet above the surrounding prairie. They are smoothly rounded on their summits, and overstrewn with stones and boulders, the latter showing frequent glacial surfaces, even on the top. The grass and weeds are short. The soil is thin. Little gravel stones almost cover the surface. The knolls themselves consist largely, without doubt, of stratified gravel and sand, like a great many others that have been seen in different parts of the drift latitudes, (*Geol. of Iowa*, 1870, *Vol.* 1, *p.* 99; *Geological Survey of Ohio*, under Hardin, Allen, Delaware and Angalaize counties; *Proceedings of the American Association*, 1872, *p.* 164.)

They can be seen to extend six or eight miles, and perhaps are traceable further than that distance. From their tops a magnificent view of the prairies on all sides, and of the Coteau toward the west, can be had. A similar range

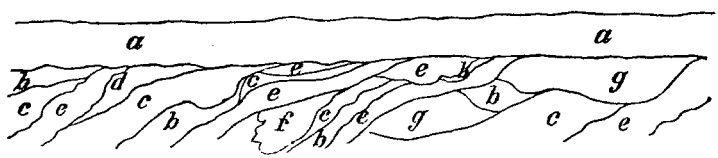
of drift knolls, but much smaller, was seen about six miles east of this range, running also in the direction N. and S. For reasons that cannot be here enumerated, these gravel ridges are believed to mark the location of the strike of different formations of rock, which, with each other, formed such inequalities in the surface passed over by the great glacier as to fracture the ice profoundly. The streams of water that entered and ran through such cravasses were sufficiently powerful to wash out the clayey portions of the drift, and to arrange the coarser in various stratification. After the withdrawal of the ice, the ridges of gravel mark the general location of such glacial streams. These must not be confounded with other drift ridges that accumulated about the borders of the ice field, known as moraines, of which the Coteau des Prairies seems to be a stupendous example. This remarkable topographical phenomenon was visited at the point where the Winona and St. Peter R. R. meets it. The country from Lac qui Parle to that place is of the same general character as the rest of southwestern Minnesota, but is perhaps freer from sloughs and impassable places than the country in the region of the Silurian rock. It is mostly entirely destitute of timber. The Lac qui Parle and its tributaries are wooded a few miles from the Minnesota, but very sparsely. The timber entirely disappears before reaching the state line. The soil shows in dessicated places the color of the alkaline deposit common on the western plains, becoming more and more abundant toward the west. There is not, enough, however, in this direction within the state of Minnesota to interfere seriously with agriculture or stock raising. The productiveness of the soil seems not to be affected by it. The state line, where the Winona and St. Peter R. R. passes it, is a short distance west of the foot of the *coteau*. At a distance the *coteau* looks like a sudden and marked elevation in the western horizon, rising a great hight above the prairie level. But on reaching it the ascent is found to be gradual, the surface changing from level to rolling or hilly. It is, however, quite abrupt in some places. Good farms can be laid out in neary all parts of the *coteau*, many of them far preferable to farms very highly valued in Ohio, Pennsylvania or New York. There is no timber except along the tributaries of the Lac qui Parle, or other small streams. No rock can be seen *in situ*. Although the railroad affords very frequent cuts in getting through this rolling country, it discloses no known rock as far westward as lake Cam-

peska. This point was particularly examined for over six miles beyond the foot of the *coteau*, with the hope of seeing, in some of the frequent cuts, some indication of a rocky sub-structure. Nothing can be seen but drift. This drift consists of glacial clay. The surface is generally stony, especially on the tops and brows of knolls. Boulders of northern origin are very common. Some large fragments of Silurian limestone were seen, but generally the erratics are granitic. Beyond the first ascent to the knobs of the *coteau*, there is a stretch of less rolling country reaching westward about ten miles, when another still higher range of hills and bluffs appears. The divide, east of the Sioux river, is about fifteen miles west of the state line, at an elevation (by the Winona and St. Peter R. R.) of 1,448 feet above Winona. The ascent from the prairie level, a few miles east of the state line, to the top of the *coteau*, fifteen miles west of the state line, is about 650 feet. On the top of the high country are occasional pleasant lakes. At De Graff, just beyond the state line, in Duell county, Capt. H. H. Herrick burns lime from a dark surface deposit of tufa. This deposit shows impressions of leaves and twigs, and others that appear like rushes. It has some iron stains, and a trace of bituminous matter. It occurs in a number of places on the sides of the knolls, overlying the drift gravel and clay. The general appearance of the surface of the *coteau*, especially near its base, as well as the surface of the *antelope hills*, aside from this surface deposit of tufa, where no water is now running, indicates the former prevalence of a much greater amount of water running over it than now. The boulders and gravel that lie so thick on the top and upper slopes came from the drift, the clayey parts having been carried away by drainage. They are all water worn—though not so but that the boulders sometimes show glacially striated surfaces. That this water was running, and not standing, is evidenced by the tufa, which is only deposited where the atmosphere has access, and by the manner of its occurrence, which is only on the lower slopes of the knolls, though at varying elevations, so far as seen. That there was vegetation near is proved by the leaves and other impressions. That the flow was of short duration, comparatively, is also proved by the universality and uniform character of the drift sheet, and by the lack of rocky outcrops. That the water which deposited the tufa was heavily charged with lime, is proved by the abundance of the deposit and by the coarseness of the in-

closed impressions. That it was the same that washed the light drift from the tops and brows of the knolls, is evident from their associated occurrence. That this water was from the retiring glacier, which would inevitably have given off water of a milky color, stained with the fine debris and soluble portions of the rocks it had ground up in its course, is probable.

At St. Paul, near the St. Paul and Sioux City depot, the lower part of the drift is exposed in the excavated river bluff, and is chiefly hardpan clay (or glacier drift). It is conspicuously colored by the shale of the Trenton. The alternating blue shale and copper-colored hardpan drift show successive accretions with such regularity as to attract immediate attention. The bands slope at an angle with the horizon, the drift holding stones and occasionally large boulders, and the shale showing fragments of the bedded lamination not yet obliterated, as well as the usual fragments of *Chaetetes*. At a higher level is a heavy stratum of 25 feet, overlying the foregoing, consisting of gravel and boulders, with many pieces of limestone. The following diagram illustrates the alternation of materials in the drift at this place.

Section in the drift at St. Paul.



a. Gravel with many stones, 25 or 30 feet.
b. Green, shaly clay,
c. Blue, shaly clay,
d. Greenish, shaly clay.
e. Red clay,
f. Brown drift clay, stony,
g. Ashen drift clay.

25 feet above the river. — 25 or 30 feet.

The bluffs of the Minnesota require a special mention, as they form a very important element, not only in the topography of the southwestern part of Minnesota, but also in any description of the drift of that portion of the state and of the northwest. The level of the river itself, in the summer season, is about 180 feet below the prairie level. The water runs in a very winding course back and forth between

the bordering bluffs, the direction of which, not regarding the little angles caused by streams that enter the Minnesota, is very regular. They have some long bends, but in general maintain a remarkable constancy of direction and hight. The bluffs, especially on the north side, are often treeless. The bottom-land itself is very often treeless. On the south side, on the contrary, the river bottoms and the tributary valleys, as well as the slope of the main bluff, are usually wooded. Hence the abruptness, and at the same time, the regularity of slope, direction and outline, are most marked on the north side. These bluffs appear, superficially, to be formed of drift alone above Mankato.

Below Mankato the Silurian rocks are frequently seen exposed in them, causing long terraces at various altitudes. Throughout the whole length of the valley, boulders and stones of a northern origin are seen on the brows of these bluffs, and on their abrupt faces, or on the slopes themselves. They literally cover, sometimes, the Silurian terraces below Mankato, as at Shakopee, Louisville, Ottawa, St. Peter, Mankato and Judson. There is a good illustration of this in the terrace that extends along the east side of the river below Mankato, and also toward South Bend. Where the hard rocks of the Silurian lie deeper, the boulders that otherwise would be visible seem to have sunk into the softer alluvium. They are always met with in penetrating through the alluvium, before striking the rock. They pertained to the general sheet of drift, before the excavation of the valley, and have been left simply lodged where they may have fallen, sometimes on rock terraces, as the river has slowly carried away the fine clayey portions of the drift. Notwithstanding the drift characters are the only apparent ones, yet there is a canopy of Cretaceous that lies below and gives levelness to the country, hiding the granite and the Silurian rocks. This, mixing with the drift, has greatly augmented its volume beyond what it would have been had harder rocks existed in western and southwestern Minnesota. The existence of this canopy of Cretaceous under the drift is demonstrated by the occasional exposure of such beds in the little ravines that enter the Minnesota. Such beds are intersected by the bluffs themselves, and cut by the river channel, though they are rarely seen in the main bluffs of the river itself. They are hid by the downfalling of the drift. They are so frail themselves that they cannot endure the exposure exhibited by the Silurian limestones, (see page 184,) and hence do not make

so manifest terraces in the main bluff. This main bluff, therefore, above Mankato, generally exhibits a regular slope from the prairie to the bottom land. There is sometimes a dim outline of a terrace, or shoulder, in this slope, caused by the unequal demolition of the Cretaceous, but *throughout the valley there are no alluvial terraces that can be attributed to successive reductions in the volume of the river.* Such appearances are visible at New Ulm, as well as at various places below Mankato, at Lower Sioux Agency and at Beaver Falls. At places below Mankato the semblance to constant terraces is due to the effect of the Shakopee limestone on the banks, combined with that of the erosible nature of the underlying Jordan sandstone. Such occasional benches occur at different elevations as far as the Silurian rocks extend. Above that they are due to the Cretaceous. Such occur at Fritz's quarry, a few miles below New Ulm, and at Gruebel's a little further up the river. At the former place a sandstone in the Cretaceous offers a more persistent obstruction to the water, at the latter the terrace is caused by a hard clayey layer over one that is soft and arenaceous. At New Ulm a similar combination of layers may be seen near Dauffenbach's pottery, and in some of the highway cuts for grading the streets running down from the city (which is situated on this terrace) to the R. R. depot. At and below Redstone, and on the opposite side of the Minnesota near the mouth of the Waraju river, a calcareous mem ber of the Cretaceous causes a terrace that rises about 40 feet above the river. This may be seen at Winkelmann's lime kiln and quarry. This terrace is prolonged for several miles below Redstone, on the north side of the river. Its level for some distance is kept up by the red quartzite in outcrop there, but it is doubtless due mainly to the Cretaceous.

At Lower Agency a dim outline of a terrace is seen near the top of the bluff running along about half a mile. Its cause is not discoverable, but may be reasonably regarded some member of the Cretaceous, which can be seen at a lower level in the highway ascending from the ferry to the top of the bluff. It is most observable from a distance, and especially from the north side of the river.

There is a semblance at Beaver Falls, though faint, of two terraces, near the top of the bluff, visible from the opposite side of the river, the upper one having about the po sition of the faint terrace seen at Lower Sioux Agency.

A terraced condition of the bluffs may be seen at a little lake, caused by the enlargement of the river on T. 120, R. 44, as well as in the bluffs of Lac qui Parle. Here an observation was made that plainly indicates the origin of these benches. They exhibit a slope or dip towards the S. E., running successively down to the bottoms, higher ones occurring in their places. This can plainly be seen from the opposite bluff. This slope is believed to be due, in like manner, to the dip of the rocks of the Cretaceous, though no outcrop of those rocks was seen at that place, the bluffs of the river and of all ravines being smoothly turfed over.

The general hight of the bluffs that enclose Big Stone lake is about 150 feet. They are treeless. Their crests are usually crowned with boulders. The only wood that is seen lies in the "gulches" or short ravines that enter the lake from both sides, and on the islands, some of which are densely wooded with small trees. There is also a thin, continuous row of small trees and shrubs growing on the immediate shore, just above the boulder-row. The bottom-land is usually not marshy but arable, constituting really the most desirable farms. It is first taken by settlers. It is wide enough for one or two good fields. The settler also has his garden and cabin on the low land invariably, and generally at the opening of some one of the little ravines, which afford water without digging*, and protection from the winter winds, as well as convenient fuel. Along this lake, also, are terraces that have a slope or dip striking across the bluffs. One may be seen at Mr. Hurley's, eight miles above the foot of the lake, where it can be traced three or four miles, passing, in that distance, down from union with the prairie level to the bottoms, or so far down as to be blended in the bottom land. A similar vanishing terrace can be seen on the Dakota side, from the bluff on the north side, about twelve miles above the foot of the lake, and midway between Hurley's and Mireau's. Within the space of about three miles, its form can be seen to pass obliquely across the face of the main bluff, from top to bottom, sloping to the east or southeast, and disappearing in the bottom-land. A similar terraced appearance has been described as occurring at Brown's Valley, at the head of Big Stone lake, in connection with an exposure of the Cretaceous (see p. 190.) The interval between Big Stone lake and lake Travers (6 miles) has a fall toward Big Stone Lake of six feet. The bluffs approach each other toward the end of the lower

*The water of the lake is clear and apparently deep.

lake, but do not unite. A continuous valley, between bluffs of the same form and appearance, and of nearly the same depth, connects the two lakes, giving the impression of one valley instead of two. The short interval constituting the divide between the two lakes is usually without water, but is often overflowed by the spring freshets, when a continuous overland watercourse is established between the gulf of Mexico and Hudson's bay, in British America. It was on one of these occasions that the attempt was made by the late Hon. Joseph R. Brown,* to float a steamboat from the Mississippi to the Red river of the North. Its remains still lie a few miles below the foot of Big Stone lake, where it was wrecked by the unexpected subsidence of the water. There is a very perceptible ascent in the smooth surface of the prairie, toward the north, from the bluffs of Big Stone lake.

Several points have been mentioned at which local terraces have been seen along the valley of the Minnesota river. They are occasioned, as has already been said, by the varying resistance of the underlying rock, when undergoing erosion by the river. This is evident from the following facts:

1st. They have a varying elevation, corresponding with the dip of the formation which causes them. They occur near the level of the flood-plain, blending sometimes with it, and also at all hights, to near the top of the bluffs.

2nd. The rock itself can be seen at many of the places where such terraces have been observed; and where it has not been seen, the face of the bluff has been unfavorable for exposure, the surface being smoothly turfed over.

3rd. There are hundreds of miles along the river, on both sides, where no such terraces can be seen, the bare bluffs being smoothly rounded off, and descending at one change from the prairie level to the flood plain. Indeed, the existence of terraces is quite an exceptional thing.

4th. In many cases, the terraces can be referred directly to their cause, layers of varying resistance in the Cretaceous.

5th. Where there is no rock in the river banks, as shown by fresh slides, there is no appearance of terraces.

A short distance below Minnesota Falls the bluff rises, on the north side, 159 feet 1 and ¾ inches above the flood plain, measured by Locke's level.

There is an old valley of the Minnesota river, extending from Lac qui Parl lake eastwardly, and joining the Chippewa valley about five miles above its mouth. This old valley has bluffs like the present river valley, but it is not

*It was Capt. John B. Davis, see vol. 1, of the final report, p. 134. (N H. W.—1885.)

quite as deep. It is nearly dry, a little water standing only in one or two spots, near the west end, and slowly passing into the Minnesota, the bottom being a level and handsome meadow. The appearance of this valley is rather novel and striking. The slopes are perfectly treeless, and very smooth, luxuriantly covered with grass and ornamented with flowers of various colors. There are short ravines or "gulches," that descend from the prairie, but they do not show a tree, nor a shrub. They are smoothly grassed over, and near their mouths can be crossed with a team. The bluffs themselves, though often overstrewn with stones and coarse gravel, are yet composed of hard drift clay, and are rarely too abrupt to be ascended by a horse. Toward the west end of this old valley the slope from the prairie shows a terrace about thirty feet from the top, but nothing can be seen on it, or even in the excavation cut for the road, but drift materials, though boulders are rather more numerous at that point in the cut than above or below. Below the level of this bench, twenty feet, is a row of springs which keep the rest of the slope wet and soft. The whole appearance, taken together, indicates a stratified condition of the bluff, probably in Cretaceous rock.

THE ECONOMICAL GEOLOGY OF THE MINNESOTA VALLEY.

Coal.

The separation of the region of the Minnesota valley from all the important coal fields, and its comparatively sparse supply of wood for fuel, have directed the attention of the settlers to the possible supply of fuel from the lignites of the Cretaceous. Mention has already been made of the localities of outcrop of this coal (pp. 221-224) with some description of the modes of its occurence. The subject has also been summarized in the letter to the President introductory to this report. There are coal deposits of the Cretaceous age that are likely to prove valuable. They occur at various places, scattered over the western territories. Such coal is also sometimes in the condition of good anthracite. A valuable bed of coal is reported to exist a few miles west of Bismarck, on the Missouri river. There can be but little doubt that such or similar coal accompanies the lower Cretaceous rocks throughout their extent in Minnesota. From the wide extent of territory in which "float coal" is found in the drift, it seems very probable that the Cretaceous

ocean at first covered the most of the state. So far as discovered; however, there is not enough coal embraced in the Cretaceous, in this state, to warrant sanguine expectations of its becoming economically useful. This coal occurs in two distinct forms, which may be distinguished, until further investigations demonstrate some error in the designations here given, as *charcoal* and *cannel coal*. The former, while it is the more abundant, is of less value for use as fuel. It is light, and quickly ignites, but it is generally in fine pieces that appear to be matted down with the ash that resulted from the combustion of other portions of the wood from which the coal is derived. It lies in irregular sheets generally, not more than half an thick when pure, but may be disseminated through a thickness of six or eight feet. It is very fragile, hardly bearing transportation. The latter is black, or brown-black, lustrous, compact, rather hard, and presents every aspect of a valuable coal. It occurs in isolated lumps or pockets, in the same beds as the charcoal, but less abundantly. It readily burns, making a hot fire. In the air, when it has become dry, it cracks and crumbles something like quick lime, but not to a powder. It is this which is found in the drift. If it could be found in sufficient quantity, this would be a valuable fuel.

The Iowa coal field, of Carboniferous age, does not reach as far northwest as the valley of the Minnesota.

Iron.

The only iron ore that is known to occur in southwestern Minnesota, is in the form of an imperfectly hydrated peroxyd, or brown hematite. It is, so far as seen, so impure as to constitute a clay iron-stone. It was first mentioned as occurring on the Le Sueur, a mile and a half above its mouth, by Dr. B. F. Shumard (Owens' Report, p. 487), who describes it as "nodules of oxide of iron, and argillaceous iron ore," and gives it a thickness of two feet, remarking that: "The superficial indications render it probable that this bed of iron ore may be both extensive and readily accessible." Similar indications of iron ore were seen the past season at a number of places on the Le Sueur and on the Watonwan. So far as observed, however, the iron seems to be largely, if not entirely, superficial, and pertains to the horizon of separation between the drift and the bedded rock. It is a circumstance of frequent occurrence, in all parts of the northwest, to see ferriferous

springs issuing from the gravel of the drift. When such water comes in contact with the air it invariably gives an iron stain to substances over which it runs. If the process be continued a brown hematite iron ore will be formed. It will partake of the impurities of the surface on which it forms. There is besides a considerable thickness of argillaceous iron-stone that coats the Silurian limestones, when they are found overlain by the clays of the Cretaceous (see pages 133 and 179.)

Mineral paint.

At Redwood Falls the kaolin which has resulted from the decomposition of the granite rock, has become stained with iron, and has a brownish or greenish-brown color. It contains, generally, some silicia. From this stained kaolin a good mineral paint has been manufactured. Messrs. Grant and Brusseau commenced the enterprise, and carried it far enough to demonstrate the quality of the product. The manufactured article is said to have been equal to that of Brandon, Vt., but that the cost was so great that, after transportation to St. Paul, it could not be offered in the market as cheaply as the Brandon paint. Their process was very simple. The raw material was obtained from the banks of the Redwood river (p. 168), and was of a rusty-brown color, having also a greenish tinge. It was broken, or crushed to the fineness of corn or wheat. It was then dried in a large pan placed over a fire, and ground by water-power, between two burr stones. In that condition it was ready for use by simply mixing with boiled or raw linseed oil. It was found that lead or ochre could not be used to advantage with it. The lead is said to have "come out and looked like a mildew." The color produced was a reddish umber. By making some selections various lighter shades, of the same general character, were produced. It had a heavy sediment, consisting probably of iron and silica. The quality of the paint is said to have been superior to that from Ohio, and fully equal to that from Brandon, Vt., or Horicon, Wis. The surface of the wood painted, becomes hardened and glazed, but remains smooth.*

It is evident that the best methods for economy were not employed in this enterprise. The mine is situated about a mile from the mill. The rock is easy of access. It cost a

*The mills of Worden, Ruter & Co., at Redwood Falls, and of Austin & Worden, at Minnesota Falls, are painted with it.

sum between three and four dollars per ton to deliver the raw material at the mill. It could probably be done for less than a dollar. The total cost of manufacture ought not to exceed a dollar per hundred, or twenty dollars per ton. The Brandon paint sells for about $40 per ton. These statements are on the authority of Mr. Park Worden, of Minnesota Falls.

Although the foregoing is the only systematic attempt that has been made to manufacture paint from this substance in the Minnesota valley, it occurs in great abundance at a number of places. It is also found in greater purity, at least with much less quartz and iron, at several other places. Indeed it seems to exist wherever the granitic rocks were buried beneath the ocean of the Cretaceous age, and where the glacier period has not disrupted it.

Quick-lime.

For common quick-lime the region of the upper Minnesota has no suitable stone. Here is a great extent of fertile country, destined to be thickly inhabitated, that must always depend on the Silurian limestones, situated further southeast, for one of its necessary articles of construction. At the present time the only resort is to the limestone boulders that occur in the drift. These are being rapidly gathered up and converted into quick-lime, and will soon entirely disappear. The nearest Silurian quarries capable of being useful for quick-lime are at Mankato. The limestone found in the Cretaceous at New Ulm is also very valuable to this region, but the shaly nature of the stone there will always make it difficult to compete with the lime from Mankato. At the same time the quality of the lime made there renders it applicable to uses of which the Mankato quick-lime is not susceptible. The Mankato lime is of a dark leather color, slacking to a cream color. It has a considerable sand that appears as a sediment. The stone itself is an arenaceous magnesian limestone, and the lime partakes of the nature of those limes. It sets more slowly, burns more easily, and slacks with less heat than the pure limestones. It is useful for brick and stone work, but will not answer for hard finish. For common brown plastering it is very useful. The lime made at New Ulm, on the other hand, is nearly white, and in that respect has the advantage of the Mankato quick-lime. It is very hot, and sets quickly. It is more nearly a pure lime, without magnesia. While it

has no sand, as an impurity, it has alumina. Associated with it in the shales of the Cretaceous, is more or less of sulphate of lime in the form of transparent crystals, or selenite. When there is much of this it would materially affect the quality of the lime, giving it somewhat the character of plaster of Paris. Below Mankato there is no lack of good stone for quick-lime. The Shakopee limestone is calcined at a number of places, and outcrops in the banks of the river at a great many others.

At Shakopee the kilns are owned by Baptiste Contre and Isaac Lincoln. They are constant, or "draw kilns." Mr. Contre burns from 17 to 18 hundred barrels per month, and seven months per year. His markets are St. Paul, Minneapolis and St. Cloud, in bulk, two hundred pounds making a barrel. Lime is produced in 30 hours. Wood costs two or two and a half dollars per cord, mixed. He "draws" every six hours.

Mr. Lincoln's kiln is considerably larger than Contre's, and requires from two to four days to produce lime, which sell at the kiln at 75 cents per barrel, twenty-two or twenty-four hundred barrels being produced per month, during seven or eight months of the year. The lime made at Shakopee is of a leather color, sometimes approaching burnt umber.

At Louisville, five miles above Shakopee, Mr. Contre owns another kiln similar to that at Shakopee. Mr. Folsom, of Minneapolis, also has a kiln here which is in operation some portions of the year. The lime produced here is of the same character as that at Shakopee. It is shipped to St. Paul, Minneapolis, and occasionally to Duluth and St. Cloud. Four or five cords of mixed wood, at two and a half dollars per cord are required for each hundred barrels.

John P. Rinshed burns lime from the Shakopee stone, at Ottawa.

About a mile above Kasota Conrad Smith burns lime from the Shakopee limestone, which he sell at one dollar per barrel. Eight or nine cords of mixed wood, at $2.75 per cord, are consumed in producing 100 barrels of lime. He has a draw kiln, but not enough demand to keep it in constant blast. The lime is dark and in nearly all respects like the Shakopee lime. It shows a bluish tint, and, Mr. Smith says, slacks to a *blue-white*, instead of a *yellow-white*, and is preferred for that reason.

Five miles below Mankato George C. Clapp burns a lime that is bluish, or ashen colored. He takes the stone from

the upper portion of the Shakopee limestone, and produces a purer lime than any seen in the valley, except that derived from the Cretaceous at New Ulm, which probably comprises over 80 per cent. of pure carbonate of lime. Mixed wood costs here $2.25 per cord, and five or six cords are required for a hundred bushels. (See page 144.)

At Mankato, besides the kilns of Maxfield & Sons, Capt. J. R. Beatty has recently erected a fine draw kiln.

At New Ulm are the lime-kilns of Wm. Winkelmann, Francis Baasen and John Heiman, all burning lime from the Cretaceous. Winkelmann burns about 1800 barrels per year, selling at the kiln, and at New Ulm, for $1.50 per barrel. It here requires 20 cords of mixed wood, at $3.00 per cord, to produce 120 barrels of lime. When freshly burned this lime has very much the same color as the stone, though a little lighter, and slacks white. His kiln stands on the bank of the Minnesota, facing the water, and is built of red quartzite and boulders. Mr. Heiman's kiln holds 150 barrels. Forty cords are needed to burn the kiln well, when filled. Wood costs $2.50 or $3.00 per cord. Lime sells at a dollar or a dollar and fifteen cents per barrel.

Above New Ulm boulders only are used for lime, the kilns being of rude construction. Such are owned by John Edget and Charles Folsom, a short distance below Beaver Falls, and by Andrew Brandin, M. C. Brace, Wm. Davis and brother, ——— Brennan, and R. R. Cory, above that place. Large limestone boulders occur about Redwood Falls. At Yellow Medicine the only lime made is derived from large boulders. Peter Casting burns a little lime from such boulders at Jannetteville, nearly opposite the mouth of the Yellow Medicine. At Granite Falls such boulders, occurring in a little ravine on the land of R. H. Baldwin, have been taken for rock *in situ*. At Mr. Hurley's, eight miles above the foot of Big Stone lake, excellent quicklime is burned from surface boulders, some of which is marketed at Morris, in Stevens county.

Gypsum.

The Cretaceous, at Big Stone lake, holds large crystals of selenite. They lie on the surface of the weatered slope made by the outcropping of a dark shale, and can be gathered in considerable quantity. They are, of course, embraced within the shale. From the existence of sulphate of lime in quantities that render it of economical importance

in this formation in various parts of the country, it is presumable that this horizon of outcrop is nearly, or exactly the same; and that at some future time, when sufficiently detailed exploration has been made, it may here prove equally valuable. This place has been already described under the head of the Cretaceous.

Fire clay.

From the Cretaceous, near New Ulm, Mr. Christian Dauffenbach manufactures a good fire brick. The bank from which he takes the clay is fifteen feet above the river. It is of light color and when wet is plastic, but if dry it is hard and difficult to quarry, the use of powder becoming necessary. Horse power is used for his machinery. He has three kilns. This fire brick clay lies below a heavy stratum of white sand. If the white sand that occurs on the Maple, a few miles above its union with the Blue Earth, be the same horizon, this fire clay ought also to be found in the banks of the Blue Earth, a short distance above its mouth. In the settlement and material development of that part of the state, this stratum in the Cretaceous is destined to play an important part. (See page 185.)

Potter's clay.

The Cretaceous also supplies, near the same place, but from a higher stratum, a good potter's clay, which is largely employed at New Ulm and at Mankato. It is owned by Silas Barnard. Mr. H. B. Kaufer, potter at Mankato, regards it as equal to the Carboniferous potter's clay of Ohio. The manufacturers at New Ulm are Winkelmann and Dauffenbach, and John Stoerket. The pottery sells for twelve and fifteen cents per gallon. (See page 186.)

Kaolin or China clay.

It has been said already, in connection with the description of the granites of the valley, that the upper surface of the granites, where protected by the Cretaceous, is overlain by a heavy bed of kaolin clay, resulting from the decomposition of the granite itself. There can be no question but that this deposit, or rather kaolinized granite, since it is decomposed and lies *in situ*, will become of great economical importance. Kaolin is not a common mineral in the drift

latitudes. It is common in New Mexico, where the granite is likewise found to be decomposed to the depth of 50 or more feet. It is also found in the Blue Ridge in Virginia, the mountain rock there being changed to impure kaolin to a considerable depth.* Although the purity of the kaolin of the Minnesota valley has not been established by tests, either practical or chemical, it is highly probable that some portions of it, at least, will be found to answer all the purposes for which such clay is generally used.

Building stone.

For construction, the Shakopee limestone holds at present a high position in the regard of builders. Its best estate is not seen at Shakopee but at Ottawa, Kasota and St. Peter. The Mankato quarries are equally as fine. The quarries at Kasota show a deeper shade of pink than those at any of the other foregoing places. The best stone yet furnished by this formation, was that put into the recent enlargement of the asylum at St. Peter. It was taken out near the asylum, and lies in very heavy and regular layers. The quarries at Kasota and at Ottawa have not yet penetrated so deeply into the rock, but will prove to be thicker bedded as they are further wrought. The Episcopal church at St. Peter, made of this stone, has a dark brown cornice, window frames and blinds, and the wall is painted dark-brown, making, although perhaps too somber, yet a very tasty and appropriate edifice for worship. It is low, and of gothic build.

South from Mankato, on the Blue Earth, the Maple and the Watonwan, are several very favorable openings, but there has not been much working in this stone, nor in any other, in that part of Blue Earth county, the dependence being entirely on the quarries at Mankato. There is no reason, however, why the counties of Martin and Faribault may not derive all their stone for walls and for all building, from these southern quarries, saving themselves the labor of transportation six or ten miles. Stone from these quarries was used in the culverts and bridge piers along the new railroad from Mankato to Wells. At Garden City, the exposure in the bed of the river is owned by J. Willard. This outcrop has more the aspect of the Shakopee limestone, at Shakopee, than any other seen,

*Compare *Am. Jour. Sci. and Arts*, III, Vol. VII, p. 74.

and will not be found to furnish as handsome layers as the quarries at Mankato.

At Jordan, the sandstone lying next below the foregoing limestone is somewhat employed for foundations, and has been put into some large buildings. It cuts well, and is in blocks about eight inches thick. It is rather too friable, however, for general use.

The St. Lawrence limestone is a very fine stone for building. It is tough, compact, and of a good color. Its bedding is symmetrical and of convenient thickness. The only quarries known are those at St. Lawrence and at Hebron and Judson. The Presbyterian church at Belle Plaine is built of the St. Lawrence stone, the trimmings being from Ottawa. In the Potsdam at Redstone, quarries are opened by Francis Bassen, Wm. Winkelmann and Frederick Meyerding.

Of the granites and associated rocks there is a great variety. There is also every desired facility for quarrying them. The "gray" and "red" granites afford every kind of shading of color, and a great many beautiful combinations of mineral contents and crystallization. The time cannot be far distant when a great many valuable openings will be made in the granites of the Minnesota valley, for the convenience of the southern part of the State and of Iowa.

Brick.

Common red brick, sometimes also brick of a lighter shade, are manufactured from the alluvium of the river at New Ulm and Mankato, as well as at other points further down the valley. The Mankato brick have a high reputation, and are extensively shipped to St. Paul. The makers are Meihofer and Whitrock, Reed and Mather, Jager brothers, and Mr. Schlafle. At New Ulm, Wm. Winkelmann owns the only brickyard. At Jordan, Charles Rodel makes a light-colored brick.

Copper.

At Shakopee a stock company exists for sinking a shaft to explore for copper. It is said that in sinking a common well pieces of native copper were found. The shaft is to be as deep as that well which, when vigorously pumped, is said to afford particles of copper with the water. The limestone was struck at 18 feet. The work has not progressed

far enough to indicate the probable result. The limestone at Shakopee being of the same age as Calciferous sandrock of the east, recalls the fact that they both belong to the Quebec group of Canada, which is regarded there as holding the upper copper-bearing rocks of lake Superior.

Timber and fuel.

"The big woods" of Minnesota, consist of a southward prolongation of the timber belt about forty-five miles wide, in the central part of the state. The boundary of this prolongation on either side, is not well marked, the trees gradually becoming thinner and smaller, and more and more restricted to the valleys of streams, till the country is changed to a treeless prairie. The surface itself is more rolling than on the east or west. It may be thus described in general: Beginning a few miles west of Minneapolis the eastern edge of the big woods crosses the Minnesota in a line towards Lakeville, in Dakota county. Continuing in a southerly direction, it passes about a mile east of Cannon City, and of Owatonna, when it makes a short bend to the west and northwest, passing about six miles north of Waseca, and near E. Janesville, in Waseca county. In Blue Earth county it is variously modified by the valleys that are tributary to the Minnesota from the south. Continuing west, about six miles south of South Bend, it turns north, and crosses the Minnesota. Running along the west side of the Minnesota, distant from it about four miles, it begins to bear off to the northwest at St. Peter, and runs in nearly a direct line to Darwin, on the St. Paul and Pacific R. R., bending a little to the east, toward Glencoe, in McLeod county. In passing through these woods from Farmington, in Dakota county, to Shakopee, in Scott county, the following species of trees and shrubs were seen. For ten or twelve miles after entering the woods very few trees are seen, the oak shrubs being the largest and almost the only tree-like vegetation. About half way to the Minnesota river the maple and large elms, bass and iron wood appear.

Oak shrubs. Apparently Quercus ilicifolia. *Wang.*
Hazelnut. Corylus rostrata. *Ait.*(?)
Bur oak. Quercus macrocarpa. *Michx.*
White oak. Quercus alba. *L.*
Wild red cherry. Prunus Pennsylvanica. *L.*
Trembling aspen. Populus tremuloides. *Michx.*
Sumac. Rhus typhina. *L.*
Choke cherry. Prunus Virginiana. *L.*

Wild plum. Prunus Americana. *Marshall.*
White ash. Fraxinus Americana. *L.*
Sumac. Rhus glabra. *L.*
Thorn. Cratægus.
Rose. Rosa blanda. *Ait.*
Juneberry. Amelanchier Canadensis, Var. Botryapium. *Torr. and Gray.*
Round-leaved cornel. Cornus circinata. *L'Her.*
Common elder. Sambucus Canadensis. *L.*
American crab-apple. Pyrus coronaria. *L.*
The young twigs and the under surface of the leaves are very woolly-pubescent.]
Black cherry. Prunus serotina. *Ehr.*
Frost grape. Vitis cordifolia. *Michx.*
American elm. Ulmus Americana. *L. (Pl. Clayt.) Willd.*
High bush cranberry. Viburnum Opulus. *L.*
Two or three species of willow. Salix.
Green ash. Fraxinus viridis. *Michx. f.*
Prickly ash. Zanthoxylum Americanum. *Mill.*
Cockspur thorn. Cratægus crusgalli. *L.*
Red raspberry, Rubus stirgosus. *Michx.*
Black currant. Ribes floridum. *L.*
Cottonwood. Populus monilifera. *Ait.*
Large-toothed aspen. Populus grandidentata. *Michx.*
Bass. Tilia Americana. *L.*
Red mulberry. Morus rubra. *L.*
Ironwood. Ostrya Virginica. *Willd.*
Sugar maple. Acer saccharinum. *Wang.*
Soft mapel. Acer rubrum. *L.*
Alternate-leaved cornel. Cornus alternifolia. *L.*
Bitternut. Carya amara. *Nutt.*
[Rare east of Spring Lake.]
Butternut. Juglans cinerea. *L.*
[Very rare except at Spring Lake and westward.]
Slippery elm. Ulmus fulva. *Michx.*
Staghorn sumac. Rhus typhina. *L.*
Tamarac. Larix Americana. *Michx.*
Box elder. Negundo aceroides. *Moench.*
Wolfberry. Symphoricarpus occidentalis. *R. Br.*
Panicled cornel. Cornus paniculata. *L'Her.*
[The most common species of *Cornus.*]

In ascending the valley the following additional species were seen:

Kentucky coffee tree. Gymnocladus Canadensis. *Lam.*
Red cedar. Juniperus Virginiana. *L.*
Black walnut. Juglans nigra. *L.*
Hackberry. Celtis occidentalis. *L.*
The hickory grows to about six inches in diameter and then is invariably winter-killed. A tract of many acres is now being cut near St. Peter for fuel, having been killed the past winter. All the trees are small. The hackberry is used for fuel, and for furniture. It is commonest in the heavy timber. The butternut is rarely large. The box-elder sometimes exceeds three feet in diameter.]
Blue beech. Carpinus Americana. *Michx.*
Yellow or gray birch. Betula lutea. *Michx. f.*
There is said to be a species of locust at St. Peter, but it has not been recognized by the survey. The above species of birch has oblong catkins, and spreading lobes on the scales which are 3 inches long. The lobes are obtuse.]

The trees and shrubs of Big Stone lake.

At Mr. Hurley's, eight miles above the foot of Big Stone lake, on the north side, the following trees and shrubs were seen growing:

Trees—In the order of abundance.

White ash. Fraxinus Americana. *L.*
Bur oak. Quercus macrocarpa. *Michx.*
Basswood. Tilia Americana. *L.*
Elm. Ulmus Americana. *L. (Pl. Clayt.) Willd.*
Box elder. Negundo aceroides. *Moench.*
[This makes a very fine "maple sugar" and syrup. It is abundant on the islands.]
Cottonwood. Populus monilifera. *Ait.*
Hackberry. Celtis occidentalis. *L.*
Ironwood. Ostrya Virginica. *Willd.*
Soft maple. Acer rubrum. *L.*
Wild plum. Prunus Americana. *Marshall.*
Slippery elm. Ulmus fulva. *Michx.*
Willow. Salix nigra. *Marshall.*

Shrubs.

Grape. Vitis æstivalis. *Michx.* (?)
Gooseberry, (prickly). Ribes Cynosbati. *L.*
Gooseberry, (smooth). Ribes rotundifolium. *Michx.*
Wolfberry. Symphoricarpus occidentalis. *R. Br.*
Black currant. Ribes floridum. *L.*
Prickly ash. Zanthoxylum Americanum. *Mill.*
Red raspberry. Rubus strigosus. *Michx.*
Black raspberry. Rubus occidentalis. *L.*
Sweet elder. Sambucus ?
Sweet viburnum. Viburnum Lentago. *L.*
Red osier dogwood. Cornus stolonifera. *Michx.*
Bittersweet. Celastrus scandens *L.*
Choke cherry. Prunus Virginiana. *L.*
Red rose. Rosa lucida. *Ehr.* (?)
White rose. Rosa blanda. *Ait.*
Virginia creeper. Ampelopsis quinquefolia. *Michx.*
Waahoo. Euonymus atropurpureus. *Jacq.*
Smooth sumac. Rhus typhina. *L.*

[The list of plants of Minnesota by Dr. I. A. Lapham, alluded to in the address to the president, is withheld for future publication.]

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